CRC for
Water Sensitive Cities

Appropriate Flood Adaptation

Adapting in the right way, in the right place and at the right time

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Appropriate flood adaptation
Adapting in the right way, in the right place and at the right time
Socio-technical flood resilience in water sensitive cities − Adaptation across spatial and temporal scales
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Preface

The current version of this guideline provides the key elements for successful application of adaptive planning but still lacks examples from Australian practice to be used without further support. The authors acknowledge this omission and are currently working on a next version of the guideline, in which many of the steps are accompanied by water sensitive urban design examples. The next version will be available in July 2017, following the reporting of demonstration activities in case studies of Melbourne and Perth.

Summary

What is the issue?

Climate change induced extreme weather events call for a reconsideration of how built-up areas are designed and are already forcing incremental adaptation of existing cities, neighbourhoods and properties. Yet, the magnitude of climate change and the associated consequences for the urban water cycle are highly uncertain. Even when minimised by further scientific progress, the propagation of uncertainties from the global climate models to local weather models and its associated consequences will remain. Apart from climate change, other environmental and societal changes might be even more unpredictable. Who could have foreseen 50 years ago to what extent many cities have grown, how the service economy has changed the shape of cities' central business districts and how citizens commute from the extensive suburbs to their jobs? Simply extrapolating past trends would have never predicted the world we are living in now. Although there has been significant scientific progress, creating reliable future predictions remains intrinsically problematic; partly because we are actively changing the conditions that influence that future, including the climate. The question, therefore, becomes how to anticipate future conditions without striving for reliable predictions, i.e. how to manage uncertainty?

This question is particularly relevant, because current plans and interventions typically cover 50 years or more and have lasting effects on the future. With increasing financial pressures, it is ever more important to make the 'right' decisions today for addressing future challenges in relation to ecosystem health, liveability, safety and resiliency to natural hazards. In short, a practical challenge is how to maintain tolerable risk levels in built-up areas, given the uncertainties about future conditions?

An approach that embraces future uncertainties and incorporates them into a theoretical framework is Adaptive Planning, which was introduced for environmental management in the late 1970s by Holling (1978) and has recently been adapted for the context of water management in the UK, Netherlands and many other countries (e.g. Haasnoot et al., 2012). Although the approach includes various different planning methods, the method presented here is based on the concepts of Adaptation Tipping Points (ATP) and Adaptation Pathways (AP). This method has been applied from the strategic to the project level and from the national to the neighbourhood scale, primarily in water-related endeavours.

What is this guideline about?

The purpose of this guideline is to provide an accessible step-by-step approach for adaptive planning aimed at increasing resilience against climate-related natural hazards. Adaptive planning addresses an essential prerequisite for enhancing resiliency, namely: managing uncertain future conditions. The adaptive planning approach does not necessarily focus on a single threat, but can be used to manage a wide range of bio-physical or socio-economic drivers. Neither is the method aimed at a particular scale or type of response, but it covers the entire range from long-term strategic policies to actual projects on the ground.

The guide does not provide extensive coverage of the scientific foundations of the approach, nor a detailed off-the-shelf manual that will guide you through the planning process. The guideline offers operational, hands-on principles for use of a relatively complex planning approach.

The guide provides:

- background information explaining why adaptive planning is important;
- a step-by-step process showing how to apply the method;
- pointers as to how to mainstream adaptation into urban (re)development;

- information about common misconceptions regarding the method and its components; and
- an overview of existing adaptive planning tools.

Who is this guideline aimed at?

This guideline is mainly aimed at local government departments, particularly in urban planning, environmental management, and urban drainage and water management. It is also relevant to other professionals working with water and also those engaged in the delivery of other infrastructure and service systems that interact with water, such as highways. It is mainly of interest to those with a long-term planning agenda, who can benefit from the guideline and adopt the method for the realisation of projects within their respective domains.

Theory: What are the potential benefits?

Application of an adaptive planning approach to increase resilience against natural hazards can have significant benefits, irrespective of the nature of climate change, socio-economic policy, or for instance environmental protection standards. Instead of aiming for a single 'optimised' plan, adaptive planning focuses on the development of multiple measures aiming for robustness and flexibility[1]. In order to do this, continuous monitoring and evaluation of the process and outcomes is essential. Adaptive planning is especially valuable in the face of uncertain future conditions.

The main benefits of adaptive planning can be summarised as follows: *effective* and *efficient* policies, strategies, plans and associated pathways that aim at reaching pre-defined objectives (i.e. what is required) under uncertain future conditions, while seizing opportunities for integration into independent (autonomous) developments. Where:

- *Effective* means that policies, strategies or designs include technical, spatial or other instruments to ensure that the objectives are reached.
- *Efficient* means that a policy, strategy or design is sought that provides the highest societal returns; no over-dimensioning of measures (i.e. being designed to withstand a worst-case scenario), when future conditions might be moderate and require only modest adjustment.
- Strategies developed using an adaptive planning approach often contain both robust and flexible elements to be able to cope with future uncertainties. Both are valuable elements and in practice, no strategy focuses exclusively on one or the other.

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[1] Here, policy robustness expresses how well a policy, strategy or design performs under different conditions, whereas flexibility describes the ability to change the performance level of policy, strategy or design over time, at limited costs or resources.

Adaptation tipping points and pathways

Theoretical overview

Adaptive planning is a generic concept that encompasses different planning methods like assumption based planning, robust decision making, adaptive policy making (e.g. (Walker et al., 2013). The method that we promote in this guidance is Adaptation Tipping Points (ATP) and Adaptive Pathways (AP). What these methods have in common is that they explicitly incorporate future uncertainties in the form of different scenarios that address single or multiple drivers. This is especially relevant in the context of climate change, but also in regions where rapid urban development is significantly changing the bio-physical context of cities.

While originally developed with a focus on water management, ATPs and APs are generic methods that can be applied in many different policy domains where systems have to maintain performance over significant periods of time.

> ***An ATP is that point in time when a strategy is no longer able to meet the policy objectives and adaptation of the strategy is therefore required.***

This implies that an ATP shows us how long our (current) plan will work, given a changing future. In order to determine an ATP, our planning framework needs to contain a number of elements:

1. ***Policy objectives.*** In an ATP context, objectives are translated into a set of strict criteria. This means that **tolerable risk levels** (thresholds) need to be clearly defined in order to establish when those levels might be exceeded. This is not always a straightforward task. While in some cases levels can be easily derived from existing norms and regulations, in other cases establishing these levels might require an intensive stakeholder consultation process to define what risk level is socially or politically acceptable. Also, it is possible to encounter conditions in which tolerable risk levels are already exceeded. In case the tolerable risk levels cannot be defined, alternative methods exist to come to comparable outcomes, e.g. the 4-points approach or matrix (Salinas Rodriguez et al., 2016)

2. ***Future scenarios.*** In many domains, the future is highly uncertain, so multiple futures have to be defined to plausibly represent the range of different conditions. This can be done by developing scenarios: plausible futures that describe the external conditions our policy, strategy, measure or design has to perform in (See B4.2.1 report). Such scenarios may include an extrapolation of current trends: a business-as- usual scenario, although this is recommended only as a baseline against which to compare the performance under future scenarios. Scenarios can be defined in quantitative terms, but also as narratives in which key-drivers are defined in semi- quantitative or qualitative terms. This approach to scenario development differs from using a scenario to describe a desired future or a trajectory how to reach a desired future. In any case, an extreme scenario should also be postulated, ideally one that appears to be highly improbable (potentially what is termed a ‘black swan’) but against which the strategy can be ‘stress-tested’.

3. ***Policies, strategies, plans and/or measures.*** Obviously, to reach the objectives (translated into tolerable risk levels), a policy, strategy, plan or measure has to be formulated. Do not forget to include the implementation period; since especially large scale engineering projects might become effective (far) beyond the time at which the tolerable risk level has been exceeded.

4. ***Assessment method*.** In order to evaluate if ATPs are reached (i.e. if tolerable risk levels are exceeded), an assessment method needs to be defined to measure the performance of a policy, strategy, plan or measure. Such a method can be based on actual monitoring, but in prospective cases (when we have to estimate future performance) can be undertaken using models or expert judgement.

5. **Monitoring, Evaluation and Transfer.** Adaptive planning requires continuous monitoring to assess if tolerable risk levels have been exceeded and if subsequent action needs to be taken. This can result in the transfer to alternative policies, strategies or measures. Preferably, the monitoring is performed by an independent organisation.

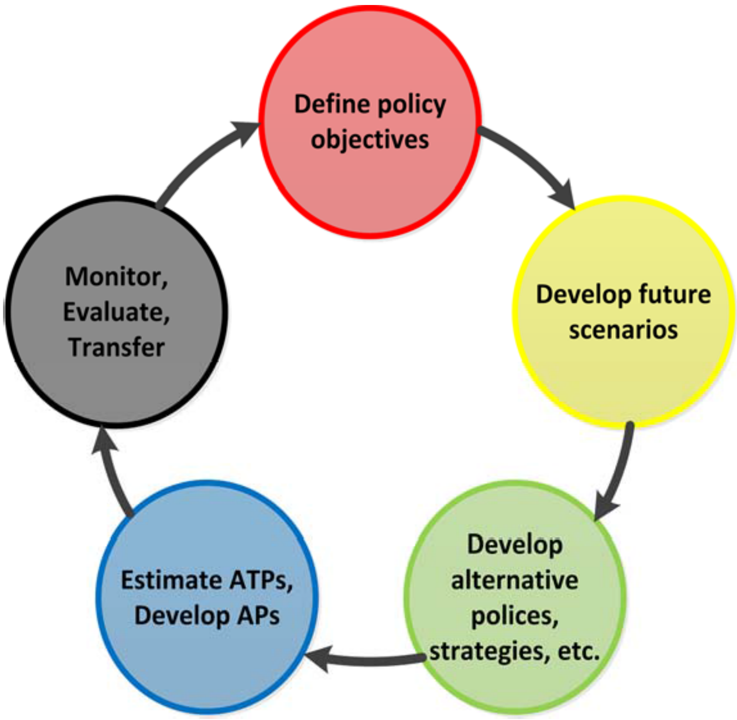

Figure 1. Five stages of Adaptive Planning with ATPs and APs (Adapted from Bosomworth et al. (2015))

Outcomes are multiple points in time that signify when the current strategy no longer meets the objectives for different future scenarios (see figure 2). For a given strategy and scenario, the ATP might occur relatively soon. Thus, alternative strategies for which the ATP is located further into the future need to be considered, i.e. strategies that will meet our objectives for a longer period in time.

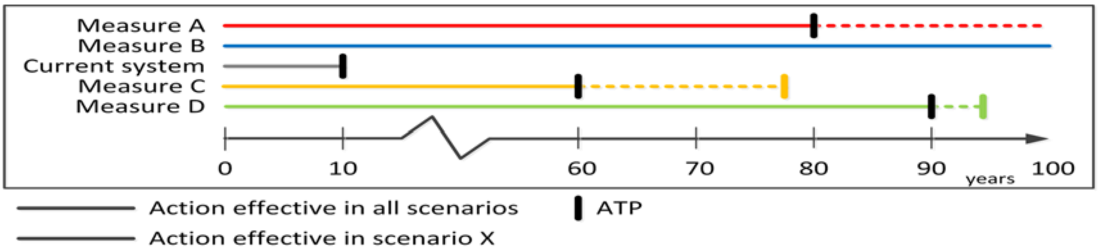

Figure 2. ATPs for the current management system and 4 alternative measures that extend ATPs (Adapted from Haasnoot et al (2012))

The question rises how easily one strategy can be left for another, i.e. how flexible one is to change when conditions dictate the need? This might only be possible at significant costs because, for instance a large amount of structures need to be decommissioned first to make space for alternatives. Or maybe this is not even technically or socially feasible and one is locked into a specific strategy. This is problematic because in time the acceptable risk level might be exceeded. To assess the flexibility to transfer from one strategy to another, so-called adaptation pathways (APs) need to be identified: trajectories over time that identify different routes in order to postpone the ATP further into the future.

An AP entails the sequencing of actions within different strategies in order to identify potential adaptation trajectories over time to changing climate, socioeconomic or other conditions (adapted from Walker et al. (2013))

APs are typically visualised in a Metro map style (see Figure 3), where the different routes show the pathways over time across different policies, strategies, plans or designs.

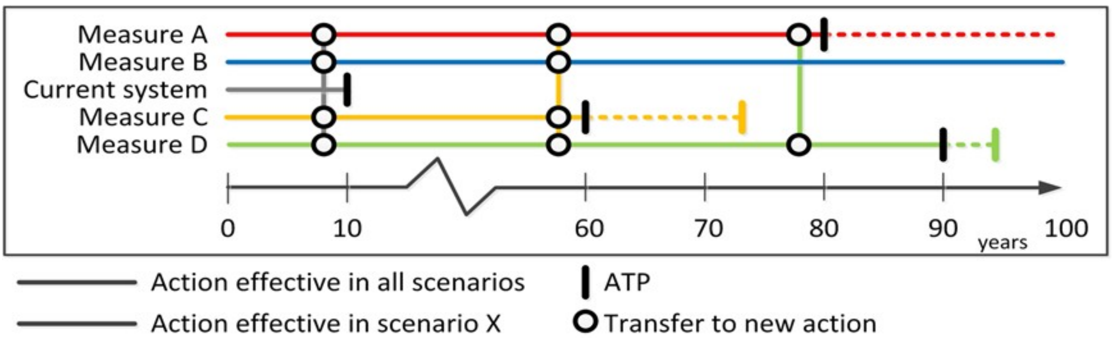

Figure 3. Metro Map showing ATPs and possible APs for the current management system and 4 alternative measures. (Adapted from Haasnoot et al (2012))

APs do not necessarily provide information when to transfer from one strategy to another, i.e. when to transverse vertically from one strategy to another (see example). The only information the pathway provides is the maximum available period to transfer in time before an ATP is reached. While many frameworks or criteria can be used to assess the optimal moment to adopt and implement new strategies or measures, an alternative approach is to adjust the timing to urban (re)development to which the proposed measures can be linked. The timing of the implementation is therefore determined by the urban (re)development initiative that might not be aimed at managing future water-related hazards. We refer to this approach as Adaptation Mainstreaming (AM) which is further elaborated in (Rijke et al., 2016).

AM refers to taking advantage of the ability of a system to adapt its structure and processes based on anticipated (re)developments within the assessment period (Lim et al., 2005), so that it will become more resilient to undesired changes.

The advantage of AM could be that resources can be shared between the original function (e.g. a building, road, neighbourhood) and the water management function (e.g. flood protection, drainage, water quality). When compared with a more mono-functional approach, this might affect the spatial claim of the proposed design, the acceptance of the measures by the affected stakeholders and the combined costs required to realise both functions.

The consequence of this approach is that a context is created that requires coherence over time, where policies, strategies and measures are not defined as one-off stand-alone fixes, but require a continuous process of pro-actively adjusting to new challenges in a structured manner.

Common misconceptions about ATPs, APs and AMOs

- Scenarios in the context of ATPs are plausible future conditions. They are not desired futures or trajectories that describe how to reach desired futures or states;
- APs show you which strategy is most desirable. No, they only show the possible ‘transfer routes’ between different strategies within a given horizon;
- From the “Metro map” in which the APs are visualised, one can identify the best pathway. The “Metro map” only shows the possible sequences in which to transfer between strategies, but leaves the choice of preferred pathway open.
- Adaptation Mainstreaming implies the integration of measures into existing (re)development of urban areas at zero cost. Although the integration of measures can be more cost effective since systems allow for multiple use and benefits, the inclusion of measures is not necessarily free of costs. Yet, when compared with stand-alone measures, the costs of delivering all of the expected outcomes are often significantly lower. Furthermore, the resulting design might be less resource intensive, and lead to smaller spatial claims (i.e. footprint).

Differentiation between strategic, tactical, operational

The application of ATPs, APs, and AMO is not limited to a specific problem domain or scale. The approach can be used on strategic, tactical and/or operational level, thus covering the complete scope from long-term, large scale development to the very tangible scale of individual project development on a neighbourhood, block or street level. This is especially important in the case of adaptation mainstreaming, where opportunities can be identified within different domains and scales (both space and time). Yet, the level does define which stakeholder or organisation will take the lead in the process. On a strategic level, this is mostly the state or in some cases the local government authority (LGA). On a tactical level, which involves a thorough assessment of the local context, the initiating parties are often a development company or a LGA. On a local level, any or all of the stakeholders together can take the lead. In practice though, this is often a project developer in the case of property development or a LGA department in the case of infrastructure works.

Operational adaptation

A step-wise process

The following section shows the different steps involved in applying adaptive planning on strategic, tactical and operational levels. This section focuses on mainstreaming policies, strategies and measures into existing and future developments. To provide some insight into how the different steps apply for the delivery of WSUD, some examples are provided.

Level 1: Strategic

This level is essential to connect or mainstream different policies and associated tasks.

Recommended steps	Example
1. Analysis of the challenges ahead within the specific policy domain (e.g. climate adaptation): when do the subsequent tasks become critical, i.e. lead to intolerable risk levels? Are the challenges associated with legislation and existing norms? The analysis can range from a global quick-scan to a very detailed assessment.	Analyse for instance how future flood risk might become a critical factor at a regional metropolitan scale due to increased river discharge or rainfall runoff, or due to increased exposure and vulnerability as the result of urban development. Define what are tolerable flood risk levels based on for instance return periods (e.g. 100-Year flood event) and/or associated impacts (e.g. damages, failure of critical infrastructure or even casualties).
2. Formation of feasible strategies to successfully manage the tasks. A strategy consists of objectives and coherent sets of measures. Additionally, adaptation pathways which show at which point in time shifts are required (i.e. ATPs) should be explored to identify if future flexibility is sufficient to adjust to future scenarios;	Strategic development of for instance appropriate land-use legislation (zoning laws), construction of levees and other flood defence works or setting legislation for pro- active adaptation of built structures to withstand flood impacts. Additional strategies can include reservation of relief funds, insurance schemes, as well as effective coping mechanisms (e.g. evacuation plans). Possible pathways might include the shift from initial land-use legislation to the construction of levees to protect areas that might be exposed to increased future river discharge levels. An alternative pathway might consist of switching from flood-adapted construction to the development of flood relief funds for those that are still impacted despite local adaptation efforts.
3. Identification of possibilities to connect the developed pathways to other tasks and developments resulting in	These might include upcoming new building codes, national stimulation programmes for purging the

so-called mainstreaming opportunities;	construction industry, new national road programme, a new insurance policy or environmental policies including for instance wetland preservation acts.
4. Establishing the strategy within overarching policies, legislation and/or associated practices in order to reach a fitting normative framework.	Does the land-use legislation conflict with the current zoning laws including those for existing structures? Do proposed elevated structures and raising of property thresholds in flood prone areas conflict with existing legislation regarding accessibility of structures and public space for wheelchair users and others that require easy access?

Level 2: Tactical

This level is for creating an actual overview of where in the region projects are planned, i.e. an inventory of the ‘playing field’, which is essential for coherence and spatial integration.

Recommended steps	**Example**
1. Inventory of the actual locations in which urban (re)development or other projects are planned, including major maintenance, upgrading or repair works. Assessment of when those projects are planned within the short to medium term;	This requires for instance a detailed zoning or urban development plan, insight for any large scale reconstruction of, for instance, social housing projects, infrastructure maintenance or upgrading as well as development of natural conservation areas. Furthermore, an estimation is required as to when these projects will commence and what duration is estimated for implementation.
2. Identification of actual Adaptation Mainstreaming Opportunities, including an appraisal of which opportunities provide wider benefits and are feasible candidates for implementation;	This encompasses for instance the delineation of major roads suitable for elevation (combining levees and roads), perimeters of housing blocks fit to be located on mounts, natural areas that can be vegetated to act as breakwaters.
3. Provision of (co)financing to implement the identified adaptation mainstreaming opportunities.	Securing (part of the) budget for flood management to be applied within other project budgets (e.g. road or natural areas); dissolving departmental budgetary constraints; developing public-private partnerships to share budgets.

Level 3: Operational

This is the actual level in which measures are adopted and implemented on the ground.

Recommended steps	Example
1. Signposting opportunities for mainstreaming adaptation measures: whenever large maintenance, repair works or (re)development is planned, the stakeholders involved should recognise that mainstreaming opportunities might exist.	Whenever planning initiatives are proposed, water management authorities, consultants or other relevant stakeholders should be notified to signpost potential opportunities for mainstreaming.
2. Establishing the requirements that are provided by the different tasks at hand, e.g. norms, regulations and specifications including additional constraints or issues associated with a multi-functional approach;	When for instance combining road construction with levees, the requirements for the foundation are extended to ensure the base of the elevated road can withstand water pressure.
3. Estimation of the added value that is generated by combining multiple tasks, programmes or developments into a multi- functional design. The added value can occur in multiple domains;	Combining of a road and levee can for instance provide a perimeter to close off a low-quality logistics or industrial area from a residential neighbourhood.
4. Well established agreements about the responsibilities of the partners involved as well as the budgeting including co-financing of the design;	This requires for instance synchronisation between the maintenance (and budgeting of those cycles) of the roads and underlying levee structures. Furthermore, clear agreements need to be made regarding for instance, structural changes in order not to compromise traffic flows as well as continuous provision of protection.
5. Development of detailed requirements regarding the implementation, including specifications for quality criteria, monitoring and maintenance.	Tailored procedures to assess the quality standards, incremental inspections, reporting and maintenance cycles that combine the water management function as well as the main function (e.g. road).

Although these three different levels encompass an integrated process for the development and implementation of a long-term, adaptive flood risk strategy, the application of ATPs, APs and seizing AMOs does not require any specific sequencing. Flood adaptation can be initiated on operational, tactical or strategic level without necessarily leading to worse or better outcomes.

Practical considerations

Tips for using ATPs, APs and AMOs

- Defining tolerable risk levels can give rise to much discussion among stakeholders. Also the tolerable risk levels can become part of a political debate since they might emphasise responsibilities or even liabilities.
- The plausible future scenarios for inclusion in an adaptive planning framework should differ substantially from each other. It hardly makes sense to for instance have a scenario with 1% GDP growth and one with 3%, if that does not significantly change the flood impact on the social-ecological (sub)system.
- Gaining the necessary insights into the dynamic properties of urban redevelopment over longer periods of time requires extensive data, additional monitoring as well as expert knowledge to assess when future opportunities for mainstreaming might occur.
- Decision trees can be a useful way of diagrammatically visualising and (subsequently) valuing the cost and benefits of APs, including the occurrence of ATPs.

Available tools

- **ATP tool:** This tool is based on the extended ATP approach, comprising the design and exceedance domain of flood risk management. The ATP tool is a set of MS-excel spreadsheets, formulated based on the relationship between pressure and impact on the urban area. The tool visualises the ATP of drainage systems, based on predefined design and exceedance thresholds. The drainage system is subject to varying degrees of pressure and corresponding impacts (determined through a model). The pressure-impact relationship is then plotted graphically. Pressure-impact data sets obtained through hydraulic modelling are prerequisite for using this tool. Furthermore, the areas affected by inundation may be grouped into critical areas, using a spatial analysis tool such as ArcGIS, so as to ascertain the nature of the extent of the exceedance in the system; i.e. is exceedance isolated in small pockets or distributed throughout the system, or is exceedance prevalent in contiguous regions which do not overlap with each other.
- **Tolerable risk level matrix:** Managing a wide range of events (incl. extreme rainfall) can be better done by dividing the range of events according to their return period and associated magnitude into four categories: 1-10, 10-100, 100-1000 and over 1000 years. The magnitudes of the events will depend on the characteristics of the location of application. For example, for the Netherlands, corresponding magnitudes of rainfall are: 20, 40, 60 and 80 mm per 2 hours. The frequency of these events is then combined with the severity of impacts, which can also be divided into four categories: nuisance, minor damage, moderate damage and major damage. The combination of the frequency of occurrence and the severity of damage gives an indication for the flood risk of an area, as well as its associated level of tolerability. Figure 4 presents a matrix for the categorisation of tolerable flood risk.

- **Pathways Generator:** The Pathways Generator helps users to explore policy pathways in an interactive way, for example, together with stakeholders. The results are shown in a pathways map. See also: http://pathways.deltares.nl

	Minor event	Moderate event	Major event	Extreme event
Description	Smaller/ often			Bigger/ less often
Return period	1 - 10 yr	10 - 100 yr	100 - 1000 yr	> 1000 yr
Magnitude	20 mm/2h	40 mm/2h	60 mm/2h	80 mm/2h
Nuisance (e.g. Areas are affected with shallow water (up to 5 cm and 60 min duration)	Low risk Tolerable	Low risk Tolerable	Very low risk Tolerable	Very low risk Tolerable
Minor damage (e.g. Low-lying areas are inundated, minor roads may be closed)	Medium risk Intolerable over long term	Low risk Tolerable	Low risk Tolerable	Very low risk Tolerable
Moderate damage (e.g. Main routes may be affected, some buildings may be affected above floor level)	High risk Intolerable over short term	Medium risk Intolerable over long term	Medium risk Intolerable over long term	Low risk Tolerable
Major damage (e.g. Main routes are affected, buildings are affected above floor level)	Very high risk Intolerable over short term	High risk Intolerable over short term	Medium risk Intolerable over long term	Low risk Tolerable

Figure 4. Tolerable risk level matrix

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