BULLER RIVER

WESTPORT FLOOD MITIGATION

ENGINEERING REPORT

BUSINESS CASE

ENGINEERING DESIGN & RISK ASSESSMENT

Report prepared by

Gary Williams

JUNE

2022

G & E WILLIAMS CONSULTANTS   Otaki

BULLER RIVER — WESTPORT FLOOD MITIGATION
ENGINEERING DESIGN & RISK

1 INTRODUCTION

Investigations of flood mitigation measures have been undertaken for Westport to provide flood hazard information and mitigation options for a business case to government for central government funding. This has followed the significant flooding of Westport in July 2021, and further flooding in February 2022.

The West Coast Regional Council [WCRC] has a flood mitigation scheme on its books, from investigations undertaken in the mid 2010s, and a specific option has been included in its Long Term Plan [LTP], following public consultation in 2021.

Land River Sea Ltd [LRS] was commissioned by the WCRC in 2014 to undertake hydraulic modelling of the Buller River system, in order to identify the likely extent of flooding in the Westport area for a range of return period events, as well as to be able to use the model for investigating potential flood mitigation options. This modelling was completed in 2015 and is detailed in the modelling report of LRS (Gardner, 2015). [1]

In 2017, the WCRC requested a formal review of the hydraulic modelling so that flood maps could be published for Westport and formally adopted in the District Plan of Buller District Council [BDC]. This report was published in September 2017. An updated report was published in December 2017, following a peer review of the modelling.

The scheme included in the WCRC LTP was based on these investigations and the options considered. The alignment of the flood defences (earth stopbanks or walls) was, though, based on previous investigations, with the flood defences being aligned within public land of BDC or reserves, as much as possible.

The investigations for the business case commenced with a 2-day workshop at the end of 2021, with field inspections on 30th November, and follow up discussions, briefings and the setting up of a Technical Assessment Group [TAG] on 1st December. The investigations have then been considered and guided by TAG meetings, with further site inspections on 13th April and a workshop in Westport on 14th April this year.

Detailed hydraulic modelling and consideration of flood risk has been undertaken, based on the original LRS model, but with updated topography from the latest aerial survey (LiDar), and the revised alignments and options agreed upon by the TAG. The options included:

- excluding the Snodgrass area on the east side of the Orowaiti estuary;

[1] Gardner, M. 2015: Buller River — Hydraulic Modelling Study. Land River Sea Consulting Ltd, Christchurch.

- extending the Carters Beach stopbank east to the Buller River to include more homes, the golf course and the airport;
- reducing the area protected to the south of Westport town, with two alternative alignments being modelled;
- investigating the impacts of the causeway at the State Highway crossing of the Orowaiti estuary, and the railway embankment alongside Stephens Road;
- investigating the impacts of a forest regeneration at the overflow area to the Orowaiti in the Organs Island area.

The results of the hydraulic modelling and the implications of the model findings is covered in the LRS report (Gardner 2022). [2]

This report covers an assessment of flood risks and mitigation alternatives, concept engineering design for the flood defence structures, and preliminary cost estimates for the options investigated in the hydraulic modelling. It also covers a range of issues around the construction of the flood defences, including construction methods, materials and temporary effects, adaptability, failure mechanisms and consequences, limitations and opportunities for social and environmental benefits, as well as the staging of works and future flood damage risks and maintenance requirements.

The report also covers river management aspects of flood mitigation, including river bank protection measures, channel management and a wider river corridor in the Organs Island area, with the retirement and re-vegetation of land in this overflow area.

2 BACKGROUND

The Buller River has the largest flood flows (for a given frequency of recurrence) of rivers in New Zealand. It also has a very small floodplain at the coast, with the coastline controlled by the headland of Cape Foulwind. Where the river leaves its confinement by hill country there is a natural overflow area, with floodwaters spilling from the main channel down to the Orowaiti River and its estuary. A location plan is shown on Figure 1, with a Google Earth aerial base.

Westport was developed as a port town, and in the late 19th century very substantial harbour works were undertaken, including the construction of long moles into the sea, to provide a fixed navigation channel. These moles have acted as a control point within the coastal embayment of the Cape Foulwind headland, giving rise to coastal progradation with coastal spits forming on both sides of the harbour entrance/river mouth.

On the west side Carters Beach and the airport are on this reclaimed land, and on the east side a very substantial spilt has formed in front of the Orowaiti River, giving rise to a long estuary area to the present river mouth at the eastern extent of

[2] Gardner, M. 2022: Buller River — Flood Mitigation Options Assessment. Land River Sea Consulting Ltd, Christchurch.

the coastal spilt and floodplain land. This development has profoundly affected flood flows and flooding characteristics on the floodplain of the Buller River. [3,4]

Managing the Buller River itself, the alignment of the main channel, and associated bank erosion, has been required since the establishment of Westport. At the upper end of the floodplain, the Buller River is sharply defected by a bluff, and across the short reach from where the river exits its gorge to this bluff, the river would naturally have a tightly curving channel. This is a natural river adjustment to a sharp deflection, with the river taking different courses as it winds into the bend.

In the late 19th century, the river was diverted with a much more direct path, and quarry rock was place along the outer convex side where there is erosion pressure. This was done using a railway siding to bring the rock to the site. Additional rock has been placed to maintain the bank protection and to add protection at other outer bend banks downstream.

Much of this work would have been undertaken by the Harbour authority, but during the time of Catchment Boards (from the Second World War to the late 1980s) such river management works would have been carried out by the West Coast Catchment Board. Over that time central government provided substantial assistance from taxpayer funds, with high levels of assistance for comprehensive river and whole catchment schemes, and for regions with affordability issues, such as the West Coast.

This assistance was not only for natural hazard mitigation measures, it also included other infrastructure, such as the treatment of water supplies and waste discharges.

Since the 1990s river management and flood mitigation schemes have been funded solely from ratepayer funds, and affordability issues or high debt levels has meant that no major new scheme has been implemented in the last 30 years. This has also meant that the assistance with flood mitigation has been reversed, as government land and assets do not pay rates. Local authority rate payers have been subsidising central government, given the protection these schemes give to government assets.

Providing flood mitigation for Westport, thus, raises many policy, design and construction issues, and there are no national standards to guide decisions on design parameters, such as the standard of protection in terms of flood flows or sea conditions. In this case flood defences have to be retro-fitted into an existing urban area, with all the infrastructure of railways, roads, bridges, stormwater management and community facilities of an urban area.

At present there are no significant flood defences for Westport. The town is only flooded in rare events, partly because the power of the Buller River is such that it can maintain a large main channel out to sea, and partly because of the relatively well-defined overflow area to the Orowaiti estuary. However, the continual

---

[3] Gardner, M. & Williams, G.J. 2021: Buller River Gravel Extraction Recommendations. Land River Sea Consulting Ltd, Christchurch.

[4] Gardner, M. 2022: Westport Community Engagement Presentation. Land River Sea Consulting Ltd, Christchurch.

increase in the size of the coastal spit in front of the Orowaiti River is increasing the flood hazard from Buller River flooding. This is, though, beneficial for sea storm surge and tsunami erosion and flooding.

While the structures being proposed are straight forward to construct, it is the construction process that would be highly constrained in many places, with closely adjacent houses, construction between houses and the estuary edges, road crossings and the difficulties of access to the flood defence alignments, albeit within reserve land, all the while maintaining road use and private access.

A significant issue is achieving land access agreements, and this will require a close working relationship and cooperation with landowners and directly affected people. The land and people directly affected by the construction activities are also the people on the front line from flooding, and would take the brunt of fast floodwater inflows and debris collection when flooding occurred.

The matter of how to achieve a balance between vulnerability, temporary construction impacts and long-term costs and benefits from flood mitigation measures is complex and can be difficult to resolve. This depends on the rating approach taken and whether there will be a return of central government assistance.

If there is a substantial contribution from central government, then financial compensation for the impacts of construction and for the long-term presence of flood defence structures on land, could give rise to perverse outcomes. This compensation could exceed the rates that the frontline landowners pay in rates. They would then, essentially, be paid to be protected, while being the most vulnerable.

Central government contributions to flood hazard mitigation also raises the issue of how the assistance is distributed. Both structural and non-structural measures are being considered, and where structural mitigation is not proposed, what assistance would there be for non-structural measures.

Flood mitigation for Westport raises many of the issues facing New Zealand, and humanity as a whole, including both river and sea flooding, risks from rising groundwater levels and liquefaction, structural and non-structural measures to reduce vulnerability or assist in adaptation. Then there is the connectivity with other natural processes, such as earthquakes and tsunami. The most significant valley and floodplain forming flows come from the bursting of landslide blockages, and these flows can be much greater than the climate driven rainfall/runoff flows of rare frequency, such as a 100-year return period flow.

All the matters discussed above make this business case investigation especially difficult. The decision-making of the TAG is based on technical matters of risk, design requirements, protection standards and the (direct) costs of protection, while being aware of the impacts of different arrangements on the people of Westport, and the local environment, with its estuaries and wetlands.

This is all being done to a very short timeframe, which must affect the quality of the assessments carried out and the decision-making about options and their implications.

3 ASSESSMENT of ALTERNATIVES

3.1 GENERAL

A broad range of alternatives have been considered, from doing nothing to flood defences of a high climate change scenario standard of RCP 8.5. The damages for present conditions, with no significant structural flood defences, have been assessed for a range of flood flows and sea flooding, using estimated return periods or frequencies of recurrence. The likelihood parameters have to be estimated for changing climate conditions, as well as what the past record would indicate. This involves qualitative assessments of changing frequencies, given the predictions for climate changes in the future.

The flood damage assessments for the existing risk and the reductions for the various options that have been modelled hydraulically has been undertaken by NIWA.[5]

Of the river management measures considered, two channel management options deserve some comment.

The Buller River channel along its lower reaches and out to the river mouth bar has been dredged for harbour development and maintenance purposes, and rock tide walls have been used to confine flows in the main channel. However, experience has indicated that this has not had much effect, on the bar or on channel depths. The extraction of gravel bed material from the bed of the river has been investigated and reported on in the "Buller River Gravel Extraction Recommendations" report and in the LRS report on the potential impacts of gravel build up (Gardner 2020).[6]

The Buller River has the power in large flood events to determine its own bed levels and bed profile, and will scour and deposit bed material to suit its sediment transport capacity.

An overflow cut has been put forward for the Orowaiti estuary, from where it bends to the east, directly out to the sea, through the spit. The changes in the coastline and in the Orowaiti estuary over time, due to the coast protrusion of the harbour moles, has been demonstrated in the presentations and reports of LRS.

The long length of a cut now, and the lack of hydraulic grade, makes any overflow inefficient. The cut would have to be wide and shallow to have some capacity while fitting the level limitations of the estuary and sea. The tidal range gives rise to a small useable height across the spit. An opening in this area would also increase the sea surge and tsunami hazard.

3.2 FLOOD DEFENCE OPTIONS

The flood defence assessment started with the proposal of the LTP, and the options that have been hydraulically modelled are outlined in the LRS report

---

[5] Williams, S. et al. 2022: Direct Damage Analysis for Scenario Flooding in Westport. NIWA, Christchurch.

[6] Gardner, M. 2020: Buller River — Assessment of Potential Impacts of Gravel Buildup. Land River Sea Consulting Ltd, Christchurch.

(Gardner 2022). In summary they are as follows (using the numbering of the LRS report):

OPTION 1 — Comprehensive scheme (of the LTP)
Extensive ring bank, including Carters Beach and Snodgrass area

OPTION 2 — Comprehensive scheme – but excluding the Snodgrass area
Extensive ring bank, including Carters Beach, but excluding Snodgrass area

OPTION 3 — Inland Embankment - excluding southern farm land
Reduced area ring bank excluding southern area farm land, but including Carters Beach and Snodgrass area

OPTION 4 — Remove S H causeway
Extensive ring bank, including Carters Beach and Snodgrass area, with the State Highway causeway at the bridge crossing of the Orowaiti Estuary removed.

OPTION 5 — Extend Railway opening
Extensive ring bank, including Carters Beach and Snodgrass area, with an extended opening (100 m) in the Railway embankment at Stephens Rd.

OPTION 6 — Exclude Snodgrass with floodway
Extensive ring bank, including Carters Beach, but excluding Snodgrass area and including a Snodgrass floodway

OPTION 7 — Revegetate overflow area
Extensive ring bank, including Carters Beach and Snodgrass area, with revegetation of the Organ's Island overflow area.

The alignment of the flood defences in these options is broadly shown on Figures 4 to 13, which will be referred to in the Cost Estimation section below.

These options were modelled for the estimated 100-year flood flow based on the historical record and for the estimated flows and sea levels for the climate change scenarios of RCP 6 and RCP 8.5. A mix of historical 100 year for the Orowaiti estuary area and RCP6 100 year for Buller River flooding was modelled for the Reduced Area ring bank option, for two alternative alignments of the embankment across the south side of Westport town.

The modelling is complicated by the different flood risks, of river and sea, and by the effects of alignment changes on the flood flow split between the Buller main channel and the Orowaiti overflow. Thus 100-year coastal flooding events have been modelled for the historical and RCP6 100-year events. The modelling of the Organ's Island revegetation had to take into account the different flow splits at the overflow for the initial (existing) conditions and for a fully developed forest condition.

3.3 ASSESSMENT of FLOOD DEFENCE OPTIONS

OPTION 1

This is the most comprehensive mitigation proposal and is based on the LTP proposal, but with modifications from the present investigations and consideration of alternatives. These modifications include changes in the lengths of stopbanks and walls, and in the wall design, as well as location and access refinements. Crossings of streets, main roads and railway lines have been identified along with private access ways, as well as outlets for open drains and the position of stormwater pipes under the stopbanks or walls.

There are a number of sub-options that involve realignment of the mitigation banks or walls, without greatly affecting the area protected. This includes at the north end by the rock mounds of the port moles, along Craddock Drive and around the waste transfer station, along Excelsior Road, below Stephens Road, and along Snodgrass Road.

In the Carters Beach area, the stopbank has to be extended west to accommodate the climate change scenario. Extending it to the east along Schadick Avenue to include houses along this road and the airport has also been modelled. Including this additional area would protect the airport as an infrastructure lifeline, providing a secure operational facility for planes and helicopters during and immediately after flood emergencies.

This proposal includes all the urban area of Westport, with a ring bank along the Buller River and around the Orowaiti overflow system, plus a separate bank/wall around the low-lying Snodgrass area, and a bank around Carters Beach. Under the climate change scenarios, the Carters area would remain vulnerable to sea flooding and wave-generated erosion, unless other measures were implemented along the coastline.

The farm land to the south of the main urban area was included within the ring bank, by following the higher ground of a low terrace formation of old alluvial floodplain channels. At the time of the original drafting of the ring bank location, this area was being considered for urban expansion. Comment on this area is given under Option 3 below.

This option can be considered the base option against which the other options can be compared and evaluated.

The worth of the option depends on an evaluation of the costs and benefits of the proposed flood mitigation to the agreed climate change scenario, including social, economic, environmental and cultural criteria. This would be undertaken on a 'with' and without' basis.

OPTION 2

Options 2 and 3 involve the exclusion of areas from the Option 1 proposal. Option 2 excludes the Snodgrass area, which is a low-lying area on the right (east) side of the Orowaiti estuary. The older settlement area is on what was an island before the foreshore accretion that accompanied the construction and extension of the port moles. The rest of the area is very low and flood-prone, and can be flooded in medium sized events, from the Buller River overflows or from sea flooding.

Houses in this area were very severely damaged in the recent flood events, with some still awaiting final insurance assessments.

Protecting this area affects flood levels in the Orowaiti system, and requires higher flood defences along the left side of the main urban area of Westport. This is then a significant extra cost above that of the Snodgrass flood defences themselves.

The protection of the main area of Westport from the Orowaiti does not make flooding worse in the Snodgrass area from design (100 year) flood events of present or climate change scenario conditions. However, it would increase flood depths in lesser events.

OPTION 3

Options 3 excludes the southern farm land, which was originally included for urban expansion.

This farm land is outside the main overflow area and channels to the Orowaiti estuary, and thus less prone to flooding, but is floodable from the Buller River, with old overflow channels alongside the existing Buller River.

The area protected could be reduced by linking the stopbank from the Buller River to where the Orowaiti overflow system bends towards the Buller River channel. The first proposal was to follow an existing paper road reserve, which would form a straight link.

However, this bank alignment would cut directly across flooding flows, and the bank would give rise to significant ponding heights upstream. A V-shaped link was then been investigated, with overflows being deflected back to the Buller River or the Orowaiti overflow system.

The stopbank beside the Buller River along this farm land has been set back at least 50 m from the existing bank edge. This provides a berm area between the river channel and the stopbank, giving rise to a flood flow separation that reduces the flow forces alongside the stopbank, while providing a buffer area within which bank erosion can be managed.

The lower reach of the Buller River has a relatively fixed meander pattern, with erosion pressure along the outer bank of the channel curvature, and a gravel bar along the inner side. Aerial photography since the 1940s and historical plans show a progressive erosion of the river bank along the outer bank lengths, and substantial rock works have been placed along these erosion areas in the past.

The longer-term costs of the proposed scheme will mostly be the costs of managing bank erosion, and this southern area of the scheme is most at risk from bank erosion.

The bank around the southern end is not high, but there are many drains and swale depressions going down to the main overflow area, which would all have to be piped with outlet flapgates.

Flooding of this land is a rare occurrence, and the full extent stopbank would be relatively expensive to protect farm land that is only rarely flooded. It would also not be sensible to do the full stopbank and then apply planning restrictions to prevent its conversion to urban use.

The pertinent question is, then: will the urban expansion of Westport take place in this area, or will it be directed elsewhere that does not have the same risk from floods? If it is to be directed elsewhere, then there is really no justification for the inclusion of this southern area farm land, with its bank erosion hazard.

OPTION 4

Options 4 to 7 investigate the impacts of alterations to restrictive features or to the overland flows, to determine scheme cost savings.

Options 4 assesses the effect of removing the causeway that links the S H 67 bridge across the Orowaiti estuary to the right bank of the estuary. It investigates the impacts of the short bridge and causeway as compared to a full-length bridge.

Removing this hydraulic restriction has little effect as the causeway is mostly drowned out in large flood events, depending on the size of the event. The cost is thus not considered worthwhile, and construction would take place in the sensitive area of estuary mud flats.

OPTION 5

The Railway embankment across the Orowaiti at Stephens Road acts as a weir control on the overland flood flows, and the existing bridge/culvert openings are small compared to the length of the embankment restriction.

A relatively short (100 m) extension of the waterway opening has been modelled to assess impacts both upstream and downstream of the Railway embankment. This has only very localized effects, partly because of the poor hydraulic linkage across Stephens Road to the low wetland area below the Railway line.

The Railway embankment was severely damaged by flood flows in the recent overflow flood events, and an enlarged waterway capacity could have significant long-term benefits for the Railway.

OPTION 6

This option investigates the effects of a floodway along the lowest land of the Snodgrass area, alongside the terrace face, if this area is excluded from flood mitigation. It would provide a relief area from upstream of the State Highway 67 causeway, and thereby eliminate the restriction effects of the state highway and lower upstream flood levels, and hence the cost of flood defences.

However, the benefits in terms of lower flood levels in the Orowaiti from a floodway were found to be relatively small, while the costs would be high. Bridging or a set of box culverts would be required for floodwaters to pass under the state highway, and there is a substantial area immediately downstream of the state highway that has been infilled, and this fill would have to be removed.

OPTION 7

There is a large area of contiguous public land at the Organ's Island overflow, which includes the old channel of the river. In the past this land had been kept in tall vegetation to restrict overflows down to the Orowaiti system. There is also the long rock lining that is constraining the river channel in its present course, and the lower length of this lining was severely damaged in the recent large flood event.

The land is in various types of public titles, with lease agreements on at least some of the land.

This area could be revegetated as a wide area of native riparian forest, which would provide a vegetative filter and moderator of flood overflows down the Orowaiti system. As this vegetation established the hard control of the rock lining could be relaxed, with the river able to move within this wider space, prior to its entry into the sharp bend downstream at the valley side bluff. This would reduce long-term rock maintenance costs of the flood mitigation scheme, while allowing a more natural river movement within a forested floodplain environment.

3.4 ASSESSMENT COMMENTS

Assessing the costs and benefits of flood mitigation measures is not a straight-forward task. There are many uncertainties in the natural dynamics and variabilities of sea and river flooding. There are also many different social and environmental effects, as well as economic, which impact people in different ways, and for which people have differing appreciations

A design protection standard is determined in terms of flood flows, of levels and velocities for rivers, and sea levels and wave impact for coastal flooding. The probability of a given design standard is a statistical estimate based on past data of river and sea levels and conditions. The statistics assume a stable population of events, and are based on maximum values within a given (year) time period.

In reality, changing catchment conditions and climatic variations over time change the flooding frequencies and hence the statistical likelihood of recurrence of a given design condition.

The relatively rapid changes in climate that are being predicted increase the uncertainties, and the unforeseen consequences of any mitigation measures. There will always be over-design events at some point in time, and the effects of scheme measures on flooding under such over-design conditions should be considered in any mitigation design.

The relative merits of options also depend on the design standard, as the change in standard from a 100-year event based on past data to the climate change scenarios has shown. Higher sea levels and larger flood flows change the balance of costs and benefits of different options.

Excluding the Snodgrass area from structural protection would be based on its inherent vulnerability, under present climatic conditions, and the potential impacts of sea level rises and increased storm intensity. The area is not made worse off by the structural protection of Westport. The low-lying areas around the Orowaiti estuary will be directly affected by any sea level rise, through the rise in groundwater levels back from the sea. The area is, thus, especially vulnerable, as the recent flood events (of both river and sea flooding) have shown, and assistance should probably be non-structural.

The standard of protection – for any of the alignment alternatives – is a matter of risk preferences. This can be guided by the evaluation process of economic, social and cultural assessments.

A lower standard for flooding from the Orowaiti estuary would be based on the less dangerous nature of this flooding, the longer-term viability of a higher standard, and the amenity impacts of higher flood defences, including the greater temporary impacts of construction.

4 DESIGN

4.1 FLOOD DEFENCES

A general concept design for the flood defences has been based on the requirements of stopbanks and walls for flood mitigation purposes. The likely ground conditions have been assessed from the overall nature of the Buller River floodplain, and the information obtained from the recent flood events.

Concept cross-sections for the stopbanks and walls are shown on Figure 2.

No geotechnical investigations have been undertaken at this stage, however the stopbank and wall heights are at the low end of the scale for flood defences. A 2 m high stopbank is considered a low embankment, with very low risk of instability or seepage generated failures. The standard crest width for construction and maintenance access is wide for such a low height bank. An allowance has been made in the cost estimates for a cut-off key under the stopbank, as a standard feature for seepage control, and to cover areas with unsuitable ground conditions. A shallow key would be sufficient as it is only seepage at the stopbank surfaces that is important for stopbank security.

A geotechnical assessment of ground conditions along the stopbank alignments would be necessary for final design purposes. The most common method is digging shallow pits at intervals to assess subsoil conditions over a depth of 2 to 3 m, using a small excavator.

The use of walls for flood defences is very rare in New Zealand. They have been used to top up stopbanks, or to reduce stopbank heights and footprint size, and very occasionally where there are tight space limitations. They have also been used as temporary measures during flood events, for instance, to block of roads below the stopbank height. In this case walls have been proposed because of the space constraints in an urban environment, however they are relatively low as retaining walls. Concrete walls require slab foundations, and can not be simply raised in height by raising the wall itself.

Timber walls have been considered as a single pile and board wall, with tongue-in-grove boarding and waterproof sealing, or as a double wall with an earth infill between. Mostly timber walls have been used in the cost estimation. The unit costs used for the walls are given in the table below.

Wall Type	Cost ($ per m2 of wall facing)
Concrete wall	900
Single t&g board wall	750
Double earth filled wall	1250

Concrete or timber walls could be used, and this would not change the relative cost of options, or significantly affect an option cost estimate. Timber walls are, though, preferred for a number of reasons. They can be constructed by simple pile driving, without the excavation and forming of the foundation of a concrete wall. They can be increased in height without altering an existing wall, by adding another wall behind, which can be braced off the existing wall. They are more robust in earthquakes and when liquefaction occurs, and more easily repaired.

4.2 RIVER MANAGEMENT – BANK ROCK WORKS

The proposed rock works along the Buller River channel are repair works following the recent flood events. In two cases – the Organ's Island and upper O'Connor sites – the works are to repair rock bank protection that has been damaged and outflanked. The lower O'Connor works is where lateral bank erosion has extended downstream of existing rock bank lining works. This bank erosion is typical of what occurs in a large flood event, where channel migration moves the active erosion area off the end of existing bank protection works.

These works have been designed on the basis of channel and bank surveys, and scour depth and rock sizes have been estimated from hydraulic parameter values given by the modelling, to determine appropriate foundation depths and rock grading and quantities.

These works are flood damage repair works of bank protection assets for river management purposes. The main on-going effort will be ensuring that the river does not erode away the land in front of the flood defences and undermine these structures, or significantly alter the flood flow split at the overflow area.

They are not part of the flood mitigation proposal of the LTP, which concerned flood defences around Westport.

5 ESTIMATED COSTS

5.1 COST ESTIMATION

Preliminary budgetary costing of proposed flood mitigation measures has been based on the following:

- Flood levels along the alignment of the proposed flood defences.
- Preliminary assessment of stopbank and wall foundation conditions and construction requirements to estimate unit costs and volumes.
- Identification of all stopbank or wall crossings, for access and internal drainage (private access, street, main road and railway crossings + open drain and stormwater pipe crossings).
- Preliminary assessment of crossing requirements (for different access types and drainage outlet sizes) to estimate costs by type and size.
- Assessment of construction access requirements and mitigation of injurious effects during construction, including temporary measures for access and to mitigate adverse effects.
- Estimation of general costs of construction establishment, project management, insurances, traffic management, health and safety, dis-establishment and clearing up.

- Determining an appropriate contingencies margin, based on the costing data and potential variations in quantities, unit costs and general lump sum costs.

The unit costs have been obtained by TAG members based on current prices and contractor rates. These rates are given in the cost spreadsheets, with a separate file for each of the options, of alignment and protection standard, that have been hydraulically modelled.

The cost of the flood defence options has been estimated on a contract schedule basis, but with a preliminary estimate of unit costs and volumes, and not as an engineer's estimate for tendering purposes. The stopbank volumes and wall heights have been determined from a single central point along the proposed alignment – as amended, and as shown in the plans attached to the LRS report (Gardner 2022). Given this, a 20 % contingencies allowance has been added, to give a reasonable estimate for budgetary purposes.

A cost to obtain landowner access agreements, for construction and on-going maintenance, has been included, but this only covers likely costs for willing party agreements. The estimates include a percentage for engineering fees. Consent and other approval costs are not included.

This provides a sound basis for a cost comparison of the options. Once a decision is made on the preferred alignment and standard, a more detailed cost exercise should be undertaken, to firm up the cost of this alternative, as the flood mitigation scheme to be taken forward. The costs of landowner agreements should be re-assessed as well, given firm commitments to specific alignments.

The flood defences have been split into sections, based on site conditions and constraints, and their type and ease of construction. These sections could be constructed under separate contracts, and the staging of a scheme can be based on these contract lengths.

The costs of the Buller River rock works are based on a final design, and the estimates can be used for tendering purposes, as an engineer's estimate, with a 10% contingencies allowance. Specific costs for the works have been obtained from contractor rates, with survey plans being made available for the tender documents.

5.2 OPTION COSTS for FLOOD DEFENCES

Stopbank volumes and wall heights have been determined from the hydraulic modelling for each modelling run of a specified flood flow, with the data split into sections for costing purposes. An example of these splits is shown on Figure 3, for the town ring bank, with the location of walls highlighted.

The estimated cost of each of the options that have been modelled are shown on an aerial plan of the option, which shows the alignment and the costs for each section, for the protection standard used in the modelling.

These plans are Figures 4 to 14. The cost estimates for all these options are given in Table 1.

The estimated cost for the council LTP proposal at the 100-year historical flood standard is $17.3 million. This increase to nearly $25 million for a RCP6 100-year standard. Removing the Snodgrass area reduces these costs to $14.3 million and $20 million respectively. As well as eliminating the costs of protecting Snodgrass, which is relatively expensive, this reduces the costs on the west (main town) side of the Orowaiti estuary – by $0.65 million and $1.4 million for the respective standards.

Decreasing the area within the ring bank around Westport reduces costs by around $1 million and $2 million for the respective standards, when the ring bank finishes where there is the shortest connection between the Buller River and the Orowaiti. Decreasing the ring bank further to the outskirts of the town, reduces costs by around $2 million and $3 ½ million respectively.

Increasing the area protected on the west side of the Buller River adds $ 1 ½ million and $2 ¼ million respectively.

The estimated costs of the mixed standard options are $18.9 million for the town ring bank finishing at the shortest connection point, and $17 ½ million for the town only ring bank. This excludes Snodgrass and includes the Carter's extension.

The later cost is, thus, virtually the same as for the original LTP proposal.

The planting costs for the re-vegetation option at Organs Island have been based on an initial planting of bands of native plants alongside the existing riparian vegetation by the Buller River channel, and the old channel and overflow area, with two connecting corridors. The aim is to allow a natural spread from these sources, with a progressive reduction in farm grazing over time, as the native vegetation becomes established. The cost of this planting, as shown on Figure 14, is 1 ½ million.

5.3 OPTION COSTS for RIVER WORKS

The cost estimates for the flood damage repair works have been determined from the site surveys and design parameters for rock works along river banks. These estimates, as given in the cost spreadsheets, give a combined total of $3.3 million, as shown on Figure 15.

The total estimated cost of proposed flood mitigation measures as shown on Figure 16, for an Inland Embankment option, the Organs Island revegetation and the rock repair works, is just under $24 million. A round budget figure for this proposal would then be $25 million.

6 CONSTRUCTION

6.1 STAGING

A preliminary staging of the flood defences has been based on a qualitative assessment of risk. The approach taken considers the risk matrix of likelihood of occurrence and consequences of occurrence, plus a consideration of constructability, or relative ease of construction. This approach has been applied for prioritisation in New Zealand, and follows international practices.

The sections used for the staging assessment are shown on Figure 17, which are similar to the contract sections used in the cost estimation, but with some further subdivision.

A reasonable timeframe for constructing the defence system would be 3 construction seasons. This depends, of course, on the availability of suitable contractors, and the general commitments of contractors on the West Coast and around New Zealand generally. It also assumes that machine repair and material shortages do not affect construction.

The materials for the flood defences are, though, on-site or locally available, being river sourced crushed gravel and directly obtained silt for the stopbanks, and timber piles and boards for the walls and/or concrete with reinforcing.

The rock works for the Buller River banks would also be constructed from locally sourced rock.

A staging of all the proposed scheme works for the Reduced Area ring bank option is given in Table 2. This gives a consistent expenditure over the 3 years, while fitting the staging priorities.

6.2 CONSTRUCTABILITY

The flood defences are straightforward works to construct. The stopbanks would be constructed using readily available earthmoving equipment. In general, there is plenty of space available for the topsoil stripping and stockpiling; on-site cut to fill from adjacent borrow areas; and importing and spreading the gravel fill. In some places, such as the reserve land beside Orowaiti Road, and at the north end by the rock mounds of the mole construction, silt would have to be obtained off-site and carted to the site. None of this has any engineering difficulties.

The walls would be constructed in relatively confined areas — hence the walls. Another advantage of the timber walls is that the relatively low walls proposed could be built used rubber-tyred tractors of a fencing contractor for the pile driving, and the timber can be easily carted to site. For concrete walls the concrete itself has to be brought to site to pour and cast, and compacted access would have to be constructed (and later removed) to bring Ready-mix trucks to site. Where concrete walls have been proposed there is direct road access to these areas.

The important construction matters that will need careful consideration and explanations to landowners, and the public in general, is the temporary measures required for access and health & safety, as well as the mitigation measures for dust, noise, visual screening, rainfall and sediment runoff during construction, and other such matters. This depends very much on the site, and the contract sections have been based on the different site and confinement issues along the flood defence alignments.

A more detailed assessment of these construction issues and consultation with affected parties should be carried out once a decision has been made on the preferred scheme, and prior to contract tendering. The first stage works, as proposed, are along the Buller River, with one section alongside a public road on reserve land, and the other on farm land, except for the domain length.

Specific engagement on the details of construction can be undertaken in sequence as part of contract preparation, over the 3-year period.

The more general engagement would be part of, or in conjunction with, the consenting process.

There is a length of stopbank by Craddock Drive that could be constructed by the road on the estuary side, or on the inland side where it would cross a small wetland area and then go around the side of the old dump. For the cost estimates the more expensive alignment on the estuary side has been used. In this case, the proposal is to construct a wide bench into the estuary in the high tide zone and plant this area with reeds or grasses suitable for inanga spawning.

This is an example of an ancillary work included to mitigate adverse effects through providing beneficial effects instead. This could be done elsewhere along the estuary. For the stopbank length along the reserve by Orowaiti Road the proposal is to construct a wider gently sloping mound to fit in with the recreational and amenity purposes of the reserve. Here, as well, the estuary side could be sloped down over the high tide zone and planted for amenity and inanga spawning purposes.

Such ancillary works to provide beneficial effects as a compensation for adverse effects has been allowed for in the cost estimates for all sections of the flood defences.

As well as the flood defences themselves, there are other works required, principally drain/stormwater outlets and road/access crossings.

The drain outlets are standard structures of concrete pipes and headwalls, with a backflow preventing flapgate on the outer exit. They are constructed prior to the embankment construction, in sequence as construction progresses. Their construction requires excavators to prepare the site and lift the concrete elements into place, but this activity is very localised to the site, and the embankment covers the outlet except for its ends.

The outlets of the Westport stormwater system that require flapgates or backflow valves have been identified. As part of the preferred scheme these mechanisms would be added to the pipe outlets. Again, this involves some very localised activity at the pipe ends.

The road crossings are not that expensive to construct, but there would be significant traffic issues during construction, especially for main streets and roads. These would also be one railway crossing, which would require close coordination with KiwiRail.

6.2 CONSTRUCTION FOOTPRINT

The economic costs of construction only cover the financial requirements of the proposals. There are a number of ways of measuring the wider external footprint of construction activities. The most comprehensive would be an ecological footprint assessment. More common, especially for engineering and general construction activities, is an energy audit, which assesses the lifetime energy requirements of different materials, construction methodologies and the use and maintenance of products, facilities or buildings.

Different approaches are taken for these assessments, with some being limited to the materials or activities themselves and their input/output flows, while others are more comprehensive in taking account of the back linkages to supporting facilities and infrastructure.

A carbon footprint assessment is a subset of an energy audit, which focuses on the carbon cycle. This can be simply a off-gassing assessment, or it can be more comprehensive and take account of the carbon sink effects as well as the carbon source effects.

As an engineering assessment, a broad qualitative energy footprint can be considered for the proposed structural works of the proposal, as compared to non-structural measures that limit risks or alter vulnerabilities.

Re-directing activities and urban development to places less at risk from natural hazards has an energy impact through differences in construction and building techniques at these places, compared to that on the flat alluvial land of the Westport area.

Re-locating existing housing, commercial buildings and urban infrastructure has a very large energy impact, compared to staying in place. Raising dwellings may, or may not, be more efficient than re-locating them. This depends on the servicing requirements of the re-location site, and the inefficiencies that may arise at the existing site. Piecemeal raising of houses can be disruptive (of services and amenity), while being a slow and inefficient way of reducing both risk and energy requirements.

Abandoning an area, as in red zoning, also has large energy costs in demolition and rehabilitation, as well as requiring the energy for full re-building elsewhere.

The energy requirements (and carbon footprint) of the construction of flood defences are very low compared to these non-structural alternatives, with the possible exception of re-zoning new development. However, this re-direction of new development does nothing for the existing development and its vulnerability. Neither does it reduce future flood damages of the existing development and the costs (economic and social or energy) of recovery.

Flood defences are, generally, very inexpensive compared to the assets they protect, in economic cost or energy terms. This is why they are so frequently used, extended and upgraded.

Their carbon footprint is, thus, also low compared to alternatives.

Non-structural measures clearly have a role to play in reducing vulnerabilities and making mitigation measures easier to implement, but they raise many questions about both short and long-term impacts and unforeseen consequences.

When compared with structural measures, a well investigated multi-objective assessment should be undertaken, which at least covers all of the foreseeable consequences.

7 MAINTENANCE

7.1 STRUCTURAL FAILURE

All flood defences can be overtopped by a larger than design event. In the Westport case, the hydraulic modelling of overtopping, based on a RCP6 scenario for an historical standard, and a RCP8.5 scenario for a RCP6 standard, shows that the flooding which would occur would be no worse than for the existing situation.

Ponded floodwater inside the ring bank could be released after the flood event by opening up a gap in the defences. The logical first place for this would be the embankment by the estuary at Craddock Drive. This would drain the low lying areas, and directly to the estuary where the embankment would have a particularly wide base below tide levels.

However, flooding behind flood defences occurs more often from structural failures than from overtopping. A breach failure gives rise to concentrated outflows, with high velocities and turbulence. These flood flows are, therefore, more dangerous to people and more destructive of buildings and other assets.

The proposed Westport flood defences are relatively low. As noted above, this is because significant flooding only occurs in rare events, particularly for the main centre of Westport, due to the size of the Buller River channel and the power of its flood flows, and the well-defined overflow path to the Orowaiti estuary.

The main risk of breach is from undermining due to lateral erosion of the river banks by floodwaters in the Buller River channel. A 2 m high, 4 m crest width stopbank is a very robust flood defence, if not undermined. Seepage and slope failures are not an issue, unless there are exceptionally poor ground conditions. Shallow overflows (of under 0.5 m deep) can also take place for hours without any substantial damage to this stopbank structure.

Flood defence walls are not as robust, and they must be designed to withstand overturning and sliding failure. The double timber walls would be the most secure from structure failures, as they would have higher in-built (not designed for) safety factors due to the cross bracing and earth fill width.

The hazard from structural failures and overdesign events is, thus, relatively low for flood defence schemes.

7.2 STRUCTURE MAINTENANCE

An estimate of on-going maintenance and repair costs has been made on a generalised basis using percentages of the capital costs.

Earth stopbanks are taken to be earth formations that are maintained and not depreciated. The main maintenance is in keeping a good turf cover, without over-grazing or rutting of the crest by animal or vehicle movements. Cattle should be kept off the stopbanks when there are wet sub-surface conditions. The gravel core of the banks will, though, provide a free draining base and would resist surface rutting penetration. Additions for access would be treated similarly, with the road surface maintenance being the responsibility of the landowner.

Walls and outlet structures, including flapgates and backflow values, would be depreciated. Timber walls would be depreciated faster than concrete walls, but the wall facing boards can be repaired or replaced on an as-required basis, without a full reconstruction. Fences would also be depreciated. Where they are boundary fences then the maintenance would be shared.

The operation and maintenance estimates are given in the cost spreadsheets for the options costed. The estimated cost of annual maintenance and averaged annual costs for depreciation repairs/replacements and for flood damages, for a Reduced Area ring bank option, is $350,000. Most of this cost would be allowances for depreciation and repairs.

Once a decision is made on the preferred alignment and standard, a more detailed estimate should be made of the operation and maintenance costs as well as the capital costs. This should be based on an asset schedule for the preferred scheme.

7.3 ADAPTABILITY

The flood defences are simple structures that can be added to if there is sufficient space. Where they are on private land, the land agreement should cover a vehicle access way where there are walls, as well as the footprint of the wall and a potential height increase. For stopbanks the access footprint should extend beyond the embankment itself to include the adjacent scheme fencing and sufficient space for access alongside the stopbank.

The stopbank could be raised by building out and up, or where space is limited by constructing a (low) wall on the outer side of the crest, allowing walking and 4-wheeler access along the inside.

The structures are, thus, easily added to, as well as easily maintained. As low embankments and walls they are robust, and can accommodate earthquake movement and liquefaction, or be easily repaired. They can also accommodate overflows from flood events or tsunamis.

7.4 RIVER MANAGEMENT

Managing the Buller River to keep its active channel away from the flood defences is the long-term most challenging task.

An estimate of the bank protection costs has been made on a rough-order basis using the construction costs at present day prices of the rock works in place along the river. The extent of some works is known, but there may be other old works that are covered by vegetation, and could fail in a future flood event. These works are shown on Figure 18, with identified lengths and potential other lengths based on the channel form and outer bank pressures areas.

The estimated cost of annual maintenance and averaged annual costs for flood damages, for river management measures, is $300,000. Most of this annual cost would be for a flood reserve fund, which would be called on only intermittently, with the larger expenditures being after severe flood events.

The full extent of rock works and any other protection measures that would require maintenance, such as along the old harbour wharf, should be identified and recorded. They would then be assets of the scheme.

8 CONCLUSIONS

8.1 FLOOD DEFENCES

The assessment of flood defence measures for Westport started with the proposals of the WCRC LTP. An intensive investigation of flood risks and mitigation measures has been undertaken, with hydraulic modelling of flood depths, velocities, and hazard status for a range of alternative flood defence alignments and protection standards. This has covered both river and sea flooding. The differences between the options and their relative impacts have been demonstrated through difference maps, and flood spread modelling.

The construction methods and construction effects of stopbank and wall defences has been assessed, and cost estimates determined for all the modelled options. The longer-term risks and resilience of the options have also been considered, taking account of other natural hazards, including groundwater levels and liquefaction, earthquakes and dam burst flooding, and tsunamis.

The estimated costs of the options considered range from $16 million to $26 million (at present day prices).

8.2 RIVER MANAGEMENT

The recent flood events have highlighted the requirement for bank protection measures along the Buller River, as well as structural measures to mitigate flooding in Westport. Significant flood damage occurred to rock protection works in two places, with bank erosion extending off a rock lining in another place.

These sites have been surveyed and restoration rock works designed for the sites. The combined cost of these repairs, estimated on a tendering basis, is $3.3 million.

8.3 FLOOD MITIGATION SCHEME

The investigations undertaken allow a flood mitigation scheme to be proposed for the Westport area, based on a number of alternative alignments and protection standards. The costs and benefits will vary for the different options, but a selection process has been undertaken by the TAG in terms of risk and hydraulic effectiveness, considering the relative likelihood of flooding, the consequences of flooding and construction implications, including temporary construction impacts.

A mid-range scheme would have a total construction cost of around $25 million.

The potential on-going costs of flood damage repairs and structural maintenance has been roughly estimated for such a scheme at $650,000 on an average annual basis.

Engineering fees have been included in these cost estimates. However, consenting issues and the professional fee costs of a consent process have not been considered, and are not covered by the estimates.

Once a decision is made on the preferred alignment and standard, a more detailed cost exercise should be undertaken, to firm up the cost of this alternative, as the flood mitigation scheme to be taken forward. The costs of landowner agreements should be re-assessed as well, given firm commitments to specific alignments.

June 2022 G J Williams
Water & Soil Engineer

G & E Williams Consultants Ltd,
R D 3,
OTAKI. (06) 3626684

REFERENCES

1. Gardner, M. 2015: Buller River — Hydraulic Modelling Study. Land River Sea Consulting Ltd, Christchurch.
2. Gardner, M. 2020: Buller River — Assessment of Potential Impacts of Gravel Buildup. Land River Sea Consulting Ltd, Christchurch.
3. Gardner, M. & Williams, G.J. 2021: Buller River Gravel Extraction Recommendations. Land River Sea Consulting Ltd, Christchurch.
4. Gardner, M. 2022: Buller River — Flood Mitigation Options Assessment. Land River Sea Consulting Ltd, Christchurch.
5. Gardner, M. 2022: Westport Community Engagement Presentation. Land River Sea Consulting Ltd, Christchurch.
6. Williams, S. et al. 2022: Direct Damage Analysis for Scenario Flooding in Westport. NIWA, Christchurch.

ATTACHMENT 1

TABLES

		Table
FLOOD DEFENCES — OPTION COSTS	(Summary)	1
SCHEME — 3 YEAR PROGRAM	(Staging)	2

FIGURES

		Figure
LOCATION PLAN		1
FLOOD DEFENCE SECTIONS	(Stopbank and Wall cross-sections)	2
COST ESTIMATION	(Estimation sections and Wall locations)	3
COSTS — COUNCIL LTP — Historical 100-year standard		4
COSTS — LTP excluding Snodgrass — Historical 100-year standard		5
COSTS — REDUCED AREA + Airport — Historical 100-year standard		6
COSTS — COUNCIL LTP — RCP6 100-year standard		7
COSTS — LTP excluding Snodgrass — RCP6 100-year standard		8
COSTS — REDUCED AREA + Airport — RCP6 100-year standard		9
COSTS — REDUCED AREA + Airport — RCP8.5 100-year standard		10
COSTS — TOWN RING BANK + Airport — RCP6 100-year standard		11
COSTS — REDUCED AREA + Airport — Mixed 100-year standard		12
COSTS — TOWN RING BANK + Airport — Mixed 100-year standard		13
COSTS — ORGANS ISLAND — Retirement		14
COSTS — BANK PROTECTION WORKS — Flood Repairs		15
COSTS — POTENTIAL SCHEME — Reduced Area + River management		16
STAGING — REDUCED AREA + Airport — Mixed 100-year standard		17