



International
Standard

ISO 24566-2

**Drinking water, wastewater and
stormwater systems and services —
Adaptation of water services to
climate change impacts —**

**Part 2:
Stormwater services**

*Services et systèmes d'alimentation en eau potable,
d'assainissement et de gestion des eaux pluviales — Adaptation
des services de l'eau aux impacts du changement climatique —*

Partie 2: Services de gestion des eaux pluviales

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 224, *Drinking water, wastewater and stormwater systems and services*.

A list of all parts in the ISO 24566 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The occurrence of climate change is recognized globally. Mitigation programmes have been introduced in many nations, as well as internationally through a number of agreements.

Locally, operators of water services have had to assess the impacts and options for responding to the effects of climate change, some of which are slow and long-term, while others are acute, arising from extreme weather events and changes.

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Drinking water, wastewater and stormwater systems and services — Adaptation of water services to climate change impacts —

Part 2: Stormwater services

1 Scope

This document provides guidance on identifying and assessing the impacts of climate change on stormwater systems and on developing strategies for adapting to these impacts. The assessment of the impacts is based on the assessment principles described in ISO 24566-1.

This document also provides examples of some of the impacts of climate change on stormwater systems and of the responses that have been implemented by municipal water services or by the relevant jurisdiction (e.g. municipality or region served by the service). The examples of responses illustrate adaptation strategies that have been applied.

NOTE Combined sewer systems are included in this document in relation to the activities of collection, transport, storage and treatment of stormwater. Non-combined wastewater systems are covered by ISO 24566-4¹⁾.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 24513, *Service activities relating to drinking water supply, wastewater and stormwater systems — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 24513 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

governance

system of directing and controlling

[SOURCE: ISO/IEC 38500:2015,²⁾ 2.8]

1) Stage at the time of publication: ISO/DIS 24566-4.

2) Withdrawn.

3.2

metric

data

verifiable measure that captures performance in terms of how something is being done relative to a standard, allows and encourages comparison, supports business *strategy* (3.4)

[SOURCE: ISO/TS 18864:2017, 3.20, modified — the admitted term “data” has been added.]

3.3

stormwater

water resulting from rainwater, melted snow and ice draining from roofs, roads, footpaths and all other ground surfaces

Note 1 to entry: Stormwater can either be collected and stored for direct use or collected and discharged into a sewer system or environment and/or infiltrated into the soil.

[SOURCE: ISO 20670:2023, 3.91]

3.4

strategy

organization's approach to achieving its objectives

[SOURCE: ISO 30400:2022, 3.1.6, modified — “Organization” was added to the definition and notes to entry were removed.]

3.5

user

user of this document

one who applies the recommendations of this document for whatever purpose

[SOURCE: ISO 14258:1998, 2.1.4, modified — “User” was added as a preferred term; in the definition, “requirements” was changed to “recommendations”; examples were removed.]

4 Objectives

4.1 General

The main objectives for this document are:

- to demonstrate how the assessment principles set out in ISO 24566-1 can be applied to the management of stormwater in urban areas;
- to assist water services to identify, assess and adapt to climate change's expected impact on stormwater services.

4.2 Other

Other objectives may be established from time to time, to suit changing circumstances within the community.

5 Impacts of climate change on stormwater systems and responses

5.1 General

The impacts of climate change on stormwater systems should be established and responses considered.

5.2 Impacts

The impacts of climate change are dependent on the:

- nature and effects of climate change;
- condition of the stormwater system and its assets;
- design parameters of the system and its components;
- nature of the system's service area;
- nature of the stormwater system's catchment;
- operation of the system.

The impacts on stormwater systems include:

- infrastructural capacity problems:
 - increased flows;
 - overwhelmed retention and treatment facilities;
 - increased number of bypass discharges;
 - changes in the receiving water bodies including sea level rising;
- infrastructural structural problems:
 - subsoil subsidence, changes in subsoil conditions and collection system damages caused by drought or freeze-thaw cycles;
 - damage or loss of assets due to more intense storms, hurricanes, typhoons;
 - operational problems;
 - increased interactions with wastewater collection and treatment systems;
 - increased pluvial flooding from the surrounding areas;
 - increased flooding through capacity problems changing receiving body water qualities (e.g. untreated overflows, increased pollution);
 - increased health and nuisance problems (e.g. toxic, noxious or greenhouse gases, insects, including insect-borne disease, and other vectors, odours) which can arise from changing flows.

The impacts on the service area of the stormwater system can include:

- risk to lives and public health;
- extensive property damage through flooding;
- damage or loss of infrastructure assets;
- long-term impacts on the development of the service area:
- deterioration of assets;
- less economic and social development potential;
- depopulation.

5.3 Responses

Responses are essentially adaptive, generally regarding:

- infrastructure;
- operation and maintenance;
- management;
- governance;
- societal behaviour and issues.

Adaptive responses can also have a consequential mitigative character in regard to climate change, i.e. they reduce the production of greenhouse gases. Adaptive responses tend to anticipate longer-term climate change conditions, such as continuing higher frequencies of events or longer durations of events beyond the capability to adjust through operational changes.

Adaptive responses can require changes of a continuing nature to:

- stormwater system design;
- infrastructure;
- treatment processes;
- operations and asset management.

Adaptive responses within the structure and management of the organization itself can include:

- risk management, including risks due to climate change impacts;
- adapting monitoring and early warning systems to determine climate change impacts;
- adopting a catchment management approach, including forming partnerships with other organizations;
- crisis management programmes adapted to climate change impacts;
- increasing preparedness and the range of possible actions of urban actors (e.g. communities, public and private enterprises);
- establishing permanent data backup systems outside the risk zones;
- improve data sharing with other affected organisations.

Adaptive response strategies and their development are covered in [Clause 10](#).

6 Methodology

6.1 General

It is recommended that users of this document follow a five-step approach:

- a) understand and assess the current situation, vulnerabilities and opportunities;
- b) assess future situations and vulnerabilities, including awareness and communication;
- c) develop adaptive strategy(ies) including a target-setting process;
- d) conduct a financial risk assessment;
- e) monitor, review and update.

Individual steps may be repeated as necessary in the methodological process.

6.2 Key functions

Within each step the following key functions should be considered:

- governance;
- strategies;
- risk management;
- operation and asset management;
- metrics and targets.

7 Assessment of current situation, vulnerabilities and opportunities

7.1 General

Users of this document should assess and document the current situation, risks, vulnerabilities and opportunities relevant to the stormwater system they manage. The following outline is recommended.

7.2 Describe and characterize the current stormwater system

7.2.1 Typical assets of a system

The infrastructure assets of a stormwater system will typically comprise:

- the pipe networks;
- ancillary facilities (e.g. pumping stations and electro-mechanical controllers such as motorized weirs and gates, retention tanks);
- discharge structures (e.g. combined sewer overflow, outfalls, infiltration facilities);
- pollution control structures [e.g. Gross Pollutant Traps (GPTs), screens, retention and settlement basins];
- water-sensitive urban design elements (e.g. constructed wetlands, rain gardens, sponge city systems, rainwater tanks on public and private land, re-use facilities).

7.2.2 Governance

In order to make plans for adapting stormwater management to the impacts of climate change, current governance arrangements should be assessed. The assessment should cover the entire service area and, if possible, the entire catchment area and should include the following.

- Describing how stormwater is governed currently, including:
 - which organization is responsible for which parts of the stormwater system;
 - which organisations are in the catchment area, what their responsibilities are and how they can contribute to stormwater management.
- Determining what level of development phase best characterizes the stormwater system. This can help to determine the most appropriate management or adaptation response to climate change impacts.

- Identifying other relevant organisations related to such services/resources in the service area or catchment area that can be affected by climate change impacts to the stormwater systems. For example, such organisations can be responsible for or contribute to managing:
 - surface water run-off (e.g. pluvial and fluvial flooding, run-off from roads, sewer backups);
 - wastewater (e.g. non-separated and separated systems, treatment plants);
 - receiving waters;
 - groundwater;
 - water supply;
 - irrigation and drainage.

Such organisations can include:

- regulatory authorities;
- governmental entities;
- public organisations or agencies;
- public or private owners or operators;
- the community at large.

7.2.3 Strategies

The current management strategies for the stormwater system and their interdependencies e.g. from or with all relevant organisations) should be identified, documented and reviewed in order to assess their suitability for:

- managing the impacts of climate change;
- identifying gaps in the analysis;
- considering stormwater as a resource (either potable or non-potable).

The user should review operational strategies and procedures, as well as operation and asset management plans, asset condition and other asset-related information, in order to characterize the stormwater system from an operations and asset management perspective.

Guidance on the identification, assessment and management of assets and operation is given in ISO 24516-3.

Key factors included in operations and asset management include vulnerability to flooding events, power losses and societal impacts, including mental health and post-traumatic stress disorder (PTSD) effects.

Reviews should be performed for each of the critical components involved in the functioning of the system.

7.2.4 Risk management

The current procedures for the identification, assessment and management of climate-related stormwater risks and how they are currently integrated into the overall risk management policies and practices of the system should be described and documented. In particular, including the existing procedures and means dedicated to crisis management and whether they are formalized in emergency action plans or not should be clearly identified.

Guidance on risk identification, assessment and evaluation is given in ISO 24516-3.

7.2.5 Operation and asset management

The current operation and asset management practices established and followed in the management of the stormwater system should be identified, described and documented.

Guidance on identification, assessment and evaluation of assets and operations is given in ISO 24516-3.

7.2.6 Metrics and targets

The current metrics and targets (i.e. desired metric levels) used for the management of the stormwater system should be identified, described and documented, together with sources used to establish these metrics and targets, such as local monitoring points [e.g. hydraulics, meteorology, natural organic matter (NOM)³⁾], Geographical Information Systems (GIS) or hydraulic models. These can include annual, seasonal, peak or non-peak and frequency metrics appropriate to the locality. An assessment of strengths and weaknesses of the collected data (e.g. level of confidence in the accuracy of the data, its completeness and plausibility) should be carried out. If necessary, plans to improve the metrics and targets should be developed. This applies particularly to jurisdictions with smart water systems, see for example ISO 24591-1 and ISO 24591-2.

Relevant metrics and targets include:

- assets (e.g. number, age, size):
 - network (e.g. length of network, condition, renewal rate);
 - ancillary facilities (e.g. pumping stations, electro-mechanical controllers, such as motorized weirs and gates, and retention tanks);
 - discharge structures (e.g. combined sewer overflow outfalls, infiltration facilities);
 - pollution control structures (e.g. gross pollution traps, settlement basins, screens);
 - water-sensitive urban design elements (e.g. constructed wetlands, rain gardens, sponge city systems, rainwater tanks on public and private land, re-use facilities);
- stormwater run-off:
 - flows and volumes;
 - percentage catchment imperviousness and directly-connected imperviousness;
 - trends (i.e. are flows increasing, decreasing or stable);
 - frequencies;
- stormwater discharges to:
 - receiving waters (outfalls, combined sewer overflows);
 - treatment plants;
 - groundwater infiltration;
 - reuse facilities;
- stormwater reuse demand:
 - current demand for stormwater reuse;

3) NOM is preferred to BOD (biochemical oxygen demand) which may be indicated with TOC or DOC (total/dissolved organic carbon)

- demand for environmental purposes (e.g. maintenance of wetlands, augmentation of flow-stressed water bodies);
- stormwater quality:
 - pollutant loads [e.g. sediment, NOM, total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), pathogens, oils and chemicals];
 - accidental spills (e.g. kinds, number of potential sources, frequency);
 - gross pollution (e.g. litter, garbage, wind-blown plastics);
- other relevant metrics, for example regarding:
 - operation and maintenance;
 - regulatory purposes;
 - public health and safety;
 - occupational health and safety;
 - land use and site coverage regulations;
 - ecosystems;
 - service interdependencies (cascading effects);
 - financial situation [capital expenditures (CAPEX) and operating expenditures (OPEX)].

Numeric models of the stormwater system should incorporate many of the metrics and targets mentioned in this subclause. The result of numeric models is additional, aggregated information about the system and its performance that goes beyond the information provided by individual metrics. Such models include:

- flow models;
- precipitation-runoff models;
- water quality models;
- integrated models with combinations of the aforementioned models.

Such models should be integrated with smart water systems, see for example ISO 24591-1 and ISO 24591-2.

7.3 Identify and assess current climate-related hazards to stormwater services

7.3.1 Current climatic conditions

The current climatic conditions in the locality (taking into account average and extreme conditions and their durations) should be identified and documented, including:

- precipitation (e.g. rain, snow, ice and hail);
- groundwater (e.g. levels, flows and renewal rates);
- receiving waters (e.g. flows, levels and quality);
- coastal waters (e.g. levels, tides, storms and quality);
- temperature (e.g. droughts, freeze-thaw cycles and heat waves);
- wind speeds and directions;
- extreme storms (e.g. hurricane or typhoon forces, tornadoes and lightning).

The identification and documentation of current conditions should be based on data derived from observations by competent relevant meteorological, geological or hydro-geological services. The level of detail and the data observation period should be appropriate for the planned use of the data.

7.3.2 Current climate-related hazards

7.3.2.1 General

Extreme events relevant to stormwater services occurring within the chosen observation period should be reviewed and their effects documented (including approximate costs or damages, if known). This should be done with an understanding of events differing in nature, for example short-term acute events (sub-day rainfall) versus long-term stressors or events (e.g. saturated catchment areas compounding acute events).

The identification and evaluation of stakeholders and their interdependencies (e.g. impact on power service provision, operation of transportation corridors and supply routes, need for evacuation and rehousing of residential and non-residential populations, including special needs populations) should be carried out and documented.

Examples of climate-related hazards to stormwater services and, via the stormwater system, to the service area or catchment include:

- flooding events (pluvial, fluvial, coastal, sewer and groundwater);
- damage, destruction or disruption of system infrastructure;
- pollution events (impact on drinking water supply, receiving waters, groundwater);
- damage, destruction or disruption of buildings, facilities and infrastructure;
- erosion events;
- power losses (e.g. if stormwater system is pumped);
- societal impacts, including mental health effects and PTSD;
- economic impacts (short-, mid- and long-term), including impacts on urban growth (greenfield and brownfield);
- interdependency failures.

7.3.2.2 Flooding events

Flooding events can be caused or exacerbated by poorly designed, managed and maintained stormwater and combined sewer systems. Flooding events arise in different forms:

- pluvial flooding;
- fluvial flooding;
- sewer flooding;
- coastal flooding;
- groundwater flooding.

The primary focus of this document is to deal with flooding while noting that there are a number of sources of risks and vulnerabilities to stormwater services.

Where the flooding event, regardless of its source, is limited to the local area within the user's jurisdiction, the governance issues are likely to concern the organization and coordination of the emergency response:

- is the emergency response organization the same one that manages the stormwater system?

- is there an emergency management structure in place?
- is there an emergency response plan?
- does the emergency response plan include communication to the affected community?
- has the plan been tested by actual events or simulated through desk-top exercises recently?
- is funding available to implement the plan and/or pay compensation to those suffering damage?

If the flooding event is not-local in nature, then these governance issues remain, but are compounded by the issue of inter-jurisdictional collaboration and coordination:

- have coordination and collaborative arrangements been established with neighbouring jurisdictions?
- have coordination and collaborative arrangements been established with senior jurisdictions?
- have those arrangements been tested by actual events or simulated through desk-top exercises recently?

7.3.2.3 Pollution or erosion events

Where the event involves pollution or erosion and is limited to the local area within the user's jurisdiction, the governance issues are likely to concern the organization and coordination of the pollution or erosion response:

- is there a pollution or erosion response management structure in place?
- is there a response plan?
- does the emergency response plan include communication to the affected community?
- has the plan been tested by actual events or simulated through table-top exercises recently?
- are resources (e.g. contractors, in-house equipment and personnel) available to implement the plan?
- is funding available to implement the plan?
- do neighbouring or senior jurisdictions need to be notified?

If the pollution or erosion event is not local in nature, then these governance issues remain, but are compounded by the issue of inter-jurisdictional collaboration and coordination:

- have coordination and collaborative arrangements been established with neighbouring jurisdictions?
- have coordination and collaborative arrangements been established with senior jurisdictions?
- have those arrangements been tested by actual events or simulated through desk-top exercises?

7.3.2.4 Power losses

Power losses can impact the functioning of:

- critical components of stormwater systems, such as pumping stations and electro-mechanical controllers like motorized weirs and gates;
- monitoring and supervision system;
- any powered treatment or pre-treatment system, such as screens.

Aspects that should be considered while reviewing and evaluating the risks associated to the potential loss of power impacting on stormwater management include:

- internal back-up power systems:
 - is there a back-up power system available?
 - has the back-up power system been regularly tested with positive results?
 - does it meet the current needs for power or is it only capable of meeting essential needs and, if so, which needs?
- external power systems:
 - does the external power source supplier prioritize restoring services to the organization?
 - have previous events demonstrated adequacy of restoration services?
 - has this priority been recently confirmed?

7.3.2.5 Societal impacts, including mental health and PTSD effects

Climate change impacts and events can have significant effects on the affected populations. These are often exhibited in general mental health concerns among the population, particularly children and the elderly, for example “will it happen again?”, “will I survive the next event?”.

PTSD effects are a form of acute mental health conditions and are generally grouped into four types: intrusive memories, avoidance, negative changes in thinking and mood, and changes in physical and emotional reactions. Symptoms can vary over time or vary from person to person.^[19]

As the stormwater service is the organization responsible for managing risks within the community, it should have plans in place to provide counselling and support to direct and indirect victims of the event.

Collaboration of the stormwater service with and supporting local public health units and other counselling resources is an essential responsibility.

7.3.2.6 Interdependency failures

In today's world, most organizations and services are dependent on other organizations for the provision of products and services. Water services, for example, are reliant on energy supplies (for pumping stations and electro-mechanical controllers, such as motorized weirs and gates), chemical supplies (for treatment), transportation companies, telecommunications and health services to keep employees healthy.

Stormwater events can interrupt provision of such products and services. Flooding of road and rail systems can interrupt “just-in-time” deliveries of chemicals for water and wastewater treatment systems, including any redirection or reuse of stormwater flows.

Managers of stormwater services should:

- identify and analyse the interdependencies that exist with external and internal product and service providers;
- review past events to determine weaknesses or failures;
- consult with providers to rectify any past weaknesses or failures and to ensure continued reliability;
- confirm relationships by updating, if appropriate, interdependency contracts and arrangements.

7.4 Identify and assess current system risks and vulnerabilities

7.4.1 General

Based upon the review of previous documented stormwater events, the user should identify and assess the risks and vulnerabilities of the current system to determine current system opportunities for risk or vulnerability reduction. Risks and vulnerabilities will vary depending on combined or separated stormwater and sewer systems, asset conditions, local geography and development legacy.

7.4.2 Governance

Users of this document should identify and document the risks and vulnerabilities that arise as a result of the current governance of the stormwater system. This should include the following aspects:

- which organization(s) is (are) responsible for managing stormwater?
- how, if shared, is the responsibility shared?
- what are the risks or vulnerabilities related to this?
- is the interface with asset owners well identified?
- is (are) the stormwater management organization(s) set up and funded properly to manage stormwater?
- what is the programme of asset maintenance or upgrading?
- what are the trends for nutrient pollution, stormwater volumes going to receiving waterways and stormwater reuse, i.e. are these increasing, decreasing or stable?
- what is the trend in urban growth, densification and the presence of impervious surfaces?
- are there legislative, regulatory or policy changes anticipated or planned that will impact how stormwater is funded and managed (e.g. integrated water management programmes, water-sensitive urban design (WSUD) programmes or incentives, imperviousness charges)?

Existing governance arrangements should be reviewed with a view towards understanding whether climate adaptation planning can be integrated into the current governance structure. If not, governance-related adaptation responses can be found in [10.2.3](#).

7.4.3 Strategies

7.4.3.1 General

The strategies already in place in the organization (or other organisations that have a role in managing stormwater) to address the risks and the vulnerabilities should be identified and evaluated. Such strategies can include those in the [7.4.3.2](#), [7.4.3.3](#) and [7.4.3.4](#).

7.4.3.2 Hazard identification and risk assessment studies

Hazard identification and risk assessment studies should include:

- regularly conducting and documenting hazard identification and risk assessments of climate change effects (particularly those identified in [7.3](#));
- reviewing past hazard analyses and risk assessments against events that have occurred and identifying key system failure points;
- identifying vulnerabilities;
- involving stakeholders in such activities;

- publishing for public review hazard identification and risk assessment documents.

7.4.3.3 Response planning activities

The purpose of these strategies is to identify current risks and vulnerabilities with the view to reducing them through the identification and implementation of response activities that can be based on either infrastructural or operational changes.

The strategies should include assessment of risks to stormwater as a resource if it is being used for alternative water supply (potable or non-potable) or environmental water (e.g. to maintain wetlands or augment low river flows).

7.4.3.4 Related issues

In the conduct of these strategies, the user should take into account the likelihood of:

- increased urban densification;
- reduction or increases in impervious surfaces;
- changes to land use planning;
- development policies, such as mandating green roofs, rain gardens or other blue-green infrastructures.

7.4.4 Risk management

Users should identify and document how climate-related risks to stormwater management are currently managed. Such management activities can include:

- all stormwater management studies being documented and published for stakeholder review;
- key staff participating in regional consultation and planning forums and conference events;
- exercises being performed at regular intervals to sensitize staff and the public, and to test and improve current practices;
- continuously researching climate change and stormwater management practices.

7.4.5 Operation and asset management

7.4.5.1 Operations management

Managers of stormwater services should be aware of the objectives of wastewater systems (including those combined with stormwater systems) as set out in ISO 24511 and operate the service in a manner that allows the achievement of the following objectives:

- protection of public health;
- meeting users' needs and expectations;
- provision of services under normal and emergency situations;
- sustainability of the wastewater utility;
- promotion of sustainable development of the community;
- protection of the environment.

This includes the following management practices:

- activities and process management;

- resource management;
- asset management;
- customer relations management;
- information management;
- environmental management;
- risk management.

7.4.5.2 Asset management

Managers of stormwater systems have a responsibility to identify, inventory and manage the assets of the systems which often are principally public domain assets, such as:

- stormwater drainage assets (e.g. feeder and main line drain assets, such as pipe networks, generally located within roads and public parking areas);
- stormwater storage reservoirs (e.g. retention ponds, underground tanks, bypass infrastructure);
- ancillary facilities (e.g. pumping stations and electro-mechanical controllers such as motorized weirs and gates);
- WSUD assets (e.g. green roofs on public buildings, constructed wetlands, rain gardens, rainwater tanks on public land, swales).

Managers should establish a full inventory of the assets related to stormwater, including:

- the length, location, type of materials of construction, age and condition of all drainage assets;
- the size, location, materials of construction, age and condition of all storage reservoirs;
- the size, location, materials of construction and age and condition of all WSUD assets.

Critical assets based on previous studies or past hazard analyses should be clearly identified.

Asset management assistance can be provided to WSUD assets on private, commercial and institutional properties.

Where possible, information on any WSUD assets on private, commercial and institutional properties should be collected and kept up to date.

All asset information should be held digitally, at least within an asset management framework and ideally in a digital twin^[20] or similar digital modelling software, in order for climate scenarios to be more easily applied to model and to stress-test the stormwater system for vulnerabilities.

7.4.6 Metrics and targets

Users should consider the risks and vulnerabilities of current metrics:

- do they measure what needs to be measured?
- are there gaps in the current metrics?
- how accurate and reliable is the data or are they just estimates?

Targets should be set using current data as the baseline, and can include:

- stormwater flows (volumetric);
- stormwater flooding (e.g. critical areas, flooded volumes, depths);

- stormwater quality, e.g. BOD, TN, TP, TSS, litter (concentration or load-based);
- current flows and quality of receiving bodies;
- number of critical stormwater assets.

The goal or outcome of the targets should be defined and documented, i.e. what are they trying to achieve?

It is important to determine the vulnerabilities of current targets:

- are they sufficient to meet defined objectives?
- is there a target for each climate change situation?
- how do the targets compare to other similar jurisdictions?

If the flooding event is not-local in nature, then the aforementioned governance issues remain, but are compounded by the issue of interjurisdictional collaboration and coordination:

- have coordination and collaborative arrangements been established with neighbouring jurisdictions?
- have coordination and collaborative arrangements been established with senior jurisdictions?
- have those arrangements been tested by actual events or simulated through desk-top exercises?

7.5 Assess current system opportunities

Having completed the inventory of system assets in 7.4.5.2, assessed the current climate hazards in 7.3 and assessed current system risks and vulnerabilities in 7.4, managers of stormwater systems should assess opportunities for expanding or adapting current stormwater system elements against potential future climate risk hazards and risks.

That assessment should take into account opportunities for financial assistance or investment and cooperation with or from neighbouring jurisdictions or senior levels of government.

Collaborative response agreements within the region can achieve better outcomes for lower total investments.

Examples of current opportunities include:

- centralising stormwater governance into one organization if currently spread across multiple organizations;
- working towards a shared vision for stormwater management across responsible agencies if centralising governance is not possible;
- seeking opportunities to manage (or partner with other organisations to manage) stormwater more holistically using WSUD at a catchment level, for example in new urban greenfield growth areas, as well as in brownfield redevelopments, which can include influencing urban development typologies that minimize stormwater generation and maximize reuse opportunities at source;
- identifying opportunities to capture and reuse stormwater, either for non-potable uses such as irrigation of open spaces and trees or opportunities to bring stormwater into the potable network;
- leveraging funding opportunities to upgrade assets or reduce pollution levels;
- understanding whether stormwater offsets (e.g. collecting fees to invest in stormwater elsewhere) can play a role in better management now and under climate change;
- identifying opportunities to improve the robustness of the stormwater conveyance system through new interconnections and redundancies.

8 Assessment of future situation, vulnerabilities and opportunities

8.1 Identify and assess future climate change hazards

Climate change causes global hydro-meteorological variations of several kinds: heatwaves and cold waves, droughts, intense rains and storms, a rise in sea levels and even modification of rainfall patterns with excess or lack of water. The entire water cycle is concerned (precipitation, snow cover, rivers, groundwater, lakes and wetlands), from both a quantitative (depletion of water resources or sudden excess during heavy rainfall) and a qualitative (concentration of pollution, turbidity, eutrophication) point of view. These variations have different dynamics, being either progressive (chronic) or extreme (acute) climatic events which are becoming more frequent and intense.

- Chronic events include:
 - increase in average temperatures;
 - scarcity of water resources;
 - sea level rise, coastal erosion and slow submersion;
- Acute events include:
 - heatwaves, droughts;
 - cold spells or frost;
 - extreme precipitation, storms, flooding and submersion.

These considerations are presented more extensively in ISO 24566-1.

The objective of this subclause is to determine which climate hazards are relevant to the stormwater system and what the trends and uncertainties are. The following should be considered:

- establish climate horizons of interest, 2030, 2040, 2050, etc;
- start assessment with previously encountered climate hazards, as listed in 7.3, as they are likely to occur more frequently in the future due to climate change;
- build climate hazard scenarios using meteorological services, including prominent trends and uncertainties.

Climate futures are uncertain and robust adaptation to climate change should rely on solutions that remain valid for a wide range of future scenarios.

The complex nature of the climate system, climate models and human factors make it difficult to determine exactly what the changes will be at any given location or time. Considering uncertainty is key to making more informed decisions. There are three main sources of uncertainty in climate projections: natural climate variability, greenhouse gas emission scenarios, and the climate models themselves. The relative importance of the three sources of uncertainty changes over time. For instance, when it comes to projection of global temperature, the contribution of uncertainty from natural climate variability dominates in the shorter term, model uncertainty is more important over the first half of the century and greenhouse gas emission scenarios become the dominant source of uncertainty afterwards. Assessors need to work with these uncertainties and should consider local past climate events, multiple climate models and emission scenarios for future planning.

Meteorological services provide climate change information to assist decision-making. They make the best climate science available to all, with climate projections (e.g. temperature, precipitation) available according to different greenhouse gas emission scenarios, different time horizons and different climate models. Many services exist in many regions of the globe, at more or less fine spatial scales. For example, The Interactive Atlas of the IPCC^[21] gives projections for major regions of the globe. Finer resolutions are recommended when available. National or regional weather services or environmental authorities may provide local data to better assess vulnerabilities and the various impacts on a finer scale.

The climate scenarios chosen should be agreed upon by a group of experts, as they are the basis of the utility's climate change adaptation approach. Once defined, future climate scenarios should be consistently applied across the adaptation planning process, until the need to review and amend them arises. Other key variables, such as human factors (e.g. population trends and water use projections, location of settlements), should be assessed by the group of experts to be included in future planning.

8.2 Identify and assess future vulnerabilities to stormwater systems

8.2.1 Governance

A focus at this stage should be to determine the following:

- what are the key governance-related risks arising as climate change hazards increase over time (e.g. financing costs for renewals or retrofits could increase beyond serviceability)?
- what are the opportunities to adapt governance to suit changing climate hazards?
- what are the risks and vulnerabilities for the stormwater managing organization(s), such as at the interface of asset owners?
- is (are) the stormwater management organization(s) set up and funded properly to manage stormwater system adaptation?
- are there local policy, plans and documents related to climate change and stormwater management?

8.2.2 Strategies

The user should also identify what strategies are in place that impact on how stormwater will be managed in the future.

8.2.3 Risk management

The user should give consideration to:

- possible alternative management practices for potential future climate-related risks to stormwater;
- whether or not the risk management framework needs to be changed to incorporate that possibility.

This should include assessment of risks if stormwater is planned to be or is being used as a resource for alternative water supply, either as potable or non-potable water or as environmental water (i.e. to restore wetlands or augment low river flows), and if there are risks arising from potential or actual competing uses.

8.2.4 Operation and asset management

The following questions need to be examined.

- Whether and to what extent climate hazards could change the risks to assets and operations in the future.
- Where are the key vulnerabilities? These can include, for example:
 - new flooding areas due to both climate hazards and urban growth;
 - inability to maintain gravity discharges due to increased sea level;
 - increased pollution impact on surface-receiving water bodies due to increased stormwater overflows, reduced river flows and increased river temperature;
 - long-lasting winter flooding;
 - increased runoff due to soil drying or compaction;

- failures in pumping stations and electro-mechanical controllers, like motorized weirs and gates, due to energy loss because of flooding events;
- pipes breaking due to low temperature or drought;
- reduced intervention time for workers due to extreme temperature events;
- interdependencies and cascading effects;
- How will climate hazards change the risks to assets in the future?
- What are the likely system failure points in the future?

8.2.5 Metrics and targets

The user should assess whether the current metric data set defined in [7.4.5](#) will be sufficient in the future with projected climate changes and define as necessary new metrics for any areas where gaps identified previously have been found (see [7.4.6](#)), for instance:

- diversification of water sources (new or not used versus needs for more or new connections);
- modelled stormwater runoff in 2030, 2040, 2050, etc.

The user should assess any vulnerabilities in the current targets, for example whether they are sufficient to meet defined objectives, and define new targets if necessary (e.g. stormwater reuse volume at various time horizons, pollutant load targets).

8.3 Assess future opportunities

The user should provide a summary of the potential strengths and weaknesses of the metrics and targets for 2030, 2040, 2050, etc., to support identification of opportunities to adjust plans.

Adaptation of the stormwater system may involve short- and long-term responses with, for example:

- new asset design rules, based on the modelling of expected future rainfall events or 2D flood modelling;

NOTE 2D flood modelling interprets the 2D equations of flow to find out the water depth and depth-averaged velocity on a grid or mesh. It uses digital terrain modelling and bathymetry of the water channel in question to outline the 2D-flow of an expected flood. With 2D flood modelling, there is no need to predefine the flow routes. 2D modelling is also suitable for mapping future floods because it takes velocity variation on floodplain into account and provides flood maps and depth grids as direct outcomes. Also, it can be more accurate than 1D flood modelling.
- changes in drainage assets (both main drain and small line assets), to be increased in length, size or location;
- WSUD assets (e.g. constructed wetlands, rain gardens, rainwater tanks), in which locations and types of assets;
- gross pollutant traps and screens, and where they should be located;
- removable barriers or walls to either divert or contain stormwater runoff;
- opportunities that stormwater management provides for reducing stormwater impacts on waterway health and liveability in the face of climate change (e.g. maintaining the right balance between consumptive harvesting approaches and soil infiltration, that in turn supports appropriate flow regimes to waterways and urban vegetation).

In assessing these adaptation opportunities, consideration should be given to prioritization in the use of available funding.

More significant stormwater system transformation may also be considered to:

- develop a city-wide global water strategy to solve complex challenges;
- co-design solutions and combine ideas from stakeholders, including local communities and experts;
- design solutions for multiple functions and benefits, for instance:
 - dewatering of urban surfaces through porous surfaces to reduce stormwater runoff;
 - extensive implementation of nature-based solutions.^[22]

Further information on nature-based solutions can be found through the International Union for Conservation of Nature.^[23]

9 Financial assessments

9.1 General

All responses should be assessed for their long-term economic viability over the expected lifetime of the response. Such assessments should take into account both the initial investment and the continuing operational costs. There are two aspects to the financial assessments:

- financing adaptation;
- conducting a cost-benefit analysis (CBA).

9.2 Financing adaptation

Climate change may affect operations, alter the stormwater service or damage assets. Financing adaptation may seem too big to handle, but many experts underline that inaction will be more expensive in the long run. This is referred to as the “cost of inaction”.

Water utilities need to ensure that resources are allocated and supported to deliver successful adaptation responses. Ensuring the availability of funds will be a long-term consideration and will require ongoing decisions and adjustments.

The following aspects should be investigated:

- what is the cost of the adaptation strategy (CAPEX and OPEX)?
- what would be the cost of inaction:
 - for the service (damages, staff, regulatory)?
 - for the territory (damages, human, regulatory, health, economic)?
- is the funding for the project ensured? Opportunities and sources of financing exist to finance climate change adaptation (through public subsidies, private funds, etc.);
- what are the local consequences or benefits of the adaptation project (e.g. economic, health, social)?

The evaluation should be for value and not just cost.

Assessment of uncertainties surrounding the proposed response may support implementation:

- are there potential side-effects that will have to be remedied and at what cost?
- does the project meet all regulatory requirements or are waivers required and obtainable?
- what is the likelihood of the project going over-budget?
- is the project sustainable in terms of greenhouse gas emissions?

- which risks remain?

Conducting a CBA will help in providing economic information and value for the project.

9.3 Cost-benefit analysis

Cost-benefit analysis (CBA) is an analysis contributing to decision-making on whether to adopt a project or a plan by quantifying and comparing its costs and benefits. CBA estimates the value against the cost of the project in terms of a cost-benefit ratio (CBR) and allows for ranking of alternatives. CBA is largely used to support decision-making about investments in projects and for water management projects.

CBA relies on at least two scenarios: with-project and without-project. Additional scenarios with alternative projects may also be analysed. The without-project scenario is used as the baseline. Benefits are calculated by comparing with-project and without-project scenarios on the set time horizon, rather than on a before-and after-project scale.

Difficulties with the conduct of CBA are the following.

- Costs and benefits are not capable of being readily identified and numerically valued.
- Costs and benefits are not easily represented in monetary terms, especially environmental and social benefits (also called co-benefits or non-market values) and should be monetized as far as possible, see ISO 14007.
- The valuation depends on the recipients of the benefits and the bearers of the costs.
- Benefits may be for society collectively as well as individuals (e.g. public or private).
- Costs may be borne by society collectively, for example by governments or individually or corporately.

Correctly identifying and expressing these variables is important and should be documented in the report of the analysis. Uncertainty should also be addressed, including providing a sensitivity analysis.

In many cases, the process of assessing a project using CBA is inherently complex. Simplified methodologies exist and conducting a simplified CBA may be valuable in the first instance and useful in order to have a first-level analysis of a project.

Users calculating CBRs should consider that not all costs can always be monetized. The New South Wales (NSW) Floodplain Development Manual discusses flood damage cost, which includes tangible and intangible costs (direct and indirect for both).^[24] For most flood studies, only tangible direct costs are calculated, hence when a CBA is carried out, CBRs lower than 1 can be included in the recommendations to proceed for flood mitigation works. It can be advisable to accept a CBR of 0,5 instead of 1.

10 Development of adaptation strategy

10.1 General

It is likely that some adaptation options are within the control of the stormwater service organization while others are not, or are related to land-use policy or governance rather than stormwater asset management specifically. Adaptation options chosen by users of this document will need to account for that, for example a land-use policy mandating maximum imperviousness of a property of, say, 60 % or something like a mandated green roof to reduce stormwater problems downstream and help climate adaptation of the service.

10.2 Adaptation strategies

10.2.1 General

In developing an adaption strategy, the user should:

- define short-term and long-term responses or system transformations;
- formulate and set out a systematic approach to documentation (this can include a table such as [Table 1](#));
- include reporting on the elements of governance, strategies, risk management, operation and asset management and relevant metrics and targets;
- develop a communication plan with its stakeholders covering the following sub-sets of information:
 - building an understanding on climate change-related stormwater issues within the stormwater utility;
 - identifying the adaptation strategies available and why the chosen one has been selected;
 - setting out training requirements (if any);
 - ensuring the stormwater adaptation strategy is part of an integrated water management approach.

10.2.2 Governance

Governance activities should:

- define changes to governance to improve adaptation to climate change and to maximize new opportunities;
- encourage creation of policy approaches to define stated levels or ambitions of adaptation;
- consider implementing a water sensitive city (WSC) approach to assess what governance adaptation response may best suit the circumstances and desired objectives for the stormwater system.

NOTE It is important to distinguish between WSUD and WSC. A WSUD approach comprises land planning and engineering design to integrate the urban water cycle, including stormwater, groundwater, and wastewater management and water supply, into urban design in order to minimize environmental degradation and improve aesthetic and recreational appeal. A WSC approach considers the entire water supply catchment, acknowledging the range of different water sources on a range of different scales, and for a range of different uses; it plans for ecosystem-wide services and a healthy natural environment, in order to offer a range of social, ecological, and economic benefits to its citizens. These citizens have the knowledge and desire to make wise choices about water, are actively engaged in decision-making, and demonstrate positive behaviours to water use and management. Both approaches can result in a city where people want to live and work. They are most effective when implemented in tandem.

10.2.3 Strategies

Strategies for development include:

- defining a prioritization or decision-making framework for adaptation options;
- quantifying the previous qualitative indicators, CAPEX and OPEX, expected impacts and Green House Gas (GHG) emissions;
- providing for staff training and promoting climate literacy of clients, stakeholders and customers.

The development of a workable adaptation plan for stormwater services depends on continued momentum and resourcing, as well as understanding the limitations and successes of previous strategies, if any exist. Once the user has reviewed current strategies ([7.2.3](#)), assessed the risks and vulnerabilities arising from them ([7.4.3](#)) and reviewed the future risks, vulnerabilities and opportunities arising through their application under the impact of climate change ([8.2.2](#)), an informed strategy and response can be developed.

This can include:

- defining a prioritization or decision-making framework for adaptation options;
- undertaking scenario planning and detailed risk assessments;
- agreeing on priority areas, including source control;
- developing, documenting, quantifying and prioritising adaptation options;
- determining roles, responsibilities and measures of success;
- embedding adaptation options into investment decisions and relevant business planning frameworks and plans.

10.2.4 Risk management

It can be necessary to consider changes to risk management processes and frameworks. Users will need to understand how climate risk will or should be integrated (or not) within existing risk management practices. If there are already defined risk tolerances for stormwater systems, it is about integrating climate change into their mode of assessment.

Stormwater service providers will already be managing risk, but climate change can test the adequate integration of complex risks with multiple time horizons. Therefore, the user should critically analyse risk assessment systems.

Users of this document should be aware of and review AS 5534-2013.

Elements from this approach that need careful attention include the following.

- Consultation: more than for non-climate risks, engagement with external stakeholders – customers, local government, emergency response agencies and other community support agencies – is critical as they may bear part of the risk or be part of the response.
- Continuous improvement: climatic events, crossing of trigger points or warning thresholds should trigger reviews of risk estimations and adaptation responses; this is essential as the organization will still be in a learning process and uncertainty around impacts and interdependencies will be high.
- Risk context: climate risks have specific characteristics in terms of time-lag, uncertainty and cumulative factors (climate events of different nature occurring in rapid succession). This should be explored to support the risk analysis and prioritization. Useful elements for the risk context will have been defined during the vulnerability assessment.
- Risk analysis: climate trends are a key input into the analysis. Scenario planning techniques can be used to avoid being locked into one specific climatic future. It is essential to recognize the inadequacy of using past climatic data to predict future trends without integrating any correction factor for climate change.
- Screening and evaluation: this step can be more complex than for other risks, due to the complex cumulative and interdependent relationships between risks and the various time horizons to consider.

While not specific to climate change adaptation or stormwater services, ISO 31000 provides more general guidance on risk management.

10.2.5 Operation and asset management

The user will need to define how asset management practices and frameworks will change in response to expected climate change, taking into account:

- investment profiles for the system;
- design events;
- exceedance tolerances.

Some of the management practices will include:

- drain clean-out frequency;
- drain daylighting and waterway naturalisation;
- street cleaning frequency,
- pervious surface improvements (through land use policy change, etc.);
- retention basin construction programme;
- other WSUD asset construction programmes.

10.2.6 Metrics and targets

The user should define new or revised metrics and targets, based upon the understanding of risks and vulnerabilities gained through implementing [Clause 7](#).

10.3 Assess revised system

At this stage of implementing the guidelines in this document, the same assessment process as set out in [Clauses 7](#) and [8](#) should be repeated in order to identify the trend (assumed to be a reduction of risks and vulnerabilities) and confirm the maximization of opportunities, within expected or planned time horizons.

The assessment should allow replies to the following questions.

- Asset management: is it necessary to review stormwater or wastewater collection network renewal rates?
- Stormwater generation: has the pattern changed, increased or decreased?
- Stormwater as a resource: what is the pattern of availability and diversification? What are the alternatives and possible interconnections?
- Water resources pollution or eutrophication: how may water resources be protected? Has there been any contribution to climate change mitigation versus changing the balance or reducing GHG emissions (under Scope 1, 2, and 3 of any applicable GHG reporting program)?

NOTE Green House Gas reporting program requirements establish three reporting circumstances:

- 1) "direct emissions" from sources that are owned or controlled by the company;
- 2) emissions released into the atmosphere from the use of purchased energy;
- 3) all other indirect emissions that occur across the value chain and are outside of the organisation's direct control.

- Management of natural risks (e.g. fire, flood, water stress, geology): which risk plans need to be constructed?

10.4 Assessment protocols

At this stage of implementing this document, the same assessment process as set out in [Clauses 7](#) and [8](#) should be repeated in order to identify the trend (assumed to be a reduction of vulnerabilities) and confirm the maximization of opportunities, within expected or planned time horizons.

All contemplated adaptation responses should be assessed in accordance with the provisions of ISO 24566-1. These include whether and to what extent the adaptation response:

- integrates with urban and regional planning activities;
- contributes to sustainability of the community and the environment;
- contributes to the resilience of the community and the region;

- follows a whole-business approach;
- takes into account the principles of asset management for both existing and planned assets;
- lends itself to a long-term economic viability assessment;
- can be readily and accurately monitored.

10.5 Implementation

In order to implement the adaptations, the following should be met.

- The business planning and funding should be completed and confirmed.
- Governance options, roles and responsibilities should be confirmed, satisfactory and documented.
- Performance indicators addressing such items as assets, services, economic achievements, social matters, contractual achievements and customer satisfaction (e.g. complaints), should be established and calculated.

Once the adaption strategy has been assessed and evaluated, the assessment protocols determined, and the funding, governance and performance indicators established, the strategies should be implemented.

11 Proposed templates

11.1 Template for response options and actions

[Tables 1](#) and [2](#) are proposed as generic templates for recording relevant actions and effects.

[Table 1](#) is a proposed generic template for recording and reporting response adaptation options and actions. The contents relate to the examples shown in [Clause A.1](#) but with a different format.

Table 1 — Template for recording and reporting response adaptation options and actions

Part	Physical climate hazard	Potential impact	Type of measure: asset, service, economic, social, contractual, governance, strategic, risk management, metrics or targets	Short-term measure, long-term measure or system transformation	Description
1	Temperature changes	Outdoor employee discomfort; yielding sick leaves	Social Governance	Long-term	Adapt working hours when air temperature > x °C, e.g. working day becomes 5 am to 12 am during the event
2a	Intense precipitations	Stormwater overflows polluting and eroding receiving waters, network flooding causing human and urban damage, road closures or building inundation	Asset Strategic and risk management	System transformation	Disconnect all networks and retain all precipitation at the source by implementing SUDs (sustainable drainage system) or WSUD largely
2b	Water level rise	Inflow of water through stormwater or combined sewer overflows that have become lower than ambient adjacent water levels – rivers, lakes or sea	Asset Strategic, risk management and metrics or targets	Can be short-term but is likely to be long-term with general global warming.	Build or elevate sills or dykes
3	Severe winds	Loss of power, severe terrestrial damage	Asset Strategic and risk management	Short-term and long-term	Clean up damaged area and replant forests if appropriate
NOTE Other impacts can be assessed, such as those on biodiversity, pollution or the circular economy, according to the needs of the user.					

[Table 2](#) sets out in the 4th column the responsible organization to address the impacts and side effects.

Table 2 — Assumed responsible organizations, impacts and side effects

Part	Phasing: before, during and after the event	CAPEX and OPEX + / + / + / + + + ^a	Governance	Expected impact and side effects + / + / + / + + +	Impact in terms of climate change mitigation during implementation and operation (negative, neutral or positive)
1	Before: define plan During: apply	CAPEX: + OPEX: ++	Utility	Impact: + Side effect: no half day break	Implementation: neutral Operation: neutral
2	Before	CAPEX: ++ OPEX: +	Municipality	Impact: +++ Side effect: stronger flow in m ³ /s	Implementation: negative Operation: neutral
3	Before	CAPEX: +++ OPEX: +	Municipality	Impact: ++ Side effect: major events will not be fully retained	Implementation: negative Operation: negative
^a + = low, ++ = medium, +++ = significant					

11.2 Template for response categorisations

The user can also wish to record how adaptation options (based on [Table 1](#)) reflect local water supply situation within the city. This is set out in [Table 3](#) relative to the water supply situation in the city and the categories of responses. The categorization of the water supply situation is based on a categorization used in Australia.^[25]

[Annex A](#) sets out examples of responses to climate change and specific examples are given in Clauses [A.2](#) to [A.5](#) which have been cross-referenced in [Table 3](#). The examples in Clauses [A.2](#) to [A.5](#) can be applied under governance discretion to any of the city types.

Table 3 — Allocation of responses made

Water supply situation	Governance	Strategic	Risk management	Operation and asset management	Metrics and targets
City has water supply and distribution systems in place.	green roofs A.1 flood-proof buildings A.3	green roofs A.1 flood-proof buildings A.3	green roofs A.1 flood-proof buildings A.3	green roofs A.1 flood-proof buildings A.3	green roofs A.1
City has wastewater collection and treatment systems in place.	flood-proof buildings A.3	flood-proof buildings A.3	flood-proof buildings A.3	flood-proof buildings A.3	
City has stormwater collection and treatment systems (including wetlands) in place.	green roofs A.2 flood-proof buildings A.3 retention ponds A.4	green roofs A.2 flood-proof buildings A.3 retention ponds A.4	flood-proof buildings A.3 retention ponds A.4	green roofs A.2 flood-proof buildings A.3 retention ponds A.4	green roofs A.2 retention ponds A.4
City has natural waterways (rivers, lakes, etc.) fully integrated with drinking water, wastewater and stormwater systems.	tree pits A.2 permeable paving A.5	tree pits A.2 retention ponds A.4 permeable paving A.5	tree pits A.2 retention ponds A.4 permeable paving A.5	tree pits A.2 retention ponds A.4 permeable paving A.5	tree pits A.2 retention ponds A.4 permeable paving A.5
City has natural waterways (rivers, lakes, etc.) fully integrated with drinking water, wastewater and stormwater systems and provides for water reuse and recycling with the objective of minimizing fresh water use while meeting customer needs and preserving or improving the natural aquatic environment.	retention ponds A.4 permeable paving A.5	retention ponds A.4 permeable paving A.5	retention ponds A.4 permeable paving A.5	retention ponds A.4 permeable paving A.5	retention ponds A.4 permeable paving A.5

12 Monitor, review and update

Climate change adaptation requires an adaptive approach because of its nature; thus, reviews based on relevant monitoring should be conducted as frequently as necessary, including after extreme stormwater events. Monitoring and reviewing help to identify when key trigger points are approaching, measure overall planning or adaptation success and provide a benchmark for assessing the effectiveness of adaptation responses. Monitoring and review should be in accordance with the provisions of ISO 24566-1.

Monitoring is a fundamental ongoing process to assess changes in the environment and risk context, and can trigger or form a basis for the review of adaptation responses. Besides the metrics of stormwater management, it is important to monitor stormwater service standards, such as:

- the annual frequency of stormwater flood events;
- the projected duration of a stormwater flood event;
- the maximum population evacuation caused by a stormwater flood event.

It is also important to monitor other key relevant variables to climate change, including ocean and lake body temperatures, wind speeds and directions. Climate science and climate understanding are changing, and it is possible that government and non-government regulations and policies and organizations' own governance structures will also change.

Stormwater utilities should periodically review adaptation strategies and performance of adaptation responses, including after extreme stormwater events. This is because the effectiveness of some adaptation responses can only be evaluated after stormwater events. The review should confirm that the adaptation strategies are being effectively implemented and that adaptation responses in place are successful. After review, adaptation strategies should be updated as necessary, see ISO 24566-1:2023, 8.8.

Annex A (informative)

Examples of stormwater management responses

A.1 Green roofs

Table A.1 — Green roofs

Topic	Response
Nature of response	A longer-term response of an infrastructural nature imposed by the municipal authority as a requirement of obtaining a building permit. It is applied to developers of new industrial, commercial and institutional projects within the urban area.
Response approach	This is a whole-business approach by the urban authority as it seeks to minimize municipal investments in stormwater management and consequent insurance pay-outs to flooded properties. For the developer concerned, it can be a whole of business response with opportunities for other benefits to offset the investment costs (e.g. reduced air conditioning requirements in the building or offering employees recreational areas, including rooftop gardens).
Is it a risk-based approach?	Yes: the impacts of climate change, in particular changes in intensity and frequency of precipitation events, are well projected. Green roofs can absorb precipitation and at the same time withstand droughts, thus reducing risks.
Is it integrated with urban or regional planning activities?	Yes: consultations were taken with environmental groups, conservation authorities, building developers and other engineering firms within the urban area. There was no need to consult or take into account regional planning activities, but regional authorities were aware of the consultations.
Does it contribute to sustainability?	Yes: green roofs promote energy reduction within buildings by lowering the need for air conditioning, promoting air quality in the urban area through the absorption of carbon dioxide and the release of oxygen, reducing stormwater runoff and helping manage stormwater treatment to improve receiving body water quality.
Does it contribute to resilience?	Yes: but of a minor nature. Lowered demands for urban water service infrastructure and operations can benefit interdependencies such as consumption of power and reduced use of chemicals for stormwater treatment.
What key elements of the response apply?	There are several elements of the whole-business approach that apply to adaptive responses. These include: — embedding climate adaptation needs into asset strategies and plans; — understanding the community, including their willingness to pay for various adaptive options or responses; — embedding regulatory obligations within the climate change context; — using consistent risk assessment frameworks, methodologies and climate scenarios; — noting that assets need to be overdesigned or redesigned to account for future climate conditions.

Table A.1 (continued)

Topic	Response
Is it economically viable in the long term?	Green roof requirements have been determined in a number of studies to have long-term benefits for the property owner, largely due to reduced operating costs within the building, and social benefits arising for both the employees (access to a roof garden) and the community from cleaner air. These studies have determined the application of the requirement to new ICI (industrial, commercial and institutional) projects and have led some existing ICI projects to retrofit their roofing systems where possible. Some cities may offer an incentive plan to encourage the installation of green roofs.
Can the outcomes of the response be measured?	Yes. Studies can measure the reflectivity of green roofs compared to conventional roofs; localized air quality measurements can determine higher oxygen and lower carbon dioxide levels in the immediate area of larger roofs. In addition, projected cooling costs within the building compared to comparable buildings indicate lower operating costs.
Does the response support climate change mitigation?	Yes. The lower reflectivity of heat patterns and lower carbon dioxide generation both help to mitigate climate change.

A.2 Tree pit installations

Table A.2 — Tree pit installations

Topic	Response
Nature of response	The response involves the planting of trees (normally on sidewalks) in deep pits and surrounding the trees at surface level with porous surfaces that allow water to enter the pit and nourish the tree, with excess water being drained into the water table. This is a longer-term response of an infrastructural nature implemented by municipal authorities as a response to increased flows of stormwater from sidewalks and adjacent buildings. The long-term planning horizon is due to the rate of growth of the trees and their lifespan (up to 200 years).
Response approach	This is a long-term adaptive response which has a whole-business approach by the urban authority (seeking to minimize municipal investments in stormwater management and consequent insurance pay-outs to flooded properties). The whole-business approach takes into account the major social and environmental benefits of greening urban areas (cooling, air quality and social amenities).
Is it a risk-based approach?	Yes: the impacts of climate change, in particular changes in intensity and frequency of precipitation events, are well projected. Introducing urban tree planting programmes allows for the absorption of precipitation and at the same time provides shade from the sun and transpiration of groundwater to cool air temperatures.
Is it integrated with urban or regional planning activities?	Yes: consultations were taken with environmental groups, conservation authorities, community associations, land developers, landscaping firms and tree nurseries within the urban area. There was no need to consult or take into account regional planning activities, although regional authorities were aware of the programme.