Stopbanks Renewal Prioritisation

A risk based approach for planning asset renewals

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ABSTRACT

The Waikato Regional Council owns and manages more than 620 km of flood control stopbanks. The stopbanks provide flood protection for approximately 120,000 hectares of farmland and several urban settlements and towns. The asset management plans provide for condition and performance assessment of the stopbanks, based on annual visual inspections, regular surveys, monitoring during floods and regular reviews of the hydrology and hydraulics of the flood protection systems.

The service levels of the stopbanks are defined by their ability to withstand a specific design flood event without overtopping. Stopbanks heights are determined on the basis of the design flood level with an additional freeboard allowing for uncertainties in flood estimations and stopbank settlement. Maintaining the stopbanks at their design crest level requires regular surveys of crest levels, comparing these to design flood levels and topping up of stopbanks to required levels. In preparation for the Long Term Plan (LTP), a full review of stopbanks heights was carried in 2013 which found that approximately 90 km of stopbanks have lost the freeboard height through settlement and significant renewal works are required.

To ensure that budgets are spent to reduce risks to Council within the shortest timeframes, a risk based prioritisation process was developed to establish the LTP renewal works programme. The process has been applied utilising all the asset monitoring information and formed the basis for planning, and renewal works programme decision making during the last LTP.

This paper provides an outline of the process followed and examples of the resulting programme options to assist Council decisions making and adoption through the LTP.

KEYWORDS

STPP **Stopbank Renewal Prioritisation Process**

WRC **Waikato Regional Council**

ICMD **Integrated Catchment Management Directorate**

PRESENTER PROFILE

Ghassan Basheer holds a Bachelor of Science Degree in civil and construction engineering and a Masters Degree in Urban and regional Planning, University of Baghdad/ Iraq and is a member of the Rivers Group of IPENZ. Ghassan has more than 36 years experience covering a wide range of civil and environmental engineering design and construction fields especially river, flood protection and drainage engineering. Over the last 20 years Ghassan has been working with the Waikato Regional Council (WRC) and has filled a number of roles including the Assets Manager, Technical Services Programme Manager, Special Projects Manager and is currently the Principal Technical Advisor for the Integrated Catchment Management Directorate.

1 INTRODUCTION

1.1 BACKGROUND

The Integrated Catchment Management Directorate (ICMD) of the WRC is responsible for the management, maintenance and renewal of the flood protection systems in the region. The major flood protection systems are located within two Zones, namely the Waihou-Piako Zone and Lower Waikato Zone. The systems include stopbanks, spillways, designated flood storage areas, pump stations, floodgates, control structures and major river and stream works. Together, these assets and works are designed to provide specific levels of flood protection (Level of Service) for people and property. The stopbanks within these systems form the main defences to floods and have a total length of more than 620 km with a total asset value of approximately $300 million.

In 2013, a full assessment of stopbank heights against design levels revealed that nearly 90 km of the stopbanks had their crest levels below or close to the design flood levels, with no adequate freeboard to withstand a design flood without overtopping. The overtopping failure is considered the most obvious mode that is avoidable through appropriate programmes of monitoring and renewal.

Legal advice obtained by Council in relation to Council's responsibility for delivering a level of services included that Council's duty of care requires that all reasonable steps are taken to address deficiencies in terms of stopbank height (or any other category of under performance). The legal advice also acknowledged that financial constraints could be expected to limit the ability to address all under performance at once.

Therefore, the risk to Council could be managed and minimised if landowners were informed of the current situation, and stopbanks were prioritised for renewal within an agreed long term programme. To this end, Council carried out a targeted consultation programme as part of the 2013/2014 Annual Plan process.

Council also needed to ensure that there was a transparent, consistent, robust, and defensible process in place for assessing how stopbank renewals had been prioritised to derive a work programme.

The above led ICMD to develop the Stopbanks Renewal Prioritisation Manual, which adopted a prioritisation process based on Council's risk management policy and framework.

1.5 STOPBANKS RENEWAL PRIORITISATION PROCESS

ICMD technical engineering staff Murray Mulholland and Ghassan Basheer established a project to develop a prioritisation process based on a risk management framework in line with Council's risk management policy. To ensure robustness of the process, Casey Giberson of Tonkin and Taylor Consultants was employed to assist in the development of the process document. Following completion of the draft document, it was internally reviewed by Mark Pennington and David Bouma of Tonkin and Taylor and finally peer reviewed by Neil Jacka of AECOM consultants. The Manual was consulted on through Council's Catchment Committees and formally adopted by Council for prioritisation of stopbank renewal programmes during the last Long Term Plan.

2 OBJECTIVE AND SCOPE

2.1 OBJECTIVE

The objective of the process:

- Allow WRC to systematically identify and classify overtopping risk
- Enable a better understanding of potential liabilities, and
- Provide a clear and auditable process for prioritisation of stopbank renewal works.

The intent of the prioritisation manual is to broadly classify stopbank overtopping risks to inform decision making on capital expenditure.

2.2 Scope and Process

The scope includes development of a process for assessing the risks associated with overtopping of stopbanks that have a crest level lower than their respective design level. The process adopts a risk-based framework for prioritising these stopbanks and establishes a long term stopbank renewal programme to address the risks in the order of these priorities.

The Waikato Regional Council has adopted a risk management policy and framework in line with AS/NZS ISO 31000:2009.

The risk management process developed for the stopbank prioritisation broadly aligns with Council's risk management policy and generally follows the process set out in the joint Australian and New Zealand Standard AS/NZS ISO 31000:2009 *Risk management – Principles and guidelines*, from which Figure 1 below has been developed for this process.

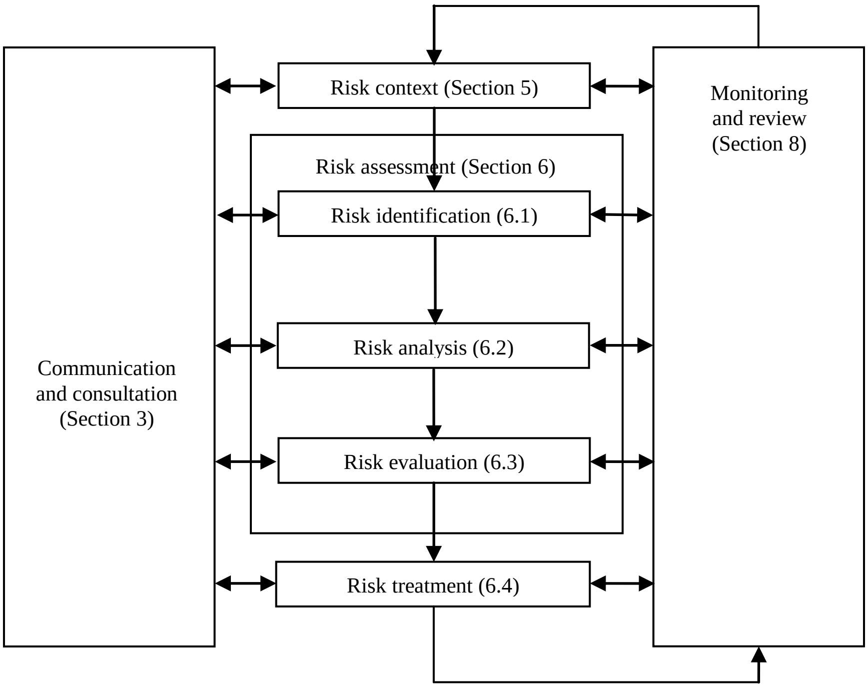

Figure 1 AS/NZS 31000:2009 Risk management process adopted by this document

The risk-based prioritisation framework outlined is inherently limited. Specific limitations and assumptions include:

- This risk management process is based on likelihood of overtopping and excludes other stopbank failure mechanisms such as seepage, heave, scour and erosion. These other geotechnical risks are more

difficult to predict and are managed by Council through the flood monitoring procedures and are treated as they become evident.
- It is assumed that when a stopbank is overtopped floodwaters will inundate the entire compartment protected by the stopbank.
- Establishment of the agreed Level of Service for each individual stopbanks has been carried out elsewhere and is outside the scope of this document.

2.3 Base Information

It was important to develop a process that relies on available literature and information held by Council as well as local knowledge of the flood protection systems. The information used included the following:

A. Asset information ; Stopbank lengths, design flood levels, design freeboard/crest level, actual surveyed crest levels.

B. System design; Flood system design and critical elements for its performance including spatial information of protected areas, and levels of inundation.

C. Financial information; stopbank upgrade costs, land value, capital value and generic assumptions on flood damage costs based on historic records and available literature.

2.4 Process Outline

The proposed methods of identifying, analysing, and evaluating stopbank overtopping risk are described in the following subsections. The proposed process is outlined in Figure 2 below. Formal discussion on each of the process steps is described in the following sections.

The first step described is risk identification. Steps 2 to 4 comprise the risk analysis portion of risk assessment. Steps 5 and 6 comprise the risk evaluation process. Risk treatment is essentially Council's decision making process, and comprises steps 7 and 8. Note that ongoing communication, monitoring, and review of the risks, their analysis and evaluation, and the residual risks is required by AS/NZS ISO 31000:2009.

2.4.1 STEP 1 - RISK IDENTIFICATION

Council's monitoring programme includes regular surveys of stopbank crest levels at 100-m intervals, cross section surveys of rivers and hydraulic modeling of design floods to establish current design flood levels. (Note that design flood levels change with changes in channel cross sections and catchment hydrology)

Comparison of the actual monitoring information with design standards defines the deficiencies in stopbank heights and remaining freeboard allowance, if any. This information is used in a number of ways later in the process to define performance grades, probability of failure and generic costs for upgrading the stopbanks.

Performance is graded on a one to five scale and is based on the ratio of available freeboard to the design freeboard (where the available freeboard is the difference between the surveyed actual stopbank crest level and the design flood level). However, for the purposes of this process the overtopping risk is identified using the actual ratio of current freeboard to design freeboard. Key ratios are described in Table 1 below.

Table 1 Key ratios of current freeboard to design freeboard

Ratio of actual freeboard to design freeboard	**Description**
R ≥ 1.00	More than the design freeboard is currently provided
R = 1.00	All of the design freeboard is currently provided
R = 0.50	Half of the design freeboard is currently provided
R = 0.00	There is currently no freeboard above the design flood level
R < 0.00	The design flood level is above the current crest level

2.4.2 STEP 2 - RISK ANALYSIS

Flood protection schemes are designed as complete systems to convey the design flood flows safely through a catchment. The system design generally employs a number of engineered structural and natural physical characteristics to provide the protection standard.

Different levels of protection standards are also considered within each scheme depending on the level of risk and economic feasibility of protection. To simplify the prioritisation process, these system design consideration were taken into account and stopbanks were categorised as follows:

Category 1 – Stopbanks protecting urban areas

Category 2 – Stopbanks protecting critical assets and infrastructure

Category 3 – Stopbanks protecting rural land

2.4.3 STEP 3 – IDENTIFY VALUED COMMUNITY PLACES

This step aims at identifying areas protected by stopbanks that are valued by the communities and could have an additional weight when compared to other areas. These areas are identified through workshops with community representatives. The key values considered are cultural, social and environmental values.

It should be noted that this step is key for ensuring community/stakeholder involvement in the risk assessment and prioritisation process.

2.4.4 STEP 4 – RISK ANALYSIS

Within each Category the following risk analysis tool is used to assess the annual monetary risk to Council associated with the failure of each stopbank. A detailed description of the proposed risk analysis tool methodology is outlined below.

$$Estimated\ Risk = \begin{bmatrix} Probability \\ of \\ design\ flood \end{bmatrix} \times \begin{bmatrix} Estimated \\ probability \\ of \\ overtopping \end{bmatrix} \times \begin{bmatrix} Estimated \\ consequences \\ of \\ overtopping \end{bmatrix} \times \begin{bmatrix} Critical \\ infrastructure \\ factor \end{bmatrix}$$

where,

- "Probability of design flood" is the likelihood of a design flood event occurring in a particular year.
- "Estimated probability of overtopping" is the likelihood of a design flood event overtopping a stopbank given its stopbank prioritisation class.
- "Estimated consequences of overtopping" is the estimated value of direct, tangible damages related to overtopping of a stopbank. For the purposes of this screening level assessment, it is assumed that indirect damages are proportional to direct damages.
- "Critical infrastructure factor" adjusts the "estimated consequences of overtopping" depending on the nature of the critical infrastructure protected by the stopbank.

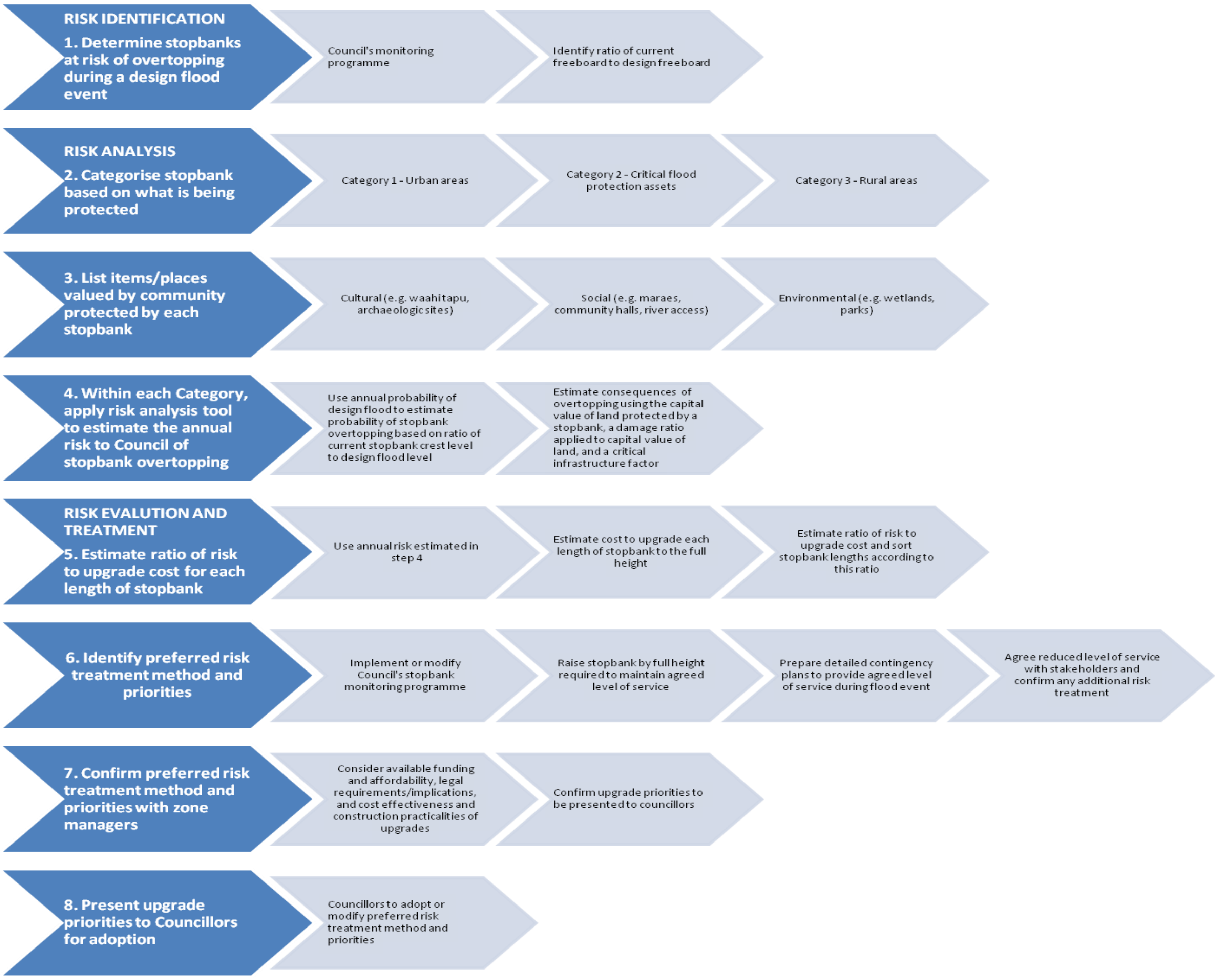

Figure 2 Proposed stopbank upgrade risk assessment and prioritisation process

2.4.5 STEP 5 – RISK EVALUATION AND TREATMENT

AS/NZS ISO 31000:2009 states that "risk evaluation involves comparing the level of risk found during the analysis process with risk criteria established when the context was considered".

Risk treatment is described as the selection of one or more options to modify the risk. Risk treatment involves a cyclic process of assessing a risk treatment, deciding if the residual risk is tolerable, and if not, generating a new risk treatment, and so on. If the residual risk is tolerable (that is, the stopbanks are raised to the full design height) no additional work is required, except Council's regular monitoring programme.

Development of the upgrade programme includes the results of the risk analysis tool, information about the cost of the renewal works, and qualitative information about area-specific considerations. This will enable decision makers to make an informed decision as part of Step 8.

A preliminary construction cost estimate is prepared by Council staff for each stopbank length having a crest level below the design level. The cost estimate is prepared on the basis of raising the crest level of each portion of stopbank in isolation (i.e. no economies of scale are considered), and includes allowances for engineering design, contract administration, as well as the physical works.

The ratio of the estimated risk (from Step 4) to the estimated cost of each stopbank upgrade is then calculated. This ratio is the reduction in annual risk that would be achieved by upgrading a stopbank, per dollar of capital expenditure invested.

Stopbanks are then ranked in descending order (greatest to smallest) within each category based on the ratio determined. Ranking in this manner will result in upgrade projects having a large risk reduction relative to capital cost being preferred over those with a small risk reduction relative to capital cost.

2.4.6 STEP 6 – PREFERRED RISK TREATMENT

Based on the information gained in Steps 3 through 5, options for risk treatment are identified and recommendations for the preferred risk treatment method for each stopbank are made. Once agreed by Council's catchment committees, the upgrade priorities are established.

The risk treatments that Council consider are as follows (listed in descending order of priority):

- Implement and/or modify Council's stopbank monitoring programme
- Raising a stopbank to the full height required to provide the current agreed level of service (including freeboard)

- Prepare detailed contingency plans in consultation with affected landowners to ensure agreed level of service is met during a flood event
- Agree a reduced level of service with affected landowners and either:
  - raise a stopbank to a level to meet the reduced level of service,
  - do nothing, if the stopbank height meets the reduced level of service, or
  - prepare detailed contingency plans to provide the reduced level of service.

2.4.7 STEP 7 – CONFIRM TREATMENT METHOD AND PRIORITIES

Council Catchment Committees are the owners of the stopbank renewal programmes and priorities set. Hence, staff present options for discussion with managers and Committees including preferred risk treatment method for each stopbank, and the upgrade priorities. These discussions include an assessment of area-specific considerations, including funding availability and project affordability, legal requirements and/or implications (e.g. consent conditions), and economies of scale and practicalities of construction (particularly with regard to combining renewal projects).

2.4.8 STEP 8 – ADROPT RENEWAL PRIORITIES AND PROGRAMMES

This is a normal Council approval and programme adoption step. Upon approval of the Catchment Committees, priorities and programmes of stopbanks renewal are recommended to Council for adoption. Council will consider the proposed programmes in light of qualitative information collated. Council might direct staff to review the priorities and/or programme in light of the area management priorities/considerations at the time, after which the programme would be finalised and formally adopted.

3 CONCLUSIONS

Asset owners are responsible for the management, maintenance and renewal of assets to ensure these continue to provide the agreed levels of services.

The financial and practical constraints on asset owners to ensure the availability of the services at all times does not relieve the owners from potential liabilities and legal challenge when the assets fail to deliver.

The risks to asset owners could be minimised if they identify the potential risks of asset failure to their customers and establish a prioritised programme of works to ensure its performance.

A simple risk based prioritisation process was developed to assist the Waikato Regional Council develop the renewal programme for their stopbank assets.

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Riskscape Fragility Function Example – Single Story Timber Weatherboard House (https://riskscape.niwa.co.nz/features/vulnerabilitymodule)

APPENDIX 1

SUPPLEMENTARY FIGURES AND TABLES

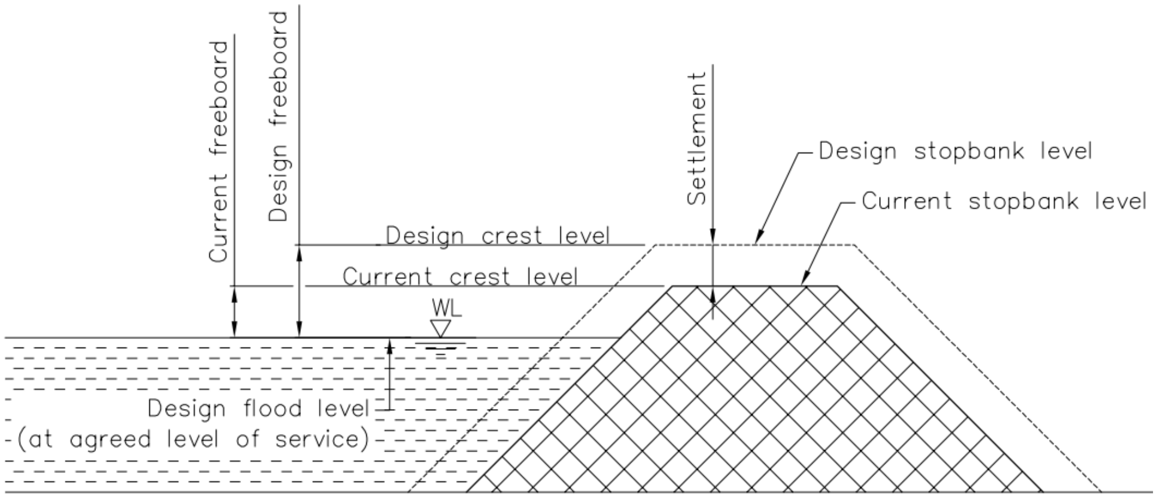

Figure 3 Typical stopbank section showing key levels in the risk assessment

Estimated probability of overtopping

The likelihood of a stopbank overtopping during a design event is estimated based on the amount of freeboard available relative to the design freeboard. This quantity the ratio of actual freeboard to design freeboard is designated as "R". It is assumed that the probability of failure has a triangular probability density function as shown in Figure . The resulting failure probability function is shown in Figure 7.Key features of the probability density function are:

- If R ≤ -1 (i.e. AFB ≤ -DFB) then the probability of failure in a design event is 100%
- If R = 0 (i.e. AFB = 0) then the probability of failure is 50%
- If R ≥ 1 (i.e. AFB ≥ DFB) then the probability of failure is 0%

Using the above assumptions, and measured R values it is possible to assign a failure probability to each stopbank as illustrated in Figures 5 and below.

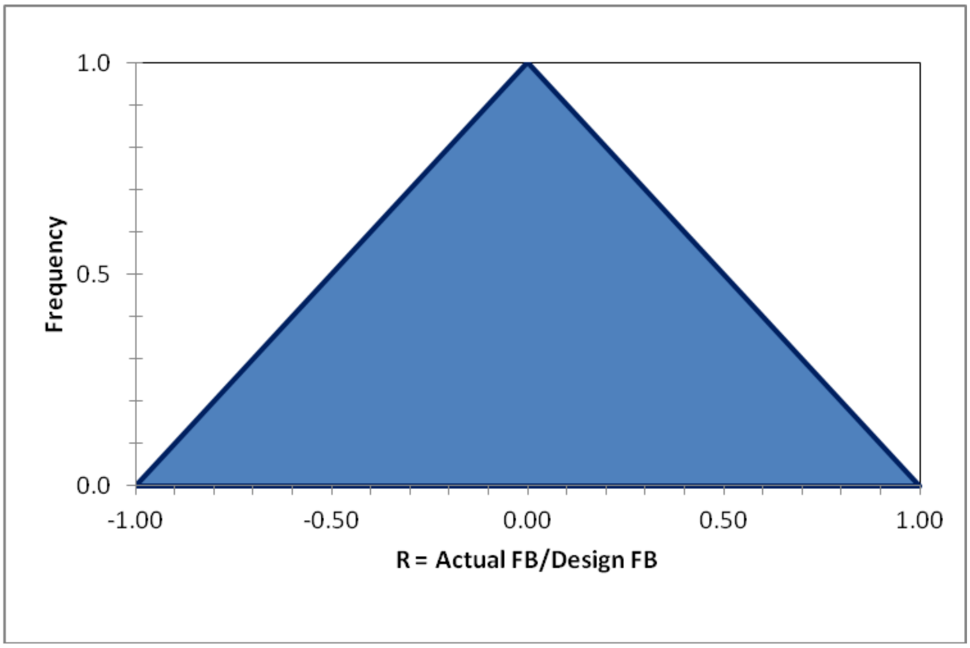

Figure 4 Failure probability density function

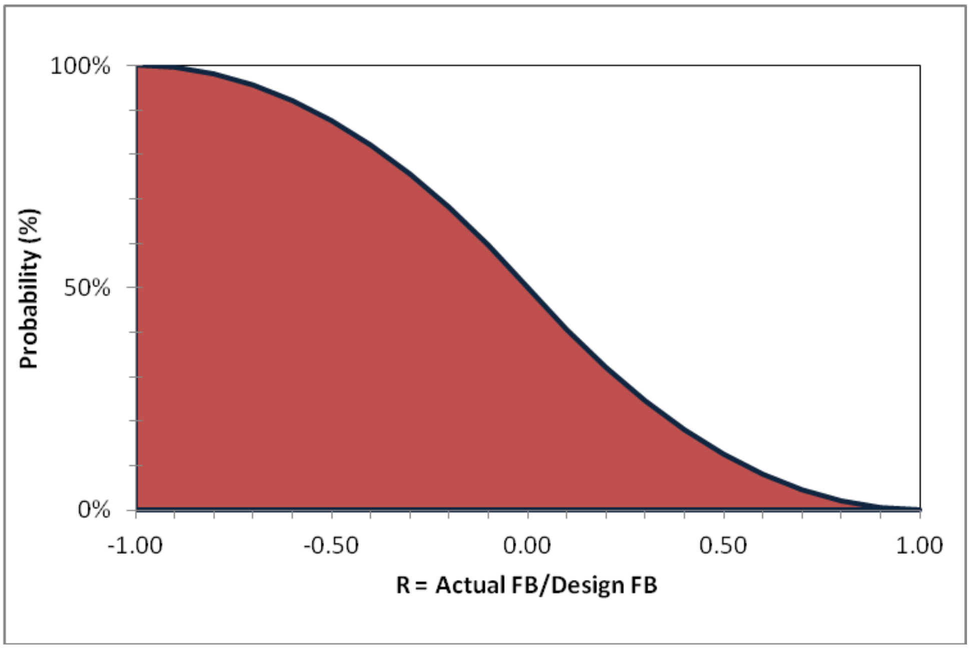

Figure 5 Cumulative failure probability

Table 2 Annual probability of occurrence of flood events

Common name of flood event	Annual probability of occurrence	
10-year	1 in 10	0.10
25-year	1 in 25	0.04
50-year	1 in 50	0.02
100-year	1 in 100	0.01

Table 3 Land use categories and damage ratios

No	Land use category	Damage $/ha	Damage ratio	Source
1	Dairying	$1,875.00	0.12	Wallace, 2004
2	Grazing beef and sheep	$836.25	0.13	
3	Market gardens and horticulture	$22,500.00	1.07	
4	Cropping	$22,500.00	0.58	
5	Forestry	$0.00	0.00	
6	Utilities	N/A	0.10	Estimate
7	Storage	N/A	0.20	
8	Recreational	N/A	0.10	
9	Industrial and transport	N/A	0.10	
10	Commercial	N/A	0.25	
11	Residential and community	N/A	0.20	
12	Multi use	N/A	0.15	Estimate
13	Other	N/A	0.10	

Table 4 Critical infrastructure factors

Critical infrastructure description	Critical infrastructure factor
State highways and main rail lines	2.0
Arterial roads and local rail lines	1.7
Strategic telecommunications or energy corridor	1.5
Locally significant telecommunications or energy corridor	1.3
Other (as identified for a specific stopbank compartment)	1.2