Impacts of Climate Change on Urban Infrastructure & the Built Environment

A Toolbox

Tool 4.4: Individual house flood mitigation measures – Costs and benefits

Author

Ian Page

Affiliation

BRANZ, Private Bag 50 908, Porirua

Contents

1. Introduction

1.1 Background

This document gives details of one of a number of tools developed to assist councils and others to take account of long-term climate change effects in their ongoing asset management. The broad aim of this work is to make urban infrastructure more resilient to climate change effects.

This tool is to aid in the screening and short-listing of flood damage reduction measures for existing housing at the small-scale level. It is equally applicable to current flood scenarios as to future climate change effects on flooding scenarios.

1.2 Purpose of Tool

The Individual House Mitigation Tool [Tool 4.4] is specifically designed to assist in the identification of plausible damage reduction measures, and the short-listing of these prior to a more formal assessment of options. It gives approximate costs and benefits, and provides a starting point for a more detailed investigation of particular cases. It was developed for existing housing but some of the options in the tool are also applicable to new housing.

1.3 Obtaining this Tool

Contact the author of this report for information about obtaining and using this tool.

2. Overview of the Tool

This tool provides approximate costs for various mitigation options for individual houses. The net benefits are also provided when users enter data on flood heights, floor heights and annual expected occurrence of floods. The results apply for both timber and concrete floor housing and all types of cladding.

2.1 Theoretical Basis of Decision Tool

The basic concept of the tool is to compare initial costs of flood mitigation measures with the expected future benefits. Future benefits are discounted using a discount factor which users can change along with many other variables appropriate to their flood situation.

2.2 Data Needs

The following are the minimum data needs for assessing individual houses:

- Floor area
- Design flood height above floor level
- Annual Exceedance Probability (AEP) of design flood
- Height of floor above ground
- Flood heights, AEPs for one or two lesser floods.

Users can also enter unit costs for various measures shown in the tool if they have local data. Otherwise the default values will be sufficiently accurate for preliminary analysis.

2.3 Decision Outputs

The tool output is the initial costs of various mitigation measures, and the net benefits of each measure expressed as a Net Present Value (NPV) per house. Positive NPVs indicate the measure is worthwhile over the analysis period.

2.4 Assumptions and Limitations

The model benefits are based on flood damage avoided. Flood damage is calculated as the replacement cost for the house multiplied by the damage ratio for the flood height. The damage ratios are based on RiskScape data [see Tools 3.2 and 3.3] and are averages for the house types (i.e. timber framed or masonry construction). In fact, there is a wide variation in damage to similar houses with the same flooding depth. Actual damage depends on house materials, flooding duration and velocities, and other factors.

The estimated flood depths at year 2040 should be used for the analysis. The modelling ignores the change in flood depths over time with climate change, so taking the depths at 2040 will provide an approximate average value for an analysis period of 50 plus years ahead. For short analysis periods, i.e. less than 15 years, the user could use current year flood data.

Single-storey houses only are considered and personal injury costs are not included. Damage to contents is not included and will vary widely depending on the household and warning time. Consideration of contents damage and personal injury would have improved the net benefits and hence the tool results are conservative.

3. How to Apply the Tool

3.1 Application Framework

The tool can be used from various perspectives. Individual owners can use it for mitigation measures funded by them. Generally their time horizon is quite short in terms of payback, so they would use an analysis period of say 10 years or less and see what measures are expected to be cost-effective over that period.

Government (local or central) will often have longer timeframes and may consider mandating mitigation measures for individual houses (possibly with subsidies). The tool provides the net benefits for the total initial expenditure and can be compared with other mitigation measures such as area-wide schemes.

3.2 Tool Structure and Content

The tool calculates the trade-off between the up-front costs of the mitigation measure against the expected savings in flood damage to the house. The expected savings are a continuous series into the future where the saving in any single year is the house replacement cost x damage ratio (for flood depth) x AEP. The AEP is the likelihood of the design flood in any single year. The Uniform Series Present Worth Factor (USPWF) is the discounting factor used to bring future benefits back to present values using well-established financial analysis methods (Fraser et al., 2008). If the present value of expected benefits is greater than the initial cost of the mitigation then the measures are worthwhile.

4. Example Inputs and Outputs

4.1 Illustrative Examples

The tool provides a quick analysis of the net benefits of mitigation measures, and the output for a typical house and flood regime is shown in Figure 4.1. A brief description of the measures are:

1. *Do nothing – no mitigation measures*. Repair the houses after each flood.

2. *Dry flood-proofing – install a flexible membrane barrier up to 1.2 m above floor level*. The membrane sheet normally sits in a concrete trench with a cover and runs around the house perimeter. It is manually extended and fixed in place to the walls of the house. This assumes adequate flood warning.

3. *Earth bund around section perimeter*. The bund is assumed to have side slopes of 2:1 (horizontal to vertical). Note that bund height is restricted to 1.5 m, otherwise it covers most of the section and there may be insufficient room between the house and the boundary. The costs include a small pump to discharge water within the bund perimeter.

4. *Earth bund around groups of houses*. As above, but the bund is more economically constructed around a group of at least four adjacent houses.

5. *Raise house*. The house remains with same footprint but is raised above the expected flood height plus freeboard. It includes the cost of sub-floor bracing, new foundations for chimneys, reconnecting services and providing steps to the entrances. The cost increases with flood height due to longer pile lengths and the need for stronger bracing as the lateral load on the piles increase. The costs assume minimal debris load on the sub-floor and low water velocities (<1.5 m/sec). If the debris load and/or water velocities are high then the costs will be larger than shown.

6. *Relocate house*. The house is relocated to a new site above the expected flood level. The costs allow for transport up to 7 km, land section and services at the new site at a minimum of $170,000 per house.

7. *Demolish and rebuild*. Abandon the existing house and rebuild anew on a site above the flood level. The costs include demolition, land, services and a new house.

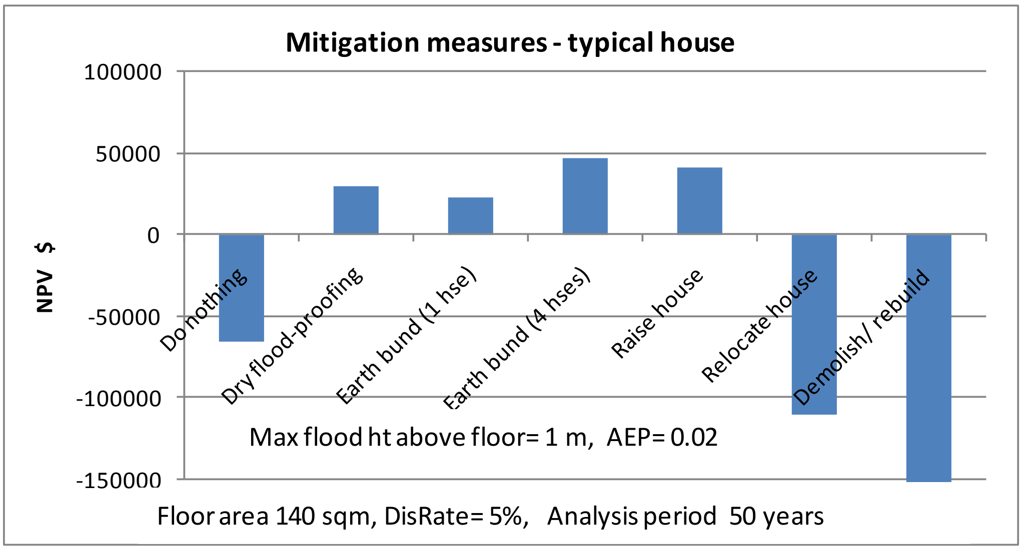


Figure 4.1: Net Present Values for various mitigation measures

Figure 4.1 indicates that if nothing is done the net outcome is an expected cost of about $60,000 in damage in present value terms for the particular house and flood regime shown. Relocation to a new site (above the flood level), and demolition and re-build on a new site, are not cost-effective options due to their large initial costs, i.e. it is better to periodically repair the flood damage to this particular house than move to a new site.

The other four measures shown are cost-effective, the best being to build a bund surrounding several adjacent houses. Raising individual houses by 1.3 m (1.0 m plus 0.3 m freeboard), is also cost-effective.

Further details of mitigation measures for existing houses can be found in a number of publications (FEMA 2009, 2008, 2001). A BRANZ publication (BRANZ, 2004) describes measures to reinstate a home after a flood and is particularly applicable to the New Zealand situation.

4.2 The Next Steps

The spreadsheet model applies to individual houses and indicates which options are better from a cost viewpoint. The results for all houses in a particular area could be added together and compared to area-wide mitigation schemes e.g. stop-banks, diversion channels etc [see Tools 4.2 and 4.3].

5. References

BRANZ Ltd. (2004). "Restoring a house after flood damage". *Bulletin* 455. BRANZ Ltd, Judgeford, New Zealand.

NIWA/GNS. (2009). "RiskScape – A tool for analysing risks from multiple hazards". *RiskScape Manual*. Available online at www.riscscape.org.nz

Fraser N, Jewkes E, Bernhardt I and Tajima M. (2008). *Global Engineering Economics: Financial Decision Making for Engineers* (4th Ed.). Pearson Education, Canada.

FEMA. (2009). "Homeowner's guide to retrofitting – Six ways to protect your home from flooding". *FEMA* (2nd Ed.) P-312 (2009).

FEMA. (2008). "Flood damage-resistant materials requirements for buildings located in special flood hazard areas in accordance with the National Flood Insurance Program". *Technical Bulletin* 2 (2008).

FEMA. (2001). "Engineering principles and practices of retrofitting flood-prone structures". FEMA (2nd Ed.) P-259 (2001).

Appendix A: Illustrative Inputs and Outputs

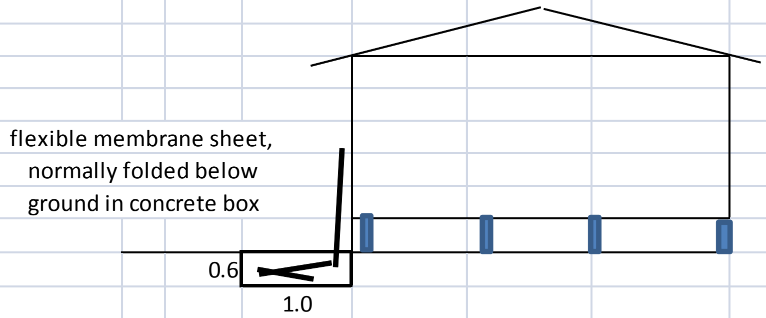
The spreadsheet model is shown in Table A1. Users enter the individual house characteristics (floor height above ground, flood height above floor, AEP, and house floor area). Other values in the boxes can also be changed but the default values will be approximately correct for most locations. The bottom line in the first panel gives the result as an NPV. There are a large number of assumptions behind the modelling and details are provided in Table A1 to Table .

Table A1: Net benefit model for individual houses

Indicative costs of flood resilence measures for individual houses											
	Timber framed single story house.										
					Initial cost of resilience measures (for largest flood, $ per house)						
Height floor level above ground			0.5	metres	Do	Dry flood	Earth bund	Earth bund	Raise	Relocate incl	Demolish
					nothing	proofing	One house	3-5 houses	house	land cost	& re-build
	Flood height					(2)	(3)	(3)	(4)	(5)	(6)
	above floor		Damage		0	35,504	42,565	18,872	24,000	176,417	350,000
	level		ratio	AEP							
	m				**Benefits (as present value per house for each flood)**						
Largest flood	1.0		0.45	0.02	-32,347	32,347	32,347	32,347	32,347	32,347	32,347
Smaller flood 1	0.7		0.37	0.05	-26,434	26,434	26,434	26,434	26,434	26,434	26,434
Smaller flood 2	0.1		0.09	0.1	-6,657	6,657	6,657	6,657	6,657	6,657	6,657
Total benefits					-65,437	65,437	65,437	65,437	65,437	65,437	65,437
					Net present value $ per house for all floods (benefits less costs)						
					-65,437	29,933	22,873	46,565	41,437	-110,980	-284,563
AEP = Annual exceedance probability				na= not applicable.			Bund cross section	7.4	sqm		
140	sqm house							One house	Four houses		
$1,400	per sqm total reconstruct						Bund volume	964	422	cum/house	
$196,000	house cost										
5%	discount rate			50	years analysis period.						
			USPWF	18.26							
(1) Measures are raising power outlets, installing solid core doors in place of MDF, solid timber skirting and architrave in place of MDF,											
and using closed cell polystyrene insulation in place of fibreglass insulation, when undertaking refurbishment.											
(2) For timber or slab foundation. The measure is a retractable flexible membrane over the exterior of the cladding.											
			Cost per lin m =	634	$ per lin m		Not applicable for floods over 1.5m high.				
(3) Bunds. Compacted fill in-place $/cum				40	$/cum	Waste& storm water one-way valves, small pump $					4,000
			Bund & house raising freeboard	0.3	m		Double above for 4-6 house group.			Bunds cost for flat site.	
(4) Raising house - the cost variations with flood height are due to increased pile length and bracing. Includes steps, & chimney											
reconstruction. Basic cost $20,000 per 130 sqm house. Cost is to raise house above largest flood plus freeboard.											
(5) Relocate. Assume approx 7 km shift , and land / infrastructure cost = $							150,000	per house.			
(6) Land and new house cost on new site above flood plain site $ =							$346,000				
					Demolition costs =		4,000	$/ house			
Costs assume minimal debris impact damage and water velocities less than 1.5 metres per sec, otherwise											
hydrodynamic effects on the structure need consideration.										= values can be changed.	

Table A2: Cost details

Cost details								
Dry proofing		Find perimeter length						
			2x	House perimeter = 6x				Area A=2x^2
						Perim/A =	6/(sqrt(2*A)	
		x	house plan			A (sqm)	TR (transfer ratio)	
						130	0.37	
						200	0.30	
						use	0.4	



	Butyl membrane on decks is about $90/sqm, use 180$/sqm for flood membrane							
						m		
0.5m below grd +sub-floor + flood ht + freeboard =						2.3	414	$/m
	Treated timber cover to pit, top & bottom sheet fixing						50	$/m
			Concrete fdn pit 100mm thick =	0.22	cum/m		220	$/m
			Excavation & concrete $	1000	per cum		634	

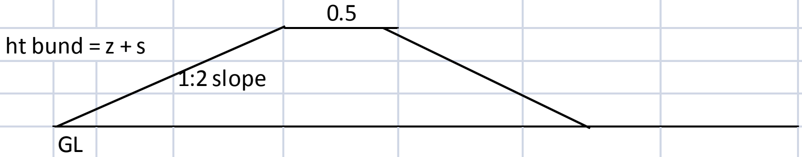
Table A3: Further cost details

Cost details (continued)

Bunds volume

z= flood height above floor + freeboard

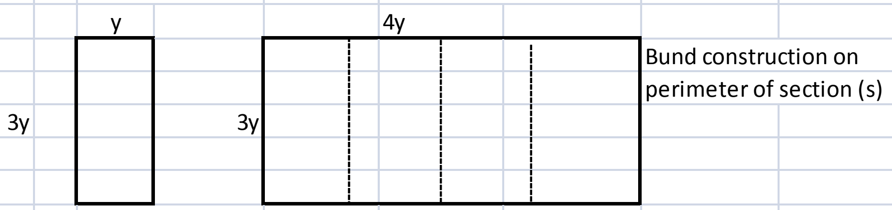
Floor to ground = s



Cross sect area =2(z+s)(z+s) + 0.5*(z+s)

Bunds length

Assume 800 sqm sections 3:1 y= 16.3 m



One house perimeter		Four houses perimeter		per house	
131	m	229	m	57	m

Elevate house in place

m	Raise house $
0	20,000
0.5	20,000
1	21,000
1.5	24,000
2	27,000
2.5	30,000

6. Contact Details

This spreadsheet financial tool was developed by BRANZ. Should territorial authorities wish to make use of the tool they will need to provide data for each house they wish to assess. The data needed are the flood heights and return periods for each house. BRANZ will run the data through the model and quickly provide answers on net benefits for each house for the various options. Contact Ian Page or Johannes (Hans) Roberti at BRANZ, ph. (04) 237 1170, for further details.