DARWIN FLASH FLOODING – IS A LEVEE THE SOLUTION?

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Abstract

Rapid Creek, in the northern suburbs of Darwin, experiences flash flooding. The most recent major flood occurred as a result of Cyclone Carlos in February 2011. A significant number of houses were inundated in the adjacent suburbs and major roads were cut by the floodwaters. Local residents and emergency services had very little time to react.

The NT Government responded by creating an interagency Project Control Group and provided funding for floodplain risk management studies to develop an Action Plan to reduce the risk to life and damages.

The flood study, mapping and damages assessment showed that over 350 properties would be impacted by the PMF event and the average annual damage (AAD) was estimated to be about $0.5 million, with the NPV of the potential AAD being about $12 million.

A range of flood mitigation options were investigated, including a levee along Rapid Creek Road in the suburb of Millner. This levee would prevent inundation of some 67 properties in the 1% AEP event and would need to be up to 2 metres high in some sections. Key considerations include cost; the visual amenity for the community with the levee adjacent to the creek riverine corridor; and management of local catchment runoff that needs to drain to the Creek through the levee.

Recommendations from the options assessment include a mix of measures that will provide information to the NT Government in the development of their Action Plan.

The paper describes the results from the studies and the recommendations from the options assessment including the issues associated with the Rapid Creek Road levee option.

Introduction

There have been a number of studies into flooding along Rapid Creek since the establishment of the Darwin Northern suburbs. In the late 1990s, a study by Connell Wagner [May 1999] produced floodplain mapping of the area between Trower Road and McMillans Road for the Department of Lands and Planning. A number of properties were identified as being at risk. A major flood occurred in February 2011 during the formation of Cyclone Carlos over Darwin. A number of properties were inundated and floodwater was understood to have entered houses in the suburb of Millner (refer to **Figure 1** for location).

The NT Department of Natural Resources Environment, The Arts and Sports (now Department of Land Resource Management) commissioned an update of the previous study at the end of February 2012. This flood study consisted of the following:

- Updated hydrology study using the URBS model [SKM Jan 13(a)]
- Updated hydraulic study using the TUFLOW model [SKM Jan 13(b)]
- Floodplain mapping from the Flood Control Weir (1,500m upstream of McMillans Road) to the sea [SKM Mar 13(c)].

This was followed by a preliminary examination of mitigation options and a flood damages study which was carried out from February 2013 [SKM Aug 13(d)]. The most recent study for the NT Government commenced in August 2013 and was a more thorough examination of flood mitigation measures [SKM Jan 14(e)]. The objectives of the current study are:

- Determine the most likely feasible mitigation options or combinations of mitigation options
- Recommend the most cost effective mitigation strategy.

Flood Risk

The floodplain community of Rapid Creek, particularly in the Millner area, experiences flooding that allows little time to respond. In a major storm, Rapid Creek can inundate Rapid Creek Road and areas in suburban Millner within 1.0 to 1.5 hours of the onset of heavy rainfall. A number of residents, whose properties mainly front Rapid Creek Road, experience difficulties evacuating to higher ground due to the restricted time to react and the early loss of access to Rapid Creek Road.

It is estimated that 67 houses are located on allotments that are wholly or partially below the 1% AEP flood level. Of these, it is estimated that 28 have habitable areas constructed at or near ground level so there is a risk of personal safety and property damage.

The damage bill caused by the 2011 Cyclone Carlos event was estimated at $6 million [SKM 2013(d)]. A number of properties along Rapid Creek Road also experience potential flooding from Storm Surge.

Rapid Creek Catchment

Description

Rapid Creek rises in the Marrara Swamp at the eastern end of Darwin Airport, and flows for 9.8 km discharging into the sea (Beagle Gulf) at the southern end of Casuarina Beach (Refer **Figure 1**). The Rapid Creek catchment covers an area of 28 sq. km and includes parts of the suburbs of Karama, Malak, Anula, Moil, Jingili, Wagaman, Alawa, Casuarina, Wanguri, Nakara and Brinkin, Millner and Rapid Creek.

In these built up areas of the catchment, runoff enters the Creek via underground piped drainage systems as well as unlined and lined open drains. Large parts of the catchment to the south of McMillans Road are still undeveloped.

The Marrara Swamp is drained by two separate drainage lines, on the north western and south western sides of the Swamp. Where the two drainage lines re-join to form Rapid Creek, a Flood Control Weir exists which attenuates the peak discharge and delays the floodwaters. The Flood Control Weir was constructed in 1985.

Road crossings of Rapid Creek can be found at Henry Wrigley Drive, McMillans Road (where the crossing is known as Kimmorley Bridge), and Trower Road.

A stream gauging station has operated continuously at Rapid Creek since the 1960s. It is located at the upper end of the Freshwater Gardens.

Figure 1 Rapid Creek Catchment and Features

History of development

Rapid Creek catchment has been progressively developed along with the City of Darwin. At the time of Cyclone Tracy in 1974, the inner northern suburbs of Rapid Creek and Millner were well established. After suffering severe damage from Cyclone Tracy, an intensive re-building programme re-established the existing northern suburbs and completed those under construction at the time of that Cyclone's occurrence. Further development took place in the 1970s and by the time of the 1991 flood, all the current residential suburbs were well established.

Most recent development has been in the Darwin International Airport precinct, including the terminal facilities, car parking areas and new buildings in the General Aviation and Cargo areas. Future development is likely to include further expansion of Darwin International Airport Business Park and in-fill development in existing suburbs.

Brief flooding history

Major floods have occurred in December 1974 (associated with Cyclone Tracy), 1977, 1991 and 2011 (associated with Cyclone Carlos.) The arterial roads Trower Road and McMillans Road are major routes north and east out of the inner suburbs and some of the northern suburbs of Darwin. Floods cut McMillans Road at the Kimmorley Bridge

almost every year. Trower Road is known to have been overtopped near the intersection with Rapid Creek Road (i.e., the western approach to the Bridge.) during the 1974 and 2011 floods. Rapid Creek Road was overtopped at more than one location between McMillans Road and Trower Road in 2011 and was likely to have been similarly overtopped during other major floods. Flooding in, and around, low-lying houses in Millner occurred in 2011 and probably in 1974.

Flood behaviour

Overview

Floods in Rapid Creek result in filling of the Marrara Swamp, with overflow to areas behind the existing Flood Control Weir. Downstream of the Flood Control Weir, the floodwaters proceed under the Henry Wrigley Drive Bridge and, in sufficiently large storms, over the right bank approach to the Bridge.

Floodwaters frequently overtop the Kimmorley Bridge at McMillans Road and, to some extent, back up into drains entering the Creek from the Darwin International Airport land and undeveloped low lying land between Henry Wrigley Drive and McMillans Road. Downstream of McMillans Road, the floodwaters begin to spread towards Trower Road to the north. In moderate to major floods, say 10% AEP or larger, Rapid Creek Road is flooded and floodwaters threaten low-lying properties in the Millner area. A 5% AEP flood is where floodwaters will start to threaten low-lying homes in Millner and floods larger than this are considered “major floods”. The flood that occurred during Cyclone Carlos on 16 February 2011 is estimated to be a 0.7% AEP event.

A 1% AEP (Q100) flood (**Figure 2**) will spread into the entire lower part of Millner. Floodwaters will flow over Trower Road at the Rapid Creek Road intersection and will spread to properties near the northern side of that intersection (in the suburb of Rapid Creek). On the right (eastern) bank, the lower parts of properties in the Freshwater Farms area are inundated. Water will flow over Trower Road on the eastern approach to the Trower Road Bridge between the Bridge and Freshwater Road.

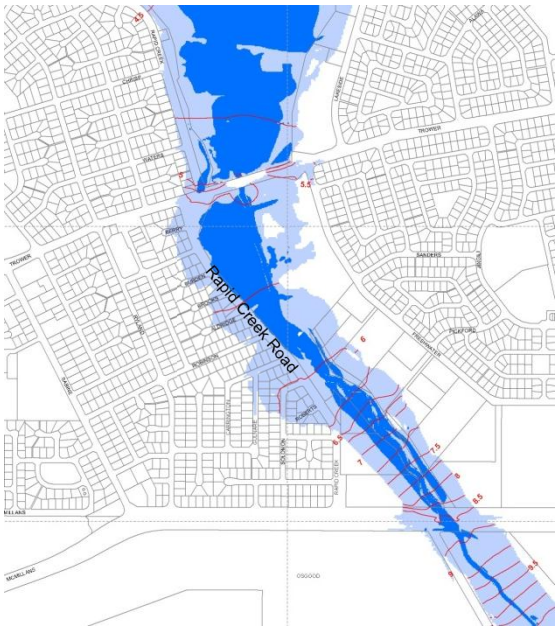

Figure 2 1% AEP Flood Extent

Downstream of Trower Road the slope of the creek is very flat and floodwaters spread in a wide corridor between Lakeside Drive in the east and Rapid Creek Road. Floodwaters are expected to be high in the floodplain downstream to the Gulf.

Note that the 2% AEP and 5% AEP floods are 200mm and 480mm lower than the 1% AEP flood level, respectively, at the gauging station midway between McMillans and Trower Roads. Also, the defined flood event for protection of property when economical to do so is typically 1% AEP (Q100). This is the case under the NT Planning Scheme.

Timing

Rapid Creek is a small catchment and during a major storm, the time between the onset of heavy rain and flooding in the suburb of Millner is short.

For the design storms considered, typical flood waves are two-peaked. The first peak represents a spike of runoff from the urban areas contributing downstream of the Flood Control Weir and a second peak comes from the upper catchment.

For the design storms considered, the calculated first peak occurs at around 1 to 1.5 hours after the onset of heavy rain and the second peak from 1.5 to 4.5 hours depending on the size of the storm being considered.

Duration

For the purposes of discussion it is assumed that flooding over Rapid Creek Road commences at a 10%AEP flood at the gauging station. For short duration storms and smaller floods the duration of inundation indicated is of the order of 0.5 hour. For longer duration and larger storms the effect of the 'second peak' kicks in and the duration of inundation may be up to 4.0 hours.

Floodplain Risk Management Options

Introduction

The objective of the floodplain risk management options assessment was to derive an appropriate mix of options to effectively manage the full range of flood risk for the Rapid Creek floodplain. This process has been guided by the NT Government. Key activities include:

- Examination of NT's flood risk management policies and planning instruments
- Review of existing flood warning arrangements
- Consultation with the NT Government about local issues and emergency responses
- Flood and hazard mapping
- Identification and assessment of flood risk management options
- Recommendations for priority options

This paper focuses on one of the flood modification options, namely the consideration of a levee adjacent to Rapid Creek Road for the protection of properties in the Millner area. The comprehensive report to the NT Government, covering all the other options both structural and non-structural, is still under consideration and will form part of an overall floodplain risk management strategy for the catchment.

Rapid Creek Levee

Description

Levees are built as a means of eliminating the inundation of buildings and yards during a flood event (up to the design flood height of the levee together with a freeboard allowance of say 0.5m). Flood gates can be considered as a separate modification measure or as part of a levee design. Flood gates allow local waters to be drained from an area when the level of the creek is low but prevent floodwaters from entering (or exiting) when the creek is elevated.

Pumps are sometimes associated with levee designs. They are installed to remove local floodwaters behind levees when flood gates are closed or there are no flood gates. They are generally only suitable for small volumes of local floodwaters and have a high likelihood of failure (due to loss of power, lack of maintenance etc.).

A levee along Rapid Creek Road to prevent inundation of properties in Millner was considered. To determine appropriate heights of a levee the existing design flood profiles along Rapid Creek Road were plotted and are shown in **Figure 3**. To provide protection for the 1% AEP (Q100) event with an appropriate freeboard, a levee along Rapid Creek Road would need to be up to 2.0m high near the intersection with Trower Road.

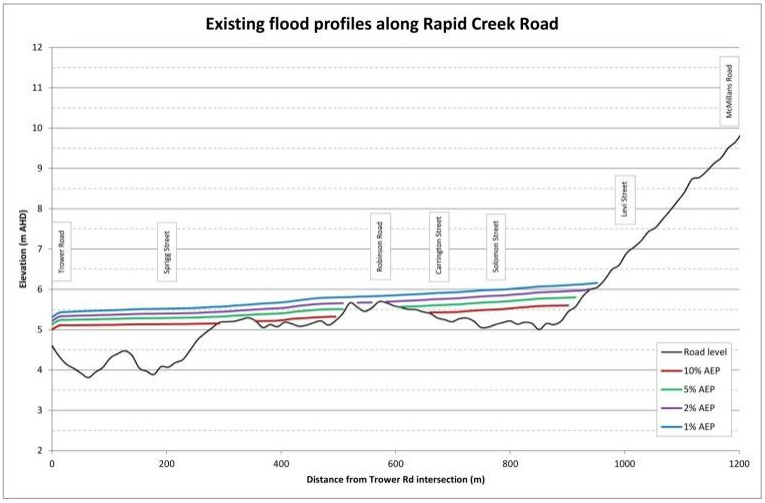

Figure 3 Design flood profiles along Rapid Creek Road

A levee option to provide protection for the 1% AEP (Q100) flood event was assessed in the TUFLOW hydraulic model. The levee would commence near Levi Street and would extend along Rapid Creek Road for approximately 1.1km. The average height of the levee would be about 1.5m.

Alignment options

Two alignments of the levee near the Trower Road intersection were tested as shown in **Figure 4**:

- Levee Option 1 – levee continues east along Trower Road until the bridge, thereby obstructing the existing flow path over the intersection.
- Levee Option 2 – the levee alignment was selected so the existing flow path remains clear. Modifications to the intersection are required to accommodate this option.

The relative change in 1% AEP flood levels as a result of Option 1 was appreciable (greater than 300mm) so was not considered viable. Option 2, however, had a relatively minor impact on flood levels, with a maximum increase of 80mm, and could be considered viable in relation to flood impact.

There are a number of issues that need to be considered before construction of a levee along the western side of Rapid Creek. These are:

- Impact on local drainage
- Increase in flood levels
- Amenity
- Ownership
- Operation and maintenance
- Residual risk
- Benefit and Cost

These issues are discussed in the following sub-sections.

Figure 4 Levee alignment options

Local drainage

If a levee was constructed along the left (western) bank of Rapid Creek, it would keep floodwaters from Rapid Creek entering the low-lying parts of Millner. In order to do this, flood gates would be constructed to prevent water from flowing back up stormwater drains when the creek level is high.

This means that for the period when the Creek is high, the local runoff generated from the Millner sub-catchments cannot drain out. Any runoff coming from the Millner area during this period will lie in the streets of Millner until the Creek level falls.

The length of time when local drainage is prevented depends on the size and nature of the flood event. Typically, for a 1% AEP flood, that would be between one (1) to four (4) hours.

There are 12 sub-catchment areas of Millner defined by the underground drainage system in the streets. The sub-catchments vary in area up to 18.2 ha, the largest being directed across Rapid Creek Road at Carrington Street, about half way along the proposed levee. From these sub-catchment areas, a significant volume of local water could potentially be stored behind the levee because it cannot escape through the levee due to elevated Creek flood levels. For example, an estimated 15,000 cubic metres of runoff could potentially egress the largest sub-catchment in the 1% AEP storm. The runoff travel time from this sub-catchment would be approximately 15

minutes so there is an opportunity for some of the local runoff to drain to the Creek prior to the obstruction from the rising Creek flow (time to peak in the Creek's 1% AEP event is about 60 minutes). Clearly the levee floodgates would be impacted prior to this as the flood levels rise quickly in the Creek, however some drainage of local runoff is likely. A more detailed hydrologic assessment is required to accurately estimate the local catchment runoff in relation to the timing of the flooding of Rapid Creek Road.

The residue runoff volume, during the time of peak flooding in the Creek, would cause local flooding to properties fronting Rapid Creek Road. To manage this trapped runoff, it is possible to:

- Pump this flow beyond the levee and maintain reasonable volumes in street storage but would require very large and expensive high volume, low head pumps.
- Re-arrange the underground drainage outlets to divert the largest local catchment areas away from the lowest areas where levee protection is most required. However this too would have a substantial cost. The cost of nearly 1 km of new drain linking up the 11 local catchment outfalls and carrying flows to the north of Trower Rd is estimated to be $10 million.
- Construct detention basin(s) near the levee adjacent to Rapid Creek Road.

Amenity

A levee up to 2.0m high in the northern low lying section, will constitute a physical and visual barrier between the residential areas on the western side of Rapid Creek Road and the creek corridor. This will change the character of the area and reduce the amenity of the creek corridor. It also has the potential to reduce 'passive surveillance' of the creek corridor, which already has some problems with unsocial behaviour of some recreational users. These problems diminish in areas where a lesser levee height is required.

A lesser height levee may be possible to manage only more frequent events ie the 5% AEP event, or accommodate a reduction in the levee freeboard.

Increase in flood levels

The hydraulic model showed that introduction of a levee would increase flood levels in the main channel and right bank. Levee Option 1 was found to increase flood levels by 300mm at Trower Road with the impact extending to just upstream of Levi Street near the Gauging Station. Blockage of the Rapid Creek Road/Trower Road intersection flow path (Option 1) would cause more flow to be diverted to the right (east) bank of the Creek and this would cause new areas to be inundated near the intersection of Trower Road and Freshwater Road. For Levee Option 2, the increase in flood levels is only 80mm and the effect will not extend as far upstream.

Ownership, operation and maintenance

Clear arrangements would need to be made for who owns, operates and maintains the levee and any associated structures such as flood gates, pumps, flood walls and so on. It is clear that Darwin City Council has responsibility for the Millner drainage systems and therefore has a stake in the flood gates or pumped systems. It could be argued

that this work is significant enough for ownership to fall to the NT Government. This issue would need to be resolved if the option was advanced.

Typical maintenance requirements for earth levees include:

- maintaining appropriate vegetation to minimise erosion,
- making good any erosion that does occur
- ensuring that any settlement does not compromise the design levee height
- removing any inappropriate vegetation
- ensuring flood gates are free of debris and silt and remain operational
- normal pump maintenance including switchboard/controls/power supplies

Residual risk

A properly maintained levee and local drainage system will eliminate inundation by floods up to the adopted design flood. For example, if a 1% AEP design flood is adopted, then no damage would be expected for floods up to and including this flood. However, if a flood larger than the 1% AEP (Q100) flood occurs, the levee will be overtopped, floodwaters will enter the streets of Millner and damage can be expected.

Benefit and Cost

The estimated cost of a levee along the left bank of Rapid Creek in the Millner area and the additional associated drainage works required is uncertain but would be substantial.

The main benefit of a Rapid Creek Road levee is the protection of 67 properties (and residents) from the 1%AEP flood. Benefits can also be identified using the estimate of reduction in flood damages [SKM 2013 d]. The estimated Net Present Value (NPV) reduction in damages for the 1%AEP event for the levee is $8.9 million. Hence, investment in a levee and drainage mitigation works could be to this amount to obtain a benefit to cost ratio of 1, which could be considered favourably for government funding. Realistically it is likely the construction cost will exceed this target.

Summary and Discussion

Rapid Creek in the northern suburbs of Darwin has a history of flooding. The most recent major flood occurred in February 2011 with the formation of Cyclone Carlos. A relatively large number of properties (71) were inundated in the suburb of Millner and arterial roads were cut by the floodwaters. Warning times are short and risks to people and property are high.

A number of studies have been undertaken to understand the nature and impact of flooding in the catchment. The most recent study investigated a broad range of options for flood mitigation. Mitigation options include:

- Flood modification options: levees to prevent floodwaters from getting to the areas where the most damage and largest risk exist; flood control weirs and detention basins; modification to the channel with a view to carrying more floodwaters in the Creek and less in the floodplain

- Response modification options: flood warning, raising community awareness of how to more safely respond to floods and how to best manage flood recovery.
- Property modification options: planning controls, house raising, voluntary house purchases, flood proofing properties, modifying construction techniques to reduce the vulnerability of buildings when they are invaded by floodwaters.

The option study identified that there is no single mitigation option that 'solves' the problem of flooding in the suburb of Millner. A levee along Rapid Creek Road could form a structural solution possibly in combination with catchment detention basins. This, in concert with non-structural measures, such as, improved flood warning systems, and strategic precinct planning to redevelop the Millner area with commercial and residential development that mitigates flood risk, may form part of successful future risk reduction measures.

The study also identified the many issues associated with levees located in catchments that have a coincidence of flooding from both larger upper and local catchment areas. Local drainage, if not managed, has the potential to create flooding issues for communities near the levees.

The current study didn't allow for this to be explored in more detail due to the NT Government's requirement to first address all possible flood mitigation options and then develop a strategic Action Plan for floodplain risk management. It remains under consideration.

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