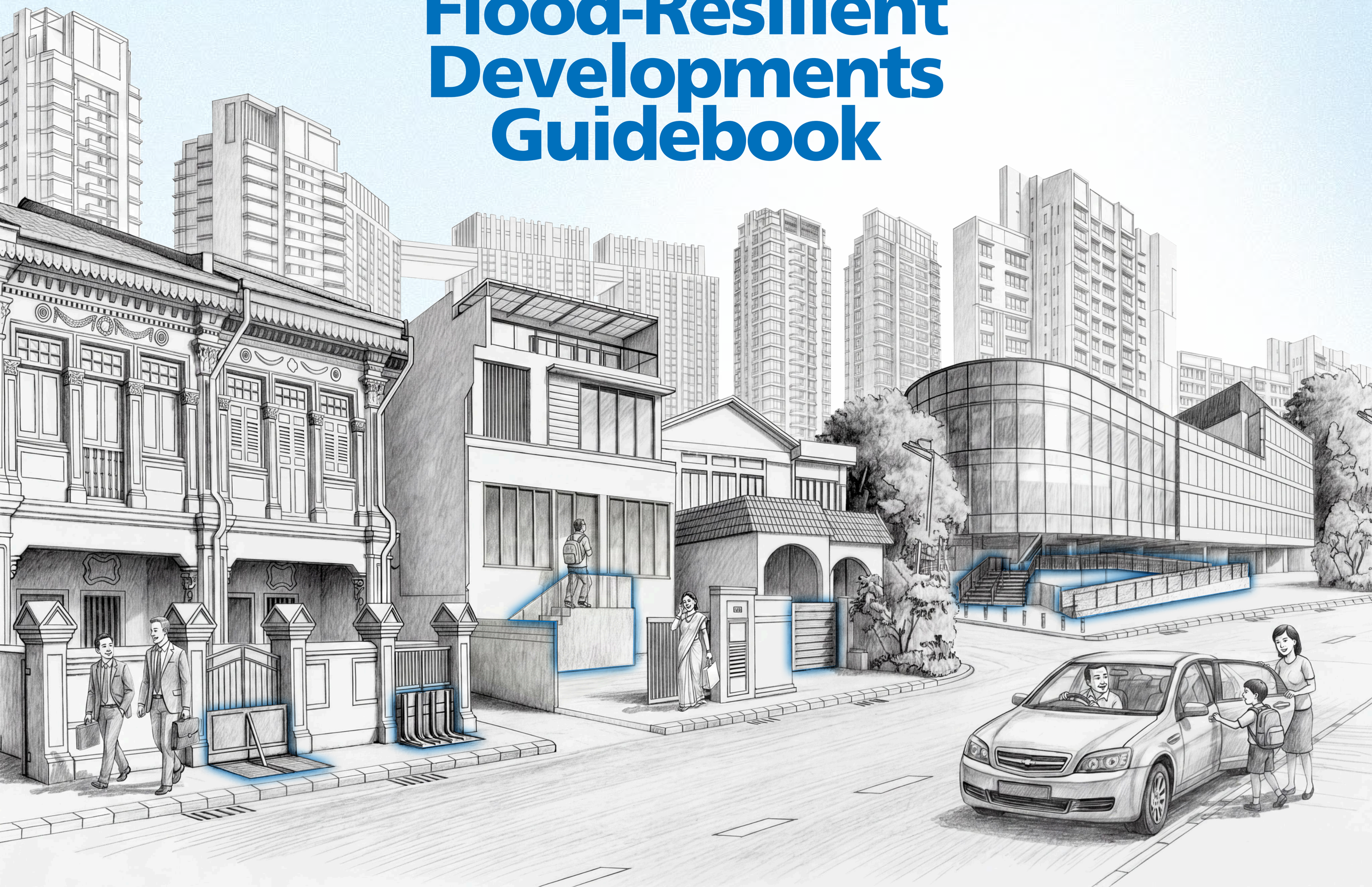
Flood-Resilient Developments Guidebook



Foreword

By Co-leads of the Alliance for Action to develop the Flood-Resilient Developments Guidebook



This guidebook, under the Alliance for Action framework, provided opportunities for the industry to work together with PUB in developing the book. As representatives of our fields, we were able to share our thoughts on the objectives and contents of the guidebook, and make the contents useful to the Property Owners, Design Professionals and Property Management Professionals.

All of us will play a part in making Singapore flood-resilient, starting with property owners, who are the decision makers on the extent and type of measures to take up. They can then seek advice from both the design professionals and property management professionals on the technical solutions to adopt. I hope all parties will find this guidebook useful in creating a flood-resilient Singapore.

Er. Lim Peng Hong
President, Professional Engineers Board Singapore
Managing Director, PH Consulting Pte Ltd



In the face of increasing climate variability and urban challenges, it is imperative for all stakeholders in the built environment to equip ourselves with the awareness and knowledge to better protect our properties.

This Flood-Resilient Developments Guidebook brings together the collective expertise of public and private sector representatives, offering practical tools spanning risk assessment, actionable mitigation strategies and proven solutions. Thoughtful design and proactive planning can protect our built environment while safeguarding communities. Flood resilience is no longer just a technical necessity—it is fundamental to ensuring the sustainability, safety, and longevity of our homes and infrastructure.

This guidebook bridges professional expertise and community action, reflecting our shared commitment to resilient urban spaces. I encourage industry professionals, developers, and homeowners alike to leverage it as we work collectively towards a safer, more resilient Singapore.

Ar. Melvin HJ Tan
Immediate Past President, Singapore Institute of Architects
Joint Managing Director, LAUD Architects Pte Ltd



Climate change is leading to more frequent intense rainfall and rising sea levels. These heighten flood risks in Singapore. Achieving flood resilience, which is about reducing the risk of, responding to and recovering from floods, requires collective effort across the People, Private and Public sectors.

This shaped our vision for this guidebook from the outset: to raise awareness of the "what" and "why" of flood resilience, while providing tools for the "how". We adopted an Alliance for Action (AfA) approach in co-creating the guidebook. We engaged over 70 stakeholders—from homeowners to built environment industry professionals.

This guidebook is a culmination of that collective effort. I hope it will come in handy for you as we work together to build a more climate-resilient Singapore.

Mr. Ong Tze-Ch'in
Chief Executive, PUB

Overview

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Explore Measures to Enhance Flood Resilience

Learn from Success Stories

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01

Introduction

1.1 Becoming Flood-Resilient in a Changing Climate

1.2 Singapore's Multi-Pronged Approach to Flood Resilience

1.3 Everyone Has a Part to Play in Singapore's Flood Resilience

1.4 Your Flood Resilience Journey Begins Here

At a glance:
Strengthening Singapore's collective resilience.

As climate change introduces greater uncertainty into our weather patterns, our approach to flood management must evolve.

This introduction sets the context for development-led resilience, outlining how PUB and industry partners work together to safeguard our built environment. Explore the concept of "living with water"—an approach that integrates transiently floodable areas into our urban fabric—and understand the roles each stakeholder can play.

This chapter is most useful for:

- Design Professionals
- Developers and Property Owners
- Property Management Professionals
- Homeowners

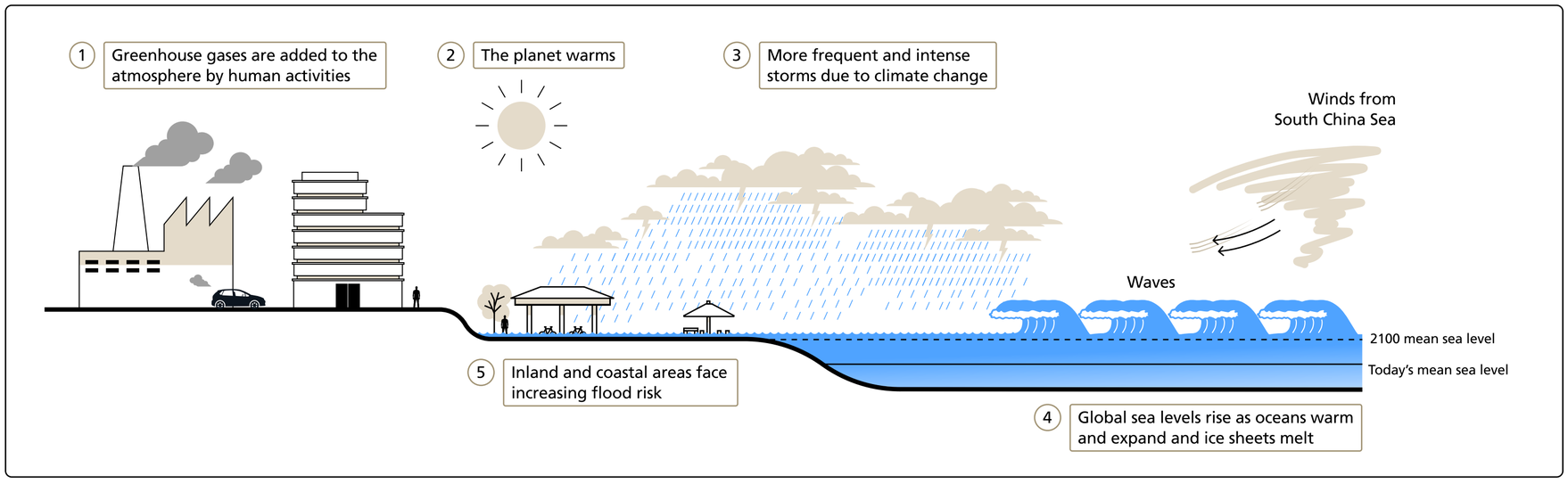
1.1 Becoming Flood-Resilient in a Changing Climate

1.1.1 Singapore Faces Increasing Flood Risks Due to Climate Change

According to Singapore's Third National Climate Change Study released in January 2024, rainfall is becoming more intense and unpredictable, and mean sea levels are projected to rise up to 1.15 metres by 2100. When storm surges coincide with high tides, they can also cause water levels to rise up to 5 metres in rare and severe events. With around 30% of Singapore's land lying at less than 5 metres above mean sea level, this makes us highly vulnerable to inland and coastal floods, especially in low-lying coastal areas.

Over the last few decades, the Government has built and maintained flood infrastructure. But in land-scarce Singapore, it is not feasible to expand public infrastructure indefinitely. Therefore, we must look towards managing risk, minimising damage and recovering quickly. Action needs to be taken at the individual development level to understand location-specific flood risks and incorporate flood resilience considerations in the planning and design of projects. Everyone can play a role to enhance flood resilience.

What causes climate change and how does it affect Singapore's flood risk?



1.1.2 Who This Guidebook is for

Design Professionals

- To gain a comprehensive understanding of flood-resilient design from planning to design stages, and the suite of potential measures suited to Singapore's context.
- To conduct flood risk assessments at the development level and recommend suitable flood-resilient measures to developers and property owners.

Developers and Property Owners

Homeowners

- To understand and conduct simple flood risk assessments for their properties, so as to make informed decisions on the next steps.
- To have a common pool of knowledge of flood-resilient measures to facilitate conversations with design professionals and property management professionals.

Property Management Professionals

- To plan for the operation and maintenance of flood-resilient developments on a day-to-day basis.
- To execute response plans effectively.

1.2 Singapore's Multi-Pronged Approach to Flood Resilience

As part of infrastructure planning and design, PUB has been adopting the "Source-Pathway-Receptor" approach since 2014 to achieve higher stormwater capacity and flood protection for developments. This is a systems-level approach to enhance Singapore's flood resilience, by ensuring that stormwater runoff from developments ("**Source**") into public drains is controlled, public drains have sufficient capacity to safely carry stormwater away ("**Pathways**") and developments ("**Receptor**") are protected from floodwaters.

Source

The area where rain falls and generates stormwater

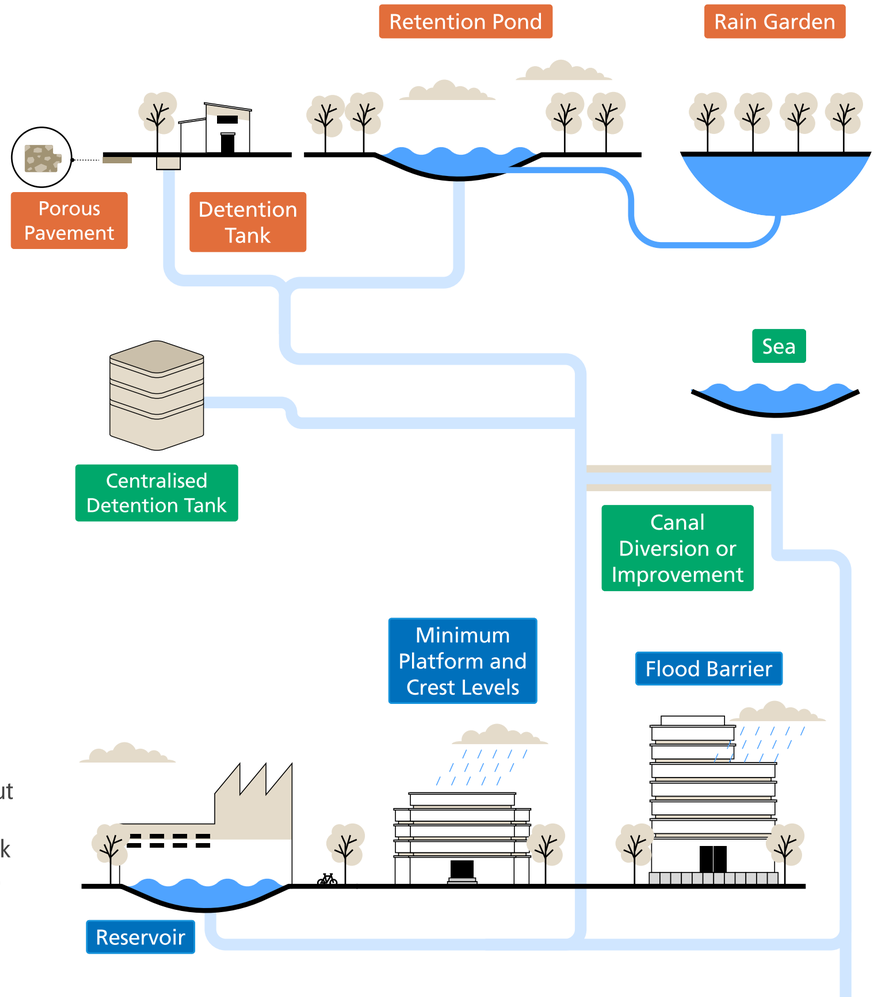
Pathway

The routes through which stormwater is carried away.

Receptor

The area where floodwaters may flow to and cause impact.

Want to know more? Find out more about the Source-Pathway-Receptor framework and how to apply it in PUB's Managing Urban Runoff Drainage Handbook.



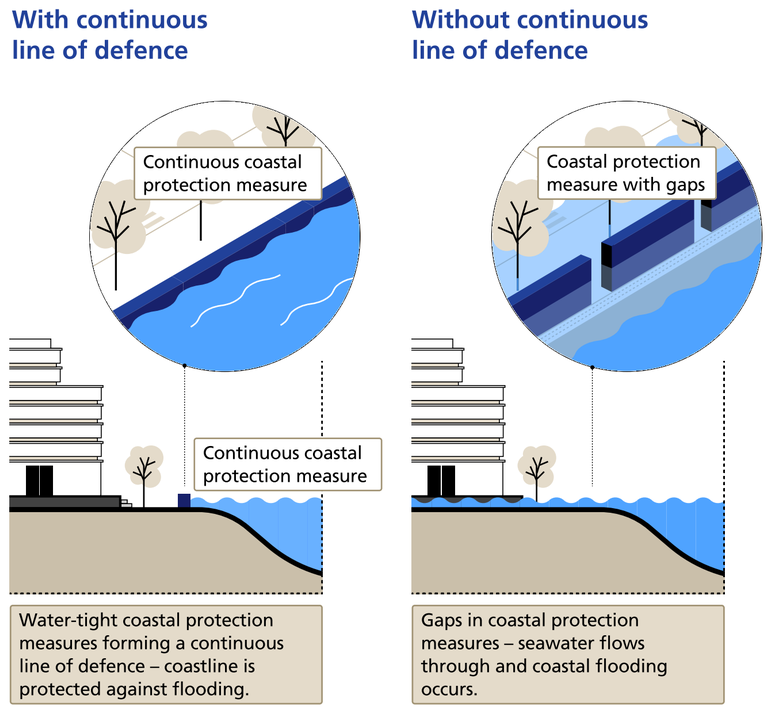
PUB takes a multi-pronged approach towards flood resilience, including:

- Development and Review of Legislation and Codes of Practice
- Implementation of Drainage and Coastal Protection Infrastructure
- Community Engagement to Raise Awareness and Preparedness
- Flood Response Operations

To achieve end-to-end flood resilience, PUB manages both coastal and inland flooding holistically. A continuous line of defence will protect Singapore against coastal flooding. To guide and support the implementation of coastal protection measures, PUB has published a Code of Practice on Coastal Protection (CPCOP) that defines the planning, design, operations and maintenance requirements.

The design of flood management infrastructure needs to consider not only current flooding conditions but also to cater for climate change impacts. However, Singapore has limited land, making it challenging to continually expand our coastal measures or drainage systems to protect all developments from every extreme weather event.

Given these realities, making Singapore flood-resilient requires **collective effort.**



1.3 Everyone Has a Part to Play in Singapore's Flood Resilience

Flood resilience depends on everyone knowing their roles.



PUB, Singapore's National Water Agency

- Build and maintain public drainage and coastal protection infrastructure
- Set standards and regulatory requirements
- Raise awareness of flood risk and response



Homeowners

- Maintain drains to prevent blockages
- Maintain flood preparedness
- Prepare flood barriers or other protective measures



Property Management Professionals

- Inspect and maintain flood-resilient measures
- Prepare response plan and conduct periodic flood drills

Flood Resilience



Developers and Property Owners

- Determine appropriate investment budget for flood-resilient measures
- Decide on the level of effort and appropriate means to address flood risks



Design Professionals

- Integrate flood-resilient design into developments
- Comply with regulatory requirements

1.3.1

Flood Resilience Can Bring Benefits to Developers

Achieve a performance criterion under Green Mark

The BCA Green Mark Certification Scheme is a sustainability framework and rating system for Singapore's built environment. The highest certification is awarded to developments deemed to demonstrate a high level of energy efficiency and environmental sustainability, including flood resilience. Obtaining this certification can lead to rental and value premiums, attain operational savings, and unlock green finance opportunities for developers throughout the development's lifecycle.

Comply with mandatory climate-related risk reporting

Since 2025, SGX-listed companies are required to disclose how they manage material physical climate risks, and how those risks could affect asset performance, business continuity and financial outcomes. For non-listed developers, this is not a requirement, but expectations on due diligence are changing. This could mean that those who move quickly to align themselves with these expectations could gain a stronger foothold in a competitive environment.

1.3.2

"Living with Water" as an Approach to Flood Resilience

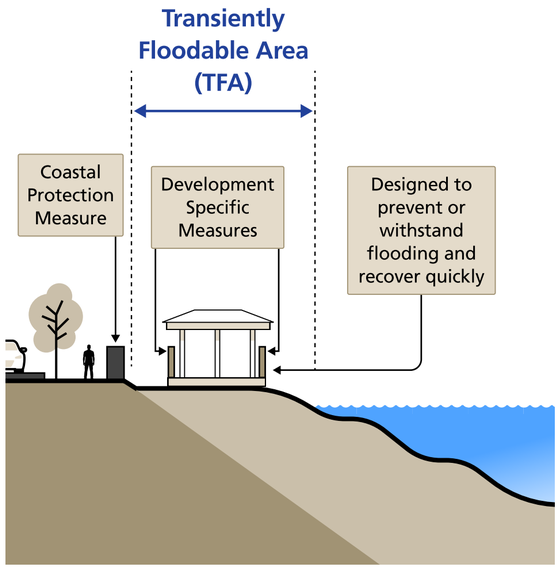
It may not be feasible or cost effective to eliminate all floods in Singapore. Hence, we should start thinking whether it is possible to design for an area that can withstand some degree of flooding.

This approach involves identifying areas that can safely accommodate floodwaters if a flood occurs and designing them so that damage and operational disruption is minimised and recovery is quick.

Developments at the forefront of "living with water"

A Transiently Floodable Area, or TFA, is a designated area specifically designed to allow temporary flooding during high tides or extreme weather events. Such areas may include beaches and coastal parks, where flooding is part of the natural tidal cycle that sustains marine ecosystems and supports outdoor activities. Further inland, parks like Alkaff Lake and Bishan-Ang Mo Kio Park are designed with floodplains to function as recreation space during dry weather, but serve as additional storage for stormwater during heavy rain.

While TFAs may be allowed to flood transiently, structures within these areas that are intended for human use must be designed to prevent or withstand flooding and recover quickly. This includes amenities such as restrooms and boardwalks. Thus, owners of developments within TFAs have to carefully consider which areas can tolerate flooding, which must be protected in all circumstances, and which measures are suitable to be implemented. In addition, early warning systems and response plans must be in place to manage floods when they occur.

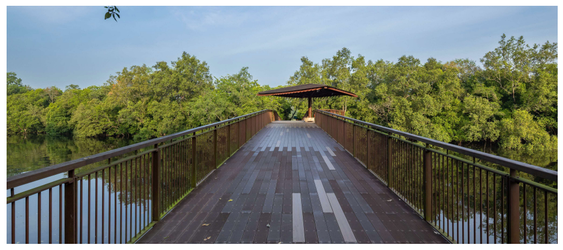


Coastal Transiently Floodable Area

Examples of TFA in Singapore



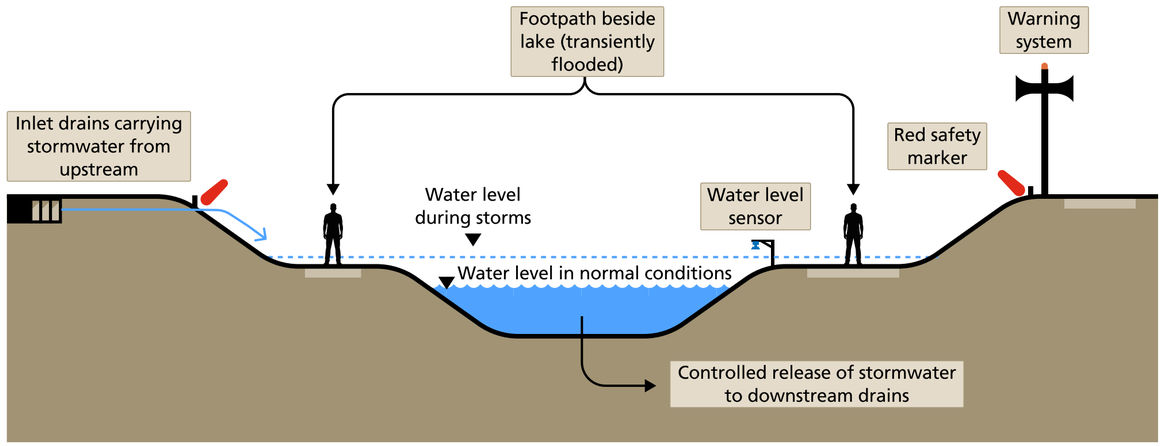
Bishan-Ang Mo Kio Park



Sungei Buloh Wetland Reserve

Design considerations to support "living with water"

- **Design for Priority**: Features that direct water flow towards designated floodable spaces (e.g. landscaped areas) can help to prevent floodwaters from reaching areas deemed critical (e.g. switch rooms).
- **Design for Safety**: Structures housing any valuable assets or intended for human use should be designed with protective measures, so that occupants and assets are protected against water damage.
- **Design for Recovery**: Adequate drainage and water-resistant materials or surface treatments on exposed facades can help to discharge water quickly after a flood event. This will allow the development to revert to its pre-flood condition with minimal damage to structures.



Inland Transiently Floodable Area

1.4 Your Flood Resilience Journey Begins Here

Development-led flood resilience is key

While flood risks are expected to intensify with climate change, property owners, homeowners, design professionals, and property management professionals can benefit by taking early action.

The journey begins in **Chapter 2** by outlining the **key principles** that inform flood-resilient designs, establishing the theoretical basis for all subsequent recommendations. In **Chapters 3.1** and **3.2**, the focus shifts to technical implementation, detailing how to **assess a development's specific flood risk** and decide on the necessary next steps.

Effective resilience also requires operational readiness. **Chapter 3.3** explains **what flood management entails** and provides a framework for how to plan for flood response.

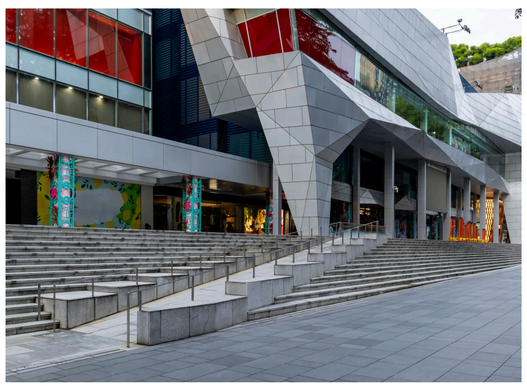
Chapter 4 contains a **toolkit of flood-resilient measures**, offering a range of physical and structural solutions. Finally, **Chapter 5** provides **case studies** showcasing how these flood-resilient measures have been applied in Singapore, illustrating the practical success of these strategies in a real-world context.











Top left to bottom right: Deployable flood barrier, slot-in flood barrier, detention pond, rain garden, elevated building entrances

02

Key Concepts

2.1 Understanding Flood Risk: Hazard, Exposure, and Vulnerability

2.2 Flood-Resilient Design Principles

At a glance: Resilience starts with a shared language.

This chapter breaks down the factors of risk—Hazard, Exposure, and Vulnerability—and introduces the four guiding principles for flood-resilient design. Use this as your blueprint for building a more resilient Singapore.

This chapter is most useful for:

- Design Professionals
- Developers and Property Owners
- Property Management Professionals
- Homeowners

2.1 Understanding Flood Risk: Hazard, Exposure, and Vulnerability

Flood resilience begins with an understanding of the factors that contribute to risk. This guidebook aims to explain the underlying drivers of flood risk.



Coastal flooding at East Coast Park, Mar 2024
Source: PUB

2.1.1

Understanding Flood Risks

What factors can contribute to flood risk in a development?

Lack of maintenance and operational readiness

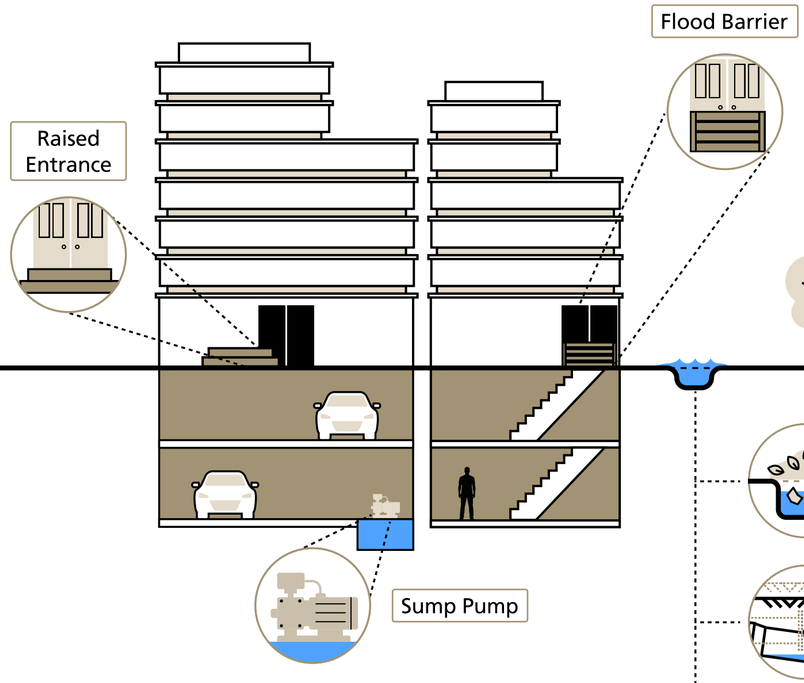
Flood-resilient measures (e.g. barriers, pumps) only work effectively if they are well-maintained and personnel are trained to deploy them when needed.

Low-lying area

Rainwater flows via gravity towards low-lying areas and the nearest drain. Low-lying areas naturally collect water from surrounding higher ground.

Climate change and extreme weather

Singapore faces rising sea levels and intensifying extreme weather events.



Inadequate drainage capacity and poor condition

Flood risk may be higher if drains are blocked or inadequate. Leaves, trash and silt can clog drains; older drains may become sunken or settle over time, which may cause stagnation of water.

Low platform level

A development may face higher risk of flooding if it has a low platform level.

Exposure to coastal waters

Premises located at Transiently Floodable Areas (TFAs) by the coast are at higher risk of flooding from transient events such as high tides and storm surges.

[All diagrams are for illustrative purposes and not to scale.]

Understanding the cause of flood risks is the starting point for taking effective action.

With this knowledge, property owners can better protect critical assets or plan for emergencies, while designers can make informed decisions about flood-resilient designs and drainage strategies.

Building this awareness enables individuals and communities to play an active role in keeping Singapore resilient against flooding.

2.1.2

Three Components that Define Flood Risk:

Hazard
The physical threat

Exposure
What lies in harm's way

Vulnerability
How much damage can be incurred

Each component, on its own, provides only a partial view of risk. **Hazard** describes the characteristics of the flood event; **exposure** identifies what is at risk; and **vulnerability** determines how much damage could result. When all three components interact, they paint a complete picture of flood risk, showing where the consequences are likely to be most serious and where action would make the greatest difference.

By fostering a common understanding of hazard, exposure, and vulnerability, stakeholders will have the knowledge to anticipate risks, implement adaptive strategies, and enhance overall resilience.



Hazard

A flood hazard refers to the physical event itself, e.g. the characteristics of flooding that could cause damage. It includes factors such as:

Source and Type of Flood

Singapore experiences (i) flash floods, which occur due to heavy rainfall; and (ii) coastal floods, which are a result of high tide or storm surges.

Depth and Velocity

Floods that have higher depth and velocity are more severe. Higher depths result in stronger forces exerted on buildings, structures and humans. Fast-flowing waters can also carry debris and objects like cars.

Duration

Flood duration varies according to the type of flood. Flash floods may recede within an hour, while coastal flooding may be a single event lasting a few hours or multiple events occurring periodically over a few days.

Extent

Typically, floods occur in areas with lower ground elevation where water accumulates. Depending on the type of flood, this may include low-lying coastal or inland areas, or localised areas with depressed ground elevation.



Flash flood due to heavy rainfall



Coastal flooding due to high tide or storm surges
Source: The Straits Times © SPH Media Limited

Exposure

Exposure refers to the people, infrastructure and assets, and ecosystems located in areas that could be affected by flooding.

People

Occupants of developments in low-lying or flood-prone areas, with particular attention to vulnerable groups whose ability to respond to flood incidents may be limited (e.g. persons with mobility issues).

Infrastructure and Assets

Buildings, utilities, roads and transport networks, and critical facilities such as hospitals and data centres that are located in low-lying or flood-prone areas

Ecosystems

Mangroves and coastal or riverside habitats that provide natural flood buffers but face increasing pressure from urbanisation and sea level rise.

Exposure alone does not determine impact. Some exposed areas can still be resilient due to robust design. For example, developments with elevated platform levels or designed to contain flooding within ancillary areas.

Vulnerability

Flood risk is not just about being in areas affected by flooding (exposure) or faced with higher rainfall or coastal surges (hazard). Vulnerability describes how much a development, or its occupants, can be impacted when flooding occurs.

At the site level, vulnerability in Singapore depends on several key factors:

Ground Elevation

Buildings with low platform levels are more susceptible to flooding than those with raised platforms.

Drainage

Poorly designed drains, insufficient capacity, or lack of backflow prevention increases vulnerability.

Water-Sensitivity of Assets

Using non-water-resistant materials and placing critical assets such as electrical systems at the ground level heightens vulnerability.

Maintenance and Operational Readiness

Even well-designed developments can be vulnerable if drains are clogged or flood-resilient measures are poorly maintained.

Awareness and Emergency Preparedness

Development occupants who are unfamiliar with how to respond to flooding may be more vulnerable.

Reducing vulnerability typically involves improving infrastructure, strengthening operational regimes and building community preparedness.

2.2

Flood-Resilient Design Principles

Four principles of resilient design frame the response to flood risk. Each addresses a distinct dimension of the risk profile.

Knowing where risk can arise and why consequences can be severe is only the first step. Reducing risks requires strategic planning and deliberate action with resilience in mind.

These principles enable developments to withstand, respond to, and adapt in the face of flooding.

While flood risk cannot be eliminated entirely, particularly given climate change and resource constraints, the four principles of flood-resilient design —adaptability, recoverability, robustness, and redundancy—can guide flood resilience efforts at any stage of the development's lifecycle.

Adaptability

Designing for Change

Why it matters:

Adaptability is the capacity to adjust as flood conditions evolve. Climate change results in more intense rainfall and higher sea levels, so what worked in the past may no longer be enough. Adaptive design anticipates change, accommodates flexibility and builds in room for expansion or strengthening.

Design implications:

Adaptable design could include modular and upgradable flood defences, convertible open space and blue-green systems for temporary stormwater storage, and response plans that are re-evaluated periodically.



Deployable flood barrier, Singapore
Source: FloodX (Singapore) Pte. Ltd.

Robustness

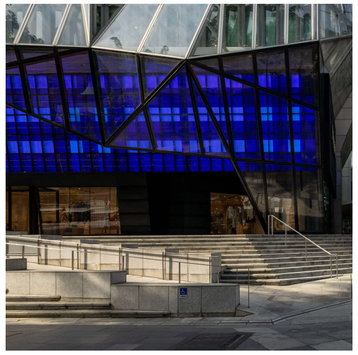
Strength to Withstand Flood Forces

Why it matters:

Robustness refers to the inherent strength and stability of physical structures and systems to endure stress. Designing for robustness means ensuring that critical systems and structures (e.g. building foundations, utility elevations, protective barriers) can withstand the pressure, impact and erosive forces or floodwaters so that damage and disruption is minimised during flood events.

Design implications:

Robust strategies include using sufficiently sturdy materials against water pressure and debris impact or relocating critical assets out of the path of floodwaters.



Elevated building with ramps and stairs, Singapore

Recoverability

Bouncing Back After a Flood

Why it matters:

Recoverability is about minimising damage and restoring normal operations as smoothly as possible after a flood. Evidence from global post-disaster analyses shows that rapid service restoration accelerates economic recovery and resumption of livelihood.

Design implications:

Recoverability strategies include using waterproof materials to protect assets that may be exposed to water, engineered or green measures to support drainage, and planning operational protocol to assess damage and return to operations smoothly post-flood.



Waterproof coating

Redundancy

Backup for Critical Systems

Why it matters:

Redundancy is distribution of risk by providing alternate capacity, routes, and services. Resilient systems are diverse and have fail-safes embedded in their design, so that if a primary element fails or is compromised, essential functions can continue without cascading outages.

Design implications:

Planning for redundancy means providing backup for critical systems. For deployable measures like flood barriers, this could mean storing extra units. For structural measures, it could mean providing dual conveyance routes, backup power sources, or segmenting networks to isolate faults.



Dual-design drain for conveyance and temporary storage

03

How to

3.1 Conduct a Flood Risk Assessment

3.2 Identify Options for Flood Resilience

3.3 Develop a Flood Response Plan

At a glance: Move from theory to action.

This chapter is your roadmap for applying risk principles to real-world sites. Learn to:
3.1 Conduct a flood risk assessment;
3.2 Identify the right options for flood resilience; and
3.3 Prepare a robust Flood Response Plan.

This is an essential screening phase for every development.

This chapter is most useful for:

Design Professionals
3.1 3.2

Property Management Professionals
3.1 3.2 3.3

Homeowners
3.1 3.2 3.3.8

Preface

How do we plan for and design flood-resilient developments?

This chapter is divided into the following three sections. It is recommended for all developments to prepare a Flood Response Plan (FRP), regardless of the flood risk assessment outcome, flood-resilient measures in place, or age of the development.

Recommended flow:

3.1
Flood Risk Assessment

Guides users to uncover the development's flood risk profile.

Users may start thinking about how risk outcomes affect the FRP and which measures can be implemented to enhance flood resilience.

3.2
Options for Flood Resilience

Guides users to identify which flood-resilient measures are appropriate.

Identified measures may determine how the development should respond in a flood event.

3.3
Flood Response Plan

Guides users to ensure the development is prepared against and can recover from flood events.

Considerations for the FRP may determine what kind of measures are preferred.

3.1 Conduct a Flood Risk Assessment

How do we analyse a development's hazard, exposure, and vulnerability?

The Flood Risk Assessment Matrix is a simple framework that enables design professionals, homeowners, and property management professionals to assess risk at the development scale without needing technical expertise, and to decide on the next course of action. This framework can be applied to all developments, whether they are inland or near the coast.

Applying judgement

This risk assessment will provide a high-level understanding of a development's risk profile and is intended to guide users on the next steps rather than prescribing specific solutions. If a detailed flood risk assessment is required, or if site conditions are highly complex, it is recommended to engage the right professionals.

3.1.1

Understanding the Flood Risk Assessment Matrix

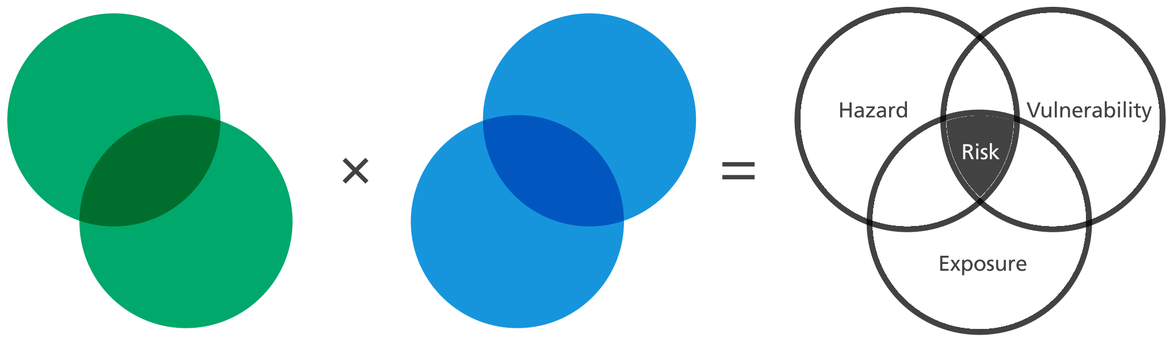
The assessment approach comprises three steps:

Step 1 Determine the Likelihood of Flooding (potential for floods)

Step 2 Determine the Impact of Flooding (severity of consequences)

Step 3 Determine the Risk Category using the Flood Risk Matrix

Likelihood and impact relate to the components of flood risk introduced in Chapter 2:



Likelihood × Impact = Risk

The Flood Risk Matrix

Likelihood \ Impact	Minor	Moderate	Major
Likely	Medium	High	High
Possible	Low	Medium	High
Unlikely	Low	Low	Medium

3. 1. 2

How to Assess Your Development

The assessment is to be conducted across three areas to allow users to focus on the specific conditions and functions of each space.

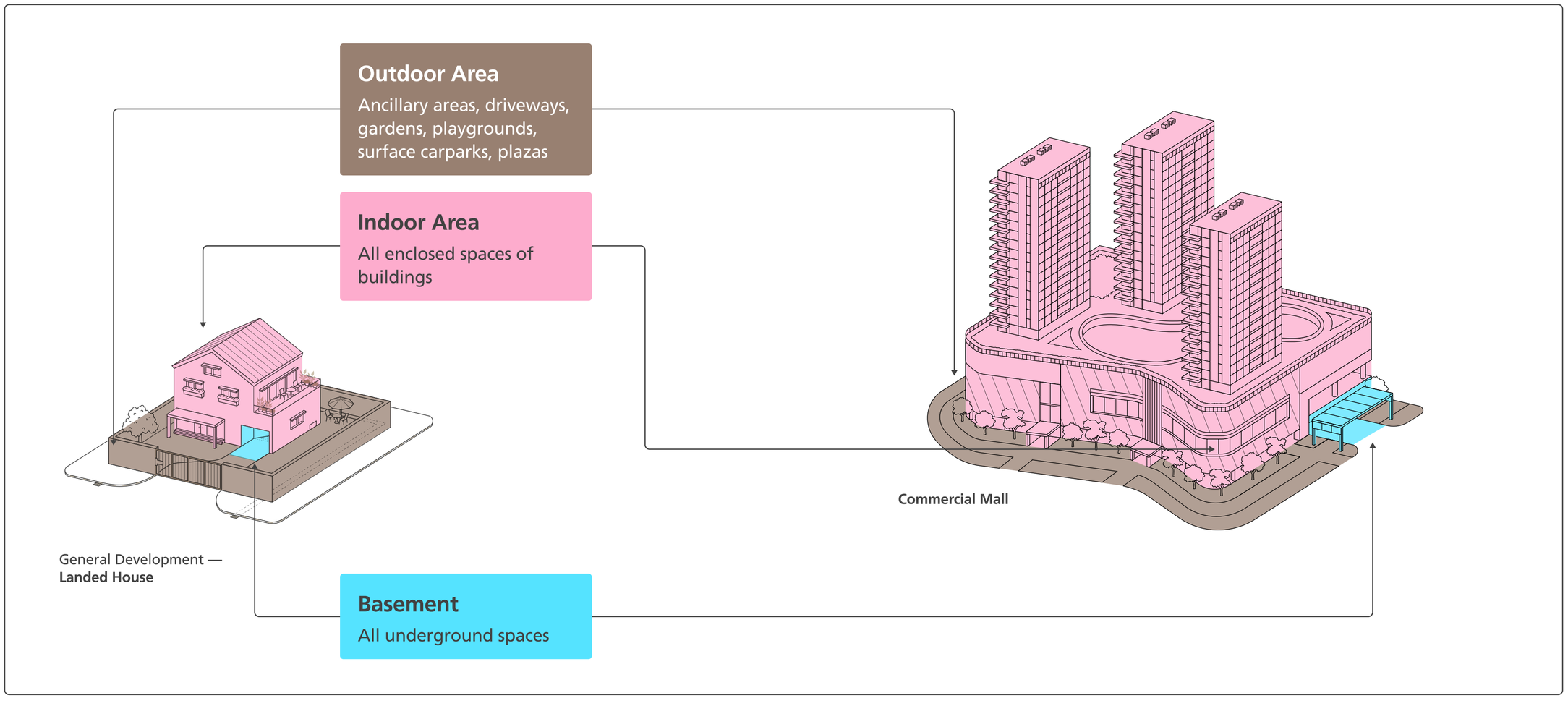
The risk assessment should be conducted for every **applicable area of the development separately**.

This means that if your development has Outdoor and Indoor Areas, but no Basement, you will obtain two risk categories – one for each area.

Separating risk assessments by area enables better understanding of where and how flood risk affects the development. It can help to identify which area is potentially most severely impacted, allowing for more targeted decision-making.

What about above-ground, open-air spaces like sky gardens and balconies?

These spaces are typically considered part of the Outdoor Area. If designed with adequate drainage, they are usually less susceptible to flooding from heavy rainfall or coastal events than ground-floor outdoor spaces. Thus, they are not the primary focus of the risk assessment.

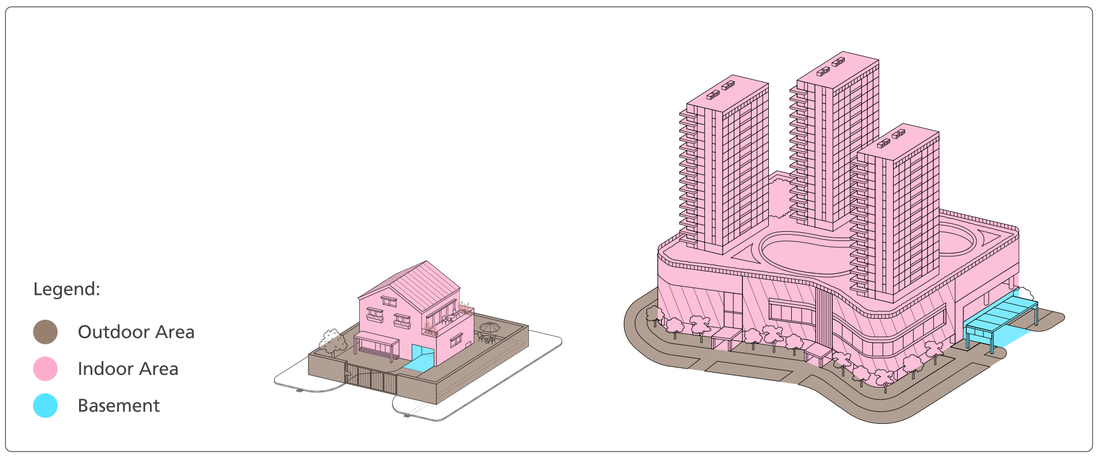


Step 1: Determine the Likelihood of Flooding

The first step in assessing flood risk is to evaluate how likely floodwaters can reach different parts of a development. This can be done through simple visual observations of the current conditions of your development during a site walkthrough.

The likelihood assessment should start with the Outdoor Area, then the Indoor Area, and finally the Basement (if applicable). The flow of the assessment reflects how floodwaters from the surroundings tend to pass through outdoor areas before flowing to enclosed or underground spaces.

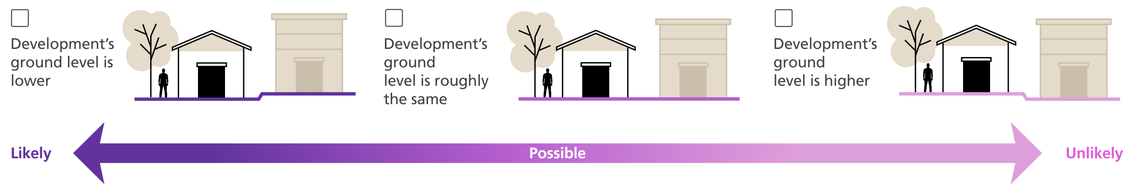
Within each area, there are one or more factors to assess. For each factor, users should determine a likelihood rating of **Likely, Possible, Unlikely.**



Outdoor Area

For Outdoor Areas, assess these three factors and assign each factor a likelihood rating:

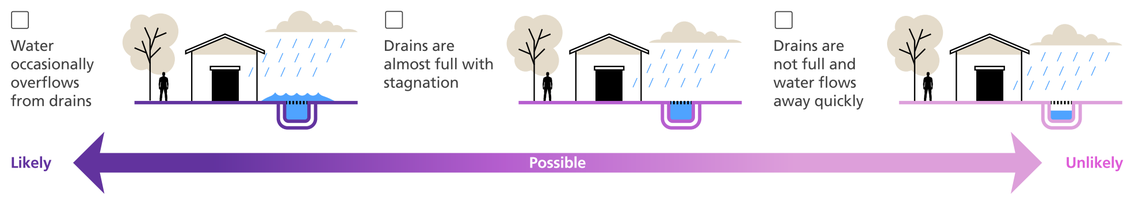
1. **Development's ground level compared to ground level of adjacent developments:** Floodwaters from the surroundings naturally flow towards lower-lying sites.



2. **Entrances to the development compared to adjacent road level:** "Entrances" include any part of the development boundary that is not walled and where water can flow freely – e.g. main gates, secondary entrances, and any open access points.



3. **Drainage capacity and condition:** Drainage issues observed during or just after rain could be a sign of insufficient capacity or poor design. Developments near the coast should also observe drain capacity during high tides, regardless of rain.



The overall likelihood for the Outdoor Area is determined by the **highest likelihood observed across the three factors**. For example, if one factor is rated Possible and the other two are rated Unlikely, the overall likelihood for the Outdoor Area is Possible.

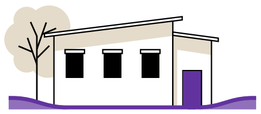
Indoor Area

For Indoor Areas, assess the following factor:

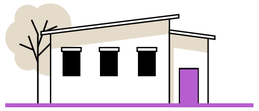
- **Building opening(s) in comparison to the outdoor area of the development:** "Openings" could include doors, loading bays, windows, vents, etc. Openings higher than the Outdoor Area prevent floodwaters from entering the building up to the height of the opening.

Take note that the likelihood for Indoor Area should not be higher than the likelihood assigned to Outdoor Area, regardless of the building opening levels. This is because floodwater will generally affect Outdoor Areas before it can reach enclosed building spaces.

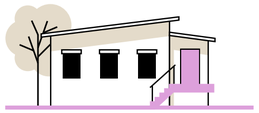
☐ Building openings are lower



☐ Building openings are flush with Outdoor Area



☐ Building openings are raised



Likely — Possible — Unlikely

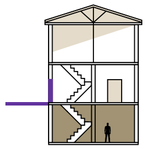
Basement

For Basement(s), assess the following factor:

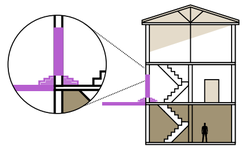
- **Entrance(s) to basement areas and the presence of sump pumps:** "Entrances" could include any ramps, staircases, or other service penetrations that lead to the basement. In addition, consider whether there is an operational sump pump in the basement.

For this factor, consider where the basement can be accessed from. If access is only via Indoor areas, the likelihood for the Basement should not exceed that of the Indoor area. This is because flooding must first affect indoor spaces before reaching the basement. However, if there is at least one entrance via Outdoor Areas, conduct the likelihood assessment for the Basement independently of other areas.

☐ Entrance to basement is flush with the Outdoor Area and no sump pump

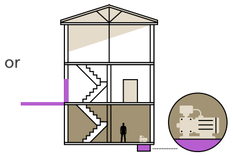


☐ Entrance to basement is higher, but there is no sump pump

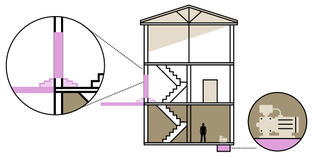


☐ There is a sump pump, but entrance to basement is flush with the Outdoor Area

or

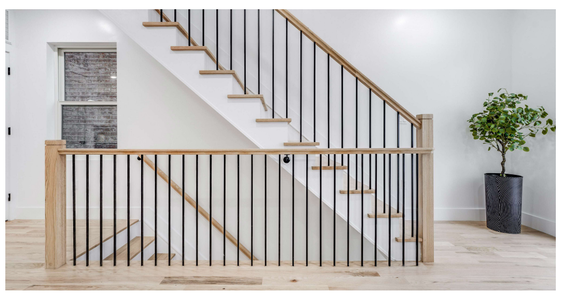


☐ Entrance to basement is higher with sump pump



Likely — Possible — Unlikely

A printable Likelihood Assessment Table is provided in Annex 2.

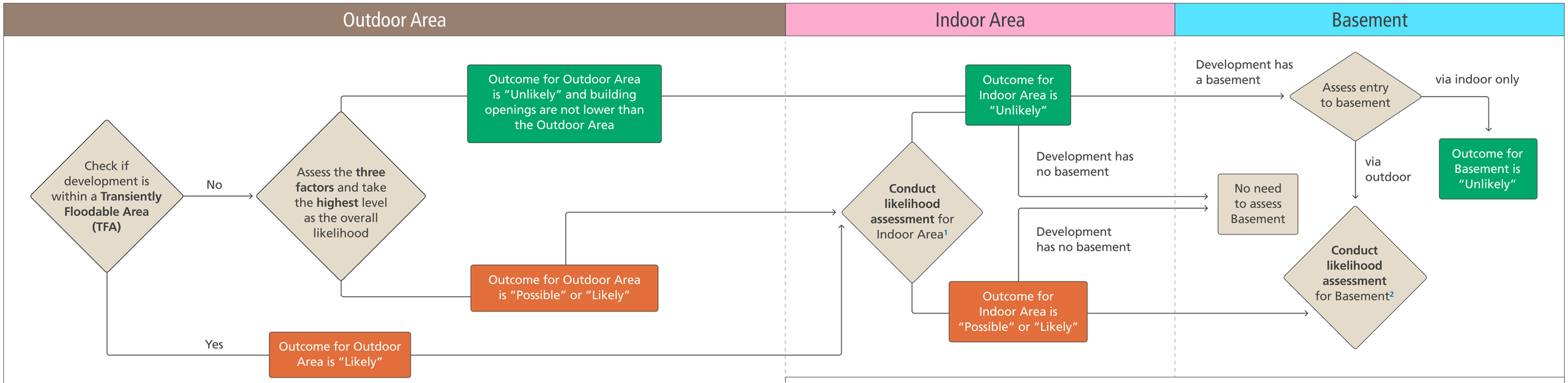


Entry to basement via indoor area(s)



Entry to basement via outdoor area(s)

Summary of the likelihood assessment by Area



Adjustments to Likelihood

After completing the initial likelihood assessment, users may adjust the likelihood rating for each area based on **three compounding factors that can directly impact the development's likelihood of flooding**. This is an optional step but can improve the accuracy of the assessment. If information on these factors is not available, the assessment can still be completed to give a high-level evaluation of the development's risk profile.

Factor 1: History of flooding

Identify any area that may have been flooded in the past. The likelihood rating should be revised to **"Likely"** if both of the following conditions apply:

- The flood incident was caused by a flash flood or coastal flooding (i.e. not due to internal causes such as pipe bursts) and water levels reached ankle-to-knee depth or higher.
- No structural or design modifications have been made to the flooded area—such as raising of ground or crest levels, or drainage improvements—since the flood incident.

Factor 2: Transiently Floodable Areas (Outdoor Area only)

Developments within Transiently Floodable Areas (TFAs) tend to be low-lying and are allowed to flood under certain circumstances, thus outdoor areas will have a likelihood rating of **"Likely"**.

Factor 3: Sump pump design (Basement only)

A sump pump is an automatic pump system built into the floor of a basement to drain accumulated water by transferring the water to a higher level. To prevent backflow when external water levels are high, the discharge pipe must be designed with a swan neck.

If a basement has a sump pump, check whether it is designed with a compliant swan neck as required in the Code of Practice on Surface Water Drainage. If there is no swan neck or it is non-compliant, select the scenario that reflects **"No sump pump"** and adjust the likelihood accordingly.

Step 2: Determine the Impact of Flooding

Next, evaluate the development's vulnerabilities to understand the potential impacts of flooding. This step is to be done separately for each area. For Outdoor and Indoor Areas, assume flood depths are near ground level, i.e. ankle-to-knee depth. For the Basement, assume flood depths will be much higher, since water can accumulate and may not drain via gravity. Similar to Step 1, conduct the impact assessment for Outdoor Areas first, and assume that all previously assessed areas remain flooded when completing this step.

Flood impact focuses on three key categories and each category has one or more factors to assess. Users should answer the guiding questions before filling in the Impact Assessment Table.

Guidance to evaluate flood impact

Category	Factor	Guiding questions	Considerations
Human Safety	Ability of occupants to react to floods	• Are there any spaces where occupants may be resting or sleeping that are affected by floodwaters?	Occupants in these states may not react in time, especially if they are vulnerable (e.g. have mobility limitations, have disabilities, or are very young or elderly).
	Accessibility of safe areas to seek shelter	• Are safe areas to seek shelter still accessible if a flood occurs?	User should first identify where the safe areas are, and the evacuation routes occupants would use to get there. Spaces on upper floors or high ground are generally considered safe areas. Safe areas and evacuation routes are considered inaccessible if they become blocked, significantly submerged, or dangerous to pass through.
	Risk of immediate physical dangers	• Is there any physical danger (injury or threat to life) while moving/attempting to move to safety?	Occupants may need to wade through water. Visibility could be affected and there is a risk of tripping and falling. In more severe cases, swimming may be required for evacuation; occupants may be trapped in an enclosed space with the potential of drowning.
Damage to Assets	Critical assets	• What are the critical assets that are essential to a development's key operations and where are they located? • At the assumed flood depth, how will the critical assets be affected?	Critical assets may include: utilities, electrical/switch rooms, lifts, fire safety equipment, water supply, etc. Critical assets that are at or near ground level or in basements are most likely to be affected, especially if they are sensitive to water damage.
	Non-critical assets	• What are the other assets or property considered highly valuable and sensitive to water damage, even if they are not critical? Where are these assets located? • At the assumed flood depth, how will these non-critical but valuable assets be affected?	Non-critical assets may include items of high financial or sentimental value. The subjective judgement of the property owner should be taken into consideration.
Disruption to Operations	Length of disruption	• Once a flood occurs, how much time will be required for the development to return to basic operations?	Operational downtime may result if: • Critical assets including utility and building systems fail • Time is required to clean, dry, and repair the site • Occupants/tenants need to be evacuated. For residential developments (e.g. landed homes, condominiums), a situation of no/minimal disruption may be possible, if occupants are still able to continue residing there even if a flood occurs.

Impact Assessment Table

Category		Guiding Questions	Minor	Moderate	Major
Human Safety	1a	Are there any spaces where occupants will be resting or sleeping that are affected by floodwaters?	☐ No	☐ Yes, but no vulnerable populations (e.g. able-bodied adults)	☐ Yes, for vulnerable populations (e.g. young children, elderly, persons with disabilities)
	1b	Are safe areas to seek shelter and evacuation routes to these safe areas still accessible if a flood occurs?	☐ Safe areas are accessible and evacuation routes are not affected	☐ Some inaccessible, but occupants are still able to move to safety	☐ All safe areas are inaccessible
	1c	Is there any physical danger (possibility of injury or threat to life) while moving/attempting to move to safety? (If answer to 1b is "Major", select "Major" here too)	☐ No possibility of injury; evacuation routes unaffected	☐ Possibility of injury but no threat to life (e.g. tripping, wading through water, visibility affected)	☐ Threat to life possible or unable to move to safety (e.g. swimming required, drowning, entrapment)
Damage to assets	2a	At the assumed flood depth, how will the identified critical assets be affected?	☐ No damage	☐ Minor damage but still able to function	☐ Significant damage
	2b	At the assumed flood depth, how will the non-critical assets (highly valuable and sensitive to water) be affected?	☐ No or minor damage	☐ Some damage; repair needed	☐ Damaged beyond repair or replacement needed
Disruption to operations	3a	Once a flood occurs, how much time will be required for the development to return to basic operations?	☐ No disruption or up to several hours	☐ One or two days	☐ Several days or weeks
Take the highest level of the assessed factors as the overall impact level. E.g. if there is one tick in Major and all other ticks are in Minor, the overall impact level is Major.			Area Assessed: ☐ **Outdoor Area** ☐ **Indoor Area** ☐ **Basement**		Overall Impact Level: ☐ **Minor** ☐ **Moderate** ☐ **Major**

When completing the impact assessment, take the highest level as the overall impact rating for each area. For example, if most factors are rated as Minor, except for one which is rated as Moderate, the overall impact level for that area should be Moderate.

This ensures that the assessment reflects the most serious potential consequence of flooding for your development.

A printable Impact Assessment Table is provided in Annex 2.

Special Considerations for Human Safety

The aspects of human safety as defined in this risk assessment are intended for general developments. However, for **high-occupancy or sensitive developments**, human safety may be of highest importance. Where necessary, users may supplement the factors and guiding questions to ensure the evaluation of human safety is sufficiently comprehensive for the development's unique needs.

Such developments may include:

- Hospitals and clinics
- Elderly care facilities, nursing homes, and assisted living facilities
- Educational facilities such as childcare centres, schools and universities
- Multi-unit residential developments
- Large assembly buildings, including community centres, theatres, stadiums, and places of worship
- Correctional facilities and detention centres
- Emergency services buildings, such as fire stations and police stations

Step 3: Determine Risk Category Using the Flood Risk Matrix

Finally, the risk category of each part of a development is determined by combining the likelihood and impact ratings using the risk matrix.

Your Flood Risk Matrix and what it means for your flood resilience

Impact →

Likelihood ↓

	Minor	Moderate	Major
Likely	Medium	High	High
Possible	Low	Medium	High
Unlikely	Low	Low	Medium

Each category signals the degree of risk and the level of action that may be warranted:

Low risk	Development is adequately resilient to flooding.
Medium risk	There is some flood risk. If you wish to reduce the exposure to flood risk, take steps to enhance flood resilience.
High risk	Immediate and comprehensive action to enhance flood resilience is recommended.

How does the Flood Risk Assessment help you?

The outcome of the flood risk assessment does not prescribe specific actions, but helps users decide the following:

- Whether action is needed now or later
- What level of intervention is required
- Where to focus investment for the greatest resilience benefit

For design and property management professionals, it also provides a basis to justify decisions to key stakeholders.

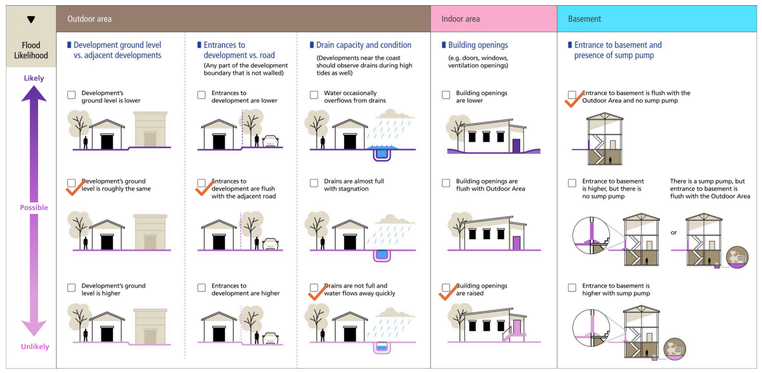
Guidance on using the risk assessment outcomes to inform next steps is provided in Chapter 3.2: Identify Options for Flood Resilience.

3. 1. 3

Worked Example 1: Landed House

This example shows an **existing landed house** which was built many years ago. The owner has no immediate plans to redevelop the property, but is concerned that it may be more susceptible to floods due to in view of climate change. The owner thus conducted a flood risk assessment to better understand the property's flood risk.

Step 1 Determine the Likelihood of Flooding



Likelihood by area:

Outdoors	**Possible**
Indoors	**Unlikely**
Basement	**Likely**

No adjustments are required based on additional considerations.

Step 2 Determine the Impact of Flooding

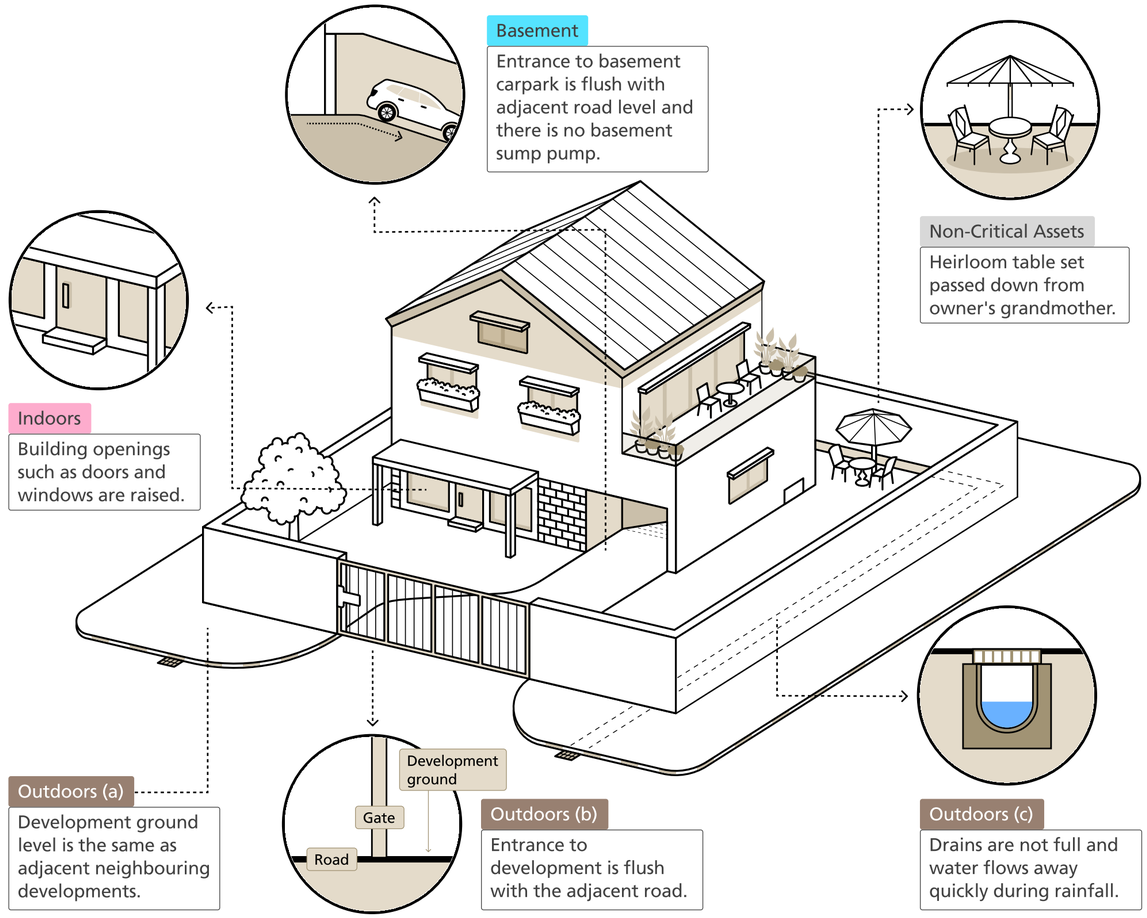
Impact of flooding was assessed for all three areas separately. Below is the record for Outdoor Area. This assessment was repeated for Indoor Area and Basement.

Category		Guiding Questions	Minor	Moderate	Major
Human Safety	1a	Are there any spaces where occupants will be resting or sleeping that are affected by floodwaters?	☑ No	☐ Yes, but no vulnerable populations (e.g. able-bodied adults)	☐ Yes, for vulnerable populations (e.g. young children, elderly, the persons with disabilities)
	1b	Are safe areas to seek shelter and evacuation routes to these safe areas still accessible if a flood occurs?	☑ Safe areas are accessible and evacuation routes are not affected	☐ Some inaccessible, but occupants are still able to move to safety	☐ All safe areas are inaccessible
	1c	Is there any physical danger (possibility of injury or threat to life) while moving/ attempting to move to safety? (If answer to 1b is "Major", select "Major" here too)	☑ No possibility of injury; evacuation routes unaffected	☐ Possibility of injury but no threat to life (e.g. tripping, wading through water, visibility affected)	☐ Threat to life possible or unable to move to safety (e.g. swimming required, drowning, entrapment)
Damage to assets	2a	At the assumed flood depth, how will the identified critical assets be affected?	☐ No damage	☑ Minor damage but still able to function	☐ Significant damage
	2b	At the assumed flood depth, how will the non-critical assets (highly valuable and sensitive to water) be affected?	☐ No to minor damage	☐ Some damage; repair needed	☑ Damaged beyond repair or replacement needed
Disruption to operations	3a	Once a flood occurs, how much time will be required for the development to return to basic operations?	☑ No disruption or up to several hours	☐ One or two days	☐ Several days or weeks
Take the highest level of the assessed factors as the overall impact level. E.g. if there is one tick in Major and all other ticks are in Minor, the overall impact level is Major.			Area Assessed: ☑ **Outdoor Area** ☐ **Indoor Area** ☐ **Basement** Overall Impact Level: ☐ **Minor** ☐ **Moderate** ☑ **Major**		

The owner greatly values the heirloom table set in the garden so there would be major damage to non-critical (but valuable) assets if a flood occurs. In contrast, the impact of floods in Indoor Area and Basement is less severe.

Impact by area:

Outdoors	**Major**
Indoors	**Moderate**
Basement	**Moderate**



Step 3 Determine Risk Category Using the Flood Risk Matrix

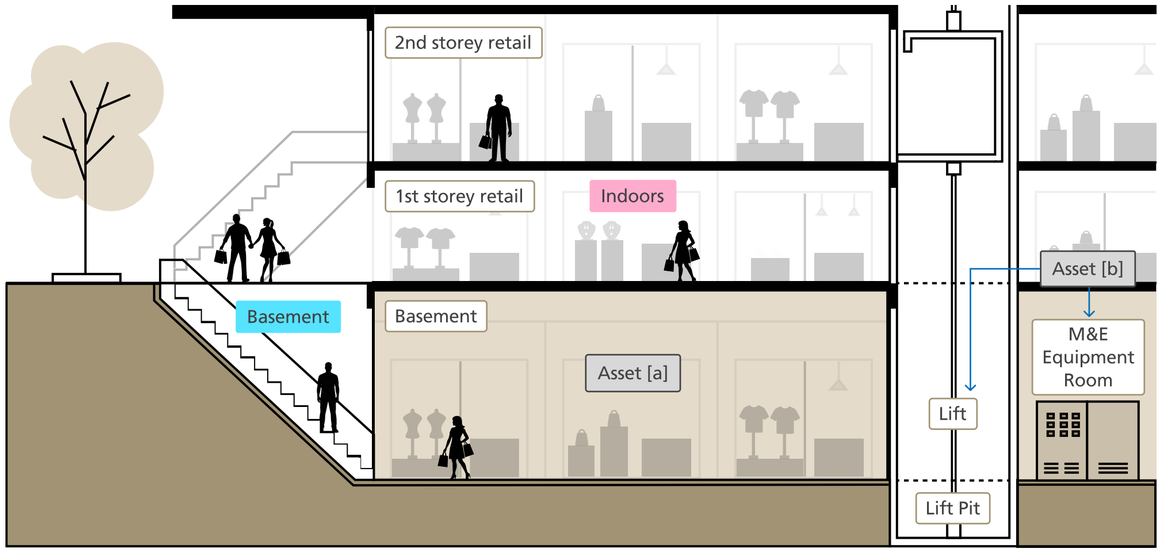
	Outdoor Area	Indoor Area	Basement
Likelihood	Possible	Unlikely	Likely
Impact	Major	Moderate	Moderate
Risk Level	**High**	**Low**	**High**

Outcome: Flood risk is assessed to be "High" in Outdoor Area and Basement.
The owner now knows that if they want to enhance the flood resilience of the house, they should focus their efforts on these two areas.

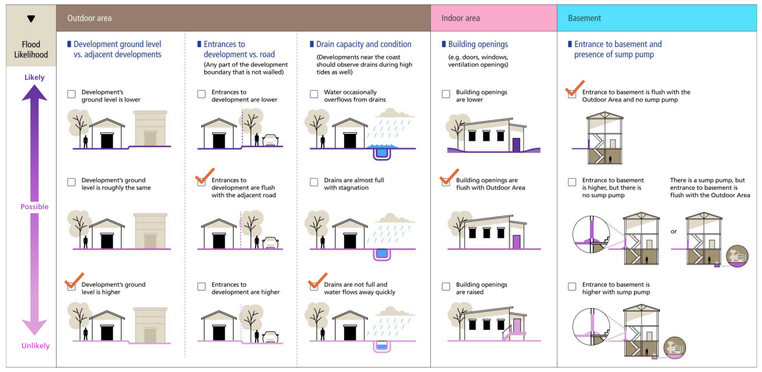
3. 1. 4

Worked Example 2: Commercial Development

This example is of a coastal **commercial development**, where flooding has the potential to disrupt business, impact tenants, and damage assets. To support informed risk management and long-term planning, a flood risk assessment was undertaken.



Step 1 Determine the Likelihood of Flooding



As the development is by the coast, the likelihood assessment also included observing internal drain capacity at high tides.

Likelihood by area:

Outdoors	**Possible**
Indoors	**Possible**
Basement	**Likely**

Step 2 Determine the Impact of Flooding

Impact of flooding was assessed for all three areas separately. Below is the record for Basement. This assessment was repeated for Outdoor and Indoor Areas.

Category		Guiding Questions	Minor	Moderate	Major
Human Safety	1a	Are there any spaces where occupants will be resting or sleeping that are affected by floodwaters?	☑ No	☐ Yes, but no vulnerable populations (e.g. able-bodied adults)	☐ Yes, for vulnerable populations (e.g. young children, elderly, the persons with disabilities)
	1b	Are safe areas to seek shelter and evacuation routes to these safe areas still accessible if a flood occurs?	☐ Safe areas are accessible and evacuation routes are not affected	☑ Some inaccessible, but occupants are still able to move to safety	☐ All safe areas are inaccessible
	1c	Is there any physical danger (possibility of injury or threat to life) while moving/ attempting to move to safety? (If answer to 1b is "Major", select "Major" here too)	☐ No possibility of injury; evacuation routes unaffected	☑ Possibility of injury but no threat to life (e.g. tripping, wading through water, visibility affected)	☐ Threat to life possible or unable to move to safety (e.g. swimming required, drowning, entrapment)
Damage to assets	2a	At the assumed flood depth, how will the identified critical assets be affected?	☐ No damage	☐ Minor damage but still able to function	☑ Significant damage
	2b	At the assumed flood depth, how will the non-critical assets (highly valuable and sensitive to water) be affected?	☐ No to minor damage	☐ Some damage; repair needed	☑ Damaged beyond repair or replacement needed
Disruption to operations	3a	Once a flood occurs, how much time will be required for the development to return to basic operations?	☐ No disruption or up to several hours	☐ One or two days	☑ Several days or weeks
Take the highest level of the assessed factors as the overall impact level. E.g. if there is one tick in Major and all other ticks are in Minor, the overall impact level is Major.			Area Assessed: ☐ **Outdoor Area** ☐ **Indoor Area** ☑ **Basement** Overall Impact Level: ☐ **Minor** ☐ **Moderate** ☑ **Major**		

Due to the presence of critical equipment and retail areas in the Indoor and Basement Areas, flooding in these areas could lead to significant disruption to operations. In contrast, flooding within the Outdoor Area is expected to result in relatively minor impacts, as it does not contain critical equipment.

Impact by area:

Outdoors	**Minor**
Indoors	**Major**
Basement	**Major**

Step 3 Determine Risk Category Using the Flood Risk Matrix

	Outdoor Area	Indoor Area	Basement
Likelihood	Possible	Possible	Likely
Impact	Minor	Major	Major
Risk Level	**Low**	**High**	**High**

Flood risk is assessed to be "High" in Indoor Area and Basement.
The owner now knows that risk management and planning should focus on these two areas.

3. 1. 5

Detailed Flood Risk Pre-Assessment for Design Professionals

Design professionals such as engineers and architects may wish to build a more comprehensive and holistic understanding of the site's exposure and vulnerability to flooding.

This subsection guides design professionals to perform a detailed site assessment and create an inventory of critical and non-critical assets, which can be completed as a preliminary step prior to filling in the Likelihood and Impact Assessment Tables. The resulting risk category can then be cross-referenced against the annotated site or building plans to identify specific vulnerabilities within each area.

Within project life cycles, the flood risk assessment can be incorporated into the typical site analysis conducted during the early stages of development.

Functions and Characteristics:

Begin by reviewing building permits, operational schedules, and occupancy data to determine how the site is used and when it is most active.

How to do it:

- Using the floor plan, identify locations with vulnerable occupants, such as elderly residents, children, or individuals with limited mobility.
- Identify critical-use periods and operating hours.
- Document areas that house essential services or high-value contents (e.g. electrical switchgear, backup generators, hazardous material storage).

Terrain and Drainage:

Understanding the site's topography and drainage systems helps determine where water is likely to flow and accumulate.

How to do it:

- Review and annotate the site's existing plan or topographic survey.
- Inspect the site for visible indicators such as watermarks, sediment deposits, erosion, or damaged drainage infrastructure.
- Review flood incident records. If not available, interview occupants or nearby residents for anecdotal flood history.



Structures and Systems Sensitive to Flood Damage:

Certain structures and systems are particularly vulnerable to flood impacts. Design professionals can review architectural and mechanical, electrical and plumbing (MEP) drawings, verify information through site walkthroughs, and document the data in an inventory log.

How to do it:

- Identify basements and below-grade spaces on building plans.
- Inspect entrances, vents, and other openings to check height of those openings and any indication of past water ingress.
- Document exposed materials such as façade finishes and flooring for water sensitivity and log them in an asset inventory.
- Document the location and placement of critical assets including mechanical and electrical systems, e.g. switchboards, heating, ventilation and air conditioning (HVAC) units.

Services, Access, and Dependencies:

Finally, evaluate site services, access routes, and external dependencies to understand the development's overall operational resilience. This applies predominantly to medium- and large-scale developments, rather than individual landed homes.

How to do it:

- Review utility diagrams to check if power, water, and telecommunications are designed with redundancy (e.g. backup systems).
- Identify external dependencies such as shared infrastructure or upstream drainage systems. Failure upstream can cause cascading impacts within the development.



Example of a critical asset inventory log

Asset Tracker	Asset Name / Description	Location	Function	Notes	Date
001	Main electrical switchboard	Basement	Provides power to entire building	Flood sensitive	15 Jan 202X
002	Backup generator	Roof / Plant room	Emergency power for critical systems	High importance	10 Jan 202X
003	Water pump/ Sump system	Basement	Flood mitigation / drainage	Key for flood response	12 Jan 202X
004	Elevator control panel	Ground floor	Vertical transport	Flood sensitive	08 Jan 202X
005	Fire alarm / sprinkler control	Various	Life safety system	Must remain operational	05 Jan 202X
006	IT server rack/ communications	Server room	Critical communications and data	Sensitive to water and power outage	14 Jan 202X

3.2 Identify Options for Flood Resilience

Flood Risk Assessment Matrix supports the systematic documentation of flood risks and provides high-level recommendations. It does not prescribe specific actions or measures. This section guides users on how to translate the risk assessment findings into appropriate next steps.

Property owners should lead key decisions on the level of effort and investment they are willing to commit to addressing flood risks and determining the appropriate timing to act. Design and property management professionals can support this process by translating the property owner's considerations into tangible intervention proposals.

3. 2. 1

Understanding Risk Appetite

Risk appetite reflects how much flood risk the property owner is personally willing to tolerate before acting. It is inherently subjective: what feels acceptable for one owner may feel too risky for another. Differences in risk appetite arise due to two major factors:

1. **Consequence:** The owner's priorities and views on how essential certain spaces or assets are, considering the flood risk.
2. **Capacity:** The available financial or operational resources for the development to respond to and recover from a flood.

Although a subjective exercise, understanding risk appetite is an important step to translate the technical risk assessment into practical decisions on what to do next. Being clear about your risk appetite ensures that the actions you take are aligned with your needs and expectations—it helps you prioritise where to invest, how urgently to act, and how much risk you are comfortable living with.

3. 2. 2

How to Identify Appropriate Flood-Resilient Measures

Measures should be well-matched to their intended use and appropriate for their context. Beyond technical soundness, factors such as cost, operational complexity, and visual impact are equally important considerations. International best practice shows that even well-designed measures can underperform when they are poorly matched to operational constraints, maintenance requirements, or the building's use and design intent.

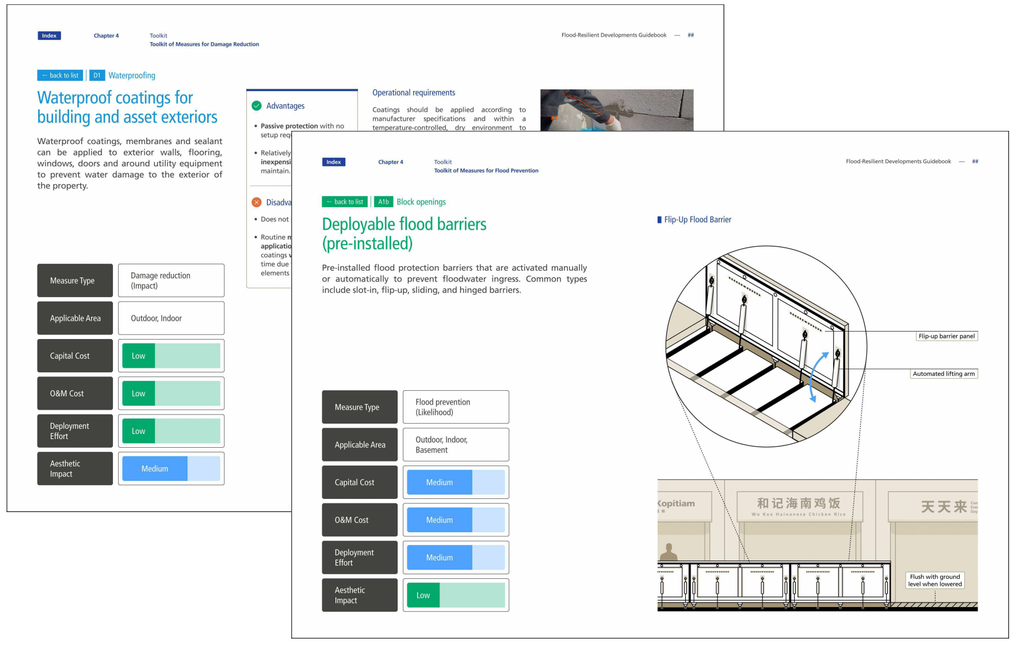
A range of measures to enhance a development's flood resilience can be found in Chapter 4: Toolkit. Users can begin by selecting suitable measures from the Toolkit based on the development's conditions and flood risk profile.

A quick preview of Chapter 4: Toolkit

List of measures for quick reference:

Group	Measure Name	Applicable Area(s)	Capital Cost*	O&M Cost	Deployment/ Activation Effort	Impact on Aesthetics
A. Block Openings	A1a Deployable flood barriers (temporary)	Outdoor, indoor, basement	Low	High	High	Low
	A1b Deployable flood barriers (pre-installed)	Outdoor, indoor, basement	Medium	Medium	Medium	Low
	A2 Floodproof doors and gates	Outdoor, indoor, basement	Medium	Medium	Low	High
	A3 Permanent flood walls	Outdoor	High	Medium	Low	High
	A4 Flood bags	Outdoor, indoor, basement	Low	High	High	Low
	A5 Raised building entrances	Indoor, basement	Medium	Low	Low	Medium
	A6 Raised ventilation openings	Indoor, basement	Low	Low	Low	Medium
	A7 Movable water dams	Outdoor, indoor, basement	Medium	Medium	High	Low
B. Block Water from Drains	B1 Backflow prevention devices	Outdoor, indoor	Medium	Medium	Low	Medium
	B2 Sluice gates	Outdoor	High	Low	Medium	Medium
E. Reduce Floodwaters	E1 Upgrading of internal drainage (retrofit)	Outdoor	Medium	Medium	Low	Medium
	E3 Stormwater detention storage system	Outdoor	High	Medium	Low	Low
	E4 Rooftop water storage	Outdoor	Medium	Medium	Low	High
	E5 Stormwater infiltration trench	Outdoor	Medium	Medium	Low	Medium
	E6 Bioswales and rain gardens	Outdoor	Medium	Medium	Low	Medium

Detailed pages to describe each measure and its uses:



Below are the steps that can help inform the appropriate choice of measures:

Step 1

Review the Risk Assessment Findings

The risk category of each area indicates where interventions are most likely to be needed. Before identifying specific measures, it is important to review the likelihood and impact assessments to understand the underlying drivers of risk and frame an appropriate response.

A key distinction to make is whether flood risk is driven by operational or maintenance factors which can be managed; or, by inherent exposure and vulnerability that require design interventions. For example, if the Likelihood rating in the Outdoor Area is Likely because internal drains frequently overflow during rainfall, the user should determine whether this stems from issues like blockages or upkeep, or from insufficient drainage capacity which requires a different scale of action.

The property owner's risk appetite would guide this step, as it affects the type and extent of interventions considered. For example:

- If the Indoor Area is assessed as Medium risk, with potential Major impact to human safety and critical equipment but likelihood of flooding is unlikely, a risk-averse property may implement precautionary flood-resilient measures, while a property owner with higher risk tolerance may choose to react only when a flood warning is issued.
- If the Basement with critical M&E equipment is assessed as High Risk, the user should consider whether their primary objective is to prevent flooding in basement altogether, to protect the critical equipment should flooding occur, or both. The objective shall guide the selection of appropriate measures in the next steps.

Step 2

Determine Suitable Measure Type

The flood-resilient measures in Chapter 4: Toolkit fall into two categories:

- **Flood prevention measures** that aim to keep floodwater out of spaces and can directly reduce the **likelihood** of flooding. These include flood barriers, raised thresholds, flood walls, and sealing strategies.
- **Damage reduction measures** that function on the basis that floodwater may enter a space and focus on limiting damage and enabling rapid recovery. These measures can help to reduce flood **impact**. Examples include resilient materials, raised services, water-proof finishes, and equipment protection.

The **likelihood** and **impact** outcomes of each area, together with the property owner's risk appetite, can guide the selection of the appropriate measure or measures. In many cases, applying both types of measures—flood prevention and damage reduction—in combination can yield the greatest flood resilience benefit.

Step 3

Identify Appropriate Groups of Measures Based on Function

Measures in the Toolkit are sorted by function. The risk assessment findings in Step 1 should provide guidance on the group of measures relevant to each area.

Group	Measure Function	Purpose
A	Block Openings	Prevent floodwaters from entering rooms, spaces, or gaps.
B	Block Water from Drains	Prevent water intrusion from external drains into a development.
C	Protect M&E Equipment	Relocate critical M&E equipment to higher ground.
D	Waterproofing	Prevent water seepage into sensitive areas or assets.
E	Reduce Floodwaters	Prevent or reduce accumulation of rainfall or surface runoff that can enter sensitive areas of the development.
F	Reduce Physical Impact	Safeguard buildings or infrastructure against damage from floating debris carried by floodwaters.

Step 4

Align Measures with Priorities and Constraints

Within each group, measures should be selected based on the property owner's needs and priorities. Each measure in the Toolkit is assessed by considering the below four key factors:

1. **Capital Cost** indicates the initial capital expenditure for procurement and installation.
2. **O&M Cost** indicates the recurring costs and labour for operation and maintenance.
3. **Deployment Effort** indicates the level of human intervention required to deploy or activate the measure during a flood event.
4. **Aesthetic Impact** indicates the degree of visual impact and how well the measure integrates with the development.

Worked example for identifying appropriate measures

Property Owner



You manage an older development and you want to make it more flood-resilient.

While your budget for major works is limited, you have a low tolerance for flood risk and cannot easily accept potential flood impacts. To better understand the development's exposure and identify proportionate risk management measures, a flood risk assessment was undertaken.

Step 1

Review your risk category

The flood risk assessment showed that the basement is at **high risk of flooding**.

Notable factors:

- No hump or step at the entrance to your basement and no sump pump.
- No critical assets, but the walls and tenant's belongings are sensitive to damage

Step 2

Determine suitable measure type

Measures for flood prevention will be most useful. But should consider measures for damage reduction if a flood occurs too.

Step 3

Identify function

Barriers at the basement opening for flood prevention + Waterproofing of interiors for damage reduction.

Step 4

Shortlist by priorities

Shortlist measures with lower capital and O&M cost, and those with low aesthetic impact.

2

Toolkit of measures for flood prevention ●

Group	S/N	Measure Name
A. Block Openings	A1a	Deployable flood barriers (temporary)
	A1b	Deployable flood barriers (pre-installed)
	A2	Floodproof doors and gates
	A3	Permanent flood walls

Toolkit of measures for damage reduction ●

Group	S/N	Measure Name
C. Protect M&E Equipment	C1	Elevation or relocation of mechanical and electrical equipment (retrofit)
D. Waterproofing	D1	Waterproof coatings for building and asset exteriors
	D2	Wettable finishes for building interiors

3

Toolkit of measures for flood prevention

Group	Measure Name	Applicable Area(s)	Capital Cost	O&M Cost	Deployment Effort	Aesthetic Impact
A. Block Openings	A1a Deployable flood barriers (temporary)	Outdoor, indoor, basement	Low	High	High	Low
	A1b Deployable flood barriers (pre-installed)	Outdoor, indoor, basement	Medium	Medium	Medium	Low
	A2 Floodproof doors and gates	Outdoor, indoor, basement	Medium	Medium	Low	High
	A3 Permanent flood walls	Outdoor	High	Medium	Low	High
	A4 Flood bags	Outdoor, indoor, basement	Low	High	High	Low
	A5 Raised building entrances	Indoor, basement	Medium	Low	Low	Medium
	A6 Raised ventilation openings	Indoor, basement	Low	Low	Low	Medium

Toolkit of measures for damage reduction

Group	Measure Name	Applicable Area(s)	Capital Cost	O&M Cost	Deployment Effort	Aesthetic Impact
C. Protect M&E Equipment	C1 Elevation or relocation of mechanical and electrical equipment (retrofit)	Indoor, basement	High	Low	Low	Medium
D. Waterproofing	D1 Waterproof coatings for building and asset exteriors	Outdoor, indoor	Low	Low	Low	Medium
	D2 Wettable finishes for building interiors	Indoor, basement	Low	Low	Low	Medium
	D3 Puddle flanges	Indoor, basement	Medium	Low	Low	Low

3. 2. 3

How to Develop Holistic Options for Flood Resilience

Effective flood resilience often requires more than one single measure. A holistic approach combines complementary measures to address flood risk.

Multi-Layered Strategy for Enhanced Protection

Layering measures means combining complementary actions rather than relying on a single line of defence. This may be especially important to property owners with low risk appetite.

- **First 'protective' layer:** Building-level measures that shield occupied spaces, essential services, and critical systems during a flood, or landscaping features like rain gardens and bioswales that help to capture excess stormwater and release it in a controlled manner.
- **Second 'recovery' layer:** Design choices that facilitate rapid drainage, cleaning, and reinstatement, allowing the development to return to normal use quickly.

For example, to mitigate flood risk in a basement housing critical M&E equipment that cannot be relocated, a property owner might consider:

- **First 'protective' layer:** Flood barriers at building and basement entrances.
- **Second 'recovery' layer:** Mobile pumps in the basement to drain any accumulated water; waterproof coatings on the housings of M&E equipment to reduce water damage.

New developments have greater flexibility to incorporate design solutions from the outset, such as using site layout and landscaping to reduce their development's exposure to flooding. Additionally, good design practices like ensuring adequate platform and crest levels, can also help developments meet engineering requirements for stormwater management.

Solutions Beyond Physical Measures

Physical measures are not always the most effective means to mitigate flood risk. In some cases, targeted changes may be simpler and more cost-effective.

For example, if a homeowner's ground floor bedrooms are prone to major impact from a flood, a practical solution may simply be to relocate the bedrooms to an upper floor and repurpose the ground-level rooms—avoiding the need for physical measures altogether.

Where changes to an existing development's layout or function are not possible, or in ecologically sensitive areas where the environmental impacts of installing physical measures must be managed, a Flood Response Plan can be prepared so that all occupants and personnel are ready to react in the appropriate manner if a flood occurs. Technological interventions such as water sensors and early warning systems can further support flood readiness.

Prioritisation and Phased Implementation of Measures

Not all measures offer the same level of protection, cost, and ease of implementation. Some measures are easier to implement, but offer limited or short-term protection, while others provide robust, durable protection but may be disruptive or costly to immediately implement. The development's life cycle should therefore be taken into account to guide the timing of interventions and identify the appropriate measures at each stage.

For existing developments, interventions for Medium and High risk cases need not be implemented all at once. Upgrades can be phased over time and prioritised accordingly to the site's vulnerability, the criticality of assets or spaces at risk, and the owner's risk tolerance.

For new developments, it is most effective to incorporate flood-resilient measures at the planning and concept design stages—whether it is meeting minimum platform levels, positioning critical systems on higher ground or designing drainage networks with sufficient capacity. Doing so allows measures to be seamlessly integrated, and maintenance needs to be factored in upfront.

Is there an ideal measure?

It is important to keep in mind that there is no single optimal solution. Flood resilience relies on informed, context-specific choices shaped by site conditions, the development's priorities and constraints, and its operational realities. Any proposed solution should also consider the structural, architectural and safety requirements that developments are required to comply with.

Time horizon	Examples of suitable measures (non-exhaustive)
Short-term	• Deployable flood barriers • Mobile pumps • Waterproof coatings
Medium-term e.g. in line with CAPEX cycles or next renovation	• Upgrading of internal drains (simple works, e.g. widening at a single choke point) • Permanent flood walls • Elevation/relocation of M&E equipment
Long-term e.g. next redevelopment or Additions and Alterations (A&A)	• Raising of ground/platform level • Upgrading of internal drains (extensive improvements) • Steps/ramps to elevate entrances • Detention tanks

3.3 | Develop a Flood Response Plan

The Flood Response Plan (FRP) is a document that outlines the flood-resilient measures in place, the current maintenance and monitoring regime, and the operational protocol to be activated when floods occur.

3. 3. 1 What is an FRP?

The FRP is a structured, live document that:

- Lists how a development should prepare for, respond to, and recover from flooding;
- Defines the roles and responsibilities of each relevant party; and
- Is reviewed and updated periodically.

In Singapore, the Emergency Response Plan for fire risks and the live Design for Safety (DfS) Register are essential to a development's emergency preparedness. Similarly, **the FRP can enhance the operational readiness of all developments in the event of a flood.**

3. 3. 2 What Kind of Developments is the FRP for?

The FRP is most relevant for all larger developments, except single-unit landed houses or shophouses.

A FRP is valuable and strongly recommended even for developments where flood risk is assessed to be low. Just as fire response plans are useful for all developments regardless of fire risk level, pre-emptive planning ensures that occupants and personnel can respond in a timely and coordinated manner should flooding occur.

What if I am a landed house owner or a shophouse owner?

A detailed FRP may not be right for you. Instead, see section 3.3.8 for a simple Flood Safety Guide on how to prepare for and what to do in the event of a flood affecting your property.

3. 3. 3 When Should the FRP be Developed?

The FRP may be developed at any point during the operational life of a development, but it is strongly encouraged to be done as early as possible, ideally following a flood risk assessment and the implementation of any flood-resilient measures. Early development of the FRP offers several advantages:

1. **Relative ease of gathering relevant data;** such as information on site context, risk profile, or operational implications of the measures implemented.
2. **Enhances emergency preparedness** by ensuring that personnel are familiar with their roles and responsibilities, enabling effective coordination and clear communication with occupants and stakeholders during a flood event. The FRP can also be tested and refined over time through drills and actual flood events.
3. **Reduced risk of major financial losses,** property damage and extended downtime that floods can cause.

3. 3. 4 Who Should Create and Maintain the FRP?

The FRP is most effective when developed collaboratively. Property management professionals should lead the process, with property owners making key decisions to ensure the plan is comprehensive, practical, and implementable. For new developments, design professionals can contribute insights and data to ensure that flood management measures are properly integrated with the building's structural, mechanical, and electrical systems.

Once developed, the FRP should be formally handed over to the property owner to be placed in charge of its administration. Property management professionals appointed by the property owner are responsible for implementing and periodically reviewing the FRP. The roles and responsibilities should be clearly defined within the FRP and may be tailored to suit the specific development.

3. 3. 5

How to Keep the FRP Up to Date?

Site conditions, operational practices and flood risks can change over time. Therefore, it is important to regularly test and review the FRP throughout the development's life cycle to ensure that it remains effective. These include:

- **After significant rainfall events**, official flood alerts, or activation of flood response measures to incorporate lessons learned.
- **When Additions and Alterations (A&A)** or other significant changes to the site are made.
- **Periodically**, a review cycle of at least once a year is recommended.

3. 3. 6

What Should an Effective FRP Contain?

The FRP should describe, using clear and simple language, how flood risks will be managed. It should outline the steps taken to reduce flood risk **before, during and after a flood event.**

Structure of the FRP



Before a Flood Event

- Introduction
- Site Description
- Flood Risk Assessment Outcomes
- Flood-Resilient Measures
- Routine Maintenance
- Routine Drills
- Flood Monitoring
- Communication Plan

During a Flood Event

Triggers and Key Actions for each **Action Level: Yellow, Orange, and Red.**

After a Flood Event

- Recovery Procedures
- Post-Flood Stakeholder Communication
- Incident Review and Improvements

3. 3. 6. 1

Before a Flood Event: Ongoing maintenance and preparation

The first section defines actions that ensure a development is ready for potential flood events. These include maintenance of flood-resilient measures, preparatory works, and organisational arrangements required in advance to reduce flood risks and impacts. This section should also document the site context and key features that may influence flood risk, as well as state the outcomes of the flood risk assessment.

Subsection	What it should contain	Additional guidance
Introduction	**Describe** Intended use of the FRP	• Who the FRP is for • Date of when the FRP was created • Author of the document; Approver's name
	List Key personnel and their roles	• Person(s) responsible for preparing each measure for implementation and use • Person(s) overseeing updates to the FRP • Person(s) responsible for approving updates to the FRP
	Describe Outline of the FRP	• How users should navigate the FRP's contents and structure
Site Description	**Describe** Overall site context	• Location, land use, development type, and surrounding developments • Site layout and levels, including critical flood pathways and vulnerable areas (use drawings, sections, and diagrams where appropriate) • How the site interfaces with its surroundings and runoff flow paths
	List Key site features relevant to flood risks	• Examples of key site features: ground level, basement, drainage
	List Known flood events within the development and its vicinity, as well as the levels of adjacent roads and neighbouring developments	• Timeframe for listing known flood events: past ____ years • List when the flood(s) occur and its causes
Flood Risk Assessment Outcomes	**List** Details of assessment	• Date of when the assessment was conducted
	Describe Summary of assessment outcome	• Include areas or aspects (assets, functions, services and human safety) that face significant risk
Flood-Resilient Measures	**List** Chosen flood-resilient measures based on the Flood Risk Assessment outcome and toolkit from the Guidebook	• Include deployment location and details of the chosen measures
	Describe Flood-resilient activation procedures (to prevent flood from spreading)	• Outline equipment, measures, storage location and protocols for activation or deployment
	Describe Maintenance of flood resilient measure	• Installation, inspection and maintenance regime according to manufacturer's SOPs • Refer to measure-specific manuals where available
Routine Maintenance	**Describe** Routine inspection and maintenance protocols	• Include all inspection, servicing and testing regimes for drainage systems, pumps and any other flood-management features
Routine Drills	**Describe** Flood drills	• Flooding scenario(s) to be conducted during drills • Frequency of regular drills • List evacuation equipment to be prepared. Examples: emergency lighting, signage, first-aid kits, portable radios, safety ropes • List personnel involved in the drill and their respective roles and responsibilities
Flood Monitoring	**Describe** Flood warning and activation protocols	• Use the Three-Tier Action Level framework to define the triggers for each tier • List alerts that have been subscribed to: myENV app alerts of nearby water level sensors; heavy rain SMS alerts, PUB's Flood Alerts Telegram Channel, etc.
Communication Plan	**Describe** Key Personnel and Communication Plan	• List personnel and their roles: monitoring of flood alerts, activation of emergency response protocol, deployment of flood-resilient measures, evacuation of occupants, communication with external parties (e.g. emergency services) • Include contact details of the key personnel • Include communication tools and protocols with clearly defined roles and responsibilities for sending, receiving, and approving communications

3. 3. 6. 2

During a Flood Event: Emergency response and activation protocols

This section details the emergency response and evacuation procedures that will need to be activated during a flood event. It should follow a Three-Tier Action Level framework that defines activation triggers and key actions to be taken according to the severity of the flood event.

Subsection	What it should contain	Additional guidance
Emergency Response and Evacuation	**Describe** Actions to be taken when a flood occurs including evacuation procedures	• Refer to the Three-Tier Action Level framework for detailed guidance • Verify that the activation triggers for each level apply to the site. Otherwise, define appropriate triggers for the development • Describe the specific key actions to be taken for each level based on the generic actions provided in Three-Tier Action Level.



Overview of the Three-Tier Action Level Framework

Action Level	What happens at this level
YELLOW (CAUTION)	**Heightened readiness** Normal operations may continue but the situation should be monitored. Personnel should be ready to activate emergency procedures.
ORANGE (WARNING)	**Active protection** Actions focus on protecting critical assets, operations and ensuring the safety of occupants and personnel within the site.
RED (DANGER)	**Full defence** All non-essential operations should be suspended, and safety and emergency response prioritised. Preparation for evacuation out of the site may be needed.

The activation triggers for each tier are based on observable and measurable conditions, as well as alerts from official channels. An action level is then activated if any one of its corresponding triggers are observed.

Key actions fall into four categories:

- **Infrastructure Readiness** includes maintenance and monitoring actions, as well as standby and deployment of active flood-resilient measures.
- **Site Operations** include the management of operations and access, including suspension where necessary.
- **Communications** include relevant communication protocol and status updates.
- **Safety & Evacuation** includes management of occupants and personnel movements to ensure their safety.

Actions at each level build upon and do not replace the actions of the preceding level. In other words, once the Red level is activated, key actions for Yellow and Orange levels should already have been taken.

Three-Tier Action Level Framework

Action Level	Activation Trigger	Possible Key Actions
YELLOW (CAUTION) Heightened readiness	• **Alerts from official channels**[1]**:** Flash flood forecast or heavy rain alerts received near/at your development's location; or nearby public drains have reached 75% capacity • **On-site observations:** Internal drains observed to be almost full; or for coastal developments with direct access to the sea, sea levels are approaching development's ground level (e.g. during high tides)[2]	**Site Operations:** • Maintain normal access and operations, with enhanced monitoring of site conditions and water levels **Communications:** • Verify that communication channels, reporting lines, and status update frequency are fully functional **Infrastructure Readiness:** • Verify drainage conveyance and pumping systems (e.g. detention outlet controls and sump pumps for basement) are fully operational • Be ready to activate/deploy flood-resilient measures. If deployment is time-intensive, begin preparation and set-up **Safety & Evacuation:** • Be ready to evacuate occupants, relocate vulnerable assets and elevate sensitive equipment
ORANGE (WARNING) Active protection	• **Alerts from official channels**[1]**:** Nearby public drains have reached 100% capacity; or flash floods currently occurring near/at your development's location • **On-site observations:** Internal drains are overflowing or standing water observed in some areas, but not yet affecting critical assets or key operations; or for coastal developments with direct access to the sea, sea levels are almost at development's ground level.	**Infrastructure Readiness:** • Activate/deploy flood-resilient measures to protect critical assets or vulnerable areas **Site Operations:** • Turn off non-essential electrical systems or suspend non-essential electrical services (e.g. lighting in non-critical areas, decorative signage, non-critical mechanical systems, suspend lift operations to flooded or at-risk floors) to reduce the risk of short circuits, equipment damage, or fire when water is present. Maintain critical safety and emergency systems **Safety & Evacuation:** • Restrict occupant/personnel access to flooded areas • Evacuate occupants and personnel to safe areas in accordance with site procedures
RED (DANGER) Full defence	**On-site observations:** • Floodwaters (due to rain or seawater) accumulated across all areas of the development, affecting critical assets and key operations; or • PUB flood response teams deployed to the site; or • Evacuation routes affected and immediate risk to human safety by incoming water Note: Notifications from official channels are not available for this Alert Level. Development should use on-site observations as triggers.	**Communications:** • Activate full emergency response and communication protocol, including status reporting **Site Operations:** • Suspend all non-essential operations **Human Safety:** • Prepare for emergency rescue out of the development if required (e.g. if occupants are trapped)

[1] Official channels for rain alerts and drain capacity include: **myENV app, @pubfloodalerts Telegram channel, or PUB's SMS alert system.**

[2] To find out whether sea levels are expected to rise or subside within the immediate period, forecasted timings of high and low tides are available through MPA's Singapore Tide Tables or NEA's Tide Timings webpage.

3. 3. 6. 3

After a Flood Event: Safety, damage assessment, and staged recovery

This section comprises the necessary steps to restore the development to a safe and functional condition after a flood event. Communications plans to update stakeholders of the development's operational status should also be defined in this section.

Once the development has been declared safe after the flood incident, a damage assessment should be undertaken and recovery should follow a staged and controlled approach. Property management professionals can use the outcome from the Flood Risk Assessment Matrix from Chapter 3 to prioritise inspections and recovery actions.

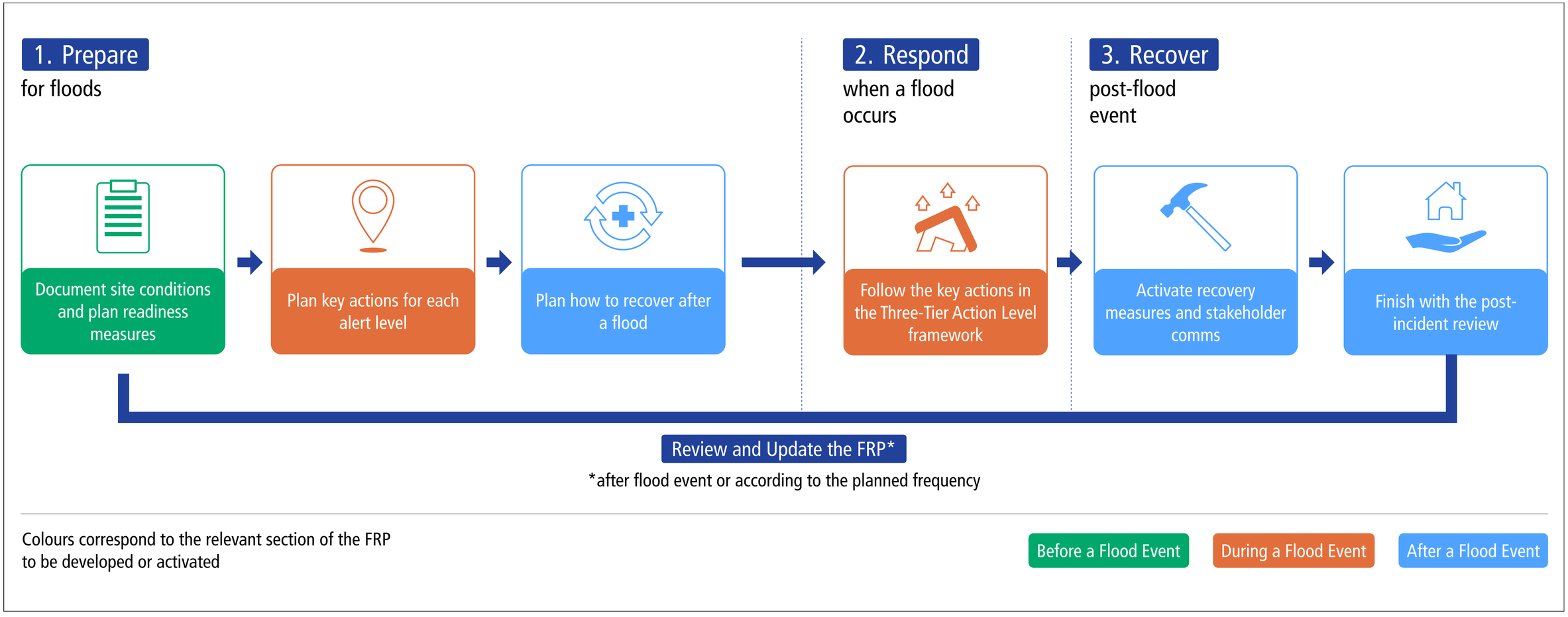
Finally, the FRP should also be reviewed to capture any lessons learned, with findings used to inform future FRP refinements, training, and site design.

Subsection	What it should contain	Additional guidance
Recovery Procedures	**Describe** Procedure for damage assessment	• Include inspection plan of buildings, systems, equipment and flood-resilient measures to identify damage, determine operational impact, and assess safety concerns
	Describe Procedure for clean-up operations	• Detail the method(s) used to remove flood water, debris, and contaminants in a controlled and safe manner
	Describe Procedure for repair and restoration of operations	• Specify how damaged building elements, M&E systems, and flood-resilient measures shall be repaired/replaced, and tested prior to restarting • Include details of vendors that will be required for the above procedures
	Describe Summary of the recovery process to resume operations in a controlled manner	• Examples: Recovery shall be conducted in stages, beginning with confirmation that the flood threat has ceased, followed by safety inspections, remediation works, system testing, and gradual reinstatement of operations.
Post-Flood Stakeholder Communication	**List** Stakeholders who need to be informed after a flood event	• Examples: building management, occupants, tenants, service providers, emergency responders, authorities, insurers, contractors • Record stakeholder's contact details
	Describe Information to be prepared and provided to each stakeholder	• Examples: Site safety status, access restrictions, service availability, recovery timelines, next steps • How the information will be communicated (e.g. email, messaging platforms, notice boards, briefings, hotlines) • Create message template and escalation protocols for efficient communication
	List Personnel assigned to prepare, approve and issue communications	• Include main point(s) of contact
	Describe Timing and frequency of communication	• Specify when initial communications should be issued • Specify frequency of updates during recovery
	Describe Frequency of review	• Specify how often the communication plan will be reviewed to ensure accuracy
Incident Review and Improvements	**Describe** Incident review process	• List person(s) involved in the review process • Describe process to capture lessons learn from the flood event (e.g. post-mortem). Example format: ◦ Reconstruct the incident timeline, including key decisions taken, persons involved ◦ Identify causes of flooding and contributing factors, including performance of flood-resilient measures, adequacy of operational procedures. Identify any failures or near-misses ◦ Assess impacts on safety, operations, assets, services, any and wider disruptions ◦ Extract key lessons: what worked, what did not, and recommendations for new measures or design and operational improvements ◦ Update the FRP, such as refining Action Levels, communications flows, and information about the site's risk and flood-resilient measures.

3. 3. 7

How to Use the FRP

FRPs should be developed early to ensure personnel are familiarised and ready, before a flood occurs. When immediate response to floods is needed, personnel should follow the pre-determined procedures in the “During a Flood Event” section. After the flood has subsided, they may initiate recovery by following the steps laid out in the “After a Flood Event” section to return to normal operations.



3. 3. 8

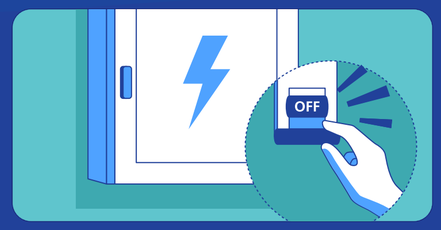
Flood Safety Guide for Landed Homes and Shophouses

Flood Safety Guide for Landed Homes and Shophouses

HOW TO

PREPARE FOR A FLOOD

Resource Website:
https://go.gov.sg/flood-safety-tips



Locate the distribution board (DB box) and know how to turn it off.



Store important items in high spaces and move your car to high ground.



Check that flood barriers are in good working condition.



Plan your evacuation routes. If you are in a multi-storey house or shophouse, the safest place is the highest floor.



Regularly check drainage system to ensure it is well-maintained with no blockages.

WHAT TO DO

WHEN A FLOOD IS COMING

- Turn off the DB box to prevent electrical short circuits.
- Put up flood barriers, if any.
- Go to high ground or upper floors. Assist vulnerable individuals to evacuate.
- Do not walk or drive through floodwaters.



Stay Informed with Flood Alerts

Telegram Channel

t.me/pubfloodalerts

PUB's Flood Alerts Telegram Channel **(@pubfloodalerts)** provides updates on heavy rain, locations with flood risk, and more.

myENV App

Download on the App Store
GET IT ON Google Play

myENV is a one-stop platform for environment and water services.

Overview

04

Toolkit

4.1 Classifying the Toolkit Measures

4.2 Toolkit of Measures for Flood Prevention

4.3 Toolkit of Measures for Damage Reduction

At a glance: Your technical toolkit for resilience.

This chapter serves as a comprehensive repository of flood protection measures—from nature-based bioswales to permanent flood barriers. Use the summary table for a quick comparison of factors like capital costs, O&M requirements, and deployment effort before diving into the detailed specifications for each of the measures.

This chapter is most useful for:

- Design Professionals
- Property Management Professionals
- Homeowners

The Toolkit is a repository of practical measures that can be implemented in developments at different points of the lifecycle.

Each measure listed within this chapter helps mitigate flood-related risks and enhance long-term resilience.

Each measure can be applied across a range of development types, including residential, commercial, industrial, and essential services, as well as across new build and retrofit scenarios. Users should understand the **advantages**, **disadvantages**, and **requirements** of each measure in order to identify the measures that can meet the unique needs and constraints of each site.

Where can I acquire flood-resilient measures?

Measures introduced in the Toolkit are curated to be suitable for and accessible in Singapore. Suppliers for various measures (e.g. flood barriers, rooftop water storage systems) can be found through online searches. For blue-green measures such as bioswales or more structural interventions like drainage improvements, users may wish to engage a design and engineering professional.

Each measure contributes in different ways to the **four core principles of flood-resilient design:**

Adaptability

Adaptability: Allow developments to respond to evolving conditions

Robustness

Robustness: Strengthen structures and reduce susceptibility to physical damage

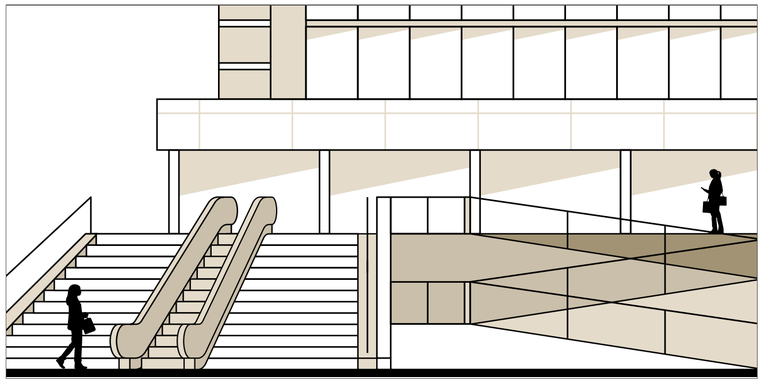
Recoverability

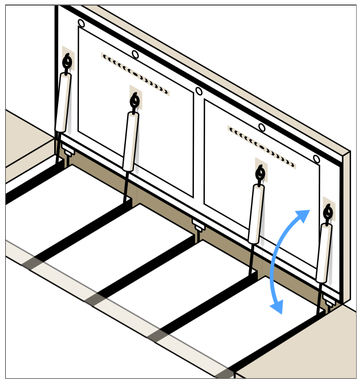
Recoverability: Enable faster restoration of function after a flood event

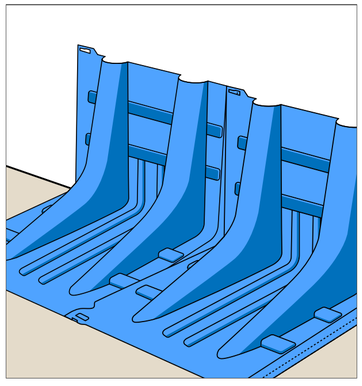
Redundancy

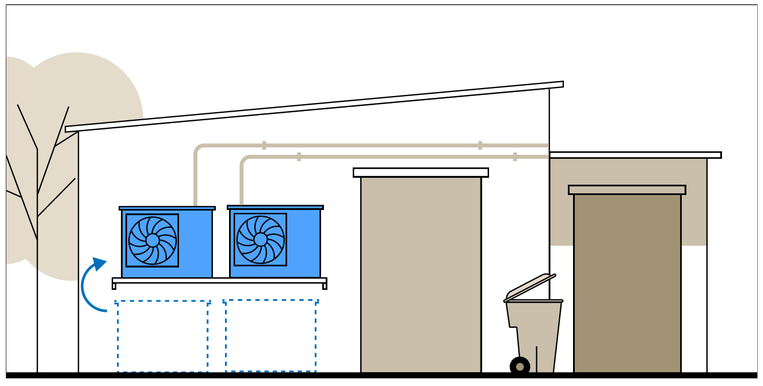
Redundancy: Design multiple systems to maintain essential services even when one component is compromised

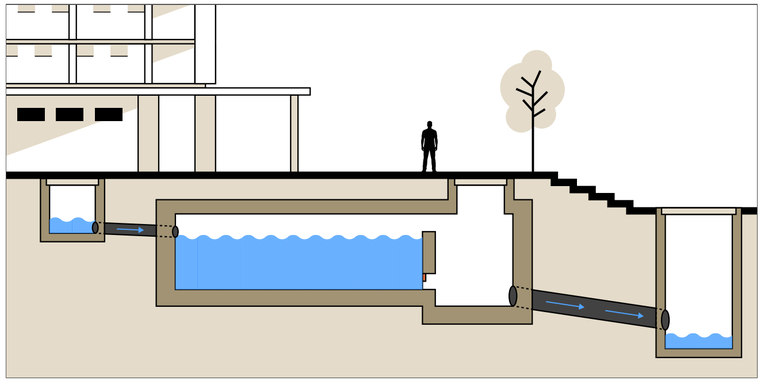
A **summary** of all measures in the Toolkit is provided in the next few pages to help users to quickly identify measures that suit their needs, and compare between options.

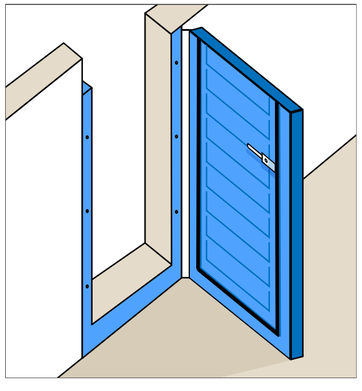












Top left to bottom right: Raised building entrances, deployable flood barriers (pre-installed), deployable flood barriers (temporary), elevation/relocation of mechanical and electrical equipment, stormwater detention storage system, floodproof doors/gates

4.1 Classifying the Toolkit Measures

A glossary of the terms used in the Toolkit is provided below to help users understand how measures are classified based on the standard criteria. This includes the category of flood resilience measure; the areas of the development it is suited to, and an indication of costs, manpower requirements, and aesthetic impact.

4.1.1 Measure Type

Flood prevention

Measures designed to reduce likelihood of flooding by preventing floodwater from entering the development or a space within a development.

Damage reduction

Measures focused on minimising flood impact and enabling rapid recovery post-event. They do not prevent flooding.

4.1.2 Functional Group

A. Block openings

Measures designed to prevent floodwaters from entering rooms, spaces, or gaps.

B. Block water from drains

Measures designed to prevent water intrusion from external drains into a development.

C. Protect M&E equipment

Measures that require a relocation of critical M&E equipment.

D. Waterproofing

Measures that prevent water seepage into sensitive areas or assets.

E. Reduce floodwaters

Measures that prevent or reduce accumulation of rainfall or surface runoff that can enter sensitive areas of the development.

F. Reduce physical impact

Measures designed to safeguard buildings or infrastructure against damage from floating debris carried by floodwaters.

4.1.3 Applicable Area

Outdoor
All open spaces between the boundary wall or line of the development and the building.

Indoor
All enclosed spaces of buildings within the development.

Basement
All underground spaces within the development.

	Low	Medium	High
4.1.4 Capital cost* The initial capital expenditure required for procurement and installation. * Relative costs provided refer to implementation in new developments, except where indicated.	Off-the-shelf or simple measures, requiring basic installation only.	Measures with specialised components or some level of customisation, requiring professional installation.	Large-scale or highly technical measures including major structural modifications, civil works, or integrated mechanical and electrical systems, requiring professional installation.
4.1.5 Operational and maintenance (O&M) cost The recurring costs required to operate and maintain the measure.	Minimal recurring costs or specialised labour requirements for operation and maintenance.	Moderate recurring costs from ongoing operations and/or periodic maintenance.	High recurring costs from operations and/or frequent maintenance or asset replacement.
4.1.6 Deployment effort The level of human intervention required to activate/deploy the measure.	Passive measures or simple manual triggers that do not require specialised tools.	Active measures that require a simple or automated procedure within a set lead time.	Active measures that require significant personnel, training, time, mechanical assistance, or a complex activation sequence prior to a flood event.
4.1.7 Aesthetic impact The degree of visual impact and whether the measure blends in with the development.	Largely concealed or blends seamlessly with the development, or can be kept away when not needed.	Permanent features that are visible but designed to complement existing development's character.	Permanent and prominent additions that alter the external appearance or the immediate site surroundings.

4.2 Toolkit of Measures for Flood Prevention

Click on any measure name in the table to navigate directly to its dedicated page.

Group		Measure Name	Applicable Area(s)	Capital Cost*	O&M Cost	Deployment/ Activation Effort	Impact on Aesthetics
A. Block Openings	A1a	Deployable flood barriers (temporary)	Outdoor, indoor, basement	Low	High	High	Low
	A1b	Deployable flood barriers (pre-installed)	Outdoor, indoor, basement	Medium	Medium	Medium	Low
	A2	Floodproof doors and gates	Outdoor, indoor, basement	Medium	Medium	Low	High
	A3	Permanent flood walls	Outdoor	High	Medium	Low	High
	A4	Flood bags	Outdoor, indoor, basement	Low	High	High	Low
	A5	Raised building entrances	Indoor, basement	Medium	Low	Low	Medium
	A6	Raised ventilation openings	Indoor, basement	Low	Low	Low	Medium
	A7	Movable water dams	Outdoor, indoor, basement	Medium	Medium	High	Low
B. Block Water from Drains	B1	Backflow prevention devices	Outdoor, indoor	Medium	Medium	Low	Medium
	B2	Sluice gates	Outdoor	High	Low	Medium	Medium
E. Reduce Floodwaters	E1	Upgrading of internal drainage (retrofit)	Outdoor	Medium	Medium	Low	Medium
	E3	Stormwater detention storage system	Outdoor	High	Medium	Low	Low
	E4	Rooftop water storage	Outdoor	Medium	Medium	Low	High
	E5	Stormwater infiltration trench	Outdoor	Medium	Medium	Low	Medium
	E6	Bioswales and rain gardens	Outdoor	Medium	Medium	Low	Medium

* Relative costs provided refer to implementation in **new developments**, except where retrofit is indicated

4.3 Toolkit of Measures for Damage Reduction

Click on any measure name in the table to navigate directly to its dedicated page.

Group		Measure Name		Applicable Area(s)	Capital Cost*	O&M Cost	Deployment/ Activation Effort	Impact on Aesthetics
C. Protect M&E Equipment	C1	Elevation or relocation of mechanical and electrical equipment	(retrofit)	Indoor, basement	High	Low	Low	Medium
D. Waterproofing	D1	Waterproof coatings for building and asset exteriors		Outdoor, indoor	Low	Low	Low	Medium
	D2	Wettable finishes for building interiors		Indoor, basement	Low	Low	Low	Medium
	D3	Puddle flanges		Indoor, basement	Medium	Low	Low	Low
	D4	Re-pointing of brickwork	(retrofit)	Outdoor, indoor	Medium	Low	Low	Low
E. Reduce Floodwaters	E2	Mobile pumps		Outdoor, indoor, basement	Low	High	Medium	Low
F. Reduce Physical Impact	F1	Pavement edge protection		Outdoor	Medium	Low	Low	Medium
	F2	Bollards and guardrails		Indoor	Low	Low	Low	High

* Relative costs provided refer to implementation in **new developments**, except where retrofit is indicated

← back to list | A1a Block openings

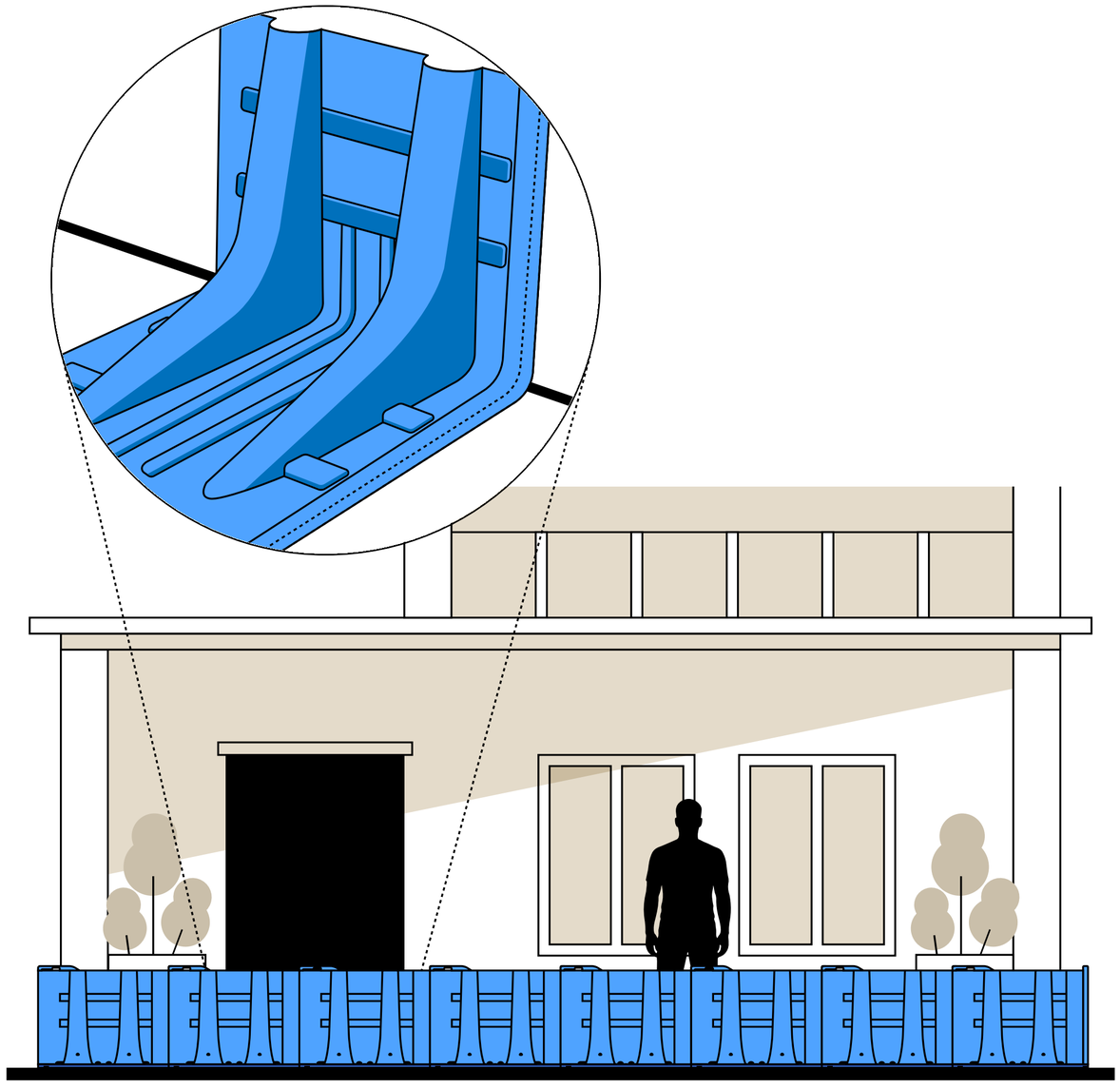
Deployable flood barriers (temporary)

Mobile, reusable barriers that are designed for rapid assembly and removal at entrances and vulnerable areas to actively prevent floodwater ingress.

These temporary systems are typically available as L-shaped barriers or adjustable flood panels for doorways.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor, Indoor, Basement
Capital Cost	Low
O&M Cost	High
Deployment Effort	High
Aesthetic Impact	Low

Modular L-Shaped Plastic Barrier



← back to list | A1a

Deployable flood barriers (temporary)

Advantages

- **Rapid deployment** possible when resources are available
- **Flexibility** in use due to adjustable lengths and can be deployed in areas with immediate needs
- **Reusable** and durable for multiple flood incidents
- **Minimal aesthetic impact** as storage barriers may be kept away when not required

Disadvantages

- **Basic training** needed for correct setup
- **May require anchoring** or weights in high-flow situations
- Typically protects up to **limited flood heights** of 0.5-1.2m

Operational requirements

All staff involved must be fully trained in the Standard Operating Procedure for the barrier system. Training must cover efficient deployment, ensuring correct sealing and anchoring techniques, and rapid dismantlement and storage procedures immediately following a storm event to return the site to normal operation quickly.

Regular cleaning is mandatory to remove any debris, silt, or residue from the barrier surfaces and seals. Periodic performance testing (e.g. pressure washing, integrity checks) must be conducted to ensure the effectiveness of waterproofing and structural performance of the barriers during emergency use.

Logistics and storage requirements

A sufficient quantity of modular barriers must be stored to cover the entire length of entry, plus a minimum of 10% spare capacity for damage replacement. The barriers must be stored in a dry, accessible location above the flood level to ensure rapid retrieval regardless of weather. All units should be stacked in a compact manner as recommended by the manufacturer.

Resilient design principles



Temporary flood barriers are **adaptable** as they can be repositioned or combined as conditions change. **Redundancy** can be provided for by storing extra barriers.



Modular L-shaped plastic barrier | **Source:** PUB



Adjustable flood panel for doorways
Source: FloodX (Singapore) Pte. Ltd.

Additional resources
PUB Flood Safety Tips Brochure

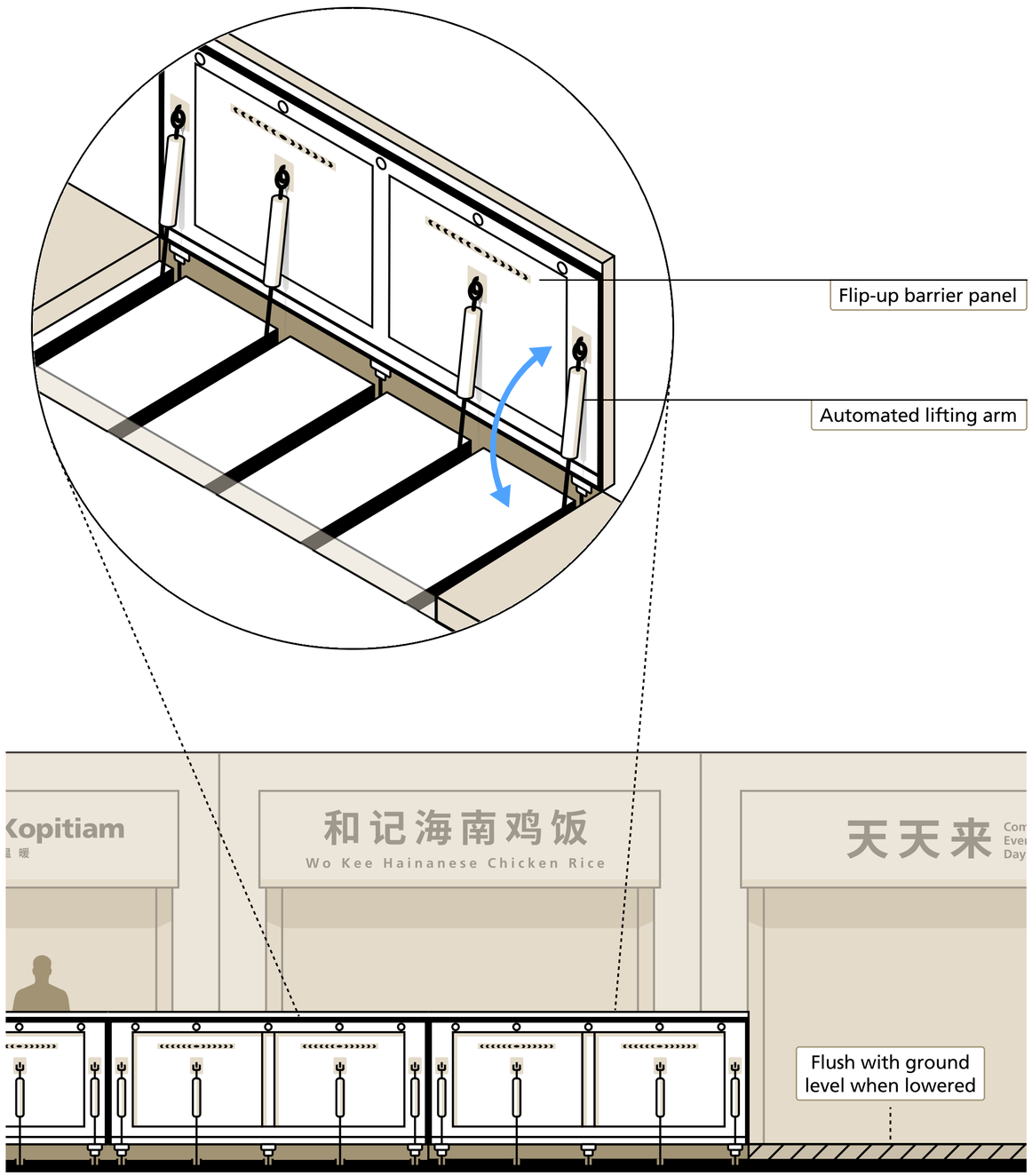
← back to list | A1b Block openings

Deployable flood barriers (pre-installed)

Pre-installed flood protection barriers that are activated manually or automatically to prevent floodwater ingress. Common types include slot-in, flip-up, sliding, and hinged barriers.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor, Indoor, Basement
Capital Cost	Medium
O&M Cost	Medium
Deployment Effort	Medium
Aesthetic Impact	Low

Flip-Up Flood Barrier



← back to list | A1b

Deployable flood barriers (pre-installed)

Advantages

- **Made to fit** each doorway or opening, so it closes tightly with a reliable seal against floodwater ingress
- Strong enough to hold back **deep floodwaters**, even above depths of 1.2m
- **Rapid deployment** with less manpower (compared to temporary flood barriers) as barriers are already pre-installed on site. Some automated types can be activated within seconds

Disadvantages

- **Regular maintenance** is needed to keep moving parts and seals in good condition, so that the barrier works properly when it is needed
- Components such as side posts or ground tracks **may be visible** and could affect the design aesthetic, daily operations, or pose tripping risks if not well-designed
- Barriers **cannot be repositioned** to other locations that may also be prone to flooding

Additional resources

PUB Managing Urban Runoff Drainage Handbook – Chapter 5

Operational requirements

Designated personnel must be trained in the specific deployment sequence (e.g. bottom-to-top for slot-in panels) to ensure a watertight seal during flood events. All tracks, side-posts, and grooves must be kept free of debris and silt, as obstructions can compromise the integrity of the seals. Periodic dry-run deployments and pressure washing of seals must be conducted to ensure structural performance and waterproofing remain effective for emergency use.

Logistics and storage requirements

While the main units are pre-installed, any removable components must be stored in a dedicated, clearly labelled rack adjacent to the point of use. Additional 10% spare panels are recommended to be kept on-site for emergency replacement. Ground housings for flip-up barriers must have integrated drainage to prevent the accumulation of stagnant water or silt within the mechanism.

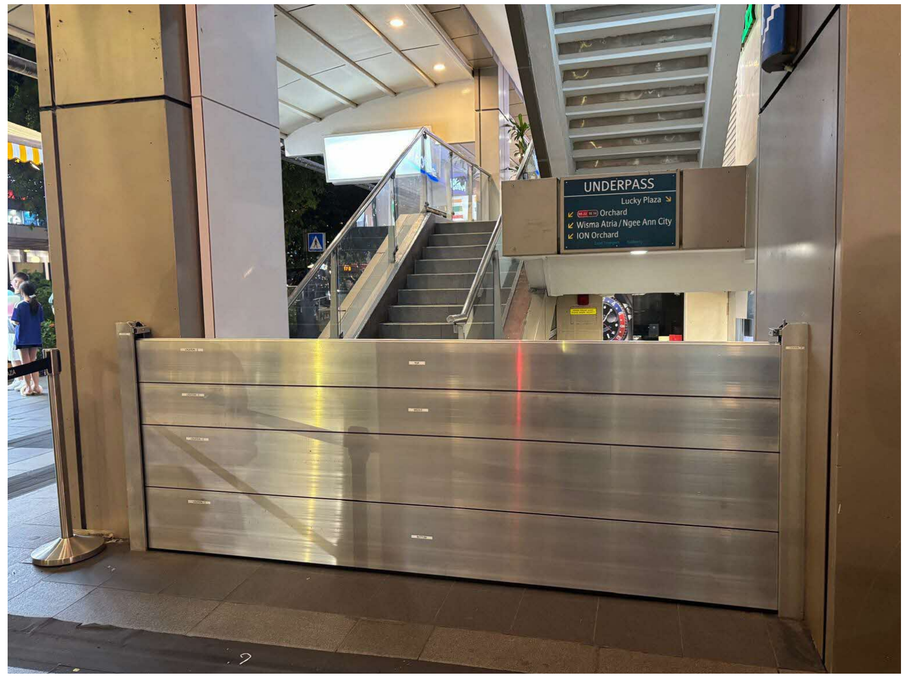
Resilient design principles



Pre-installed barriers provide high **robustness** through fixed anchoring points that transfer flood loads directly into the building's structural foundations. **Redundancy** can be achieved for slot-in barriers by storing extra panels.



Modular slot-in barriers at doorways | **Source:** FloodX (Singapore) Pte. Ltd.



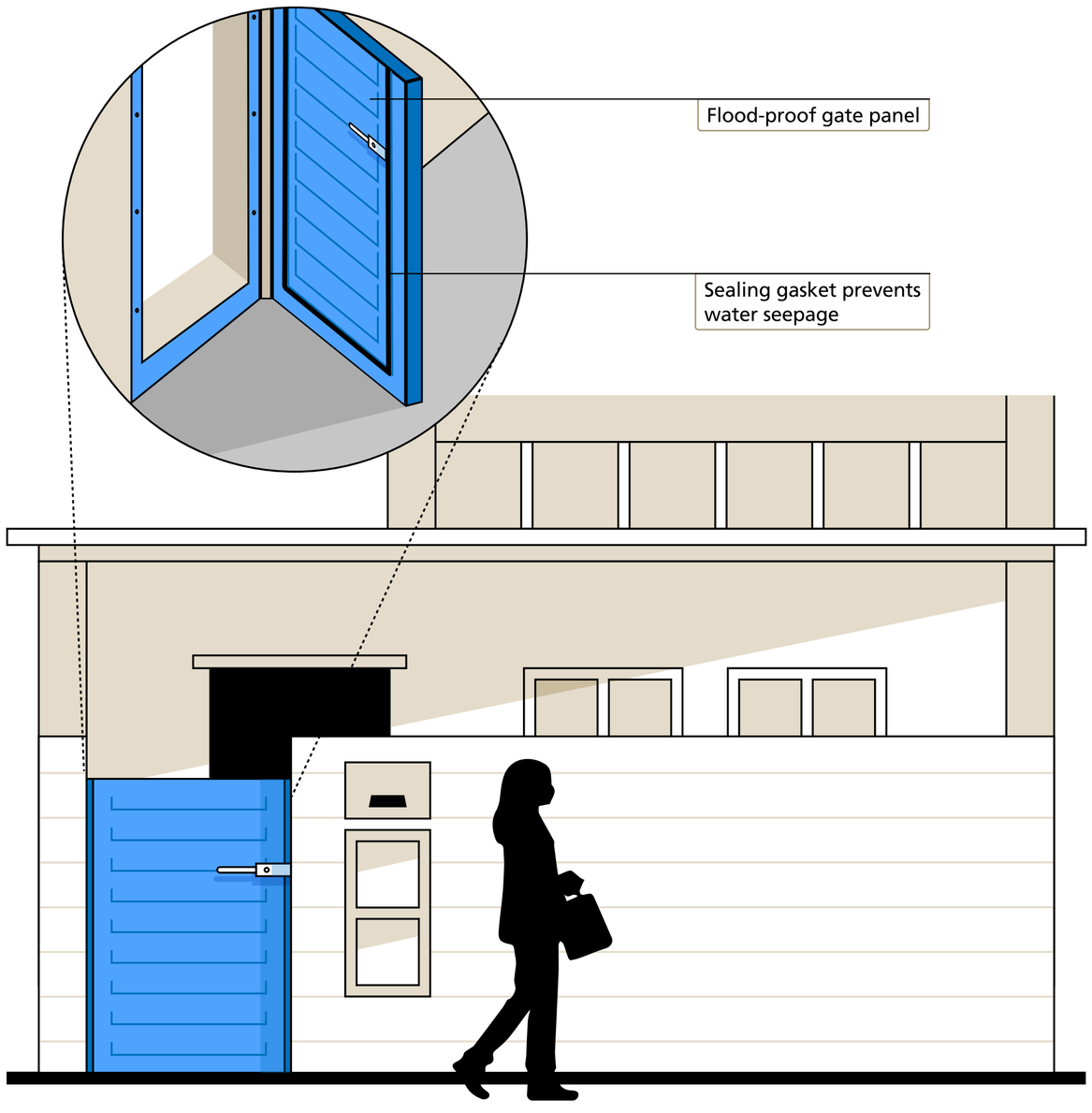
Barriers at underpass entrances to prevent water ingress | **Source:** FloodX (Singapore) Pte. Ltd.

← back to list | A2 Block openings

Floodproof doors and gates

Floodproof doors and gates are pre-installed barriers fitted at entrances, loading bays and basement accesses to prevent floodwater ingress. Unlike deployable barriers, they are present at all times and may serve as normal doors.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor, Indoor, Basement
Capital Cost	Medium
O&M Cost	Medium
Deployment Effort	Low
Aesthetic Impact	High



← back to list | A2

Floodproof doors and gates

Advantages

- **Made to fit** each doorway or opening, so it closes tightly with a reliable seal against floodwater ingress from the gaps
- Strong enough to hold back **deep floodwaters**, even when water levels rise to more than 1.2m
- Because the doors and gates are already installed on site, they can be **deployed very quickly**

Disadvantages

- **Regular upkeep** is needed to keep moving parts and seals in good condition, so that the doors/gates work properly when it is needed
- As these doors/gates are built into the site, they **cannot be moved or reused** at other locations that may also be prone to flooding

Operational requirements

Before heavy rain, ensure tracks and grooves are clear of debris and silt and the floodproof door/gate is functioning normally.

When rain arrives, barrier should be closed with an even seal along the edges. After the event, the floodproof door/gate should be wiped and checked for nicks and other damage so it is ready for the next storm.

Resilient design principles

Robustness

Floodproof doors and gates are **robust** as they can handle high flood depths and hydrostatic loads and are durable when kept clean and tested. They also work well alongside mobile pumps which can quickly drain minor seepage on the protected side.



Steel-reinforced floodproof door (open)
Source: FloodX (Singapore) Pte. Ltd.



Steel-reinforced floodproof door (closed)
Source: FloodX (Singapore) Pte. Ltd.

← back to list | A3 Block openings

Permanent flood walls

Reinforced concrete or masonry walls provide passive, always-on flood protection. They are often placed around perimeters or compound yards. Common materials can include concrete or glass.

Properly engineered foundations, movement joints, overtopping allowances and internal drainage are essential so the wall resists water loads while maintaining structural stability.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor
Capital Cost	High
O&M Cost	Medium
Deployment Effort	Low
Aesthetic Impact	High

Advantages

- **Passive and durable** protection for multiple assets
- **Customisable** wall design according to desired protection level and site needs
- **Minimal operational burden** due to low maintenance needs and no deployment required

Disadvantages

- Higher **capital cost** and **spatial footprint**
- Potential **aesthetic and circulation impacts** if poorly integrated

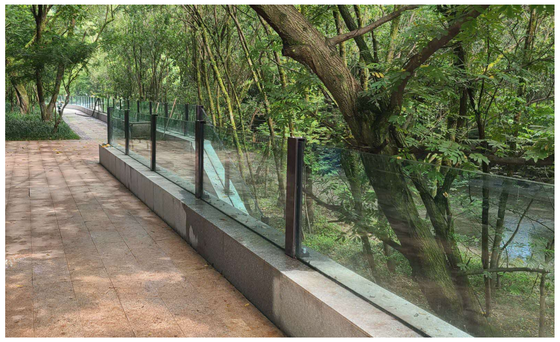
Operational requirements

A regular inspection routine should be set so that the wall is checked for hairline cracks, loose sealant at joints or signs of scouring near the base. After any flood incident, inspect the wall to confirm nothing has shifted or chipped.

Resilient design principles

Robustness

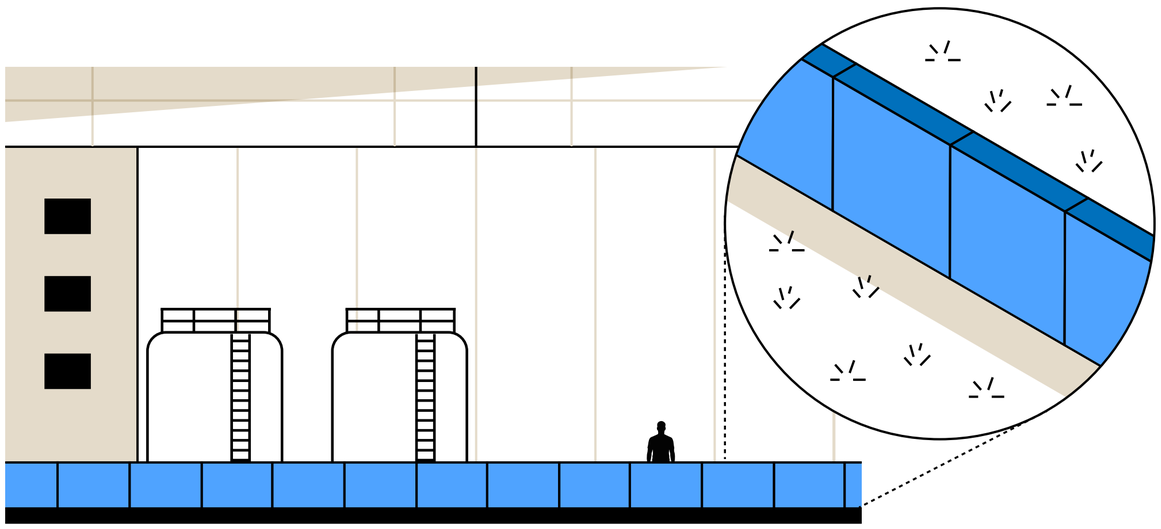
A fixed wall is **robust** as it offers always-on protection and stands up well to repeated floods.



Permanent glass wall for enhanced visual aesthetics
Source: FloodX (Singapore) Pte. Ltd.



Permanent flood wall integrated into the building perimeter



← back to list | A4 Block openings

Flood bags

Compact, super-absorbent 'sandless' bags are designed to expand upon contact with water, creating effective low-level barriers across doorways, vents, and skirtings. They are ideal for managing short-duration flooding or serving as a secondary seal around flood barriers.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor, Indoor, Basement
Capital Cost	Low
O&M Cost	High
Deployment Effort	High
Aesthetic Impact	Low

Advantages

- **Low cost** and easy to mobilise
- **Customisable** arrangement that can conform to irregular gaps and thresholds
- Useful as an **interim/ secondary defence**

Disadvantages

- Deployment is **labour-intensive** and requires time
- **Single-use** due to contamination after flood; disposal planning needed
- Best suited to **low flood depths**
- **Leakage** under prolonged flooding

Operational requirements

During the planning phase, define areas for deployment of flood bags, train personnel on recommended arrangement patterns, and routinely verify stock levels. When deploying, prioritise stability by building firm, moderate-height rows, and monitor for localised seepage.

Logistics and storage requirements

Flood bags should be stored in a dry room on pallets to keep them above floodwaters. Equipment and tools needed for setup should be kept nearby for easy access when needed.

Resilient design principles

Adaptability

Flood bags are **adaptable** as bag arrangement is flexible and can suit awkward corners or steps.



Water-activated flood bags
Source: FloodX (Singapore) Pte. Ltd.



Stacked flood bags deployed in a doorway
Source: FloodX (Singapore) Pte. Ltd.

← back to list | A5 Block openings

Raised building entrances

A raised building entrance—achieved with a ramp, stair or kerb-hump—raises the threshold above the building's entryway so that floodwaters are deflected from the opening. This measure can be implemented at all building and basement entryways.

When detailed with anti-slip finishes and drainage, it provides reliable day-to-day protection with minimal operational burden.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Indoor, Basement
Capital Cost	Medium
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	Medium

Advantages

- **Passive protection**; no deployment required
- Can be made compliant to various regulatory requirements and **visually integrated**

Disadvantages

- **Space and accessibility** trade-offs in tight sites
- Careful design needed to ensure accessibility is maintained with no **tripping hazards**

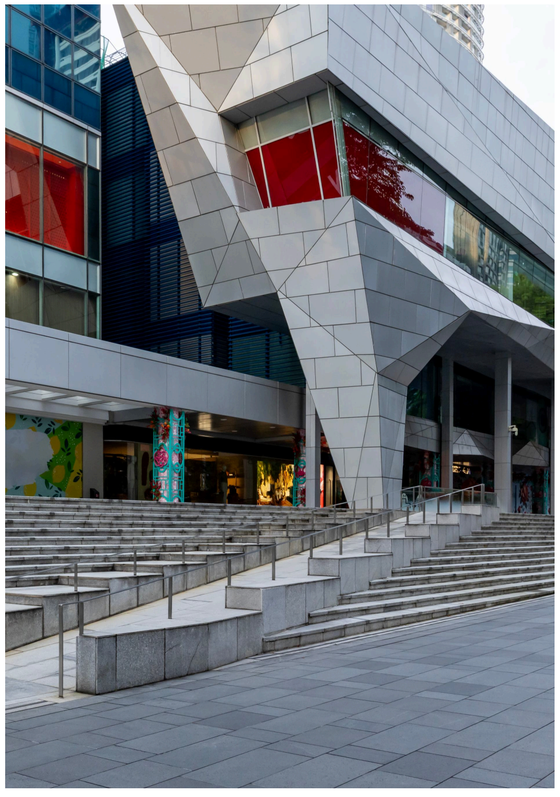
Operational requirements

Maintenance is generally not required; however, regular inspections should prioritise surface integrity, anti-slip functionality, and the clearance of drainage paths. Post-event protocols include monitoring for localised ponding and the immediate remediation of any faded safety signage or markings to ensure continued site safety.

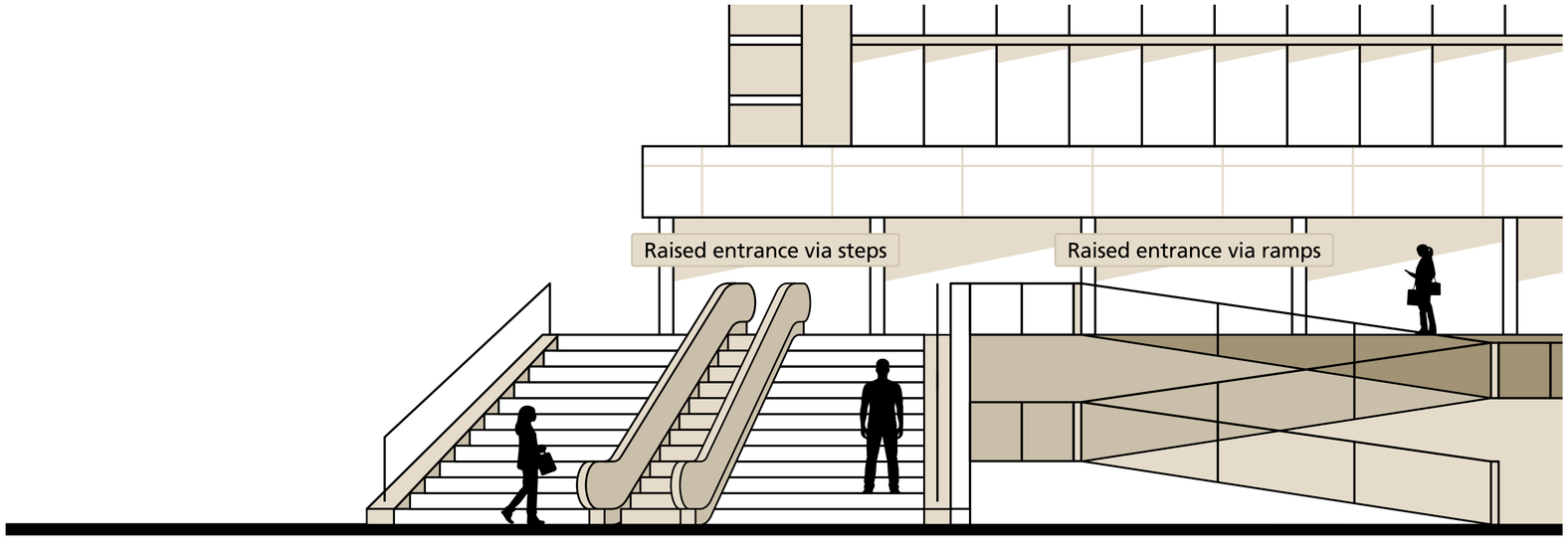
Resilient design principles

Robustness

Raised building entrances are **robust** measures, offering reliable, passive protection requiring no active deployment or monitoring, which is further enhanced by their durability. They work well alongside complementary measures like flood barriers for extra protection, or mobile pumps for damage reduction if flood height exceeds the height of the crest.



Raised entrance to the mall via stairs and ramp



← back to list | A6 Block openings

Raised ventilation openings

In new developments or redevelopments, ventilation openings can be designed sufficiently above the ground, so that water cannot enter. For existing developments, low vents can be sealed and new openings installed at a higher position.

The measure is common for basements, substations, plant rooms and corridors that sit close to the ground.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Indoor, Basement
Capital Cost	Low
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	Medium

Advantages

- Only **modest works** required to achieve protection
- Reduces risk of **water entering ducts and rooms**
- Often **cheaper** than repeated repair/clean-up, especially of sensitive assets

Disadvantages

- Attention to **structural integrity and finishes** essential for older buildings
- Must verify **compliance with other requirements**, e.g. fire, acoustic and airflow

Operational requirements

Maintenance is generally not required; however, regular inspections should prioritise surface integrity and ensure airflow is not obstructed. After a flood incident, note the water level and review if opening height is sufficient or alterations are to be made.

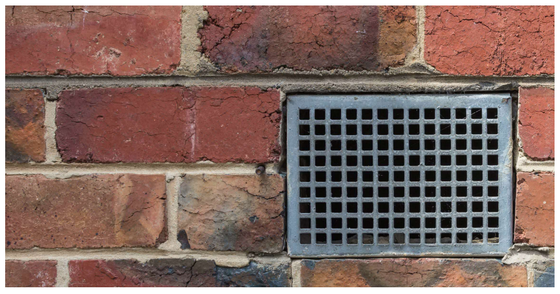
Resilient design principles

Robustness

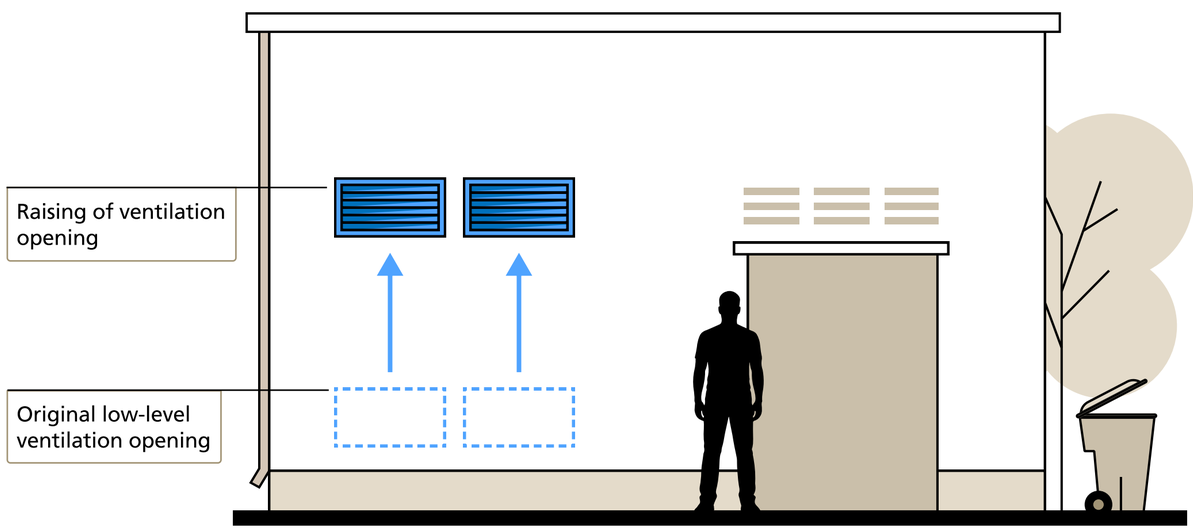
By raising the vent, **robustness** is achieved as the direct path for water infiltration is blocked. When utilised in a hybrid strategy with floor drains or mobile pumps, this solution ensures minimal impact even if if the flood level still exceeds the raised vents.



Strategic placement of ventilation openings to prevent water ingress



Raised ventilation opening in masonry walls



← back to list | A7 Block openings

Movable water dams

Proprietary tubes or modular water-filled dams are laid along entrances or development perimeters and filled in situ to divert floodwaters.

Sections of the dams can interlock to form a continuous barrier and be redeployed to other locations within the site as risks evolve.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor, Indoor, Basement
Capital Cost	Medium
O&M Cost	Medium
Deployment Effort	High
Aesthetic Impact	Low

Advantages

- **Scalable** across wide frontages
- **Reusable** and can be moved between locations
- **Lower environmental footprint** versus non-reusable flood bags

Disadvantages

- **Manual deployment** requiring manpower, pumps, hoses and anchors
- **Space and transportation** required for storage and deployment
- Unsuitable for **wave action** or **deep water**; best suited for **low flood depths**

Operational requirements

A simple deployment plan that shows where each section sits, how the ends join and how units are filled should be prepared and routine drills conducted. During use, personnel should check for gaps and keep fill levels consistent. Dam sections should be drained, rinsed and dried before storage.

Logistics and storage requirements

Sections should be stored indoors on pallets with straps and repair patches kept together. Space should be provided for a transportation equipment (e.g. trolley, forklift) where needed.

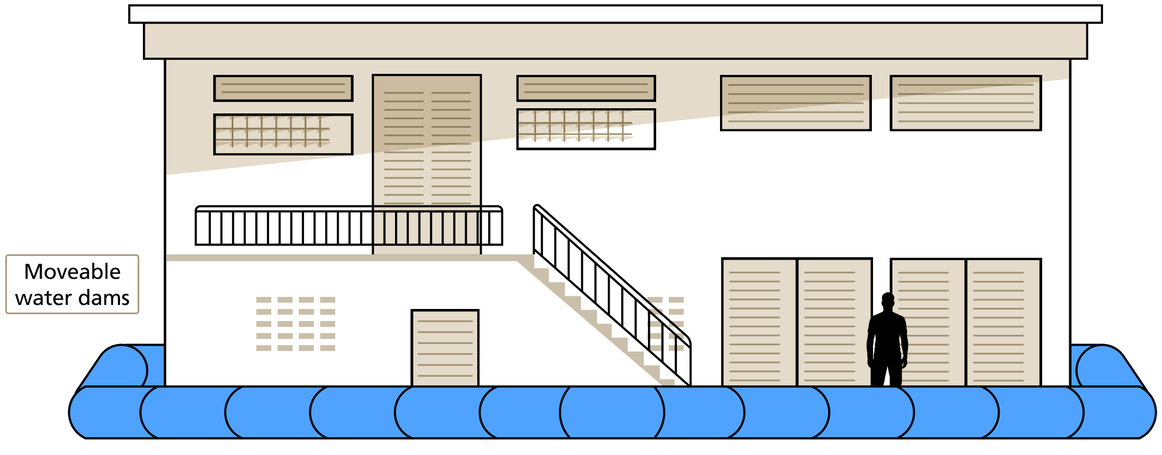
Resilient design principles

Adaptability

Water dams offer **adaptability** due to their high geometric flexibility, allowing for seamless deployment around curved perimeters or entrances. They work best by serving as a secondary layer of defence in addition to permanent measures.



Movable water dam deployed to divert floodwater
Source: FloodX (Singapore) Pte. Ltd.



← back to list | B1 Block water from drains

Backflow prevention devices

A non-return valve installed in a development's internal drain that acts as a one-way gate, allowing water to flow out but automatically closing to prevent a reverse flow of stormwater from the public drainage system back into the development's internal drain. This is particularly useful in periods of high rainfall when the water level in public drains may be high.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor, Indoor
Capital Cost	Medium
O&M Cost	Medium
Deployment Effort	Low
Aesthetic Impact	Medium

Advantages

- Effectively **stops flow of water** into development during heavy rainfall.
- Relatively **simple and inexpensive** to install and maintain.
- Valves for various pipe sizes are **readily available**

Disadvantages

- Only manages **water backflow from external drains**; does not address other flooding sources/ causes.
- **Routine maintenance** required to prevent risk of failure.

Operational requirements

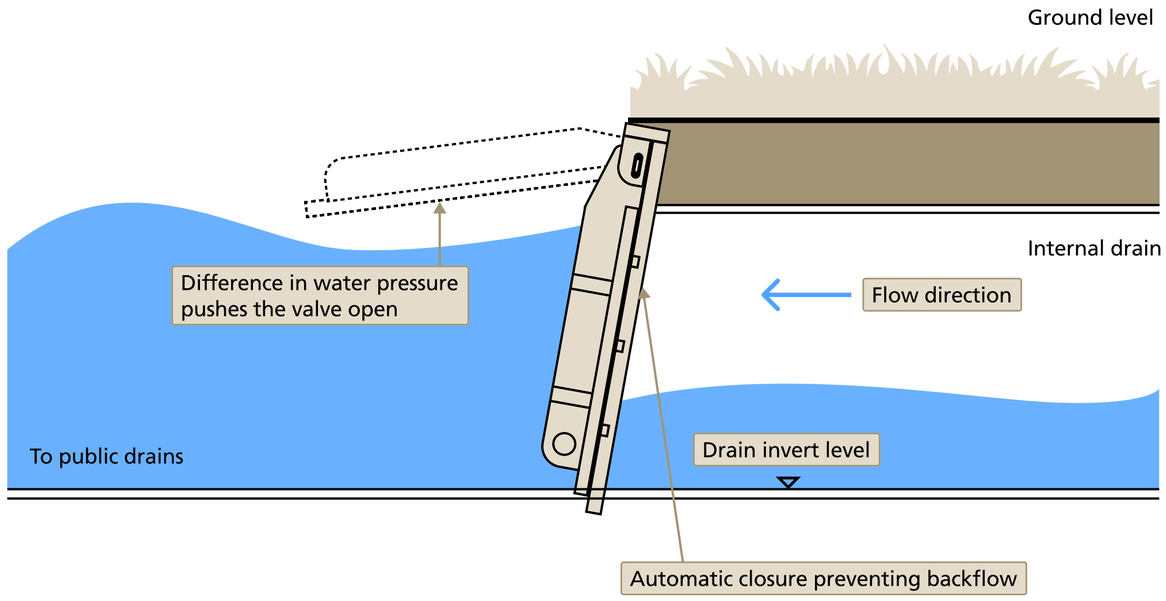
Regular maintenance and cleaning are needed to ensure reliable function. Maintenance should focus on clearing the valve of sediment and debris (such as leaves, sand, or silt) that could prevent the flap from closing properly.

Regular inspections are required to assess the structural integrity of the valve body, seat, and operating mechanism for damage. Additionally, the mechanism must be checked to ensure the flap can swing freely to its designated opening angle and return under gravity to provide an effective backflow barrier during extreme weather events.

Resilient design principles



Backflow prevention valves are **robust** as they safeguard drainage systems from external water sources, and can rely on corrosion-resistant materials and seals to maintain performance. **Redundancy** could involve installing multiple valves at critical points to ensure protection even if one fails.



← back to list | B2 Block water from drains

Sluice gates

Vertically sliding sluice gates at a development's internal drain discharge point activate to isolate the drain during heavy rainfall, preventing backflow and enabling controlled discharge. The gates can be lowered and raised manually or set up for remote activation.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor
Capital Cost	High
O&M Cost	Low
Deployment Effort	Medium
Aesthetic Impact	Medium

Advantages

- **Durable** with long service life
- May be designed for **easy activation** with motorised parts

Disadvantages

- High **upfront cost** for structural and mechanical parts
- **Active deployment/ activation** of measure required before a flood event
- Regular **maintenance and testing** required
- **Training** required to ensure correct activation and maintenance of measure

Operational requirements

Personnel must be fully trained to monitor flood alerts and activate the sluice gate system, especially if a manual gate is implemented. Training must cover efficient closing before the storm and rapid reopening of the gate immediately following a storm event to return the site to normal operation quickly. Motorised or remotely-operated systems should additionally be tested regularly to ensure activation is triggered at correct water levels.

Maintenance should test for smooth movement of the gate, and clear debris jamming the channel and the gate's seat. Where the gate sits below floor level, safe standing space or a handrail should be provided so checks can be done safely.

Resilient design principles

Robustness

Redundancy

Sluice gates mitigate the risk of backflow, making the internal drainage system more **robust** against external flood sources. **Redundancy** can be provided for by establishing bypass routes or dual-gate configurations, so that the system maintains functionality even during high-stress scenarios or localised blockages.



Vertical sluice gate installed in an open drainage channel
Source: PUB

Legend:

1	Motor
2	Sluice gate
3	Open drainage channel

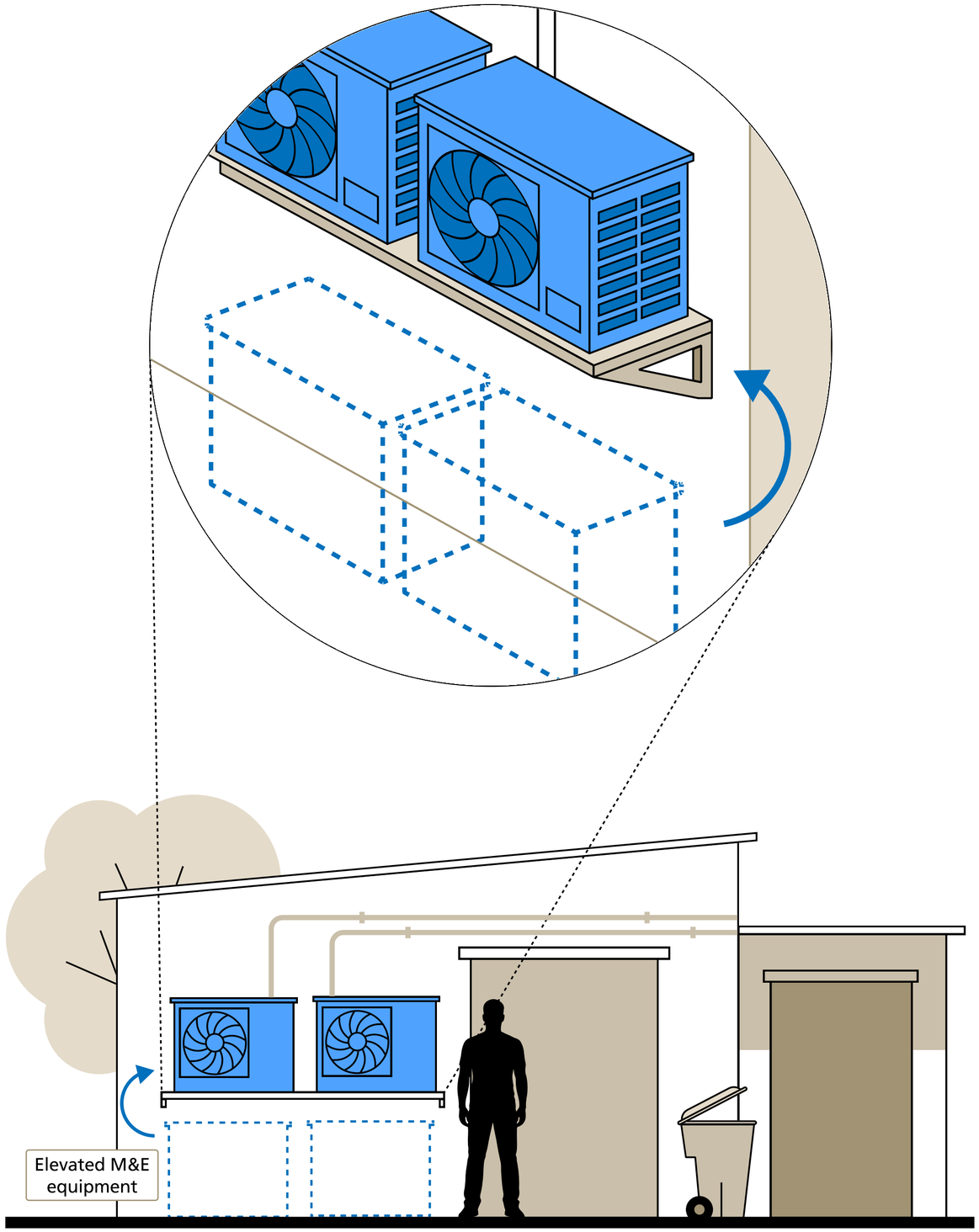
← back to list | C1 Protect M&E equipment

Elevation or relocation of mechanical and electrical equipment

Critical equipment can easily be protected from flooding by raising plinths or repositioning the equipment to higher levels. In new developments or redevelopments, they can be designed from the start to be in areas safe from flooding. This helps to minimise repairs or replacement due to water damage, while also reducing interruptions.

Measure Type	Damage reduction (Impact)
Applicable Area	Indoor, Basement
Capital Cost*	High
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	Medium

* Costs reflected are for retrofit



← back to list | C1

Elevation or relocation of mechanical and electrical equipment

Advantages

- **Passive protection** with no active deployment required.
- Reduces risk of **water damage** to critical mechanical and electrical assets and maintains **operational continuity** of the development during and after flood events
- Minimal **operational** or **maintenance** requirements

Disadvantages

- Sufficient **loading capacity** and accessible **space** required for relocation and maintenance
- Higher cost for **existing developments** where M&E equipment is already fixed in place
- Higher cost for **technical or specialised facilities** due to sensitive equipment requiring specialised treatment

Operational requirements

Once elevation or relocation is complete, operational requirements are low, requiring only periodic inspection of mounting structures for stability.

Resilient design principles

Adaptability Robustness

Depending on the equipment to be raised/ relocated, **adaptability** can be achieved through flexible mounting or relocation strategies as risk zones shift. This measure is **robust** as it offers always-on protection to keep sensitive and critical equipment out of the path of floodwaters.



Wall-mounted air conditioning condensers



Electrical distribution boards installed on plinths

← back to list | D1 Waterproofing

Waterproof coatings for building and asset exteriors

Waterproof coatings, membranes and sealant can be applied to exterior walls, flooring, windows, doors and around utility equipment to prevent water damage to the exterior of the property.

Measure Type	Damage reduction (Impact)
Applicable Area	Outdoor, Indoor
Capital Cost	Low
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	Medium

Advantages

- **Passive protection** with no setup required
- Relatively **simple and inexpensive** to install and maintain.

Disadvantages

- Does not **prevent flooding**
- Routine **maintenance and re-application** required – coatings **wear down** over time due to exposure to the elements

Operational requirements

Coatings should be applied according to manufacturer specifications and within a temperature-controlled, dry environment to prevent premature degradation of the chemical components.

A rigorous preventative maintenance regime is mandatory to ensure the continued effectiveness of the waterproof barrier. Annual inspections must be conducted to identify blistering, peeling, or cracking in wall membranes or coatings. Specialised focus is required at transition points where M&E utilities (cables, pipes, ducts) penetrate exterior walls; the seals at these points should be regularly checked for brittleness or shrinkage. Repair works must be performed on clean, dry surfaces to ensure proper adhesion and continuity of the barrier.

Logistics and storage requirements

A spares kit containing sealants, patching compounds, and applicator tools should be maintained on-site for immediate minor repairs and stored according to manufacturer specifications.

Resilient design principles

Recoverability

Waterproof coatings enhance **recoverability** by keeping the building facade or exterior of the asset dry during inundation, significantly reducing the "dry out" period and the associated costs of mould remediation and decontamination after floodwaters recede.



Reinforcing wall-to-floor joints



Protective coating applied to building exterior

← back to list | D2 Waterproofing

Wettable finishes for building interiors

Installing flood-tolerant interior finishes—epoxy coatings, ceramic tiles, waterproof panels/paints—reduce damage and mould growth if floodwaters reach indoor areas.

Measure Type	Damage reduction (Impact)
Applicable Area	Indoor, Basement
Capital Cost	Low
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	Medium

Advantages

- **Passive protection** with no setup required during a flood event
- Broad **material palette** to suit development's design needs
- **Retrofit-friendly** with limited disruption during installation

Disadvantages

- Does not **prevent flooding** in indoor areas
- Routine **maintenance and re-application** required—coatings **wear down** over time due to exposure to human activity
- Attention to **slip hazards** and **fire safety** requirements required

Operational requirements

After the flood event, standing water should be removed and surfaces left to dry out. Inspections should be done annually to ensure full functionality.

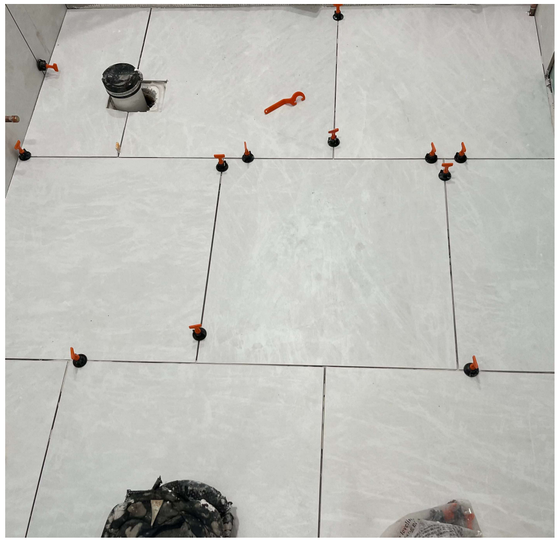
Logistics and storage requirements

Materials and equipment for touch-ups and re-applications should be stored in an accessible location so that small scuffs and chips can be fixed promptly.

Resilient design principles

Recoverability

Water-tolerant finishes increase site **recoverability** post-flood, as they reduce water damage to interior furnishings and shorten the "dry out" period required. It can be integrated with deployable barriers at building entrances to create a hybrid, multi-layered defence strategy against floodwaters.



Wettable finishes using ceramic tiled flooring



Wettable finish to create a durable, non-absorbent surface

← back to list | D3 Waterproofing

Puddle flanges

Puddle flanges are cast-in mechanical collars around pipe or conduit penetrations through walls that prevent water seepage into critical rooms. They are particularly valuable for basements, plant/pump rooms and electrical spaces with frequent wall penetrations, making them simple solutions to protect critical equipment.

Measure Type	Damage reduction (Impact)
Applicable Area	Indoor, Basement
Capital Cost	Medium
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	Low

Advantages

- **Highly reliable** watertight seal at wall penetrations
- **Low maintenance** requirements

Disadvantages

- **Retrofit** can be intrusive and space-constrained
- Cost varies by **material**, e.g. stainless steel costs more upfront

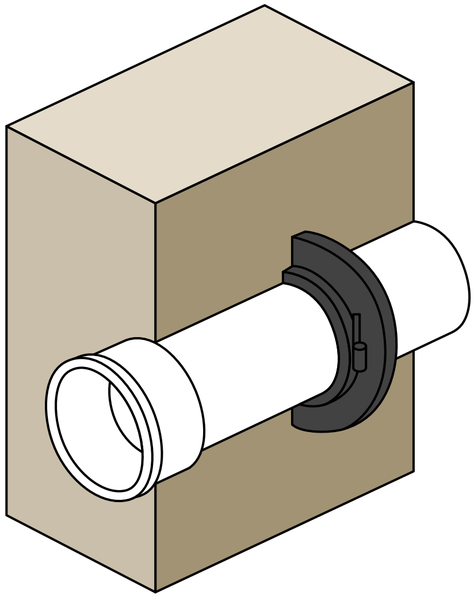
Operational requirements

Although little maintenance is required once installed, performance relies on correct installation. Conduct a leak check after installation. During routine inspection, look for damp marks around penetrations and fix promptly if found.

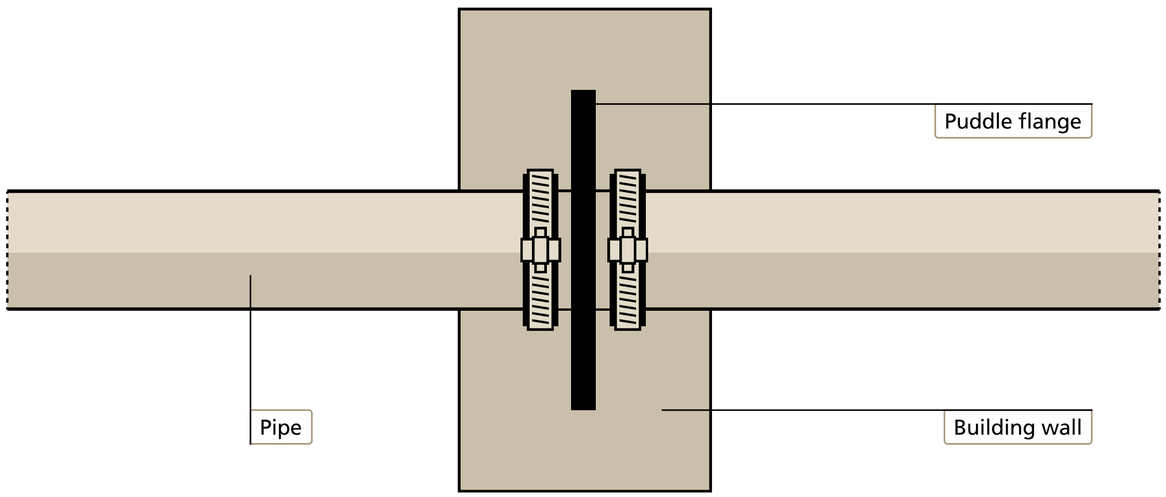
Resilient design principles

Robustness

Puddle flanges block leakages and keep plant rooms and basements dry, making sensitive spaces more **robust** even under flood conditions.



Puddle flange installed on a pipe penetration



← back to list | D4 Waterproofing

Re-pointing of brickwork

Renewing mortar joints reduces seepage and restores facade durability in brick structures, which can become cracked and porous over time due to exposure to the elements.

The measure is often paired with breathable repellents and local weeps to control trapped moisture while preserving appearance.

Measure Type	Damage reduction (Impact)
Applicable Area	Outdoor, Indoor
Capital Cost*	Medium
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	Low

* Costs reflected are for retrofit

Advantages

- Improves **water resistance** and structural stability
- **Extends facade life** with aesthetic uplift
- Passive protection with low operational burden

Disadvantages

- Does not **prevent flooding**
- Applicable only to **brickwork facades/walls**
- Requires **compatible mortar** to avoid damage to existing structure

Operational requirements

Operational requirements are minimal once completed. However, curing time is essential after application, and inspection after the first heavy rain is recommended to identify any gaps.

Logistics and storage requirements

Easy access to repair materials (e.g. matching mortar, pigment) and ladders for inspection is essential.

Resilient design principles

Recoverability Robustness

Well-repaired brickwork and mortar enhance **recoverability** as they cut down on water seepage through the wall, reducing the "dry out" period necessary after a flood. It is also **robust** within its design lifespan due to the durability of brick.



Specialised sealant to ensure a watertight finish



Traditional re-pointing to replace degraded mortar

← back to list | E1 Reduce floodwaters

Upgrading of internal drains

Widening of internal drains within developments can improve their ability to handle a larger volume of water. This reduces the risk of overflow during heavy rainfall.

For new developments, this could involve ensuring sufficient space for future upgrades is reserved.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor
Capital Cost*	Medium
O&M Cost	Medium
Deployment Effort	Low
Aesthetic Impact	Medium

* Costs reflected are for retrofit

Advantages

- **Passive protection** with no active deployment required
- **Durable**, **long-term** engineered solution
- Small-scale upgrades can be **simple and inexpensive** to implement
- **Impact on aesthetics** can be minimised through drain cover design

Disadvantages

- Large-scale upgrades may involve substantial **upfront investment** and lengthy construction periods
- Space constraints in **existing developments** may limit upgrading potential

Additional resources
LTA | Standard Details of Road Elements

Operational requirements

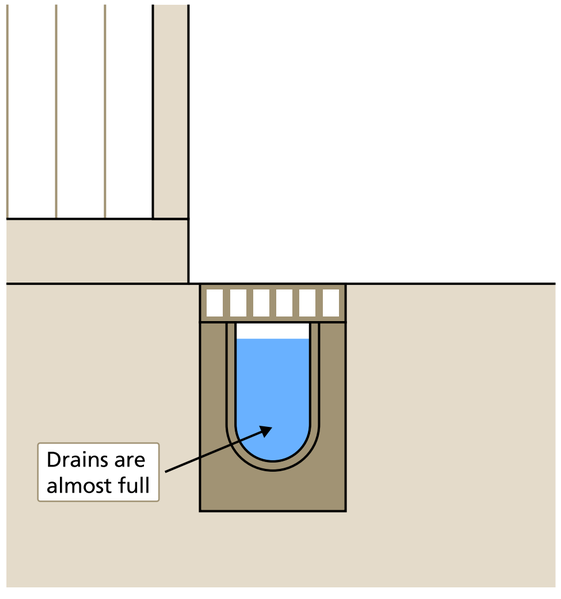
Operational requirements focus on enhancing drainage capacity and ensuring system integrity through regular cleaning of drains, sumps and gratings to maintain flow efficiency, and regular inspection for blockages, settling or erosion.

Resilient design principles

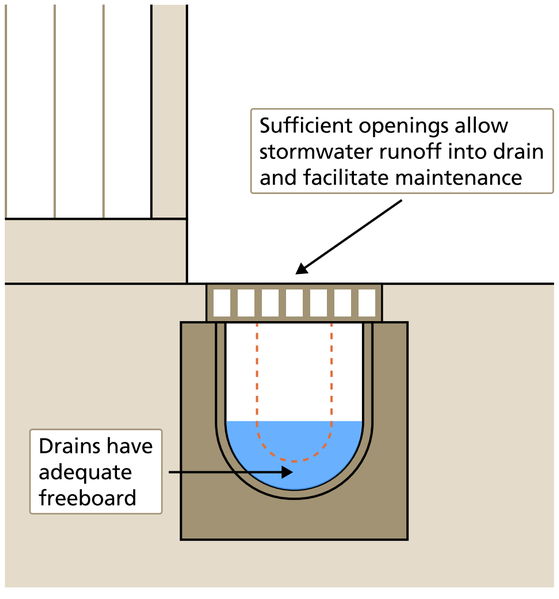


For both new and existing developments, **adaptability** means reserving sufficient buffer space for future drain upgrades when needed. **Robustness** can be achieved by avoiding poor drain design choices (e.g. acute angles, low discharge points) that reduce peak flows. **Redundancy** may involve adding overflow routes and sump pumps to handle excess water in the event that the primary drains experience blockages.

Before: Narrow drain with limited capacity



After: Upgraded drain with higher capacity



← back to list | E2 Reduce floodwaters

Mobile pumps

Portable pumps remove accumulated water from low points, basements and sumps during and after storms, accelerating dewatering and shortening downtime. Depending on the area of the development, several pumps may be deployed at once to control floods.

Due to their suction lift system, mobile pumps can work only when floodwaters are at a minimum depth of about 5-10 cm. Its effectiveness can be enhanced through hybrid solutions such as installing a sump at the lowest point where the pump can be placed.

Measure Type	Damage reduction (Impact)
Applicable Area	Outdoor, Indoor, Basement
Capital Cost	Low
O&M Cost	High
Deployment Effort	Medium
Aesthetic Impact	Low

Advantages

- Wide range of **models and capacities** available in the market
- Can be stored when not required
- **Versatile** as they can be deployed across multiple locations
- Relatively **low unit cost** compared to damages avoided

Disadvantages

- **Training** required to ensure correct deployment of pump during floods
- Does not **prevent flooding** and cannot **drain floodwaters fully** due to limitations of suction lift and hose routing
- Wear-and-tear requires regular **testing and servicing**

Operational requirements

Personnel should be trained to operate the pump, and ensure that power/fuel supply is secured in advance. When floods are imminent, pumps may be deployed at the area to be protected. Mobile pumps require a minimum flood depth of about 5-10 cm to operate and will not be able to drain water below this minimum depth, so secondary strategies such as installing a sump at the lowest point may be required. Regular testing and servicing of pumps is required due to wear-and-tear, especially after a flood incident.

Logistics and storage requirements

Pumps should be stored in a ventilated room with easy access to all components, including fuel or batteries.

Resilient design principles

Adaptability Recoverability

Mobile pumping solutions are **adaptable**, offering high operational flexibility as they can be deployed or scaled up as needed. Mobile pumps also enhance **recoverability** of the development by actively draining floodwaters, allowing quicker return to operations. They pair well with other measures (e.g. flood bags, deployable barriers) in a multi-layered defence strategy.



Diesel-powered mobile pump for emergency deployment



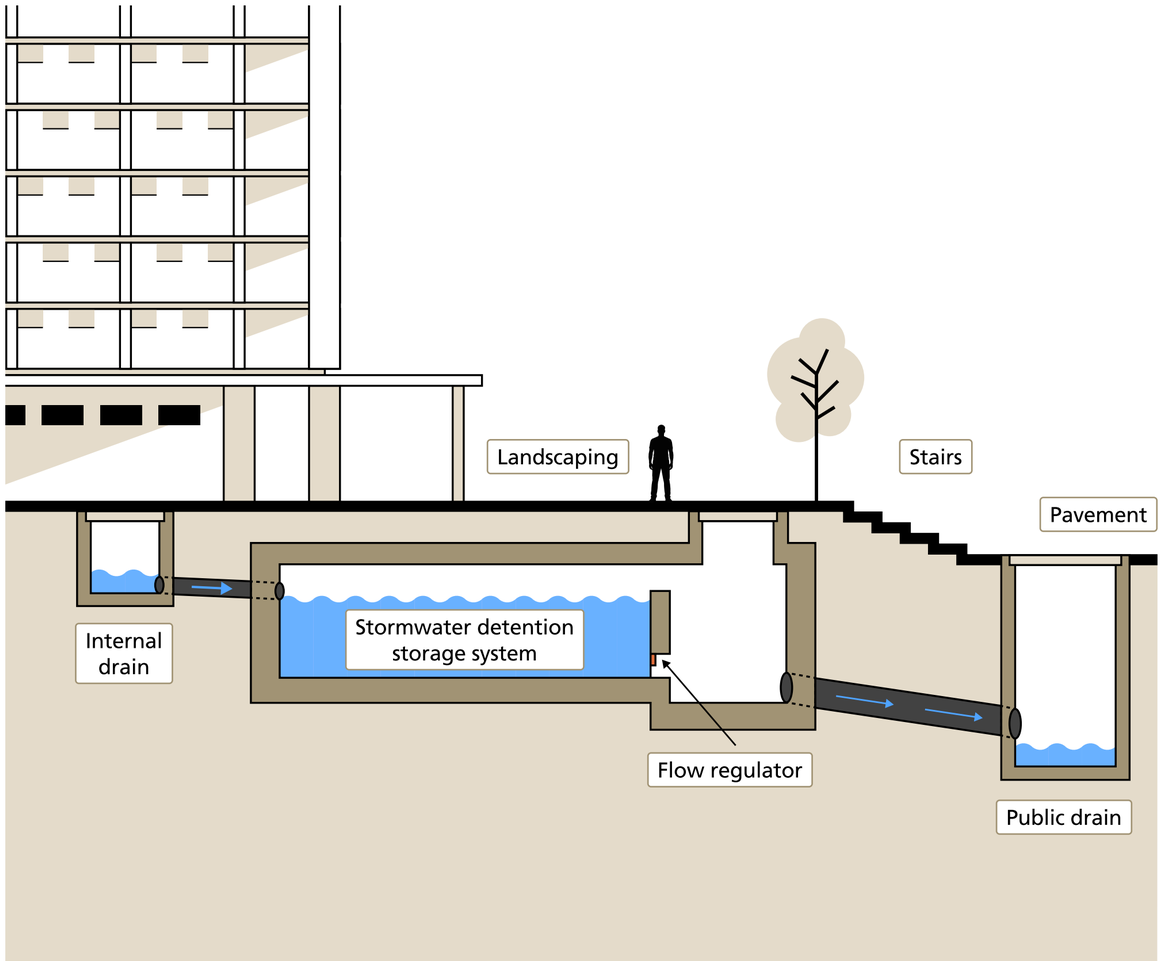
Mobile pumps deployed on site to discharge floodwater

← back to list | E3 Reduce floodwaters

Stormwater detention storage system

On-site detention storage systems enable rainwater to be temporarily stored and subsequently discharged into downstream drains at controlled flow rates. These systems are designed with integrated overflows and monitoring protocols to ensure long-term reliability. As the construction of an underground detention storage system can be disruptive, this measure is best suited to new developments or sites undergoing redevelopment.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor
Capital Cost	High
O&M Cost	Medium
Deployment Effort	Low
Aesthetic Impact	Low



← back to list | E3

Stormwater detention storage system

Advantages

- **Passive measure** increases capacity of internal drainage system without requiring deployment or activation
- Clear and standardised **design guidance** is easily available
- **Scalable**—can be deployed from small plots to large developments
- **High efficiency** in reducing flood risk with little manpower required or visual impact

Disadvantages

- Requires **underground space** and access corridors
- May be unsuitable for **existing developments** due to space constraints and potential disruption during construction
- Needs periodic **maintenance** (e.g. desilting) and confined-space provisions
- **Finite storage volume** that may be exceeded in prolonged/extreme storms

Operational requirements

Regular maintenance is required for desilting and to keep grating clear. After a heavy storm, drain channels and the tank should be cleared immediately and sediment depths should be recorded to optimise future cleaning schedules.

Resilient design principles

Robustness | Recoverability

Detention storage systems are a **robust** measure for flood resilience as they are able to accommodate large volumes of rainwater and can be paired with measures like rooftop water storage systems and upgraded surface drainage networks to attain a multi-layered defence strategy. **Recoverability** of the development is enhanced through the controlled discharge of water after a storm, which prevents both internal and external drains from being overwhelmed.



Stormwater detention storage system serving a residential estate
Source: Sika (Singapore) Pte. Ltd.



Installation of modular underground stormwater detention storage system
Source: Sika (Singapore) Pte. Ltd.

← back to list | E4 Reduce floodwaters

Rooftop water storage

Rooftop water storage systems—including green or vegetated roofs, blue roofs, and rainwater harvesting systems—offer decentralised stormwater management by using a building's roof to capture, detain, and regulate the release of stormwater into the development's drains.

By itself, this measure has limited storage capacity. This should be applied as a secondary measure in a multi-layered strategy to address significant flood risk.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor
Capital Cost	Medium
O&M Cost	Medium
Deployment Effort	Low
Aesthetic Impact	High

Advantages

- **Passive** protection with no activation or deployment required
- **Scalable** across multiple buildings
- For new developments or redevelopments, may be designed as an **attractive visual feature** or recreational space (e.g. rooftop garden)
- Provides non-potable water supply (within PUB limits)

Disadvantages

- For existing buildings, **space or structural capacity** concerns may limit effectiveness of this measure
- Rainwater **storage volume is limited** (e.g. compared to detention tanks)
- **Regular maintenance** essential

Operational requirements

Routine maintenance of system components (e.g. membranes, discharge outlets, storage tanks) are essential to ensure effectiveness. Observation should be made after rainfall to verify excess water drains away as intended.

Resilient design principles

Adaptability

Utilising rooftop water storage is **adaptability** in practice: it maximises spatial efficiency while regulating the demand on internal drainage infrastructure during heavy rainfall. It works best as a multi-layered strategy, when utilised as a secondary measure alongside ground level drainage infrastructure (e.g. upgrading of drains, detention tanks).



Landscaped rooftop water storage system
Source: Sika (Singapore) Pte. Ltd.



Installation of rainwater harvesting tanks

← back to list | E5 Reduce floodwaters

Stormwater infiltration trench

A stormwater infiltration trench is a long gravel-filled depression that allows rainwater to filter into the ground. This reduces pressure on the development's drainage system and lowers the likelihood of flooding during heavy rain.

By itself, this measure has limited drainage capacity. It should be applied as a secondary measure in a multi-layered strategy to address significant flood risk.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor
Capital Cost	Medium
O&M Cost	Medium
Deployment Effort	Low
Aesthetic Impact	Medium

Advantages

- Effectively reduces runoff arising from **low to moderate** intensity rainfall
- Relatively simple construction and modularity
- Integrates **seamlessly** along landscape design edges especially in new developments or redevelopments

Disadvantages

- **Drainage effectiveness** is limited by soil permeability and clogging risk
- **Lower drainage capacity** per unit area compared to concrete drains, thus limited effectiveness under very heavy rainfall
- Not suitable for areas with **high water tables** as infiltration will be limited
- Some **setback** from building foundations required

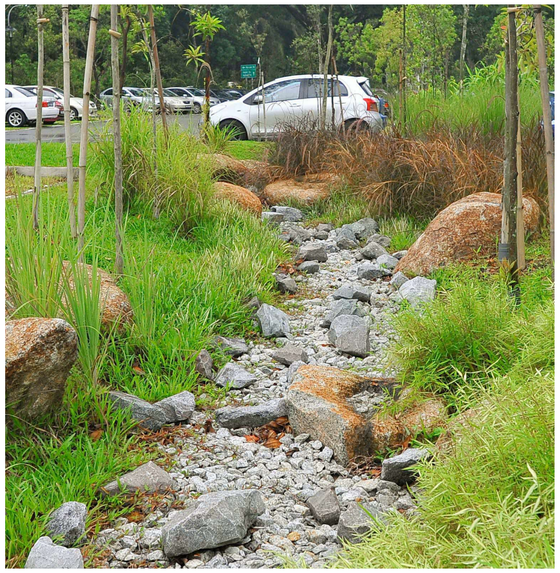
Operational requirements

Regular maintenance is required, including weeding, cleaning out silt traps, and repairing eroded areas. Care should also be taken to avoid mosquito breeding.

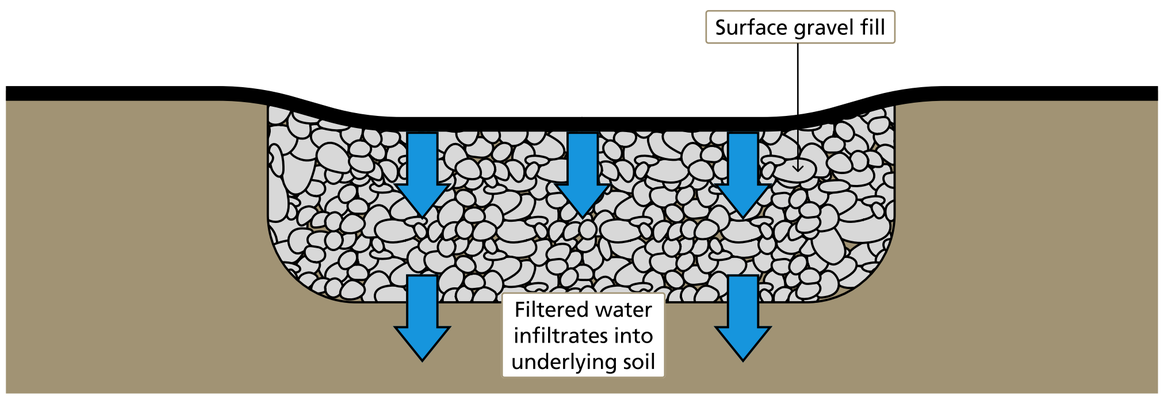
Resilient design principles

Redundancy | Recoverability

The primary purpose of infiltration trenches is to support **redundancy** by providing additional capacity for existing or conventional drainage infrastructure. If the volume of stormwater still exceeds capacity, infiltration trenches enhance **recoverability** by allowing water to naturally filter into the ground during and after rainfall, reducing disruption to the development and enabling quicker return to normal conditions.



Stormwater infiltration trench at an open carpark
Source: Sika (Singapore) Pte. Ltd.



← back to list | E6 Reduce floodwaters

Bioswales and rain gardens

Bioretention systems such as rain gardens and bioswales are engineered landscape features designed to slow down entry of rainwater into drains by mimicking natural drainage patterns using specialised vegetation and soil media.

By itself, this measure has limited drainage capacity. It should be applied as a secondary measure in a multi-layered strategy to address significant flood risk.

Measure Type	Flood prevention (Likelihood)
Applicable Area	Outdoor
Capital Cost	Medium
O&M Cost	Medium
Deployment Effort	Low
Aesthetic Impact	Medium

Advantages

- Effectively **slows rainwater** entering drains under low to moderate rainfall intensity
- **Enhances landscape** by providing green spaces for recreation during dry periods

Disadvantages

- **Limited effectiveness** in preventing water accumulation during major storms
- Requires sufficient dedicated **ground-level surface area**, though the area can be multifunctional during dry periods
- Routine **maintenance** required
- Some **setback** from building foundations required

Operational requirements

Routine inspection and maintenance should be conducted to maintain design capacity and filtration capability, including removal accumulated debris and settled silt, as well as pruning and replanting of vegetation. After heavy rainfall, monitor the time required for water to drain to ensure it remains within the design threshold.

Resilient design principles





When combined with conventional drains, bio-retention systems support **redundancy** by slowing down water flow and adding a gentle buffer to a development's drainage capacity. If the volume of stormwater still exceeds the capacity of the development's drains, bio-retention systems enhance **recoverability** by allowing floodwaters to drain naturally after rainfall, enabling quicker return to normal conditions.



Bioswale designed to convey stormwater runoff along a pedestrian pathway



Rain garden with engineered soil media and plants

← back to list | F1 Reduce physical impact

Pavement edge protection

Edging and kerbs made from sturdy material are useful in preserving the structural integrity of pavement in the flood-prone areas, especially if the pavement is made from softer materials like timber or brick. If slightly raised above the pavement, it can also function as a physical barrier against low flood depths and minor debris.

Measure Type	Damage reduction (Impact)
Applicable Area	Outdoor
Capital Cost	Medium
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	Medium

Advantages

- **Prevents edge** erosion and structural damage due to debris carried by floodwaters
- **Highly durable** and minimal upkeep needed once installed

Disadvantages

- Does not **prevent flooding**
- **Limited effectiveness** in general infrastructure protection

Additional resources
LTA | Standard Details of Road Elements

Operational requirements

Edge protection such as kerbs and edging requires minimal active management once installed, but regular inspections and periodic cleaning are essential to maintain effectiveness.

Resilient design principles

Recoverability

Edge protection supports **recoverability** of the development by reducing damage and repair costs to pavements even if a flood occurs.



Concrete flush kerb acting as a pavement edge protection



Reinforced edge between landscape area and paved walkway

← back to list | F2 Reduce physical impact

Bollards and guardrails

Installation of protective features like bollards and guardrails at building corners and exteriors can safeguard against damage from floating debris collision during major flood events, as deep and rapid floodwaters can move cars and other large objects with great force and speed.

Measure Type	Damage reduction (Impact)
Applicable Area	Indoor
Capital Cost	Low
O&M Cost	Low
Deployment Effort	Low
Aesthetic Impact	High

Advantages

- **Enhances structural integrity** at a vulnerable point of the building by providing a physical buffer against debris
- Can be designed to be **visually appealing** or **integrated** with landscape architecture using finishing treatments

Disadvantages

- Does not **prevent flooding**
- May impact pedestrian and vehicle **access** to the building or property
- Requires adequate **on-site space** to install the bollards or guardrail system

Additional resources
LTA | Standard Details of Road Elements

Operational requirements

Operational requirements for bollards and guardrails focus on structural soundness and corrosion resistance to ensure continued protection. These include regular inspection and maintenance to prevent rust, cracks or loosening of anchor bolts, especially after flood events. Designs allowing for durability and easy replacement are recommended.

Resilient design principles

Recoverability

Bollards and guard rails support **recoverability** by reducing damage and repair costs to the building even if a flood occurs.



Stainless steel bollards along building perimeter



Heavy-duty fixed bollards for impact reduction



Pre-cast concrete bollards with reflective banding

05

Case Studies

5.1 Tanglin Mall: Proactive and Thorough Flood Preparedness

5.2 People's Association Headquarters: Targeted Measures at the Asset-Level

5.3 Funan: Flood Resilience as a Value-Driver

5.4 Singapore Institute of Technology Punggol Campus: Weaving Blue-Green Measures into Community Spaces

5.5 Sungei Buloh Wetland Reserve: "Living with Water" by the Coast

5.6 National University Health System: Protecting Essential Public Infrastructure

5.6 National University Health System: Protecting Essential Public Infrastructure

At a glance: See the principles in practice.

This final chapter brings the guidebook full circle. From major new developments to retrofits of existing buildings, see how various developments have successfully integrated flood-resilient design and operational strategies. These examples are proof that flood resilience is both achievable and effective.

This chapter is most useful for:

- Design Professionals
- Developers and Property Owners
- Property Management Professionals
- Homeowners

5.1 Tanglin Mall: Proactive and Thorough Flood Preparedness

Resilient design principles:

Adaptability | Robustness | Recoverability

Tanglin Mall is a commercial development located at the junction of Tanglin Road and Grange Road. As it is surrounded by areas on higher ground such as Napier Road and Nassim Hill, stormwater flows tend to converge here during heavy rain.

To address the risk of flooding, Tanglin Mall's owner, Allgreen Properties Limited, has adopted an informed, strategic and forward-looking approach to enhance the flood resilience of the development.

Instead of a one-size-fits-all solution, Allgreen implemented a variety of measures to protect the critical revenue-generating spaces, including the retail and basement areas. It took into careful consideration the site characteristics as well as the topography, human and vehicular traffic, and existing design.

As an existing development located at a prominent junction, Tanglin Mall's flood-resilient measures were also designed with the following key criteria in mind:

- To maintain seamless connectivity throughout pedestrian access areas
- Not to negatively impact the visual attractiveness of the mall

Three Key Strategies that Chart Tanglin Mall's Flood Resilience Journey

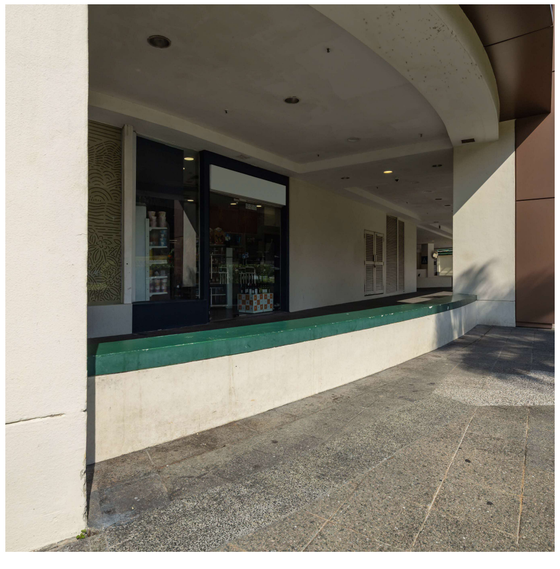
Allgreen undertook a comprehensive review of flood risks and adopted three key strategies to enhance Tanglin Mall's flood resilience.



Strategy 1

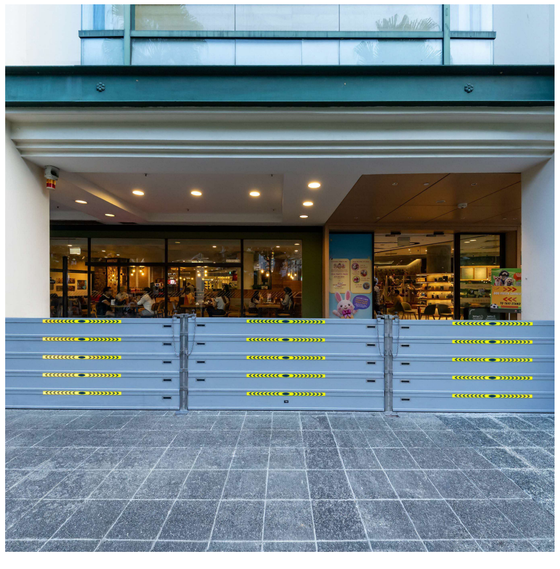
Designing Seamless Flood-Resilient Measures

Allgreen has adopted a mix of permanent and deployable solutions that would work in tandem to enhance flood resilience, yet blend seamlessly into the exterior design of Tanglin Mall. Some of these measures also doubled up as public amenities, to maximise their utility.



Flood walls with integrated seating along the development's perimeter, designed to block floodwaters.





Flip-up and slot-in flood barriers in areas where permanent solutions were not feasible to maintain barrier-free pedestrian and disabled-friendly access.

Strategy 2

Highly Adaptable Flood-Resilient Measures in Tanglin Mall

Flip-up and swing-type flood barriers were also located at **key accessways**: such as basements, the underground carpark, and the entrances to the mall. This ensures that access to the mall is not impeded during normal conditions. On the other hand, these accessways could be quickly sealed off if there is an imminent risk of flooding.



Flip-up barrier at staircase leading to basement where critical M&E equipment are located (closed condition).



Manual swing-type flood barrier near the carpark.



Flip-up barrier near alfresco retail area (open condition).

Strategy 3

Maintaining Operational Readiness

Allgreen has adopted a strict maintenance and monitoring regime at Tanglin Mall to ensure that the flood-resilient measures can be activated and function effectively whenever required.

These include:

- **Regular servicing and testing of measures** These activities, often take place after peak hours to minimise disruption to tenants and customers. Tanglin Mall can access timely maintenance support and after-sales service from the local vendor as needed.

- **Training of staff and regular practice drills** This ensures that staff are aware of their roles and responsibilities in normal operations and during flood events. Staff are proficient at operating and monitoring installed systems, as well as deploying measures if flood incidents occur.



Personnel from the local vendor power-hoses the grating of a flip-up flood barrier to remove debris and sediment, ensuring the barrier can deploy quickly and reliably when needed.



Regular inspection includes full deployment of slot-in barriers to ensure they remain robust and function as needed.

Harnessing Innovative Technology

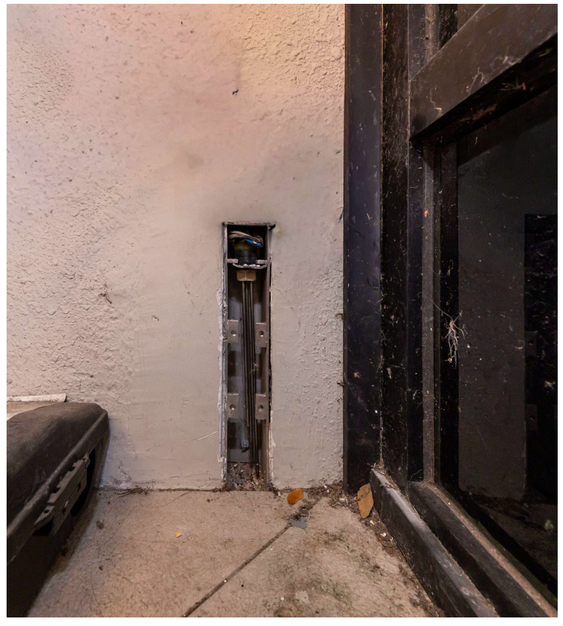
To complement on-site manpower, Allgreen has implemented technology-driven solutions at Tanglin Mall. It is also exploring how new technologies can be effectively implemented.

Sensors that monitor water levels and automatically trigger alerts have been installed near the alfresco dining area outside the mall's side entrance. When floodwaters are detected outdoors, barriers can be deployed as a precautionary measure to prevent water from reaching the mall's interior spaces. This reduces potential disruption to retail activities and helps protect critical M&E equipment enabling the mall to remain operational.

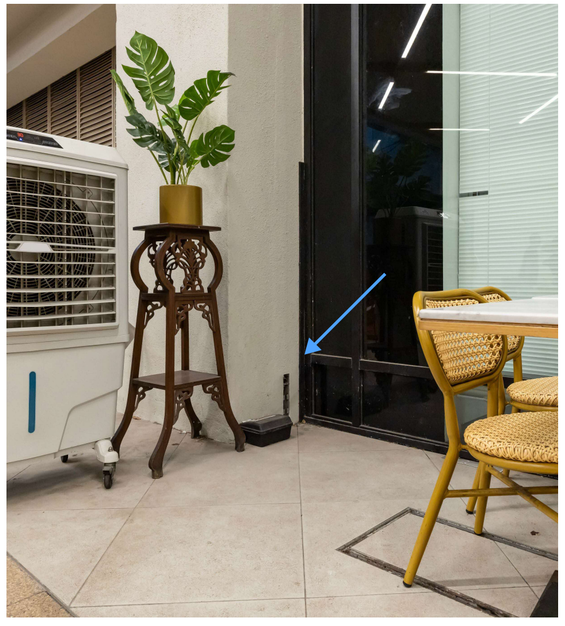
When a sensor detects that a certain water level has been reached outside the mall, a pre-assigned action is triggered:

- When the water level is **20mm above finished floor level**, an audio-visual warning alerts the operations team at the Fire Command Centre to closely monitor the level of floodwater.
- When the water level is **50mm above finished floor level**, automated announcements over the PA system and flashing warning lights alert shoppers to steer clear of the area while the operations team deploys the flood barriers.

Moving forward, Allgreen plans to further enhance the robustness of its measures by further integrating them onto its upcoming smart Building Management System (BMS), so that there could be more advanced flood risk planning and optimisation of operations. Allgreen recognises that the effectiveness of additional measures can only be attained by building capacity in its staff to use the enhanced system. This means training staff with key roles and responsibilities to make the most of these new transformative systems.



Close-up of the integrated water level sensor. Sensors add robustness to flood-resilient designs when properly integrated.



Water level sensor positioned near the alfresco dining area.

Sustaining Readiness for Flood Resilience

Tanglin Mall demonstrates how building owners can achieve proactive and thorough flood preparedness. Their chosen strategy:

- Allows for the operational protocol triggered at each warning level to be **adaptable** if flood conditions evolve with climate change
- Is **robust** in both design as well as maintenance regimes
- Promotes **recoverability** of the development as floodwaters are prevented from entering sensitive interior spaces

By pairing robust design measures with strong maintenance and monitoring practices, the mall remains operationally ready while providing a safe and attractive environment for tenants and shoppers alike.

5.2 People's Association Headquarters: Targeted Measures at the Asset-Level

Resilient design principles:

Adaptability

Recoverability

Located in a historically rich part of Singapore's city centre, The People's Association (PA) Headquarters at King George's Avenue comprises two structures: a two-storey conserved heritage building—the former Victoria School—completed in 1933, and an adjoining five-story office block completed in 2009.

Alongside public drainage improvements and the construction of Syed Alwi Pumping Station undertaken by PUB, developments like PA have taken up flood-resilient measures, especially targeting heritage buildings within their premises.

A Targeted Strategy for Flood Resilience

PA has implemented a targeted protection strategy focusing on the building's Mechanical and Electrical (M&E) room.

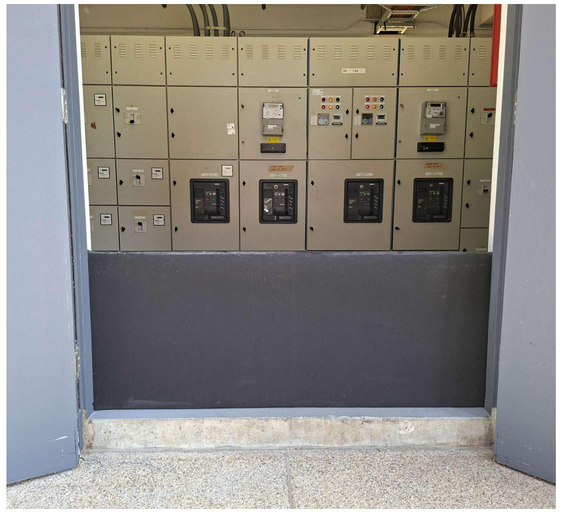
In typical developments, rooms housing the M&E systems are among the most vulnerable areas. If they are flooded, the building could lose power and communications, causing disruption that persists even after floodwaters recede. By providing sufficient flood protection for the M&E room, the core functions of the PA Headquarters are sustained even if the surrounding premises experience floods. For PA, the most effective solution was to focus on the entrance to the M&E rooms.

Attaining Precise and Robust Protection

To safeguard their M&E assets, the PA decided to use **modular manual flood barriers**, a type of deployable barrier designed to stop floodwaters at doorways. This is a tried-and-tested measure in many developments.

Why modular manual flood barriers?

- **Rapid deployment:** These barriers are designed for quick activation. In the event of a heavy rain warning, a small team can install the lightweight panels across doorways within minutes.
- **Fitted protection:** The adjustable frames allow these barriers to be adapted for use across doorways of varying widths, ensuring a watertight seal without the need for customisation or precision engineering.
- **Seamless design:** When there is no rain or flood, the barriers are stored away without affecting the building's design and accessibility.
- **Cost-effectiveness:** The cost of a single unit of flood barrier is very low compared to the value of the critical assets protected and the potential losses that would arise from the loss of the building's core functions in the event of a flood.





PA HQ staff demonstrate manual flood barrier deployment at the entry point to the M&E room
Source: PA

Simple Solutions for Effective Protection

By acknowledging flood risks and responding with practical asset-level interventions, PA exemplifies targeted and cost-effective urban flood resilience and preparedness in Singapore.

PA's strategy, focusing on the exposure of its M&E "nerve-centre," proves that flood-resilient design does not require technical expertise and large infrastructure investments. Their targeted approach of deploying modular manual flood barriers at key ingress points helps the development:

- Be **adaptable** in deploying temporary protection when needed
- Raise its **recoverability** by ensuring flood damage is kept away from the most vulnerable operational nodes
- Utilise resources efficiently while working within site and space constraints

Ultimately, this demonstrates that by prioritizing targeted solutions, meaningful resilience and rapid operational recovery remain attainable regardless of the scale of development or resource constraints.

5.3 Funan: Flood Resilience as a Value-Driver

Resilient design principles:

Robustness | Recoverability | Redundancy

CapitaLand Investment (CLI)'s Funan is an integrated mixed-use development located along North Bridge Road in Singapore's Civic District. Reopened in 2019 following a comprehensive redevelopment, the site comprises a vibrant retail podium, two office towers, a serviced apartment block, and an underground linkway to City Hall MRT interchange (via Capitol Singapore) that was not present in the original development.

As a major mixed-use development providing connection to a high-traffic, underground public transport node in one of Singapore's densest urban areas, Funan's ability to resist and recover from floods and other water intrusion events was an important consideration in its 2019 redevelopment.

Turning Risk into Reward through Careful Planning

Developments that activate underground space (e.g. basements) and provide a connection to underground pedestrian networks stand to gain enormous commercial and placemaking advantages, especially in Singapore's hot and humid climate. However, such underground features also create potential exposure to physical flood risk. For Funan, strengthening its climate resilience is about protecting people and property while maintaining the customer experience and operational continuity that a mixed-use destination depends on.

CLI conducted a global portfolio baseline study to better understand its portfolio's physical climate risk in relation to floods and the readiness of its portfolio in responding to such risks.

During Funan's redevelopment, flood-resilient features were incorporated into the property as part of its Sustainable Building Guidelines. Funan's occupants and interior spaces are protected by flood barriers at key ingress points, including:

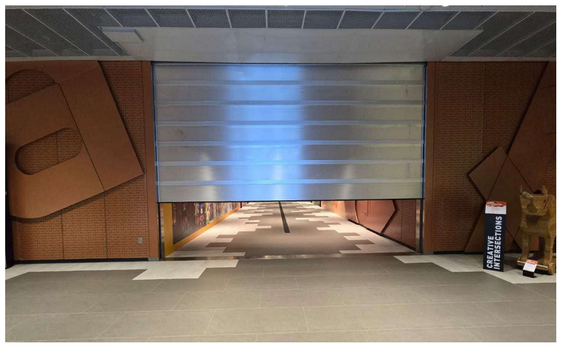
- **manual raise-up barriers** at the outdoor escalator leading to the basement, exterior ground-floor lift lobbies, and access point to the switch room;
- **automatic flood barriers** at basement carpark entrances along North Bridge Road and Coleman Street; and
- **raised ramp platforms**, including at the pick-up/drop-off along North Bridge Road.

In the event that any water manages to enter the premises, flood barriers are available to isolate the basement from the underpass to City Hall MRT, and water pumps are on standby to extract the water.

Together, these measures form a multi-layered system intended to create redundancy for effective flood resilience, by preventing and enabling quick recovery from water ingress where it matters most.



Funan's redeveloped façade includes sustainable elements, including a rooftop garden and urban farm
Source: CapitaLand Investment



Flood barriers allow Funan's basement to be hydraulically isolated from the underpass to City Hall MRT
Source: CapitaLand Investment

Pairing Measures with Operational Resilience

Flood-resilient infrastructure is only as robust as the day-to-day discipline behind it. Funan's operations team carries out routine checks consistently, including an annual inspection by a professional engineer to validate compliance and functionality of the flood barriers. Its Company Emergency Response Team also developed robust standard operating procedures for flood, water backflow and sprinkler activation events, to minimise damage, ensure safety, and accelerate recovery. CLI plans to test this readiness through coordinated exercises spanning multiple buildings across CLI's portfolio.

Value Unlocked: What Flood Resilience Makes Possible

By regarding flood risk mitigation as a design opportunity, Funan is able to maximise the use of its basement levels for retail and community programming while protecting its occupants and property during extreme weather events. This is an especially valuable consideration for developments within Singapore's Civic and Cultural District, where land is scarce and experience-led destinations face intense competition for returning footfall.

In the process of integrating Funan seamlessly with the area's underground pedestrian network, CLI also met stricter requirements for underground developments—delivering all-weather connectivity that supports uninterrupted human traffic while maintaining universal design principles.



Routine checks and maintenance for flood barriers protecting Funan's underground carparks
Source: CapitaLand Investment

Sustainability and Resilience: Core Components for Future-Readiness

Funan is designed according to the CapitaLand Sustainable Buildings Guidelines and managed in alignment with the objectives of CLI's 2030 Sustainability Master Plan to build portfolio resilience and resource efficiency. This includes safeguarding CLI's portfolio against flood risk through risk-informed planning and structural protection.

Funan's resilience story is reinforced by wider sustainability features, such as being the first integrated development to have a chiller using low global warming potential refrigerant which emits lower greenhouse gas emissions; the largest rooftop garden and urban farm in the city (at 18,000 and 5,000 square feet, respectively), with the latter supplying a food retailer located in the mall; a Bicycle Hub that encourages green mobility choices; and a rainwater harvesting system which auto irrigates Funan's green features, such as the seven-storey green wall. It also has a food digester to speed up the decomposition of food waste generated by its food and beverage tenants. Together, these features support Funan's positioning as a climate-aware, resource-efficient destination that can enable thriving, future-adaptive communities.

Beyond Funan, other properties under the CLI Group also incorporate flood resilience measures, such as flood barriers, inflatable sandbags, water level sensors, water pumps and flood emergency response plans[1].

Best Practices for Singapore's Built Environment

Regardless of the type of development and footprint, all developers and property owners can benefit from these best practices:

- **Start with insight.** Understand your flood risk—either through a quantitative portfolio-wide analysis or through the Flood Risk Assessment (Chapter 3)—and factor the risks into design and operational requirements early to arrive at solutions that are sufficiently robust.
- **Build layers for redundancy and recoverability.** Combine barriers at critical ingress points with other measures that reduce exposure or facilitate recovery, avoiding single points of failure.
- **Upkeep what you build for robustness.** Routine inspections, clear activation procedures and regular exercises ensure reliable performance of resilience features under stress, and allow a quick resumption of operations should a flood event occur.
- **Measure value beyond avoided loss.** Resilience can unlock underground space for commercial opportunities, strengthen connectivity, and provide a compelling retail experience that drives footfall and positive tenant outcomes.

1 For example, CapitaSpring Bedok Mall, Tampines Mall and Westgate also incorporate flood barriers, while inflatable sandbags are procured for standby at its other retail malls and office buildings such as Raffles City Singapore, Plaza Singapura, The Atrium @ Orchard, Bugis Junction, CQ @ Clarke Quay and Capital Tower, among others.

5.4 Singapore Institute of Technology Punggol Campus: Weaving Blue-Green Measures into Community Spaces

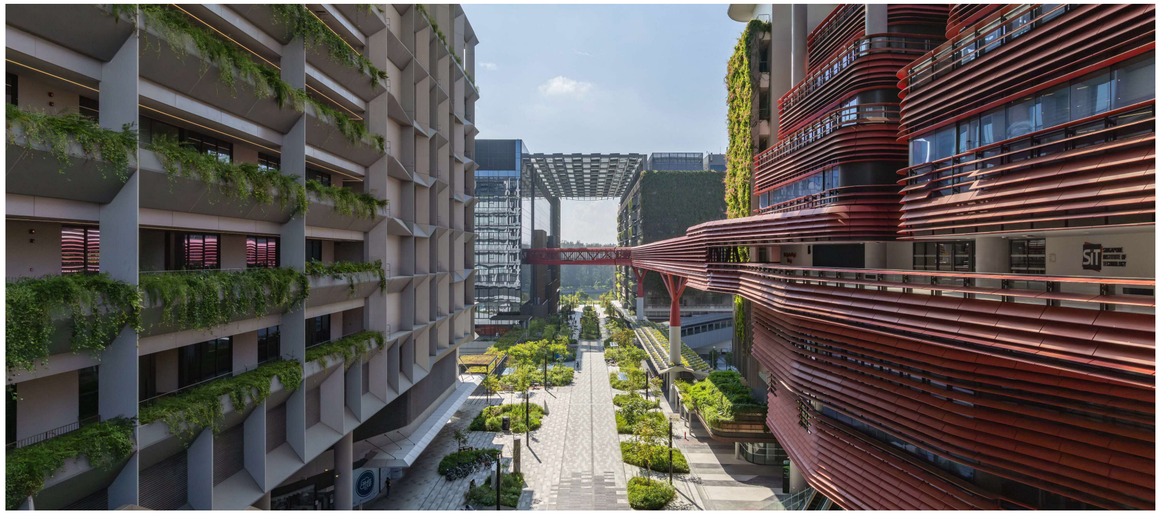
Resilient design principles:

Robustness | Adaptability | Recoverability

Situated with the Punggol Digital District and completed in 2025, the Singapore Institute of Technology (SIT) Punggol Campus is surrounded by the Serangoon Reservoir and Coney Island. Based on its "Campus-in-a-Park" philosophy, the campus intentionally integrates green and blue elements into its design and architecture, and harnesses nature to enhance flood resilience.

A Strategy Balancing Aesthetics & Functionality

The campus manages stormwater through a network of green and blue spaces—such as gravel swales, bioretention basins, cleansing biotopes, and wet detention ponds. These spaces serve a dual purpose: they are inviting and conducive gathering spots for the campus community in dry weather while doubling up to slow, capture, filter and store stormwater during rain. By making water a visible and celebrated feature of the campus, flood resilience becomes an asset for placemaking.



SIT Punggol Campus' nature-forward approach allows it to blend seamlessly into its surroundings

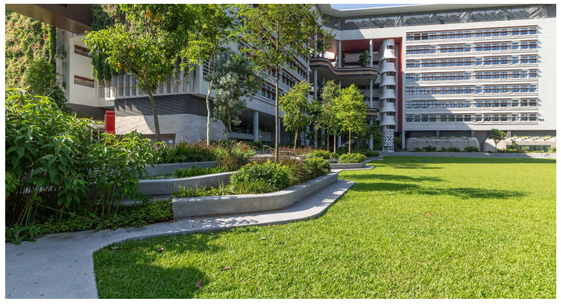
Building a Multi-Layered Defence Against Flood Risk

Taking a holistic approach to flood resilience, the campus utilises multiple ABC Waters design features[1] that are functional, adaptive, and sustainable:

- **Wet detention ponds** are cost-effective ways to manage excess rainfall runoff without relying solely on conventional underground detention tanks. Beyond that, they act as aesthetic visual anchors across the Campus Court and Campus Heart, activating otherwise "dead spaces" like traffic islands. Boardwalks provided within the cleansing biotope and rain garden at Campus Court allow users to have closer interactions with water.
- **Sunken plazas and open lawns** serve as vibrant social nodes and activity spaces, while acting as functional permeable surfaces that allow rainwater to soak into the ground, reducing the generation of rainfall runoff. The sunken plazas also transform into **floodplains** during storms to temporarily hold rainwater. Surrounding pathways ensure unimpeded movement around the plazas in all weather conditions, allowing students, staff and members of the public to wander freely along the green spine and between the campus and surroundings.



A commercial unit "floats" over a wet detention pond at Block W6



Open lawns are both functional permeable surfaces and programmable outdoor spaces

[1] Active, Beautiful, Clean Waters (ABC Waters) design features are natural systems that detain and treat stormwater runoff on site before allowing it to flow into the waterways and reservoirs. At the same time, they enhance biodiversity and the living environment.

- A network of ABC Waters design features such as **gravel swales, rain gardens, and cleansing biotopes** slow, capture and filter pollutants from rainwater. Alongside these features, vertical greenery integrated with facades, soilless green roofs, and landscape planters provide passive cooling and attract wildlife (e.g. butterflies). Vertical water flow from planter stacks along covered walkways to the internal drains is sensitively managed using rain chains. Additionally, a "waterfall" mesh screen is incorporated for inflow to the rain gardens. These features ensure water only flows to areas designed for controlled drainage. An adjacent naturalised drain connects the campus' stormwater network to public drains in the neighbouring Punggol Heritage Trail. A pedestrian bridge over the drain provides seamless public access to the park and the campus.
- Treated rainwater is harvested for automatic drip irrigation, supporting resource circularity goals.



Rain gardens filter pollutants from rainwater

Flood Resilience as a Design and Environmental Benefit

The SIT Punggol campus demonstrates that flood resilience need not be utilitarian. By integrating green-blue measures into the architectural fabric, the campus **is an exemplar of shifting from "managing" water to "embracing" water**. Green-blue flood-resilient measures can:

- Be both **robust** and aesthetic
- Help to create restful and comfortable social nodes that can be **adaptive** to changing weather conditions without compromising accessibility
- Enhance the **recoverability** of the development by directing floodwaters to areas specially designed for controlled drainage
- Invite exploration and connection with adjacent spaces
- Be cost-effective

5.5 Sungei Buloh Wetland Reserve: "Living with Water" by the Coast

Resilient design principles:

Adaptability | Robustness | Recoverability

Situated along the North-west coast of Singapore, Sungei Buloh Wetland Reserve (SBWR) is home to over 500 species of tropical flora and fauna. Managed by the National Parks Board (NParks), the reserve's primary mission is to conserve its rich biodiversity, ranging from rare migratory shorebirds to thriving mangrove systems, while serving as a hub for nature education and research.

As a coastal wetland, the reserve is naturally influenced by tidal processes, with its delicate ecosystems dependent on the ebb and flow of the Straits of Johor. This allows the mangrove habitat to continue to thrive, which in turn offers some coastal protection through wave attenuation.

Today, the reserve faces compounding pressures from sea level rise due to climate change, which raises two major challenges:

- Maintaining the ecological processes that require tidal influence
- Ensuring the safety of its visitors and the integrity of its infrastructure

Managing Flood Risk with Integrated Measures

Rather than resisting rising sea levels, NParks adopted a strategy of allowing transient flooding as a natural process. This enables greater flexibility in adapting our reserve's operations, balancing visitor experience with ecological considerations.

The reserve has implemented a suite of measures designed to mitigate flood risks arising from periodic high tides and storm surges.



Real-Time Water Level Monitoring and Early Warning Systems

To manage the high tides and storm surges, the reserve has deployed a water level monitoring system. Water level sensors are equipped with beacon lights that activate automatically when the water level reaches critical thresholds.

- The beacons provide an immediate visual cue to visitors, signalling that specific low-lying areas will be flooded. Audio alarm systems are not used, in order to minimise disturbance to wildlife in the nature reserve.
- The sensors serve as an early warning system for the reserve's flood response, providing real-time inputs to the operations team to initiate evacuation protocols.



A water level sensor with a tide ruler. Once the water level reaches the critical threshold, the sensor will trigger the park's early warning systems



Throughout the reserve, warning signs activate when flooding occurs around that area, informing visitors of areas that are out-of-bounds for safety

Specialised Flood Gates to Protect Buildings and Amenities

In low-lying areas within the reserve where buildings and essential amenities (e.g. toilet blocks) are located, NParks has deployed flood barriers. These are particularly critical during the periods of combined high tides and heavy rainfall, as the buildings have low platform levels and require additional development-specific measures to reduce their vulnerability to water ingress.

Additionally, the use of deployable barriers designed to blend in with the surrounding natural landscape ensures public safety without impeding the access of visitors.

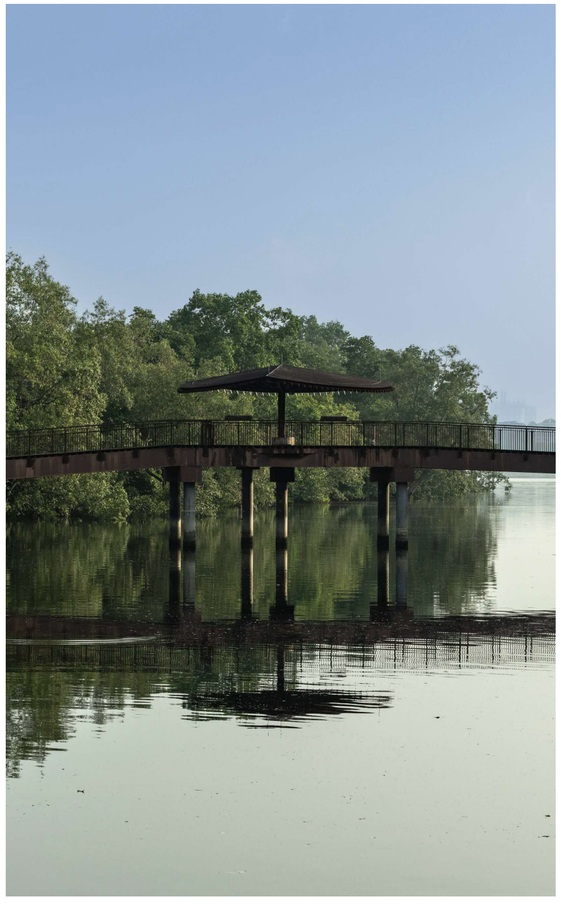


Flood barriers activated around amenities to protect and ensure rapid recovery for park operations after a flood
Source: NParks

Climate-Resilient Infrastructure: The SBWR Main Bridge

Completed in 2020 after the original structure required replacement, the new Main Bridge connects visitors from the Wetland Centre to the heart of the reserve. Functioning as a key vantage point for wildlife watching, it serves as a primary example of resilient design—built to cope with sea-level rise, maintain barrier-free access and remain sustainable in the long term. Unlike traditional flat bridges, this structure:

- Is designed with a gradually sloping elevation profile that reaches a crest elevation of 5.3m above mean sea level at its midpoint, descending to 3.0m above mean sea level at the land connection points. This ensures that even during high tide events, the central span remains above water, maintaining a critical "high-ground" corridor for barrier-free emergency response and boat passage.
- Utilises Thermoplastic Elastomer (TPE) decking—a wood-textured, recyclable plastic that is waterproof, anti-slip and highly-durable—together with rust-resistant aluminium railings to mitigate the corrosive impact of salt spray. With sea-level rise, the bridge may come into contact with or be submerged in seawater more frequently, making this choice of materials essential in reducing the risk of corrosion to the bridge structure.



The Main Bridge is specially designed to be made of water-resistant materials and to remain above high water levels

Adaptation is Key to Flood Resilience

Sungei Buloh Wetland Reserve demonstrates that flood resilience is not only about stopping floodwaters entirely. Flood resilience is also achievable when we work with water, allowing it to enter our natural environments in a controlled manner, and managing how we interact with it.

The reserve achieves a balance between nature and climate that aligns with Singapore's reputation as "A City in Nature":

- **Adaptability** through the real-time flood risk warning system that ensures public safety with minimal impacts on the natural environment
- **Robust protection** of key structures and amenities through the use of durable materials for long-term maintainability and careful design that blends in with the existing heritage buildings
- **Overall recoverability** as the impacts of transient flooding are controlled and the risk of damage to the Main Bridge is minimised
- Leveraging **environmental protection** as a nature-based solution that will adapt and thrive amid climate change
- **A shift in mindset** to designing developments in harmony with the natural environment

The success of the reserve demonstrates that all developments, including those where access to water plays a significant part in their design and operations, can effectively prioritise occupant safety in tandem with protecting sensitive and valuable assets.

5.6 National University Health System: Protecting Essential Public Infrastructure

Resilient design principles:

Adaptability | Robustness | Recoverability | Redundancy

Proactive Leadership to Set the Direction

National University Health System (NUHS) is an integrated healthcare system that serves the population in the western part of Singapore. Its institutions include: the National University Hospital, Ng Teng Fong General Hospital, Jurong Community Hospital, Alexandra Hospital, National University Polyclinics and Jurong Medical Centre.

Driven by climate change, extreme weather events and changing rainfall patterns threaten the operational continuity of essential public infrastructure, including healthcare institutions. For NUHS, a single flood event can disrupt power, water supply, or access to critical equipment, potentially endangering patients and personnel.

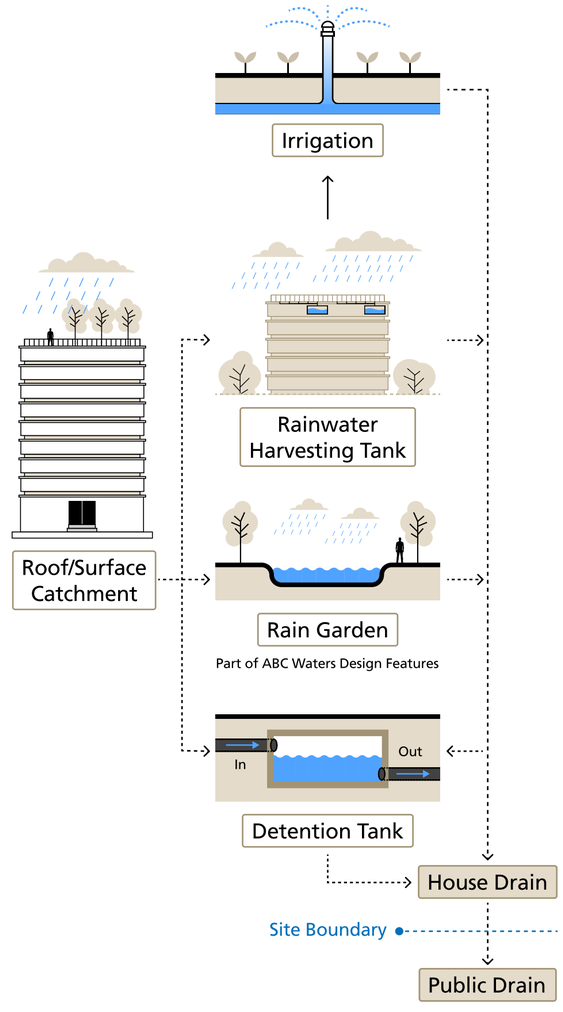
As part of NUHS' commitment towards climate resilience, operational continuity and patient safety, flood resilience has become an important component of their infrastructure planning and facilities management.

Over the years, NUHS has progressively strengthened flood-resilient measures across its institutions. Flood risk assessments are regularly conducted and flood mitigation measures are continuously reviewed and enhanced to safeguard critical healthcare infrastructure and support uninterrupted hospital operations.

This forward-looking approach extends to NUHS's future developments as well. The redevelopment of Alexandra Hospital integrated flood-resilient design upfront during the planning and development process, building long-term resilience and operational continuity into its core design. Key features that are embedded at multiple scales include:

- **High platform levels** are set for the critical Inpatient and Outpatient blocks, relative to surrounding ground levels, to provide flood protection to building interiors.
- **A site-wide hydraulic masterplan** that utilises natural terrain to define catchment zoning and flow pathways, and internal drains that are sized adequately.
- **Building-scale rainwater management** is achieved through an integrated system of rainwater harvesting tanks, rain gardens and detention tanks that provide the necessary drainage capacity during storms, enable the natural treatment of rainwater, and create green spaces that enhance the campus environment.
- **Targeted measures for critical assets,** such as positioning of substations at elevated levels on the first floor, and provision of backup generators on upper floors with adequate fuel reserves to sustain 24 hours of operation.

By integrating flood-resilient features, the redeveloped Alexandra Hospital is protected from the outset—avoiding the potentially higher costs and inconvenience associated with retrofitting these measures later.



Alexandra Hospital's integrated building-scale rainwater management strategy provides multiple benefits

Multi-layered Safeguards for Comprehensive Protection

Across their hospital campuses, NUHS has progressively enhanced flood resilience through a multi-layer approach.

Platform levels and raised kerbs safeguard the building as a whole, while flood barrier systems can be deployed at vulnerable entry points to provide additional protection for building interiors.

These measures are complemented by enhanced drainage systems capacity. Furthermore, the integration of backflow prevention devices to prevent water in public drains from entering the premises, making the system more robust.

To ensure operational continuity, critical assets such as electrical switch rooms, data rooms, medical gas systems and essential plant equipment are strategically located at elevated levels and protected through dedicated drainage systems, sump pumps, and water diversion measures.

Deployable measures such as flood bags and standby pumps serve as a backup line of defence should primary measures be overwhelmed. These can be rapidly deployed to critical areas during periods of heavy rainfall or elevated flood risk.



Deployable flood barriers protect vulnerable entry points
Source: NUHS





Standby pumps and flood bags can be easily activated when needed
Source: NUHS

Flood Risk Monitoring Systems

NUHS is also expanding its use of digital technologies to further strengthen flood resilience. A Smart Integrated Building Management System monitors real-time rainfall conditions, water levels and equipment status, with automated alerts prompting early intervention to avert operational disruption. These smart sensors have been installed at critical and flood-prone operational areas, in particular at basement facilities such as electrical switch rooms, data centres, supply and logistics hubs and clinical laboratories.

These capabilities are further supported through remote monitoring dashboards, CCTV surveillance of flood-prone operational areas, predictive maintenance and trend monitoring. Facilities teams deploy drones for building inspections to identify and rectify potential issues early. This allows early detection and prompt response when needed.

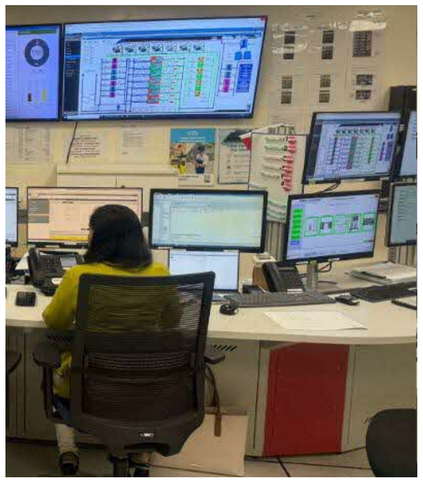
Operational Readiness and Emergency Response

NUHS has also established routine maintenance across their campuses to guide flood risk management. Facilities management personnel conduct daily checks on drains, water pumps, areas prone to flooding, and backup power systems.

During an emergency, pre-defined flood response protocols guide escalation of actions, from deployment of flood barriers and bags to post-event recovery.

To strengthen operational readiness and familiarisation with emergency procedures, staff training and simulation exercises—including tabletop exercises and Business Continuity Plan drills—are also conducted periodically at the respective institutions.









Regular inspection and maintenance of drainage infrastructure enhances flood preparedness
Source: NUHS

Flood Resilience as Healthcare Imperative

NUHS demonstrates that flood resilience is ultimately not just about protecting infrastructure but ensuring continuity of patient care during adverse weather conditions. As climate risks continue to evolve, their comprehensive strategy emphasises the importance of:

- **Leading with intent.** Embedding flood resilience into organisational strategy and future development plans ensures it is never an afterthought, but planned with foresight.
- **Designing for adaptability and redundancy.** Rather than relying on a single measure, multiple measures are designed to work together as a system: if one falls short, others can be deployed where needed to contain the damage.
- **Planning for robustness and recoverability.** In addition to a multi-layered system of flood-resilient measures, operational protocols covering routine maintenance to emergency response ensures the development can withstand extreme events and recover quickly if floods occur.
- **Leveraging technology to enhance resilience outcomes.** Digital monitoring systems enable more accurate and effective flood risk management and response.

Through regular flood response drills, deployment of smart technologies and continuous operational vigilance, NUHS remains committed to Singapore's broader national efforts towards a more climate-resilient and sustainable built environment.

06

Annex

1 Requirements of the Code of Practice on Surface Water Drainage

2 Flood Risk Assessment Templates

3 Glossary of Key Terms and Abbreviations

4 References

5 Acknowledgements

Annex 1: Requirements of the Code of Practice on Surface Water Drainage

The Code of Practice on Surface Water Drainage sets out the regulatory requirements for all new developments to ensure a minimum level of flood resilience.

Part 1: Minimum Platform Level (MPL)

The MPL is the mandatory minimum ground level for all new developments to protect against flooding[1]. The MPL is determined by the **location** and **type of development** and elevation relative to the **adjacent road/ground level.**[2]

Developments along the coast may be subjected to requirements from the Coastal Protection Code of Practice.

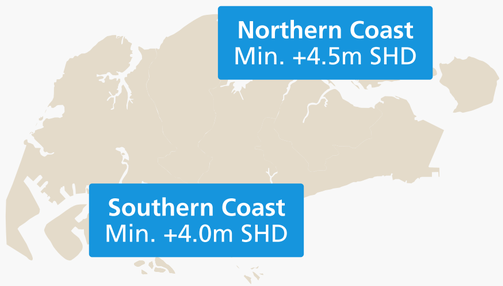
1 If your development's plans were approved before 2011, your development may not be up to current standards.
2 For Critical and Key Infrastructure, the MPL must also be 300mm above modelled flood levels as provided by PUB.

Step 1 Identify Location

New developments in the north of Singapore have to be at least +4.5m SHD, while developments in the south have to be at least +4.0m SHD.

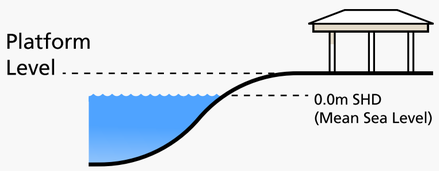
This is because sea levels at the northern coast are generally higher.

To determine your site's current elevation, refer to available resources from Building and Construction Authority (BCA) or topographical survey conducted by Registered Surveyors.



What is the Singapore Height Datum (SHD)?

The SHD is the official reference point for all height and depth measurements in Singapore. It represents the Mean Sea Level.

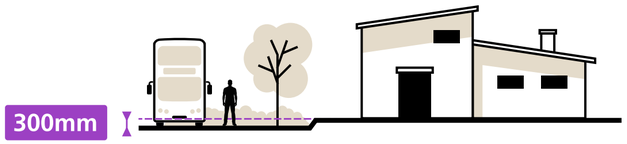


Step 2 Check Development Typology and Adjacent Road/Ground Level

As developments increase in scale or become more critical, the MPL requirements become more stringent.

General Development

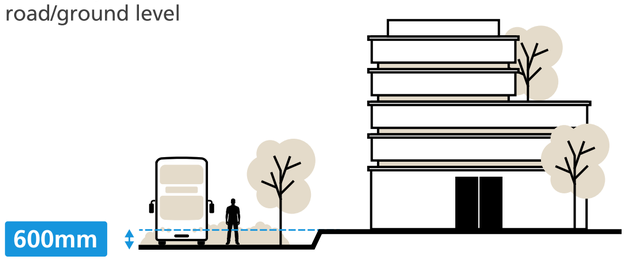
e.g. landed house, park shelters



above adjacent road/ground level

Industrial / Institutional / Commercial / Multi-unit Residential Development

e.g. HDB developments, office buildings, shopping malls



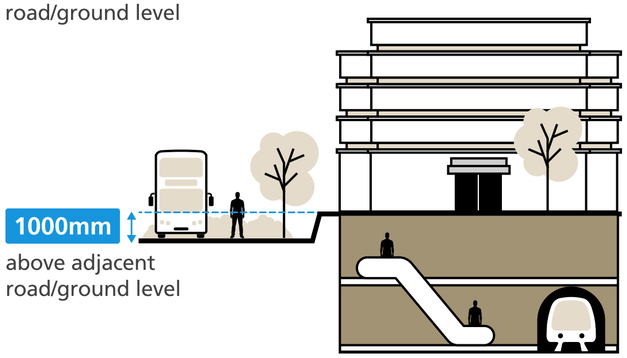
above adjacent road/ground level

Special Facilities

e.g. MRT/LRT stations, airports, power generation plants

Developments with linkages to underground Special Facilities

e.g. Shopping malls with direct link to MRT



above adjacent road/ground level

Step 3 Determine MPL

Your final MPL = The higher value resulting from Step 1 or Step 2

Always adopt the higher level to ensure maximum flood protection. Other conditions may be advised during consultation.

Part 2: Crest Level

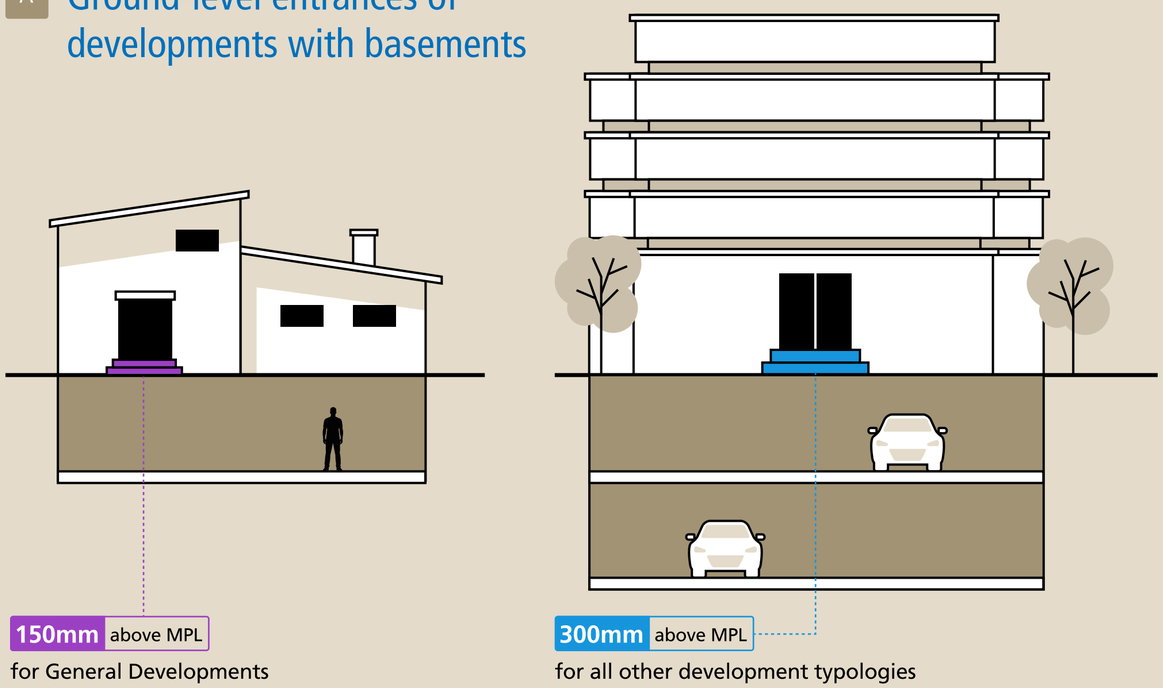
The Crest Level is an **additional elevation above the MPL** of the development to prevent floodwaters from flowing into entrances, exits or openings to **basement(s) or underground structures** (e.g. tunnels, underground facilities).

The minimum Crest Level varies according to the type of development, and is applied on top of the MPL.

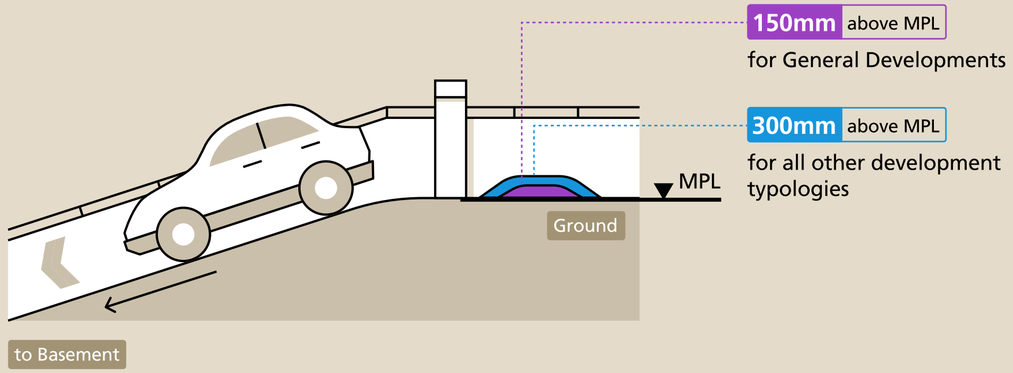
General Developments	All other development typologies
Landed houses, park shelters	Industrial, institutional, commercial, multi-unit residential developments

Examples of how crest levels are applied:

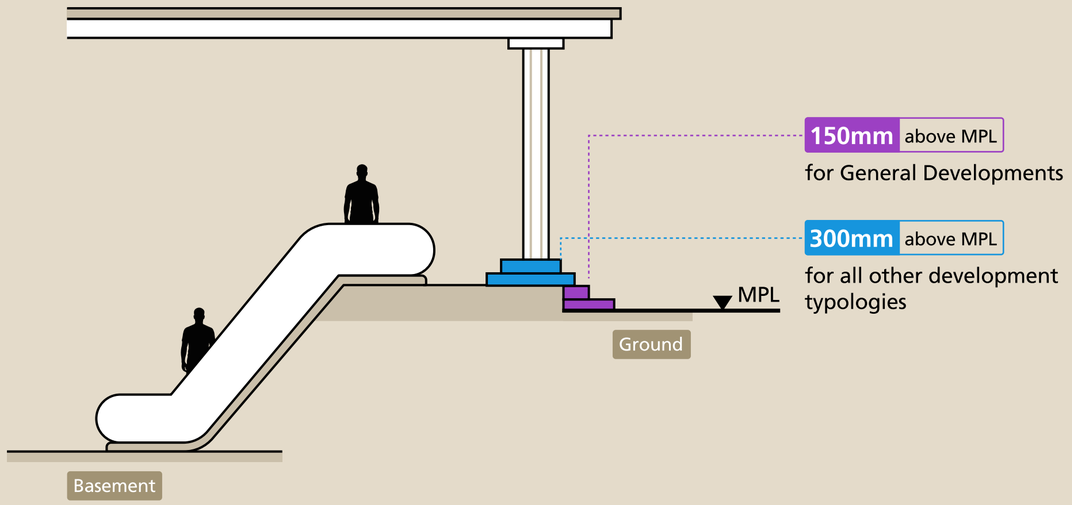
A Ground-level entrances of developments with basements



B Entrance ramps to basement carparks



C Entrances to underground developments via escalator or stairs



[All diagrams are for illustrative purposes and not to scale.]

Worked Examples

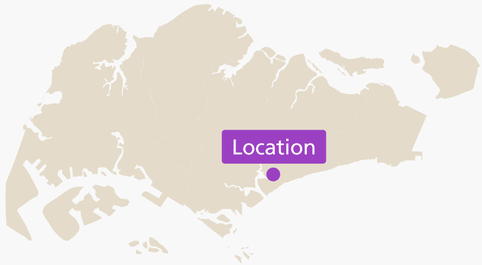
Worked Example 1:
Landed house with no basement

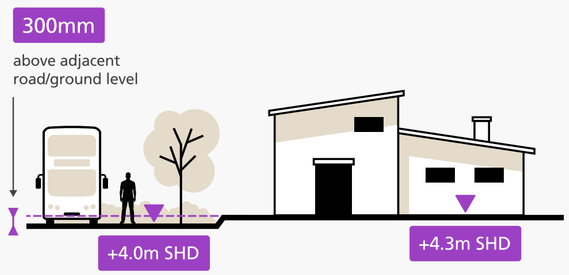
Step 1: Identify Location

Since the landed house is in the south, it needs to be at least **+4.0m SHD.**

Step 2: Check Development Typology

The landed house is classified as a "General Development." Since the adjacent road level is +4.0m SHD, the landed house needs to be 300mm higher, which gives a level of **+4.3m SHD.**





Step 3: Determine MPL

The value from Step 2 is higher than that of Step 1. Thus, the MPL will be **+4.3m SHD.**

[All diagrams are for illustrative purposes and not to scale.]

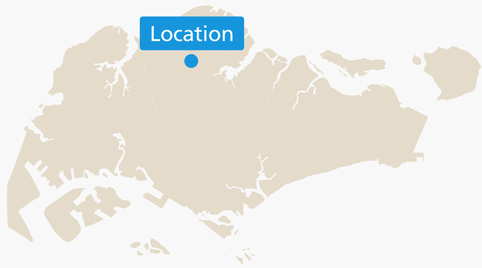
Worked Example 2:
Shopping mall with basement, connected to an MRT station

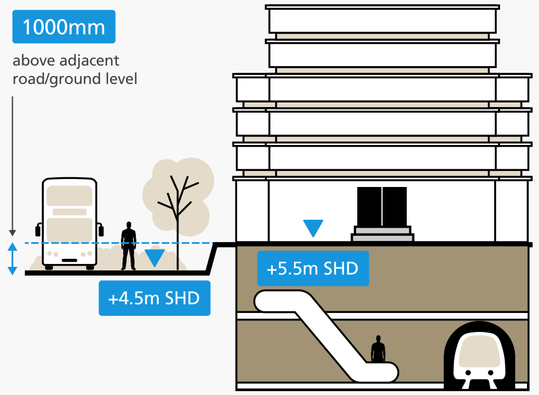
Step 1: Identify Location

Since the shopping mall is in the north, it needs to be at least **+4.5m SHD.**

Step 2: Check Development Typology

The shopping mall is classified as a "Development with linkages to underground Special Facilities." Since the adjacent road level is +4.5m SHD and the development has a basement, the development needs to be 1000mm higher, which gives a level of **+5.5m SHD**.





Step 3: Determine MPL

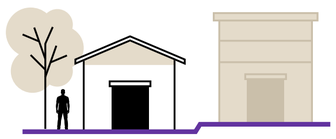
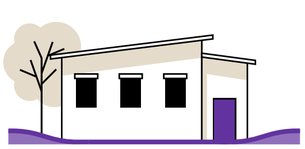
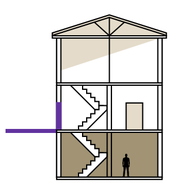
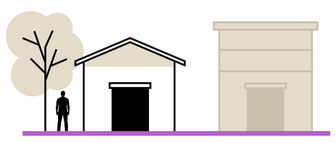
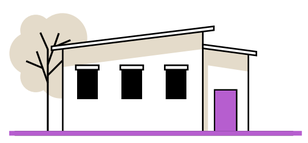
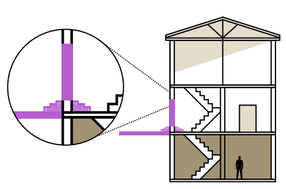
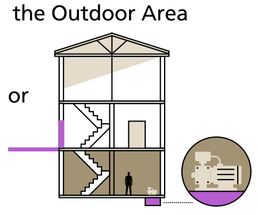
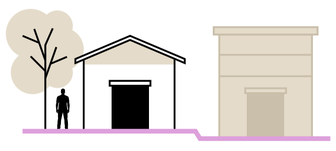
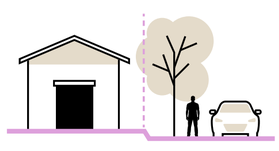
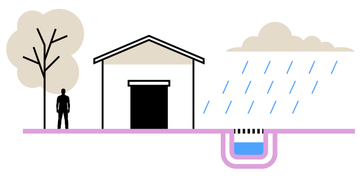
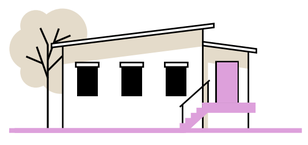
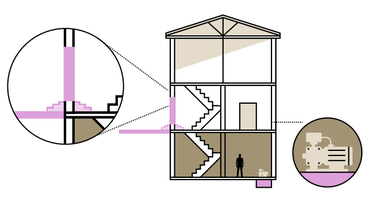
The value from Step 2 is higher than that of Step 1. Thus, the MPL will be **+5.5m SHD.**

Determining Crest Level

All entrances, exits and openings are to be **300mm** above the MPL. Thus, crest level will be **+5.8m SHD.**

Annex 2: Flood Risk Assessment Templates

Step 1 Likelihood Assessment Table

Flood Likelihood	Outdoor Area			Indoor Area	Basement	
	Development ground level vs. adjacent developments	Entrances to development vs. road (Any part of the development boundary that is not walled)	Drain capacity and condition (Developments near the coast should observe drains during high tides as well)	Building openings (e.g. doors, windows, ventilation openings)	Entrance to basement and presence of sump pump	
Likely	☐ Development's ground level is lower 	☐ Entrances to development are lower 	☐ Water occasionally overflows from drains 	☐ Building openings are lower 	☐ Entrance to basement is flush with the Outdoor Area and no sump pump 	
Possible	☐ Development's ground level is roughly the same 	☐ Entrances to development are flush with the adjacent road 	☐ Drains are almost full with stagnation 	☐ Building openings are flush with Outdoor Area 	☐ Entrance to basement is higher, but there is no sump pump 	There is a sump pump, but entrance to basement is flush with the Outdoor Area or 
Unlikely	☐ Development's ground level is higher 	☐ Entrances to development are higher 	☐ Drains are not full and water flows away quickly 	☐ Building openings are raised 	☐ Entrance to basement is higher with sump pump 	

Disclaimer: If user is unable to determine answers based on site inspection, available drawings or prior knowledge, the outcome of the flood risk assessment may not be accurate. In such cases, it is recommended to engage a professional for greater assessment accuracy.

Step 2a Guiding Questions for Impact Assessment

Category	Factor	Guiding questions	User to fill in:
Human Safety	Ability of occupants to react to floods	• Are there any spaces where occupants may be resting or sleeping that are affected by floodwaters?	
	Accessibility of safe areas to seek shelter	• Are safe areas to seek shelter still accessible if a flood occurs?	
	Risk of immediate physical dangers	• Is there any physical danger (injury or threat to life) while moving/ attempting to move to safety?	
Damage to Assets	Critical assets	• What are the critical assets that are essential to a development's key operations and where are they located? • At the assumed flood depth, how will the critical assets be affected?	
	Non-critical assets	• What are the other assets or property considered highly valuable and sensitive to water damage, even if they are not critical? Where are these assets located? • At the assumed flood depth, how will these non-critical but valuable assets be affected?	
Disruption to Operations	Length of disruption	• Once a flood occurs, how much time will be required for the development to return to basic operations?	

Disclaimer: If user is unable to determine answers based on site inspection, available drawings or prior knowledge, the outcome of the flood risk assessment may not be accurate. In such cases, it is recommended to engage a professional for greater assessment accuracy.

Step 2b Impact Assessment Table

Category		Guiding Questions	Minor	Moderate	Major
Human Safety	1a	Are there any spaces where occupants will be resting or sleeping that are affected by floodwaters?	☐ No	☐ Yes, but no vulnerable populations (e.g. able-bodied adults)	☐ Yes, for vulnerable populations (e.g. young children, elderly, persons with disabilities)
	1b	Are safe areas to seek shelter and evacuation routes to these safe areas still accessible if a flood occurs?	☐ Safe areas are accessible and evacuation routes are not affected	☐ Some inaccessible, but occupants are still able to move to safety	☐ All safe areas are inaccessible
	1c	Is there any physical danger (possibility of injury or threat to life) while moving/attempting to move to safety? (If answer to 1b is “Major”, select “Major” here too)	☐ No possibility of injury; evacuation routes unaffected	☐ Possibility of injury but no threat to life (e.g. tripping, wading through water, visibility affected)	☐ Threat to life possible or unable to move to safety (e.g. swimming required, drowning, entrapment)
Damage to assets	2a	At the assumed flood depth, how will the identified critical assets be affected?	☐ No damage	☐ Minor damage but still able to function	☐ Significant damage
	2b	At the assumed flood depth, how will the non-critical assets (highly valuable and sensitive to water) be affected?	☐ No or minor damage	☐ Some damage; repair needed	☐ Damaged beyond repair or replacement needed
Disruption to operations	3a	Once a flood occurs, how much time will be required for the development to return to basic operations?	☐ No disruption or up to several hours	☐ One or two days	☐ Several days or weeks

Take the highest level of the assessed factors as the overall impact level.

E.g. if there is one tick in Major and all other ticks are in Minor, the overall impact level is Major.

Area Assessed: ☐ **Outdoor Area** ☐ **Indoor Area** ☐ **Basement**

Overall Impact Level: ☐ **Minor** ☐ **Moderate** ☐ **Major**

Disclaimer: If user is unable to determine answers based on site inspection, available drawings or prior knowledge, the outcome of the flood risk assessment may not be accurate. In such cases, it is recommended to engage a professional for greater assessment accuracy.

Step 3 Risk Category Table

Impact →

Likelihood ↑

	Minor	Moderate	Major
Likely	Medium	High	High
Possible	Low	Medium	High
Unlikely	Low	Low	Medium

Each category signals the degree of risk and the level of action that may be warranted:

Low risk	Development is adequately resilient to flooding.
Medium risk	There is some flood risk. If you wish to reduce the exposure to flood risk, take steps to enhance flood resilience.
High risk	Immediate and comprehensive action to enhance flood resilience is recommended.

Users to fill:

Flood Risk Level of the Development		
Outdoor Area	Indoor Area	Basement
Likelihood:	Likelihood:	Likelihood:
Impact:	Impact:	Impact:
Overall Risk:	**Overall Risk:**	**Overall Risk:**

Glossary of Key Terms and Abbreviations

Arranged in alphabetical order, this glossary defines key terms and abbreviations used throughout the guidebook.

Term	Definition
Additions and Alterations (A&A)	Works carried out to modify or extend an existing building, short of full demolition and redevelopment.
Action Level	A tiered alert status within a Flood Response Plan that triggers specific pre-planned actions based on observable flood conditions and official alerts. The Guidebook defines three tiers: Yellow (heightened readiness), Orange (active protection), and Red (full defence). Actions at each level build on those of the preceding tier.
Building Management System (BMS)	An integrated, technology-driven platform used to monitor and control a building's mechanical, electrical, and operational functions. In flood resilience applications, a BMS can incorporate water-level sensors, automated alerts, and barrier-activation protocols.
Crest Level	The mandatory minimum elevation of entrances, exits, or openings to basement or underground structures, set above the Minimum Platform Level (MPL) to prevent surface water from entering below-ground spaces.
Distribution Board (DB Box)	The electrical panel in a building that distributes power from the main supply to individual circuits.
Desilting	The routine removal of accumulated silt, sediment, and debris from drains, sumps, and stormwater detention tanks to maintain their designed flow capacity. Neglected desilting is a common factor that increases flood risk in existing developments.
Design for Safety Register (DfS Register)	A live document maintained throughout the lifecycle of a building in Singapore to record residual safety risks and the measures used to manage them.
Flood Resilience	The capacity of a development, community, or system to anticipate, absorb, adapt to, and recover from the impacts of flooding. Flood resilience is built through a combination of physical design measures, operational preparedness, and the ability to restore normal conditions quickly after a flood event.
Flood Response Plan (FRP)	A structured, living document that defines how a development prepares for, responds to, and recovers from a flood event. It outlines the flood-resilient measures in place, their maintenance regimens, roles and responsibilities, the Three-Tier Action Level framework, communication protocols, and post-flood recovery procedures.
Flood Risk Assessment Matrix	A simple, two-factor framework used in this Guidebook to assess a development's flood risk by combining Likelihood and Impact ratings into a risk category (Low, Medium, or High) for each of the three areas (outdoor, indoor, basement).
Green Mark	Singapore's sustainability certification framework for the built environment, administered by the Building and Construction Authority (BCA).
Hydrodynamic Force	The pressure and drag exerted by moving floodwater on a structure or barrier. Together with hydrostatic and scour forces, hydrodynamic forces determine the structural loads that robust flood-resilient design must be capable of withstanding.
Hydrostatic Force	The static pressure exerted by standing or slow-moving floodwater against a structure or barrier. One of three key flood load types—alongside hydrodynamic and scour forces—that flood-resilient structures, barriers, and building components must be engineered to resist.
Inundation	The submersion of a structure, space, or asset by floodwater.
ISO 14090	An International Standard providing principles, requirements, and guidelines for adaptation to climate change, including vulnerability, impact, and risk assessment methodologies.
ISO 31000	An International Standard on risk management guidelines.
Mechanical and Electrical (M&E)	The mechanical and electrical systems and equipment within a building, including generators, pumps, lifts, switchboards, and HVAC units.
Monetary Authority of Singapore (MAS)	Singapore's central bank and financial regulator. MAS issues guidelines on environmental risk management that incentivise green performance by financial institutions and developers, including the rigorous assessment of physical climate risk such as flood exposure.
Minimum Platform Level (MPL)	The mandatory minimum ground level for all new developments in Singapore, set by PUB's Code of Practice on Surface Water Drainage.

Term	Definition
Plinth	A raised concrete base or platform on which mechanical and electrical equipment is mounted, elevating the equipment above anticipated flood levels to protect it from water damage.
PUB	Singapore's National Water Agency, responsible for the collection, purification, and supply of water, as well as the management of used water and stormwater.
Risk Appetite	The degree of flood risk a property owner or developer is personally willing to tolerate, reflecting their priorities, resources, and assessment of how essential certain spaces or assets are.
Scour Force	The erosive action of moving floodwater on the ground, foundations, and structural bases of a building or barrier. One of three key flood load types—alongside hydrostatic and hydrodynamic forces—that must be considered in the robust design of flood-resilient structures and perimeter walls.
Singapore Exchange (SGX)	Singapore's securities exchange.
Singapore Height Datum (SHD)	The official reference point for all height and depth measurements in Singapore, representing Mean Sea Level.
Standard Operating Procedure (SOP)	A documented, step-by-step instruction set that defines how personnel should deploy, operate, or maintain a specific flood-resilient measure consistently and safely.
Source-Pathway-Receptor Framework	PUB's systems-level approach to flood resilience specifying the management of stormwater at three points: at the Source (where runoff originates within a development), along the Pathway (public drains and canals conveying stormwater to waterways), and at the Receptor (developments protected from floodwater ingress).
Storm Surge	An abnormal rise in sea level driven by the winds and low atmospheric pressure of a tropical storm.
Sump Pump	A pump installed in the lowest point of a basement or underground space to collect and discharge accumulated water.
Swan Neck	A curved pipe fitting on a sump pump outlet that forms an inverted U-shape, preventing backflow of water from public drains into the sump when the pump is not running.
Transiently Floodable Area (TFA)	A designated area intentionally designed to allow temporary flooding during high tides or extreme weather events as part of a 'living with floods' strategy.

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