A Vision for Mitigating Hydrometeorological Hazard Impacts Through Improved Transboundary River Management in the Ciliwung River Basin

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A VISION FOR MITIGATING HYDROMETEOROLOGICAL HAZARD IMPACTS THROUGH IMPROVED TRANSBOUNDARY RIVER MANAGEMENT IN THE CILIWUNG RIVER BASIN

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VISION PAPER

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Project Partners

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- BNPB (National Disaster Management Agency)
- Balitbang PU (Ministry of Public Works, Research and Development Center)
- BAPPENAS (National Planning and Development Agency, Directorate of Irrigation and Water Infrastructure)

At provincial level

- BBWS CC (Ciliwung and Cisadane River Watershed Authority)
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For more information about the project, please visit www.resilientciliwung.com

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Table of abbreviations

Abbreviation	Longform	Translation/meaning
Bappeda - DKI	Badan Perencanaan Pembangunan Daerah	Regional Development Planning Office - DKI
Bappeda – Kota / Kabupaten	Badan Perencanaan Pembangunan Daerah – Kota / Kabupaten	Local Development Planning Office – City / Regency
BBWS-CC	Balai Besar Wilayah Sungai Ciliwung Cisadane	Ciliwung Cisadane River Basin Authority
BKB	Banjir Kanal Barat	Western Flood Canal
BMKG	Badan Meteorologi, Klimatologi dan Geofisika	Meteorological, Climatological, and Geophysical Agency
BPBD	Badan Penanggulangan Bencana Daerah	Local Disaster Management Office
BPDAS HL	Balai Pengelolaan Daerah Aliran Sungai dan Hutan Lindung	Ciliwung River Basin and Protected Forest Management Agency
CBO	Community-based organisation	
CRB	Ciliwung River Basin	
Dewan SDA	Dewan Sumber Daya Air	National Water Resources Council
Dinas SDA	Dinas Sumber Daya Air	Local Water Resource Office
DPU-DKI	Dinas Pekerjaan Umum Daerah Khusus Ibukota	Local Public Works Department in Jakarta
DRR	Disaster Risk Reduction	
FEWS	Flood early warning system	
GSM	Global System for Mobile Communication	
KPBU	Kerja sama Pemerintah Badan Usaha	Public-Private Partnership
NGO	Non-governmental organisation	
RPJMD	Rencana Pembangunan Jangka Menengah Daerah	Local Mid-term Development Plan
RTRW	Rencana Tata Ruang Wilayah	Regional Spatial Plan
SDEW	Situ, Danau, Embung, dan Waduk	River, Lakes, Reservoirs and Dams
SKPDs	Satuan Kerja Perangkat Daerah	Local Government Agencies
SPR	Source-pathway-receptor model	
TKPSDA	Tim Koordinasi Pengelolaan Sumber Daya Air	Water Resources Management Coordination Team
WFC	Western Flood Canal	

Executive Summary

The Ciliwung River is one of 13 rivers that flows into Jakarta, the current capital city of Indonesia. It is the longest and most heavily populated of Jakarta's rivers.

The Ciliwung River Basin (CRB) is prone to frequent flooding, and the flood problem will continue to worsen in the future if no action is taken.

The current governance arrangements do not provide optimal support to address the complexity of the flooding issue. Therefore, this vision paper seeks to develop recommendations for how flood and river governance in the CRB can be improved, so that flooding can be tackled more effectively.

The purpose of this vision paper is, firstly, to understand the nature of urban flood risk in the CRB under current and future conditions. The second purpose is to identify existing governance challenges, and to set out recommendations for how governance arrangements may be improved so that the flood risk can be reduced.

Two future visions are presented. The visions exhibit alternative realities of what the CRB may look like in the future. The first, an optimistic vision, where recommendations have been adopted, decisive action has been taken to address flooding in the CRB, and impacts are reduced. The second, a pessimistic vision, where recommendations are not enforced, business continues as usual, and increasingly severe impacts are realised.

While each vision presents a potential future, they are independent of climate change scenarios. Climate change may be more or less severe in each case, however, under the optimistic scenario, the CRB will be well prepared to manage climate change impacts. The pessimistic vision represents a possible future where flooding worsens, regardless of the degree of climate change severity.

Urban flood risk

The drivers of flooding in the CRB are manifold and interconnected. The source-pathway-receptor model was used to identify the drivers. The *source* drivers of flooding are rainfall, coastal conditions (storm surge, tidal floods), and the impacts of climate change on these drivers, such as sea level rise, and the increasing frequency and intensity of heavy rainfall events. Further drivers are associated with conveyance *pathways*, including the river's morphology and physiography, erosion and sedimentation, urbanisation, land use change, drainage system capacity, the presence of riverbank settlements, build-up of waste materials, and land subsidence. Flood risk is further driven by the large population present in flood risk areas, the social and economic vulnerability of those living at the greatest risk, as well as the physical vulnerability of flood control measures that *receive* the flood waters.

Flood modelling enriched the understanding of the nature of flooding in the midstream and downstream CRB. In the midstream, fluvial flooding is expected to occur frequently. Even commonly occurring river discharge magnitudes result in high flood depths alongside the river channel, particularly in the sub-districts of Kebon Manggis, and Kampung Melayu. More severe flood scenarios demonstrate that widespread flooding at a depth of 150 cm or greater can be expected in Kebon Manggis, Kampung Melayu and Manggarai sub-districts.

While in the downstream coastal zone the regular river discharge conditions are not expected to result in flooding, the presence of coastal storms has a significant impact on the severity of flood depth and extent. Very high flood depths can be expected if inland and coastal storms occur concurrently.

The combined threats of climate change and land subsidence present a major challenge. Worst case scenario modelling suggests that Jakarta could be permanently inundated by 2100 should no action be taken.

Governance challenges

The institutions with responsibilities in the upstream, midstream, and downstream CRB at national, provincial, city, sub-district, and sub-sub-district level were identified, and the governance challenges that need to be overcome to successfully address flood issues in the CRB were established. The primary governance challenges are:

- **Enforcement and compliance issues with spatial planning** have meant that development has occurred without considering spatial plans. This has been attributed to inadequate development control and economic pressures. Spatial planning is critical as it can have subsequent impacts on other flood risk drivers.

- A lack of clear roles and responsibilities and limited availability of coordination mechanisms has meant that successful **vertical coordination** has been a challenge. Attempts to establish vertical coordination have been hindered by authority and funding issues. Vertical coordination is essential, as flood management responsibilities are distributed among governance levels.

- **Mechanisms for stakeholder coordination** are well-established for water resource management, however, flood management is not addressed within this system. Where other coordination mechanisms have been implemented, they have faced issues such as lack of a legal agreement and framework for coordination, and weak leadership.

- **Flood early warning** in the CRB is not fully integrated, with monitoring and detection, warning production, and warning dissemination being handled by separate agencies. In addition, there has been less attention paid to preparedness and response, and the public do not always respond to warnings in desired ways.

The recommendations to improve transboundary governance of the CRB are to:

1. Develop transboundary governance for flood risk reduction in the CRB through synergising local policies, regulations and planning among local governments who share the basin.

2. Synergise local, provincial, and national policies, regulations and planning between vertical levels of governance.

3. Develop multi-sector and multi-stakeholder governance for flood risk management in the CRB.

4. Integrate flood risk reduction and management in to the One River policy for water management.

5. Integrate flood hazard assessment into local/provincial policy and regulation for planning.

6. Update data for modelling and make it available for scientific and applied study and decision making.

7. Formally and informally integrate the role of community groups/volunteers/NGOs and CBOs within the pentahelix.

8. Build community resilience.

9. Explicitly address the Sendai Framework for Disaster Risk Reduction actions into development plans.

10. To reflect and draw upon good practices elsewhere.

Motorcyclists driving through flood waters in Jakarta, February 2017.
Credit: Xinhua / Alamy Stock Photo

1. Introduction

Purpose

The purpose of this vision paper is, firstly, to understand the nature of urban flood risk in the Ciliwung River Basin (CRB) under current and future conditions. The second purpose is to identify existing governance challenges, and to set out recommendations for how governance arrangements may be improved so that the flood risk can be reduced.

Nature of the problem

The Ciliwung River is one of 13 rivers that flows into Jakarta, the current capital city of Indonesia. It is the longest and most heavily populated of Jakarta's rivers.

The CRB is prone to frequent flooding, in particular in downstream Jakarta. This is owing to the tropical climate of the region, the basin's geography, and the position of Jakarta on a low-lying coastal delta. Additionally, human action has led to increased urbanisation, land subsidence, reductions in permeable green space, changes in basin response, and socio-economic conditions that contribute to increased flood risk.

It is likely that **the flood problem will continue to worsen in the future if no action is taken**. Continuing urbanisation, land subsidence, as well as rising sea levels and the increasing frequency and intensity of rainfall with climate change, will mean that flooding will only increase in severity.

To tackle flooding, it will be necessary to have effective governance arrangements in place. However, current governance arrangements do not provide optimal support to address the complexity of the flooding issue. Improving river basin governance will help to make sure that the most appropriate flood measures can be identified and successfully implemented.

Target audience

The target audiences of this vision paper are the national, provincial, and local governments, businesses, academia, communities, and NGOs in the provinces of DKI Jakarta and West Java, as well as academia and the media. The vision paper will be of particular interest to those in government, including the governors, mayors, and regents of the administrations through which the Ciliwung River crosses, as well as the planning departments, environment departments, the water resource agency/departments, the local and national disaster management offices, and public works at national, provincial, and local government levels.

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Structure

The structure of the vision paper is as follows. Firstly, two visions for the CRB are presented, one optimistic and the other pessimistic (Section 2). Next, the drivers of flooding are identified (Section 3), followed by the hazard and risk profile which presents risk maps for the midstream and downstream CRB (section 4). An overview of current governance arrangements is presented (Section 5) followed by identification of key governance challenges. Recommendations are given in Section 7, followed by limitations and references.

2. Visions

Two future visions are presented. The visions exhibit alternative realities of what the CRB may look like in the future. The first, an optimistic vision, where recommendations have been adopted, decisive action has been taken to address flooding, and impacts are reduced. The second, a pessimistic vision, where recommendations are not enforced, business continues as usual, and increasingly severe impacts are realised.

While each vision presents a potential future, they are independent of climate change scenarios. Climate change may be more or less severe in each case, however, under the optimistic scenario, the CRB will be well prepared to manage climate change impacts. The pessimistic vision represents a possible future where flooding worsens, regardless of the degree of climate change severity.

Pessimistic vision

- Governance challenges remain unaddressed, with no improvement in coordination. Policies remain fragmented.
- The data required to design effective mitigation strategies is unavailable, therefore mitigation is ad hoc and ineffective.
- Flooding in the CRB worsens, with more severe economic, environmental, and social impacts.
- Community resilience is low. The community are insufficiently prepared to deal with and recover from flooding. Preparedness and response to early warning is limited.
- Targets for the Sendai Framework for Disaster Risk Reduction and Sustainable Development Goals are not met.
- Under worst case climate change scenario (RCP8.5) and continued land subsidence, with no further intervention, flooding worsens, and a substantial proportion of Jakarta is permanently under water by 2100.

Credit: SOPA Images Ltd. / Alamy Stock Photo

Credit: Afif Ramdhasuma / Unsplash

Optimistic vision

- Flooding in the CRB is effectively mitigated through both structural and non-structural measures. Mitigation interventions are targeted to address the specific drivers of flooding.
- Data on the river basin is available, which supports stakeholder decision-making and informs the selection of appropriate and targeted interventions.
- Effective transboundary governance arrangements are established within the basin that enable horizontal and vertical synergies for flood risk reduction. Policies are coordinated.
- Community resilience has been effectively built through partnership with communities and community organisations. Awareness and preparedness among the community is high.
- Efforts have been made to reduce climate change impacts, and Sendai Framework for Disaster Risk Reduction targets and Sustainable Development Goals are met.
- The economic, environmental, and human impacts of flooding are reduced.

3. Key Flood Drivers in the Ciliwung River Basin

Hydro-meteorological disasters are the most frequent urban-centred disaster with severe accumulated impact loss. These disasters have become a global concern, as highlighted in the Sendai Framework for Disaster Risk Reduction 2015-2030.

A key hydro-meteorological hazard faced in the CRB is flooding. Flooding in the Basin occurs almost annually, with particularly severe floods having affected Jakarta in 2002, 2007, 2013, 2015 and 2020[1, 2, 3, 4]. The perennial and five-yearly excessive rainfalls have caused fluvial (river) and pluvial (surface) floods. In highly populated coastal cities/regencies, such as Jakarta, these urban floods are often worsened by tidal surges, and aggravated by dynamic pressure and several underlying key flood drivers related with technological and socio-economic conditions, unplanned urbanisation, development within high-risk zones and environmental degradation, causing severe damages, loss of life, and disruption of business[5].

In particular, during the 2002 and 2007 floods, the Jakarta Metropolitan Area suffered the most; almost 60% of the city's (highly populated) sub-districts were inundated, many Central Business Districts were affected, and airport activities were disturbed due to inundation of the airport access road1. These excessive rainfalls did not only inundate marginal areas, but also middle to upper class residential areas, which had never been exposed to flooding previously. The national newspaper Kompas reported that compared to the 2002 flood event, the 2007 flood resulted in significant increases in death toll (from 32 in 2002, to 48 people in 2007), the number of displaced people (from 40,000 to 316,825 people), lifeline damages (from 132 to 2,104 electrical post, clean water disrupted, and central telephone down), and economical losses (from 6.7 T to 12 T Rupiahs).

Flooding in Jakarta in 2002
Credit: REUTERS / Alamy Stock Photo

The Jakarta Metropolitan Area (referred to as Greater Jakarta) is an urban agglomeration which includes Jakarta and the surrounding cities of Bogor, Depok, Tangerang, and Bekasi (sometimes known as Jabodetabek). Greater Jakarta is located at the exit point of 13 rivers, that are part of a larger river system composed of 27 canals, drains, and rivers. The Ciliwung River has a length of around 109 km and a total area of approximately 347 km^2, stretching from Tugu Puncak in Cianjur Regency to Jakarta Bay, passing through Bogor Regency, Bogor City, Depok City and Jakarta Province (Figure 1)[6, 7]. However, most of the water from the Ciliwung River does not flow through the original Ciliwung Basin through central Jakarta. At the Manggarai Gate, in the midstream, the river is diverted into the Banjir Kanal Barat (BKB) / West Flood Canal (WFC). The canal diverts water from the Ciliwung, and several of Jakarta's other rivers, west away from the centre of the city and 'Ring One' such as the presidential palace, embassies, and other national government offices, to discharge at the Muara Angke estuary. The 'old Ciliwung' channel receives minimal waters which pass through to the Ancol estuary. Therefore, for flood management it is important to also take the West Flood Canal into account. As such, this study considers this extended basin area (around 446 km^2).

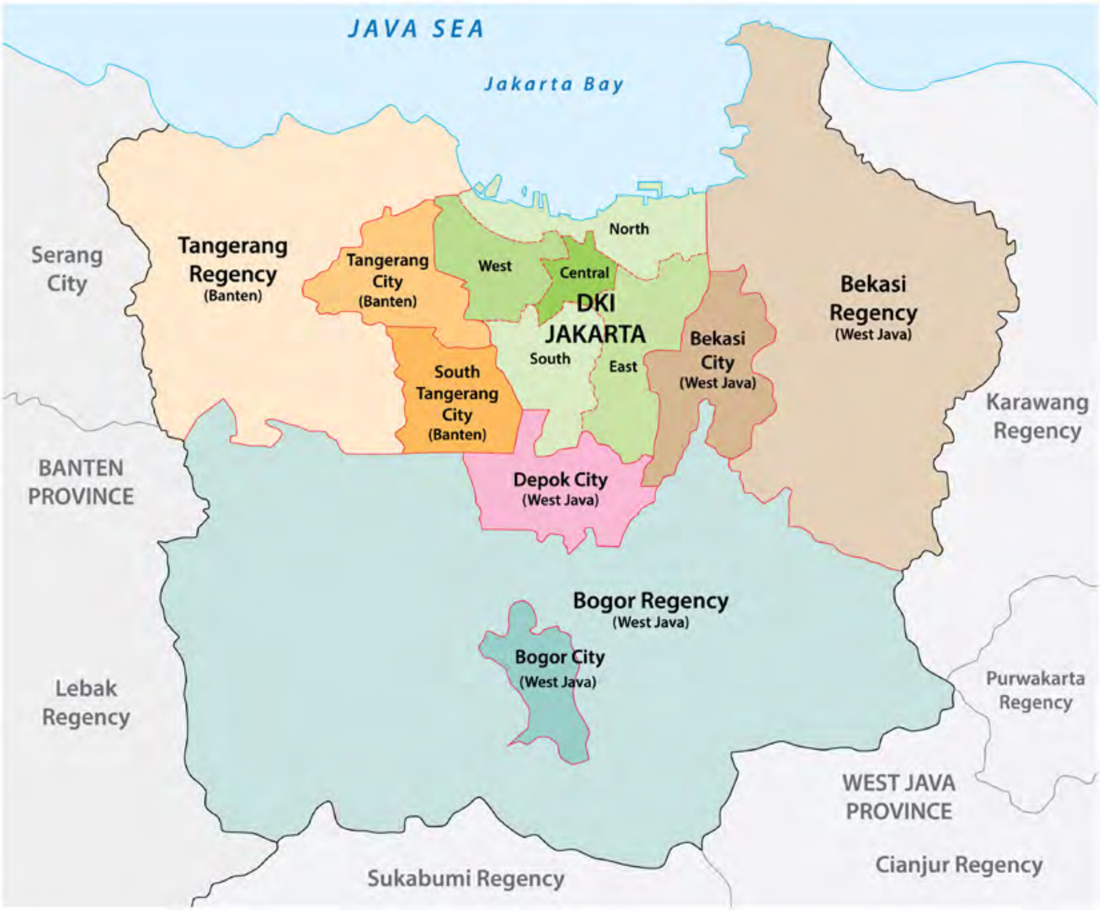


Figure 1. Map of administrative areas in Greater Jakarta (Vectorstock).

From a hazard point of view, the Greater Jakarta area is low-lying, with an average altitude of seven metres above mean sea level, and 40% of land area below sea level. With a population of more than 33 million people, Greater Jakarta has also undergone significant development. The trend of extensive horizontal and vertical physical metropolitan development, i.e., the construction of many private sector world-class super blocks, shopping malls, and waterfront cities, as well as the construction of the government owned programme on "one thousand towers for low-income high-rise apartment", has increased the city's weight, prevented the absorption of ground water, and increased run-off, subsequently contributing to flash flooding. The limited rainfall retention capacity combined with the extreme monsoonal rainfall, means that the region is naturally very prone to flooding caused by excessive saturated overflow and flash flood. In some areas, flooding is worsened by the insufficient carrying capacity of the rivers and existing drainage canals, and significant land-subsidence which has been triggered by exploitation of water extraction and the city's weight [8].

This section summarises the results of a study by [6] that identified the drivers of flood risk in the CRB using the Source-Pathway-Receptor (SPR) framework[9, 10]. As shown in Figure 2, 'sources' describe the conditions that lead to flooding (such as rainfall or rising sea level), while 'pathways' (e.g. river channels, drainage networks, urban surfaces) transfer flood waters to places where they may impact upon receptors. 'Receptors' are the aspects affected by flooding (people, built environments etc.). Such drivers are a consequence of both physical characteristics as well as human actions. It should be noted that the drivers of flood risk do not act individually and that it is often a combination of drivers that results in flooding.

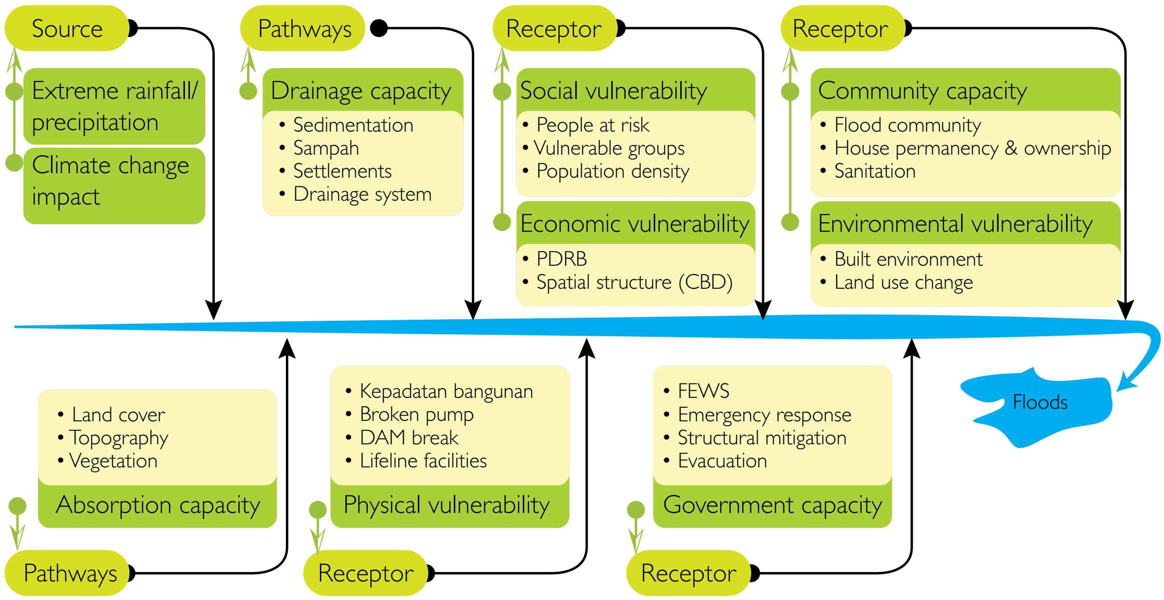


Figure 2. Key Flood Drivers in the Ciliwung River Basin[6]

3.1. Sources

3.1.1. Extreme precipitation

The intensity, duration and spatial extent of rainfall can dictate whether flooding occurs [11]. The CRB has a monsoon climate which brings heavy rainfall during the wet season and commonly results in flooding. The floods of 2014 and 2015 were associated with intensified monsoon rains resulting in extreme rainfall [3]. In addition, convective rainstorms that deliver short but intense downpours have been linked to flood events, particularly during the wet season [12]. Flooding in Jakarta is associated with heavy rainfall in the city, as well as in the upper watershed, where annual rainfall exceeds 3,000 millimetres [13].

3.1.2. Climate change impact

Climate change is likely to increase the frequency and intensity of heavy rainfall events in the future[14]. There is evidence that the rainfall in the wet season has already become more extreme, with the heaviest 1% of rainfall events showing an increasing trend[15]. Modelling suggests that further increases in the frequency and intensity of rainfall events is likely to raise the peak discharge of the Ciliwung and expand the flood inundation area and depth[16].

3.1.3. Storms surge

Coastal storms can bring storm surges along the Java coastline. A storm surge is a rise in water level above the expected astronomical tide[17]. A storm surge in combination with spring tide conditions may contribute to increased coastal flood risk in Jakarta[18]. Coastal storms can potentially lead to worsened flood impacts if occurring concurrently with river discharge[19].

3.1.4. Tidal floods (tides and backwater effect)

High tides in combination with river discharge can result in increased flooding. The backwater effect is created when the ocean tide slows down the flow of the river into the sea, which can result in increased inundation height and flood extent[11].

3.1.5. Climate change and sea level rise

Rising sea levels are a particular concern for delta cities like Jakarta where people and assets are located in low-lying vulnerable zones[20]. As global temperatures have increased, sea levels have risen, owing to the melting of polar ice, and thermal expansion of the oceans[21]. In Jakarta Bay, the rate of sea level rise is estimated to be between four and seven millimetres per year[22], and the rising trend is expected to continue in the future[20]. Sea level rise contributes to flood risk as it reduces the ability of the river to discharge into the sea, as well as reducing the effectiveness of coastal defences, especially when considered alongside land subsidence[6] (see Section 3.2.2).

3.2. Pathways

3.2.1. Absorption capacity

Urbanisation

Urbanisation throughout the river basin, driven by growing population and economic development, has contributed to increased flood risk. In recent decades, the CRB has undergone significant urban development, so that the majority is now heavily urbanised, particularly the lower and middle reaches which are dominated by settlements, trade, and industry[6]. Uncontrolled urbanisation and development has been identified as one of underlying problems contributing to the long-term flood risk in Jakarta[23]. Urbanisation has reduced the amount of green space, and increased impermeable surfaces, which reduces infiltration and increases run-off. Subsequently, this has impacted on the basin's response, increasing flood risk. Groundwater recharge is also affected, potentially worsening land subsidence[24].

Jakarta City
Credit: the authors

Land use change

Land use change has impacted upon how water flows through the river basin. While land use change, such as urbanisation, has occurred across the basin, it is currently occurring most significantly in the upstream area[6]. Land use changes, such as deforestation for agriculture[13], inappropriate agricultural activities, and urban expansion have decreased the capacity of the upstream area for infiltration and retention of water, and have subsequently impacted on the function of the upstream watershed as a catchment area[11]. Removal of vegetation has been noted to have intensified basin response, as water is no longer intercepted[24]. Trends towards decreased forest area and increased urbanisation in the upper watershed are estimated to increase the daily peak flow of the river 20% by 2030, potentially increasing flooding downstream[25].

River morphology and physiography

The size and shape of the river channel and physical geography of the basin can influence the likelihood of flooding. Basin characteristics such as vegetation cover, or permeability of soils determine the rapidity of runoff (speed at which water reaches the river channel)[10, 26].

3.2.2. Drainage capacity

Drainage system insufficiency

Inadequate capacity of the drainage system to cope with the large volumes of water during the rainy season contributes to flood risk[11]. In the CRB, the drainage systems have limited capacity to accommodate the volume of water, which results in flooding when rainfall is high and extreme. For example, during the

Riverbank settlement in Kampung Melayu
Credit: the authors

2020 flood event, rivers and drainage overflowed in 62 locations due to insufficient capacity. This problem is particularly apparent in the downstream area[6].

Erosion and sedimentation

Sedimentation can reduce the capacity of the river channel, making overtopping more likely. Removal of vegetation and inappropriate land use practices have increased rates of erosion and sedimentation[11,27]. Clearance of forested areas for agriculture in the upper watershed has been associated with increased sediment load of the Ciliwung River[24]. Sedimentation can contribute to reductions in the depth and width of the river channel, reducing its capacity.

Riverbank settlements (Slum area)

Settlements along the riverbanks have also been associated with decreased capacity of the river. There are illegal riverbank settlements along many of Jakarta's rivers, with the banks of the Ciliwung being particularly heavily populated[28]. The number of people at risk living in Ciliwung riverbank about 40% from total number of households, i.e. 72,000 households[5]. The encroachment of riverbank settlements into the river channel may contribute to reduced capacity of waterways[11].

Waste/garbage

Build-up of waste material in the river channel can further contribute to decreased river capacity[11]. The large population and significant human activity within the CRB generate large quantities of waste. Inadequate waste management has resulted in materials easily entering the drainage channel which has caused issues such as clogging and interference with the drainage channel capacity leading to flooding[6].

Land subsidence

Land subsidence has lowered the land surface relative to sea level, increasing the risk of both fluvial and coastal flooding. The sinking of the land surface has resulted in a considerable proportion of Northern Jakarta being below sea level, and this means that water from Jakarta's rivers cannot discharge readily into the sea. Land subsidence in Northern Jakarta has been rapid and severe, with annual average rates of approximately three to ten centimetres per year[29] and accumulated land subsidence in the Pluit region estimated to be around five metres[30]. The sinking has been caused by both natural compaction of alluvial soils, but also by human actions, including urbanisation and ground water extraction[8]. Continuing subsidence is estimated to increase flood inundation volume by 9.1% by 2050 compared to 2013[31].

3.3. Receptors

3.3.1. Socio-economic vulnerability

Population

Increasing population in the river basin exposes a greater number of people to flood risk. Population growth in Jakarta has been driven by economic growth and migration. While the population growth in the city itself has slowed in recent times[32], the population in Greater Jakarta, including the middle reaches of the CRB, has continued to increase rapidly. The population of Greater Jakarta expanded approximately 32%, from around 23 million in 2010[33] to over 33 million in 2020[34] see Table 1. With more people living in the basin and continued urban expansion into flood risk zones, there are more people at risk of flooding. It should be noted that these population figures (based on those possessing a resident ID card) are likely to be lower than the actual population figure, due to the presence of illegal settlers.

Table 1. Population of Greater Jakarta [34]. Cities/regencies 1-5 and 7-9 (yellow shading) concern the Ciliwung River Basin; cities/regencies 6 and 10-14 are the other administrative areas forming Greater Jakarta.

	City/Regency (Bahasa/*English*)	Population
1	Kota Jakarta Barat *(West Jakarta City)*	2,430,000
2	Kota Jakarta Pusat *(Central Jakarta City)*	1,060,000
3	Kota Jakarta Selatan *(South Jakarta City)*	2,220,000
4	Kota Jakarta Timur *(East Jakarta City)*	3,040,000
5	Kota Jakarta Utara (*North Jakarta City)*	1,780,000
6	Kabupaten Kepulauan Seribu *(Kepulauan Seribu Regency)*	30,000
7	Kota Bogor *(Bogor City)*	1,126,927
8	Kapubaten Bogor *(Bogor Regency)*	6,088,233
9	Kota Depok *(Depok City)*	2,484,186
10	Kota Tangerang *(Tangerang City)*	1,895,486
11	Kota Tangerang Selatan *(South Tangerang City)*	1,354,350
12	Kabupaten Tangerang *(Tangerang Regency)*	3,245,619
13	Kota Bekasi *(Bekasi City)*	3,075,690
14	Kabupaten Bekasi *(Bekasi City)*	3,899,017
	Total population (Jabodetabek)	33,729,508

Socio-economic vulnerability

Socio-economic changes have also placed more vulnerable people at risk. Jakarta city is very densely populated (around 15,900 people per square kilometre) (BPS in Martinez and Masron[35]), therefore competition for space is great. In addition, development has been unequal, leading to high levels of inequality[36]. As a result, access to space for residence and work has become difficult to obtain for the poorer residents of the city who have become marginalised in informal settlements on the banks of rivers [37]. These residents are highly exposed and vulnerable to flooding[28, 38]. As such, the socio-economic conditions in the city further exacerbate the risks faced.

3.3.2. Physical vulnerability

Design, operation, and maintenance of flood control measures

Limited functionality or failure of flood control measures can contribute to increased flood risk. A lack of maintenance of flood control measures has been noted to reduce their performance. For example, flood retention basins were noted to be functioning at 30% of capacity, due to not being suitably maintained[39]. Flood control infrastructure may also become broken or damaged, resulting in more severe flooding. It was identified that during the 2020 flood event, levees were broken or damaged in 44 locations[6]. Flood control infrastructure may also be vulnerable to failure in other systems, such as the breakdown of water pumps during the 2015 flood event due to power outages[7]. Alternatively, flood conditions may exceed the design criteria the infrastructure was intended for, resulting in breaching during severe floods[11].

4. Hazard and risk profile of Ciliwung River Basin

Flood risk modelling was conducted for study areas located in the midstream and downstream CRB. The types of flooding considered are fluvial flooding in the midstream, and compound fluvial and coastal flooding in the downstream. Each type of flooding was modelled under various scenarios, ranging from regularly expected conditions, to extreme 'worst case' scenarios.

4.1. Midstream fluvial flood risk profile

Fluvial flood risk was modelled in the midstream Ciliwung River[40]. The study focused on six sub-districts (Manggarai, Kebon Manggis, Bukit Duri, Kampung Melayu, Kebon Baru, and Bidara Cina) located upstream of the Manggarai Gate. Manggarai, Bukit Duri and Kebon Baru are situated in South Jakarta, and Kebon Manggis, Kampung Melayu and Bidara Cina in East Jakarta, where the river provides the border between the two districts.

The study area is significant as it is the location of the Manggarai flood gate, which is critical for controlling the flow of water from the Ciliwung and diverting it into the Western Flood Canal (WFC). Flooding is also particularly prevalent in this location. In addition, the study area includes the Manggarai station (in the Manggarai sub-district) - a rail station which connects other cities in Greater Jakarta, and which has been designated as an area for further development as a transport hub.

Fluvial flooding was considered under different scenarios, a 'regular' scenario (2-year return period), a 'moderate' scenario (50-year return period), and a 'severe' scenario (100-year return period) using 2D HEC-RAS modelling. Each of these scenarios denotes the magnitude of flooding that is expected to be equalled or exceeded in the specified number of years. For example, a 2-year return period is the magnitude of flood expected to be equalled or exceeded every two years, on average. The resulting flood risk maps (Figure 3) show the modelled inundation area extent and flood depth.

The maps display three flood depth ranges, 10-70 cm, 71-150 cm and greater than 150 cm. The height of 150 cm or greater was chosen as the highest category as it is the height at which overtopping of the river is certain, and flooding at this significant level or above results in major disruption.

Figure 3(a) shows a 'regular' fluvial flood scenario. Under this scenario much of the inundated area lies directly next to the river channel, this is except for in the Kebon Manggis sub-district, where the inundated area extends east away from the river channel (and to an extent in Kampung Melayu). Flood depths, even under this 'regular' flood scenario are greater than 150cm in many places, demonstrating that even regular river conditions (that can be expected to occur on average every two years) may still result in significant flood depths. The modelling is consistent with the observation that Manggarai, Kebon Manggis and Kampung Melayu experience annual flooding.

Under the 'moderate' 50-year return period scenario (Figure 3(b)), the inundation area increases compared to the regular scenario. In Bidara Cina and Kebon Baru, in the south of the study area, the deepest flood remains immediately next to the river, with some small areas of inundation extending away from the river channel in the north of the two districts. The greatest increase in inundated area occurs in Kebon Manggis, where a considerable proportion of the district is inundated to 150cm or greater. There is also extension of the flood into a large portion of Manggarai sub-district, however here the flood depths are lower (10-70 cm, with some areas of 71-150 cm). For further details of the impact of flooding in the Manggarai sub-district and on the railway station, please see Kesuma[41].

The Manggarai flood gate
Credit: The authors

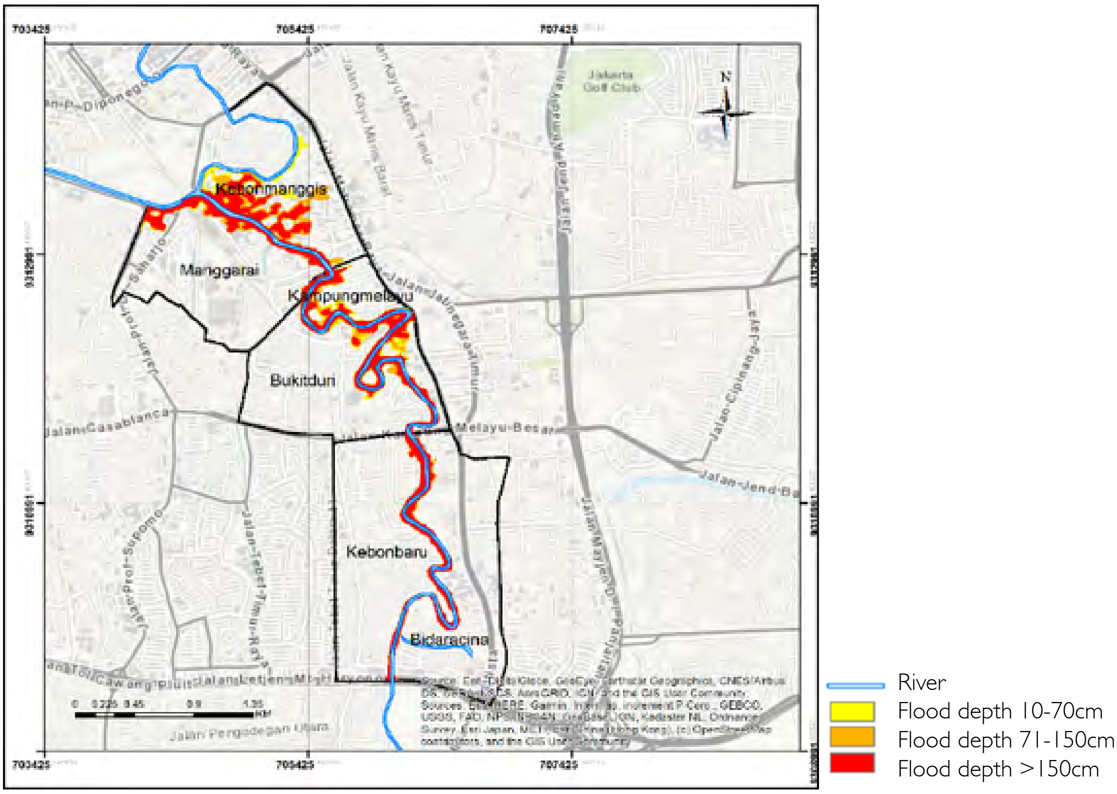


Figure 3.a: A regular' scenario (2-year return period)

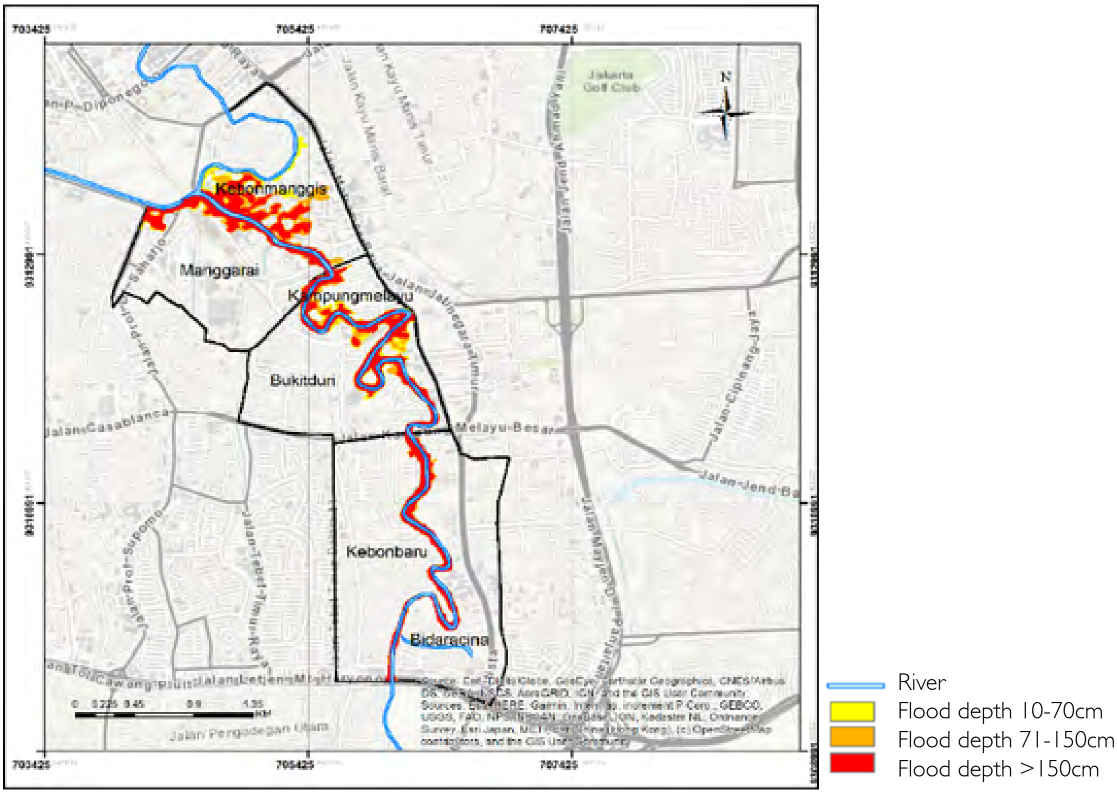


Figure 3.b: A 'moderate' scenario (50-year return period)

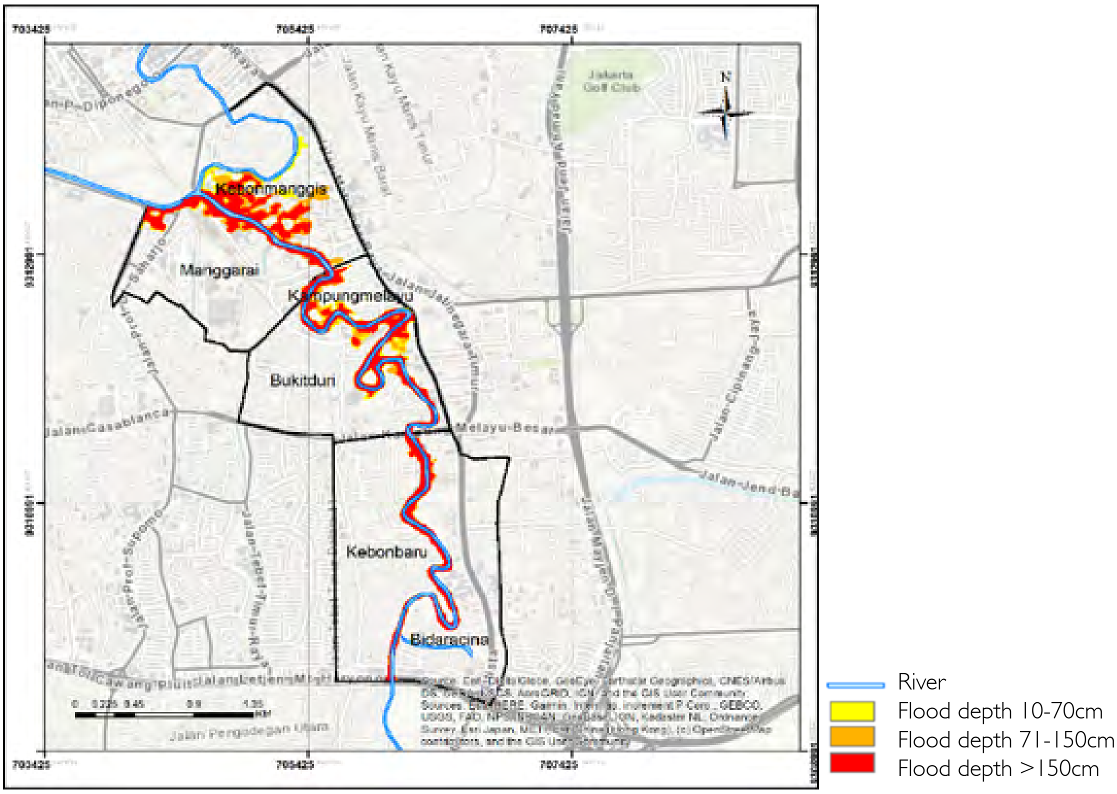


Figure 3.c: A 'severe' scenario (100-year return period)

Figure 3. Inundation maps for fluvial flood risk in the midstream[40]

Under the severe flood scenario (Figure 3(c)), most notably, the extent of the deepest flood water expands in Kebon Manggis, where most of the sub-district is inundated to 150 cm or above. Flood depths in the east of Manggarai sub-district also increase. In Bukit Duri and Kampung Melayu, the inundated area is similar to that of the 50-year scenario, however flood depths have increased in some areas.

Overall, increasing the severity of the fluvial flood scenario results in expansion of the inundated area, most notably in the Kebon Manggis and Manggarai sub-districts. This area is particularly affected, likely owing to the backing up of water behind the Manggarai gate and overtopping of the river channel. While the capacity of the Manggarai Gate has previously been increased, this issue persists[41].

4.2. Downstream flood risk profile (compound fluvial and coastal)

Compound flooding occurs when coastal storm conditions coincide with river discharge. The impacts of compound flooding were investigated for the Muara Angke study area (Figure 4) by Bennett and colleagues[19]. This site was chosen as it is where the WFC discharges into the Jakarta Bay. To calculate the impact of the compound floods, discharge hydrographs of various magnitudes were combined with the sea water levels from the coastal model[19]. The different coastal storm and river discharge scenarios are given in Table 2.

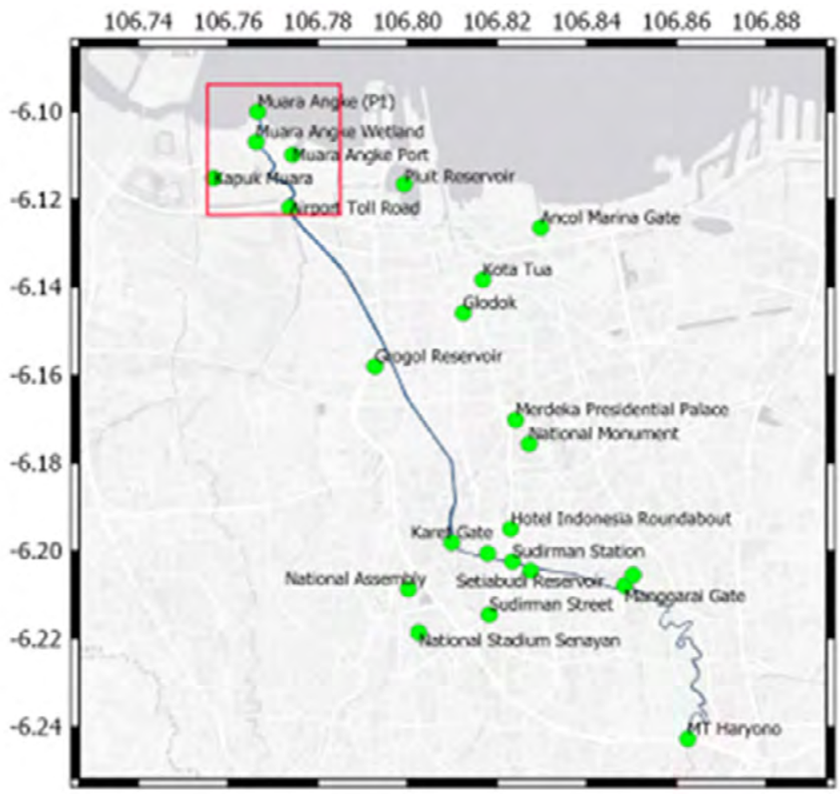


Figure 4. Map of Jakarta showing the Ciliwung River (blue) and Muara Angke study area (red box).

Table 2. The coastal storm, river discharge, and climate change conditions used to develop the compound flood scenarios (adapted from Bennett and colleagues[19]).

	Scenario	Description*	Magnitude
Coastal storm scenarios	W1	*'Regular'* A 1 in 1-year storm, equating to an annual exceedance probability of 100%.	Wave height: 1.89m Wind speed: 20.21 m/s
	W100	*'Severe'* A 1 in 100-year storm, with an annual exceedance probability of 1%.	Wave height: 2.16m Wind speed: 38.65 m/s
River discharge scenarios	Q2	*'Regular'* A 1 in 2-year event, with an annual exceedance probability of 50%.	River discharge: 223m^3/s
	Q100	*'Severe'* A 1 in 100-year event, with an annual exceedance probability of 1%.	River discharge: 563 m^3/s
Climate change scenarios	RCP4.5	Moderate emissions scenario	Sea level rise: 0.7cm/year
	RCP8.5	High emissions scenario	Sea level rise: 1.0cm/year

*Example: A 1 in 100-year coastal storm is the magnitude of coastal storm that is expected to be equalled or exceeded every 100 years, on average. This equates to an annual exceedance probability of 1%, i.e. there is a 1% chance of a storm of this magnitude or greater occurring in a given year. For example, even if a 100-year magnitude storm occurred last year, there is still a 1% chance it could also occur this year.

It was found that coastal storms have a substantial influence on whether flooding occurs in the Muara Angke study area. While *regular* (Q2) river discharge does not result in flooding in the Muara Angke study area by itself (Figure 5b), flooding occurs when this is combined with *regular* (W1) coastal storm conditions (Figure 5c). This indicates that even a compound event of *regular* magnitude can lead to significant flooding in Muara Angke.

It was also found that flood severity in Muara Angke is more sensitive to changes in the magnitude of the coastal storm, compared to changes in the magnitude of river discharge. Flood inundation area and depth increase with increasing magnitude of the coastal storm, even when river discharge remains at *regular* magnitude. In addition, flood inundation area and depth increase significantly more with increasing coastal storm magnitude, compared to the changes that are seen with increasing river discharge.

Severe coastal storm (W100) and severe river discharge conditions (Q100) were combined to indicate the possible 'worst case' compound flood scenario (under current climate conditions) (Figure 6). Compared to the regular flood scenario, the worst case scenario shows an extension of the inundated area to the west and east of the estuary, and deeper flood waters around the estuary. The same scenario was also modelled with the addition of a 1m storm surge (Figure 6b), which contributes to significantly higher flood depths and inundation extent compared to no surge. With surge, flood depths are increased by 0.8-1.4 m on average, and the flooded area extends even further west, east, and south.

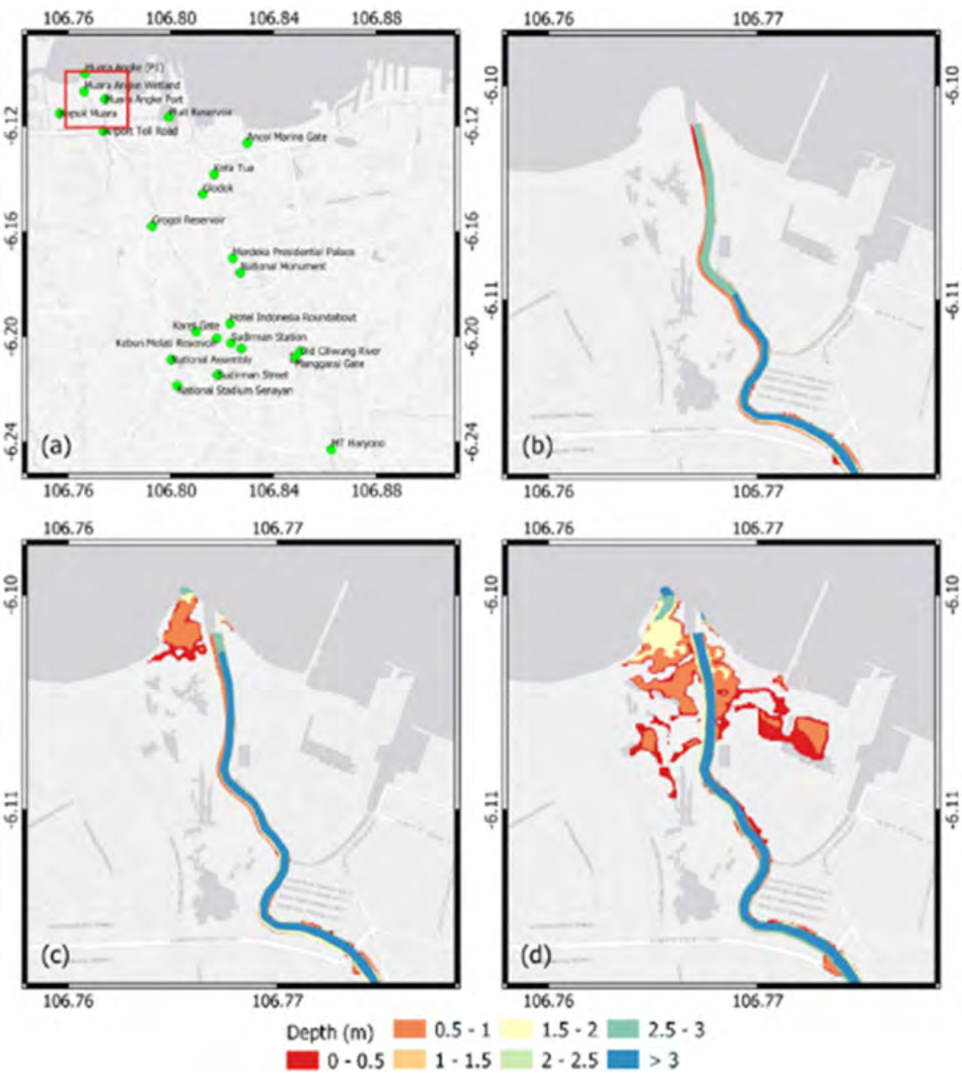


Figure 5. Flood depth and extent in the Muara Angke study area (a), arising from regular river discharge (Q2) in combination with (b) no coastal storm; (c) regular coastal storm (W1); (d) severe coastal storm (W100). All cases are with 0m storm surge.

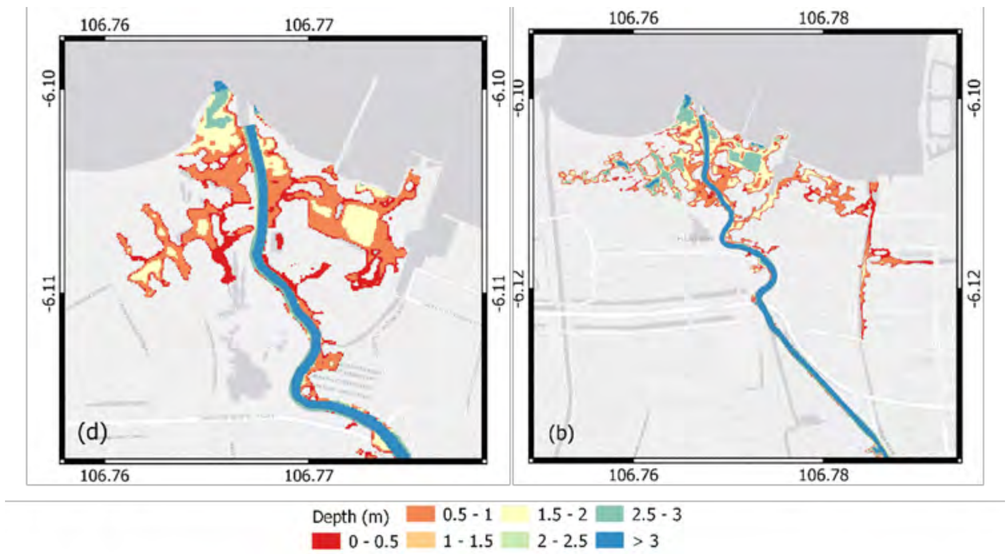


Figure 6. 'Worst case scenario' flood depth and extent in the Muara Angke study area under current climate conditions, resulting from severe river discharge (Q100) combined with (a) a severe coastal storm (W100), and (b) a severe coastal storm plus a 1 metre storm surge.

The cause of the flooding in Muara Angke is not direct overflow from the sea, as the area is protected by the sea wall. Even during a severe storm with 1m sea surge, the sea wall, at a height of approximately 4.8 m, remains above the height of the water level (around 4.3 m). Instead, the flooding occurs due to the elevated water level in Jakarta Bay, which prevents the WFC from draining, and subsequently results in breaching of the flood canal.

Lastly, the impacts of climate change and land subsidence were considered. Flood inundation in the year 2100 was simulated accounting for sea level rise with climate change and continued land subsidence (Figure 7). This can be considered an extreme worst-case scenario, as it assumes continued land subsidence (at a rate of 10 cm/year), and no alternations to sea defences. Two climate change scenarios were considered, a moderate emissions scenario (RCP4.5), and a worst-case scenario (RCP8.5). Under both climate scenarios, there is permanent and widespread inundation of Jakarta by 2100 which occurs regardless of storm magnitude. While it is acknowledged that land subsidence is unlikely to occur at a constant and spatially uniform rate, the results indicate the extreme impacts that could occur in some parts of Jakarta should no action be taken.

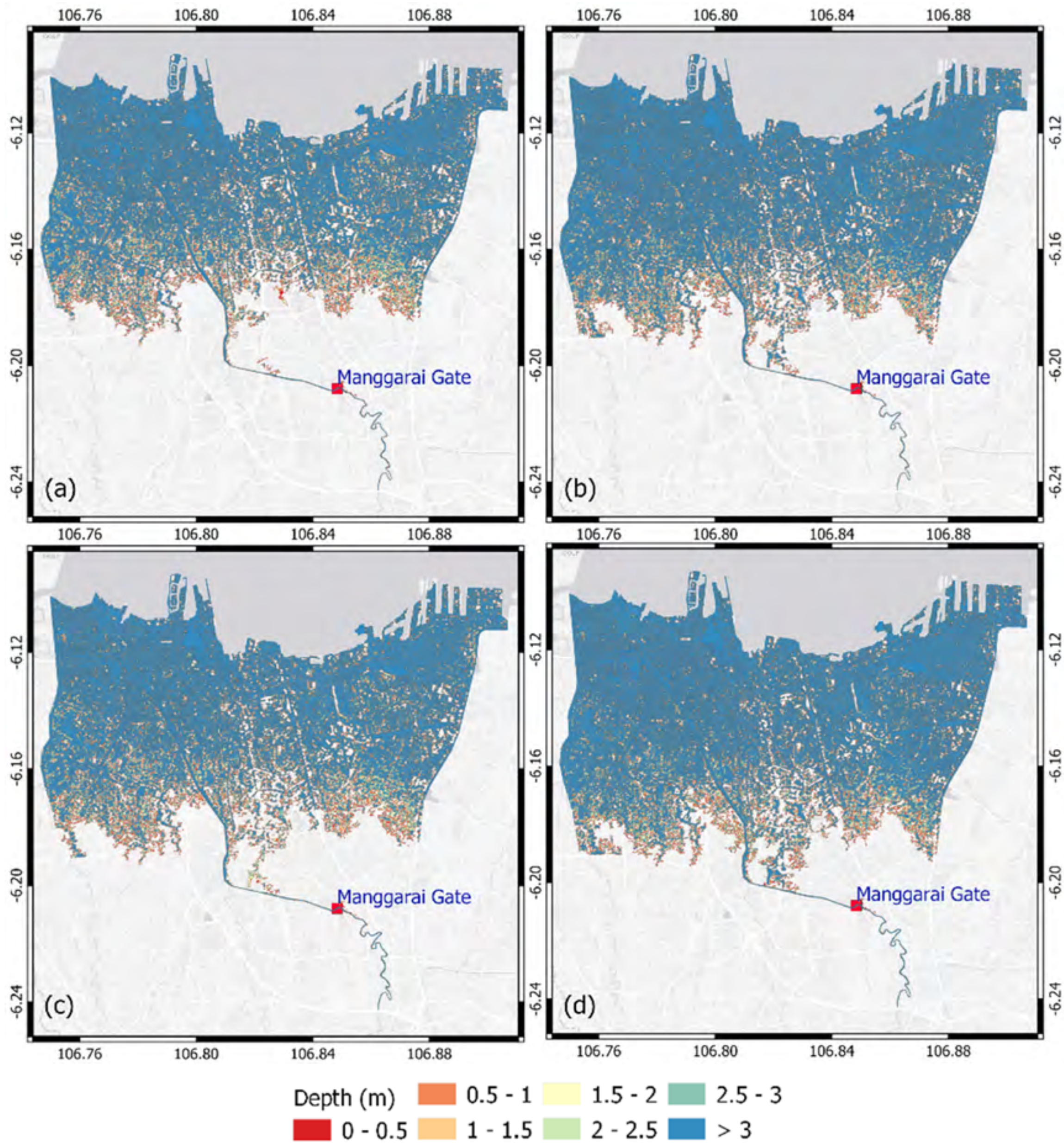


Figure 7. Flood inundation maps for the year 2100 considering sea level rise under climate change and a continued rate of land subsidence (10cm/year), with a 1m surge. Maps (a) and (b) show regular river discharge (Q2) combined with a regular coastal storm (a) and a severe coastal storm (b) under a moderate emissions scenario (RCP4.5). Maps (c) and (d) show the same compound flood scenarios under a high emissions scenario (RCP8.5).

5. Governance arrangements in the Ciliwung River Basin

The current governance arrangements and challenges in the CRB were identified through the synthesis of several inputs, including systematic literature reviews [42, 43, 44, 45, 46], and a series of interviews and focus group discussions with key basin stakeholders [6, 7, 47, 48, 49].

5.1. Governance overview

Indonesia has 34 provinces, that are subdivided into regencies and cities, and further divided into districts and villages. Since 1999, the decentralised government system in Indonesia has been in place, based on Law No. 22 of 1999 regarding local governments. The Law transferred autonomous authority to the local government (city and regency level). From the perspective of disaster management, Law No. 24 of 2007 regarding disaster management emphasises that the local government has the highest responsibility to protect the safety of the people.

Water resource management in Indonesia is conducted based on the river basin hydrological units, and there are about 133 units across the country[50]. The CRB is one of the most important and critical, as it is the longest river basin passing through Jakarta, and it also has the highest population of riverbank settlers in the city. In 2010, about 26,166 households lived on the banks of the Ciliwung river, compared to 45,106 households distributed across the 12 other river banks (Kali Cakung, Kali Jati Kramat, Kali Sunter, Kali Buaran, Kali Cipinang, Kali Baru Timur, Kali Baru/Ps.Minggu, Kali Krukut, Kali Grogol, Kali Pesangrahan, Kali Angke, and Kali Mokervart)[5].

The ecosystem of the CRB is divided into upstream, midstream, and downstream (Asdak, 2010 in Rahayu, M.S.B[7]). According to spatial planning, the upstream ecosystem is designated as a conservation area, characterised by a slope of more than 15%, no flood plain area, and a preserved forest area for water absorption. The downstream area is built environment, characterised by a slope of less than 8%, a flood plain area, and an agricultural area with irrigation system. The midstream area is the transition between downstream and upstream. In the downstream, the CRB covers not only the natural river, i.e. the old Ciliwung river, but also the man-made WFC[7].

Contrary to the decentralised government system described above, Indonesia's 'One River' policy places the mandate of flood risk management on the central government as part of their authority to manage each river basin in Indonesia. For example, the Ciliwung-Cisadane River Basin Authority (BBWS-CC) under Ministry of Public Works, has responsibility for water resource management as well the flood risk management in the Ciliwung and Cisadane river basins. However, owing to the decentralised multi-level governance system, there are multiple other organisations that manage flood risk from a variety of sectors, such as water resource management, disaster management, regional and spatial planning, and forestry. Rahayu, M.S.B[7] identified the main stakeholders/institutions and their roles in the ecosystem of the Ciliwung River Basin (upstream, midstream, and downstream), each of which is briefly described in this section.

5.2. Roles of institutions in the upstream and midstream CRB

5.2.1. Ciliwung-Cisadane River Basin Authority (BBWS-CC)

BBWS-CC is an organisation of technical implementing units of the Ministry of Public Works. It possesses duties and functions to manage water resources, as well as flood risk reduction, in the CRB, as stated in the Water Resources Management Pattern and Plan document (2015-2035). The Pattern and Plan document contains strategic plans regarding scenarios in water resources management efforts for each river basin, which are further elaborated into activities. There are five pillars of management efforts contained in the document for the Ciliwung-Cisadane: Conservation of water resources; utilisation of water resources; water damage control; water resources information system; and community empowerment.

5.2.2. Water Resources Management Task Team for Ciliwung River Basin

In addition to the Water Resources Management Pattern and Plan document, on 2nd June 2020, the Ministry of Home Affairs initiated a special joint commitment for handling floods and landslides in Greater Jakarta, which was agreed upon by six ministries and several provincial and district/city governments. This joint commitment consisted of strategies, activities, locations, persons in charge, and indicators for the implementation of activities, agreed upon by the Ministry of Home Affairs, Ministry of Agrarian Affairs and Spatial Planning/National Land Agency, Ministry of Public Works and Housing, Ministry of Forestry and Environment, and the Head of the National Disaster Management Agency, as well as Jakarta and West Java provincial governments, and district/city governments, including Bogor Regency, Bogor City, and Depok City.

5.2.3. Citarum-Ciliwung River Basin and Protected Forest Management Agency (BPDAS HL)

BPDAS HL is the technical implementation unit of the Ministry of Environment and Forestry in the Citarum-Ciliwung river basin. In 2013, BPDAS HL reviewed and developed the Ciliwung River Basin Management Plan. In 2015, the plan was subsequently internalised into the RTRW (local and regional spatial plan) and the RPJMD (local and regional mid-term development plan). These plans have accommodated the future management of the CRB, which is expected to reduce the risk of flooding through: critical land rehabilitation, optimisation of land use following the carrying capacity of the CRB, soil and water conservation, vegetation management, increasing awareness and participation of related institutions, the development of river basin management institutions to improve coordination, and building stakeholder commitment to follow up on arranged programmes.

5.2.4. Ministry of Agrarian Affairs and Spatial Planning/National Land Agency

In relation to flood risk management, the role of the Ministry of Agrarian Affairs and Spatial Planning is in the Protection and Control of SDEW Spatial Utilisation (rivers, lakes, reservoirs, and dams). This includes the Land Registration Regulation for rivers, lakes, reservoirs, and dams (Regulation No. 30 of 2019), which regards the registration or certification of water body ownership status. This is important for clarifying the ownership of a water body and subsequent assignment of responsibility. The inventory of lakes in the CRB is essential for the Regional Spatial Plan to determine the treatment chosen in planning and implementing flood risk reduction. Another important aspect for flood risk management within the Ministry is the function of the Directorate of Spatial Utilisation Control in formulating and implementing policies for controlling space utilisation and land use change.

5.2.5. Regional Development Planning Agency (Bappeda) of West Java Province

Bappeda of West Java is responsible for all development planning within the province. In terms of flood management, the Agency has coordinated with several other provincial institutions in West Java, including the Office of Management of Water Resources and the Department of Environment, to implement the Ciliwung River Basin Management Programme. Furthermore, the Agency has implemented a coordination forum for regional apparatus at the provincial level to coordinate with the government at the district level. Regional coordination forums are routinely held once a year to review or plan aspects to be prioritised. Bappeda of West Java Province has also collaborated with business entities (KPBU) in the water resources sector.

5.2.6. Water Resource Department of West Java Province (Dinas SDA)

The Water Resources Department of West Java Province plays a significant role in the structural mitigation programme of the Ciliwung River. Responsibilities are divided by river order, with the first river order handled by the national government (BBWS), and the second and third river orders handled by the province (Dinas SDA at the provincial government level). The fourth and latter orders are handled by the city and district governments (Dinas SDA at local government level).

5.2.7. Forestry Department of West Java Province

The Forestry Department of West Java Province is responsible for the programme on the rehabilitation of critical land. During 2019-2020, the Forestry Department of West Java Province coordinated planning, so that the general allocation funds were posted, and priority locations identified.

5.3. Roles of institutions in the downstream CRB

In the downstream CRB, efforts are being made to increase public awareness and preparedness to face floods. The flood warning system is an important part of the community preparedness mechanism, as it is a key factor linking the emergency preparedness and response stages. Rahayu and Iglesias[51] noted deeply that there are many partners involved at community level in Jakarta's flood early warning system. The key actors at the national and transboundary governance until subdistrict level involved in flood early warning system have been identified as strongly related with downstream warning activities[47]:

5.3.1. Meteorology, Climatology and Geophysical Agency (BMKG)

BMKG currently develops an impact-based weather forecast to support flood warning. It estimates the impact of precipitation and what the community should do to respond to the impact. The information produced by the BMKG is then be disseminated through various platforms such as the web, Instagram, and Twitter.

5.3.2. Ciliwung-Cisadane River Basin Authority (BBWS-CC)

BBWS-CC operates 41 water level monitoring stations and 31 water prediction stations using GSM telemetry. Water levels are monitored through 29 rainfall stations, 41 water monitoring stations, and 16 monitoring points through CCTV at: the Ciliwung Katulampa Dam, Panus Bridge Depok, Manggarai, Cisadane River, Batu Market, Cileungsi River, and Gunung Putri Cibodas. Information on the water level stations of the CRB is divided into three zones, namely, the Katulampa Dam as the upstream zone, the

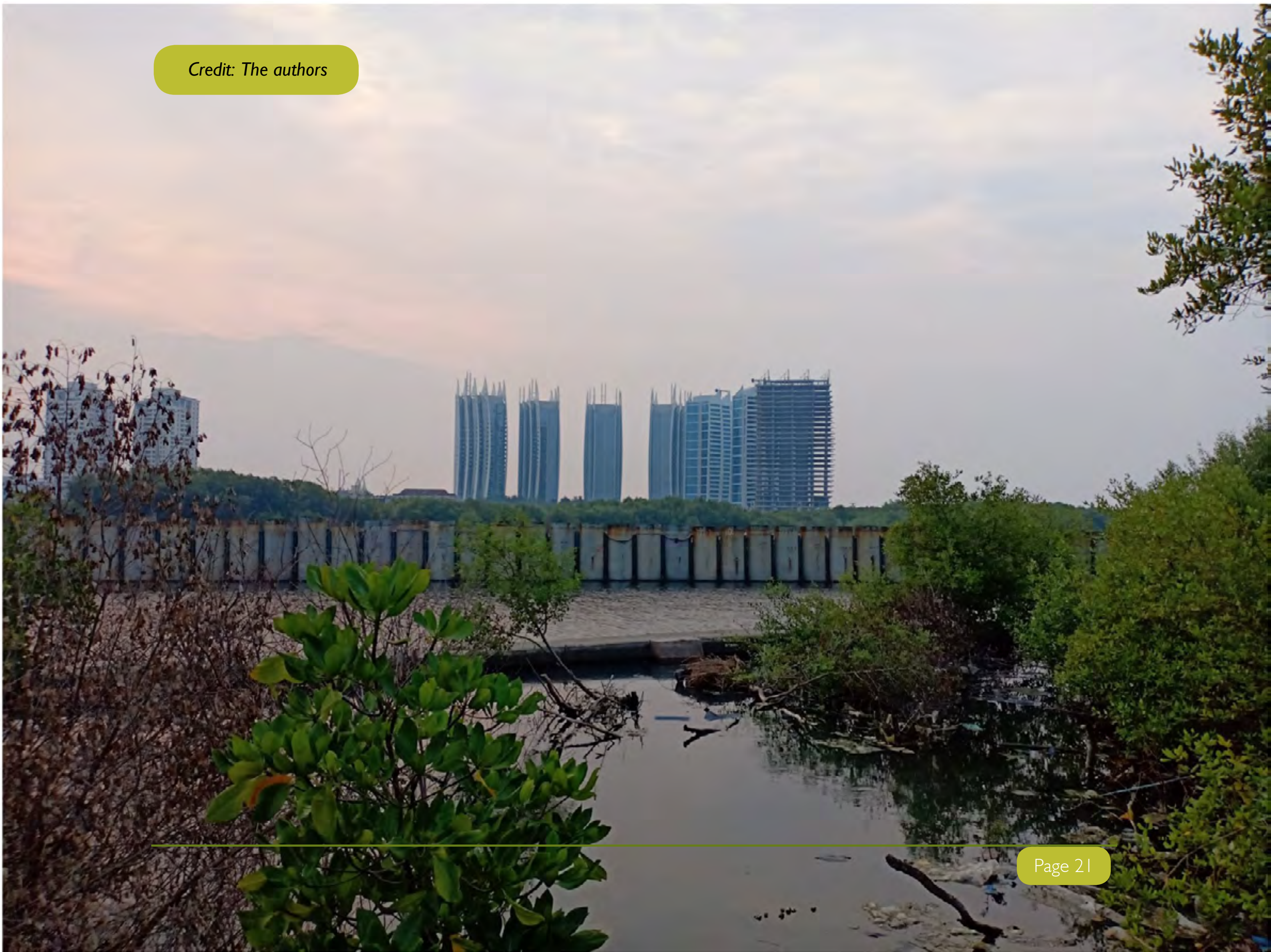
Depok area to the Manggarai floodgate as the middle zone, and the Manggarai gate to the rubber sluice gate as the downstream zone.

5.3.3. BPBD DKI JAKARTA

DKI Jakarta has a 24-hour data and information centre known as Jakarta Command Center with 112 standby. This provides a platform for collaboration with several provincial and local departments (SKPDs), which can be used to increase preparedness and flood prevention. The output of this preparedness is that Jakarta Provincial Government will receive information on Standby 1, Standby 2, and Standby 3 from SMS broadcasts, WhatsApp, Twitter, Facebook and so on, to be forwarded to the public. In addition to the use of social media, the mosque speaker, the pagoda, and the church are used for early warning dissemination.

5.3.4. Subdistrict and Village

Subdistricts (Kecamatan) and villages (Kelurahan) receive early warning information from the Command Center through WhatsApp Groups and notifications from BPBD on social media. In addition, according to Rahayu and Iglesias[51], the neighbourhood group (called RT RW) receives information on the water level measured at the Katulampa post, so that the community can prepare to take evacuation and protection measures.



Credit: The authors

Table 3. Relevant institutions identified at different levels of governance, based on Rahayu and Iglesias[51] and field work conducted 2019-2021 by Rahayu, Kusuma[47].

Institution type	Relevant institutions [47, 51]
Jakarta Provincial Government Level	• **Public Works Department (DPU-DKI) of the Jakarta Provincial Government**: holds provincial responsibilities for detecting, monitoring, and disseminating warnings, using water level information. • **Jakarta Command Center:** (previously known as the Crisis Centre of DKI Jakarta) is a regional Emergency Operations Centre of the Provincial Unit for the Management of Disaster in Jakarta that holds authority over receiving and disseminating extreme weather, flood warnings and related information to related stakeholders including the sub-district and the sub-sub-district level. • **Local Disaster Management Office of the Jakarta Provincial Government (BPBD)** • **Regional Planning Department of the Jakarta Provincial Government (Bappeda)** • **Health Department of the Jakarta Provincial Government (Dinas Kesehatan)** • **Social Department (Dinas Sosial)**
Sub-district (Kecamatan) and community authorities	• **Subdistrict Emergency Operations Centres:** disseminate warnings and information to lower levels, such as Post-Coordination hubs (Posko) and sub-subdistricts (Kelurahan).
Sub-sub-district (Kelurahan)	• **Coordination Posts of Kelurahan Kebon Baru** (Sub-Sub-District level) as well as **Posko** at neighbourhood-cluster (Rukun Warga) level, which receive information and warnings, and monitor water levels using the new Flood Reference mechanism [5].
Non-governmental (NGO) and community-based organisations (CBO) [51]	• **Indonesian Red Cross (PMI DKI Jakarta)** • **Yayasan Empati Sesama** • **Air One** • **Etc.**

6. Governance and management challenges to be overcome

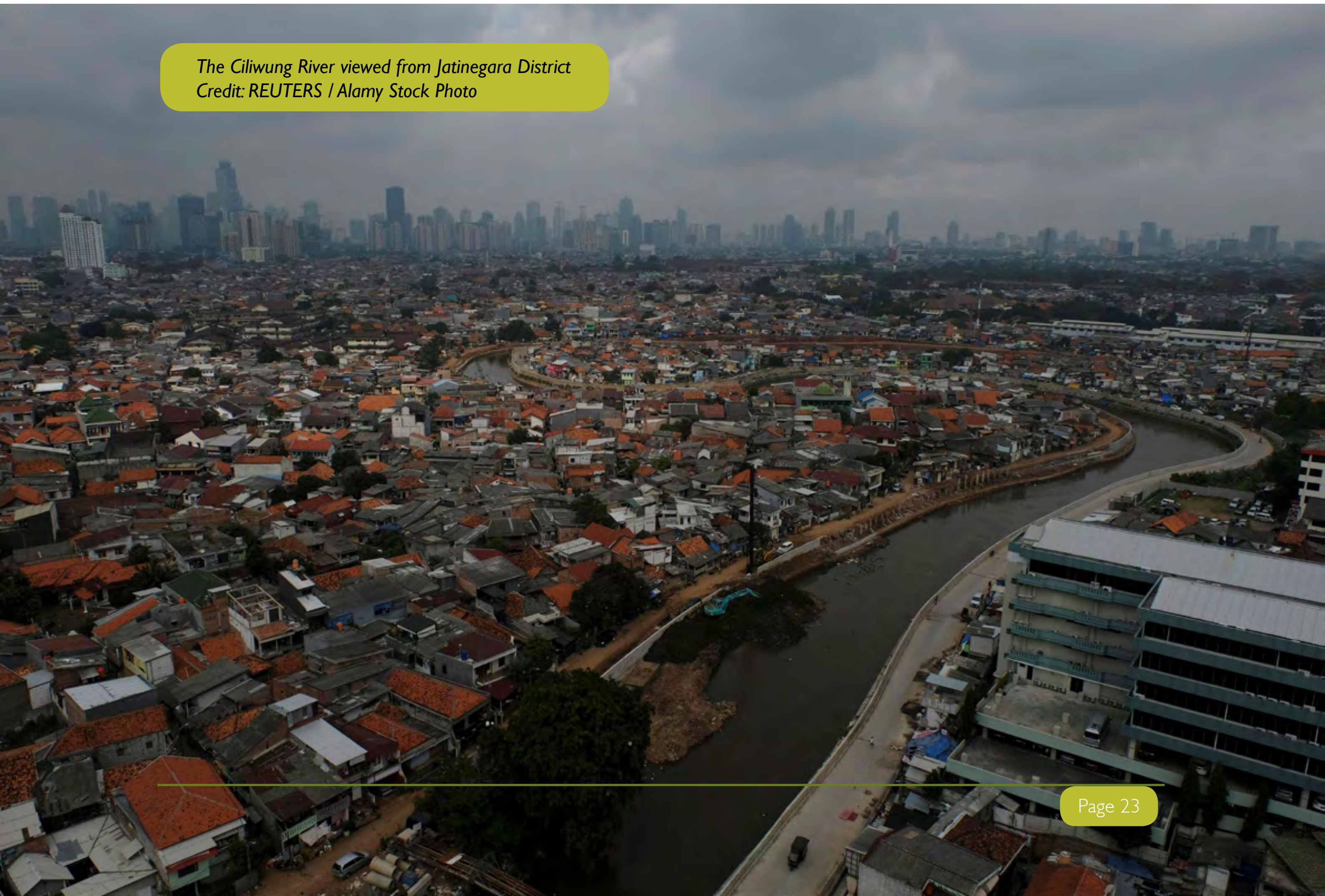
6.1. Legal/Institutional

6.1.1. Enforcement and compliance with spatial planning

Many flood risk reduction regulations are included in spatial plans, such as land use regulation, structural mitigation development, catchment area preservation, and river maintenance. Compliance with planning and regulation is important for effective implementation. However, compliance related issues have been noted in spatial planning[36, 39]. This is critical in the CRB, as it has been identified that weak spatial planning can have subsequent consequences on other flood risk drivers, namely, drainage capacity, river capacity, catchment area, and flood control development[7, 49].

The CRB and the Greater Jakarta area have undergone significant land use change, from mainly forested to urban land cover. Stakeholders suggested that this has not taken place in line with the spatial plans or the carrying capacity of the land, and that new towns have been developed without fully considering the spatial plan. This has been associated with weak development control and economic pressures to develop[7].

Weak compliance with legal frameworks is not limited to spatial planning, and has also been identified as an issue in other flood related sectors, such as water and disaster management[52].



The Ciliwung River viewed from Jatinegara District
Credit: REUTERS / Alamy Stock Photo

6.1.2. Vertical coordination

Responsibilities for flood management are distributed between levels of government in the multi-level governance system. Hence, coordination is required between the levels. However, vertical coordination has been identified as a key governance challenge[46]. Some common issues associated with poor coordination between governance levels include a lack of clear roles and responsibilities, and limited availability of coordination mechanisms[46].

Effort has been made to coordinate between government levels, but some challenges have been faced in implementation. For example, in West Java, Bappeda initiated mechanisms for vertical coordination between provincial and district governments, however, coordination was found to be constrained by authority and funding issues[7]. Similarly, programmes conducted by the Forestry Service for the rehabilitation of critical land have faced obstacles in terms of coordination between central and regional governments[7].

Nonetheless, successful examples of multi-level multi-stakeholder collaboration were identified by Rahayu and Iglesias[51], where the national, provincial and city governments, were identified to be working with local NGOs and communities for a fully integrated early warning system. The authors noted that each stakeholder actively fulfilled their roles and responsibilities, and there was a common vision and shared perspective on improving the Integrated FEWS. Stakeholders at all levels were involved in a mix of multi-level capacity building activities, such as training of trainers and simulation exercises, from government institutions to very local communities. This raised the level of readiness of the government officials in charge of disseminating warnings and hazard information, as well as preparing communities better for response, evacuation, and coping strategies. Participatory consultation was built in through creating a feedback process. The Participatory Feedback Groups attended by all stakeholders bridged the gap between government and community perceptions of flood risk reduction initiatives. The existence of a Technical Working Group consisting of experts from prominent institutions was a key factor for success.

6.1.3. Coordination mechanisms

The decentralised government system has shifted autonomous authority to the local level. This type of decentralisation is often associated with good governance and can bring many benefits, however, it tends to create fragmentation and can make stakeholder coordination more complex [23]. The decentralised administrative structure in Indonesia is widely considered to have hindered its ability to achieve an integrated, basin-wide management arrangement[23].

Cooperation and coordination of stakeholders has been identified as a key flood risk driver[49]. This is because it can impact upon other flood risk drivers, such as waste and sedimentation, river capacity, catchment area, built environment, groundwater exploitation, spatial and development plans, and flood controls[49]. It is therefore imperative to have effective mechanisms to facilitate stakeholder coordination. For some aspects of river basin management, coordination mechanisms have been established. For example, under Indonesia's 'one river policy', water resource management councils have been established at multiple governance levels. This includes the national water resource council, provincial water resource councils (Dewan SDA) and basin water resource councils (TKPSDAs). There are also operational organisations with a basin focus (BBWS)[50]. These councils provide a structured multi-level approach to coordination with a basin-level focus. One issue with this approach is that the focus of the coordination councils is on water resource management, and flood management is not addressed within this system.

While coordination mechanisms exist within the CRB and wider provincial areas, they have been noted to face challenges that limit their effectiveness[42]. In the CRB, there have been two previous coordination forums, first is the Ciliwung River Basin Forum led alternately by the governors of Jakarta Provincial Government and West Java Province, and second is the Ciliwung Water Resource Management Coordination Team, led alternately by each of the local development and planning agencies in the basin. The Forum, however, has undergone reformation several times. Stakeholders suggested that the reasons for the reforms were a lack of a legal agreement and clear framework on how coordination and cooperation should take place. In addition, actors were identified to only be concerned with their own interests, and that there was a lack of a strong leader to guide the forum which hindered its progress[7].

Beyond the basin itself, there are other coordination platforms for related policy areas, such as Disaster Risk Reduction (DRR) and water resource management that are intended to facilitate coordination between stakeholders, located at various government levels. However, these are also noted to face challenges, such as a lack of influence and power. As such, the effectiveness of coordination platforms is not an issue specific to the CRB, and the presence of these mechanisms does not necessarily indicate successful stakeholder coordination[42].

6.1.4. Flood early warning system

There has been extensive structural mitigation in the CRB. However, to obtain a flood free CRB, non-structural mitigation is also required, including flood early warning[5].

Early warnings provide people at risk with time to evacuate prior to a flood, therefore they can be critical for saving lives and assets during a flood event. One common challenge facing flood early warning is that monitoring and detection for potential flood, warning production, and warning dissemination are handled by separate agencies, and this is true for the CRB. BMKG provide weather forecasting services, DG of Water Resources PUPR and BBWS-CC conduct monitoring and detection via telemetry. Once a potential flood has been detected, information is passed to BPBD Jakarta, who formulate the warning level and disseminate the warning. BPBD pass the water level and level of warning on to the subdistrict and sub-sub-district heads (Camat and Lurah) for dissemination to the public.

In the CRB, the flood warning relies on the detection of high-water levels by BBWS, and the passing of this information to BPBD. There is currently no flood forecasting service that is integrated with weather forecasting. Due to the involvement of multiple agencies in the early warning chain, it is imperative that they coordinate and collaborate[47].

The second challenge relating to flood warning in the CRB is the response of the public to warnings. While there has been significant development of flood warning technologies in Jakarta, there has been less attention given to the more social elements of flood warning, such as preparedness and response[44]. For example, while there are both formal and informal flood warning sources in the CRB, those at risk do not always respond in desired ways. A survey of flood plain residents along the Ciliwung[48] identified that resident's decisions to evacuate rely more on their knowledge and experience, rather than the flood warning itself. Many residents also reported to prioritise remaining in the flood risk area to protect belongings, over direct evacuation. This was prevalent among those who live in poorer riverbank communities. Strengthening the social aspects of warning is essential if the end-to-end FEWS is to be established and to be effective.

Residents moving through flood water during the January 2020 flood event
Credit: Zuma Press Inc. / Alamy Stock Photo

7. Recommendations for the Ciliwung River Basin

1. Develop transboundary governance for flood risk reduction in the CRB through synergising local policies, regulations and planning among local governments who share the basin.

There are currently no transboundary regulations for flood management in the CRB. Instead, local governments are responsible individually. However, to achieve successful flood risk reduction, there is a need to develop multi-local authority collaboration. To do this, local policies, regulations, and planning should be synergised horizontally.

There are good practices being conducted by cities and regencies along the Ciliwung, however these are not yet formalised, and should be translated into a transboundary basin-wide governance arrangement.

2. Synergise local, provincial, and national policies, regulations and planning between vertical levels of governance.

Not only are horizontal synergies required across the basin, but also to establish authority collaboration vertically. For this purpose, the establishment of a governance forum for the CRB is recommended. Due to the conflicts often seen in the CRB, a governance forum is likely best served by a river basin commission, which is a more formally constituted body[53]. The commission would consist of a board of management who sets objectives, goals, policy, and strategic direction. The commission would also be supported by a technical office drawn from representatives from existing agencies operating within the basin[49].

3. Develop multi-sector and multi-stakeholder governance for flood risk management in the CRB.

Each city in the CRB has its own pentahelix (government, community, business entity, academia, media). Coordination is needed among the pentahelix in each city, as well as among cities to achieve multi-sector, multi-stakeholder governance. To enable this, clear roles and responsibilities and effective coordination mechanisms need to be in place.

4. Integrate flood risk reduction and management in to the One River policy for water management.

There are already robust multi-level governance arrangements and coordination mechanisms in place for water resource management. However, flood management is not addressed within this system. It is recommended to integrate flood management within the existing water resource management structures.

5. Integrate flood hazard assessment into local/provincial policy and regulation for planning.

Flood hazard risk assessment should be integrated as a key part of local and regional planning.

Development control itself should also be strengthened[49]. There needs to be strict development control, not only in Jakarta but throughout the CRB (including Bogor and Depok). To do this, central and local governments need to develop instruments for ensuring development control, and local governments need to carry out surveillance and issue penalties for violations. In addition, a holistic regulation regarding development control in the CRB should be legalised as a national policy (including a mechanism, instrument, zoning technique, and execution e.g. task force).

6. Update data for modelling and make it available for scientific and applied study and decision making.

To enable comprehensive modelling of flooding in Greater Jakarta, it is necessary to consider pluvial in addition to fluvial and coastal flooding. However, the ability to model pluvial flooding is obstructed by a lack of data. In particular, there is currently no up-to-date data available on the capacity of the drainage system. The collection and sharing of these data are currently not considered by the relevant authorities.

7. Formally and informally integrate the role of community groups/volunteers/NGOs and CBOs within the pentahelix.

Community groups, volunteers, NGOs, and CBOs can strengthen community preparedness and resilience. For example, they can play an important role as 'trusted intermediaries' where community groups and organisations that have good coordination with the government and the wider community can provide interfacing between the two.

There are many community groups/volunteers/NGOs/CBOs along the Ciliwung who make important contributions, but these need to be formally and informally integrated within the pentahelix. Local agencies, such as the local water resources office (Dinas SDA), and the local disaster management office (BPBD), should build processes for long-lasting communication and coordination with existing community organisations in the CRB. This may include Air One (Community Water Rescue Team) and Yayasan Empati Sesama, for example[5].

8. Build community resilience.

Flood response and evacuation need to be strengthened to enhance the flood early warning system, and to ensure it is 'end-to-end'. It is recommended to strengthen more direct evacuation planning, and to emphasise preparedness training on the areas most severely impacted by floods, also contributing to the development of community resilience.

To further strengthen flood early warning and community resilience, it is recommended that flood insurance is mainstreamed. Residents of riverbank settlements often prioritise remaining in flood risk areas to protect their belongings, rather than directly evacuating when a warning is received. Mainstreaming flood insurance would minimise the need to remain during a flood and support evacuation [48].

9. Explicitly address the Sendai Framework for Disaster Risk Reduction actions into development plans.

Responsibility for Disaster Risk Reduction (DRR) is often perceived as that of BNPB, and not necessarily a responsibility of other sectors. This may mean that DRR has not been widely mainstreamed in other sectors[54].

While the development plans refer to the SFDRR (Sendai Framework for Disaster Risk Reduction), the efforts towards Sendai goals should be made more explicit so that they become more widely integrated.

10. To reflect and draw upon good practices elsewhere.

There are good practice examples of transboundary and multi-stakeholder coordination elsewhere in Indonesia and worldwide. In Indonesia, the Citarum Harum platform provides a good example of multi-stakeholder pathway with effective participation of the pentahelix (government, community, business entity, academia, media).

In Europe, the International Commission for the Protection of the Danube (the most international transboundary basin worldwide) has shown how formal agreements between countries can support both horizontal and vertical coordination[55]. Stakeholders in the Soloway-Tweed basin district in the United Kingdom have been successful in developing networks across the England-Scotland border, and the Tweed Forum has demonstrated how a forum can act as an intermediary between national and local levels of governance, and how partnerships can be developed bottom-up[56].

11. Limitations

There are several limitations to the studies on which this document is based:

- It was not possible to model pluvial flooding as part of the modelling activities in section 4. Therefore, flood maps may not show the full extent of flood inundation area and depth. This was due to a lack of available data on the drainage system capacity.
- To determine the discharge hydrograph for the coastal modelling activities, the rainfall runoff model using the synthetic hydrograph method was used based on Indonesian national standard (SNI 2415-2016). This was due to limited availability of temporal hydrograph data for the Ciliwung River[19].
- It was not possible to quantitatively validate the downstream flood model used in Section 4.2. Instead, the model was validated qualitatively against the November 2020 flood event. This was owing to a lack of quantitative observations of flood inundation during past events, and that the observed flood maps generated using a limited number of spot measurements provide only a crude approximation of the flood-affected areas[19].

Annex: Underpinning reports and papers

Suggested further reading	Description
Bennett, W.G., Karunarathna, H.U., Xuan, Y., Kusuma, M.S.B. Farid, M., Kuntoro, A.A., Rahayu, H.P., Kombaitan, B., Septiadi, D., Kesuma, T.N.A., Haigh, R, and Amaratunga, D. (2023) Modelling compound flooding: A case study from Jakarta, Indonesia. Under review.	This paper details the coastal and river modelling processes which produced the flood risk maps for the Muara Angke coastal zone in Jakarta.
Clegg, G., Haigh, R. and Amaratunga, D. (2019) River Governance and Flood Management Arrangements in the United Kingdom. November 2019. A report of the project 'Mitigating hydrometeorological hazard impacts through transboundary river management in the Ciliwung River Basin, Indonesia'. http://www.resilientciliwung.com/portal/media/attachments/2020/11/09/uk-report.pdf	This report examines the governance arrangements for flood management in the United Kingdom, to understand the current procedures, and the governance challenges faced.
Clegg, G., Haigh, R., Amaratunga, D. and Rahayu, H.P. (2020) A literature review on community participation in flood early warning. April 2020. A report of the project 'Mitigating hydrometeorological hazard impacts through transboundary river management in the Ciliwung River Basin, Indonesia'. http://www.resilientciliwung.com/portal/media/attachments/2021/06/07/participation-in-ews-report.pdf	This report reviews the literature on participation of the public in flood early warning. It outlines how participatory approaches may support community understanding and preparedness for floods and what incentives and interventions may be necessary when designing such approaches for the Ciliwung River Basin.
Clegg, G., Haigh, R., Amaratunga, D. and Rahayu, H.P. (2020) River Governance and flood management arrangements in Indonesia. July 2020. A report of the project 'Mitigating hydrometeorological hazard impacts through transboundary river management in the Ciliwung River Basin, Indonesia'. http://www.resilientciliwung.com/portal/media/attachments/2020/11/09/indonesia-report.pdf	This report examines the governance arrangements for flood management in Indonesia, to understand the current procedures, and the governance challenges faced.
Clegg, G., Haigh, R., Amaratunga, D. and Rahayu, H.P. (2020) Transboundary river and flood governance: a comparison of arrangements in Indonesia and Europe. August 2020. A report of the project 'Mitigating hydrometeorological hazard impacts through transboundary river management in the Ciliwung River Basin, Indonesia'.	This report reviews the flood and river governance arrangements in Indonesia and the European Union, and compares them to examine the similarities, differences, and draws out lessons learned.
Clegg, G., Haigh, R., Amaratunga, D. and Rahayu, H.P. (2021) 'Transboundary River Governance Practices for Flood Risk Reduction in Europe: A Review', in Amaratunga, D., Haigh, R. and Dias, N. (eds.) *Multi-hazard Early Warning and Disaster Risks*. Springer Nature, Switzerland.	This book chapter examines the governance arrangements for flood management in the European Union, to understand the current procedures, and the governance challenges faced.

Clegg, G., Haigh, R., Amaratunga, D. and Rahayu, H.P. (2021) Flood Risk Early Warning and Decision Making in Indonesia and Europe. April 2021. A report of the project 'Mitigating hydrometeorological hazard impacts through transboundary river management in the Ciliwung River Basin, Indonesia'.	This report identifies the concepts relevant to end-to-end flood early warning, details and compares the current approaches taken in Indonesia and Europe, and examines how they are governed, based on a literature review.
Clegg, G., Haigh, R., Amaratunga, D., Rahayu, H.P., Karunarathna, H. and Septiadi, D. (2021) A Conceptual Framework for Flood Impact Mitigation Through Transboundary River Management. *International Journal on Advanced Science Engineering and Information Technology*. Vol 11 No 3. p 880-888. http://ijaseit.insightsociety.org/index.php?option=com_content&view=article&id=9&Itemid=1&article_id=14329	The conceptual framework presents the key concepts and ideas that provide a basis for understanding transboundary river management, flood drivers, and flood impacts in the Ciliwung River Basin.
Clegg, G., Haigh, R., Amaratunga, D. and Rahayu, H.P. (2023) 'Coordination challenges facing effective flood governance in the Ciliwung river basin', in: Triyanti, A., Indrawan, M., Nurhidayah, L. and Marfai, M.A. (eds.) *Environmental Governance in Indonesia*. Springer Nature. https://link.springer.com/book/9783031159039	This book chapter provides insights into the challenges facing coordinated flood governance in the Ciliwung River Basin, based on a literature review.
Kesuma, T.N.A., Rahayu H.P., Kusuma, M.S.B, Farid M., Kuntoro, A.A and Rohmat, I.W. (forthcoming) The Contribution of Land Use Control to Flood Risk in Manggarai Village, South Jakarta, Indonesia. International Journal of GEOMATE.	This paper focuses on assessing flood risk in the Manggarai sub-district and the area of the Manggarai Station which is identified as an area of transit-oriented development. Flood risk zones (low, medium, and high) are identified suitable management strategies for each zone are proposed.
Rahayu, H.P. et al. (2022) Faktor Kunci Penyebab Risiko Banjir DAS Ciliwung (Key Flood Drivers for the Ciliwung River Basin). ITB Press. Institute of Technology Bandung, Indonesia. ISBN: 978-623-297-229-2.	This report details the primary drivers of flooding in the Ciliwung River Basin, based on a literature review and focus group discussions with river basin stakeholders.
Rahayu, H.P. et al. (2022) Peran Instansi Dalam Pengelolaan DAS Ciliwung Bagian Hulu dan Tengah untuk Pengurangan Risiko Banjir (Upstream and Midstream Government's Role in Flood Risk Management Along Ciliwung River Basin). ITB Press. Institute of Technology Bandung, Indonesia. ISBN: 978-623-297-222-3.	This report describes the roles of key agencies involved in flood and river management in the middle and upstream reaches of the Ciliwung River Basin based on literature review and focus group discussions with key basin stakeholders and provides recommendations for more effective river governance.
Rahayu, H.P. et al. (2022) Peran Instansi dalam Sistem Peringatan Dini Banjir Pada DAS Ciliwung (Role of Institutions in Ciliwung Flood Early Warning System). ITB Press. Institute of Technology Bandung, Indonesia.	This report provides details on the roles key institutions play in flood early warning for the Ciliwung River Basin, Indonesia.

Rahayu, H.P., Zulfa, K.I., Khoirunnisa, D., Haigh, R. and Amaratunga, D. (2023) Unveiling Transboundary Challenges in the Ciliwung River Flood Management. Under peer review.	This paper identifies the flood risk drivers in the Ciliwung River Basin based on basin stakeholder's perspectives using MICMAC analysis. The paper identifies lack of development control and weak stakeholder coordination as critical flood drivers that subsequently impact on other flood drivers.
Rahayu, H.P., Zulfa, K.I., Khoirunnisa, D., Haigh, R. and Amaratunga, D. (2023) Closing the Gap in Flood Early Warning System using Structural Equation Modelling (SEM) with the Case Study Ciliwung River. Under peer review.	This paper uses Structural Equation Modelling (SEM) to identify causal relationship to identify the significant variables that impact people's responses after receiving a flood warning. The most influential factors identified were individual preparedness and the early warning source.
Saputra D. (2020) Kajian Pengaruh Perubahan Distribusi Hujan pada Bahaya Banjir Jakarta 5 Tahun Perakhir berdasarkan Model 2D HEC-RAS / Study on the Influence of the Rainfall Distribution Pattern to Floods in Jakarta in the Last Five Years Using 2D HEC-RAS Modelling. Fakultas Teknik Sipil dan Lingkungan. Institut Teknologi Bandung.	This paper presents the methods and modelling for the midstream flood maps presented in Section 4.1.

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For more information, please visit *www.resilientciliwung.com*

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