MAYORAL FLOOD TASKFORCE

Final Report Part C Appendix A: Temporary Flood Defence Options

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Appendix A Table of Contents

This appendix includes the toolbox of temporary flood defence measures used by the flood taskforce, including house defence, maintenance and local area schemes, as follows:

House defence measures

What is a house defence measure?

House defence measures are property specific responses which aim to help prevent house damage from floor level flooding. The measures can be either temporary or permanent and may involve physical changes to the house (e.g. house raising or house tanking) or installing flood barriers on the property. These options do not stop flooding but aim to prevent house damage from flooding.

These measures protect individual houses from flooding and are detailed on the following pages. These include:

- House raising
- House tanking
- Property re-grading
- Sand bagging
- Relocation

House raising

What is it?

House raising is the physical lifting of the house to raise the lowest floor level above the recommended flood protection level.

What does it involve?

The house is lifted, the existing foundations are removed, a new higher foundation is installed and the house is lowered back onto the new foundations.

Essentially, a new foundation will be constructed so that when the house is replaced, the floor level is above the recommended flood protection level. There are various methods of jacking a house.

Before a house is raised, a geotechnical report will be undertaken so that the new foundation requirements can be assessed.

Buildings can be lifted up to 3 metres high to allow unimpeded access under the building. The foundations of the building are then broken up and removed with small excavators. The natural ground can then be stabilised if required and a new foundation or concrete slab installed. The building is then simply lowered back on to the new foundation and secured.

It takes about 14 days to lift a 200-square-metre house, remove and replace the damaged foundation slab and lower the building.

Solution lifetime	Permanent
Effect on flood risk	This solution reduces risk of flooding within houses as the floor level is raised; however, flood water can still be present below and around the house
Implementation timeframe	3- 6 months Industry-led approach can reduce the overall timeframe and can at peak achieve up to 20 houses a month
Positives	▪ Flood risk alleviated
Negatives	▪ Consent required ▪ May breach recession planes ▪ Could affect street appeal for other residents – this should be considered ▪ Expensive and large cost variation dependent on construction type
Constraints	House and ground conditions must be checked to confirm the suitability of a house raise for each particular house. In addition, consent must be granted by the local authority. It may require offsite storage, security and temporary relocation of houses.
Implementation prerequisites	Geotechnical report and consent

House tanking

What is it?

House 'tanking' is the application of a layer of material to a wall, door or floor to increase its resistance to water entry.

What does it involve?

Walls/Floors - Water resistant paints and coatings are applied to a height of 0.9 m above ground level. This helps to prevent soaking of the wall and allow it to dry out more quickly. The applied material is compatible with the existing wall materials and is 'breathable' on at least one face of the wall to allow water vapour to escape from the wall in the future. If your property has been flooded it is important to ensure that the walls and floors are returned to pre-flood condition before any surface treatment is applied.

Doors - Flood board systems are fitted into a frame surrounding the door. During storms flood boards must be deployed by the homeowner, fitting them into the frames in order to protect apertures.

Ventilation - In a flooding event, underfloor ventilation and airbricks can be a major source of water ingress. To alleviate this, airbrick covers prevent flood water entering into or underneath the house. There are manual and automatic kits.

Pumping - The final pieces of the 'tanking' solution take the form of non-return valves and submersible pumps to remove any flood water.

Solution lifetime	Waterproofing of walls - Permanent All other measures – Temporary (during expected flood event only)
Effect on flood risk	This solution reduces risk of flooding within and below houses; however, flood water can still be present around the house
Implementation timeframe	Within 3 months
Positives	▪ Habitable floor flood protection ▪ Cheap to implement at property level ▪ Quick to install
Negatives	▪ Requires stakeholder engagement ▪ Some solutions not aesthetically pleasing ▪ New technology in New Zealand
Constraints	Time for supply of materials – 3 to 8 weeks Will need to ensure compliance with building code
Implementation prerequisites	It is necessary to understand the recent mechanism of flooding. Solutions will be site specific for property type and construction. Property owner education and information on 'What is house tanking' and what it involves will be provided.

Property re-grading

What is it?

Property re-grading involves changing the grade or slope of a property section to help floodwater flow away from a house.

What does it involve?

Before beginning to alter the slope, investigation and some design must be undertaken to understand how a property floods and the implications of redirecting water elsewhere.

The property section will be examined for depressed areas where water may pool as it drains. Soil type and conditions will be reviewed, as water is more likely to drain faster on a clay-based soil than on sand-based or loam-based soil.

Before physical works begin, the property section will be reviewed against 'service plans' to check for electrical, telephone, water or sewerage locations.

The high and low points of the section will be identified. The high point should be the point nearest your home's foundation. The lowest point should be where your water drains to.

The slope will be altered by one of three methods:

- Remove soil from the lower point of your slope.
- Add soil to the high point.
- Move existing soil from the low point to the high point.

Solution lifetime	Permanent
Effect on flood risk	Keeps flood water out of property. Provides an element of protection and would usually be in conjunction with some form of additional property level protection such as tanking.
Implementation timeframe	This is largely dependent on the size and nature of the property section. However, works can generally be undertaken imminently.
Positives	▪ Habitable floor flood protection ▪ Cheap to implement at property level ▪ Can be made to look good and blend in with surroundings ▪ Quick to install
Negatives	▪ Requires property owner buy in ▪ Can impact neighbour's property – the water will have to drain some somewhere else
Constraints	Will only be practical in some situations
Implementation prerequisites	Understand maximum flood levels and implications to neighboring properties by altering footprint levels

Sand-bagging

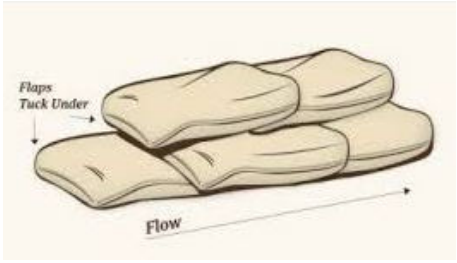
What is it?

Sandbagging on properties involves erecting a physical barrier or wall to help prevent floodwaters entering a house.

What does it involve?

Sandbagging involves creating a temporary wall/barrier to help prevent floodwater from entering a house. Traditionally this involved hessian sacks filled with sand layered on top of each other. Modern methods of 'sandbagging' or physical barriers include:

- Sandbags
- Earth bunds
- Asphalt bunds
- Hydro-snake
- Water-gate
- Water filled tubes (aqua barriers)



Solution lifetime	▪ Sand bags – Temporary, short term installation ▪ Earth bunds – Temporary, re-graded on completion of permanent solution ▪ Asphalt bunds – Temporary, removed on completion of permanent solution ▪ Hydro-snake – Temporary, product retains its bulk for three months once exposed to water, alternative to sandbags ▪ Water filled tubes (aqua barriers / watergate) – Periodic, installed only when flood warning is in place. Can be used multiple times.
Effect on flood risk	Keeps the majority of flood water out of the area it surrounds
Implementation timeframe	0-3 months, materials available quickly in most cases
Positives	▪ Can be implemented quickly ▪ Materials readily available ▪ Flood risk reduced ▪ Diversion of flow paths
Negatives	▪ Home owners may need to deploy prior to storm across entrance ▪ Access issues once installed ▪ Disposal of asphalt material
Constraints	▪ Resulting diversion of overland flow to be considered ▪ Access to private property ▪ Require storage in advance of flood event ▪ Some bunds may require building consent
Implementation prerequisites	▪ Owner and maintenance team acceptance ▪ Peak flood height needs to be determined ▪ Temporary defences can be installed on warning of flood event

Relocation

What is it?

Relocation involves temporary or permanent relocation of the property owner to new accommodation when their house is considered uninhabitable.

What does it involve?

In those cases where an engineering solution is not viable, or the house is considered uninhabitable, voluntary relocation could be considered. Agencies may consider providing funding to support residents who are already paying a mortgage and who have growing insurance costs. Options include:

Buy Back

Offers to purchase affected properties at an agreed value (or GV). The owner is given the first right to purchase the property back at purchase price after a long term engineering solution is successfully implemented in the area.

Temporary Village

A temporary village is built similar to the temporary village in Linwood Park and the University of Canterbury. The village would consist of three and/or four bedroom houses on Council or Crown owned land (yet to be identified). The property would then be let to the affected residents at no cost until the flood mitigation works are completed

Agency Finds Agency Pays

Agencies could source and secure suitable rental accommodations on a "similar replacement" basis, as practical as possible, to relocate affected property owners. Agencies could guarantee the rent for the next two years or until a long term engineering solution is delivered to remedy the issue. Affected property owners would continue to be responsible for the ongoing mortgage repayments, if any and maintenance costs of their properties during the tenancy including Tenancy Bond payments.

Resident Finds Agency Pays

A lump sum of financial support provided to the affected property owners that is equivalent to a market rental of a three bedroom house in Christchurch. Market rent could be determined and based on Ministry of Building, Innovation and Employment (MBIE)'s latest publication of rental price on its official website. Affected property owners will be responsible for finding suitable rental accommodation themselves. Affected property owners would continue to be responsible for the ongoing mortgage repayments (if any) and maintenance costs of their properties during the tenancy including Tenancy Bond payments.

Solution lifetime	Temporary relocation will continue until the long term engineering solution is fully implemented in each area.
Effect on flood risk	Household is entirely removed from the flood prone area
Implementation timeframe	Buy back – three months Temporary village – eight months Agency finds, agency pays – emergency / immediate Resident finds, agency pays - immediate
Positives	**Buy Back** – Immediate relief (financial and wellbeing) of household. **Temporary Village** – Community group stays together. Removes the stress from the resident of finding alternative accommodation solution as agencies will provide this. Agency finds, agency pays - Removes stress of household finding a solution. Resident finds, agency pays – Immediate relief (financial and wellbeing) of

	household.
Negatives	▪ Operational costs (care of property) and house protection to be included in costings to protect assets for the duration of the project ▪ Potential creation of a fragmented community needs to be monitored. All residents (staying and leaving) will need support structures to help with transition ▪ Increased risk of crime and vandalism in abandoned homes
Constraints	Voluntary relocation dependent on household decision
Implementation prerequisites	**Buy back** / **Rental options**- Confirmation of rental and housing market capacity. **Temporary Village** - Confirmation of resource to build within time frame

Maintenance measures

Maintenance measures are operational responses before, during and post flooding events to ensure that the network performs as designed. In this regard the Christchurch City Council Maintenance of Waterways and Land Drainage and the Road Maintenance Contracts are key instruments in maintaining the performance of the network and its ability to cope with storm events.

There are four road maintenance and one waterways and land drainage maintenance contracts covering the greater Christchurch area, including Banks Peninsula.

The road maintenance contract includes:

- Street cleaning
- Cleaning pipes
- Cleaning sumps

The waterways and land drainage contract comprises the following primary categories:

- General waterways maintenance
- River maintenance
- Stormwater reticulation maintenance
- Tributary & utility waterway maintenance
- Waterway maintenance items
- Stormwater reticulation and backflow control valve maintenance
- Supplementary maintenance information

The specimen design mitigation measures identified from the maintenance contracts primarily comprise clearing, cleaning, repair or replacement as appropriate of the following:

- Grates or screens
- Pipes
- Streets
- Sumps
- Obstructions
- Check backflow

More detailed descriptions of the foregoing specimen designs are provided in the following sections. Maintenance measures need to be considered within the context of the larger catchment maintenance to achieve cost efficiency.

Clear grates or screens

What is it?

Clearing grates or screens involves the physical removal of debris and silt from drainage grates and screens.

What does it involve?

The existing land drainage maintenance contracts provide for the regular cleaning of grates and screens on channels and waterways.

This mitigation measure requires an increase in the frequency of these scheduled cleaning events. It also needs to result in an increase in the scope of work to include structures and other intrusions into the waterways that trap and collect debris during periods of higher flows. These may not be included in the current scope of work.

It should also include implementing cleaning and condition inspections in response to forecast adverse weather warnings.

Solution lifetime	Contract frequency
Effect on flood risk	Risk reduction
Implementation timeframe	0-3 months – current maintenance contract states the frequency and scope of cleaning. The contract includes provisions for increasing the frequency at the contract rate but this will increase annual maintenance costs.
Positives	▪ An increased frequency of cleaning will reduce the effort to clean each grate or screen as the amount of debris collected will be less. ▪ Increased frequency of cleaning will provide improved confidence that the maximum catchment capacity will be available for most of the time.
Negatives	May require maintenance contractor to increase resources to meet short term requirements of increase in activity frequency. Potential overrun of budget over total term of contract.
Constraints	Funding
Implementation prerequisites	Approval to expand scope of work and frequency of activities, with associated additional budget for existing maintenance contracts

Clear pipes

What is it?

Clearing pipes involves the physical removal of debris and/or silt from drainage pipes, typically by jetting and trucking debris away.

What does it involve?

The existing land drainage maintenance contracts provide for the regular cleaning of specified storm water pipes with a primary focus on the main lines that discharge flows from to waterways.

This mitigation measure requires an increase in the scope of the maintenance contracts in terms of both frequency and type of activity to capture the jetting and removal of sediment from all the pipelines in the storm water network. It should also be combined with implementing cleaning and condition inspections in response to forecast adverse weather warnings.

Ensuring that a pipeline is maintained in clean condition along its full length from the curbside sumps to the point of discharge at an open waterway is critical if the maximum design capacity of the system is to be utilised.

Solution lifetime	Periodic
Effect on flood risk	Risk reduction
Implementation timeframe	0-3 months
Positives	Commercial contract conditions are in place enabling changes to the scope and cost to be readily defined and approved.
Negatives	Application of scheduled rates to longer lengths of different size pipes may not be appropriate and it may be necessary or desirable to negotiate mutually acceptable rates with the incumbent contractors
Constraints	Insufficient jetting equipment available. Additional funding required.
Implementation prerequisites	Council amendment to maintenance contract.

Clear streets

What is it?

Clearing streets involves the physical removal of debris and/or silt from road drainage and dish channels.

What does it involve?

The existing council road maintenance contracts provide for the regular cleaning of streets.

The frequency of cleaning is dependent on the road profile. Roads with dish channels are typically cleaned monthly for and once every six weeks for roads with kerb and channel. This mitigation measure requires an increase in the frequency of these scheduled cleaning events.

In addition to the increase in frequency of road cleaning, this mitigation measure provides for increasing street cleaning post flooding cleaning.

Solution lifetime	Periodic
Effect on flood risk	Risk reduction
Implementation timeframe	0-3 months
Positives	▪ Immediate implementation under the existing maintenance contracts ▪ Improvement in river water qualiity
Negatives	▪ Requires additional funding and increase to budget for maintenance contracts. ▪ Increase to scheduled frequency and the number of post event cleans may be under or over estimated.
Constraints	Limitation on available resources to carry out increased street cleaning work. i.e. road sweepers and operators
Implementation prerequisites	Council amendment to maintenance contract

Clear sumps

What is it?

Clearing sumps involves the physical removal of debris and/or silt from road sumps typically involving jetting and trucking away.

What does it involve?

The existing council road maintenance contracts provide for the regular cleaning of road sumps with a frequency related to the road profile.

Typically sumps are cleared every six months or whenever further clearing is identified. This mitigation measure requires an increase in the frequency of these scheduled cleaning events.

In addition to the increase in frequency, this mitigation measure provides for increasing sump clearing post flooding.

Solution lifetime	Periodic
Effect on flood risk	Risk reduction
Implementation timeframe	0-3 months
Positives	▪ Immediate implementation under the existing maintenance contracts ▪ Water quality benefits
Negatives	▪ Requires additional funding and increase to budget for maintenance contracts ▪ Increase to scheduled frequency and the number of post event cleans may be under or over estimated
Constraints	Limitation on available resources to carry out increased street cleaning work. i.e. road sweepers and operators
Implementation prerequisites	Council amendment to maintenance contract

Clear obstructions

What is it?

Clearing obstructions involves the physical removal and clearing of debris from waterways and channels.

What does it involve?

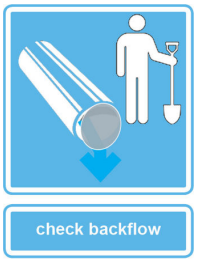
This mitigation measure utilises the scope and provisions of the existing land drainage maintenance contracts to carry out this work.

This mitigation measure requires an increase in the frequency of inspections of the waterways and channels, with a focus on locations where debris is known to collect and to remove the debris as quickly and efficiently as possible.

The scope of work includes an increase in the scheduled frequency of cleaning activities at specified locations combined with implementing cleaning and condition inspections in response to forecast adverse weather warnings.

Solution lifetime	Periodic
Effect on flood risk	Risk reduction
Implementation timeframe	0-3 months
Positives	Immediate implementation through Task Orders under the provisions and terms of the existing maintenance contracts
Negatives	May require the deployment of resources outside of normal working hours under the provisions of emergency response.
Constraints	Some areas may require more extensive clearing than others which will require the commitment of crews for longer periods of time, resulting in reprioritization of other works.
Implementation prerequisites	Council to issue Task Orders

Check backflow prevention devices



What is it?

This includes the locating, inspection, cleaning and repair/replacement of back flow prevention devices in the storm water network with a particular focus on the areas prone to flooding.

What does it involve?

The existing land drainage maintenance contracts provide for the regular cleaning of flap gates and other backflow prevention devices installed in the storm water pipe network.

This scope of work requires a review of plans and historic data followed by site inspections and investigations to confirm the location, condition and operational function of the backflow prevention devices in the storm water network.

There is a high probability that the condition and operability of a large number of these devices has been impacted by the effects of the earthquakes and therefore the extent of work required to return these assets to a serviceable condition will vary across the city. This work may result in replacement of an asset as being the most cost effective option.

Solution lifetime	Contract frequency
Effect on flood risk	Risk reduction
Implementation timeframe	0- 6 months – current maintenance contract provides for frequency and scope of inspection and cleaning
Positives	An increased frequency of inspection, cleaning and maintenance of the backflow prevention devices will result in a definitive reduction in the risk of the backflow of sediment laden storm water clogging the network system and contributing to the flooding of streets and properties.
Negatives	May require maintenance contractor to increase resources to meet short term requirements to fulfil contract requirements. Potential overrun of budget over total term of contract.
Constraints	Funding
Implementation prerequisites	Approval to expand scope of work and frequency of activities, with associated additional budget for existing maintenance contracts

Local area schemes

What is a local area scheme?

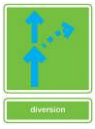
Local area schemes are flooding risk reduction measures which are implemented over an area to help prevent flooding at multiple properties. The measures can be temporary or permanent and may involve physical changes to Council assets and/or private property. They may also involve enforcement of District and Regional Plan policies. The local area schemes will typically involve multiple risk reduction measures. These options do not stop all flooding but aim to reduce above floor level flood damage to multiple properties.

These measures protect multiple houses from flooding and are detailed on the following pages. These include:

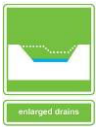
- Local bunding

- Debris screens

- Diversions

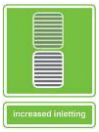


- Enlarged drains

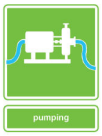


- Flap gates

- Increased inletting



- Pumping



- Raise existing stopbanks

- Sand bags - street

- Secondary flood paths

- Setback enforcement

- Dredging

- Temporary bridges

- Temporary surface storage

- Traffic management

Local bunding

What is it?

Local bunding involves erecting a physical barrier or wall to help prevent floodwaters entering an area or multiple properties.

What does it involve?

Local bunding can be constructed as part of a local flooding solution to provide additional defense against flooding at a catchment level. Flood waters are held back or redirected using a range of traditional and proprietary methods. Bunds can be installed as temporary removable barrier or installed when a flood risk is present.

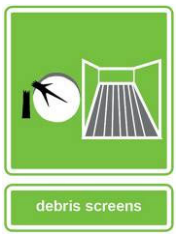
Local bunding can be split into two categories: below 300mm, and from 300mm upwards. Bunds over 900mm will require additional specifications such as handrails.

There are multiple methods of local bunding that can be used. These include:

- Sandbags
- Earth bunds
- Asphalt bunds
- Watergates
- Waterfilled tubes
- Geodesign Flood Barrier

Solution lifetime	▪ Sand bags – Temporary, short term installation for low height applications. ▪ Earth, Asphalt bunds – Temporary, re-graded on completion of final solution. Can be used as form of permanent solution. Bunds can be landscaped to suit environment ▪ Watergate, Water filled tubes (Aqua barriers / WIPP) & Water barriers – Periodic, installed only when flood warning in place. Can be used multiple times.
Effect on flood risk	Reduce flood risk to multiple properties. Bunds can be used as part of a permanent solution to reduce the flood risk.
Implementation timeframe	Within 3 months to implement simple low level bunding such as sandbags, earth or asphalt. Proprietary bund systems have a 12 week lead time. Once onshore will be constructed only when required dependent on flood risk.
Positives	▪ Local flood protection reducing flood risk ▪ Some materials readily available ▪ Quick to install ▪ Diversion of known flow paths ▪ Can be implemented as part of a permanent solution (earth / asphalt bunds)
Negatives	▪ Requires stakeholder engagement ▪ Some solutions not aesthetically pleasing ▪ Some new technologies (in New Zealand)
Constraints	▪ Resulting diversion of overland flow to be considered ▪ Access to private property may be prevented ▪ Require storage in advance of flood event ▪ Indicative timescales are up to 12 weeks for delivery of proprietary systems. This could be mitigated by using multiple suppliers.
Implementation prerequisites	Knowledge of the expected height of flood water and the surface type where the bund will be deployed

Debris screens



What is it?

Debris screens involves installing physical screens to prevent large debris from entering the piped drainage network and causing blockages.

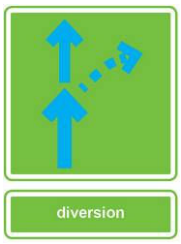
What does it involve?

Installing debris screens is an activity which is typically undertaken by Council Operations and/or Council Maintenance Contractors. Drainage screens can involve grates at the pipe inlet and/or physical barriers upstream of the inlet the reduce blockages.

Installing pre-screens can help reduce further blockages. The pre-screen would be installed at a location which is easily accessible for cleaning during a storm event.

Solution lifetime	Temporary
Effect on flood risk	Risk reduction by minimising blockage and over topping
Implementation timeframe	0-3 months
Positives	Offers better access to clean screens in a storm event
Negatives	Able to be quickly deployed
Constraints	If not monitored could themselves pose blockage risk
Implementation prerequisites	Installation locations need careful consideration for servicing access and the overflow consequences if they become blocked

Diversions



What is it?

Diversions refers to the physical changing (temporary or permanent) of a water flow path to divert it into another area.

What does it involve?

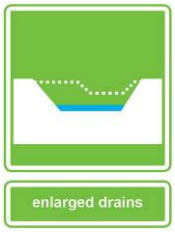
Diversions offer a means of transferring flows away from part of the waterway network or floodplain to another or to a separate system where there is sufficient capacity to convey additional flow.

It is possible to create diversions preemptively by constructing new open channels, or by laying pipes; they can also be formed by lowering berm heights at strategic locations to create spills into areas with capacity to receive water.

Where there is sufficient topography there may be opportunities to lay over-ground piped diversions. These diversions can be implemented immediately ahead of forecasted flooding or left in place. Typically if the pipe is run across the legal road it would need to be brought to site as required to avoid imposing access restrictions. Pipes left in place also run the risk of being damaged or vandalised, risking failure in the event of flooding.

Solution lifetime	Diversions can be implemented as short term measures or where beneficial implemented as part of a permanent solution.
Effect on flood risk	Diversions reduce the risk and severity of flooding
Implementation timeframe	0 – 12 months
Positives	Reduces flood risk and levels
Negatives	Can be implemented pre-emptively or ahead of forecasted flooding
Constraints	Utilises spare capacity within the existing network, potentially negating more extensive works
Implementation prerequisites	Can be used to retain water within the network, affording greater control

Enlarged drains



What is it?

This is the physical deepening or widening of an existing watercourse to improve its hydraulic capacity.

What does it involve?

Enlarging drains typically involves using an excavator to increase the width or depth of an existing watercourse or drain. Channel capacity improvements can increase the conveyance of flood flows through the existing waterway network and depending on scale can be implemented within a short time with the potential of providing a long term, permanent flood risk alleviation.

Channel capacity improvements / enhancements could be categorised as removal or reduction of constraints in the following situations:

- Service crossings, bridges and culverts
- Creating an adjacent flood flow channel to convey flood water
- Implementation of channel re-profiling to enlarge the flow area

Solution lifetime	Channel capacity improvements can provide a permanent or interim solution to flooding problems. For example, channel re-profiling and the removal of constraints can have a permanent impact if implemented in adherence with any long term solutions. They can also be implemented incrementally, for example channel widening can take place with the knowledge that further channel works will be required if immediately implemented larger scale channel re-profiling will impose greater flood risk downstream. Similarly, it is possible to remove culverts or bridges and delay their replacement until the delivery of the permanent solution is implemented.
Effect on flood risk	Channel capacity improvements are a catchment wide solution that, depending on scale, can be very effective at reducing flood risk.
Implementation timeframe	1 week+ (dependent on scale)
Positives	Reduces flood risk probability and severity
Negatives	Works can be targeted at key constrictions to achieve immediate gains
Constraints	Sustainable solution working within the existing environment
Implementation prerequisites	Offers opportunities for social and economic benefits

Flap gates

What is it?

This involves the installation of backflow prevent devices on the stormwater and wastewater drainage network to prevent river or stream flows entering back into the drainage network.

What does it involve?

Flap gates are generally made of cast iron or ductile iron, depending on the type of service. A small differential pressure on the back of the gate causes it to open automatically to allow discharge through levees, sewer lines or drainage conduits.

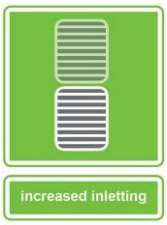
Many flap gates (and their associated pipework) have been damaged as a result of the earthquakes. In addition, due to siltation, ground settlement and the recent flooding, flap gates are 'jammed' open. The result of this is twofold:

- Stormwater backflowing through the drainage network, coming through the road drainage resulting in inundation to property
- Stormwater not draining through the road network as the outfall pipe is effectively blocked, causing flooding to the property.

This measure will install newer inline check valves which can improve the performance of the drainage network and reduce backflows.

Solution lifetime	Permanent
Effect on flood risk	Once the mechanism of flooding is understood, these works can greatly reduce or eliminate flood risk
Implementation timeframe	Within three months
Positives	▪ Increase capacity ▪ Silt management ▪ Backflow management ▪ Reduced flood risk
Negatives	▪ Requires stakeholder engagement ▪ Some are difficult to inspect ▪ Requires access at river level that will need temporary works. ▪ Working in stream beds may require resource consent.
Constraints	▪ An understanding of the condition of the stream is necessary before any works is undertaken. ▪ Digger access will have to be assessed, particularly in narrow streams.
Implementation prerequisites	Resource consent will be required for in river works. The drainage network must be assessed so that any temporary diversions can be implemented to protect the area from flooding in case of heavy rainfall during construction.

Increased inletting



What is it?

Increased inletting is the construction of new drainage inlets into the existing drainage network, where there is existing capacity to help reduce flooding.

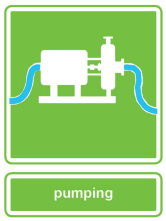
What does it involve?

Where the local stormwater pipe network has additional capacity that is not being utilised, it may be possible to improve drainage through 'increased inletting'. This is the introduction of new sumps at low points that are inadequately serviced or the upgrade of existing single sumps to double sumps were additional inlet capacity would be beneficial.

Increased inletting, and the installation of new sumps, is particularly applicable where there has been differential settlement resulting in new flow path or where roads have been re-graded. It is important that the Stronger Christchurch Infrastructure Rebuild Team (SCIRT) is consulted when considering increased inletting to avoid duplicative or abortive works.

Solution lifetime	The installation of new sumps is a permanent measure but can be used to service a temporary need.
Effect on flood risk	Increased inletting can be effective at reducing pluvial (surface water) flood risk but is dependent on the residual network capacity and the discharge conditions (whether there is a free discharge or submerged outlet).
Implementation timeframe	Within three months
Positives	▪ Can form part of the permanent solution ▪ Low cost ▪ Simple and common practice solution that does not require unique skills ▪ Quick to install
Negatives	Limited by downstream conditions and existing network capacity
Constraints	Capacity limitations of the existing stormwater and waterway network
Implementation prerequisites	▪ Details of SCIRT works in the area ▪ Confirmation of network capacity

Pumping



What is it?

Pumping is the removal of stormwater from one location to another location via a mechanical pump to help reduce flooding.

What does it involve?

Pumping involves the temporary deployment of stormwater pumps to assist in a major weather event to provide temporary storm water pumping at catchment hotspots. This could be either pumping past obstructions within the storm water network or by targeting areas where water ponds and pumping them away.

Smaller pumping could also be used in conjunction with house protection measures (i.e. sandbags or house tanking) to manage any potential leakage through the barriers.

Solution lifetime	Event specific. Periodic.
Effect on flood risk	▪ Small scale: good risk reduction in supplementation to protection works. ▪ Large scale: good risk reduction to street or catchment level, depending on application.
Implementation timeframe	▪ Small scale: 0-3 months ▪ Large scale bypass: 0-6 months
Positives	▪ Quickly mobilised following event notification ▪ Low cost of preparation works for utilisation ▪ Can be applied at immediate location of need ▪ Self-powered units available, removing risk of power requirement in storm event
Negatives	▪ Local disruption due to above ground hosing ▪ Catchment application would be ineffectual in a major event
Constraints	▪ Area pumping solutions would be best solved with large pumps (1cum/s). These units are currently have limited availability in the NZ market, and if ordered from international suppliers would be 12+ week lead time. ▪ Ensure local units are available for use within the 48hr notice period
Implementation prerequisites	▪ Establishment of pump pickup location ▪ Development and implementation of a flooding management plan identifying exact pumping needs at specific locations ▪ Establishment of deployment plan identifying pump locations and site specific requirements i.e. hosing run lengths and locations

Raise existing stop banks

What is it?

Raising existing stop banks is the physical raising of the height of a stopbank to help protect against river flooding.

What does it involve?

Stopbank raising can be undertaken in a number of ways and the methodology will be dependent on the original state of the bank, its current environment and needs such as ecological issues.

Stopbank raising is effective in quickly raising the river banks to prevent flooding either due to non performance of stopbanks or at times when a higher river or tidal effect is anticipated.

Solution lifetime	Raising of stopbanks by increased earth bunding or by use of culvert bags has been shown to have a lifetime of some two to three years. Some maintenance may be required to check these areas and top up levels if settlement or further earthquakes continue.
Effect on flood risk	This technique can eliminate or reduce flood risk if undertaken in the right areas
Implementation timeframe	▪ Earth bunding within three months ▪ Sandbagging / culvert bags within a few days
Positives	▪ Quick to install ▪ Cheap to implement where a number of properties are collectively at risk ▪ Can be vegetated over time
Negatives	▪ Some stopbank areas not aesthetically pleasing ▪ Potential loss of roading, cycling and walking amenity ▪ Can remove vegetation growth unless planting is done ▪ May not be able to be used where dense trees are present or ecological issues are encountered ▪ May crush underground water networks and damage outfalls
Constraints	▪ Access to stopbank areas ▪ Thick vegetation and trees ▪ Location of existing manholes, pump stations, outfalls or bridges ▪ Unstable banks or soft alluvial areas
Implementation prerequisites	It is necessary to understand the stability of the stopbank, ecological issues, locations of underground water infrastructure and outfalls and predicted flood levels. A resource consent may be required.

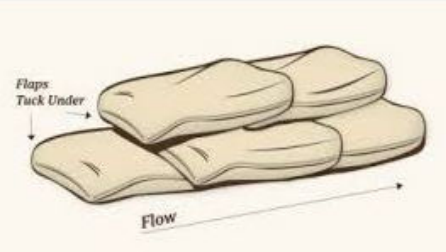
Street sand bagging

What is it?

This is the placement of sandbags for bunding, flow diversion and bow wave dissipation to help prevent flooding property floor levels.

What does it involve?

Sandbags can be laid at the perimeter of a building footprint or as part of larger solution at the property boundary. These are a simple solution are best used for diverting surface flow as over time water will penetrate through the bags. The performance of the bund can be improved by covering the sandbags with a plastic membrane.



Solution lifetime	Given the deterioration of the bags when wet, the solution can only be considered a temporary measure. Wet bags can be replaced to ensure that there is an element of flood defense present.
Effect on flood risk	Can be considered a temporary measure to divert flows and / or protect houses
Implementation timeframe	There is a stock of some 5,000 sandbags that can be mobilised immediately. Additional bags can be made as required, although an element of planning should be undertaken when a flood warning is in place.
Positives	▪ Can be implemented quickly ▪ Materials readily available ▪ Flood risk reduced ▪ Diversion of flow paths ▪ Can be part of permanent solution
Negatives	▪ Home owners may need to deploy prior to storm across entrances ▪ Access issues once installed ▪ Disposal of contaminated material
Constraints	Any flows diverted by the sandbags need to be considered in terms of detriment to downstream properties
Implementation prerequisites	The number of bags required to implement a street level flood management scheme must be assessed given the limited stock available. In addition, the maximum flood level needs to be understood so that the defense can be effective. There are height implications that will require additional health and safety and stabilization requirements.

Secondary flow paths

What is it?

Secondary flow paths are the creation of another flow path for water to help reduce the depth of flooding in a particular area.

What does it involve?

Secondary flow is when stormwater runoff flows outside the primary network (whether piped or open waterways). The secondary flow path can be the result of runoff during storm events exceeding the capacity of the primary network, blocked network inlets, or where there are constraints in the primary network.

Secondary flow occurs when ponded stormwater or stormwater within the primary network spills over and flows along the next lowest path downstream. The new flow path can be deliberately designed in advance to minimise any damage the flood flows may cause.

Solution lifetime	Secondary flow paths should be included as a component of all stormwater design work. However, sometimes secondary flow paths are required to service a temporary need.
Effect on flood risk	Secondary flow paths can be effective by directing runoff safety to a preferred alternative network location, lowering flood levels within the network and controlling excess flows and the associated flood risk. However this is dependent on the residual network capacity and the discharge conditions
Implementation timeframe	▪ Implementation is largely dependent on the ownership of the land proposed for the secondary flow path. If the land is in private ownership, easement negotiations will be required. ▪ If the land is available, a grassed swale secondary flow path could be installed within days
Positives	▪ Can form part of the permanent solution ▪ Low cost ▪ Quick to install
Negatives	▪ Requires a corridor free of obstructions, especially fencing and buildings ▪ The corridor may need to be of a significant width i.e. 5-10m ▪ The ability to discharge to another part of the network maybe limited by downstream conditions and existing network capacity ▪ The secondary flow path needs to be identified and protected to ensure its ongoing usefulness
Constraints	▪ Land ownership ▪ Capacity limitations of the existing stormwater and waterway network
Implementation prerequisites	Knowledge of the land drainage network including: ▪ Location of stormwater services and waterways ▪ Confirmation of network capacity

Setback enforcement

What is it?

Setback enforcement is application and enforcement of District Plan and Council easements on private property through education and physical means.

What does it involve?

In areas where structures, earthworks or plantings have been placed within the waterway setback the flow capacity of the waterway may be reduced. This leads to impedance of the flow and can increase flooding depths both in the immediate and wider area. Obstacles in the setback area can also divert flows pushing water out of the desired flow channel leading to flooding.

Enforcing the setback rules by preventing the placement of obstructions in the setback area and by removing existing obstructions may be able to lower flood flows and prevent property damage.

Solution lifetime	Permanent but will require ongoing monitoring
Effect on flood risk	▪ Reducing flow restrictions within the setback will allow the waterway to convey a greater volume of water and reduce flooding in the areas it drains. ▪ Removing obstacles will prevent flows from being diverted from the waterway and damaging property.
Implementation timeframe	Long time frame. Currently enforced to some extent. Removal of existing structures difficult and potentially a slow process including consultation etc.
Positives	▪ Existing regulatory systems in place ▪ Reduces flooding risk ▪ Maintains corridors for future waterway upgrade ▪ Maintains access for waterway maintenance
Negatives	▪ Causes political backlash ▪ Setback impacts on owner's ability to develop portions of their property that fall within the setback
Constraints	▪ Limited power for enforcement under City Plan and Council Water Related Services Bylaw (currently being reviewed) ▪ Existing use rights ▪ Difficulty assessing impact to be more than 'minor'
Implementation prerequisites	▪ Review of Water Related Services Bylaw improving enforcement capability ▪ Political support regarding impact on properties

Dredging

What is it?

Dredging is the physical removal of river or stream bed material to lower the bed profile and increase the hydraulic capacity of the watercourse.

What does it involve?

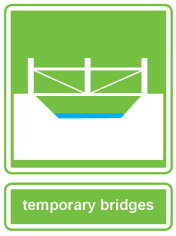
Dredging is the process of removing silt that has built up in a river bed over time. In the case of Christchurch rivers, excess silt has also entered the rivers via liquefaction during the 2010 and 2011 earthquakes.

Dredging provides an opportunity to return the shape of the rivers to 'pre-earthquake' profiles.

Dredging can be undertaken using a variety of methods, including diggers, suction pumps, barges, or manual removal.

Solution lifetime	Information reviewed (historical cross sections) indicates that there is a slow buildup of silt in the riverbeds over time. The silt influx during the earthquakes occurred over a much shorter time. The velocity of the water in the river also affects the rate at which silt builds up, so there will be differences in silt buildup rates throughout each river. For the Christchurch rivers, the solution lifetime is anticipated to be greater than 10 years.
Effect on flood risk	Dredging the rivers is expected to lower flood levels; however, the reduction in risk during high tide will be less than during low tide.
Implementation timeframe	Within 12 months
Positives	▪ Flood risk reduction in areas where channel capacity is affecting flood levels ▪ Consented under CRC121582 'to remove earthquake derived sediments from Christchurch's surface water bodies' ▪ Opportunity to revive 'smothered' ecology and create better environments ▪ Lowering of river levels during frequent rain events, particularly at low tide
Negatives	▪ Requires stakeholder engagement ▪ High capital cost ▪ Requires hydraulic modelling to quantify the effect on flood risk ▪ May not eliminate flood risk in some areas or under certain tidal conditions
Constraints	All material would require testing to establish disposal method – either secure landfill (if contaminated), or alternatives. Material is expected to be somewhat contaminated due to stormwater and historic industrial contaminants. Ecological 'hotspots' will need to be avoided / managed.
Implementation prerequisites	Notification of stakeholders is necessary before commencement. Development of a management plan, in consultation with stakeholders and ecologists is required. Testing of materials to determine disposal options.

Temporary bridges



What is it?

This is the removal and temporary replacement of existing privately owned bridges that impose restrictions on the waterways and/or where waterways are to be widened.

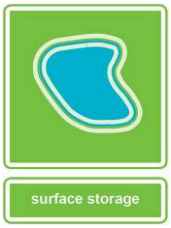
What does it involve?

This mitigation considers the removal of the existing bridge and replacement with either a temporary bridge or a more permanent bridge that provides for the future upgrade (widening) of the waterway. Both categories of bridge will be longer span bridges compared with existing bridges.

While some of these bridges are the subject of insurance and/or EQC claims for repair or replacement due to the damage sustained, a replacement bridge which provides for the upgrading of the waterway as part of a catchment solution.

Solution lifetime	3-6 months for temporary bridge, permanent for others
Effect on flood risk	Risk reduction
Implementation timeframe	0-3 months
Positives	Standard designs available for a wide range of spans. Designs are proven and compliant with building codes. Short lead time for manufacture with ease of installation and minimal site works and disruption to property access
Negatives	Restriction in access during installation and removal
Constraints	■ A requirement for a large number of bridges will extend the manufacturing time frame due to limitations of the pre-casting facilities. ■ Agreement on cost sharing between owner/EQC/Insurance for not like-for-like replacement (betterment) ■ Relocation of services
Implementation prerequisites	■ Owner acceptance and possible contribution to costs. ■ Site specific investigations to determine appropriate bridge type and foundation requirements

Temporary surface storage



What is it?

Temporary surface storage is the temporary storage of floodwater in an above ground pond via pumping or gravity to reduce localised flooding.

What does it involve?

Temporary surface storage ponds temporarily store stormwater runoff, thereby reducing the peak rate of runoff to a stream or storm sewer. They help to prevent localised flooding and, if designed to do so, provide some water quality benefits. During a storm, runoff drains from impervious surfaces directly to storm sewers or waterways.

Large storm events contribute a significant volume of runoff moving at an increased rate, which raises the potential for erosion and flooding downstream. Temporary ponds are basins that can receive and hold runoff or pumped flows for release at a predetermined rate, thereby reducing the peak runoff delivered to storm sewers and streams. The ponds can be constructed of temporary materials discussed in the bunding specimen design or by impoundment of a natural depression or excavation of existing soil. Temporary surface storage can be used to detain pumped or surface flows during a storm event for release at a determined time or rate.

Solution lifetime	Storage basins can be set up as temporary facilities, and these can be constructed independent of ground profile
Effect on flood risk	Retention of storm water during a flood event resulting in a reduction in the volume of flood flows
Implementation timeframe	▪ Simple earth bund constructed surface storage one week ▪ Using proprietary product 1 – 2 days (subject to availability)
Positives	▪ Quick to install ▪ Can be taken down once stored water has been discharged
Negatives	▪ Requires stakeholder engagement ▪ Some solutions not aesthetically pleasing ▪ Will require pumping if not downstream of flooding areas
Constraints	▪ Large volume of land required for storage ▪ Land owner consent required
Implementation prerequisites	Proposed flooding area within pumping distance of area to be protected

Traffic management

What is it?

Traffic management is the temporary control of vehicular and pedestrian access to roads

What does it involve?

Vehicle movements during storm events contribute significantly to the impact on flooded areas from the wake/wash caused. In addition to standard traffic management associated with flooding to the carriageway, proposed is the implementation of further measures to control vehicle numbers and speeds through flooded areas.

Additional measures could include:

- Allocation of dedicated TM personal to hotspot areas to man road closure sites and control residential only access.
- Specific TM to control vehicle movements at high risk points within a flooded street, e.g., moving traffic and reducing to a one lane road to shift traffic to high side and out of the water. (if possible)
- Establishment of secured parking area for residence vehicles outside of flooding area and provide shuttle service to residence door.
- Possible implementation of pilot vehicles to limit speed for residence access.

Local area letter drop outlining the need to reduce speeds, that the street will be closed to all but residents' vehicles and a contact number for the assigned TM personal for the street.

Solution lifetime	Temporary
Effect on flood risk	Risk reduction by minimising wash and over topping of protection works
Implementation timeframe	0-3 months
Positives	▪ Reduce risk of damage due to vehicle wash. ▪ Increase ability for residence to go about normal activities
Negatives	None noted
Constraints	▪ Sufficient notice period for letter drops to be undertaken. ▪ During storm events resources for TM are in significant demand so coordinating and supplying additional resources would require pre planning
Implementation prerequisites	Flood event management plan identifying installation locations and types of management to be deployed.