BRIEFING NOTE

Flooding and Stormwater Management

Image: PJjaruwan/shutterstock

Effective stormwater management will be crucial for cities in Asia and the Pacific to build resilience against climate change. This briefing note provides practical information about the importance of managing flood risk, and some of the potential adaptation options that can help to build urban resilience.

→ KEY HIGHLIGHTS

Urban flooding, exacerbated by climate-induced precipitation and storms, is undermining resilience in many cities in Asia and the Pacific.

An increase in flooding and stormwater can have physical impacts and socio-economic effects, adding to the vulnerability of cities.

A combination of 'hard' and 'soft' adaptation solutions is required to help cities better adapt to floods and build resilience of communities, assets, ecosystems and businesses.

Identifying co-benefits of these adaptation solutions can help make a better case for climate action and contribute to the overall bankability of flooding and stormwater management projects.

Building on a city's initial plans and vision, **Cities Development Initiative for Asia (CDIA)** supports city stakeholders in identifying the drivers of urban flooding, undertaking climate risk and vulnerability assessments, and devising potential interventions for flood mitigation and drainage management. CDIA also connects cities with possible sources of funding for the proposed interventions.

Cities Development Initiative for Asia *is a multi-donor trust fund managed by Asian Development Bank (ADB) and co-implemented with Agence Française de Développement (AFD). It works closely with secondary cities in Asia and the Pacific to prepare bankable and sustainable infrastructure investments. CDIA, in collaboration with local authorities, identifies the city's most pressing infrastructure gaps, following which it develops project preparation studies (PPS) for infrastructure investments that can be funded by downstream agencies. It also integrates institutional strengthening and capacity building to ensure sustainability and successful implementation of proposed projects.*

Introduction

About 64% of Asia's 3.3 billion people are expected to be living in cities by 2050. Fast-growing cities face many challenges in building resilience to climate risks. Urban flooding is already undermining resilience in many cities in Asia.

Surface, river, and coastal floods across cities are likely to become more severe due to climate change. According to the Intergovernmental Panel on Climate Change, Asia is projected to experience an increase in monsoon precipitation and associated flooding, especially in the South, Southeast and East Asian regions.

CDIA acknowledges the need for climate change to be integrated at the preparatory stages of each project to help build urban resilience. **The aim of this briefing note is to highlight climate change impacts on flooding and stormwater management, and to introduce some potential adaptation options that can be integrated into urban development projects.**

Image: daus ngongo/shutterstock

Water overflows in the Krukut River, West Jakarta, Indonesia on February 25, 2020

Key themes

- Urban resilience
- Climate adaptation
- Flood management
- Stormwater
- Nature-based solutions
- Green infrastructure

Who is this meant for?

This briefing note is designed for city officials to provide guidance on:

1) how climate change can impact city development efforts in specific sectors;

2) the different types of solutions that can be adopted; and

3) how CDIA can help cities in their efforts at integrating climate change and urban resilience into city infrastructure projects.

Briefing notes are also available for: **1** Solid waste management **2** Urban renewal **3** Private sector finance for urban resilience

Definitions of climate change terminologies can be found in the CDIA glossary

In this briefing note, "$" refers to United States dollars.

Defining the Challenge

How does climate change impact flood and stormwater management in cities?

There are three principal – sometimes interlinked – drivers of urban flooding:

1. Heavy rainfall or meltwater when the infiltration capacity of the ground is exceeded,

Image: sainan 2522/shutterstock

2. Overflowing rivers when discharges exceed the capacity of water courses and water overflows on to floodplains, and

Image: Audreycmk/shutterstock

3. Storm-surges responsible for coastal flooding.

Image: Mysong/shutterstock

Urbanization is a significant cause of increased precipitation in cities and can exacerbate runoff intensity. Coastal cities are especially vulnerable due to extreme rainfall events and sea level rise. About 12 million people in 23 East Asian cities are at risk of severe flooding from rising sea levels, with assets of an estimated value of $864 billion exposed to a 1-in-100-year flood.

The severity and impact of urban flooding is determined by many factors:

Rapid and unplanned urbanization in many cities has made them particularly vulnerable to flooding, as land-use has changed from peri-urban vegetation to a largely paved built environment.

Surfaces in cities are mostly impervious, reducing rainfall infiltration rates, increasing surface runoff and changing drainage profiles, thereby increasing the frequency and intensity of urban flooding.

Stormwater drainage infrastructure in cities is often outdated, lacks proper and regular management, and does not have the capacity to tackle the increasing incidence and intensity of rainfall.

A lack of adequate critical public infrastructure networks also contributes to urban flooding. For example, a lack of proper solid waste management infrastructure inhibits and clogs storm water drains.

The impacts of urban flooding are not felt equally across the population. Poorer residents are more likely to live in informal settlements, in flood risk zones, and have less access to good quality infrastructure. They are also less able to respond in an emergency and recover from flood-induced losses.

Citarum River, West Java Province, Indonesia. Plastic pollution causes blockages to drainage channels in cities leading to flooding.

An increase in flooding and stormwater due to climate change can have both first order physical impacts and second order social and economic impacts in urban areas:

First order impacts:

- Intense and prolonged rainfall during the wet season can trigger **surface flooding, landslides,** high rates of river discharge, and surface erosion.
- Intense, short, and localized rainfall can **overwhelm the capacity of urban drainage systems** and result in flash flooding, which is harder to manage and predict.
- High velocity water can cause **damage** to **critical infrastructure** such as bridges, channel walls, and river embankments. Fast moving floodwater also carries materials and sediment which can damage infrastructure and obstruct stormwater outlets.
- Melting glaciers can **increase volume of water in river channels** and increase the risk of exceeding the capacity of the channels posing a major challenge for cities that are near river bodies.
- Coastal storms and tropical cyclones can **increase wave height and storm surges.** Combined with rising sea levels, this can overwhelm flood management infrastructure and coastal sea defenses resulting in widespread coastal inundation, and destruction of mangroves and coastal plantations.

Second order impacts:

- Urban flooding can have **significant socio-economic impacts** on the city's population in the form of loss of life and livelihoods, and damage to households and assets. This has long-term implications for income security and quality of life.
- Urban flooding, overflow of drainage systems, and waterlogging can **contaminate freshwater sources** and water supply systems, impacting public health through an increase in water and vector borne diseases.
- Cities can incur economic losses due to the **impact of urban flooding on critical infrastructure** such as electricity, water, transportation, and communication, and on sectors such as agriculture, fisheries, businesses, and industries. Most of these infrastructure systems are interconnected so the impact of floods on one can have knock-on impacts on others.
- Sea level rise and coastal flooding can result in s**altwater intrusion** of inland freshwater and aquifer resources with impacts on vegetation, crops, and drinking water.

Implications for project preparation: Undertaking a Climate Risk and Vulnerability Assessment (CRVA)

CDIA intervenes at the early stage of project investment.

Building on a city's initial plans and vision, CDIA can help identify drivers of urban flooding and map different impacts for the city to recommend potential interventions for flood mitigation and drainage improvements.

At the early stage of the project preparation study, CDIA may conduct a Climate Risk and Vulnerability Assessment to examine climate hazards, vulnerability and exposure that are material to the design, operation, and maintenance of stormwater management infrastructure over its life.

CDIA often conducts preliminary assessments of the socio-economic and environmental impacts of proposed interventions, and the city governments' capacity to deal with various aspects of flood risk management.

It can also support cities in accessing potential sources of funding for the formulated interventions.

Flooding causes major disruption in cities in Asia frequently blocking streets. Standing water can also have health consequences from water- and vector-born diseases.

Image: manzrussali/shutterstock

The Solutions

Climate change adaptation solutions are actions to adjust to climate change related shocks and stresses, to minimize disruption and damage. A wide range of actions can be considered:

Type of intervention	Examples for flooding and stormwater management	
'Gray' (structural) interventions (Str) Engineering solutions which provide a single function or service and rely on machinery, heavy construction, concrete or other manmade materials.	Storm drains, concrete, and pipes used to collect and channel stormwater into waterways.	 Image: Philip Arno Photography/shutterstock Image: HugYou/shutterstock
'Blue-green' nature-based (structural) solutions (NbS) Management and restoration of natural ecosystems to improve urban resilience. NbS can be mixed with hard solutions such as concrete drains and pavements, typically at a lower cost of implementation and maintenance.	Green roofs for stormwater runoff management, constructed wetlands for water treatment and stormwater management and coastal reforestation of mangroves.	 Image: Piyawat Nandeenopparit/shutterstock Image: Grisha Bruev/shutterstock
Operations and maintenance (O&M) Maintenance, management, budgeting, and other practices linked to functioning of assets and operations.	Changes in frequency of maintenance regimes, regular checks of infrastructure and repairment and replacement of assets.	 Image: Lina Mo/shutterstock Image: Alfred Nguyen/shutterstock
Policies and institutions (P&I) Government-led strategies, plans, guidelines and legal mandates.	Building codes and zone ordinances for land use planning, and developing or updating existing policies to include stormwater management.	 Image: November27/shutterstock Image: UldisZile/shutterstock

The Solutions continued

Type of intervention	Examples for flooding and stormwater management
Climate Finance (CF) Local, national, or transnational financing, drawn from public, private, and alternative sources, to support mitigation and adaptation actions.	Dedicated funds to integrate climate risks in the development and upgradation of stormwater management systems. Investing in insurance solutions to recover post flood losses.
Climate information (CI) Science-based or user-specific information for creating awareness and addressing climate risks and opportunities.	Early warning systems, climate risk assessments with a focus on flood risk and vulnerability and issuing flood evacuation guidelines for citizens.
Capacity building and knowledge management (CB&KM) Processes and mechanisms for acquiring and disseminating knowledge and building specific skills to address climate change.	Building capacity of city government stakeholders, engineers, water experts and civil society on climate change, urban flooding, and stormwater management through training, skills development, and digital communication.

Image: Bannafarsai_Stock/shutterstock

Image: Bannafarsai_Stock/shutterstock

Image: CDIA

Image: CDIA

Image: CDIA

Image: CDIA

Approaches to stormwater management which use an array of blue-green infrastructure measures

Sustainable Drainage Systems (SuDS): SuDS includes a range of techniques and engineering designs used to drain water by restoration of drainage conditions prior to site development.

Low Impact Development (LID): LID mimics a site's natural hydrology and focuses on water treatment close to the point of origin of runoff, as opposed to conventional systems which are designed to move stormwater off-site through pipes, ponds, curbs and ditches.

Vegetative Best Management Practice (BMP): Vegetative BMP includes a set of landscaping practices which are designed to help reduce peak stormwater runoff downstream through infiltration and storage.

Water Sensitive Urban Design (WSUD): WSUD's approach to land planning and engineering design integrates the urban water cycle, including water supply and stormwater, groundwater, and wastewater management, into urban design. The key objective of this approach is to minimize hydrological impacts of urban development on the environment.

Integrated Urban Water Management (IUWM): IUWM is a broader approach to the integrated management of all water sources within an urban catchment, that is natural and treated water supply sources, rainwater, wastewater, stormwater, reclaimed water, etc. with the core purpose of balancing efficiency, equity and environmental sustainability.

Rehabilitation of the Simao River and flood protection in Pu'er City, China.
CDIA Project in Pu'er China

Image: Credit to CDIA.

Co-benefits

Secondary benefits arise from implementing soft and hard adaptation solutions for effective flood and stormwater management. For example, re-vegetating river and coastal embankments with vetiver or mangrove plantations for better drainage of flood water and soil erosion control also help conserve water, contribute to carbon sequestration, create natural resource-based livelihood opportunities and lead to overall beautification of urban spaces.

Implications for project preparation: Making a case for specific solutions through an assessment of co-benefits

Wider co-benefits of these solutions can help build the story line during project preparation, make a better case for taking action on climate change and contribute to the overall bankability of stormwater management projects.

Co-benefits also help build synergies within the urban planning and development space and may provide more effective and efficient approaches to building resilience of communities, infrastructure, and urban ecosystems.

The following table provides a list of examples of established adaptation solutions that can be used for flood and stormwater management. For each solution, it indicates the co-benefits of the approach and also provides an indication of the cost of the solution.

Category	Adaptation solutions	Co-benefits	Cost of solution ($, $$, $$)
Str	**Construction of levees, flood diversion culverts and pumping stations** to capture heavy discharge and surface run off	Better urban drainage Water conservation	$$$
Str	**Urban drainage systems** such as permeable pavements, smart storm water tunnels, and bioretention basins to reduce volumes of direct urban runoff	Better urban drainage Increase in groundwater levels	$$$
Str	**Structurally** raise dike/embankment height and build toe protection to secure drainage	Protection of surrounding infrastructure	$$$
NbS	**Attenuation ponds and reed beds** to slow passage of water from surface runoff to the drainage systems	Filter water pollutants and enhance rainwater infiltration Improve groundwater levels	$$
NbS	**Rain gardens and vegetable filter strips** planted along paved surfaces, designed for capture and percolation of stormwater	Enhance rainwater filtration Improve community well-being Reduce soil erosion	$
NbS	**Re-vegetating river/coastal embankments** with vetiver, or mangrove plantations and embankment roughing such as brush layering, log protection and bamboo fencing	Natural resource-based livelihood opportunities Carbon sequestration Reduction in soil erosion	$
NbS	**Floodplain protection** options such as Green Corridor which reconnects rivers to natural floodplains, urban wetland protection, dredging urban river channels etc.	Greater community spaces	$$
O&M	**Dredging** of river channels to increase capacity	Improved drainage Infrastructure cost saving	$$
O&M	**Regular inspections** of drainage infrastructure and repairment/replacement where required	Reduction in disaster-linked damages and costs through timely maintenance and repair	$
O&M	**Weeding, mulching, inlet and outlet cleaning** and sediment and debris removal around drainage infrastructure	Improved drainage Infrastructure cost saving Reduction of soil erosion	$
O&M/ P&I/ CF	**Preparation of robust O&M plan and allocation of funds** for existing and new stormwater management infrastructure, including structural and nature-based solutions	Improved flood management Repair cost saving Infrastructure cost saving	$
CF/ P&I	Preparation of **flood management strategies** with budgets allocated, financing sources identified, and responsibilities allocated to requisite authorities	Better informed regulatory planning and action Integration of additional climate change impacts in stormwater management infrastructure planning and design	$
CI	**Flood hazard mapping and climate risk and vulnerability assessments** to understand the extent of impact of climate change-induced flooding and extreme events on drainage and stormwater management	Better flood preparedness Improved coordination between regulatory authorities	$
P&I/ CB	**Integrated and participatory urban water management** with stakeholder participation and community compensation	Greater community cooperation	$
CB&KM	**Early warning systems** such as mobile phone messages, emergency shelters	Greater community cooperation	$$

Implications for project preparation: Participatory infrastructure prioritization process

- CDIA recognizes that 'hard' and 'soft' solutions are an integral part of project preparation
- CDIA's project preparation studies include an in-depth infrastructure prioritization process in close collaboration with city stakeholders including sector analysis, review of cities' policies and regulations (including risk zoning), institutional capacity and needs assessment, operating practices, participatory development and climate-related adaptative capacity assessment.
- Based on these assessments, a comprehensive roadmap is built, which includes detailed adaptation actions and pathways such as institutional adaptation changes to plans, policies, codes, and budgets.
- The CRVA conducted at the preparatory stage can be factored to develop a detailed comparative analysis of structural and non-structural adaptation actions that reduce vulnerability to projected climate impacts and are robust to a range of climate-related scenarios and outcomes.

CDIA's Approach

Case study: Valenzuela Integrated Flood Risk Management

The challenge

- Valenzuela, one of the 16 cities that constitute Metro Manila in the Philippines, is highly vulnerable to increased intensity and frequency of flooding, typhoons and tropical storms.
- The city is bordered by three interconnecting rivers and is low lying with around 25 percent of the city below sea level, making drainage difficult.
- Lack of adequate drainage and periods of heavy rainfall and high tides cause flooding, and water stagnation in the city which can last over four weeks.
- According to the findings of CDIA's socioeconomic survey, a flood event in 2014 resulted in:
  - Structural damages to housing infrastructure. The majority of the respondents had to evacuate or temporarily relocate to shelters.
  - Long-term economic consequences in terms of the inability to go to work, repair expenses, requirement of medical services for flooding related illnesses or injuries and increase in prices of food supplies and transportation costs.
- An increase in the intensity of typhoons, storm surges and rainfall due to climate change will further exacerbate these issues, indicating the urgent need to build the city's and the region's flood resilience.

CDIA's approach to integrated flood risk management

- Recognizing Valenzuela's complex flooding challenge and the need to mitigate its impacts, the city government of Valenzuela approached CDIA for technical assistance on the development of a PPS for the Integrated Flood Risk Management Project.
- The main objective of this project was to address the recurring flood risks faced by Valenzuela using an integrated and coordinated approach, including physical and non-physical interventions in the city's flood-prone areas.

Solutions

- The PPS team prepared the report in close coordination with key city officials and recommended two overarching sets of interventions:
  - **Structural:** internal flood protection measures such as enlarging drainage channels and constructing box culverts for improving the city's internal drainage system, and external measures such as upgrading and retrofitting of flood walls to prevent external flood waters from entering the city.
  - **Non-structural:** enhancing capacity of the city on flood disaster risk reduction and management through flood hazard mapping, trainings, and stakeholder engagement.

Impacts

- As of now, five out of the eight external flood protection projects and almost all the non-structural interventions have been completed.
- Total investments linked to the PPS are estimated at $100 million.
- CDIA's assessment on the impacts of the interventions indicates the following:
  - Engagement of the city government in the design of interventions has improved the city's commitment towards sustainability.
  - The high priority given by the city leadership in the allocation of resources for integrated flood risk management implies continued political support long after the completion of the PPS.

Flooding and Stormwater Management in Practice

Flood Forecasting and Early Warning System, Kolkata, India. (ADB, UCCRTF, 2018)

As part of a wider program of upgrades to Kolkata's sewerage, drainage, and water supply services, ADB helped develop and implement a flood forecasting and early warning system providing forecasts and real-time updates on rainfall and inundation levels, among other climate and environmental data.

Study: Toward Resilient Kolkata
Project: Kolkata Environmental Improvement Investment Program

Wetland Park, Yangzhou China. (CDIA, 2008-2017)

CDIA worked with the city of Yangzhou in 2008 to integrate a new wetland park area into the city's redevelopment plan, which then doubled as a recreational area in 2017. When members of the CDIA team visited Yangzhou that same year to perform a tracer study, they found that the new park had reduced pollution and improved the ecology along the city's riverway.

Study: Yangzhou, China
Project: Yangzhou Old City Renewal and Waterway Rehabilitation

Nature-Based Solutions for Cities in Viet Nam: Water Sensitive Urban Design. (ADB, UCCRTF, 2019)

The UCCRTF has applied principles of Water sensitive urban design (WSUD), an approach that integrates water cycle management with the built environment through urban planning and design to the cities of Vinh Yen, Hue, Ha Giang, and Ho Chi Minh City in Viet Nam.

Publication: Nature-Based solutions for Cities in Vietnam
Project: Secondary Green Cities Development Project

Integrated Urban Flood Management in Chennai, India (Asian Development Bank, 2021)

The project will strengthen climate and disaster resilience in the Chennai-Kosasthalaiyar River basin by (i) improving climate-resilient urban flood protection infrastructure; (ii) enhancing urban flood preparedness of the Greater Chennai Corporation; and (iii) establishing measures for sustaining the operation and maintenance of the stormwater drainage system.

Project: Integrated Urban Flood Management for the Chennai-Kosasthalaiyar Basin

Water-sensitive informal settlement upgrading, Makassar city, Indonesia. (ADB, 2021)

The RISE project used a water-sensitive approach for wastewater treatment, flood risk reduction, and urban environment improvement using decentralized green infrastructure to biologically treat contaminated and polluted water. It has a particular focus on participatory planning and decision making.

Study: Water-Sensitive Informal Settlement Upgrading
Project: Revitalising Informal Settlements and their Environments (RISE)

What Can Cities Expect From CDIA Projects?

- City stakeholders can familiarize themselves with CDIA's climate risk management framework. This approach aims to assess and manage climate risks in the design of urban projects, to ensure a city follows a pathway towards long-term resilience.
- At first, CDIA will discuss the city's climate priorities with different city stakeholders, review key documents such as climate change plans and screen the project for climate risks.
- Depending on the outcome of this initial screening phase, CDIA may choose to conduct a climate resilience workshop, and/or draft a comprehensive climate vulnerability and risk assessment for the city.
- The risks and impacts identified in the assessment will be factored in the design of the project's specifications.
- CDIA's approach and processes are designed to enable effective and efficient collaboration with cities. It has linked 103 cities with downstream infrastructure financing estimated at $ 12.2 billion. CDIA has a strong capacity building component and is a vehicle for knowledge sharing among partner cities. The trust fund also maintains strong links with a broad range of development partners throughout the region.

To collaborate with CDIA and apply for support, you can visit www.cdia.asia or write to CDIA at cdia_info@cdia.asia. Visit our Interactive Webpage to learn about our focus on resilience.

Flooding threatens critical infrastructure such as electricity substations like this one in Nava nakorn, Prathumthani, Thailand.

Image: Skynavin/shutterstock

This briefing note was developed in collaboration with the Climate and Resilience Hub,WTW.

It was produced thanks to the support of the Agence Francaise de Développement and Expertise France.
Its contents are the sole responsibility of CDIA.
© 2022 Cities Development Initiative for Asia