Brisbane City Council

Engineering Solutions for Flood Mitigation in Brisbane

Discussion Paper

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1. Introduction

1.1 Background

In January 2011, Brisbane experienced its worst flooding since 1974. Tens of thousands of properties were flooded and there were billions of dollars in damage to private and public infrastructure.

One of the characteristics of the flood was that inundation largely occurred because of elevated water levels in the Brisbane River, with very limited flooding from local rainfall in the suburban area. Among other things, this has led to further consideration of measures that might exist to reduce "backflow" from the river and reduce or eliminate flooding in parts of the city that otherwise would not have been flooded.

High tidal levels alone can also lead to localised "minor" inundation in low lying areas. These high levels also decrease the discharge of the Brisbane River at the outlet and push up river levels for some kilometres upstream. The same principles apply to all other Brisbane waterways discharging directly to Moreton Bay. The "backflow" flooding from high tide levels that occurs from time to time is similar in some ways to the 2011 flood and could be mitigated using similar strategies.

1.2 Overview

1.2.1 Causes of flooding

There are several causes of flooding that Brisbane can experience. These are described in some detail in the report *Strategies to reduce the effect of significant rain events on areas of Brisbane prone to flooding*:

- heavy or sustained rainfalls over the catchments of Brisbane’s creeks;
- overloaded stormwater systems as surface runoff makes its way into creeks (overland flow);
- heavy or sustained rainfalls over the catchments of the Brisbane River;
- storm surge in Moreton Bay;
- failure of one of the three dams in the City’s environs, Gold Creek Dam, Lake Manchester and Enoggera Dam or the SEQ Water controlled Wivenhoe Dam; and
- a tsunami in the Pacific Ocean.

In considering structural flood mitigation measures, in particular, each of these types of flooding needs to be taken into account. However the main flood risks to Brisbane are caused by heavy or sustained rainfall over the catchments of Brisbane's creeks, overland flows and heavy or sustained rainfalls over the catchments of Brisbane River.

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1 Brisbane City Council (2005), "Strategies to reduce the effect of significant rain events on areas of Brisbane prone to flooding", Report of the Lord Mayor's Taskforce on Suburban Flooding, p(iv)
It should also be stressed that structural measures that provide a benefit in one set of flooding conditions will not necessarily provide a benefit in other conditions and may, in fact, worsen the impacts of flooding.

1.2.2 Structural versus non-structural measures

Measures to mitigate the impact of flooding in suburban areas can largely be divided into two groups - structural and non-structural:

- Structural measures are those that involve physical works to lessen the effects of flooding, such as improvements to drainage infrastructure. These might otherwise be described as "engineered" solutions.
- Non-structural measures are typically linked with town planning policies and building codes and involve longer-term consideration. These might include, for example, restrictions on where construction can take place, limitations on fill in floodplains and specification of minimum habitable floor levels for buildings.

This paper considers structural measures, or "engineered" works to mitigate the impacts of flooding.

1.2.3 Passive and active measures

Structural measures can be further subdivided into active and passive measures. Passive measures require no operation whereas active measures are those that require some form of operation or movement to provide a benefit. Active measures add a layer of complexity when considering the costs and benefits, because they add a level of risk.

If something needs to be operated, there must be an associated operating plan and consideration of "failsafe" mechanisms that will allow operation in highly adverse conditions. Mechanisms that are only occasionally operated - such as when there is a major flood - are inherently subject to an even greater risk during operation. Active measures should only be used where there has been a detailed risk assessment and there is an ongoing commitment to maintenance and operational reviews.

1.2.4 Costs and benefits

Most strategies to mitigate the impact of flooding come with a cost. This can be a direct cost, such as the capital and operating costs associated with structural measures, or an indirect cost such as loss of social amenity or a reduction in property value. Inevitably, these costs need to be balanced against the benefits that are derived.

This discussion paper does not seek to quantify the costs or benefits associated with any particular measure, but detailed consideration of the costs and benefits would need to be considered prior to any commitment.
1.3 Objective of this discussion paper

The objective of this discussion paper is to provide an overview of the structural or "engineered" measures available to mitigate the impact of flooding, with particular reference to those mechanisms that may assist in reducing flooding from the Brisbane River.
2. Engineered solutions

2.1 River barriers

A river barrier is a form of floodgate designed to prevent storm or tidal surges from flooding areas upstream. They permit water to pass in normal conditions but are closed in tidal flood conditions. They range significantly in size and scale. Construction is dependent on the presence of suitable foundation conditions and additional works are often necessary along the river banks downstream of the barrier.

There are numerous installations in the Netherlands and in the UK. Possibly the most well-known example for Australians is the Thames Barrier, pictured below. Types of barriers include inflatable barriers and gates that rise from the floor the waterway. A set of gates is currently under construction in Venice.

Figure 1 Thames Barrier, London

In Brisbane, a river barrier could provide protection against a tidal or storm surge in Moreton Bay. It could also provide protection against particularly high tides and may have benefits in the longer term if sea levels rise as predicted by climate scientists.

This type of structure would have no benefit, however, in the case of river flooding. If the river were in flood the gates would need to be kept open to maximise the flow of water from the mouth of the river.

These structures are generally very expensive. The Thames Barrier was completed in 1984 at a cost of more than £500 million and it is likely that an equivalent structure for Brisbane in 2011 would be measured in the billions of dollars. The current impact of high tides in Brisbane would not appear to warrant an investment of this magnitude.

Like all active structures, there also remains a risk of faulty operation. Failure of the structure or damage due to external impacts of shipping, for example, could lead to unexpected inundation and significant flood damage. This almost occurred in London in 1997.

2.2 Flood gates

Flood gates are adjustable structures used to impede and control the movement of water in a waterway, similar to river barriers in some ways but at a smaller scale. The opening and closure of flood gates depends on a change in water level due to flooding, rainfall or tidal variation. As part of a storm or tidal surge system flood gates may be used to stop water flow entirely. In addition to flood management, flood gates and associated infrastructures can be used to improve water quality and address ecological issues within a water system.

Flood gates are typically attached to a larger structure such as a barrier, dam wall, weir, culvert or headwall within a waterway. In smaller tributaries they may be constructed independently of other structures.

Traditional flood gates include the following types:

- Hinged flap gate - self-operating gate typically attached to a headwall or culvert, suitable for tidal gating of channels when complete isolation is required. Minimal maintenance is required, but they restrict fish passage and are prone to blockage.

- Manually-operated flap gate – similar to a hinged flap gate but with remote operational control via a winch, or mechanical sluice, to allow independent control of water movement.

- Self-regulating tidal gates – as a variation of a hinged gate, self-regulating tidal gates allow automated tidal movements, but prevent flooding during high tides and flood events, primarily using a buoyancy mechanism.

Flood gates may be applicable in Brisbane to control flooding in tributaries and creeks by controlling backflow from the Brisbane River. However, detailed modelling of the hydraulic and environmental impact of any flood gates would be necessary. Among other impacts, flood gates may cause:

- Increased flood levels upstream in the case of local flooding;
- Water stagnation and sedimentation upstream;
- A deterioration of water quality within the waterway;
- Obstruction of fish passages;
- Increased ecological and plant disturbance and increased weed growth; or
- Oxidisation of acid sulphate soils.

A local example of a gated structure serving a similar purpose is the Fitzroy River Barrage at Rockhampton. Although slightly different in its functionality, the barrage provides a barrier which impounds fresh water upstream while preventing tidal saltwater downstream from intruding into the storage. The gates of the barrage are lowered to allow floods to pass.

2.3 Levees and flood walls

A levee is a slope or embankment, typically but not always constructed parallel to the waterway, that prevents or reduces flooding on the landward side. Levees have been used for thousands of years to provide flood protection.
Levees are used to manage flooding from some inland rivers in Australia. Large riverine levee systems have also been constructed in many international locations, including along the Mississippi River in the USA and in Europe along the Danube and the Rhine. Prominent large coastal levee systems have been constructed in Canada (specifically Vancouver), throughout the Netherlands, and in New Orleans in the United States.

Flood walls are similar to levees but tend to be constructed as concrete walls rather than as earthen structures. The same issues for both walls and levies need to be considered.

**Figure 2  Flood Walls - New Orleans**

*Photo: US Army Corps of Engineers*

Levees can be a valuable flood protection measure and are often seen as an "obvious" solution to river flooding. However, there are many significant considerations where levees are constructed. Levees:

- typically need to be constructed over long distances;
- increase flood levels in the river because flood plain storage is no longer available;
- pose a significant safety hazard when they fail during a flood;
- remain prone to over-topping in the event of a flood that is larger than the "design" flood, and dangerous failures can result;
- impose a barrier on the operation of drainage systems upstream of the barrier;
- may need underground drainage structures across them to allow for normal drainage.
Despite these concerns, however, levees can be a valuable option to protect specific areas - for example areas with a high population density, pieces of critical infrastructure or important industrial areas.

In Brisbane, specific challenges with levees include:

- The river has a very flat longitudinal gradient, meaning that any levees along the river would need to extend for many kilometres;
- Moving further up the river, flood events are significantly higher than the river banks, and levees would need to be of varying heights depending on the design flood level. These levees may be impractically high;
- As the "River City", construction of levees or flood walls would have a significant adverse aesthetic impact on the city, effectively blocking any view of the river from ground level;
- Construction of levees would also need to extend up several low-lying tributaries;
- Levees would directly block any "overland flow paths" which form the basis of drainage design across the city, and without extensive investment in drainage systems would lead to a worsening of local flooding across the city.

Nonetheless it may be appropriate to consider protection of specific limited areas of high value through the construction of levees. One example might be critical infrastructure such as the cold stores at the Brisbane Markets at Rocklea. Each case would require careful consideration of a range of design issues to confirm its viability and that the benefits outweigh the costs.

2.4 Backflow prevention valves

A flood-tide and backwater valve is intended to ensure one-way flow downstream and prevent water from ‘backing up’ into piped stormwater systems from downstream. Backwater valves are generally designed and constructed to minimise clogging.

Flood tide and backwater valves are used specifically on sewer overflow pipes and stormwater pipes. A wide range of valve designs is available, varying in complexity from simple flap valves (see Figure 3) through to more complex valves actuated by high downstream water levels. The most common backflow prevention valves are the simple flap valve - used extensively in Australia - and the rubber "duck bill" valve.
In both of these cases, the intention is that the valve will remain closed until there is flow from upstream. The valve will open to release flow from upstream, closing again when flow stops and the downstream water level is lower than the upstream level. Particular issues with these types of valve include the relatively high potential for valves to be stuck “open” (not uncommonly by debris or accumulated sediment downstream), thereby rendered ineffectual, and the potential for increased pressure losses in the system leading to less effective drainage.

Large urban centres in North America and Europe sometimes have a requirement for backwater valves within the wastewater and stormwater systems for specific buildings or areas prone to flooding. The City of Toronto provides a subsidy for residential and commercial installation of backwater valves. The City of New York promotes and monitors the installation of flood tide and backwater valves for all riverside

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suburbs. Both of these cities have "combined sewers" where sewage and stormwater are mixed, and
the circumstances are therefore a little different to Brisbane where sewerage and stormwater drainage
are separated.

In Brisbane, flap valves are already widely used in low-lying areas to prevent backflow. Flap valves are a
practical means of reducing the impact of tidal backflow, but cannot generally be relied upon because of
the relatively high risk that they will be blocked in an open position. If these are installed, they must be
continually maintained to ensure effective operation.

Installation is relatively simply on new drainage systems, but they can be more difficult to retrofit on
existing drainage systems.

2.5 Dredging

Dredging is the term given to excavation or removal of material to deepen waterways, create harbours,
channels, locks, docks and berths, de-silt lakes and keep river entrances and approaches to boat ramps
clear. The material removed during dredging can vary greatly and can be any combination of rocks,
clays, silts or sands.

Large Australian dredging projects included the dredging of the Port of Melbourne and the proposed
dredging of the Port of Gladstone. Neither are flood related dredging activities. In the Netherlands,
multiple parts of the major rivers are dredged annually to prevent the formation of river bars that restrict
navigation and drainage.

The Brisbane River has been dredged historically in order to improve navigability. Dredging of sand and
gravel from the river for construction materials was carried out until 1996. The dredging has increased
the length of the tidal estuary and the effects of each tide extend further upstream than occurred
historically.

Considerable dredging (and waterway straightening) was undertaken following recommendations arising
from the enquiry into the 1974 floods in Brisbane, particularly in some of the tidal tributaries of the river
and some of the tidal creeks that discharge to Moreton Bay. These included Breakfast Creek and
Schultz Canal.

Dredging provides a mitigating effect for flooding by increasing the cross-sectional area of the waterway
and reducing friction losses along the river. Dredging will also increase the impact of tidal influences in
the river, and cause an increased tidal variation upstream. An increase in tidal levels may reduce the
flow benefits provided through dredging.

Dredging has a number of other effects that need to be considered:

- impact on the environment in the areas dredged and where the dredged material is discarded;
- negative impact on water quality by increasing sediment and nutrient loads and through potential
  release of toxicants accumulated on the floor;
potential for increased erosion directly upstream of the limit of dredging due to changed flow conditions;

ongoing costs of maintenance.

The upstream benefits of dredging would require detailed analysis. The benefits can dissipate relatively quickly upstream depending on the hydraulic.

2.6 Flood mitigation storages

Upstream flood storages along tributaries of the Brisbane River and upstream sections of the Brisbane River itself could potentially be used to reduce peak levels downstream. Brisbane already experiences the benefit of considerable flood storage in Wivenhoe Dam, but the dam is upstream of two major tributaries – Lockyer Creek and the Bremer River.

Dedicated flood mitigation storages would usually be left empty, becoming active only in the event of a major flow in the waterway. Flood mitigation dams can be designed with or without gates. They work by storing water from the initial peak of the flood, with the water released over a longer period of time thereby reducing peak flows and flood levels. Flood storages are widely used at a smaller scale in urban drainage systems (“detention” basins) and at a larger scale in some cities such as Glasgow. The North Para Flood Mitigation Dam near Gawler in South Australia is a more local example.

A flood storage or series of smaller storages upstream of Ipswich on the Bremer River and/or Lockyer Creek may help to reduce peak levels in Ipswich and in Brisbane, however the timing of flows would require considerable detailed analysis. Part of the design strategy would be to delay parts of the flood so that peak flows from different parts of the catchment occurred at different times.

The main disadvantage of flood storages is that large areas of land upstream of the structures will potentially be affected. This may necessitate land acquisition and will require development and other planning controls on land inundated in the event of a flood.

Opportunity may also exist to increase the flood storage capacity of Wivenhoe Dam by raising the level of the dam wall. There have been some studies of this option over the past five to ten years.
3. Conclusions

There are no "silver bullets" to mitigate flood levels in Brisbane. The 2011 flood was characterised by high flows and water levels in the Brisbane River at a time of minimal flows in urban tributaries, and most of the flooding was therefore caused by "backflow" from the river. This was more pronounced than in 1974, for example, where flooding of tributaries such as Oxley Creek was also significant.

The major difficulty in planning for infrastructure to mitigate flooding in Brisbane is that flood events in the catchment and surrounds are rarely the same. A variety of structural measures exist that could potentially be used to reduce the impacts of "backwater" flooding in Brisbane, but none of these measures comes without other impacts and risks.

"Engineered" or structural measures with the highest potential for application in Brisbane are:

- the use of flap valves and possibly "duck-bill" valves in tidally-affected areas, subject to implementation of suitable maintenance regimes (these are already used);
- the use of levees around specific, high-value infrastructure (such as the Brisbane Markets), but not along waterways; and
- possible implementation of flood mitigation dams on the Bremer River and Lockyer Creek upstream of Ipswich.

The last two of these in particular would require further, more detailed, investigation to establish if they are viable and will provide a net benefit to the community.

Non-structural measures have not been considered in this Discussion Paper, but remain a strong longer-term option for mitigating the effects of flooding in Brisbane.