GREATER ACCRA
CLIMATE AND FLOOD RISK MITIGATION STRATEGY

Making sound investment choices for flood protection

GFDRR
Global Facility for Disaster Reduction and Recovery

WORLD BANK GROUP

The World Bank
February 2020

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Design: Alejandro Espinosa / sonideas

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Acknowledgements

The World Bank team would like to acknowledge the Government of Ghana and the many institutions and individuals that participated for their immense contribution and support for the Greater Accra Climate and Flood Risk Mitigation Strategy.

The team extends its gratitude to Hon. Samuel Atta Akyea, MP (Minister, Ministry of Works and Housing) for the overall leadership and guidance on the study, together with all key stakeholders involved, including: Hon. Joseph Kofi Adda, MP (Minister, Ministry of Sanitation and Water Resources), Hon. Alhaji Boniface Abubakar Saddique, MP (Minister, Ministry of Inner Cities and Zongo Development), Hon. Hajia Alima Mahama, MP (Minister, Ministry of Local Government and Rural Development), Hon. Prof. Kwabena Frimpong-Boateng (Minister, Ministry of Environment, Science, Technology and Innovation), Hon. Ishmael Ashitey (Regional Minister, Greater Accra Region), Charles K. Dondieu (Chief Director, Ministry Local Government and Rural Development), Gifty Mahama Biyira (Chief Director, Ministry of Inner Cities and Zongo Development), Hon. Dr. Emmanuel Lamptey (MCE, Ga Central), Hon. Mohammed Adjei Sowah (MCE, Accra Metropolitan Assembly), Hon. Dede Afagbedzi (MCE, LaNMMA), Hon. D.A. Nii-Noi Adumuah (MCE, AdMA), Hon. Janet Mensah (MCE, GEMA), Hon. Clement Wilkinson (MCE, GWMA), Hon. Emmanuel Odoi Lartey (DCE, Shai Osudoku District Assembly), Sauda Ahmed (Ministry of Finance), Dr. Mensah Abrampa (Ministry of Planning), Kwame Awuah Baffour (NDPC), Akua Sakyibea Van der Pallen (DUR), George Thompson (Lands Commission), Osei Kwame Agyeman (Past President, Ghana Institute of Architects), McJulius Agbee (Ghana Institute of Surveyors), Kwasi Poku (JEAVCO Associates / Ghana Institute of Planners), Doris Tettey (Land Use and Spatial Planning Authority), Ellen Oteng Nsiah (Housing the Masses), Gabriel Nii Teiko Tagoe (GAMADA), Farouk Briamah (People Dialogue on Human Settlements), Dr. Ernest Agyemang (Dept of Geography, University of Ghana), and Dr Dadson Awunyo-Vitor (Institute of Local Government Studies).

The Steering Committee for the study played an important role to coordinate the work and provide overall guidance and oversight. The steering committee was chaired by Frank Dei (Ministry of Works and Housing) and Dr. Ohene Sarfoh (GARID project coordinator, Ministry of Works and Housing) and was joined by Hon. D.A. Nii-Noi Adumuah (MCE, AdMA), Hon. Janet Mensah (MCE, GEMA), Hon. Clement Wilkinson (MCE, GWMA), Ernest Kusi-Minkah, Seth Kudzordzi (Hydrological

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We also express our sincere gratitude and appreciation of the tireless efforts and information provided by the Greater Accra Climate and Flood Risk Mitigation Strategy focal persons and working groups drawn from the relevant ministries, departments and agencies and the MMDAs of greater Accra. We wish to thank the following persons: Frank Dei (MWH), Mohammed Alhassan (MICZD), Sylvanus Adzornu (MLGRD), Patrick Affum (MSWR), Seth Kudzordzi (HSD), Dr Mawuli Lumor (WRC), Kofi Kekeli Amedzro (Land Use and Spatial Planning Authority), Nana Opare Djan (NDPC), Desmond Appiah (AMA), Alex AMoah (GEMA).

The Greater Accra Climate and Flood Risk Mitigation Strategy was implemented with the technical guidance and support by HKV Consultants (Ghana) in collaboration with Associated Consultants (Ghana), Bosch-Slabbers (Netherlands) and ECORYS (Netherlands). The team of flood modelling specialists, architects, engineers and planners was led by Durk Klopstra and consisted of Clim Soree, Emmanuel Dosu, Gerbrand van der Bork, Karel van Hussen, Koen Berentsen, Geerten Horn, Jan Huizinga , Job Udo, Lexy Ratering Arntz, Marco Hartman, Olivia Ahlijah, Raymond Kasei, Richard Gamadeku, Roy Daggenvoorde, and Steven Slabbers.

The World Bank team for the Greater Accra Climate and Flood Risk Mitigation was led by Asmita Tiwari and Carl Christian Dingel with contributions from Yan Zhang, Joe Gadek, Carlos Tucci, Frederick Amoako Addison, Rachael Dede Annan, Su Jung Song, Harold Esseku, Wise Ametefe, Emmanuel Nkrumah, Martin Onyach-Olaa, Demba Balde, John Richardson and Kadir Osman Gyasi. Brenden Jongman, Mathijs van Ledden, Alvina Elisabeth Erman, Stephane Hallegatte, Henk Ogink, Carlos Tucci and Giovanni Castellanos, provided useful comments as peer reviewers. Charlotte Hayfron and Roderick Babijes provided comprehensive administrative support to the team throughout the process, as well as Mary Anderson for editing and proof reading and SonIdeas for design and layout.

The study benefitted from the overall strategic guidance of Henry Kerali (Country Director, Ghana), Beatrix Allah-Mensah (Senior Operations Officer), Ivo Imparato (Program Leader), Sameh Wahba (Director), Meskerem Brhane (Practice Manager), Sylvie Debomy (Practice Manager) and Niels Holm Nielsen (Lead DRM Specialist).

The Greater Accra Climate and Flood Risk Mitigation was made possible with the technical and financial support of the Global Facility for Disaster Reduction and Recovery (GFDRR) the ACP-EU NDRR Program and the City Resilience Program managed by GFDRR. The World Bank, Government of Ghana as well as all involved partners and consultants extend their gratitude and appreciation to the many stakeholders who in many different ways contributed to the study and the development of this report.

Abbreviations

AMA Accra Metropolitan Assembly (= official name of Accra)

CBA cost-benefit analysis

DEM Digital Elevation Model

DTM digital terrain model

GAMA Greater Accra Metropolitan Area

GAR Greater Accra Region

GARID Greater Accra Resilient and Integrated Development Project

GDP gross domestic product

GIS geographic information system

HSD Hydrological Services Department

IDA International Development Association (World Bank Group)

IDF intensity-duration-frequency (curve)

IPCC Intergovernmental Panel on Climate Change (UN)

MCA Multi Criteria Analysis

MMDA metropolitan, municipal, and district assemblies

NASA National Aeronautics and Space Administration

NCCP National Climate Change Policy

NPV net present value

NDVI normalized difference vegetation index

O&M operations and maintenance

RCP Representative Concentration Pathway

TRMM Tropical rainfall Measuring Mission

PHOTO BY: © FRANK HERBEN/ SHUTTERSTOCK

Executive Summary

A Study to Better Understand, Prepare for, and Mitigate Flood Risk in the Greater Accra Region

Flood impacts are increasing in the Greater Accra Region (GAR).[1] The region, which stretches along the coast of Ghana from Kokrobite in the West to Ada in the East, is affected by floods every year at an average annual loss of US$48 million. The GAR hosts 16 percent of Ghana's population and contributes 25 percent to the national gross domestic product (GDP). It is projected to house close to 11 million people by 2050, compared with 4.7 million in 2016 (GSS 2012). As such, the region is the most urbanized in the country and one of the fastest-growing metropolitan areas in West Africa.

With a booming economy and rapid urbanization, GAR faces an increasing risk of higher flood impacts. Close to US$1.7 billion worth of assets are currently at risk of flooding impacts, projected to increase to US$3.2 billion by 2050 because of an increase in overall population and assets. The urban built-up areas and related stormwater runoff are increasing, leading to higher flood frequency and larger flooded areas following heavy rainfall. The design capacity of the main drains, especially downstream, is no longer adequate to safely discharge excess water to the sea. Moreover, the capacity of the drains has decreased because of siltation, accumulation of solid waste, and lack of maintenance. In addition, poverty in GAR is increasingly concentrated in informal settlements prone to flooding as well as other areas with limited access to services. Because the land is limited and expensive, informal settlements continue to arise in areas vulnerable to floods, further increasing the flood risk for low-income citizens of the region. Climate change exacerbates the flood risks.

Globally, there is increasing awareness that it is more cost-effective to invest in prevention than in disaster response. By one estimate, every US$1 spent in prevention can save US$6 in future disaster costs (NIBS 2018). As the population and economic assets grow in GAR, now is the most opportune time to ensure that the new growth is flood-resilient while taking steps to ensure that the existing housing, infrastructure, and services are made floodproof. Several past initiatives have been taken up in GAR, specifically in the Odaw River Basin, to deal with perennial flooding challenges. These initiatives, however, have been largely piecemeal, focusing on particular sectors, and have not led to sustainable or effective results. Long-term, multisectoral, and integrated urban watershed level efforts are needed to improve GAR's flood resilience and overall prosperity and competitiveness.

Although GAR is affected by annual flooding—the oldest documented event occurring on June 23, 1955—the flood of June 3, 2015, affected 53,000 people and heightened awareness of the growing flooding and climate risks. This disastrous flood led to a tragedy where more than 150 people seeking shelter from the rains at a gasoline station died from a fire triggered by flooding. This event was a wake-up call for many decision makers in Ghana to find lasting solutions to flood risk management for Accra and other cities in Ghana.

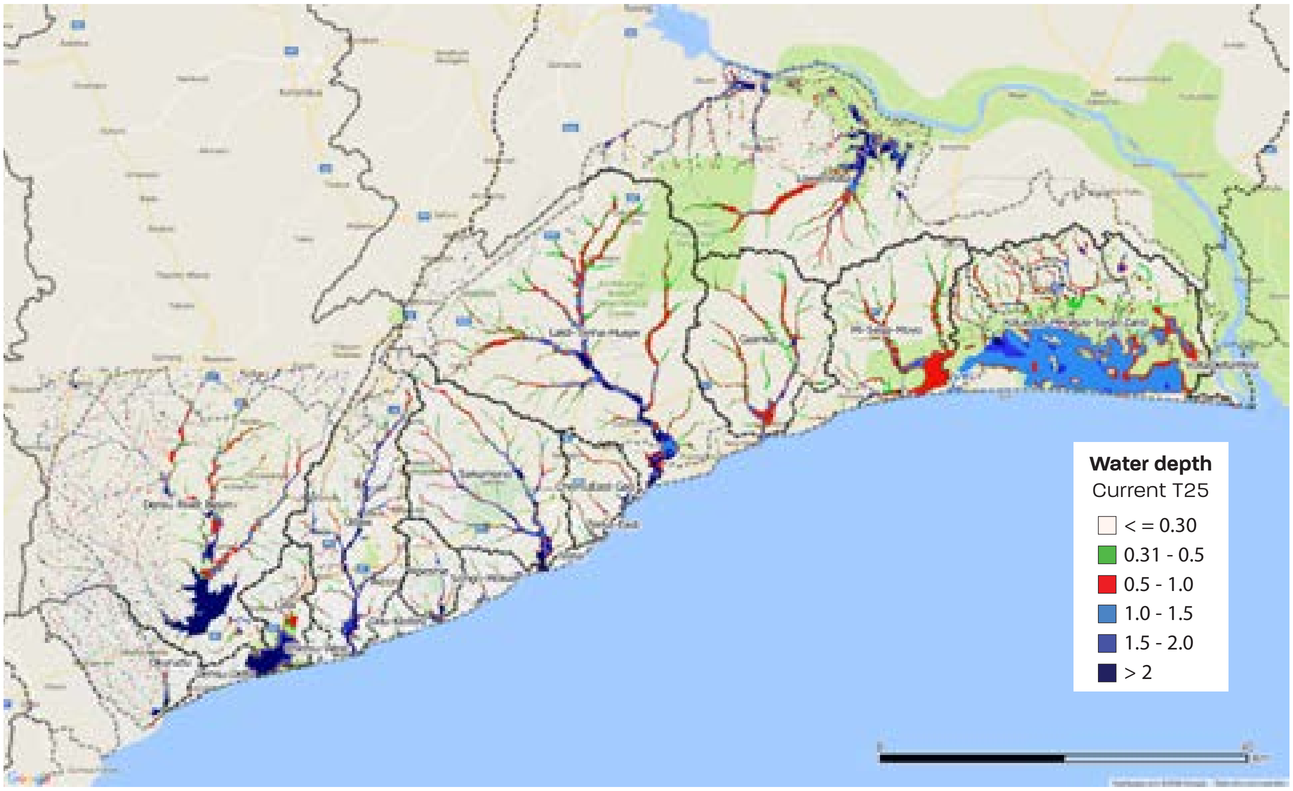
As a follow-up, the government of Ghana has been working with the World Bank to identify measures to support evidence-based decision making and investment planning for climate and flood risk mitigation in GAR, based upon an objective assessment of the region's climate hazards, vulnerabilities, and exposure. Among other questions, the "Accra Flood and Climate Risk Mitigation Strategy" focused on (a) better understanding the current and future flood exposure as well as modeling potential flood damages in the region, (b) assessing what potential solutions are available, and (c) developing an objective basis for selection and implementation of prioritized solutions. The final report of this study is meant to provide guidance to decision makers on structural and nonstructural infrastructure investments for flood and climate risk mitigation in GAR.[2]

The output of the study is based on state-of-the-art modeling and cost-benefit and multicriteria analyses, carried out with the close involvement of local stakeholders and decision makers. The study models consist of a hydrological-hydraulic model calculating the flood hazard and a damage model describing the flood vulnerability in terms of affected people and economic damages. Cost-benefit analysis (CBA) and multicriteria analysis (MCA) methodologies were applied to determine how attractive certain investment alternatives would be from a broad welfare point of view. The study was guided by a steering committee of experts from different ministries, departments, and municipalities of GAR and involved in-depth stakeholder consultations.

1 In the report, the term Greater Accra Region (GAR) describes the project area, comprising the 29 metropolitan, municipal, and district assemblies (MMDAs) of the Greater Accra Metropolitan Area.

2 The study was conducted between June 2017 and January 2019 with the technical support of a competitively selected consortium led by HKV Consultants and involving Associated Consultants (Ghana), ECORYS, and Bosch-Slabbers.

Map ES.1 Hazard Map for a Flood with 25-Year Return Period in the Greater Accra Region, Assuming No Flood Risk Mitigation Measures



Note: Maps background based on Open Street Maps; ©World Bank. Further permission required for reuse.

Understanding the Increasing Flood Risk in the Greater Accra Region

Locations, Causes, and Dimensions of Flood Risk

This study found that the entire region is at risk for flood impacts, with the following watersheds having the highest risk: the Dawhe River delta west of Prampram, the Sakomono Lagoon near Tema, and the Densu Delta (map ES.1). Out of all 18 basins in GAR, the Odaw River Basin contains the highest flood hazard and flood risk, especially the low-lying, central business area downstream of Caprice, around Kwame Nkrumah Circle and Kaneshie.[3] Model calculations show that in the current situation, on average, a flood hits this area approximately every two years, and a flood like that of June 3, 2015, is rather frequent (having a return period of 10 years).[4]

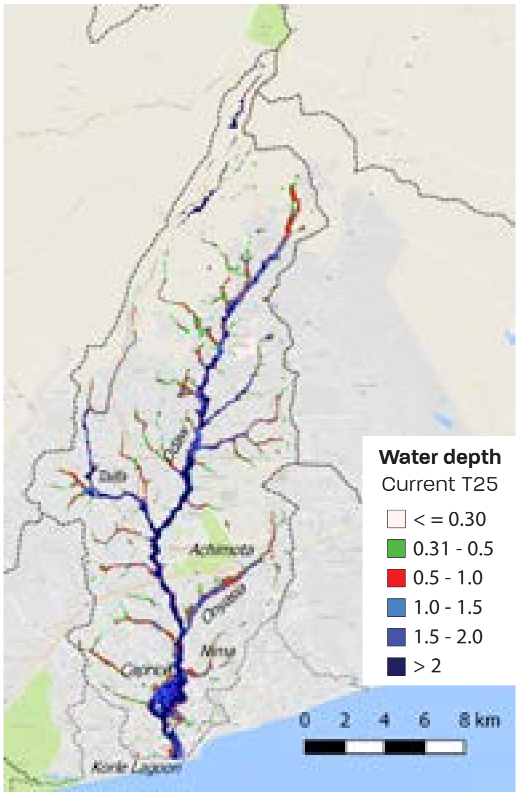
The floods are mainly triggered by heavy rainfall. The average annual flood damage is estimated at US$34 million for the Odaw Basin and US$48 million for GAR. The present value of the flood damage is estimated at US$1.2 billion for the Odaw Basin and US$1.7 billion for GAR. Model calculations show that the flood risk increases considerably by 2050, mainly because of economic growth (averaging 2.8 percent per year) and urbanization (an expected average population increase of 3 percent per year), and the estimated damage will quadruple by 2050 if nothing is done to mitigate the risk (map ES.2).

3 "Floods" in this study are defined as inundations outside of the riverbed due to overtopping of the main rivers (such as the Odaw) and their tributaries, threatening lives and causing high economic damage.

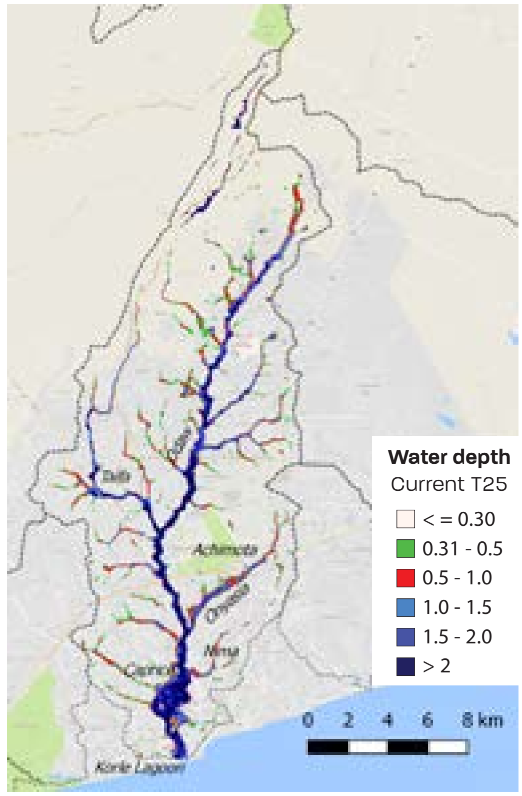
4 The "return period"—the inverse of probability (generally expressed as a percentage)—is the estimated time interval between events of a similar size or intensity. For example, the return period of a flood might be 100 years, otherwise expressed as a 1/100 probability of occurring or 1 percent in any one year. This does not mean that if a flood with such a return period occurs, then the next will occur in about 100 years' time; instead, it means that, in any given year, there is a 1 percent chance that it will happen, regardless of when the last similar event was. Or, put differently, it is 10 times less likely to occur than a flood with a return period of 10 years (or a probability of 10 percent) ("What Is a Return Period?" Natural Hazards, National Institute of Water and Atmospheric Research [NIWA], New Zealand, website: https://www.niwa.co.nz/natural-hazards/faq/what-is-a-return-period).

Map ES.2 **Hazard and Risk Maps for a Flood with 25-Year Return Period in the Odaw Basin, Assuming No Risk Mitigation Measures**

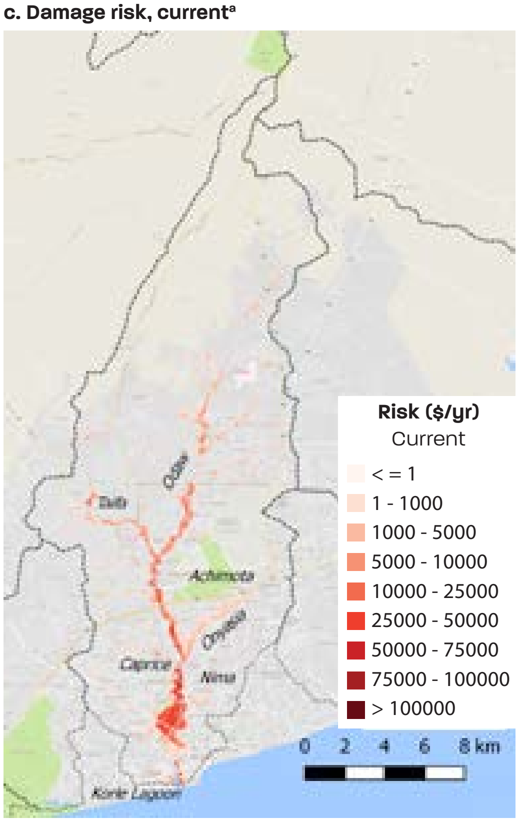
a. Water depth risk, current



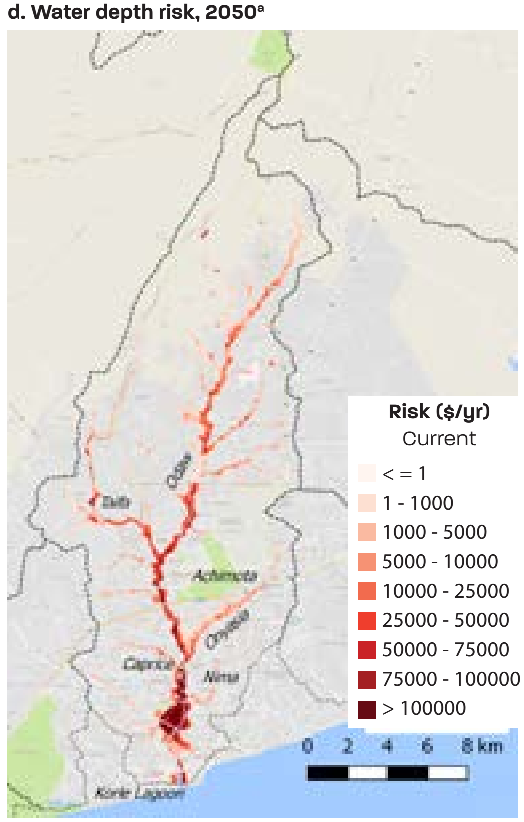
b. Water depth risk, 2050



c. Damage risk, current[a]



d. Water depth risk, 2050[a]



Notes: Background based on Open Street Maps ©World Bank. Further permission required for reuse.

It is important to note that the data, information, and maps provided in this study are based on the available information on historical flood events, existing hydrometeorological data, and digital elevation models. The hydrological-hydraulic model developed in the context of the study is based on the SOBEK modeling software. The model describes the inundation by floodwaters from the main rivers and primary drains (such as the Odaw and its tributaries) as a result of heavy rainfall. The models also include downstream boundary conditions for the sea level. The model covers the entire Odaw Basin. The highest accuracy of the assessment will be found for those sections of the Odaw and its tributaries for which the bathymetry data were available and used in the model.

Findings from Municipal Hot-Spot Survey and Planning Charettes

To better understand local flood hot spots, a survey was organized in September and October 2017 of the 16 metropolitan, municipal, and district assemblies (MMDAs), or local municipalities that formed the Greater Accra Metropolitan Area in 2017. (There are now 29 MMDAs because of regrouping.) Apart from mapping local flood hot-spot areas, the survey confirmed the following key contributors to higher flood risks in GAR:

- *Development of buildings in waterways*
- *Accumulation of solid waste* that chokes the drains
- *Challenges in the current drainage system*, including improper engineering (such as undersized culverts), insufficient coverage of drainage system, inadequate capacity of existing drains, and low or no operations and maintenance (O&M)
- *Ongoing coastal erosion*
- *Limited disaster response capacity*.

Additional workshops and public charettes on water-inclusive urban planning identified the following long-term, complex challenges: ongoing accelerated urbanization, lack of enforcement capacity, limited space available to build new houses, and climate change impacts.

Although some of the above challenges can be addressed in the short term (such as fixing drainage bottlenecks), others require long-term policy, spatial planning, enforcement, and behavioral changes. One-off or single-solution measures may thus not be enough to address the complex flood risk, but a combination of structural and nonstructural measures will be the key to achieving a paradigm shift toward a water- and climate-resilient urban development approach for GAR.

Greater Accra Flood Risk Mitigation Strategy: Toward a Resilient, Water-Inclusive Accra

A Vision for Water-Inclusive Urban Development

Accra has gone through an accelerated expansion in recent decades. However, there exists no comprehensive water-inclusive urban planning strategy for GAR that ensures proper flood risk management. The "Accra Dialogues"—a series of planning charrettes and workshops carried out as a part of the study—identified the following challenges to a water-inclusive, resilient future:

- Inadequate safety from flooding
- Poor environmental quality, especially concerning solid waste and liquid waste pollution
- Low density, which makes GAR inefficient
- Monocentric urban structure with no diversity of urban centers or focus areas
- No use of waterfronts or oceanfront for public recreation and tourism.

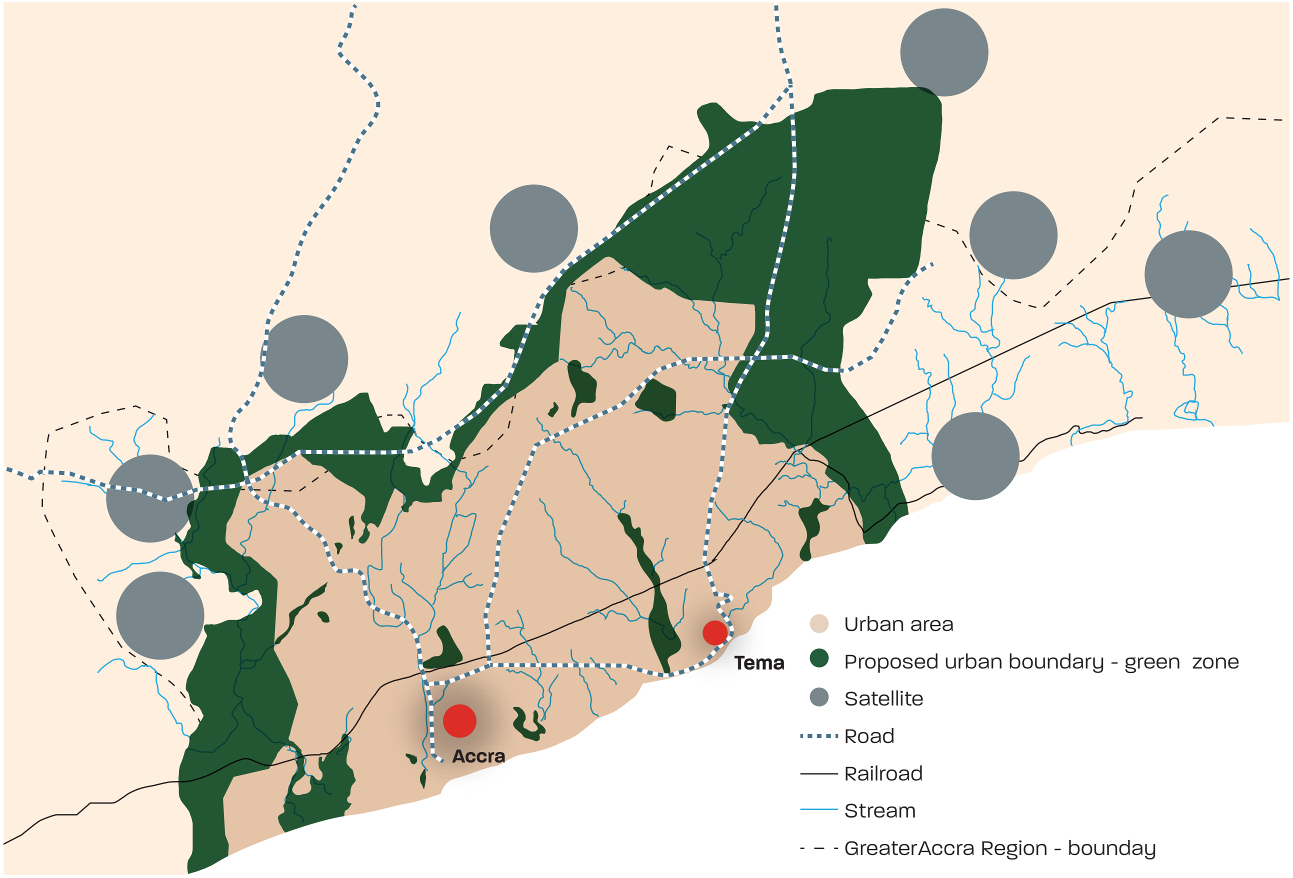
The dialogues also identified the following long-term priorities for ensuring a water-inclusive future:

- A "compact" city with infill development
- A variety of urban centers and density (two key urban centers: Accra and Tema)
- Ocean-facing development, potentially with an oceanfront drive and parks, that will require improved solid and liquid waste management
- A strong green belt surrounding the region to retain and store rainwater
- A series of creeks and rivers with their associated watersheds managed through flood zones and flood retention areas
- Railroad connections to the hinterland and to satellite cities in 2050.

The two key elements of the vision are

- Restructuring existing settlements and ensuring higher urban density of new settlements, while maintaining good street experience, and developing informal settlements into permanent living areas such that they can accommodate future space needs; and
- Ensuring room for water, as follows:

Map ES.3 Water-Inclusive Urban Development Vision for the Greater Accra Region in 2050



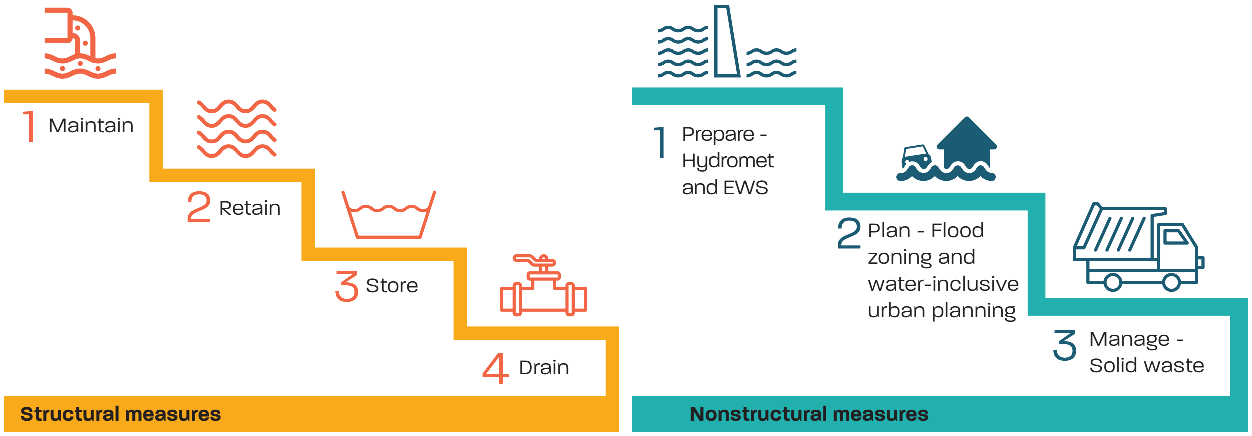
Notes: Prepared by Bosch+Slabbers based on LUSPA 2017.
The map shows compact urban development area separated by a green belt from satellite areas; two urban centers (Accra and Tema); and coastal, riverfront, and watershed development.

Figure ES.1 Potential Design for Development in Korle Lagoon Area of Accra, Including Green Spaces for Recreation and Floodwater Retention

Source: Bosch+Slabbers ©World Bank. Further permission required for reuse.

- *In the upstream area,* all measures are aimed at holding the water (retention) and on slowing down the runoff.
- *In the midstream areas,* measures focus on both water storage and improved runoff by the main drains.
- *In the downstream areas,* measures focus on speeding up the runoff to the sea, creating space to relieve the upstream system.

Figure ES.2 Cascading Priorities of Measures in the Flood Risk Management Strategy for Greater Accra



Note: EWS = early warning systems.

Apart from regional spatial and land-use planning, achieving water-inclusive growth in Accra would require adopting updated stormwater regulations and flood zoning, improving regulatory enforcement, and developing micro-scale water retention areas and green urban spaces. The vision also explored ways of involving the private sector in achieving the vision through land value capture.

Key Elements of Flood Risk Mitigation Strategy

Together with the steering committee and key stakeholders, a flood risk mitigation strategy was developed consisting of both structural and nonstructural measures. Structural measures take an integrated watershed approach, assigning cascading priorities (figure ES.2):

1. *Maintenance* of drainage infrastructure
2. *Retention* of water through new drain design
3. *Storage* of peak flows in detention basins upstream
4. *Effective, safe drainage* of floodwater to the sea.

Nonstructural measures include (a) water-inclusive and resilient urban planning, (b) early warning, and (c) solid waste management.

Flood Risk Mitigation Measures for the Odaw River Basin

Various combinations of flood risk mitigation measures were assessed for the Odaw Basin. They correspond to the planned design safety levels and were grouped as investment alternatives: baseline (only improving maintenance), T10A, T10B, T25A, T25B, and T50. These design safety levels correspond to safe conveyance of floods with return periods of 10 years (T10), 25 years (T25), and 50 years (T50) in the current situation.

The design safety levels apply to the areas downstream of Caprice, which are also GAR's most densely populated areas. Upstream, because floods there are restricted to the riverbed itself, the safety levels will be higher. The design safety levels that correspond with the various alternatives therefore can be seen as the actual minimal safety levels for the whole basin. Absolute protection against floods is not possible, so it can be assumed that some minimal water levels can remain in the areas where the flood risk is reduced.

The T10 investment plan is presented for two options: Option A, with in-line retention ponds (using a dam in the river); and Option B, with an off-line retention pond (meaning retention in the floodplain beside the riverbed). The T25 investment plan included two options: T25A would invest in improving maintenance, developing upstream flood retention ponds, and widening and repair of the drainage network. T25B would invest in improving maintenance, widening part of the Odaw primary channel, lowering the floodplain, developing floodwalls, widening the outlet to the sea, and repairing the drainage network.

The baseline investment alternative and all other alternatives include actions to improve maintenance of the drainage network, without which other alternatives or any flood mitigation measure would not make sense. The considered investment alternatives include the following structural measures (summarized in table ES.1):

- *Measure A: Maintenance and repair.* Important maintenance and repair measures include (a) deferred dredging of the lined Odaw drain between Caprice and the outlet to the sea as well as regular interval dredging, especially after floods when the sediment load are high; (b) construction of sand traps, reducing siltation; (c) rehabilitation of the interceptor weir; and (d) repair of broken drain sections at Abofu-Achimota and Nima and repair of a design flaw in the Kaneshie drain.
- *Measure B: Flood retention ponds.* About eight areas in the more upstream part of the Odaw Basin still have potential for retention. Retention is realized in these areas by construction of a diversion weir or barrier and connecting levees to increase the capacity of the retention ponds. A mechanism should be in place to release water from the retention areas immediately after a flood to provide enough storage for sequential floods.
- *Measure C: Widening of Odaw drain.* The Odaw Basin between Caprice and the Abossay-Okai Bridge is a bottleneck in the drainage system, contributing to the flood risk. The calculations for the investment alternatives estimate that the Odaw drain would be widened from 25 meters to 50 meters between Caprice and Kwame Nkrumah Circle and from 35 meters to 100 meters between the Circle and the Abossay-Okai Bridge.
- *Measure D: Floodplain lowering.* The already low-lying floodplains around Korle Lagoon, between the interceptor weir and Abossay-Okai Bridge, would be lowered to mean sea level, reducing flood levels upstream and preventing further encroachment of these flood-prone areas.
- *Measure E: Floodwalls.* Floodwalls with a maximum height of 1 meter between Kwame Nkrumah Circle and Abossay-Okai Bridge (Kaneshie) were considered to protect adjacent communities from the potential impacts of flooding, notably around the Circle. The construction of floodwalls would also require the elevation of bridges accordingly.
- *Measure F: Widening of the outlet to the sea.* The outlet to the sea would be widened, and any obstructing structures would be removed.
- *Measure G: Micro water retention and new drain design.* Retention of water on a micro scale (also referred to as wadis) would be realized in already low-lying areas on public grounds such as parks and playing fields as well as by the above-described new design of tertiary drains. These measures are more easily realized in new urban areas and can play an important role in the mitigation of the additional flood risk due to future climate change and urbanization.

The different investment alternatives were compared applying a cost-benefit analysis (CBA) and a multicriteria analysis (MCA), which considered social impacts and environmental impacts as well as political acceptance, institutional feasibility, and sustainability of the alternatives. In the CBA, construction costs; O&M; and a budget for contingencies, design studies and supervision, land acquisition, and resettlement costs were considered and discounted over the time horizon (2020–60) to obtain the net present value (NPV). The benefits are equal to the NPV of the reduction of flood losses (economic damages from floods) during the time horizon. Because the land acquisition costs are high and the extent of the required land acquisition is uncertain, the calculations in table ES.1 are presented with and without estimated land acquisition costs.

In principle, a choice for a design safety level corresponding with a safe conveyance of floods with return periods of 10–50 years is justifiable from a society welfare point of view. The assessment, based on various modeling runs, found the following key points:

- *The discounted investment costs* vary from US$62 million for the baseline (improving maintenance) alternative to US$404 million for the "Safe at T50" investment alternative (when all land needs to be acquired) or US$227 million (if no land needs to be acquired).
- *The highest NPV* is found for the T10A investment alternative, but differences with T25A and T50 are small.
- *The reduction of affected people* (yearly average) varies from 30,000 for the baseline alternative to 60,000 for the "Safe at T50" alternative (rounded numbers).
- *The number of houses to be resettled* varies from possibly "some" in the baseline alternative (because of informal houses that are built close to the Odaw channel) to more than 750 in the "Safe at T50" investment alternative. It is noted, however, that because the situation on the ground in Accra changes rapidly and no accurate data are available, the actual numbers may be considerably different.
- *Measures that require land acquisition* (widening of the Odaw and retention basins on land that is not owned by the government) are considered less favorably by national stakeholders because (a) the land ownership is not clear, (b) land acquisition may take some time, (c) it causes resettlement issues, and (d) it is expensive.
- *Political acceptance for widening the Odaw drain* is low, not only because of the necessary land acquisition but

Table ES.1 Overview of Flood Risk Mitigation Measures and Assessment, by Investment Alternative, for the Odaw River Basin

Measures and cost-benefit analysis	Investment alternatives					
	Baseline	T10A	T10B	T25A	T25B	T50
Structural measures						
A. Maintenance and repair	X	X	X	X	X	X
B. Flood Retention Pond	—	X	—	X	—	X
C. Widening of Odaw Drain	—	—	X	X	X	X
D. Floodplain lowering Agblobloshie to Old Fadema	—	—	—	—	X	X
E. Floodwalls 1 meter high, Kwame Nkrumah Circle to Kaneshie	—	—	—	—	X	X
F. Widening of the Outlet to the Sea	—	—	—	—	X	X
G. Micro water retention and new drain design	(X)	(X)	(X)	(X)	(X)	(X)
Costs and benefits						
Investment costs (US$, millions)	54	251	159	355	198	395
O&M costs (US$, millions)	8	9	8	9	8	9
Total costs without land acquisition (US$, millions)	62	112	138	187	176	227
Land acquisition (US$, millions)	—	148	28	177	30	376
Total costs with land acquisition (US$, millions)	62	260	166	364	206	404
Benefits (risk reduction) (US$, millions)	275	674	443	748	514	780
Evaluation						
Net present value (without land) (US$, millions)	213	562	305	561	338	553
Benefit-cost ratio (without land)	4.4	6.0	3.2	4.0	2.9	3.4
Net present value (with land) (US$, millions)	213	414	276	384	308	376
Benefit-cost ratio (with land)	4.4	2.6	2.7	2.0	2.5	1.9
Estimated minimum number of houses resettled	some	35	300	650	400	750

Note: — = measure not included in the investment alternative. (X) = not included in the cost-benefit analysis. O&M = operations and maintenance. T10 refers to the safety level for a flood with a return period of 10 years; T25, the safety level for a return period of 25 years; and T50, the safety level for a return period of 50 years.

also because of the long-lasting hindrance it will cause in an area with high economic activity.

- *Without measures requiring land acquisition,* a design safety level corresponding with safe conveyance of a 1-in-25-year or 1-in-50-year flood probably cannot be obtained.

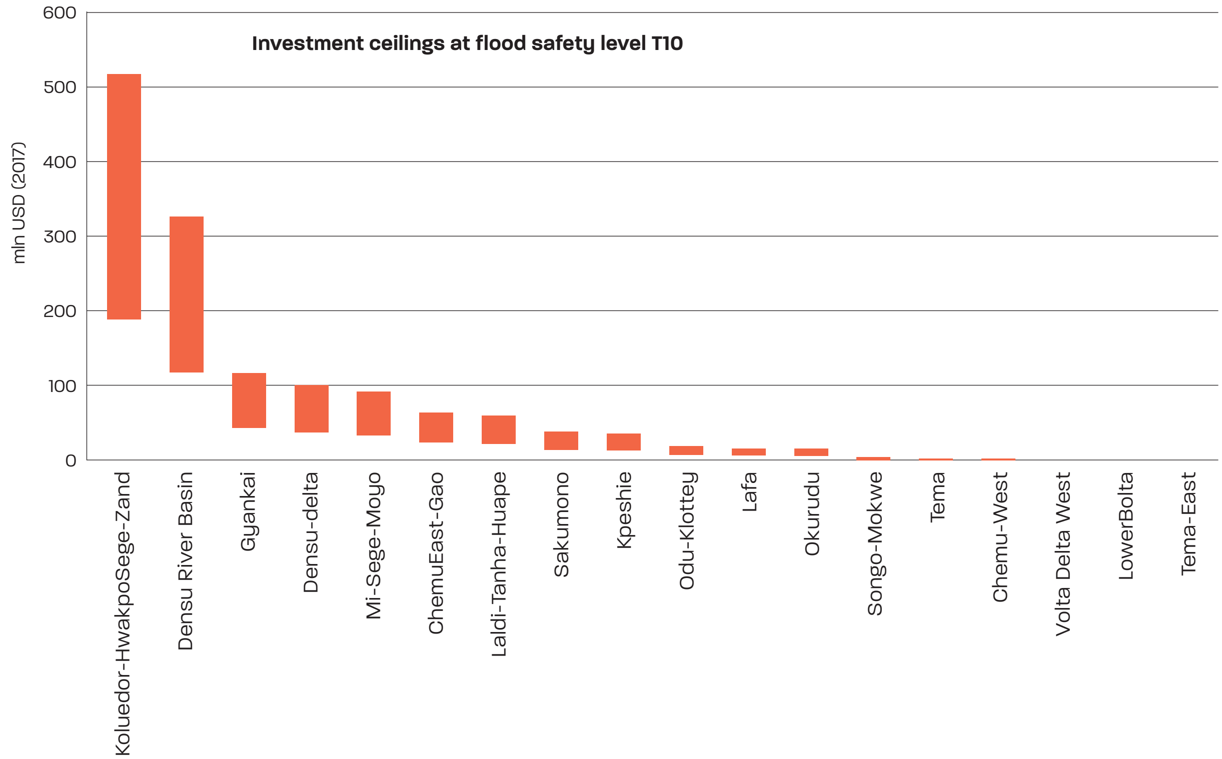
Flood Risk Mitigation Measures for Remaining GAR Basins

Building on flood mitigation measures identified in the Odaw River Basin and taking into account the regional differences in flood risk, a bandwidth for justifiable flood risk reduction investments for key river basins in Greater Accra Region was developed (figure ES.3). By analyzing the expected cost-effectiveness of flood mitigation measures, it was found that the river basins of Osu Klottey, Chemu East Gao, Koluedor Hwakpo Sege Zand, and Densu Delta are the most favorable for investing in flood risk mitigation.

From Risk Assessment to Decision Making and Investment Planning

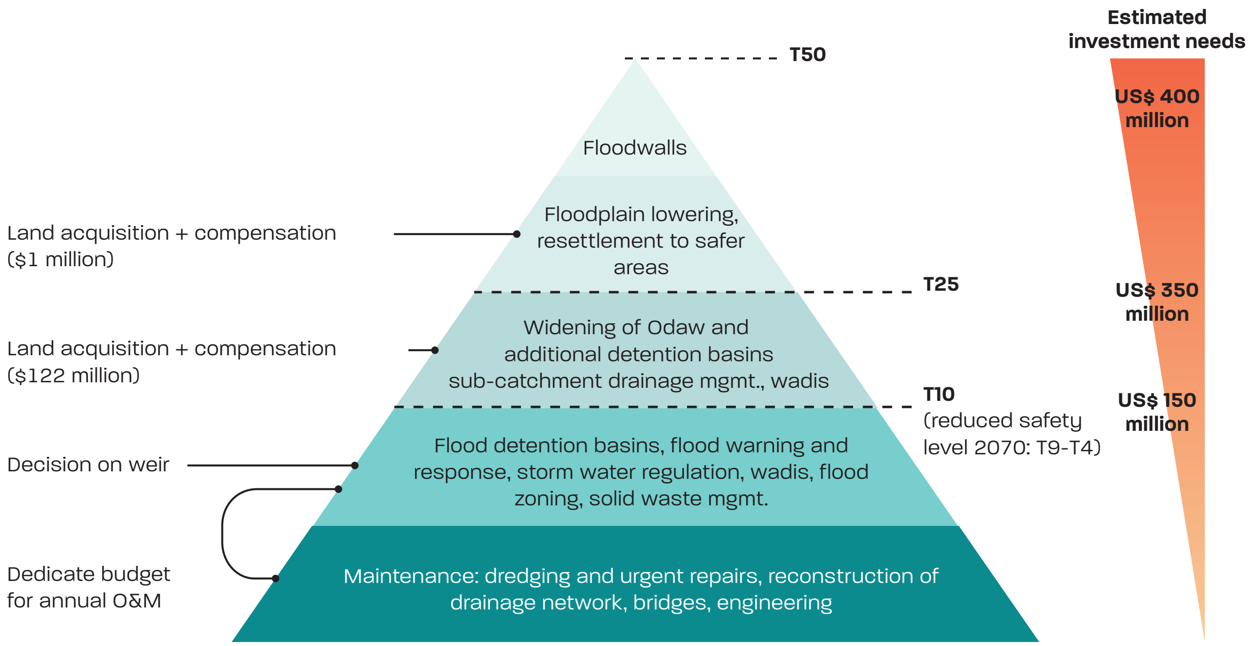
From an overall comparison of the different flood risk mitigation investment alternatives, the short-, medium-, and long-term measures were identified first for the Odaw Basin (identified as the first priority) and then over time for other priority basins of the region. The decision makers received a list of effective measures along with the overall costs, pros, and cons to achieve up to a 1-in-50-year (T50) flood safety level in the Odaw Basin (figure ES.4).

Figure ES.3 Bandwith of Investment Ceilings for Flood Safety Level T10 in Greater Accra, by Basin



Source: ECORYS/ HKV Consultants. © World Bank Further permission required for reuse.
Note: Figure shows ranges of a hypothetical investment package that guarantees a T10 safety level—that is, safety from a flood occurring once every 10 years. The upper range shows the investment needs if US$1 invested avoids US$1 of flood damage. The lower range shows the investment needs assuming the same cost-effectiveness as estimated in the Odaw Basin.

Figure ES.4 Phased Approach for Increasing Safety Levels through Flood Mitigation Measures in GAR



Source: ©World Bank. Further permission required for reuse.
Note: GAR = Greater Accra Region. O&M = operations and maintenance. "T10" refers to a design safety level of protection from a 1-in-10-year flood; "T25" to protection from a 1-in-25-year flood; and "T50" to protection from a 1-in-50-year flood.

The agreed-upon investment plan for the Odaw Basin to achieve 1-in-10-year flood safety in the short term—the T10 investment plan—was considered as a basic minimum investment to improve O&M and included development of flood retention ponds, institution of an effective flood warning and response system, and investment to keep solid waste out of waterways. Subsequent investment can build on this to achieve the T25 and finally the T50 safety levels, given that they would require land acquisition and resettlement based on widening, floodplain lowering, floodwalls, and relocation.

This study demonstrated that, in the short to medium term without land acquisition and with a limited budget, a substantial improvement to a 1-in-10-year flood safety level for the Odaw can be achieved. In the short term, those measures would go hand in hand with nonstructural measures, including investment in early warning systems; promotion of a new stormwater management policy around a nature-based, decentralized approach for stormwater management; and effective land-use zoning. In the medium to long term, an increase in the flood safety levels for the Odaw Basin and expansion of the flood protection to cover more areas in GAR would be promoted. As summarized below, some interventions need further analyses and discussion, such as those that require land acquisition; other interventions can start with the design and preparatory phase.

Flood mitigation strategy. The paradigm shifts toward a climate-resilient, water-inclusive urban development should start now. Nature-based solutions such as the localized management of stormwater through wadis as well as new roadside drains will thereby be important elements for water-inclusive, climate-resilient urban development. The promotion of localized and new drains will require getting private landowners on board and an adequate stormwater management policy and regulations.

Land acquisition and resettlement. Public open space is filling fast in Accra owing to demographic pressure. Many of the proposed flood mitigation measures, such as retention ponds and widening the Odaw drain, require land acquisition. To achieve higher safety levels (of T25 or T50), timely decisions and hard political will are needed to acquire the needed land. In many cases, the exact extent of land that must be acquired is unknown because the ownership of the land is not clear. Hence, it is advisable to investigate the ownership of such land and to start the acquisition process where possible, before these areas are further encroached.

Widening of Odaw drain. The widening of the Odaw drain is a potential measure of protection against higher-return-period floods in the area downstream of Caprice. This widening is difficult to implement because of the dense population of the affected areas and the hindrance to economic activities in the area as well as the loss of precious and scarce space. A more tailored, differentiated, and phased widening approach may be less difficult and less costly to realize while still substantially reducing flood risks. Moreover, by covering the drain, instead of losing space, additional space becomes available that can be used to generate additional economic activities and income. A feasibility study on widening and (partly) covering the Odaw drain between Caprice and Abossay-Okai Bridge, including a business case, is necessary to make a final decision.

Options for the interceptor weir. Regarding the interceptor weir in Korle Lagoon, the options include partial rehabilitation (for example, of the gates) and daily cleaning of the weir at the very least. Notably, the weir can still cause obstruction during a flash flood because debris will block the weir even when it has been previously cleaned.

Flood Risk Mitigation Investment Plan for the Odaw River Basin

The T10 investment plan was selected as the first priority because it (a) avoids land acquisition and limits any form of resettlement, (b) can be realized in a limited implementation time, and (c) can be realized within the available budget US$100 million (in 2018). This T10 investment plan includes

- Addition of two retention ponds on land already owned by the government (Atomic East and Atomic West);
- Dredging of the Odaw, at lower cost by implementing a performance-based dredging contract;
- Construction and maintenance of five sand traps;
- Reconstruction of critical obstructive bridges over the Odaw Channel between Caprice and Abossey-Okai Bridge;
- Repair of broken sections at the Odaw main channel and Nima and an increase of the Nima drain capacity from Paloma up to the downstream underground section;
- Regular cleaning of the interceptor weir; and
- Reconfiguration of the outlet to the sea.

The T10 investment plan is presented as an Option A (with in-line retention ponds) and as Option B (with an off-line retention pond, referring to retention in the floodplain beside the riverbed). The cost-benefit ratio of the pilot investment plan

Table ES.2 Cost-Benefit Analysis of the T10 Investment Plan for Flood Mitigation in the Odaw Basin

Item	T10 Investment Plan	
	Option A (in-line retention)[a]	Option B (off-line retention)[b]
Total costs (US$, millions)	53	59
Investment costs (US$, millions)	45	49
O&M costs (US$, millions)	8	10
Total benefits (US$, millions)	396	417
Risk reduction (US$, millions)	396	417
Net present value (US$, millions)	343	358
Benefit-cost ratio	7.51	7.06

Note: O&M = operations and maintenance. T10 indicates protection for a 1-in-10-year flood.
a. In Option A, Atomic East and West are both designed as in-line retention ponds (retaining water using a dam in the river, creating a lake with a variable size, dependent on the inflow).
b. In Option B, Atomic West is an in-line retention pond, while Atomic East is designed as an off-line retention pond (retaining water in an area connected with the river by a weir, inundating only when floods occur).

is high—two to three times higher than for the investment alternatives for the Odaw—mainly because the dredging costs are lower (owing to the performance-based contracting method, which considers sand reclamation from dredged material to pay for annual maintenance) and because costly land acquisitions are avoided. The NPV is highly positive, clearly showing a sound business case from a welfare point of view.

Besides expressing the CBA in monetary terms, the flood risk measures were evaluated in terms of affected people. The number of beneficiaries—people no longer affected by flooding—was estimated by comparing the average numbers of annually affected people in the Odaw Basin in the current situation with those affected after implementation of the T10 investment plan. An estimated 30,000 direct beneficiaries in the current situation and 50,000 in 2050 are expected. Beyond this definition of beneficiaries is a vulnerable "floating" population of approximately 1 million who pass every day through the flood-prone areas of Accra's central business district—here, the Kwame Nkrumah Circle area. Hence, an estimated 100,000 transient beneficiaries could be included in the number of people benefiting from the T10 investment plan in the current situation, resulting in a total of 130,000 at-risk people who would directly benefit annually.

The flood hazard for a 1-in-10-year (T10) flood in the current situation is shown in map ES.4, panel a. When the measures in the T10 investment plan are implemented—excluding the retention ponds—a safety level of T5 can be achieved (map ES.4, panel b). As a whole, map ES.4 shows that after implementation of the full T10 investment plan, the flood hazard for a 1-in-10-year flood is restricted to the riverbed itself, and large-scale inundations downstream of Caprice have diminished.

Climate Change Impacts on Flood Risk in the Odaw River Basin

To assess the long-term impact of climate change and urbanization, different climate scenarios were applied representing the median, 90th percentile (P90), and 10th percentile (P10) scenarios as well as an urbanization scenario assuming a 3 percent average annual population increase for GAR. These estimations indicate that, by 2070, the T10 investment plan may only result in a 1-in-9-year (under the median climate scenario) to a 1-in-4-year (under the P90 climate scenario) safety level. The affected population may also increase by up to 30–60 percent, calling for early actions to mitigate the potential impacts from climate change and to kick-start the paradigm shift toward a truly water-inclusive and resilient urban development pathway. The study is limited to river floods in the Odaw Basin.

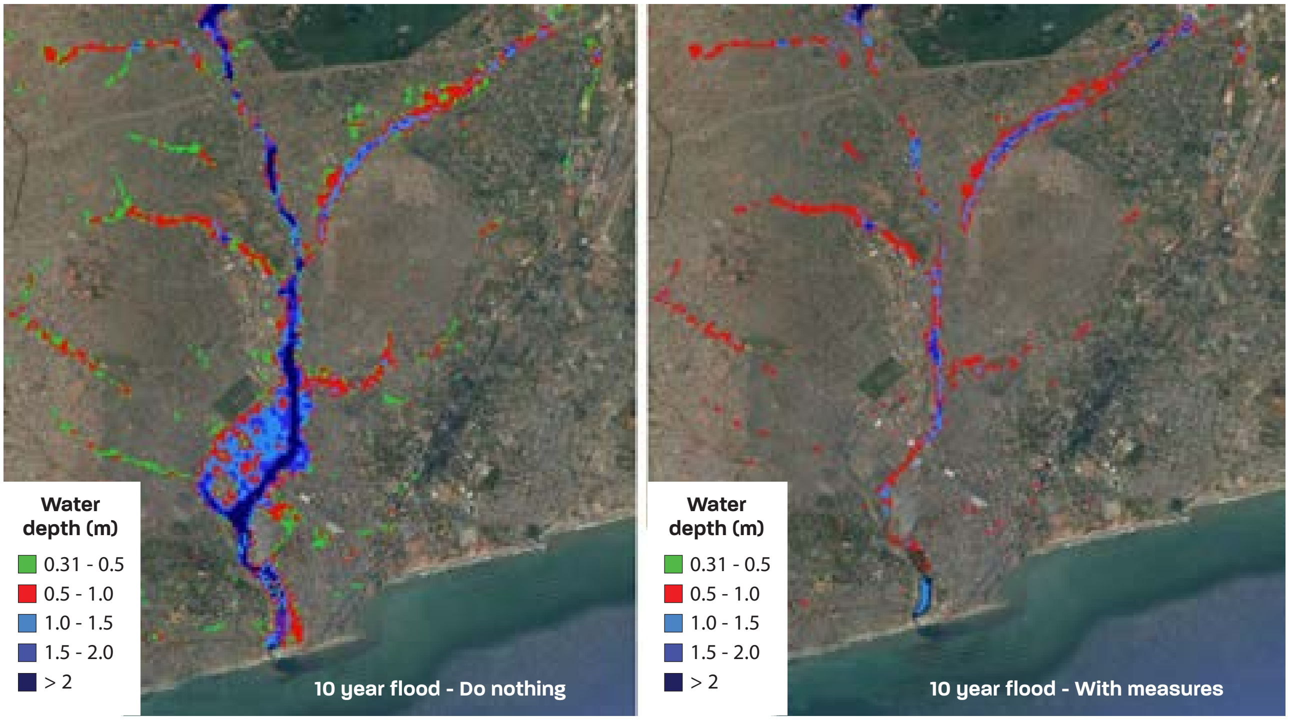
To guarantee the same safety levels in 2070 considering the expected impacts of climate change and urbanization, additional measures would be required to adapt the drainage system. Under a median climate change scenario without the effects of urbanization, it is estimated that an additional retention basin should be constructed, additional repairs of the drainage network should be made, and more bridges should be retrofitted. Without these additional infrastructure measures—which also would have an impact on land, require land acquisition, and may entail resettlement—it may be difficult to adapt the system to more-severe climate change impacts and trends in urbanization. A paradigm shift toward improved stormwater management has therefore been proposed as a key measure to ensure that stormwater is captured locally and managed in a climate-resilient manner. This can, among other measures, be implemented through a new drain design (so-called wadis) and the creation of new, localized micro retention ponds.

From Plan to Actions: Next Steps

A technical feasibility study should be rolled out to plan, dimension, and design the different interventions; get a full cost estimate; and identify O&M costs. Social and environmental impacts need to be studied in detail and fully

Map ES.4 **Modeled Flood Hazard in the Odaw Basin with and without Flood Prevention Measures**

a. T10 current situation: no measures **b. After T10 investment plan implementation**



Notes: Background based on Google Earth ©World Bank. Further permission required for reuse. T10 indicates protection for a 1-in-10-year flood.

understood and should be summarized in an independent environmental and social Impact assessment (ESIA). In addition, a full tender dossier should be developed for works and services, based on a clearly defined procurement strategy. The social and environmental issues to be assessed also include the following:

- *Number of people to be resettled* who live now on the borders of the planned retention ponds. Develop the necessary safeguard documents for resettlement.
- *Dam safety regulations* for the design and management of the retention ponds. These regulations should be in accordance with the dam regulations of the government of Ghana and the World Bank.
- *Potential health impacts* on the affected population. Retention ponds may have a negative impact on people's health if they turn into perfect breeding grounds for mosquitoes.

In addition, efforts should be made to increase the available data and information that can support decision making on flood mitigation. For example, the latest available water level data from the Odaw Basin relate to the 1990s, and since then, the discharge pattern of the Odaw Basin has substantially changed. Improving hydrometeorological data and digital elevation models (for example, with the support of a Light Detection and Ranging [LiDAR] survey) would increase the accuracy of the flood models and strengthen the planning and decision-making capacity.

PHOTO BY: © DOMINIC CHAVEZ/WORLD BANK

CHAPTER 1

Introduction and Overview

Introduction

Ghana has frequently been affected by weather- and climate-related hazards, notably floods, droughts, wildfires, and storms. Floods have impacted nearly 4 million people over the past 40 years (Guha-Sapir et. al. 2016) related both to river floods (mainly in the Volta River System) and in the urban areas, notably the Greater Accra Region. The June 2015 floods in the Greater Accra Region were a wake-up call to everyone in Ghana—government, citizens, and the private sector—to better manage flood and climate risks in Ghana's cities.

On June 3, 2015, Accra was hit by a disastrous flood due to heavy rainfall, with rainfall recordings of 130 millimeters in six hours in the southern part of the Odaw River Basin, corresponding to an approximate return period of 10 years. The floods affected 53,000 people and caused US$55 million in damages and losses in the housing, transport, and water and sanitation sectors in addition to an estimated US$105 million in reconstruction costs (MESTI 2016). The government called on all development partners to support recovery and reconstruction from the floods and even more importantly to find environmentally sustainable, socially acceptable, and economically feasible measures to address flood management in Greater Accra and other major cities.

This report summarizes the analytical work to identify flood management investment alternatives for Greater Accra and more specifically for the Odaw Basin. Chapter 1 introduces the study and provides the background of Accra's climate and flood risk challenges.

1.1 Overview of the Study Area

The study area considered in this analysis covers the Greater Accra Region, whose 4.7 million inhabitants account for about 16 percent of Ghana's total population and about 25 percent of Ghana's gross domestic product (GDP). Accra is growing rapidly and expected to have 11 million inhabitants by 2050 (GSS 2012).

Within Ghana's 10 administrative regions, the Greater Accra Metropolitan Area (GAMA) comprises 29 metropolitan, municipal, and district assemblies (MMDAs) as of 2017. GAMA, however, has no administrative body of its own; instead, there is a coordinating council of the region's MMDAs. In the context of this report, the term "Greater Accra Region" (GAR) is used. With about 1.8 million inhabitants in 2012, Accra Metropolitan Assembly (AMA) is the region's largest city, followed by the Ga South Municipal Assembly with 485,000 inhabitants and Tema Metropolitan Assembly with 405,000 inhabitants (GSS 2012). Smaller towns in the Greater Accra Region include, for example, Adenta with about 80,000 inhabitants.

Table 1.1 River Basins of Greater Accra and Their Surface Area

Basin	Area within Greater Accra Region (km^2)	Total area (km^2)
Lower Volta	624	5,256
Koluedor Hwakpo Seg Zand	425	425
Mi Sege Moyo	233	233
Gyankai	240	240
Laldi Tanha Huape	666	697
Chemu East Gao	69	69
Sakumono	276	283
Kpeshie	55	55
Odaw	246	273
Lafa	65	65
Densu	614	2,567
Okurudu	27	137
Volta Delta West	36	36
Densu Delta	23	23
Chemu West	12	12
Odu Klottey	19	19
Songo Mokwe	36	36
Tema	6	6
Z	2	2

In the Greater Accra Region, several river basins—such as the Odaw, Densu, Korle-Chemu, Kpeshie-Osu, and Songo-Mokwe (table 1.1)—stretch across several MMDAs (map 1.1, panel a). This means that the management of each river basin involves multiple MMDAs. The Odaw Basin cuts through the central parts of Greater Accra and is the most densely populated area. Because of its pronounced flood risk, it is the focus area of this study.

The Odaw Basin lies mainly within the MMDAs of AMA, Ga West, Ga East, La Nkwantanang Madina, and the southern part of Akwapim South (an MMDA outside Greater Accra). The basin covers an area of 273 square kilometers. It is

Photo 1.1 **Aerial View of Downstream Section, Odaw Basin, Accra**

Note: Background based on Google Earth. @World Bank. Further permission required for reuse.

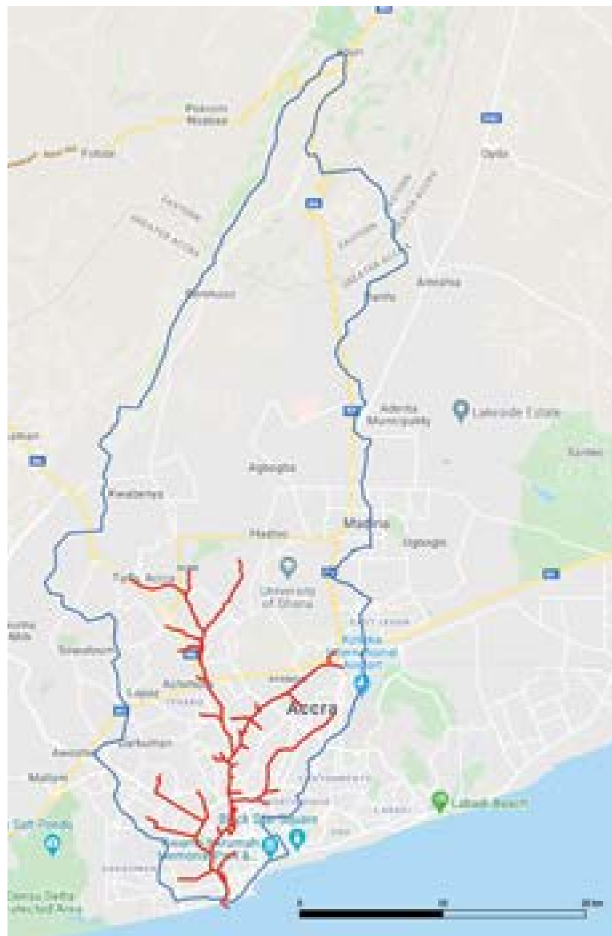
densely populated in the southern part, including the informal settlements of Nima and Old Fadama (also known collectively as "Sodom and Gomorrah"). High economic value concentrates in the business area and industrial area of central Accra around Kwame Nkrumah Circle and the Kaneshie suburb, a flat and low-lying area (photo 1.1). The northern part of the basin is still rather untouched and is characterized by the slopes of the Akwapim hills. Main tributaries of the Odaw River are the Taifa, Onyasia, Nima, and Kaneshie drains. The rivers and streams are partly concrete-lined drains, such as the downstream sections of Nima, Onyasia, and Odaw between Caprice and Abossey-Okai Road.

Among the four main catchments in Greater Accra, the Odaw catchment, which passes through the city's most urbanized areas, has the highest overall flood risk (map 1.1, panel b). It contains close to 40 percent of the US$3.2 billion in economic assets currently at risk of flooding in Greater Accra.

Map 1.1 MMDAs and River Basins within the Greater Accra Region

a. Overview including Odaw Basin (inset)

b. Detail of Odaw Basin



Notes: Background based on Google maps and OpenStreetMaps. @World Bank. Further permission required for reuse.
MMDAs = metropolitan, municipal, and district assemblies.

1.2 Climate Risks and Expected Impacts of Climate Change

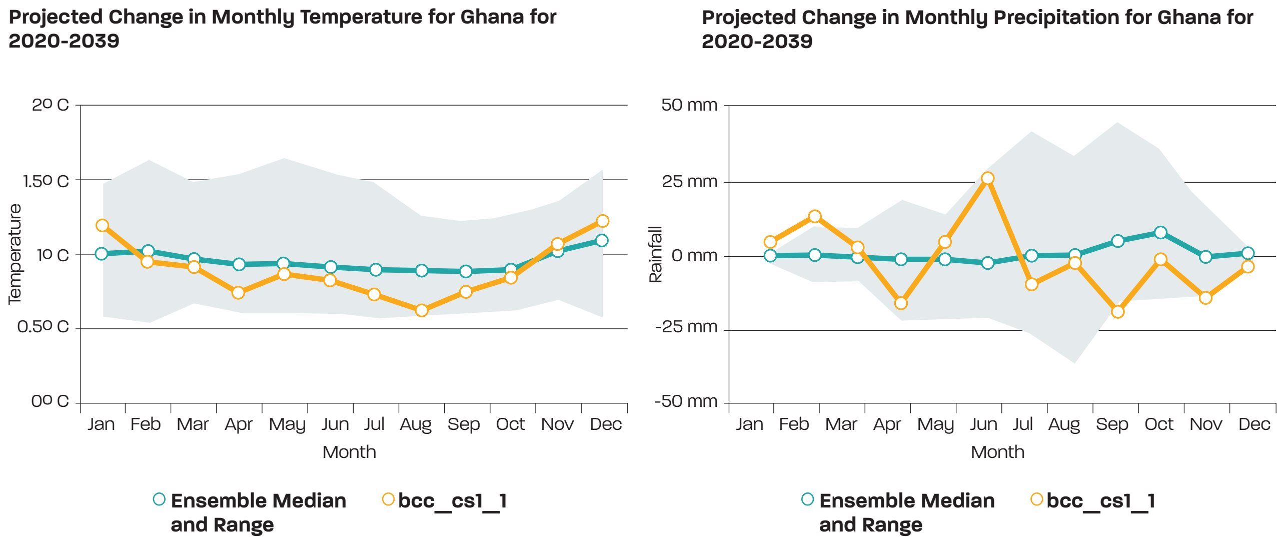
Climate change is expected to have substantial impacts and may alter seasonal climate patterns, temperature, and rainfall events. These may include, for example, more extreme rainfall peaks and would accordingly affect runoff and resulting floods. Temperature and precipitation data from 1960–2000 were analyzed in Ghana's National Climate Change Policy (NCCP) and show a progressive increase in mean temperature and a decrease in mean annual rainfall in all regions. Temperature has increased by about 0.2 degrees Celsius per decade, with a faster increase in the northern regions of the country (MESTI 2014).

No single climate model is commonly agreed upon to predict the effects of climate change for Ghana and West Africa at large (Diallo et al. 2012; Hempel et al. 2013). Combining data from different climate models—notably the Coupled Model Intercomparison Project Phase 5 (CMIP5) assessed in the United Nations Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report—the impacts on temperature and rainfall for the time horizons 2030, 2040, and beyond have been identified for Ghana.[5] Accordingly, the annual mean temperature of Ghana is projected to rise in both low and high warming scenarios. In the low warming scenario, a countrywide warming of 1 degree Celsius is projected by the 2030s and the 2040s. In the high warming scenario, a temperature increase of

5 Climate model data from the World Bank's Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/.

Figure 1.1 Projected Temperature and Precipitation Changes in Ghana, 2020–39

a. Change in monthly temperature **b. Change in monthly precipitation**



Source: World Bank 2018b
Note: Note: bcc_cs1_1 refers to climate model cs1_1 set up by Beijing Climate Centre, China and made available through the Coupled Model Intercomparison Project - Phase 5 (CMIP5) of the World Climate Research Program. We acknowledge the World Climate Research Programme's Working Group on Coupled Modelling, which is responsible for CMIP, and we thank the climate modeling groups for producing and making available their model output.

1.3 and 1.8 degrees Celsius is projected for the 2030s and the 2040s, respectively. Climate models for southern Ghana project a more pronounced increase in heat extremes, which are more intense under the high warming scenario. The mean annual temperature is projected to increase by 1.0–3.0 degrees Celsius by the 2060s and by 1.5–5.2 degrees Celsius by the 2090s.

Extreme droughts are projected to primarily affect the Brong-Ahafo and Ashanti regions consistently in both warming scenarios, even though the amplitude of the effects is projected to be lower in the low warming scenario. Total annual rainfall is projected to decline by 1.1 percent and 20.5 percent in 2020 and 2080, respectively. The projected monthly changes in monthly temperature and precipitation for 2020–39 are shown in figure 1.1. The impact of rising sea levels is not yet fully understood, but the trend of progressing coastal erosion—with Accra's coast seeing historical coast erosion rates of 1.5 meters per year—is expected to continue.

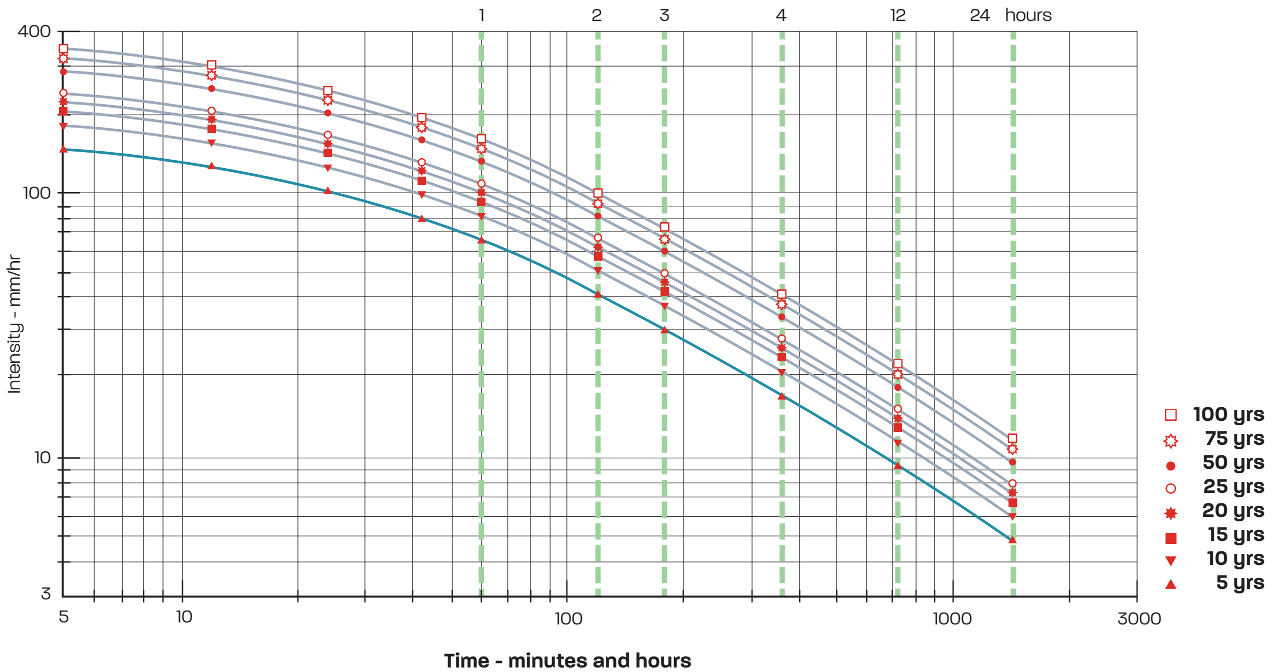
These changing precipitation and temperature patterns are projected to severely affect economic growth and poverty eradication efforts and may further increase rural-to-urban migration. By 2050, the reduction in Ghana's GDP per capita is estimated to be 6.5–11.4 percent in the low and high warming scenarios, respectively, relative to a scenario without climate change. Even by 2030, an estimated 400,000 additional Ghanaians are projected to live below the poverty line because of climate change (World Bank 2017).

Most of the rainfall occurs during the main rainy season (peaking in May and June) and a minor rainy season (in September and October). Heavy rainfall events induce floods in the densely populated areas of Greater Accra occur nearly instantly within as little as one to two hours. The statistics of those rainfall events applied in this study are derived by the Ghana Meteorological Agency (GMET) and presented as intensity-duration-frequency (IDF) curves (figure 1.2).

To obtain an indication of the possible impact of climate change on floods in the Greater Accra Region, the results of the various climate scenarios and models for daily rainfall with a return period of 10 years were analyzed (figure 1.3, panel a). A large spread is visible in the results of the different models, with future precipitation changes expected to range between −40 and +90 millimeters. The analysis of climate impacts is based on the median, 10th, and 90th percentiles of all combinations of scenarios and models (figure 1.3, panel b).

The median results show an expected increase in daily rainfall with a 10-year return period of 3–4 millimeters, but the future increase can also be considerably larger

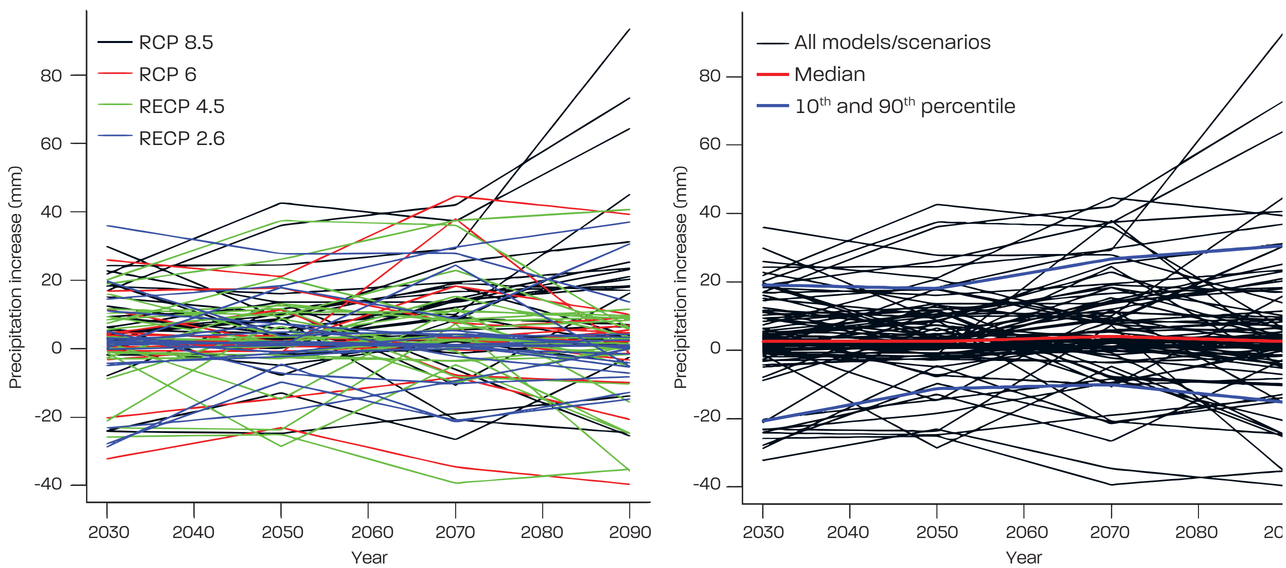
Figure 1.2 Intensity-Duration-Frequency (IDF) Curves for Rainfall, Kotoka International Airport, Accra



Source: Ghana Meteorological Agency, 2017 personal communication.
Note: Red symbols indicate the expected frequency (in years) of rainfall events of a given intensity and duration indicated along the curve.

Figure 1.3 Projected Precipitation Increases for Greater Accra Region, by Scenario, 2030 to 2090

a. Models, by scenarioa **b. Models for all scenarios, median, and 10th and 90th percentilesb**



Source: World Bank 2018b
a. RCP = Representative Concentration Pathway. (RCPs represent different possible future radiative forcing scenarios through a selected evolution of distinct emissions and land-use change [World Bank 2018].) Data were calculated for daily rainfall with a return period of 10 years. Each line represents a climate model for one of the four scenarios. [[AQ: See addition to note re: RCPs and source added to ref. list.]]
b. Black lines represent scenarios shown in panel a. Red and blue lines represent the median and 10th and 90th percentile results, respectively.

Table 1.2 Summary of Precipitation Increase Projections for Greater Accra Region, 2030 to 2090

Precipitation increase model	2030	2050	2070	2090
	in millimeters			
Median	2.6	2.5	4.0	2.6
10th percentile	−21	−11	−10	−15
90th percentile	19	18	27	31

Source: World Bank 2018b

(20–30 millimeters) (table 1.2). For the sensitivity analysis, an increase of the rainfall totals for the IDF curves of figure 1.3 of 10 percent was taken, which is between the median and 90th percentile.

The sea level is projected to rise because of climate change. In the study, a worst-case scenario of a 6-millimeter rise per year up to 2050 was applied, based on the IPCC 4th Assessment Report published in 2007 (Amoako and Boamah 2014).

Coastal threats are another factor when considering flood issues. in the eastern Greater Accra Region, the Ada Region, and Ningo Prampram District, coastal erosion threatens the coast and forces small villages to move away from the sea. The sea can also be a threat owing to high tides combined with high river discharge. This combination leads to floods in coastal areas because the river water cannot enter the sea and overflows the riverbanks. This last issue also affects the other coastal areas of Greater Accra like La Dade Kotopon, Tema, and Ledzokuku Krowor.

1.3 Urbanization, Development, and Policy Challenges to Flood Risk Management

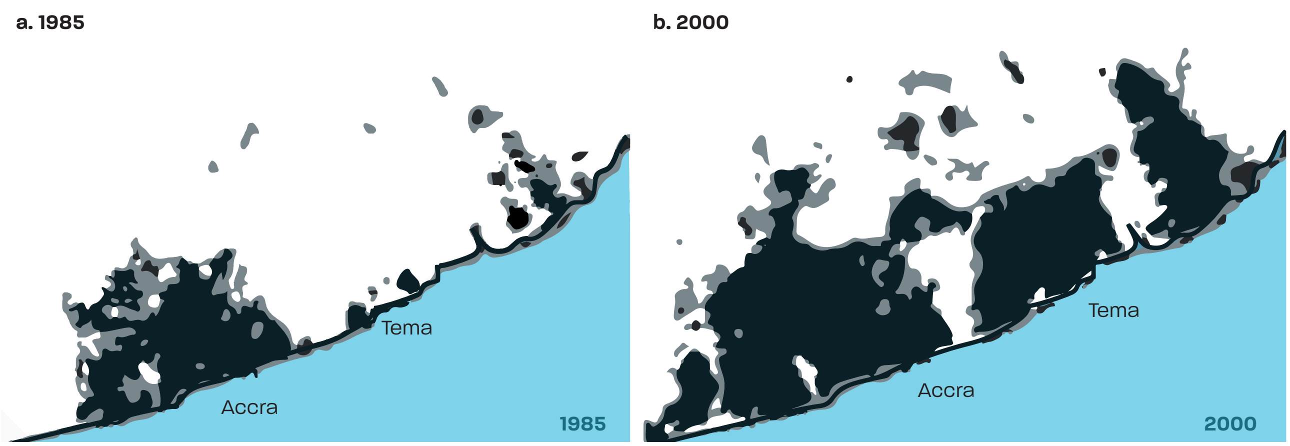
The Greater Accra Region is one of the biggest and fastest growing cities in Africa. Its 1958 population of 200,000 grew to 4.7 million by 2015 and is projected to grow by approximately 3 percent per year for the coming 20 years (GSS 2012). In 2037, 9.4 million inhabitants are expected to live in Greater Accra (LUSPA 2017). Real economic growth in Greater Accra from 1991 to 2016 was on average 2.8 percent per year.[6]

1.3.1 Overall Infrastructural and Institutional Challenges

Although 58 percent of Greater Accra's population lives in the Odaw Basin, the region has no comprehensive, water-inclusive urban planning strategy that ensures proper flood risk management. In addition to heavy rains and rising seas, many infrastructural and institutional factors contribute to the region's flood risk:

- *Failing stormwater and drainage infrastructure.* The region suffers from low to limited drain capacity as well as damaged or broken primary, secondary, and tertiary drainage infrastructure. In addition, there is no water retention capacity upstream, heavy silting and waste accumulation, deferred dredging of the Korle Lagoon,

Map 1.2 Urban Growth in the Greater Accra Metropolitan Area, Ghana, 1985–2000



Source: Arup 2016. ©Arup and Cities Alliance. Reproduced with permission

6 Real economic growth data for Greater Accra from the World Development Indicators database, World Bank: https://data.worldbank.org/indicator.

no or limited maintenance of infrastructure and adjacent areas, and poor drainage in built-up areas.

- *Poor solid waste management infrastructure.* Because of the lack of adequate solid waste collection points and transfer stations along the Odaw Channel, the solid waste often ends up in open drains, watercourses and streams, or illegal dump sites, which increases the flooding impacts and contributes to increased health and flood risks. The key solid waste management issues are (a) lack of community awareness; (b) absence of effective collection, segregation, and recycling systems; (c) limited disposal capacity; and (d) and inadequate enforcement of relevant bylaws. Urbanization means also an increase of the solid waste load.
- *Rapid, unplanned urbanization.* The rapidly increasing and unplanned urbanization leads to further increase of impervious surfaces and reduces the absorption of stormwater runoff—further increasing flood risk. Urbanization goes together with expansion of the tertiary drains alongside the roads. Those drains are only designed to keep the roads free of water, but the side effect is that stormwater flows rapidly downstream. Urbanization also implies an increased paved area, causing a faster rainfall-runoff response. The expansion of the drainage system and the pavement of the urban fabric cause higher and faster stormwater flows and contribute to flash floods.
- *Increased vulnerability and flood exposure of informal settlements.* Space is scarce and expensive. The urban poor tend to reside in low-lying or uninhabitable areas—often informal settlements associated with overcrowding, substandard housing, poor access to basic services, high exposure to natural hazards, cholera, and fire events. Already, 38 percent of the GAMA's residents live in informal settlements (AMA and UN-Habitat 2011).
- *Fragmented metropolitan planning and enforcement of spatial planning policies.* As noted earlier, the Greater Accra Region consists of 29 MMDAs, each as a planning authority with its individual plans, budgets, and institutional frameworks. This fragmentation adversely affects timely and efficient response to flooding; delivery of essential urban services including solid waste, sanitation, drainage, and roads; and land-use planning and other development controls to prevent illegal development of buildings and other structures on floodplains or watercourses that would increase flood impacts. Budgetary constraints of governments and agencies further hamper sustainable maintenance and operation of services.
- *Social issues and access to land:* The ownership of and hence access to land in large parts of Accra is not clear. Although by law, for example, a buffer zone of 100 meters along the riverbanks must be maintained, people have settled in those areas without any interference of the authorities. Finding suitable areas for flood prevention measures that limit the impact on land, land acquisition costs, and resettlement of people has therefore been a priority for the government.

1.3.2 Challenges to Adaptive Capacity for Risk Management

The urbanization challenges are intertwined with climate risks and the lack of adaptive capacity to adequately manage those risks. Critical challenges that limit the capacity to manage climate risks and the consequent flood risks include the following:

- *A drainage and stormwater management infrastructure not designed for climate change:* Considering different climate models, calculations have found that the existing and planned drainage infrastructure could not provide the same safety levels by 2070 that they would provide at the baseline (2015). For example, the drainage infrastructure, which is designed to protect the population from 1-in-10-year flood events, would only have a flood safety level of 1 in 9 years, or as low as 1 in 4 years, depending on the climate and urbanization scenario.
- *Centralized and nonresilient urban stormwater management:* With further urbanization and further paving of surfaces, the capacity to centrally manage stormwater through the Odaw Channel and Korle Lagoon will become increasingly inadequate. In contrast, cities all over the world have initiated stormwater regulations that require property owners to retain water on site (for example, parking lots). Decentralized management that enables up to 10 percent of stormwater to be captured locally would contribute to resilient, water-inclusive urban development.
- *Limited understanding of weather and climate risks and management of residual climate risks:* Ghana has invested in recent years in early warning systems. Nevertheless, it still lacks appropriate contingency planning, funds to appropriately respond to disasters, and an effective end-to-end hydrometeorological and early warning system that timely reaches the last mile to the affected population.

1.3.3 Challenges to Disaster Response and Policy Enforcement

In addition to challenges related to the drainage infrastructure and urban planning, the following institutional issues related to effective disaster response or policy enforcement have contributed to the growing flood risk in Greater Accra:

- *Limited disaster response and mitigation capacity:* The National Disaster Management Organisation (NADMO) is present in all MMDAs of Greater Accra to advocate for understanding of hazards and risks and to support the local administration rescue, relief, and recovery operations. Nevertheless, at the MMDA level, NADMO has limited resources and logistical capacity to adequately respond to disasters and implement its activities.
- *Lax enforcement of buffer-zone policy and related building codes:* The Water Resources Committee of Ghana (WRC) supports the implementation of the buffer zone policy around waterways and waterbodies. Nevertheless, the enforcement of the buffer zone policy in spatial planning and the implementation of related building codes remains a challenge and is not enforced. The WRC, the Land Use and Spatial Planning Authority (LUSPA), and the MMDAs have only limited capacity to effectively enforce the spatial planning and buffer zone policy.
- *Limited MMDA coordination across the river basins on issues such as drainage, solid waste, or stormwater management:* In the past, many of the initiatives were geographically focused or focused on relieving a "bottleneck " within a single sector (such as drainage) instead of using a multisectoral, integrated approach to manage flood risk in the entire watershed holistically.

1.4 Objectives, Approach, and Outline of the Study

Ghana has a clear vision of climate-resilient urban development in Greater Accra and other major cities such as Kumasi and Sekondi-Takoradi, as spelled out in the Greater Accra Spatial Development Framework (2017–2037) (LUSPA 2017). One of the framework's key priorities is the protection of the population against perennial floods, such as those of June 3, 2015. The government of Ghana has therefore asked the World Bank to support the establishment and financing of a comprehensive program to find sustainable, climate-smart solutions addressing the problem of perennial floods in Accra.

This report's objective, therefore, is to support evidence-based decision making for the identification of structural and nonstructural flood risk mitigation measures. As such, it supports decision makers in their infrastructure choices—from a wide range of potential measures to an investment plan—by providing a clear understanding of the technical feasibility, budget, and social and environmental implications of technically feasible measures for achieving minimum flood protection and safety for Greater Accra.

1.4.1 Approach and Overview of the Analysis

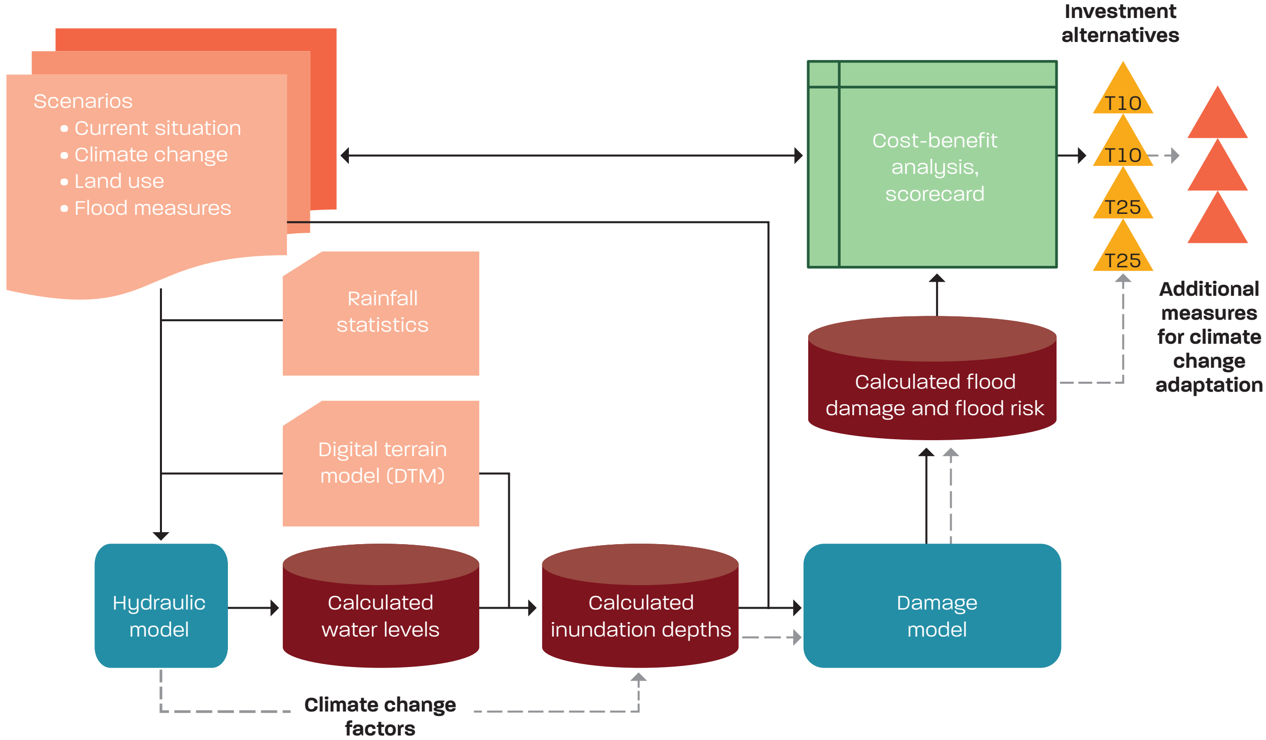
At the center of the analysis are a hydrological-hydraulic model and a damage and risk model, which simulated the potential effects of infrastructure measures and supported the identification of potential climate change impacts. The analytical work was furthermore supported with a cost-benefit analysis and multicriteria analysis that compared the different infrastructure measures. The analysis focuses largely on the Odaw Basin in Greater Accra and provides extrapolated information for the entire Greater Accra Region.

During the implementation of the project, capacity building and stakeholder engagement were elements to ensure close involvement of the government experts as well as consultations and decision making in line with the priorities and preferences of the involved stakeholders and beneficiaries. The consultations also included discussions with the affected populations in all 16 MMDAs of Greater Accra in addition to planning charrettes. The flowchart in figure 1.4 describes the report's analytical approach—from input and models to the evaluation of investment alternatives.

The various components of the assessment workflow were as follows:

- Modeling and analytical work
  - *Development of a hydrological and hydraulic model with different input scenarios.* The model receives input data, such as rainfall statistics and a digital terrain model, and calculates water levels, inundation depth, and flood hazard.
  - *Development of a damage model.* The damage model provided flood risk information and estimates potential flood damage based on (a) historical damage information (for example, from the flood impacts of June 3, 2015); (b) derived information from literature; and (c) updated cost estimations.

Figure 1.4 Workflow of the Flood Risk Assessment for the Greater Accra Region, Ghana



Note: Orange boxes refer to data, blue to models, red to model results, and green to evaluation. "T10" and "T25" refer to the return period (10 years and 25 years, respectively) of flood events that can be mitigated using the chosen investment package of structural and nonstructural flood mitigation and management measures.

- *Analysis of climate change-related information, and integration into models.*
- *Extrapolation of data from Odaw Basin to Greater Accra.*

- Identification of flood mitigation measures
  - *Identification of a flood management strategy and evaluation of flood mitigation alternatives.* A single flood mitigation measure (such as dredging alone or one retention pond) may not suffice to solve the complex issue of flood management; hence a cascade of different structural and nonstructural measures, combined with flood management alternatives, have been formulated.
  - *Identification of potential structural flood mitigation measures.* Considering existing plans from the different government departments and municipalities as well as global best practices, a long list of potential flood mitigation measures has been identified. Then the potential effectiveness of those measures, in terms of the reduction of damage and flood risk, has been determined.
  - *Design of flood management investment options.* Packages of structural and nonstructural measures were designed to achieve a safety level of T10, T25, or T50, referring to the return period (in years) of flood events that can be mitigated with the respective measures.

- Development of guidance for decision making
  - *Cost-benefit analysis.* The most cost-effective measures were identified, considering different investment criteria as well as costs for operations and maintenance and land acquisition.
  - *Analysis of financial, social, and environmental impacts using a multicriteria analysis.* The criteria were formulated in a participatory process and guided by a technical steering committee of government experts from different disciplines.
  - *Fine-tuning of the investment alternative.* The investment alternative was developed considering financial (budget), environmental, and social constraints, notably limitations of land availability and resettlement. It has been designed for a T10 (1-in-10-year return period) safety level and has also been

Photo 1.2 **Examples of Flood Damage from MMDAs in Greater Accra, Ghana**

a. Flood marks in Adenta Housing Down

b. House built in a waterway, Ga South

Note: MMDAs = metropolitan, municipal, and district assemblies.

budgeted in detail and discussed with the relevant stakeholders and the affected population.

- *Assessment of climate change impacts and the reduced level of protection.* The investment alternative is then retested with regard to the potential impacts of climate change and how different climate scenarios and urbanization trends would affect the safety levels.
- *Identification of a climate change adaptation strategy and additional measures.* The strategy and additional measures for climate change adaptation are then proposed and evaluated using the same criteria (social, environmental, and financial) to ensure that, by 2070 with climate change impacts, the same safety levels can be guaranteed.
- *Issuance of guidance for decision making and project-related investment planning.*

1.4.2 Stakeholder Involvement and Empowerment

The analysis was implemented in a participatory manner and guided by a steering committee of experts from different ministries of the government of Ghana. Stakeholder consultations were conducted at the level of the national ministries, the Greater Accra Regional Coordinating Council, and the local MMDAs (box 1.1). In addition, the preliminary findings of the analysis were discussed with the senior leadership of the involved ministries, including the Ministry of Works and Housing in December 2017, among others.

Consultations with all municipalities (MMDAs). In September and October 2017, all 16 MMDAs in Greater Accra

Photo 1.3 **Stakeholder Engagement in Flood Risk Management Planning, Accra**

a. Training session at HSD, 2017

b. Urban planning workshop, 2017

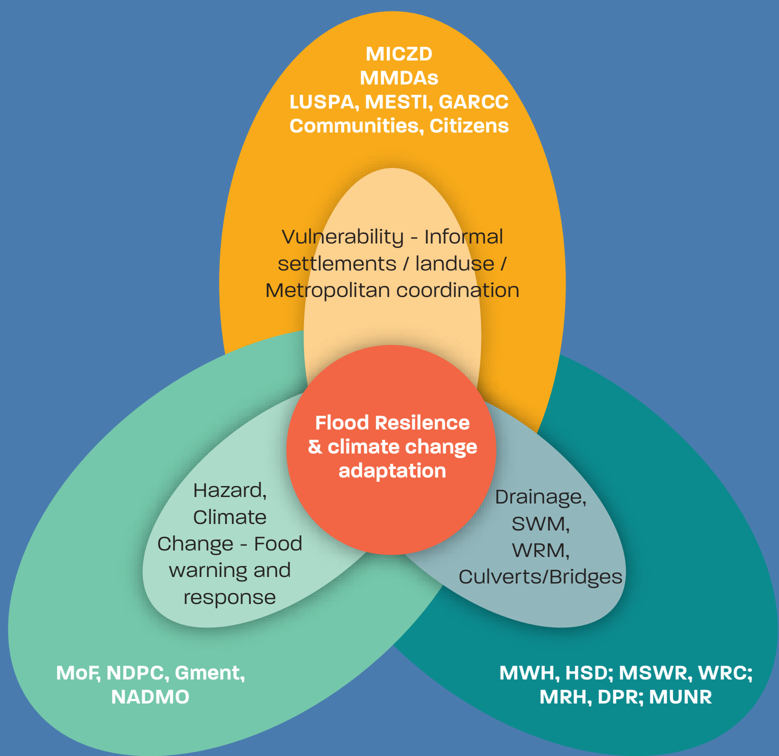
Note: HSD = Hydrological Services Department.

Box 1.1 Forming a Dedicated Stakeholder Group to Achieve Flood Resilience in the Region

The main feature of the "Accra Flood and Climate Risk Mitigation Strategy" study was the close working relationship among stakeholders over two years. During this time, key stakeholders, who had initially worked together for the CityStrength Diagnostic exercise (World Bank 2017), continued collaborating to better understand and advocate for urban resilience in the Greater Accra Region. Together, they identified actions and investments to improve flood resilience and reflected on how current and future planned policies and actions will affect the Greater Accra Region's overall resilience.

The study brought together more than 6 sectoral ministries, close to 10 departments, and all municipal governments within the region (which increased from 16 to 29 because of regrouping during the study) (figure B1.1.5) through periodic steering committee meetings, workshops on study outputs, a survey of local governments, planning charrettes, site visits, and training of government officers on the hydrological-hydraulic modeling process. The collaboration and cooperation have continued beyond the study: key stakeholders are now collaborating on the International Development Association (IDA)-supported Greater Accra Resilient and Integrated Development Project (GARID) and other regional initiatives to strengthen flood and climate resilience in the Greater Accra Region.

Figure B1.1.5 Key Stakeholders and Roles



Note: DPR = Department of Public Roads. GARCC = Greater Accra Regional Coordinating Council. GMet = Ghana Meteorological Agency. HSD = Hydrological Services Department. LUSPA = Land Use and Spatial Planning Authority. MESTI = Ministry of Environment Science, Technology and Innovation. MICZD = Ministry of Inner City and Zongo Development. MLGRD = Ministry of Local Government and Rural Development. MLNR = Ministry of Lands and Natural Resources. MMDAs = metropolitan, municipal, and district assemblies. MoF = Ministry of Finance. MRH = Ministry of Roads and Highways. MSWR = Ministry of Sanitation and Water Resources. MWH = Ministry of Works and Housing. NADMO = National Disaster Management Organisation. NDPC = National Development Planning Commission. WRC = Water Resources Committee.

were visited and residents interviewed to obtain detailed information about flood risks, causes, and possible solutions (photo 1.2). (For a full report on the consultations, see appendix C).

Steering committee. A steering committee, headed by the Ministry of Works and Housing, was formed to guide the execution of the study and to actively discuss the flood risk and possible flood mitigation alternatives. All relevant ministries and institutions were invited to the steering committee meetings (as listed in this report's acknowledgments page). Steering committee meetings regularly took place between June 2017 and January 2019 at the World Bank's office in Accra.

Workshops and planning charrettes. Two workshops, in November and December 2017, discussed the urban planning aspects of the flood mitigation alternatives with stakeholders from the national ministries, departments, and agencies as well as MMDAs. Another workshop, in February 2018, scored the effects of the flood mitigation strategies on all identified criteria.

Training sessions. Several training sessions on the developed models and the applied methodology (photo 1.3) were organized at the Hydrological Services Department (HSD).

1.4.3 Structure of the Report

This report is organized in five interrelated chapters:

- *Chapter 1, "Introduction and Overview,"* introduces and describes the study area and its climate change and urbanization challenges.
- *Chapter 2, "Understanding Flood Risk in the Greater Accra Region,"* summarizes the findings on flood hazard and flood risk analysis as well as the underlying models, data, and assumptions.
- *Chapter 3, "Greater Accra Integrated Flood Risk Management Strategy,"* describes the flood mitigation strategy for Greater Accra, focusing on a water-inclusive urban planning strategy; analyzes the different measures; and assesses the feasibility of flood mitigation alternatives to achieve different safety levels.
- *Chapter 4, "Investment Plan for Flood Risk Mitigation in Odaw River Basin,"* shows the analysis conducted for the investment alternatives leading to the T10 safety levels, including a comparison of the investment alternatives regarding financial, environmental and social issues.
- *Chapter 5, "Policy Choices and Proposed Short-, Medium-, and Long-Term Actions for Implementation,"* gives guidance on flood risk mitigation for decision making and policy planning and suggests a road map for implementation.

In addition, the report has several detailed appendixes, which summarize the analytical findings underpinning the report:

- *Appendix A, "Flood Model,"* summarizes the flood hazard analysis and underlying models and assumptions.
- *Appendix B, "Damage Model Using GIS Data,"* provides the details on the damage model.
- *Appendix C, "MMDAs of Greater Accra."*
- *Appendix D, "Guidelines for a Water-Inclusive Urban Planning Strategy for Greater Accra."*

PHOTO BY: © DOMINIC CHAVEZ/WORLD BANK

CHAPTER 2

Understanding Flood Risk in the Greater Accra Region

Introduction

Understanding the flood risk in the Greater Accra Region (GAR) is important for the identification of a suitable flood mitigation strategy and the design of different structural and nonstructural flood mitigation measures. Flood risk is a combination of flood hazard and vulnerability: Flood hazard is a latent condition, based on climate, topography, water catchment area, and rainfall. Vulnerability is dependent upon location as well as the strength or capacity of the exposed property, infrastructure, and people to withstand flooding. Land-use policies, building codes, and stormwater and drainage infrastructure and other measures can be planned to reduce exposure and vulnerability to flooding.

This chapter describes how flood risk was assessed and modeled for GAR through a state-of-the-art hydrological and hydraulic model, a damage model, risk mapping, and local hot-spot surveys. The dynamic modeling and mapping help stakeholders to understand where and why flood risk is concentrated in the GAR and to identify practical solutions for mitigating flood risk.

2.1 Development of a Model for the Odaw Basin

The details of the hydrological-hydraulic model for the Odaw Basin and the damage model and relevant assumptions are described in this chapter.

2.2.1 Hydrological-Hydraulic Model

The model describes the inundation by flood waters from the main rivers and primary drains (for example, the Odaw and its tributaries) as a result of heavy rainfall. The flood modeling process included development of a hydrological-hydraulic model with two components (figure 2.1):

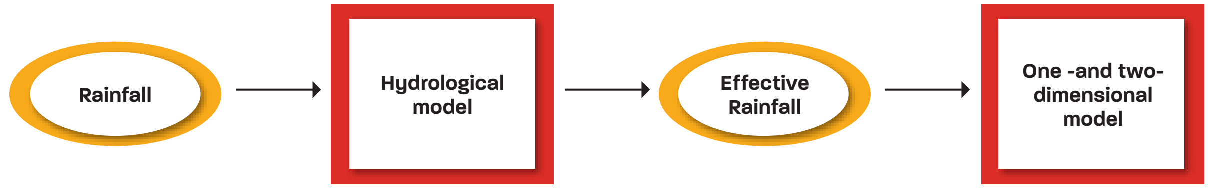
- *Hydrological component:* A precipitation runoff model that converts rainfall into "effective rainfall" (surface runoff to the drains). The runoff and inundation in the GAR model were based on elevation data.
- *Hydraulic component:* A two-dimensional overland flow model that captures the rainfall runoff routing and inundation patterns, simulating the flow pattern of the surface runoff into the main rivers and drains. For the Odaw Basin, there is also a one-dimensional model of the primary drains, including the basin's cross-sections and structures such as bridges, for a more detailed simulation of the flow through these drains.

The model includes a detailed schematization of the main drainage channels, with their respective cross-sections and layouts.

For the development and application of the model, the following data sources and modeling procedures were applied:

- **Boundary conditions**
  - *The intensity-duration-frequency (IDF) curves* for the rainfall events (as shown in chapter 1, figure 1.2), corrected for the size of the basins by an area reduction factor.
  - *The mean sea level* as a downstream boundary condition, since the study showed that the flood risk in Greater Accra is almost fully induced by heavy rainfall. High tides also occur and impose a risk, but it is comparatively much lower. The combination of heavy rainfall and high tides is rare and does not contribute significantly to the overall risk.
- **Schematization**
  - *A subdivision into pervious and impervious (paved) areas* based on the developed land-use map. For the pervious areas, a rainfall runoff model is developed,

Figure 2.1 Schematic Diagram of the Hydrological-Hydraulic Model



Note: 1D/2D = one-dimensional and two-dimensional.

accounting for infiltration losses using the Horton equation,[7] with model parameters based on literature. Also surface storage and interception losses are taken into account. The overland flow pattern of the remaining rainfall that contributes to floods is captured by the two-dimensional model, as follows:

- A digital terrain model (DTM) to build the two-dimensional overland flow model was built from the data shown in map 2.1.
- The DTM for the Odaw was built on (a) a detailed AutoCAD database from a Dredge Masters survey[8] in the direct vicinity of Odaw drain; and (b) World Digital Elevation Model (WorldDEM) data, generated by satellite observations (grid cell size 12 × 12 meters)[9].
- The vertical error of the AutoCAD-based DTM is estimated to be less than 0.5 meters. The published vertical error of the WorldDEM DTM is less than 4 meters, but when compared with the AutoCAD-based DTM, it seems to be less than 0.6 meters (Airbus 2015).[10]
- The DTM for Greater Accra was obtained from SPOT20 satellite data (grid cell size 20 × 20 meters) and a contour line database. Gaps were filled using the National Aeronautics and Space Administration's (NASA) STRM30 DTM (grid cell size 30 × 30 meters).[11]
- For the models of both the Odaw catchment and the whole GAR, the DTMs are aggregated to a grid cell size of 50 × 50 meters, to balance model calculation times and accuracy.

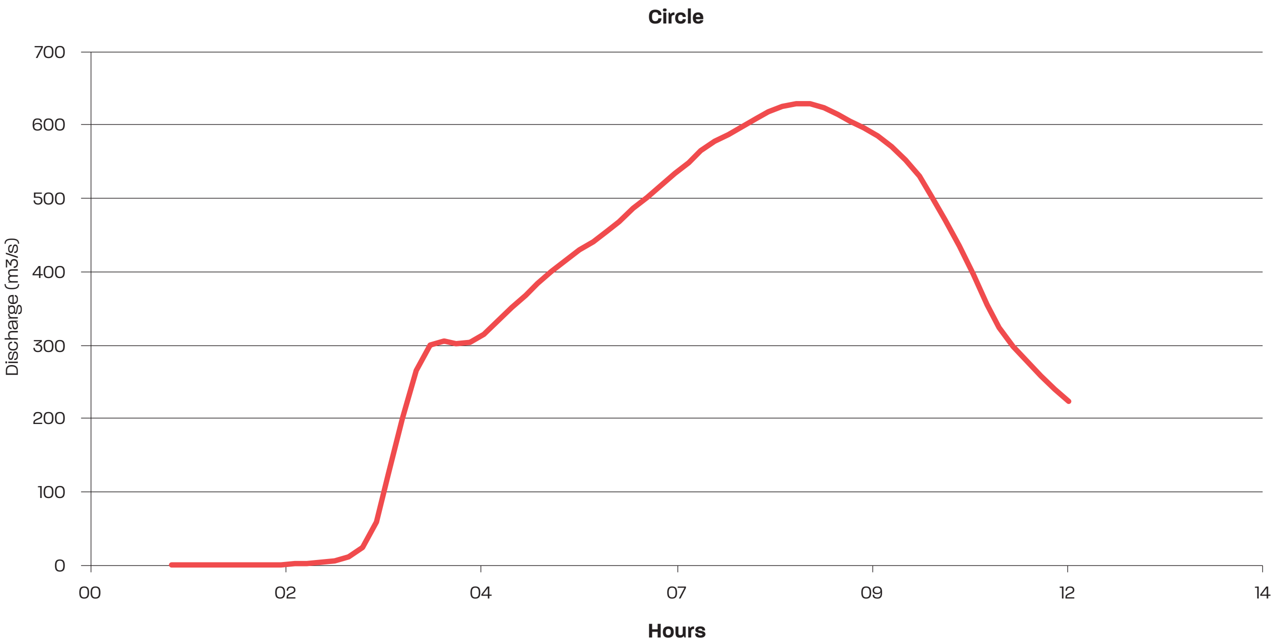
- *Cross-sections of Odaw and its main tributaries*, obtained from the Hydrological Services Department (HSD) and the Dredge Masters survey,[12] converted into the one-dimensional component of the model.
- *Hydraulic roughness parameters* from literature, both for the overland flow and the flow through the drains and rivers.
- *Locations of bridges in the Odaw Basin* from satellite images.[13] The bridge geometry was extracted from the Dredge Master survey (Dredgemaster 2017).[14] The interception weir near Old Fadama was also included with the geometry taken from the design drawings of the Dredge Master survey.

- **Validation.** The model of Odaw was validated from records (photos, movies, and testimonies of experts and affected people) of the flood of June 3, 2015, in the absence of recordings of water levels and discharges. It was concluded that the model generates plausible inundation patterns (flood frequency and flood extent). The model of Greater Accra was not validated, in the absence of accurate observations. No satellite images could be generated to find the recurrence and extent of floods, because of the short durations of inundations and the fast response of floods to rainfall (flash floods). The following data were used:
  - Rainfall recordings of the June 3, 2015, flood in the Odaw Basin[15]
  - Satellite recordings of rainfall from NASA (Tropical Rainfall Measuring Mission [TRRM] and Global Precipitation Measurement (GPM) satellites).[16] [17]

- **Software application.** The model was developed using the SOBEK modelling suite (Deltares 2016) [18], which is already available at the HSD.
- **Model results.** An example of typical model results is the calculated flood wave at Kwame Nkrumah Circle (figure 2.2). The peak value on June 3, 2015, was 620 cubic meters per second. Other examples of model results include the flood hazard maps presented in the chapter 3. For a detailed flood modelling report with

7 Horton (1933): $f_t = f_c + (f_0 - f_c)e^{-kt}$, where: ft is the infiltration rate at time t, f0 is the initial infiltration rate, fc is the saturated infiltration rate, and k is a decay constant.
8 Dredge Masters, pers. comm., 2017. Dredge Master data originates from 2015–16 before dredging of the Odaw River's main channel. Dredge Masters is a private firm hired by the government of Ghana in 2016 to dredge the Odaw Channel.
9 WorldDEM data are based on SPOT satellite information taken between January 2011 and May 2013
10 WorldDEM data were captured from December 2010 to mid-2014.
11 SPOT20 data are based on recordings during 2003–09. SRTM30 data are based on recordings from 2000. See the NASA Tropical Rainfall Measuring Mission satellite product website: https://trmm.gsfc.nasa.gov/ (NASA 2015) SRTM30 is a near-global DEM combining data from the Shuttle Radar Topography Mission (SRTM), flown in February 2000, and the U.S. Geological Survey's GTOPO30 data set ("SRTM30 Documentation," NASA ICESat [Ice, Cloud, and land Elevation Satellite] website): https://icesat.gsfc.nasa.gov/icesat/tools/SRTM30_Documentation.html).
12 Dredge Masters, pers. comm, 2017.
13 Satellite images from Google Earth, August 10, 2015.
14 Dredge Masters 2017. Personal communication
15 Ghana Meteorological Agency (GMet) 2017. Personal communication
16 TRMM satellite product, see the NASA TRMM mission website: https://trmm.gsfc.nasa.gov/
17 GPM satellite project, see the NASA GPM mission website: https://pmm.nasa.gov/gpm
18 Deltares 2016. SOBEK Suite website: https://www.deltares.nl/en/software/sobek/

Figure 2.2 **Calculated Flood Wave at Kwame Nkrumah Circle, Accra, June 3, 2015, Flood**



Note: "Hours" refers to hours from start of flood event.

an in-depth discussion of data and procedure, see appendix A.

- **Recommendations for continued model development and improvements.** Although the model is suitable for assessing flood mitigation measures on the main drains and rivers, some recommendations can be made for future improvement and use:
- The model is suitable for flood early warning in the main drains, but proper rainfall forecasting or nowcasting will be essential to provide the necessary lead time and effectively issue warnings.
- There is a need to develop a proper hydrological monitoring network enabling future calibration and validation. Gauging stations in the main drains are especially useful.

Box 2.1 Hydrological-Hydraulic Model Terms, Defined

Definition of floods: The model and thus the report describes the inundation by floodwaters from the main rivers and primary drains (for example, the Odaw and its tributaries) as a result of heavy rainfall. The models also include downstream boundary conditions for the sea level.

Areas covered and accuracy of the model: The model covers the entire Odaw Basin. The highest accuracy of the assessment will be found for those sections of the Odaw and its tributaries for which the bathymetry data were available and used in the model.

Design safety levels: The design safety levels (corresponding to protection against floods for return periods, in years, of 1:10, 1:25, and 1:50—also referred to as T10, T25, and T50) are applicable to the areas downstream of Caprice, which are also the most densely populated of Greater Accra. Upstream, since floods there are restricted to the riverbed, the safety levels will be higher. The design safety levels that correspond with the various "alternatives" therefore are the minimal safety levels for the whole Odaw Basin. Absolute protection against floods is not possible, so it can be assumed that some minimal water levels may remain in the areas, where the flood risk is reduced.

Software applications used: SOBEK, developed by Stichting Deltares 2016. Software version 2.14.

Validation of the model result: The Odaw model was validated from records (photos, movies, and testimonies of national experts) of the flood of June 3, 2015, in the absence of recordings of water levels and discharges.

- The Odaw model can be used to develop flood models for the sub-basins. In this case, the basic data can be extracted and further detailed with additional surveys of drains, culverts, and so on. The design of the smaller (tertiary) drainage network can best be determined by well-known drain design rules.
- If or when the dredging activities are carried out, update the drain geometry and calibrate or validate the model with data from the new hydrological monitoring stations. The current geometry is without any dredging.
- Proper surveying of the bridges and including these figures in the model is recommended on all primary drains if or when updating the model.

2.1.2 Damage Model

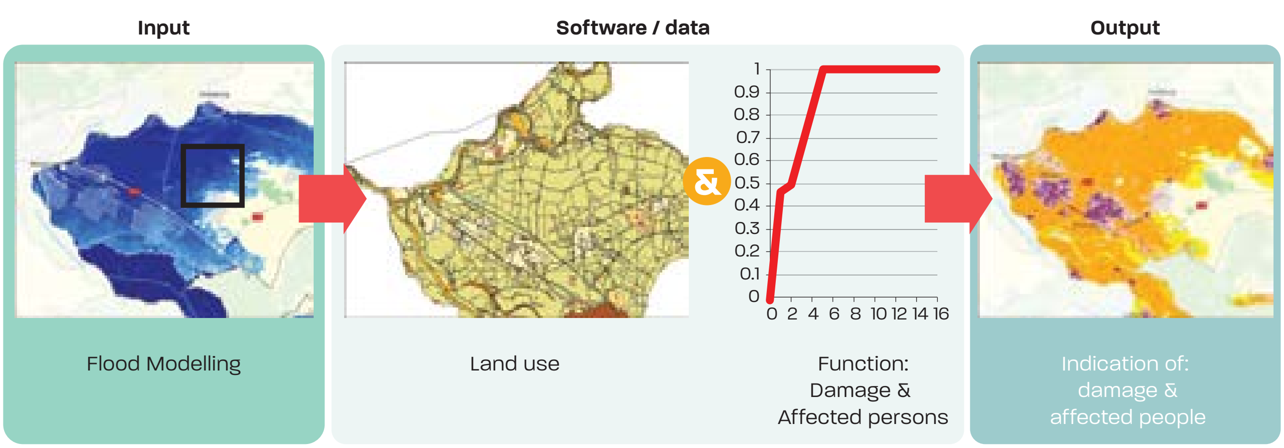
The damage model is an essential part of identifying flood risk and estimates monetary losses due to flood. It thereby supports the analysis of potential benefits from flood mitigation measures by determining benefits as reduced costs of damages. The concept of relative damage functions and maximum damage values were used in the analysis. That is, different types of buildings (such as industrial, commercial, and residential) may have *different values* per square meter, but the amount of *relative damage* given a certain flood depth may be identical. Because no information on damage functions has been published on Ghana or other countries in West Africa, the analysis used examples from literature on other countries with similar economies and climate patterns. The assumptions were then validated with experts from Ghana. For more details on how the damage model—including damage functions, maximum damage values, and geographic information system (GIS) data—was prepared and validated, see appendix B.

Workflow for damage calculation. In the workflow for calculating flood damages (figure 2.3), the inputs for the damage model are (a) the inundation depths calculated by the flood model and (b) the distinguished land-use or damage classes. Damage functions then translate the intensity of a hazard affecting a structure (such as water depth) to a damage ratio: the ratio of a building's repair cost to its replacement value (cost to rebuild the entire structure) (Ramanathan 2017). The damage factor multiplied by the maximum damage per asset yields the total amount of damage. The damage model (figure 2.3) consists of

- *Damage functions*, also called vulnerability curves, that describe the relation between inundation depths and the amount of damage, expressed as a damage factor;
- *Damage classes*, the classifications of land use and assets; and
- *Maximum damage values*, dependent on the land use and type of assets.

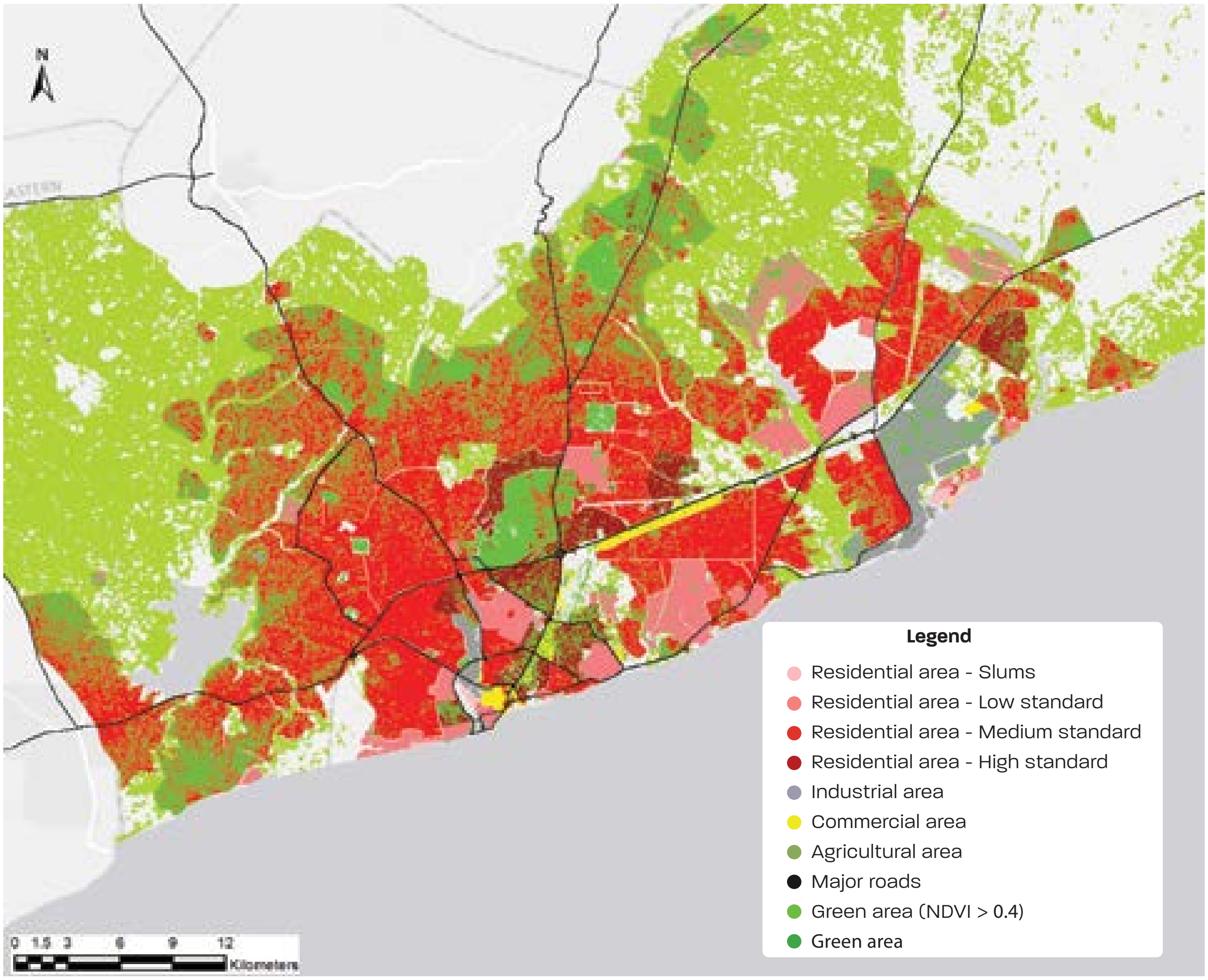
Development of damage functions. The model calculates the direct damage (for example, to infrastructure) and the indirect damage. Indirect damage is related to reduced economic activity and individual financial hardship, adverse impacts on the social comfort of a community, loss of trading time and market demand for products, disruption to business, and cost of emergency response and emergency accommodation for evacuees. Damage

Figure 2.3 Diagram of Flood Damage Assessment Process



Source: HKV Consultants.

Map 2.1 **Land-Use Map of the Greater Accra Region, from Satellite Images and Manual Digitizing**



Notes: Background based on Open Street Maps; ©World Bank. Further permission required for reuse.
NDVI = normalized difference vegetation index (ranging from –1 to +1).

functions (vulnerability curves) and GIS data have been developed for the following damage classes:

1. Residential buildings (four types: informal settlements, low income, middle income, high income)
2. Commercial buildings
3. Industrial buildings
4. Agriculture
5. Roads

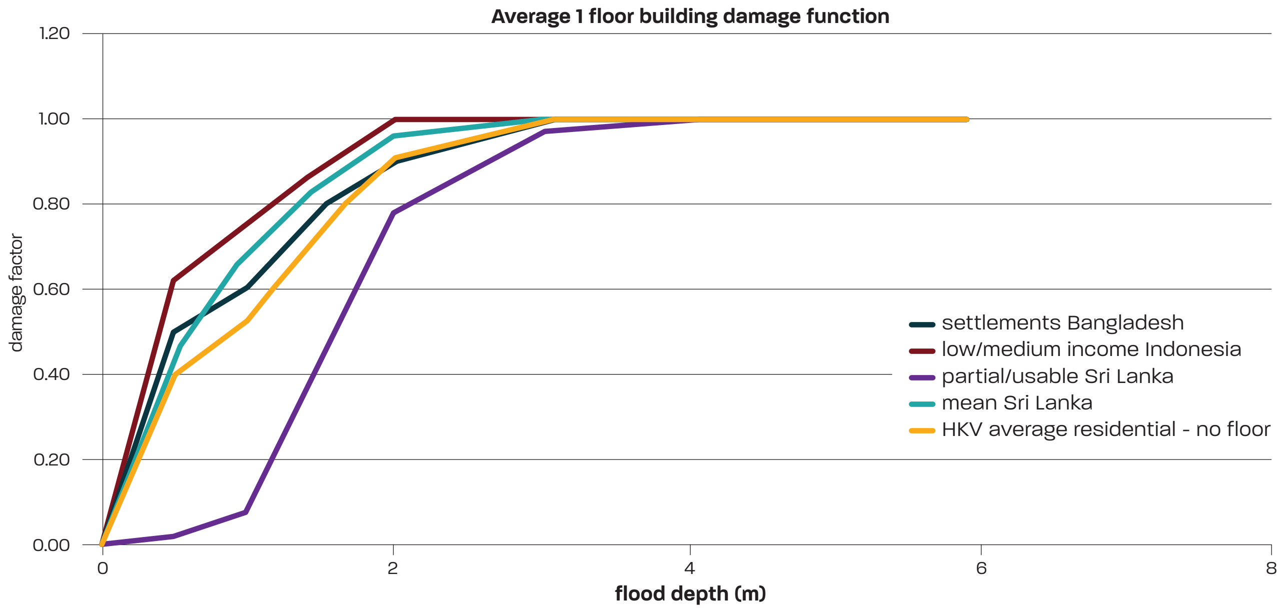
A detailed land-use map, showing all those assets—including a subdivision of types of housing (informal, low standard, medium standard, and high standard)—was developed based on satellite images (map 2.1). The map's grid cells are aligned with the flood model (50 × 50 square meters). General assumptions for the developed damage functions are as follows:

- Damage is related to the flood depth parameter only. Flood velocity, flood rise rate, and flood duration are not addressed.
- The damage functions include a range of flood depths from 0 to 6 meters and a damage factor from 0 to 1.
- For agricultural land use, one general average damage function is applied for the various crops grown in the Greater Accra Region, because the exact spatial distribution of the crops grown is unknown.

Damage functions, by class. The developed damage functions per damage class mainly follow from internationally found functions reported in literature (figure 2.4). After calibration of the damage model, the "partial or usable, Sri Lanka" damage function was applied for Accra.

Calculation of damage. For calculation of the actual damage, a distinction is made between high- and low-frequency

Figure 2.4 Damage Functions for Semipermanent and Single-Story Residential Buildings, Selected Locations



Source: Huizinga et. al. 2017.
Note: The damage functions, or vulnerability curves, show the relation between "flood depth" (inundation, in meters) and the "damage factor" (amount of damage). "Partial or usable" refers to partially damaged houses.

flooded areas. Areas that are flooded an average of once every two years (high frequency) will be assigned a damage reduction of 80 percent as a literature-based estimated effect of flood risk adaption (Wind et al. 1999). The maximum damage values (based on reconstruction costs) are assessed for various assets (houses, commercial and industrial buildings, infrastructure, agriculture, and so on). Estimates are based on literature and data of the flood of June 3, 2015 (MESTI 2016). The results are shown in table 2.1.

The damage to the inventory of the assets was taken as a percentage of the reconstruction costs, based on literature (Scawthorne et al. 2006 and FEMA 2013), as follows:

- *Residential:* 50 percent
- *Commercial:* 100 percent
- *Industrial:* 150 percent

The indirect damage is taken as an average of values found in literature, resulting in percentages of the direct damage shown in table 2.2 (Huizinga et. al. 2017).

Validation of the model. The model was validated by comparing the calculated number of affected people and flood damage values with data for the June 3, 2015, flood. The validation shows the plausibility of the model. However, a complete validation of the model results

Table 2.1 Maximum Flood Damage Values, by Asset Type (Reference Year 2016)

Damage class	Maximum damage value (US$ per square meter)	Maximum damage value (GHS ¢ per square meter)
Value slum, urban fabric	22	97
Value low standard, urban fabric	46	201
Value medium standard, urban fabric	80	346
Value high standard, urban fabric	80	346
Asset value commerce, urban fabric	178	767
Asset value industry, urban fabric	132	570
Agriculture	0.06	0.27
Roads	38	164

Table 2.2 Indirect Flood Damages, by Asset Class

Damage class	Indirect damage Percent of direct damages
Residential	15
Commercial	24
Industrial	32
Agricultural	21
Infrastructure	40
Roads	44
Rail	5

Source: Huizinga et. al. 2017.

Table 2.3 Validation Results of Damage Model for the June 3, 2015, Flood in Accra

Indicator	Flood model	Data extrapolated from MESTI (2016)a
Number of affected people	176,755	160,000
Number of affected houses	40,000	38,500
Direct flood damage to houses (US$, millions)	3.4	4.1
Direct flood damage to transport and water infrastructure (US$, millions)	37.0	27.0

Note: Validation results are based on interpreted data of the actual damage.
a. Extrapolated data based on unit values from MESTI (2016)

with the data gathered after the flood is not possible because the data on damages in the flood impact assessment were not collected within the boundaries of the Odaw Basin but rather at the level of the different metropolitan, municipal, and district assemblies (MMDAs) and only for a number of selected sectors of the economy (MESTI 2016). Table 2.3 shows the validation results, comparing the damage model results with those of (MESTI 2016). It shows that the damage model gives plausible results.

Recommendations for continued model development and improvements. The damage modeling can be further strengthened by improving the mapping of building footprints in the Greater Accra Region. One way is to digitize footprints of buildings from recent satellite images in platforms such as OpenStreetMap. In addition, capturing damages from previous disasters in a geospatial database would substantially increase the accuracy and accessibility of information for application in flood risk modeling.

2.2 Flood Risk Assessment

This section presents the findings from the risk analysis and flood risk mapping, which is based on the hydrological-hydraulic model and the damage model. It also includes findings from local hot-spot surveys in 16 MMDAs to assess the municipal officers' perceptions on flooding and to identify high-risk flood-prone areas and potential reasons for flooding.

The "flood risk" is defined as "flood hazard" multiplied by "flood vulnerability" (map 2.2). The flood hazard and flood risk are calculated in this analysis with the following considerations:

- The flood model calculates the flood hazard, defined by the flood extent and inundation depths for various return periods.
- The damage model calculates the flood damages and number of affected people based on the flood model as input.
- The combination (multiplication) of the flood hazard (probability) and vulnerability results in flood risk maps. High hazard and high vulnerability results in high risk values. Low hazard and low vulnerability results in low risk values. High hazard and low vulnerability or low hazard and high vulnerability result in intermediate risk values either in monetary terms (US$ per year) or as people affected (people per year).
- The flood risk is expressed as the present value of the future flood damages—that is, the amount of monetary compensation needed for future flood losses.

Present value of the flood risk: The present value of the flood risk can be seen as the amount of money that needs to be put aside today to compensate for all the future flood losses, calculated as follows:

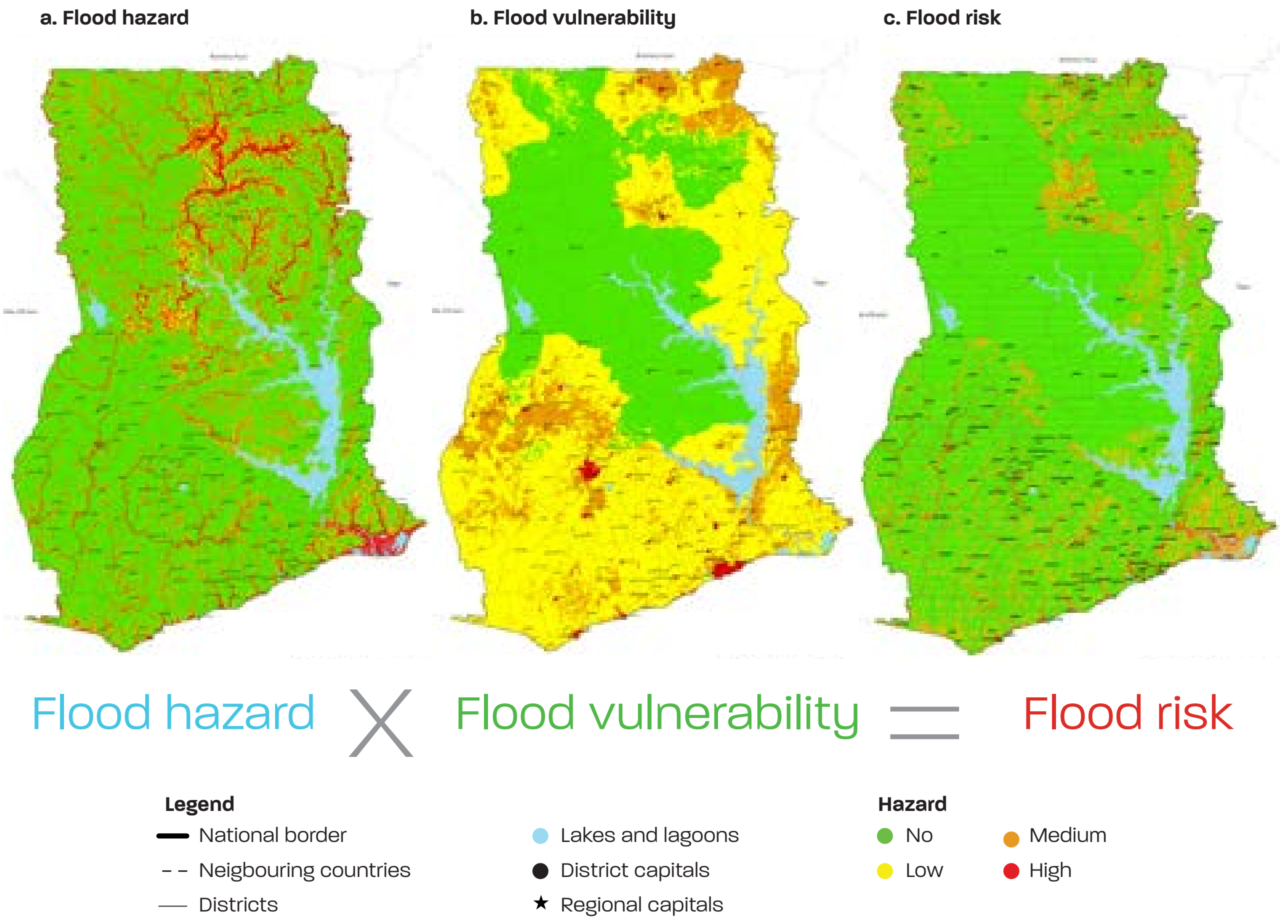
$$PV = \frac{1-(1-r)^n}{r} \times (\text{yearly average damage}) \quad (B2.2.1)$$

where PV = present value (US$ or GHC),
r = discount rate (%), and
n = time horizon (years).

Discount rate: To obtain the discount rate for this project, the following methods and sources were used:

- *The opportunity cost of capital method based on alternative investments.* The real interest rate in Ghana is about 4.5 percent (22 percent nominal rate – 17.5 percent inflation). If a risk premium is added of 2.5 percent, the total real rate is 7 percent.

Map 2.2 Sample Mapping of Flood Risk Calculation for Ghana, 2010



Notes: In partnership with United Nations Development Program (UNDP) Ghana © UNDP → change In partnership with United Nations Development Program (UNDP) Ghana (UNDP 2016) © UNDP. Red areas indicate high values for hazard, vulnerability, or risk; yellow areas indicate intermediate values, and green areas indicate low values.

- *Social time preference method based upon long-term GDP growth.* The real gross domestic product (GDP) growth rate was 7.8 percent in 2016 and 6.1 percent in 2017.
- *Cost-benefit analysis from literature.* A 2017 cost-benefit analysis by Kwesi Asante on the Soot Free Transport system in Ghana used a discount rate of 7 percent (Asante 2017).
- *Discount rates from related literature.* A World Bank study of the economics of adaptation to climate change used a real discount rate of 5 percent (World Bank 2010), and the International Union for Conservation of Nature (IUCN) cost-benefit analysis of a forestry project in Ghana also used a discount rate of 5 percent (IUCN 2016).

Based on these sources, it was agreed with the World Bank to apply a real discount rate of 6 percent for this project.

Time horizon: Water management infrastructure normally has a lifetime of 50–100 years, and climate change is a long-term phenomenon. Therefore, to realistically assess the costs and benefits of flood mitigation measures, a time span of several decades is required. For this project, 2020–60 (40 years) has been chosen as the time span, with World Bank agreement, reflecting 10 years for full implementation of the flood mitigation interventions and 30 years to lifetime of the infrastructure works.

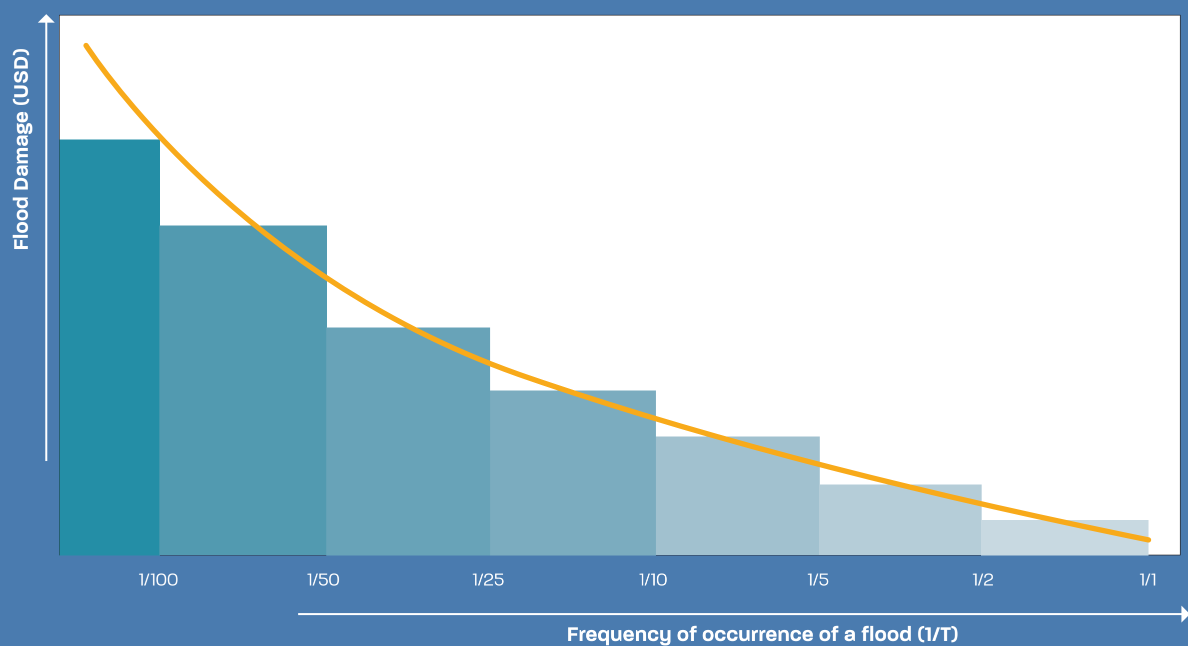
Number of affected people: This study defines the people affected by flooding as those who live in areas where inundation depths exceed 30 centimeters. The number of affected people is expressed as the yearly average (calculated similarly to the yearly average flood damage) and follows from the number of affected people calculated for all flood return periods.

Box 2.2 Flood Risk Assessment Terms, Defined

Flood return period: The probability that floods will occur is often expressed as a return period.[1] The inverse of probability (generally expressed as a percentage), it gives the estimated time interval between events of a similar size or intensity. For example, the return period of a flood might be 100 years—otherwise expressed as 1/100, or 1 percent, probability of occurring in any one year. This does not mean that if a flood with such a return period occurs, then the next will occur in about 100 years' time; instead, it means that, in any given year, there is a 1 percent chance that it will happen regardless of when the last similar event was. In other words, it is 10 times less likely to occur than a flood with a return period of 10 years (or a probability of 10 percent).

Yearly average flood damage: The present value of the flood risk is calculated by first obtaining the expected yearly average flood damage—the calculation of the damages for floods with return periods of 1, 2, 5, 10, 25, 50, and 100 years. This is done through GIS calculations for all grid cells of the damage model individually, followed by summing of these results for the study area. The expected yearly average of the flood damage is defined by the surface under the calculated damage line (figure B2.2.1) and is calculated as the area of the visualized rectangles.

Figure B2.2.1 Calculation of Expected Yearly Average Flood Damage



Source: ©World Bank. Further permission required for reuse
Note: The area beneath the calculated damage curve indicates the expected annual average flood damage for a flood of a given frequency.
1 "What Is a Return Period?" Natural Hazards FAQ, National Institute of Water and Atmospheric Research (NIWA) website: https://www.niwa.co.nz/natural-hazards/faq/what-is-a-return-period.

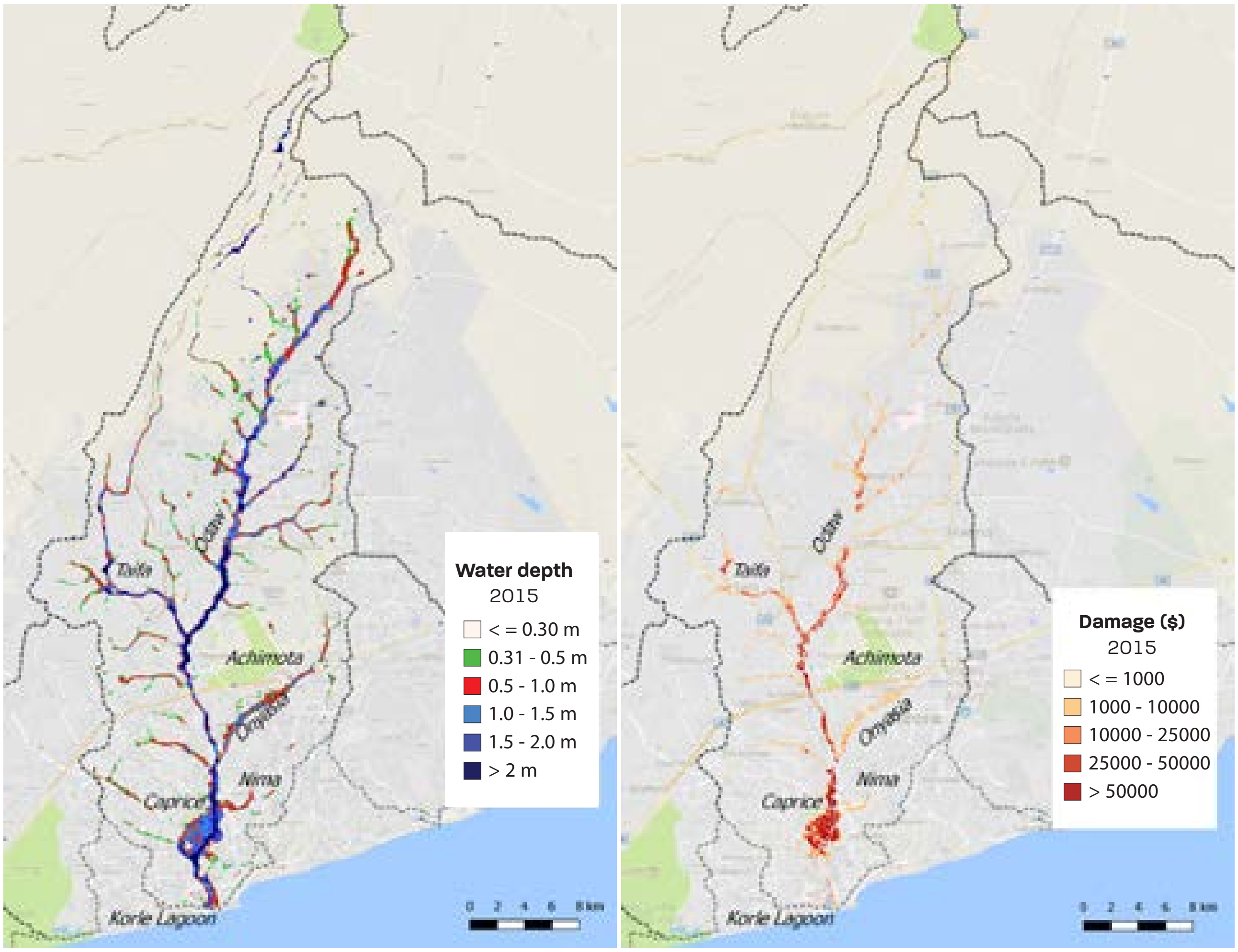
2.2.1 Modeling the Floods of June 3, 2015, in the Odaw Basin

As a first step, the analysis illustrated the extent and damages of the June 3, 2015, flood to calibrate and validate the models used in the study. Especially the business and industrial area around Kwame Nkrumah Circle and Kaneshie, where economic activities are concentrated, were heavily affected (map 2.3). Model simulations show that floodwaters accumulate there because of the downstream location (where all excess water must pass); the area's flatness and low altitude; and the lack of discharge capacity of the lined Odaw drain, which is only 35 meters wide downstream of the Circle, while the maximum discharge calculated by the model is approximately 600 cubic meters per second. The lined Odaw drain downstream of Caprice was also heavily silted at the time, further reducing the discharge capacity.

The flooding was additionally worsened by blocked and damaged gates of the interceptor weir in Korle Lagoon. Solid waste accumulating behind the weir and several bridges along the Odaw also contributed to rising water levels. Model simulations show that the peak water levels at Abossay-Okai Bridge and the Circle due to siltation and blocking of the interceptor weir increased by 1 meter

Map 2.3 **Calculated Extent and Damages of the Flood of June 3, 2015, in Odaw Basin, Accra, Ghana**

a. Flood extent, by water depth **b. Flood damages, US$**



Note: Background based on Open Street Maps; ©World Bank. Further permission required for reuse.

and 0.5 meters, respectively. This shows the importance of maintenance.

2.2.2 Flood Hazard and Risk Analysis

The key figures concerning the calculated flood risk without any risk mitigation measures are shown in table 2.4. For the corresponding flood hazard and flood risk maps, see maps 2.4, 2.5, and 2.6).

The risk assessment shows that in the Odaw Basin, as noted earlier, the flood hazard and flood risk were the highest in the industrial and business area between Caprice (the confluence of the Odaw and its Onyasia tributary) and Abossay-Okai Bridge. Model calculations show that, without mitigation measures, floods have currently a return period of once in two years. The floods of June 3, 2015, had an approximate return period of 1 in 10 years.

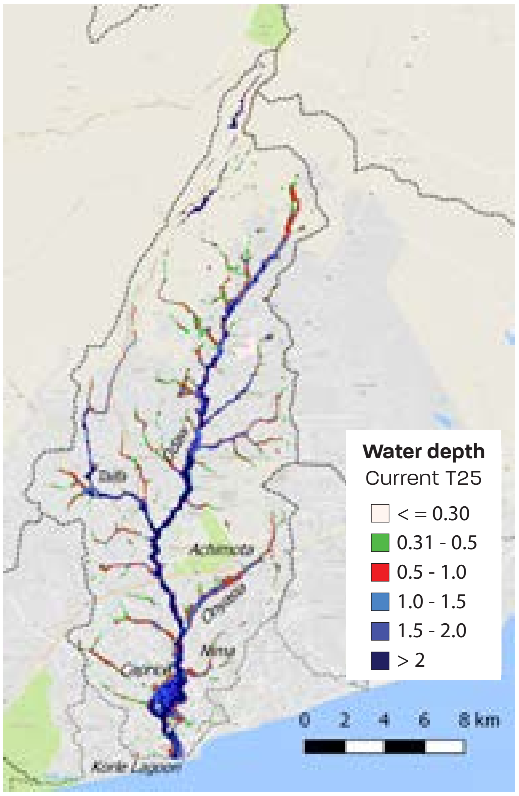
The flood hazard in the Odaw Basin is mostly caused by heavy rainfall. Floods do occur because of high sea levels,

Table 2.4 **Flood Risk in the Odaw Basin and Greater Accra Region, 2018**

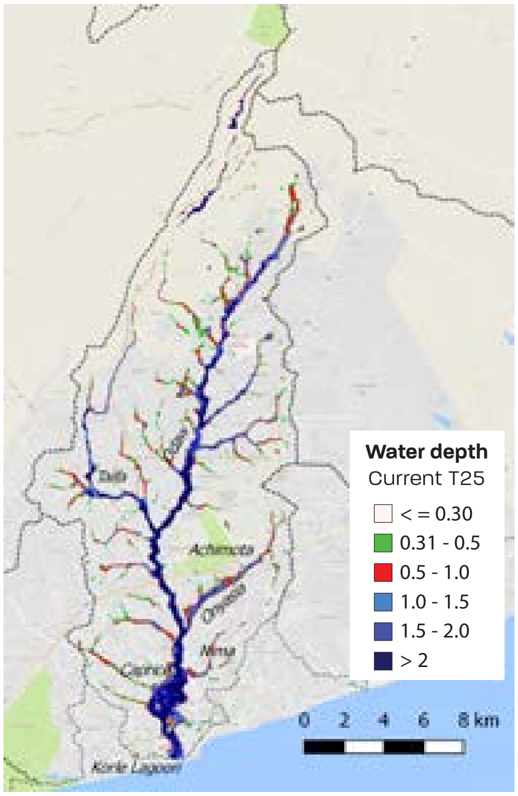
Risk indicator	Odaw Basin	Greater Accra
Number of people at risk (yearly average in 2018)	100,000	200,000
Flood damage (yearly average in 2018, US$, millions)	34	48
Flood damage (present value, US$, millions)	1,200	1,700

Map 2.4 **Flood Hazard in the Odaw Basin for a 25-Year Return Period, Assuming No Risk Mitigation Measures**

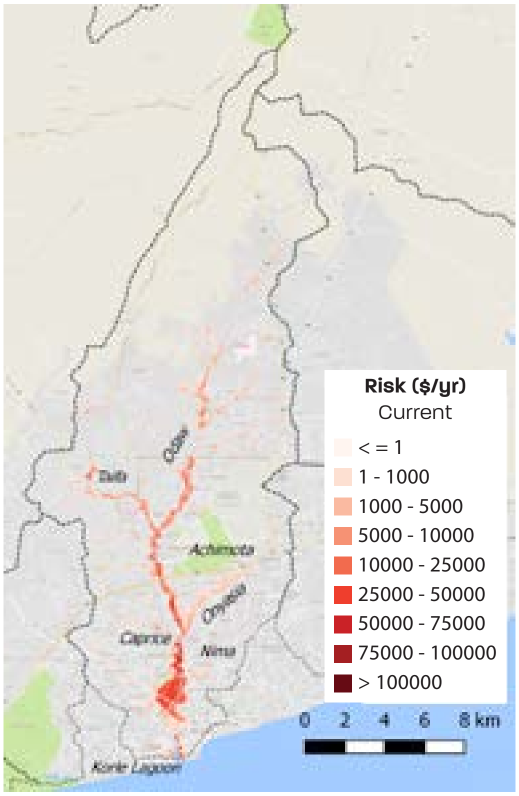
a. Water depth risk, current



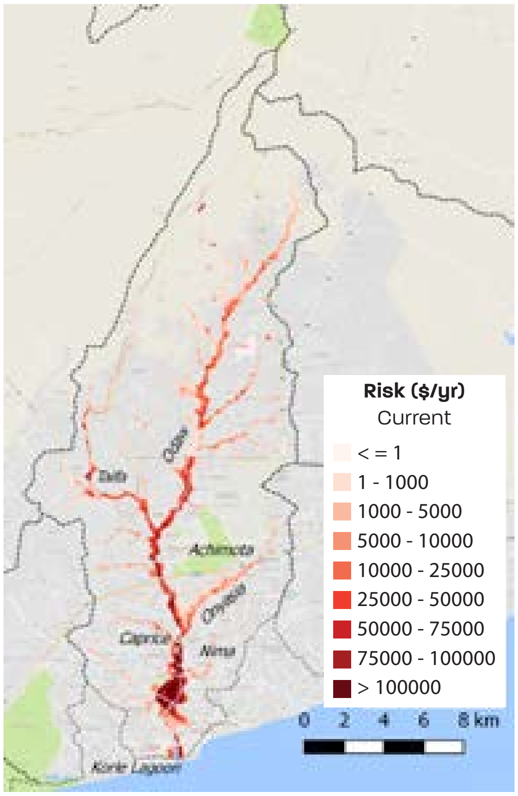
b. Water depth risk, 2050



c. Damage risk, current[a]



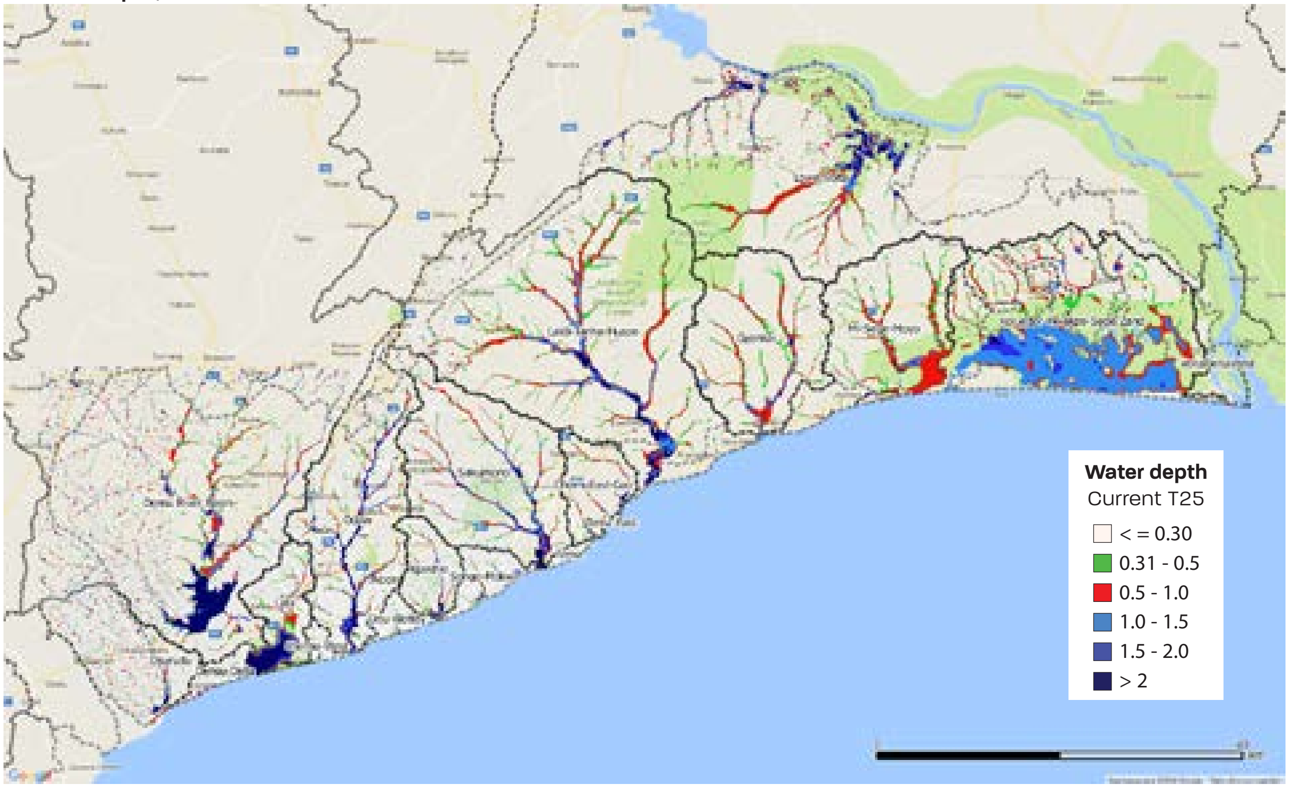
b. Water depth risk, 2050[a]



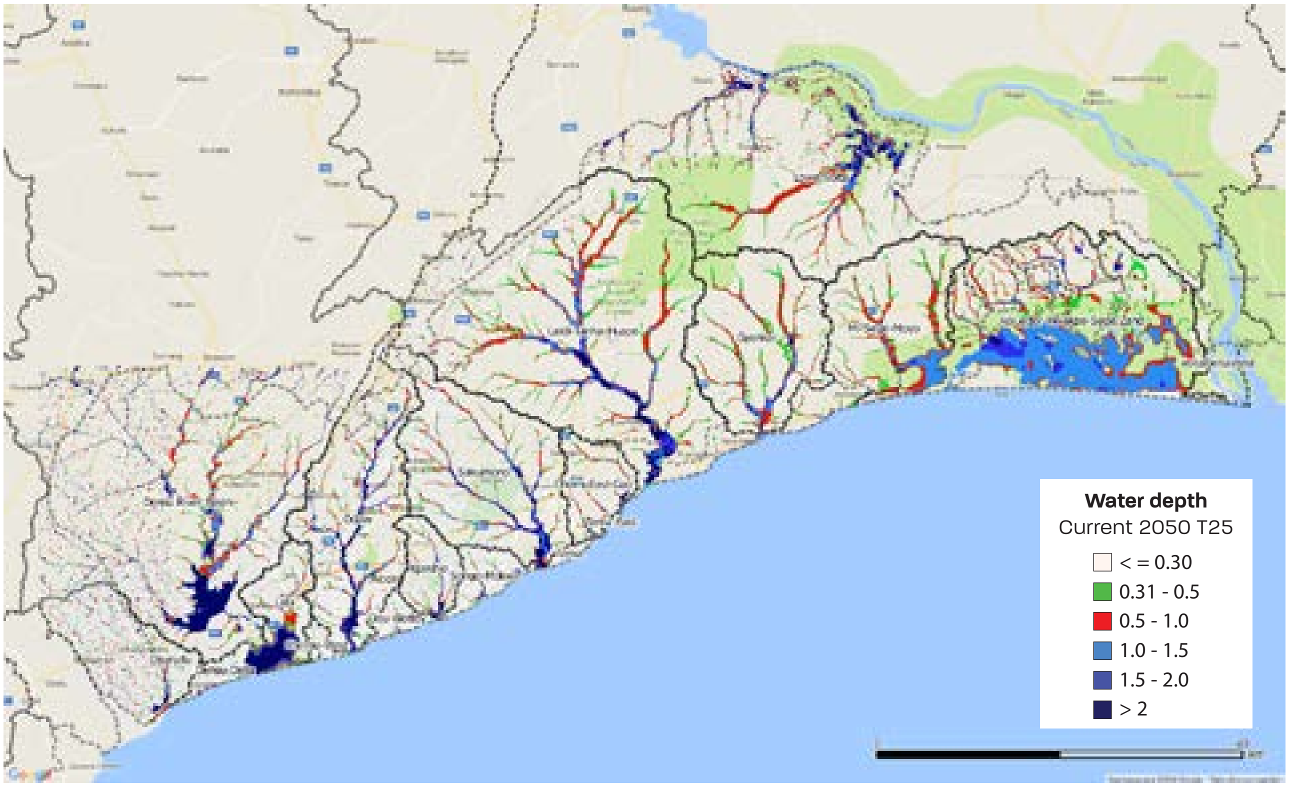
Notes: Background based on Open Street Maps; ©World Bank. Further permission required for reuse
a. The risk is shown as the expected yearly average risk in U.S. dollars.

Map 2.5 Flooding Risk in Greater Accra for a Flood with a 25-Year Return Period, Assuming No Risk Mitigation Measures

a. Water depth, current



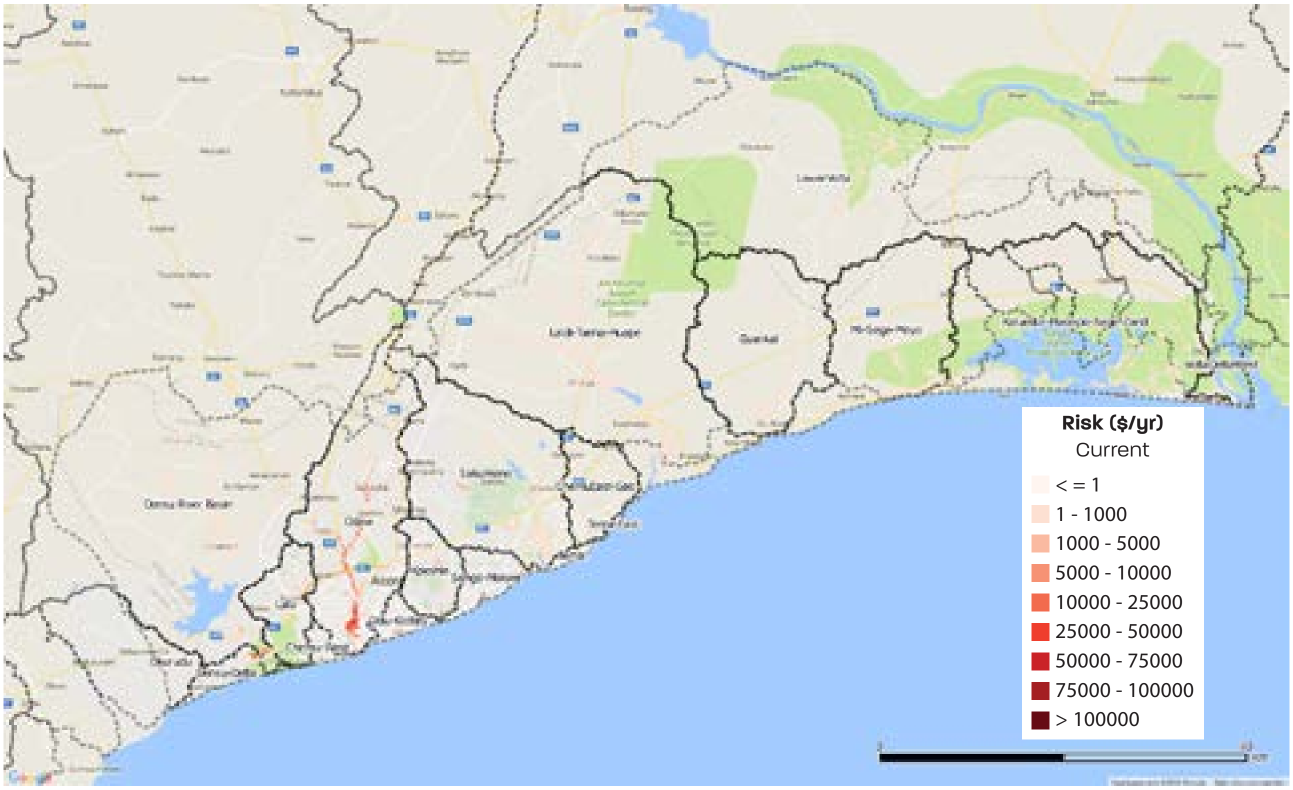
b. Water depth, 2050



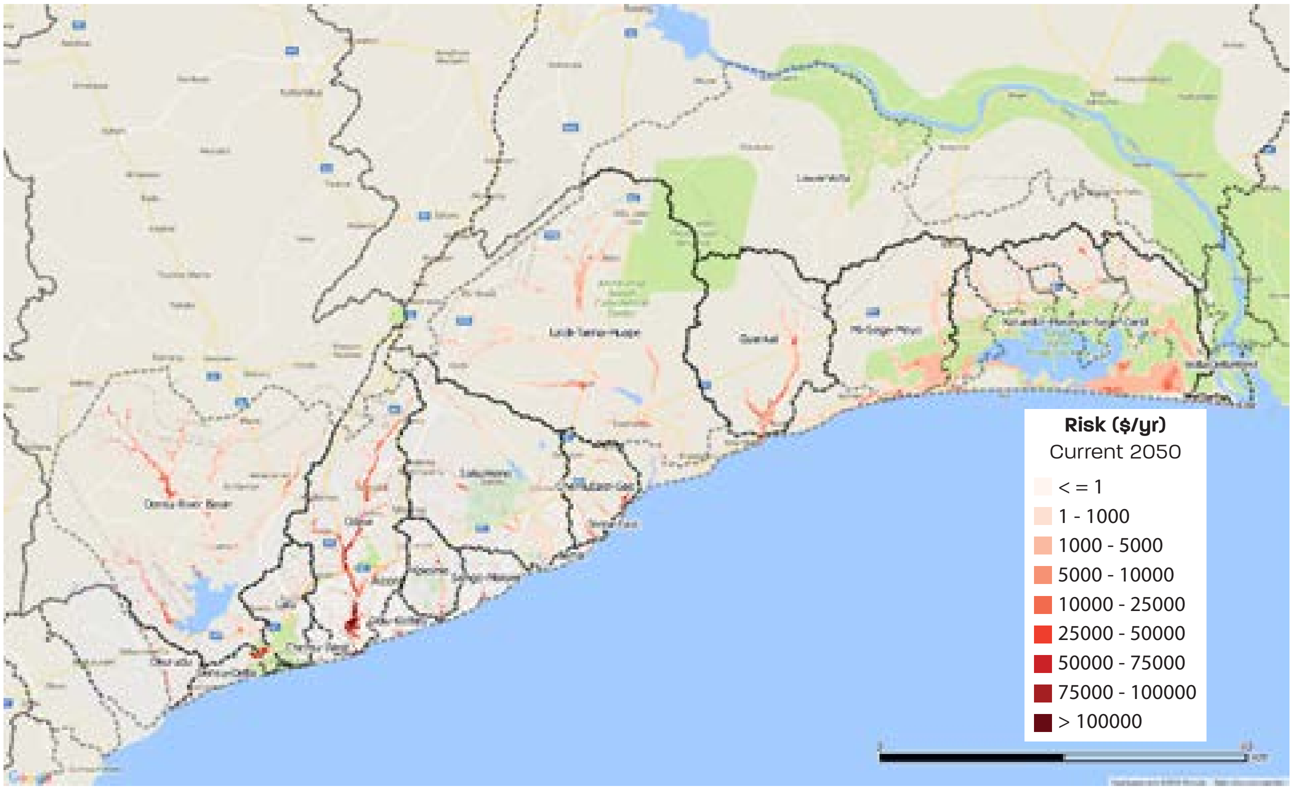
Note: Background based on Open Street Maps; ©World Bank. Further permission required for reuse

Map 2.6 **Damage Risk map in Greater Accra for a Flood with a 25-Year Return Period, Assuming No Risk Mitigation Measures**

a. Damage risk, currentt



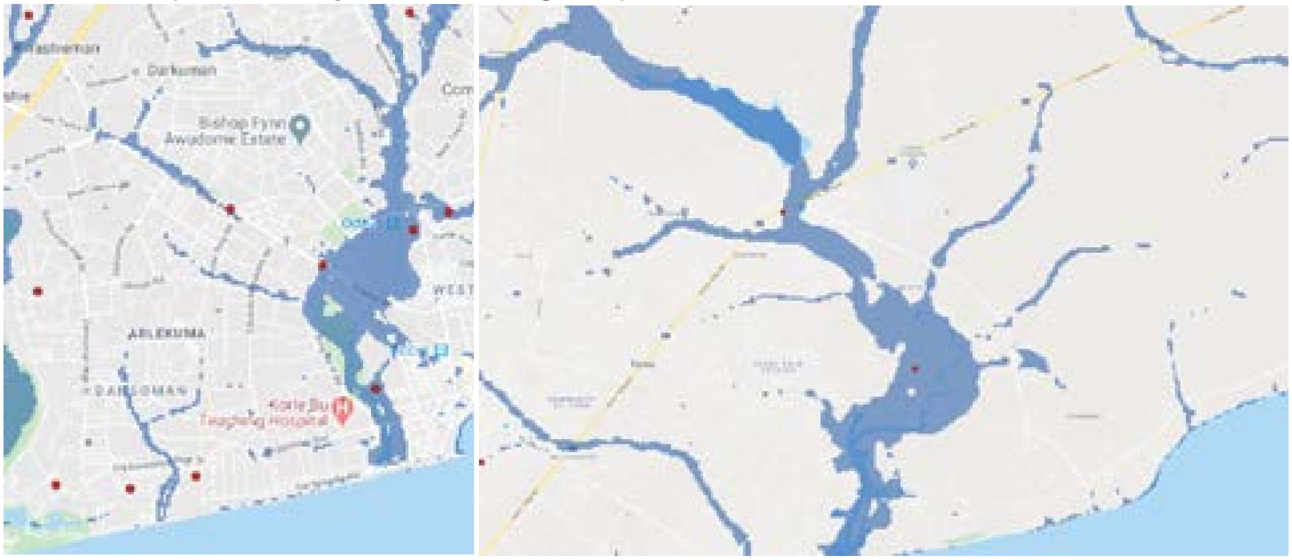
b. Damage risk, 2050



Notes: Background based on Open Street Maps; ©World Bank. Further permission required for reuse.
The risk is shown as the expected yearly average risk in U.S. dollars.

Map 2.7 Flood-Prone Areas in Sample MMDAs, Accra, 2017

a. Accra Metropolitan Assembly **b. Ningo Prampram**



Notes: Background based on Open Street Maps; ©World Bank. Further permission required for reuse
MMDAs = metropolitan, municipal, and district assemblies. Red dots highlight the most flood-prone locations.

which in rare cases coincide with extreme rainfall, but these events do not contribute significantly to the total flood risk. Simulated flood risk maps show that the flood risk increases considerably by 2050 if no flood mitigation measures are taken, mainly because of economic growth and the increasing number of people exposed to flooding (map 2.4).

The risk analysis shows that the flood risk in Greater Accra is clearly the highest in the Odaw Basin (maps 2.5 and 2.6). Other areas showing increased flood risk include the Dawhe River delta west of Prampram, the Sakomono Lagoon near Tema, and the Densu Delta. Urbanization, which will increase the number of people exposed to flooding, also increases the overall flood risk in Greater Accra by 2050.

2.2.3 Findings from Municipal Flood Hot-Spot Survey

To better understand local flood hot spots, a survey was organized in September and October 2017 of the 16 MMDAs that were part of GAR in 2017.[19] The survey focused on identifying the flood hot spots as well as assessing the causes of flooding based on the interviews of municipal officers and community members and visits to identified hot spots (map 2.7 and table 2.5). For a detailed report on the survey results, see appendix C, which documents each MMDA's flood issues, constraints, and possible solutions and includes pictures of visited sites to illustrate the issues that are important within the MMDAs.

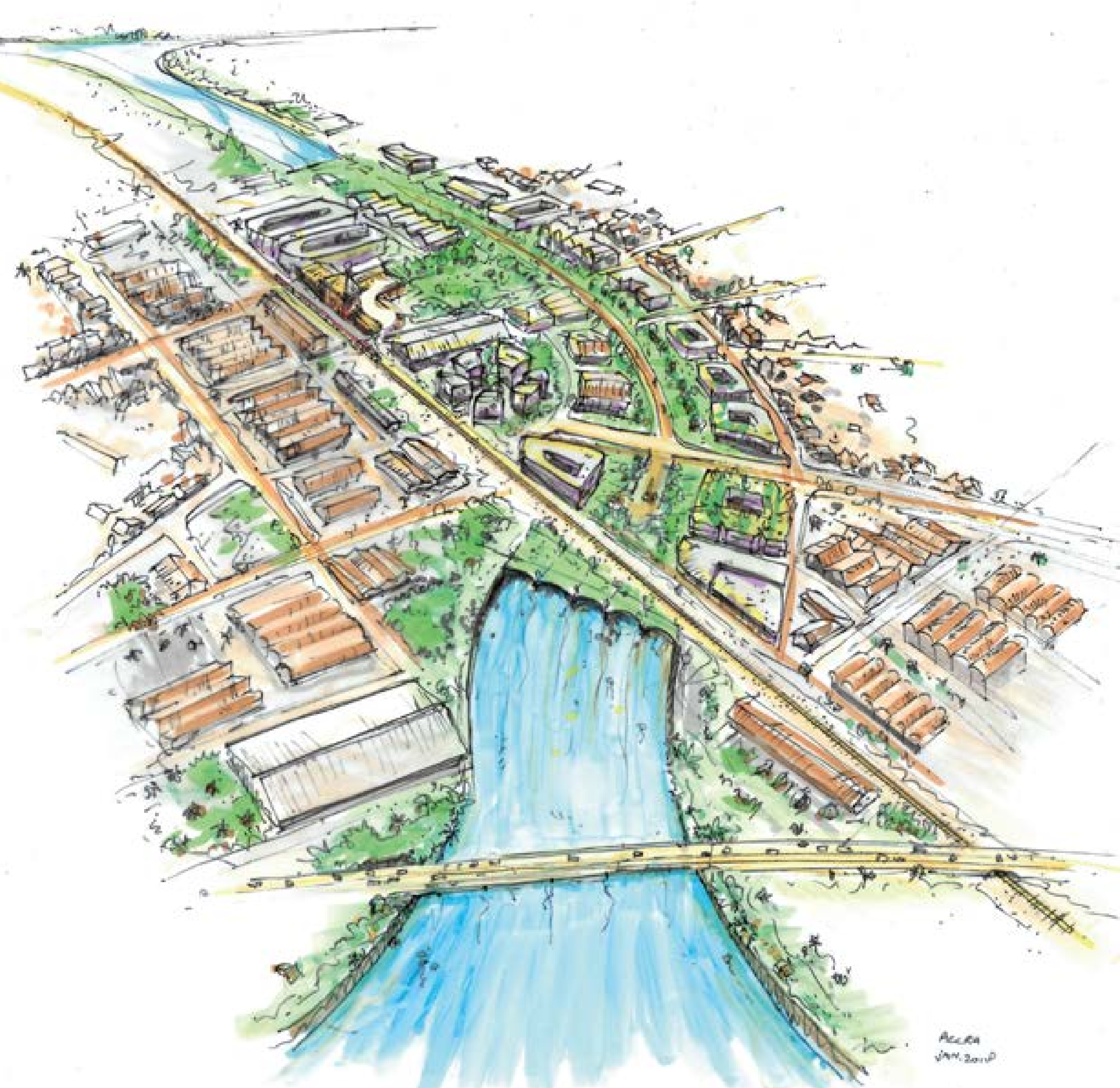
19 In 2018 the MMDAs were reorganized into 29 MMDAs.

Table 2.5 Overview of Flood Impacts in Greater Accra, by MMDA

MMDA	Flood impacts	Factors contributing to flood impacts
Ada East	Ada East gets flooded every year. No loss of life from floods has been recorded, but minor injuries do occur. In 2016, floods affected 300–400 people, while in 2009, 400–500 people were affected in Totopey alone.	Insufficient drains and inadequate waste management Buildings in waterways
Ada West	Ada West gets flooded every year. No loss of life from floods has been recorded. Heavy rains can result in knee-high water in 30 minutes.	Insufficient drains or even absence of drains Sea defense, limiting rainwater runoff toward the sea
Adentan	Adentan suffers floods every year. Floods have directly affected 250 people in 80 different households. In 2016–17, schoolchildren died because of the floods.	Insufficient drains and inadequate waste management Buildings in waterways and encroachment toward waterbodies
Accra Metropolitan Assembly	Mayor floods in AMA occurred in 2011, 2015, and 2016; smaller floods occur every year. The 2011 floods took 11 lives; the 2015 floods took 270 lives.	Refuse in drains Poorly constructed drains and large paved areas, increasing surface runoff
Ashaiman	Floods in Ashaiman occur almost every year, affecting between 100 and 10,000 people. During the most severe floods, in 2010, 18 people died.	Insufficient, or lack of, drainage Buildings in waterways and overflow of the reservoir
GA Central	The three mayor streams in GA Central—the Lafa, Onufu, and Ole—flood every year. The flash floods in GA Central can reach water depths up to 2 meters.	Lack of drains Refuse in drains High siltation due to all the rough roads in the area
GA East	Floods occur every year in GA East; those in 2015 and 2016 took the lives of two to three people and displaced about 100. Economic losses are estimated to be ₵10 million.	Insufficient drainage system Inadequate waste management Buildings in waterways
GA South	GA South recorded four lives lost in 2016 and one in 2017 due to floods. Heavy rainfall leads to water levels exceeding 1 meter in this area.	Insufficient drainage system Inadequate waste management Buildings in waterways
GA West	GA West suffered from several floods over the past few years; two people drowned in 2016. An estimated 2,000 households are affected by floods.	Overflowing rivers Undersized culverts underneath the highway, causing highway to act like a dam during heavy downpours
Kpone Katamanso	In 2017, floods affected 3,441 people in Kpone Katamanso, killing four.	High runoff from the mountains in combination with insufficient drains and buildings in waterways
La Dade Kotopon	La Dade Kotopon suffered mayor floods in 2011, 2015, and 2016. Water depths can exceed 1 meter.	Poorly constructed drains Inadequate waste management Buildings in waterways
La Nkwantanang Madina	La Nkwantanang Madina floods every year, with water depths reaching 1 meter or more; no fatalities have been recorded.	Small culverts and drains Buildings in waterways Refuse blocking drains
Ledzorkuku Krowor	Ledzokuku Krowor has had some major floods in recent years. In 2015, 2,000 to 12,000 people were affected. In the first half of 2017, 2,000 people were affected.	Poorly constructed or absent drainage system Buildings in waterways

MMDA	Flood impacts	Factors contributing to flood impacts
Ningo Prampram	Ningo Prampram gets flooded every year. In the past 10 years, no casualties have been recorded, but more than 2,000 people have been affected by floods, especially in 2012 and 2015.	Spilling of reservoirs Insufficient drainage system Refuse blocking drains Buildings in waterways
Shai Osudoku	Shai Osudoku floods every year, either from heavy rain or from high river (Volta) discharge. In the past 10 years, only one casualty has been recorded.	Spilling of Kpong Dam (Volta) Deforestation of the hills, causing higher surface runoff Insufficient drainage system Buildings in waterways
Tema Metropolitan	Tema floods every year. In 2015, the floods affected 6,593 people either from loss of or damage to property. Three people died because of the 2015 floods.	Insufficient drainage Encroachment and siltation of reservoirs Buildings in waterways Refuse in drains

Note: MMDAs = metropolitan, municipal, and district assemblies.


ACCRA

CHAPTER 3

Greater Accra Integrated Flood Risk Management Strategy

Introduction

This assessment makes clear that of all the basins in the Greater Accra Region (GAR), the Odaw Basin has the highest flood hazard and flood risk, especially in the low-lying area downstream of Caprice, around Kwame Nkrumah Circle and Kaneshie, which is an area with high economic activity. Floods in this study are defined as inundations outside of the riverbed due to overtopping of the main rivers (such as the Odaw) and its tributaries, threatening lives and causing high economic damage.

Model calculations show that currently, on average, a flood hits this area approximately every 2 years, and a flood like that of June 3, 2015, will occur on average once every 10 years. The flood hazard is predominantly the result of heavy rainfall. Floods in the coastal area also occur because of storm surges, and in rare cases, high sea levels coincide with extreme rainfall, but these events do no contribute significantly to the total flood risk.

To effectively address floods in the Odaw Basin and GAR, no single measure alone would be sufficient; instead, a combination of different measures is required, guided by an effective flood management strategy. As a start, a long list of structural and nonstructural measures was prepared by the project steering committee, comprising experts from various ministries, departments, and agencies, including the Ministry of Works and Housing; National Disaster Management Organisation; Water Resources Commission; Ghana Meteorological Agency; Ministry of Sanitation and Water Resources; Ministry of Roads and Highways; Ministry of Inner City and Zongo Development; Ministry of Local Government and Rural Development; and the metropolitan, municipal, and district assemblies (MMDAs) in GAR.

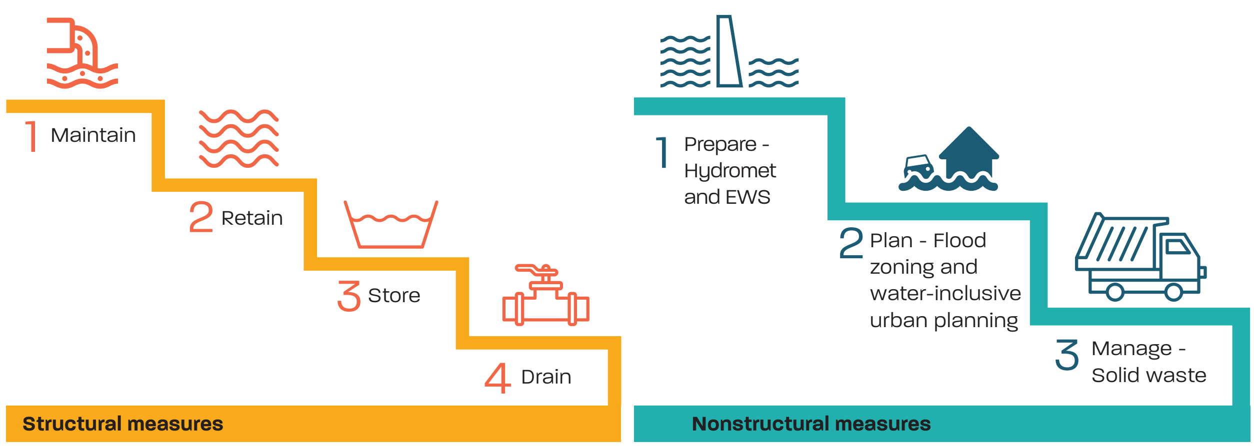
This chapter describes the flood management strategy developed by the project steering committee along with its list of structural and nonstructural measures. It also outlines the boundary conditions for the effective analysis of the different measures.

In a second step (see chapter 4), the flood management measures have been grouped according to various scenarios or "alternatives" that would jointly achieve different possible levels of safety and protection, by return period: 10 years, 25 years, and 50 years. These alternatives are then compared using social, environmental, and financial criteria, and this comparison provides the basis for decision making considering different constraints including budgetary constraints and social and political constraints such as, for example, the costs and challenges related to land acquisition.

3.1 Principles of the Flood Risk Management Strategy

The analysis of flood hazards and flood risks in the chapter 2 highlighted the complexity of the underlying causes, climate risks, and interrelated effects of different flood risk mitigation measures. As noted, the Odaw Basin has the highest flood risk of all river basins in GAR and was therefore selected by the government of Ghana as the priority basin for the implementation of the flood risk mitigation strategy. In May 2017, the government of Ghana adopted an integral master plan (referred to below as "Urban Master Plan 2037") for the spatial, social, and economic development of the area of GAR (LUSPA 2017). The plan sketches the main features of the socioeconomic and spatial development up to 2037 and gives attention to climate change adaptation and water management, making flood protection a key priority.

Figure 3.1 **Cascading Priorities of Measures in the Flood Risk Management Strategy for Greater Accra**



Note: EWS = early warning systems.

Box 3.1 Design and Planning Guidance for Water-Inclusive Urban Planning

Urban Master Plan 2037 rightly notes a lack of diversity in the urban area. The city can be described as "an ocean of relatively small houses." For a city with 4.7 million inhabitants, Accra is built at a remarkably low density. It also does not take advantage of the benefits of the water: the city is not oriented to the ocean, lagoons, and rivers. Furthermore, it lacks touristic quality and largely ignores its cultural heritage. Accra, and especially the coastal area, has an interesting history. Many elements still tell the story of Accra, such as the lighthouse, the harbor of Jamestown, Ussher Fort, the James prison, and Osu Castle. But they are all in bad condition and not connected to each other. With this in mind, two workshops with national stakeholders developed a sketch for the layout of GAR.

Photo B3.1.1 Urban Design Characteristics of the Greater Accra Region

a. Low-density, one-story buildings

b. Lack of ocean orientation

c. Inattention to cultural heritage

d. Street life

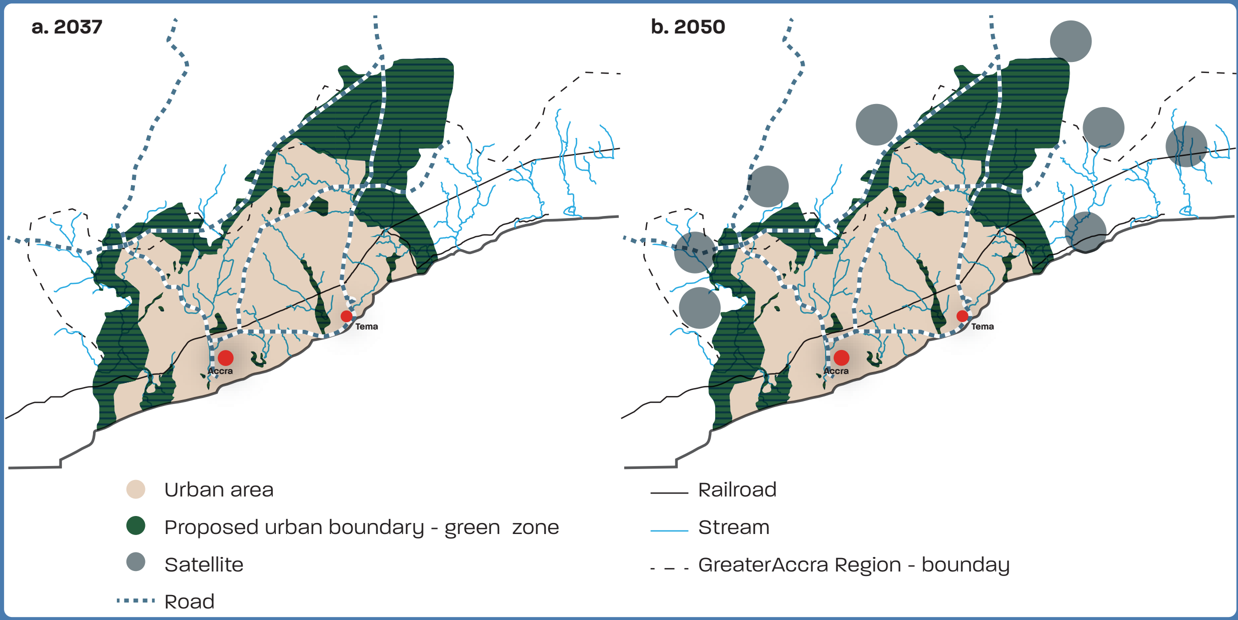
Source: Bosch+Slabbers

The proposed long-term development of Greater Accra, to 2037 and 2050, reflects the following main principles (map B3.1.1):

- A more or less "compact" city
- Diverse spheres and density
- Two urban focus points: Accra and Tema
- Ocean-facing orientation
- Strong green belt as an urban boundary
- Series of creeks and rivers with their associated watersheds
- Connection of railroad to the hinterland
- Satellite urban areas by 2050.

A "compact" city means that the urban area doesn't take more space than necessary, such that the rural and natural areas east of the city—between Tema and the Volta River—should be conserved. The urban area contains a variety of atmospheres and densities. In the Urban Master Plan 2037, Accra and Tema are developed as urban focus points, or "hot spots," with a wide range of cultural and economic facilities. In Accra and Tema, the area adjacent to the ocean is most suitable for the development of the central business district, followed by a densely developed downtown area. The midstream area is suitable for middle-density urban development, whereas lower density is preferred in the upstream area. The area between the upstream parts of the river basins and the green belt gets developed as an "urban sponge": an area where the water is retained and stored in retention ponds and waterparks. This helps relieve the drainage system in the vulnerable downstream areas.

Map B3.1.1 Sketch of a Master Plan, Greater Accra



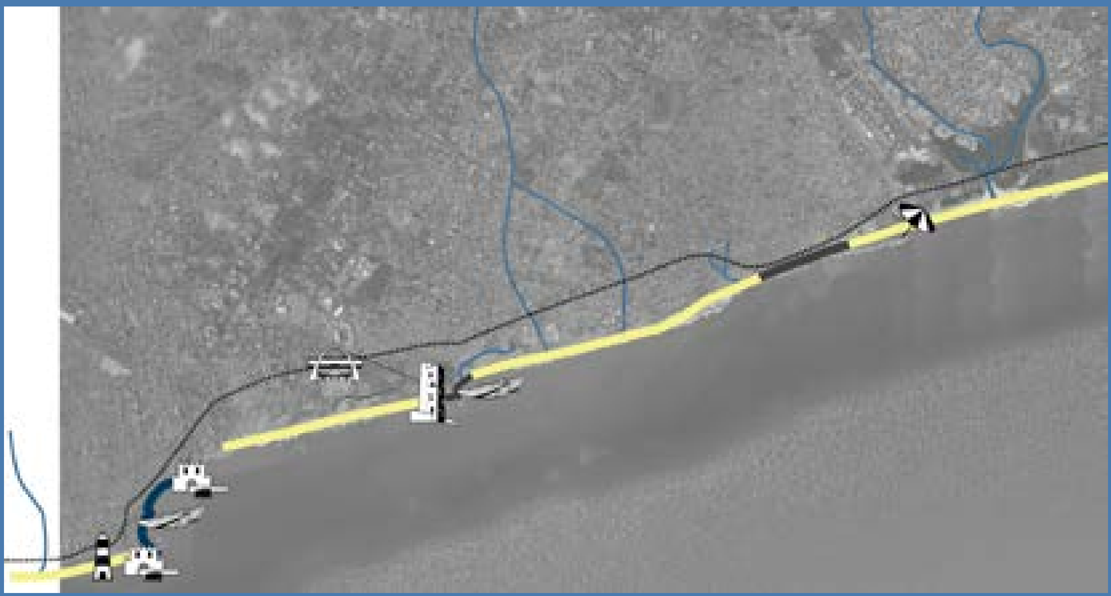
Note: Prepared by Bosch+Slabbers based on LUSPA 2017.

The green belt is not an ultimate border for urban development. During the first decades of the plan, the urban use of the area inside this green belt must be optimized—meaning development at a higher density, using the free space still available in the urban fabric. After that, when more room is needed, Greater Accra can cross the belt, developing satellite cities on the other side of the green belt.

Along the ocean, the "ocean drive" is developed as a boulevard, connecting the beaches and the highlights of a rich cultural history and heritage and places of ecological or natural interest (figure B3.1.1 and photo B3.1.2).

Figure B3.1.1 Aerial View of 28 Ocean Drive, Accra

a. Along Korle Lagoon and Osu Lagoon **b. Along Kpeshie Lagoon**



Note: Bosch+Slabbers; Background based on Google Earth. ©World Bank. Further permission required for reuse.

Photo B3.1.2 Areas of Interest and Cultural Heritage in Accra

a. Korle Lagoon

b. Lighthouse at Jamestown

c. Ussher Fort and prison

d. Osu Castle, Osu Lagoon, and Labadi Beach

Note: Bosch+Slabbers.

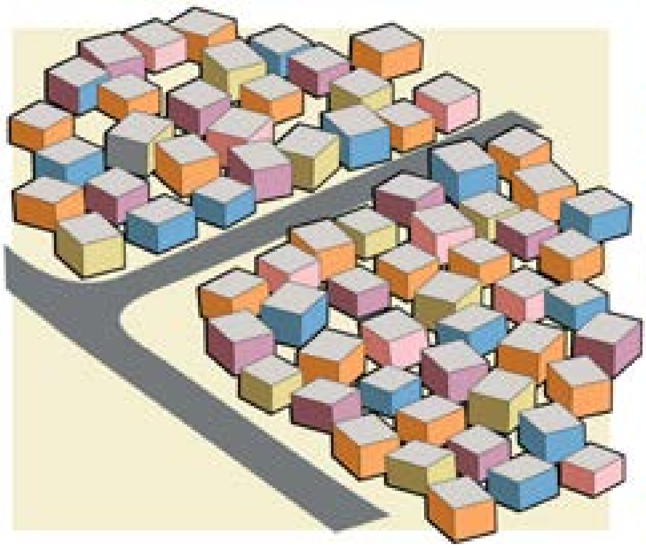
Intensifying the railroad connection with the hinterland improves the accessibility of the center of Accra. Thereby, a much larger area can benefit from a strong city center, providing labor, education, and medical and cultural facilities.

A compact city also means that existing urban areas must be restructured at a higher density. Parts of Accra are developed over an extensive area, largely covered by "one-floor buildings" on relatively large plots. The informal settlements are largely temporal structures and densely populated. In the future, one of the key urban development questions would focus on restructuring the urban fabric to enable a more compact city that would allow the same number of households while also providing adequate space for water and green space to avoid heat stress and create a more water-inclusive, resilient city layout, following these principles (figure B3.1.2):

- *Scale:* Areas must be redeveloped at a scale that allows the people who live there to still feel connected with the ground level. That is a precondition for maintaining street life. To realize a human scale, the plan calls for multifloor buildings, not high rises.
- *Space for water:* Any redevelopment must supply room for water storage and room for water to infiltrate.
- *Avoiding heat stress:* Any redeveloped area has to offer cool, shady places.

Figure B3.1.2 Principles of Proposed Urban Restructuring for Higher Density in Accra

a. Current single-floor residential development



b. Planned mid-rise development

Source: Bosch+Slabbers. ©World Bank. Further permission required for reuse.

The flood management strategy is defined by its objectives and definitions and designed around integrated, cascading measures within a watershed or basinwide approach for the Odaw Basin. In this report, floods are defined as inundations outside of the riverbed due to overtopping of the Odaw River and its tributaries that threaten lives and cause high economic damage. Floods in the Odaw Basin mainly occur in the area between Caprice (confluence of the Onyasia and the Odaw) and Abossey-Okai Bridge, which is the low-lying downstream section of the Odaw Basin. The flood vulnerability in this area is also the highest in GAR because of its high economic activity and population density.

The objectives of the flood management strategy are therefore to reduce the flood risk in the area downstream of Caprice and to ensure the protection of assets, livelihoods, and economic activity in that area according to a set of agreed-upon and defined design safety levels (flood protection for 10-, 25-, or 50-year return periods). Complete protection against all floods in the basin is not feasible (for example, against floods with a 100-year or higher return period). Hence, nonstructural measures and, notably, operational early warning systems and hydrometeorological services in all of GAR would be important parts of the flood management strategy.

3.1.1 Flood Mitigation Measures

Individual flood mitigation measures have different impacts on the water level and protection of areas depending on their specific water management objectives and locations within the basin. As part of a comprehensive flood management strategy, those measures can be assigned cascading priorities based on their specific roles and functions (figure 3.1).

Structural measures. The structural measures are needed to (a) *maintain* infrastructure; (b) *retain* water upstream, including soil and water conservation measures; (c) *store* peak flows; and (b) *drain* water effectively to the sea. The highest priority was thereby the *maintenance* of the existing infrastructure (ensuring that channels are repaired, areas dredged, sand traps emptied, retention ponds cleaned, weirs operated, and so on), without which no other measure can be effectively implemented.

Nonstructural measures. The nonstructural measures would (a) *improve* flood preparedness, including through efficient flood warning and response systems; (b) *plan and implement* flood zoning, stormwater regulations, improved watershed management, and resilient building codes; and (c) *manage* solid and liquid waste efficient. Following the same cascading priorities, additional measures to adapt the flood management strategy to the impacts of climate change have been defined.

3.1.2 Design Safety Levels

Design safety levels describe the planned level of flood safety to be achieved with the combination of different flood management measures. They are particularly important from a planning and policy perspective because they indicate the level of protection or safety and the residual risk. In the analysis, design safety levels of T10, T25, and T50 were considered—corresponding to 1-in-10-, 1-in-25-, and 1-in-50-years flood protection—whereas a design safety level of T100 was considered to be unrealistic considering potential infrastructure, land, and budgetary constraints.

The design safety levels apply to the area downstream of Caprice. Upstream, because floods there are restricted to the riverbed itself, the safety levels will be higher. The design safety levels that correspond with the various alternatives therefore can be seen as the minimal safety levels for the whole basin. The assessment is most accurate for those sections of the Odaw River and its tributaries, for which the bathymetry data were available and used in the model. This is the case for the focus area downstream of Caprice. For the other sections, upstream of the main drains, the hydraulic model is less accurate, and thus the accuracy of the found safety levels will also be lower.

An important goal is to find the optimal safety level for flood protection and the attractiveness of the investment alternatives from a broad welfare perspective. The assessment of costs and benefits (for example, reduction of people at risk and economic damage) of the investment alternatives, each with its own specific design safety level, will determine which safety level will be most favorable from a welfare point of view. For example, "safety" at T10 means that, downstream of Caprice, the risk of a 1-in-10-year flood has been substantially reduced and minimized. It will also show with which combination of measures these safety levels can be obtained, what the costs are, and whether there are any constraints for implementation.

Nevertheless, the government's choices on different safety levels are based on the legal requirements as well as budgetary constraints and limitations to access to land. It is understood that achieving the desired safety levels for protection from a 1-in-50-year flood of the densely populated areas and from a 1-in-25-year flood for the less densely populated areas can only be achieved with substantial investments, impacts on land, and therefore a sequential implementation over the period of several cascading projects.

3.2 Assessment of Structural Flood Mitigation Measures

The individual measures were first assessed with regard to their specific hydraulic effectiveness. This hydraulic effectiveness is expressed as the reduction of the water level compared with the June 3, 2015, flood (with a return period of approximately 10 years) in the area between Caprice and the outlet to the sea. Table 3.1 provides an overview of the different structural and nonstructural measures, which were considered in the assessment and the combinations, which contributed form the investment alternatives to achieve different flood protection levels.

3.2.1 Priority 1: Maintain the Drainage System

Any flood management strategy and related investments need to first ensure that the existing drainage system is adequately operated and maintained at any time (photo 3.1). Failure to maintain infrastructure, including frequent dredging, has in the past contributed to floods. Without the assurance of regular maintenance, any new investment in the flood management infrastructure will not make sense.

Maintenance requires many measures in the drainage system of the Odaw Basin, including (a) the gates of the interceptor weir in Korle Lagoon being operational (or at least opened);[20] (b) the interceptor weir being kept free of solid waste accumulation; and (c) the main Odaw Channel between Caprice and the outlet to the sea being dredged to maintain the design cross-section. Maintenance can be seen as a baseline measure—that is, to be included in all flood risk mitigation alternatives.

The following "maintenance" measures are considered in the calculations:

- Deferred dredging of the lined Odaw Channel between Caprice and the outlet to the sea

20 The interceptor weir was constructed as part of the Korle Lagoon Ecological Restoration project and has the objectives of managing the dry flow from the Odaw River, providing a basic mechanical cleaning of the water, and pumping polluted water far into the sea, thereby restoring the ecological function of the Korle Lagoon and increasing its recreational and ecological value. However, the interceptor weir has not been operational for years and has contributed to flooding due to the blockage of the weir. Model results suggest an opening or removal of the weir to ensure better flood protection and avoid any blockage. The final decision on the use and rehabilitation has not yet been made.

Table 3.1 **Overview of Flood Risk Mitigation Investment Alternatives for the Odaw Basin, Accra**

Type of measure	Investment alternatives					
	Baseline	Safe at T10A	Safe at T10B	Safe at T25A	Safe at T25B	Safe at T50
Structural measures						
A. Maintenance and repair	X	X	X	X	X	X
B. to Flood Retention Pond	—	X	—	X	—	X
C. Widening of Odaw Drain	—	—	X	X	X	X
D. Floodplain lowering, Agbogbloshie to Old Fadama	—	—	—	—	X	X
E. Floodwalls (1 meter high), Circle to Kaneshie	—	—	—	—	X	X
F. Widening of the Outlet to the Sea	—	—	—	—	X	X
G. Micro water retention and new drain design	(X)	(X)	(X)	(X)	(X)	(X)
Nonstructural measures						
Flood zoning and land use planning	(X)	(X)	(X)	(X)	(X)	(X)
Early warning and contingency planning	(X)	(X)	(X)	(X)	(X)	(X)
Flood resilience measures (floodproofing buildings)	(X)	(X)	(X)	(X)	(X)	(X)
Solid waste management	(X)	(X)	(X)	(X)	(X)	(X)

Note: "Baseline" refers to baseline measures, which need to be considered in all investment alternatives. "X" indicates a measure included in the investment alternative and also assessed in the cost-benefit analysis (CBA). "(X)" indicates a measure included in the investment alternative but not considered in the CBA. "T10" refers to a design safety level of protection from a 1-in-10-year flood; "T25" to protection from a 1-in-25-year flood; and "T50" to protection from a 1-in-50-year flood. — = not applicable.

Photo 3.1 **Needs for Essential Drainage Network Maintenance Measures, Greater Accra Region**

a. dredging and maintenance works in the Odaw channel

b. Collapsed walls of the Nima Drain

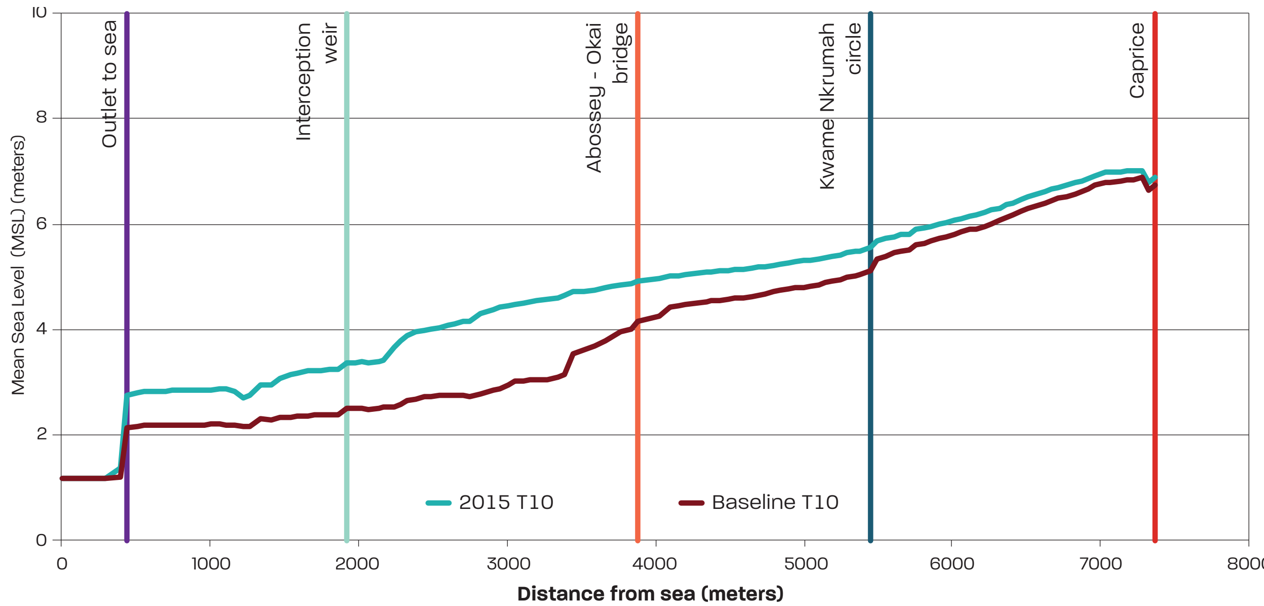
Source: HKV Consultants.

- Dredging at regular intervals (especially after floods when the sediment load is the highest) to maintain the design cross-section
- Construction of sand traps to reduce the siltation of Odaw channel[21]
- Upstream water conservation measures
- Rehabilitation, regular cleaning, or removal of the interceptor weir in Korle Lagoon
- Repair of broken drain sections.

The hydraulic effectiveness of the "maintenance" measures was assessed with the model and is presented as

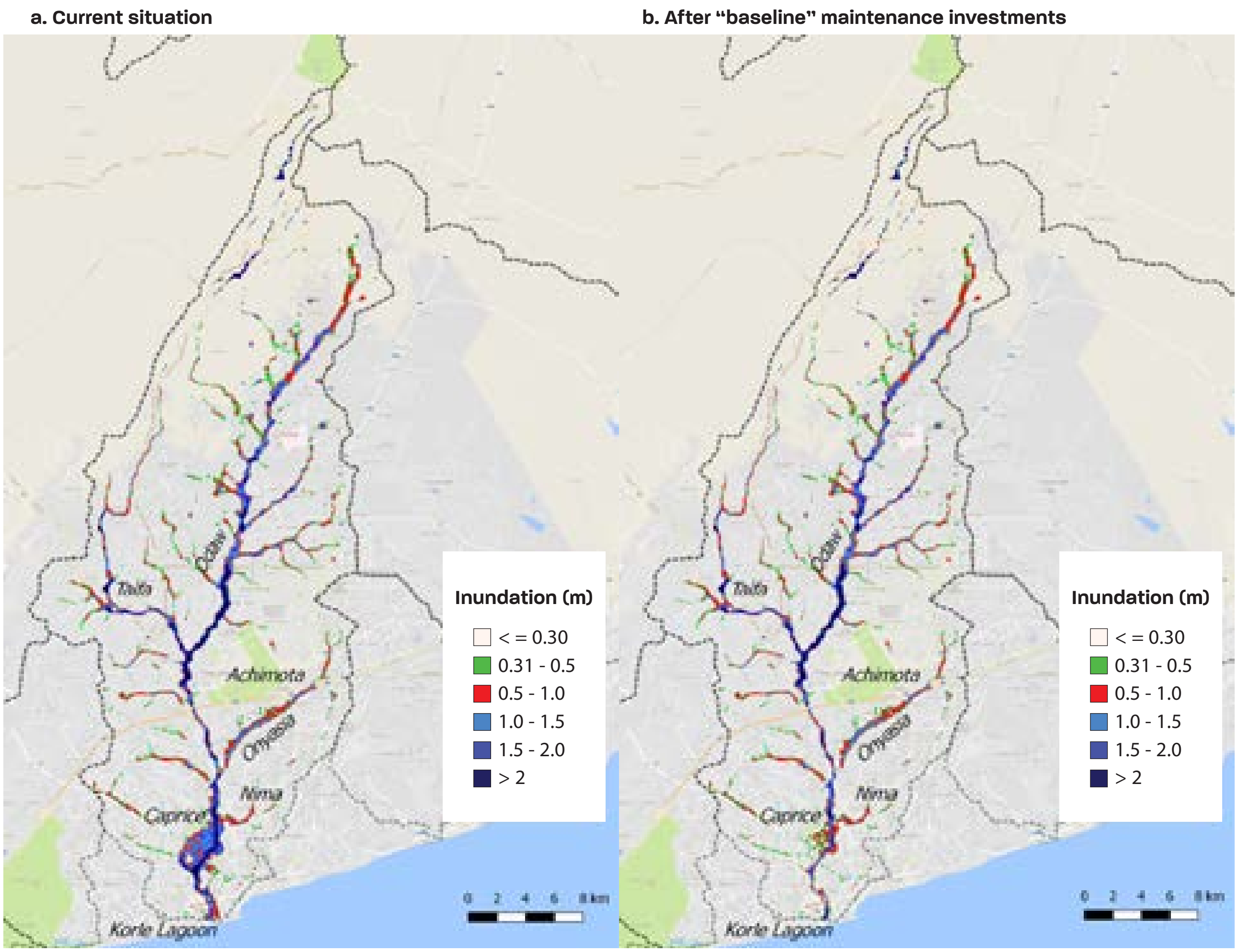
21 The exact location of these sand traps is not yet determined, but most likely they should be located in the downstream sections of the tributaries to prevent the sediment from entering the Odaw Channel at Caprice, where the riverbed slope reduces, flow velocities decrease, and hence siltation increases.

Figure 3.2 Estimated Reduction of Flood Levels from Maintenance Measures in Odaw Basin of Accra, by Location



Note: "2015 T10" refers to water level for a 1 in 10 year return period flood at current (2015) conditions; "Baseline T10" refers to water level with the implementation of the "baseline" measures

Map 3.1 Estimated Flood Hazard for a 1-in-10-Year Flood, Before and After Implementation of Maintenance Measures



Note: Background based on OpenStreetMaps; ©World Bank. Further permission required for reuse.

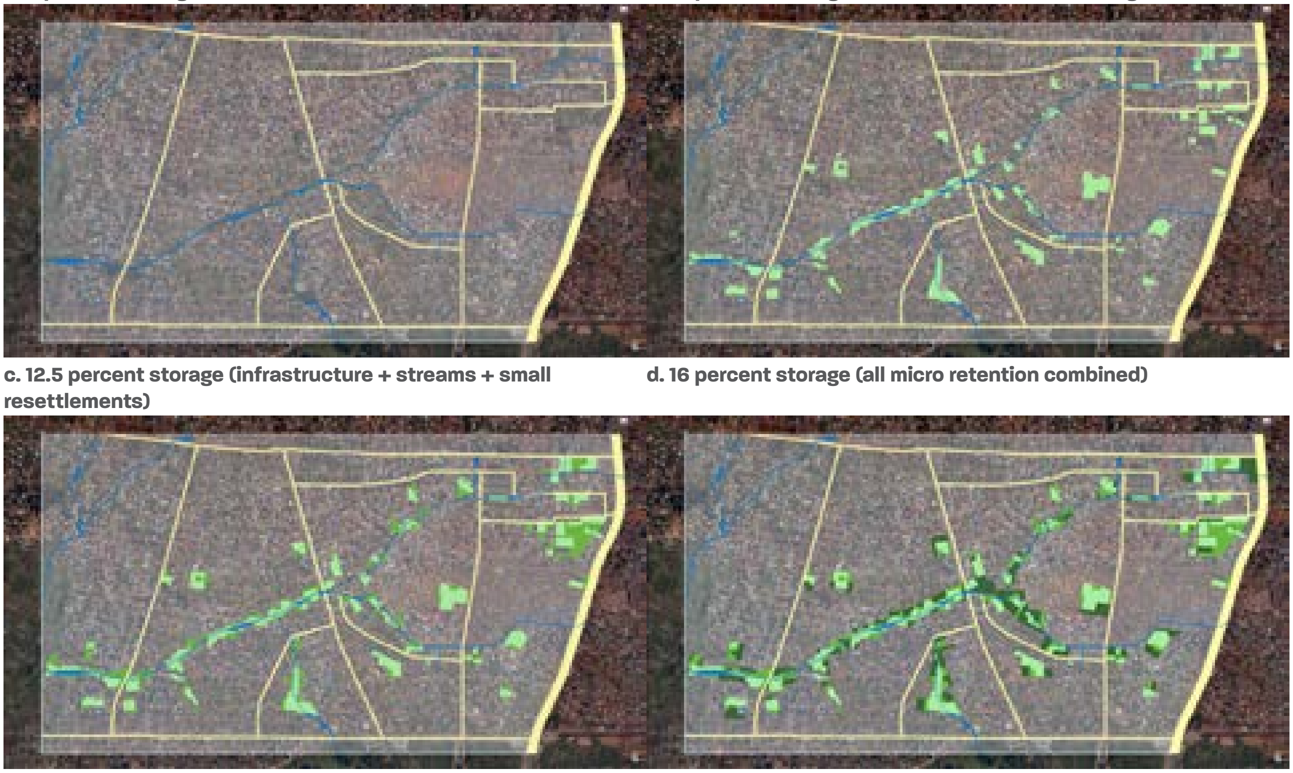
Map 3.2 Showcase of Public Space Available for Micro Retention of Water in Greater Accra, by Types of Measures Taken

a. 6 percent storage (infrastructure + streams)

b. 10 percent storage (infrastructure + streams + green areas)

c. 12.5 percent storage (infrastructure + streams + small resettlements)

d. 16 percent storage (all micro retention combined)



Notes: Background based on Google Satellite; ©World Bank. Further permission required for reuse.
"Micro retention" refers to water retention in (a) low-lying areas that are almost always dry except after intense storms, or (b) tertiary drains of new design (here, "infrastructure").

a reduction of the flood levels for the June 3, 2015, flood (figure 3.2 and map 3.1). Figure 3.2 shows that the reduction of flood levels is high, from 1 meter at Abossey-Okai Bridge to still 0.5 meters at Kwame Nkrumah Circle. Although the flood hazard is reduced significantly, it has not disappeared.

3.2.2 Priority 2: Retain Water Upstream

Flood mitigation starts by preventing the free flow of floodwaters to vulnerable areas downstream. Upstream water retention delays the runoff and reduces peak discharges downstream. The basin starts to act as a sponge, and rainfall infiltrates the soil and evaporates (thereby also cooling the city).

The following water retention measures are considered in the calculations, some of which are further discussed below:

- *Wadi drains* and new design of the tertiary drains alongside the roads
- *Retention in public low-lying areas* on a micro scale in the neighborhoods
- *Sustainable stormwater management,* preventing people from paving their building plots and gardens.

3.2.2.1 Wadis and New Design of Roadside Tertiary Drains

"Wadi" is an Arabic word for a river in the desert that is almost always dry and only carries water after intense storms. In this context, it expresses retention of water on a micro scale, in so-called wadis. Wadis can be realized in already low-lying areas on public grounds such as parks and playing fields but also through a new design of tertiary drains. They are more easily realized in new urban areas than in the existing urban fabric and can play an important role in mitigating additional flood risk due to future climate change and urbanization. These are small-scale measures that can be multiplied numerously, thereby effectively mitigating floods downstream.

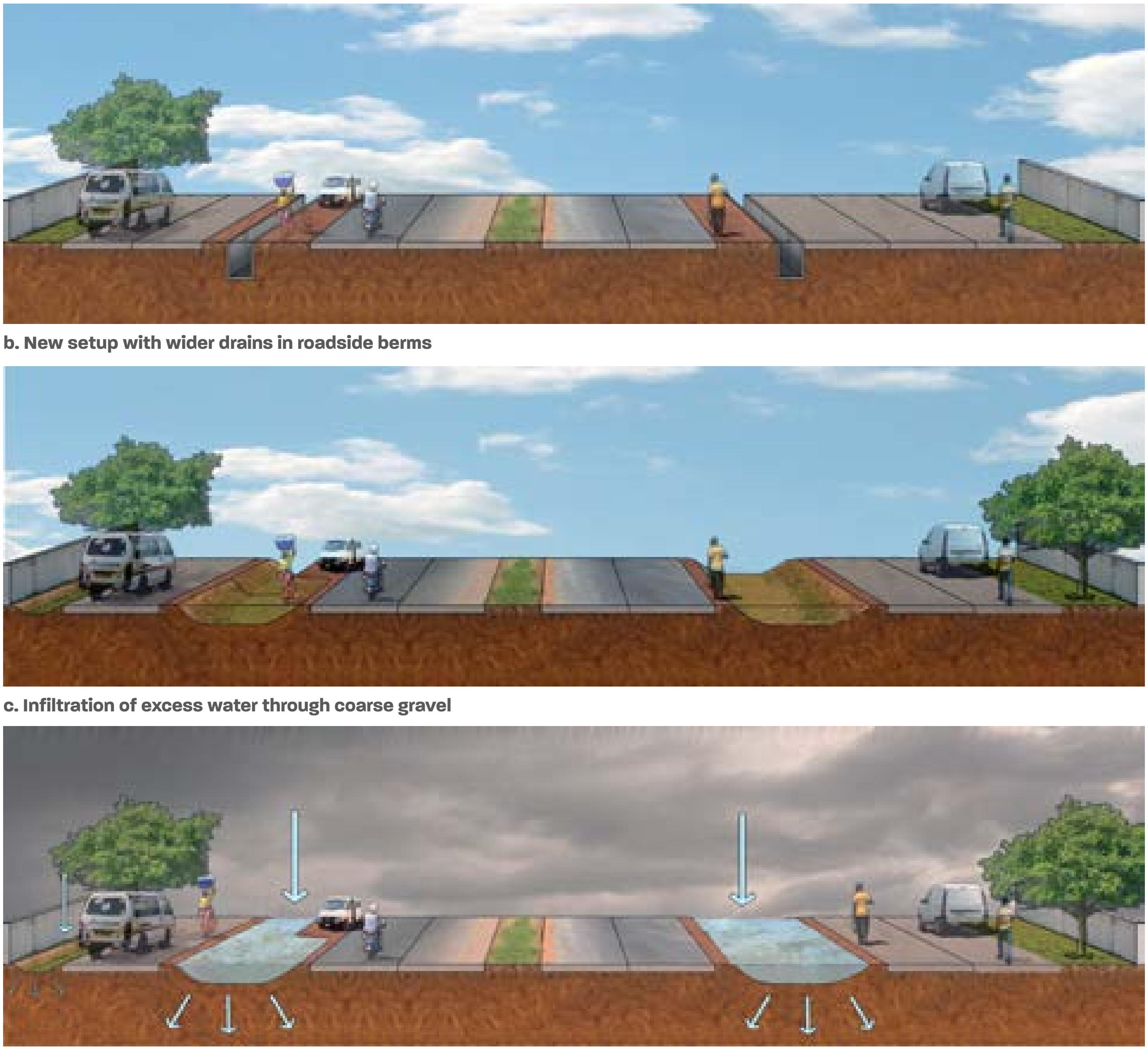
The transformational shift toward nature-based, localized stormwater management in GAR should start with the construction guidelines and training of the construction companies and ministries involved. Like the other micro detention measures discussed below, it is recommended to start with a number of pilot projects in different areas

Figure 3.3 New design for tertiary drains

a. Current setup of tertiary drains

b. New setup with wider drains in roadside berms

c. Infiltration of excess water through coarse gravel



Source: Bosch+Slabbers. ©World Bank. Further permission required for reuse.

where existing or planned road improvement projects can be used to develop the new drain design. Because these measures take a long time to implement on a large scale and to become effective (map 3.2), micro detention and new drain design should be promoted and gradually implemented.

Another retention measure is the adapted design of the tertiary drains alongside the roads. In the new tertiary drain design, the roads are still kept free from inundation after heavy rainfall, as in the current situation (figure 3.3, panel a). But instead of full discharge downstream of the excess water, part of it is stored in the berms alongside the roads (figure 3.3, panel b). Those berms can also be filled with coarse gravel to keep a flat street level along with capacity for retention (figure 3.3, panel c). In Accra, plenty of space is available for such infiltration berms.

Space is available for such infiltration berms along roads in Accra's neighborhoods. The berm retention volume could be designed with a width of 2 meters and depth of 0.5 meters. The roadside retention solution can be applied on both sides of the road, resulting in a retention surface of 2 square meters per meter of road.

The redesigned drain would overflow into the berm retention at a water depth of 1 meter. The increased roughness of the bed adds extra friction to the drainage flow. How the new design affects the peak and delay of the resulting discharge is simulated in a conceptual hydrodynamic calculation.

The extracted road network from OpenStreetMap (map 3.3) is at least 2,500 kilometers long. (In reality, the road network is much longer.) With urbanization expected to increase to 100 percent of the Odaw Basin, we estimate the road network to increase to 3,700 kilometers. The new drain design could be implemented in the tertiary roads in the neighborhoods first.

Potential flood mitigation from implementing the new drain design is expressed in stored millimeters of excess rainfall per kilometer of road (figure 3.4). The storage created decreases the effective runoff from a rainfall event.

The costs of the new drain design depend on the chosen design. Excavation of earth is required. The berms can be lined with grass or with concrete. The costs are estimated to be between US$0.5–US$1.0 million per kilometer of road. When the new drain design becomes a standard regulation, the costs might be borne by other projects or ministries.

3.2.2.2 Micro Retention in Neighborhoods

Depending on the type of micro detention solution implemented, the costs vary significantly. Excavated retention ponds equipped with minimal required infrastructure for safety (photo 3.2) from less costly alternative (US$ 15 per cubic meter), while placing sub-surface infiltration systems requires more investment (US$ 140 per cubic meter).

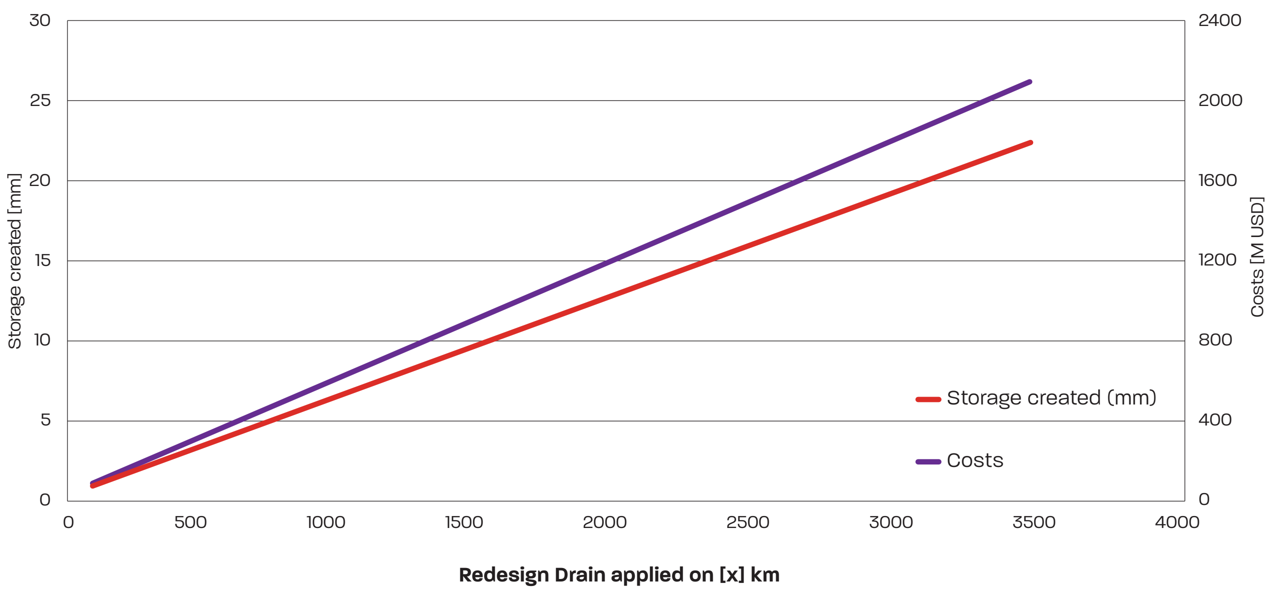
The public buildings, parking lots, or school playgrounds vv to be converted to retention areas have been mapped. A quick analysis of open spaces with the urban area of the Odaw Basin points to 1,200 hectares of potential green spaces (map 3.4, panel a). Around 339 public buildings are mapped in the Odaw Basin (yellow points on map). Included is a picture of a school playground like many in Accra (map 3.4, panel b). An example of open green space to be converted to micro detention is also included (map 3.4, panel c).

The potential flood mitigation from implementing micro detention ponds with a depth of 1 meter is expressed in stored millimeters of excess rainfall (figure 3.5). The storage created decreases the effective runoff from a rainfall event.

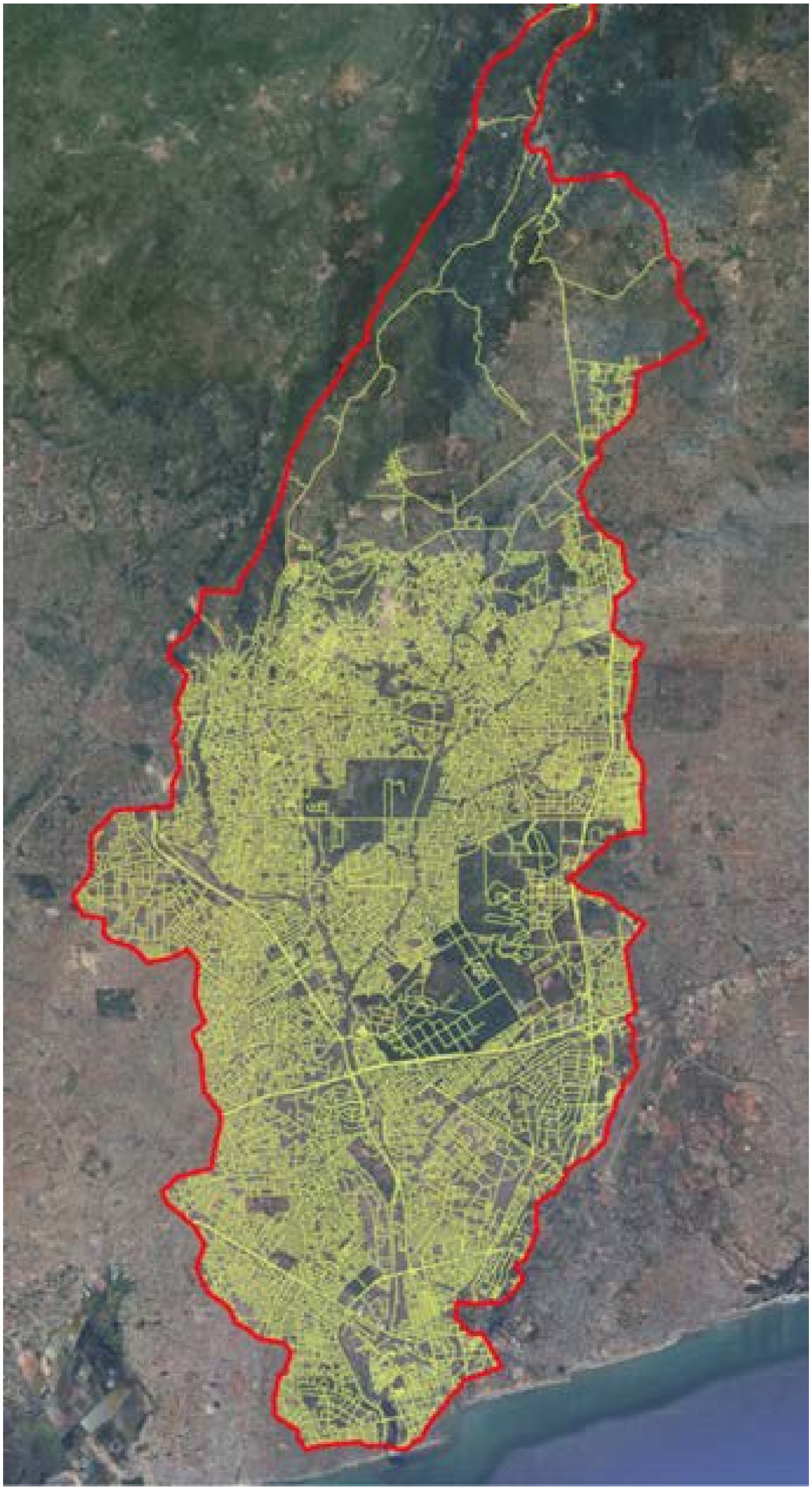
3.2.3 Priority 3: Store Water in Upstream Retention Ponds

In Greater Accra, areas are still available to be transformed into retention ponds, especially in the northern upstream parts of the basins (map 3.5). These retention ponds are basins where floodwaters are stored temporarily. Some already exist, but the capacity can be enlarged by implementing a small barrier and levees. Other existing

Figure 3.4 **Estimated Water Storage Created and Costs of Redesigned Roadside Drains**



Map 3.3 **Road Network in the Odaw Basin, Greater Accra, 2019**



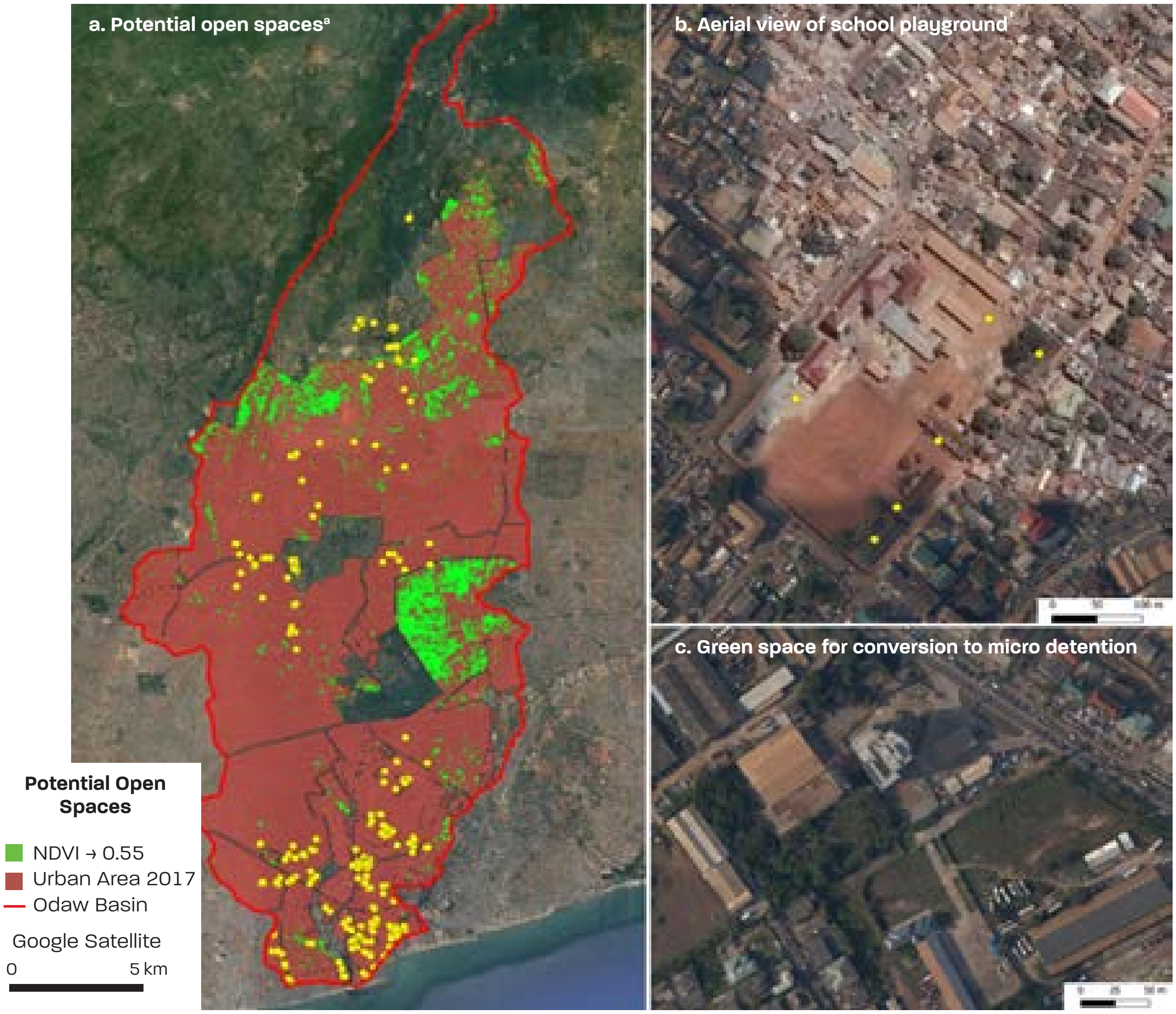
Note: Map based on OpenStreetMap ©World Bank. Further permission required for reuse.

Photo 3.2 **Examples of Suitable Neighborhood Micro Retention Solutions**

a. Examples from Micro Retention Solutions in The Netherlands **b. Urban Water Buffer Sparta, Rotterdam**

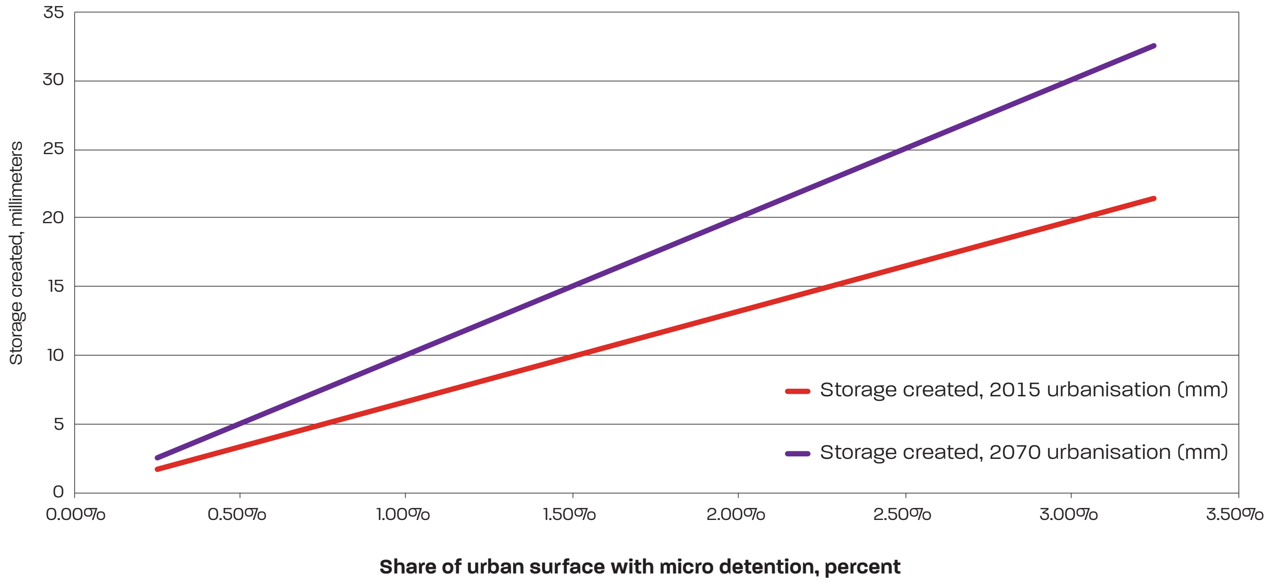
Source: Field Factors 2019 Urban Waterbuffer Sparta, Rotterdam https://fieldfactors.com/nl/uitgevoerde-projecten/urban-waterbuffer-spangen © Field Factors reproduced with permission from field factors, further permission required for reuse

Map 3.4 **Potential Locations for Nature-Based Micro Retention in the Odaw Basin, Accra, 2017**

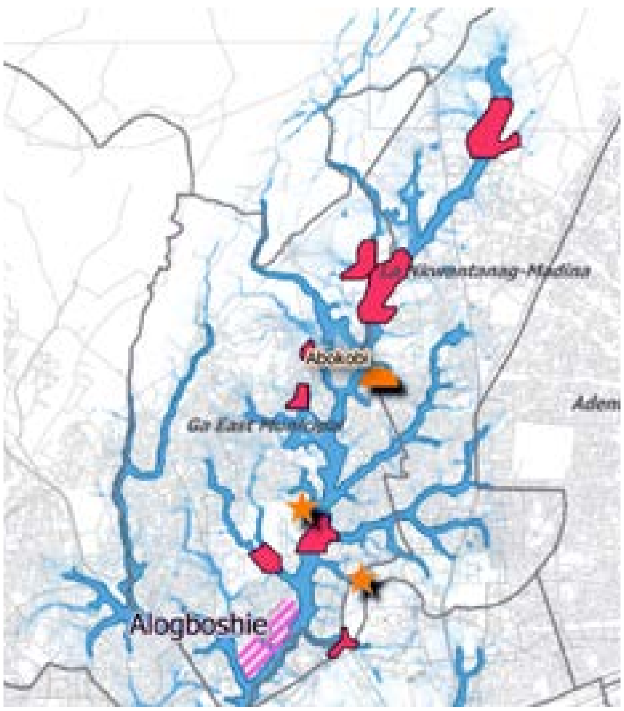


Notes: Background based on Google Earth; Yellow dots in panels a and b designate locations of public buildings. ©World Bank. Further permission required for reuse.
a. NDVI = normalized difference vegetation index (ranging from –1 to +1).

Figure 3.5 Estimated Water Storage Added through Micro Retention in Accra, 2015 and 2070



Map 3.5 Eight Potential Sites for Upstream Retention Ponds in the Odaw Basin



Notes: Background based on Open Street Maps; *@World Bank. Further permission required for reuse.*
Locations (designated in red) were identified as potential retention pond sites by the Hydrological Services Department (HSD), Ministry of Works and Housing.

retention ponds are under threat of encroachment. Given the rapid urbanization of Accra, it is of utmost importance to secure the existing space for retention ponds (photo 3.3). They can be designed as either off-line or in-line retention ponds (figure 3.6).

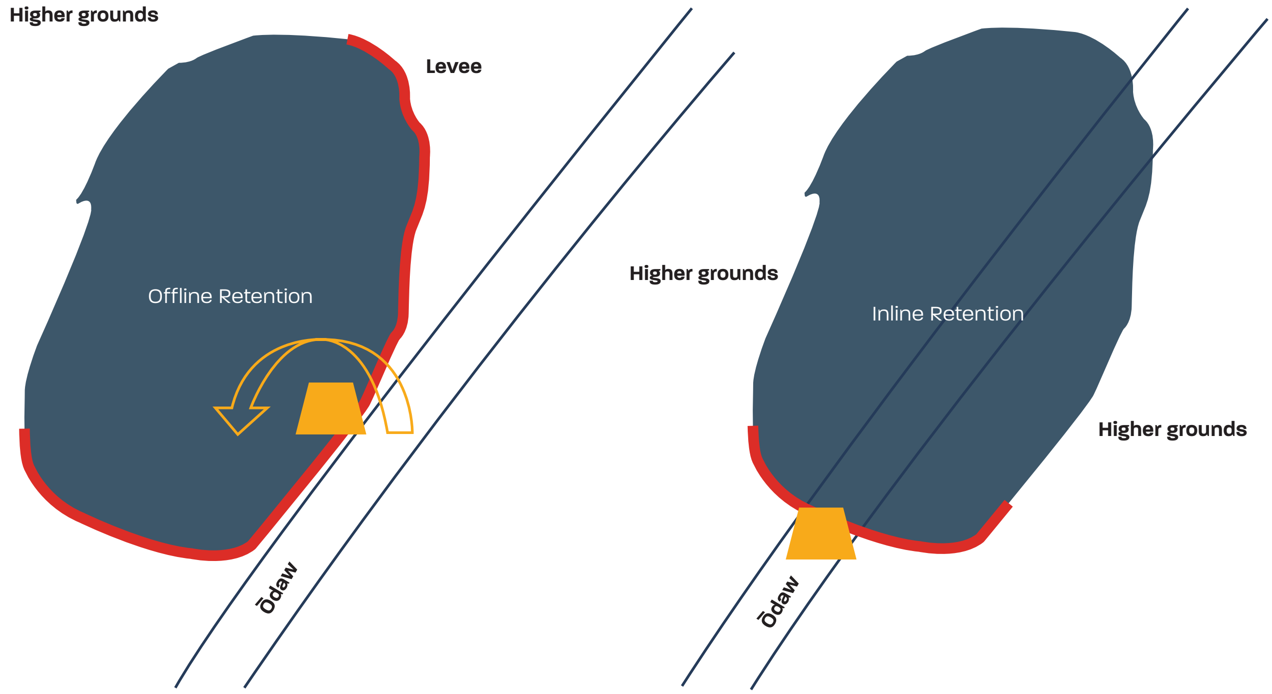
Photo 3.3 Abokobi, a Potential Retention Pond in the Odaw Basin

Source: Bosch+Slabbers. @World Bank. Further permission required for reuse.

In the Odaw Basin, there is still room for the construction of retention ponds as critical structures to withhold flood water upstream. For example, the additional reduction of the flood levels is 0.5 meters when two retention ponds are placed upstream (figure 3.7).

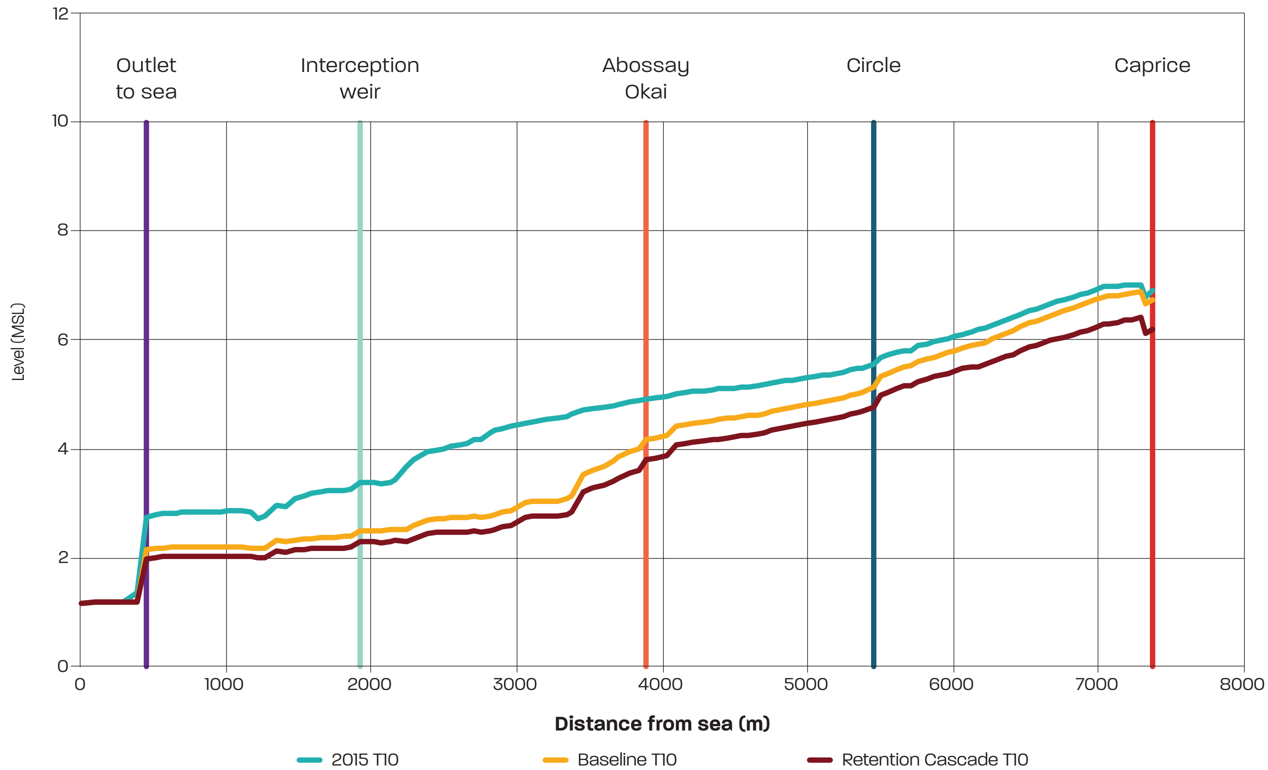
The retention pond storage measures are considered in the calculations. In total, eight areas in the upstream part of the Odaw Basin have been identified by the Hydrological Services Department (HSD) as potential sites for retention ponds. To a large extent, the location for retention ponds have rapidly been taken up by the local population, are on private land, or in some cases have been built up already. Retention is realized in these areas by construction of a diversion weir or barrier and connecting levees to increase the capacity of the retention ponds. The retention

Figure 3.6 Conceptual Drawings of Off-line and In-line Retention Ponds



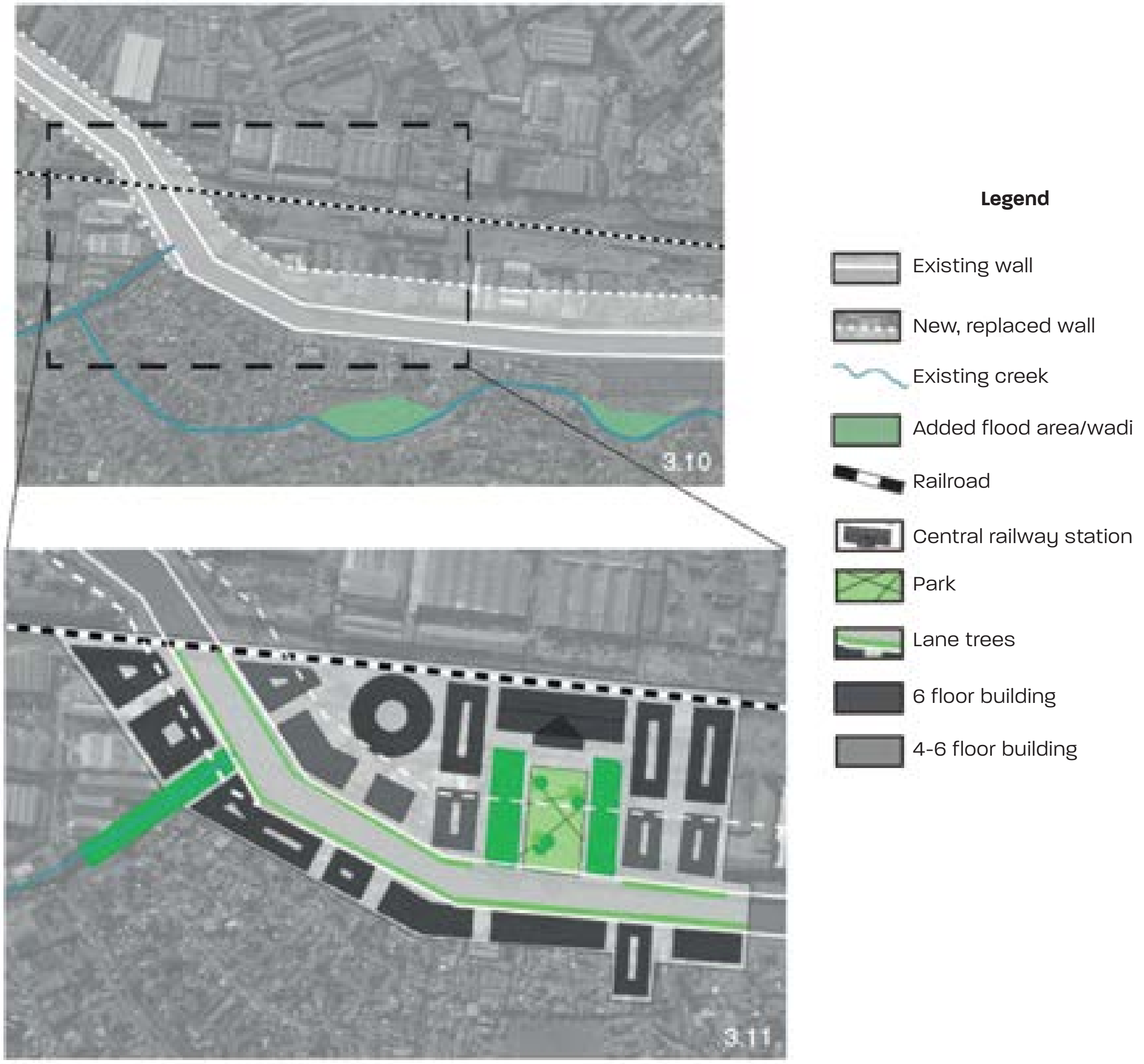
Source: HKV Consultants. ©World Bank. Further permission required for reuse.
Note: "In-line" and "Off-line" referring to siting either on or beside the Odaw Channel, respectively. Red lines designate the location of embankment or dyke/dam.

Figure 3.7 Estimated Reduction of Flood Levels from Implementation of Two Retention Ponds in Odaw Basin, by Location



Note: "2015 T10" refers to water level at 1 in 10 year flood event (reference year 2015); "Baseline T10" refers to water level with the implementation of "baseline" measures at 1 in 10 year flood event (reference year 2015); "Retention Cascade T10" refers to water level with the implementation of two retention ponds upstream at 1 in 10 year flood event (reference year 2015).

Map 3.6 Impression of Widening the Odaw Riverbed (Upstream of Abossay-Okai Bridge) for Potential Upgrade of the Greater Accra Urban Environment



Source: Bosch+Slabbers. ©World Bank. Further permission required for reuse.

ponds need to be desilted regularly by dredging or flushing. A mechanism should be in place to release water from the retention areas immediately after a flood to provide sufficient storage for sequential flood events.

3.2.4 Priority 4: Drain Floodwaters to the Sea

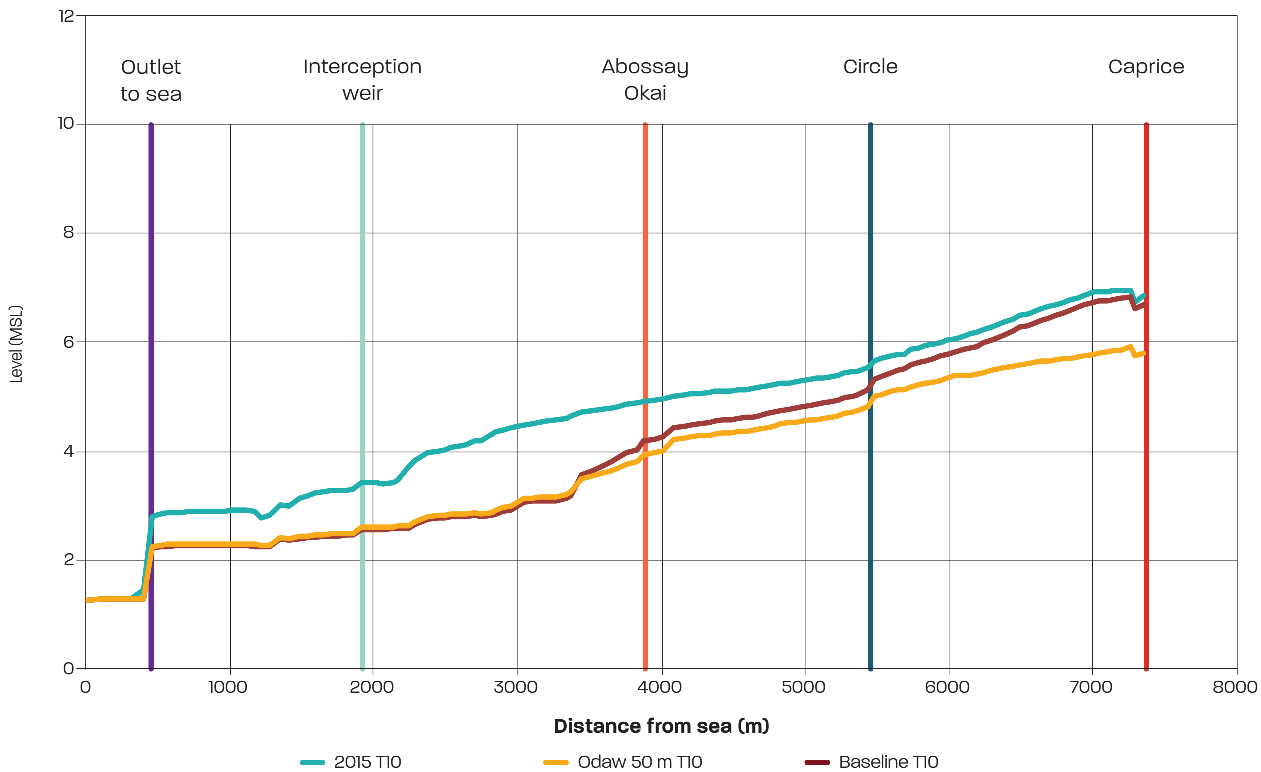
If retention and storage of water is not sufficient, an increase of the discharge capacity of the rivers and primary drains, especially in the midstream and downstream areas, is the remaining option for flood mitigation. Possible obstruction of the main drainage flows should be reduced where possible.

The following measures are considered in the calculations:

- Widening the channel or riverbed
- Removing, widening, or raising bridges
- Lowering floodplains and widening the outlet
- Lowering to mean sea level the already low-lying floodplains around Korle Lagoon between the interceptor weir and Abossay-Okai Bridge
- Constructing floodwalls
- Widening of the Odaw outlet to the sea.

Widening the Odaw channel. Widening the riverbed or channel also increases the discharge capacity and reduces floodwater levels. Widening may be restricted by the available space and becomes more expensive in the case of concrete-lined drains. Bridges in the widened sections would also need to be extended or rebuilt.

Figure 3.8 Estimated Reduction of Flood Levels from Widening Odaw Drain



Note: "2015 T10" refers to water level at 1 in 10 year flood event (reference year 2015); "Baseline T10" refers to water level with the implementation of "baseline" measures at 1 in 10 year flood event (reference year 2015); "Odaw 50 m T10" refers to water level with a widening of Odaw drain to 50 meters.

Iterative calculations found that it is necessary to widen the Odaw Channel considerably between Caprice and the Abossay-Okai Bridge to improve flood safety levels (map 3.6). This section of the Odaw is a true bottleneck. In the investment alternatives, the Odaw Channel is widened from 25 meters to 50 meters between Caprice (confluence of the Odaw and its tributary, the Onyasia) and Kwame Nkrumah Circle (confluence of the Odaw and its tributary, the Nima). Widening from 35 meters to 100 meters is needed between the Circle and Abossay-Okai Bridge. In a feasibility study, the necessary widening can be further optimized.

Removing, widening, or raising bridges. The extent of the widening means that the bridges also need to be rebuilt. Calculations with the flood model show that the capacity of the rectangular lined Odaw drain between Caprice and Kwame Nkrumah Circle (current width, 25–32 meters) and between the Circle and Abossay-Okai Bridge (current width, 32–37 meters) is too low for safely discharging floods into the sea. Figure 3.8 shows the reduction of the floodwater levels when the drain is widened to 50 meters and the bridges are extended accordingly. Flood levels drop by 1 meter at Caprice and by 0.25 meters between Abossay-Okai Bridge and the Circle.

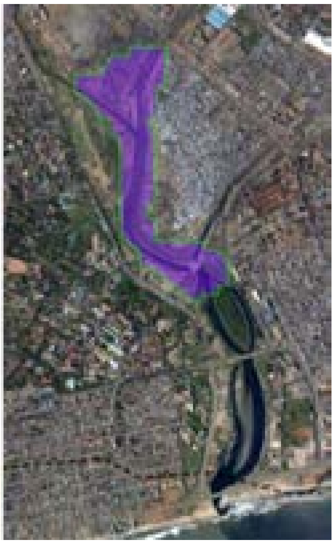
Floodplain lowering. In the area between the interceptor weir and Abossay-Okai Bridge, already low-lying flood plains can be lowered further to increase the flood conveyance capacity but also to prevent people from encroaching upon these high-flood-hazard areas (photo 3.4). An extreme scenario would additionally evacuate and lower to mean sea level the informal settlement of Old Fadema (also known as "Sodom and Gomorrah").

Floodplain lowering increases a river's discharge capacity and lowers peak water levels. The side effect of floodplain lowering is that the floodplains are inundated so often that encroachment becomes less attractive. Moreover, floodplain lowering often has positive effects for the environment (biodiversity).

However, these scenarios for floodplain lowering are not effective in terms of floodwater level reduction (figure 3.9). Specifically, this is because the bottleneck in the drainage system is the Odaw drain's lack of capacity upstream of Abossay-Okai Bridge. If this bottleneck is mitigated (for example, by widening Odaw drain), floodplain lowering in the area considered here will become more effective.

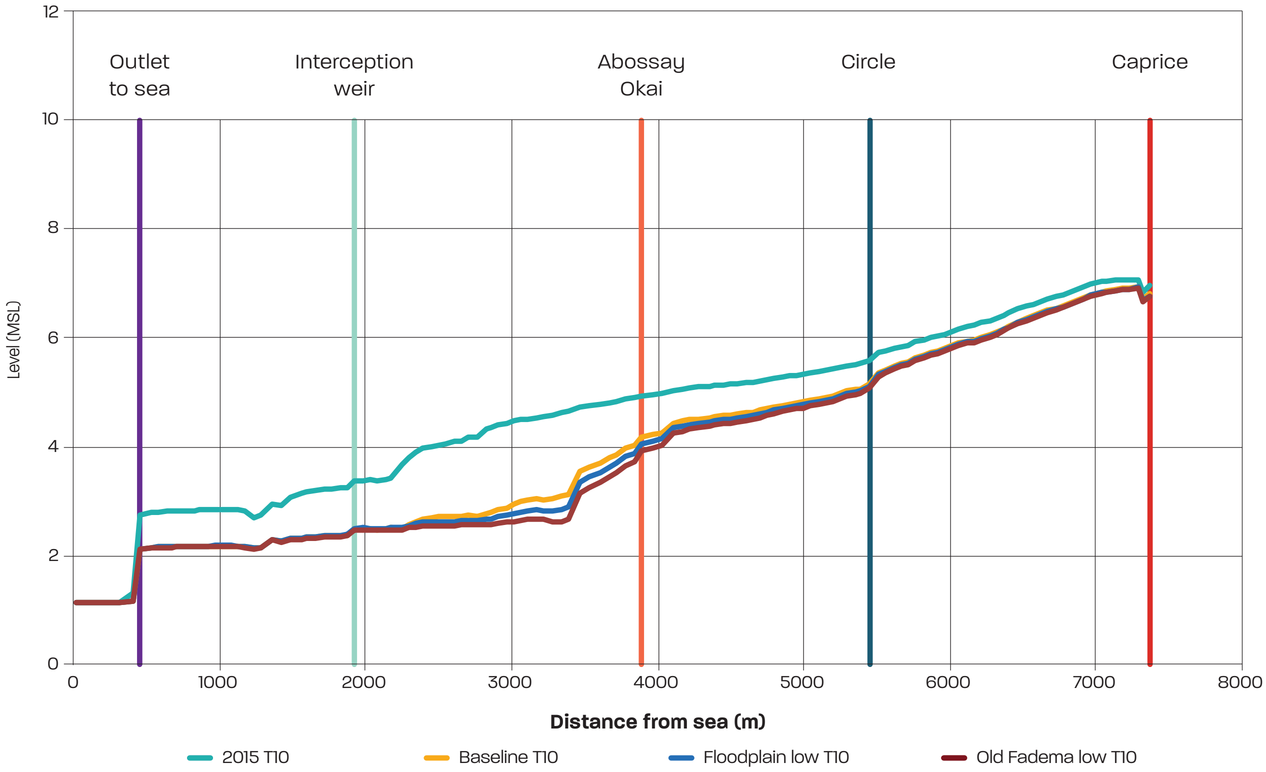
Photo 3.4 **Potential Site for Floodplain Lowering in the Odaw Basin**

a. Korle Lagoon between interceptor weir and Agbogbloshie scrapyard **b. Aerial view**



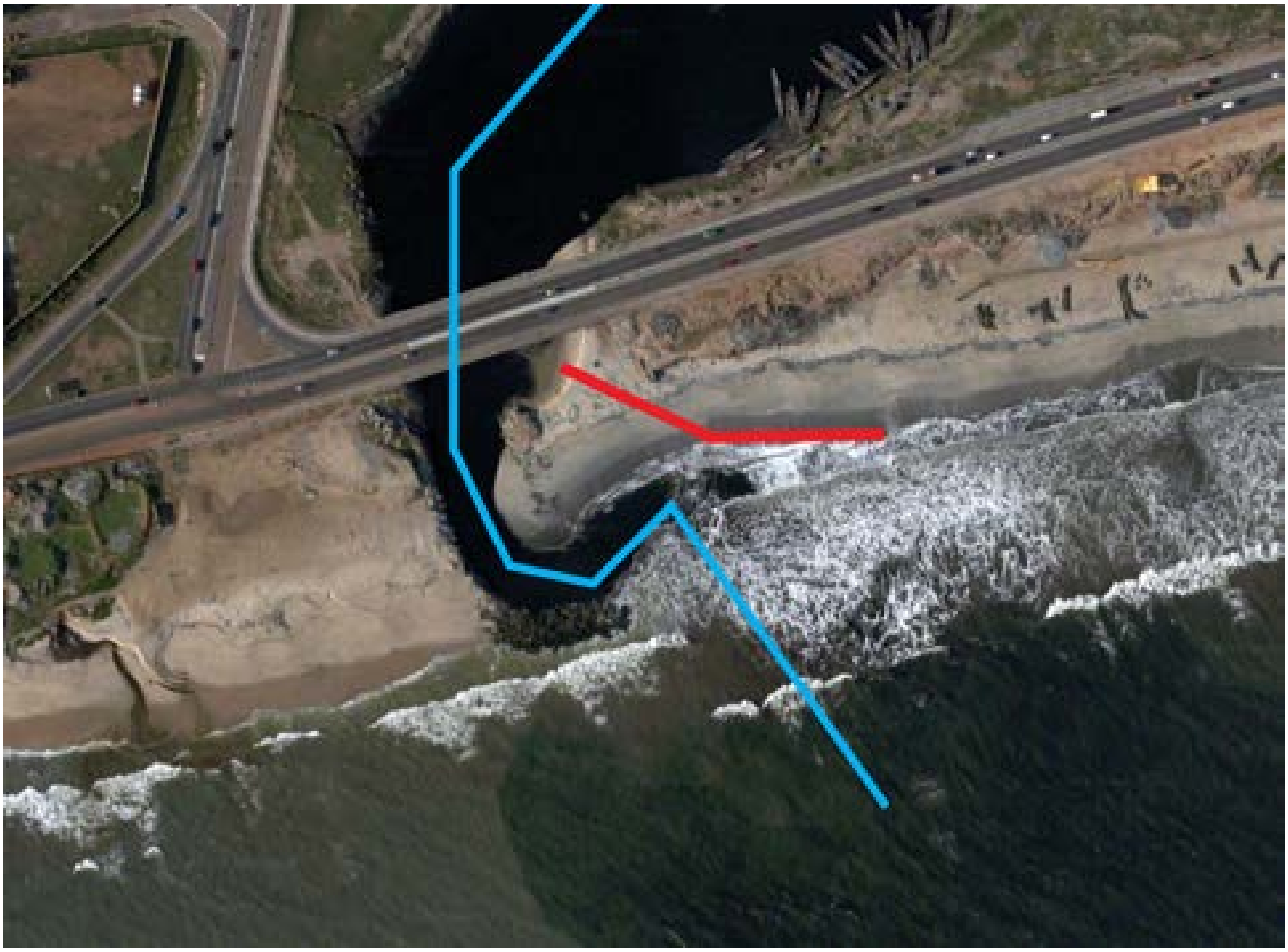
Sources: HKV Consultants (panel a) ©World Bank. Further permission required for reuse.
Note: Panel b: Background based on Google Satellite ©World Bank. Further permission required for reuse.

Figure 3.9 **Estimated Reduction of Flood Levels from Lowering the Odaw Floodplain**



Note: "2015 T10" refers to water level at 1 in 10 year flood event (reference year 2015); "Baseline T10" refers to water level with the implementation of "baseline" measures at 1 in 10 year flood event (reference year 2015); "Floodplain low T10" refers to water level with lowering of flood plains at 1 in 10 year flood event (reference year 2015); "Old Fadama low T10" refers to water level with lowering of flood plains at Old Fadama at 1 in 10 year flood event (reference year 2015)

Photo 3.5 **Aerial View of Small Outlet for Widening (Odaw Outlet at Korle Lagoon)**



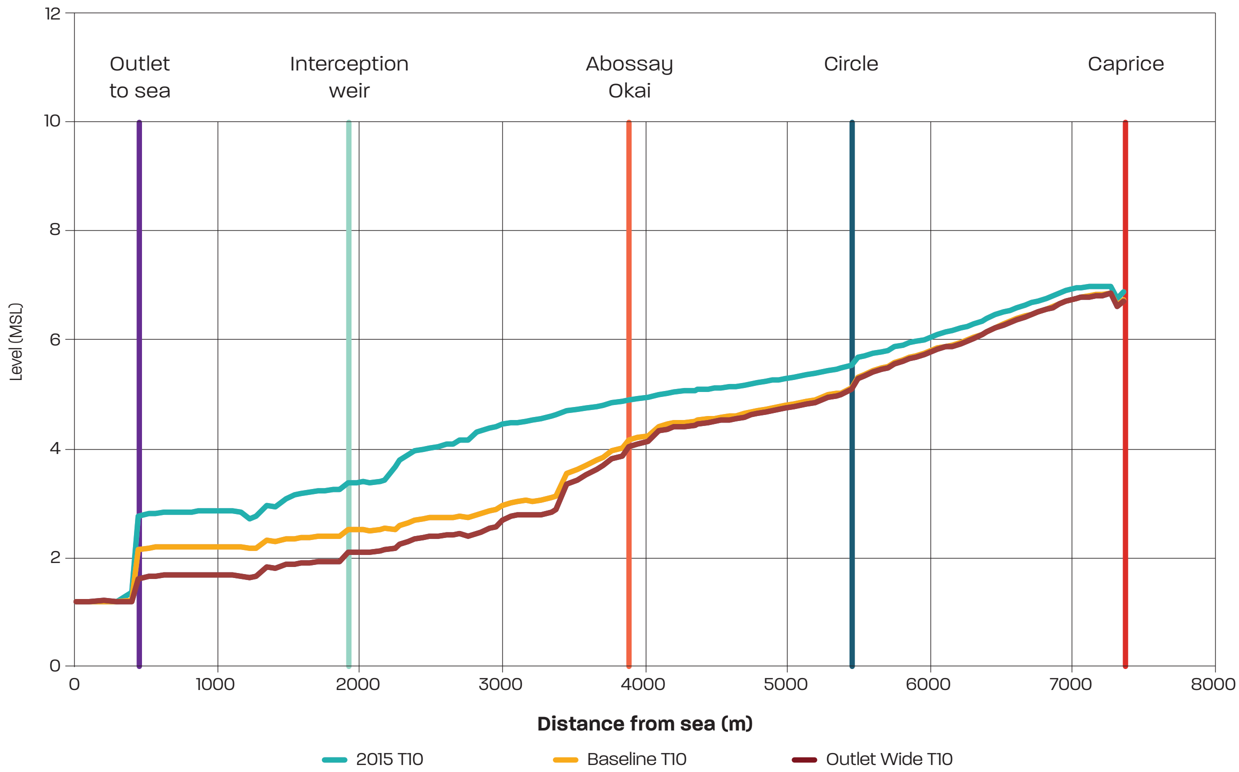
Note: Background based on Google Earth, ©World Bank. Further permission required for reuse.

Constructing floodwalls. If floodplain lowering or widening of the riverbed is not possible (for example, if the required space is not available), flood walls may be necessary to increase the discharge capacity. Floodwalls, however, do not lower the peak water levels and in many cases will even increase the peak levels. This causes additional risks: people will feel safe behind the floodwalls, but when the walls collapse during a flood, the number of casualties will be high. Floodwalls therefore are not the preferred first option for flood mitigation. A negative side effect of floodwalls is also that they split the area into two.

Floodwalls with a maximum height of 1 meter between Kwame Nkrumah Circle and Abossay-Okai Bridge (Kaneshie) are included in some investment alternatives. In that case, the roads to the bridges also need to be elevated by 1 meter. A section along the Nima drain, just upstream where the drain goes underground, will also be protected by floodwalls, reducing inundation of the area around the Circle.

Widening the outlet to the sea. The outlet of the Odaw (Korle Lagoon) to the sea is quite narrow. Widening the outlet will lower the flood levels upstream, but the reduction will almost diminish at Abossay-Okai Bridge, upstream of which is the area with highest flood risk (figure 3.10). In some cases, the river basins and lagoons have only a small outlet into the sea. Widening this outlet (the red line in photo 3.5) increases the discharge outflow capacity and lowers peak water levels upstream.

Figure 3.10 Estimated Reduction of Flood Levels from Widening of Outlet to the Sea



Note: "2015 T10" refers to water level at 1 in 10 year flood event (reference year 2015); "Baseline T10" refers to water level with the implementation of "baseline" measures at 1 in 10 year flood event (reference year 2015); "Outlet wide T10" refers to water level with the widening of the outlet to the sea at 1 in 10 year flood event (reference year 2015);

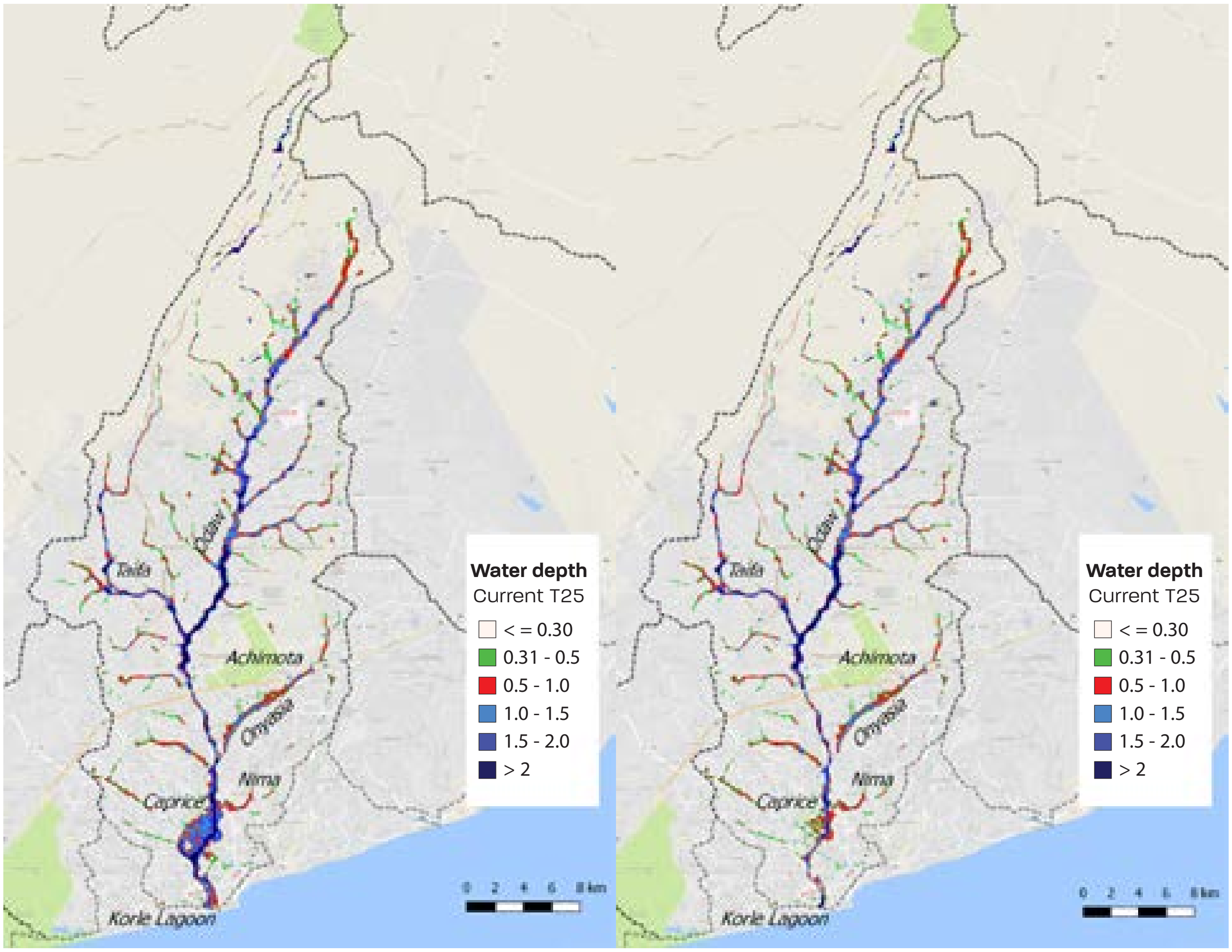
3.3 Nonstructural Measures

Flood mitigation is not only about structural measures that increase the prevention of floods. Nonstructural measures also are effective to mitigate the flood risk, among them the following:

- *Flood early warning:* If people are warned in time, the damage and casualties due to floods may be reduced significantly. For GAR, a timely warning is critical and also challenging given the rapid response of runoff to heavy rainfall. In most basins, floods develop within several hours (flash floods).
- *Flood zoning:* Flood zoning—keeping flood-prone areas free of buildings—is an effective way to reduce the flood risk and also to maintain the natural capacity of the riverbed and slow down the runoff. Enforcement of the ban on building in the flood zones is a key issue for flood zoning and risk management in GAR.
- *Relocating people:* In some cases, there may be no option to relocating people who live in flood-prone areas.
- *Solid waste management:* Solid waste is a long-lasting problem in GAR. The waste blocks the drains, causing numerous small-scale inundations at the tertiary drain level and, when piling up, also in secondary and primary drains.
- *Local floodproofing:* In some cases, floodproofing on a very local scale may be the most efficient option to reduce the flood risk. For example, the Toyota company at Graphic Road moved all its cars to higher floors of the building to reduce damage from the area's regular floods.

Map 3.7 Flood Hazard in the Odaw Basin under Current Situation and Baseline Investment Alternative for a T10 Flood

a. Current hazard, T10 flood[a] **b. Baseline hazard, T10 flood[b]**



Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
a. The hazard map illustrates the estimated inundation given the "current situation" (based on the flood of June 3, 2015).
b. The hazard map illustrates the estimated inundation under a "baseline" investment alternative that includes maintenance measures for flood mitigation.

3.4 Identification of Suitable Investment Alternatives for the Odaw Basin

Suitable investment alternatives for different design safety levels (T10, T25, T50) were calculated with iterative running of the flood model, thereby identifying suitable combinations of different flood mitigation measures. An overview of all alternatives is shown in table 3.1. The text below describes the investment alternatives in more detail.

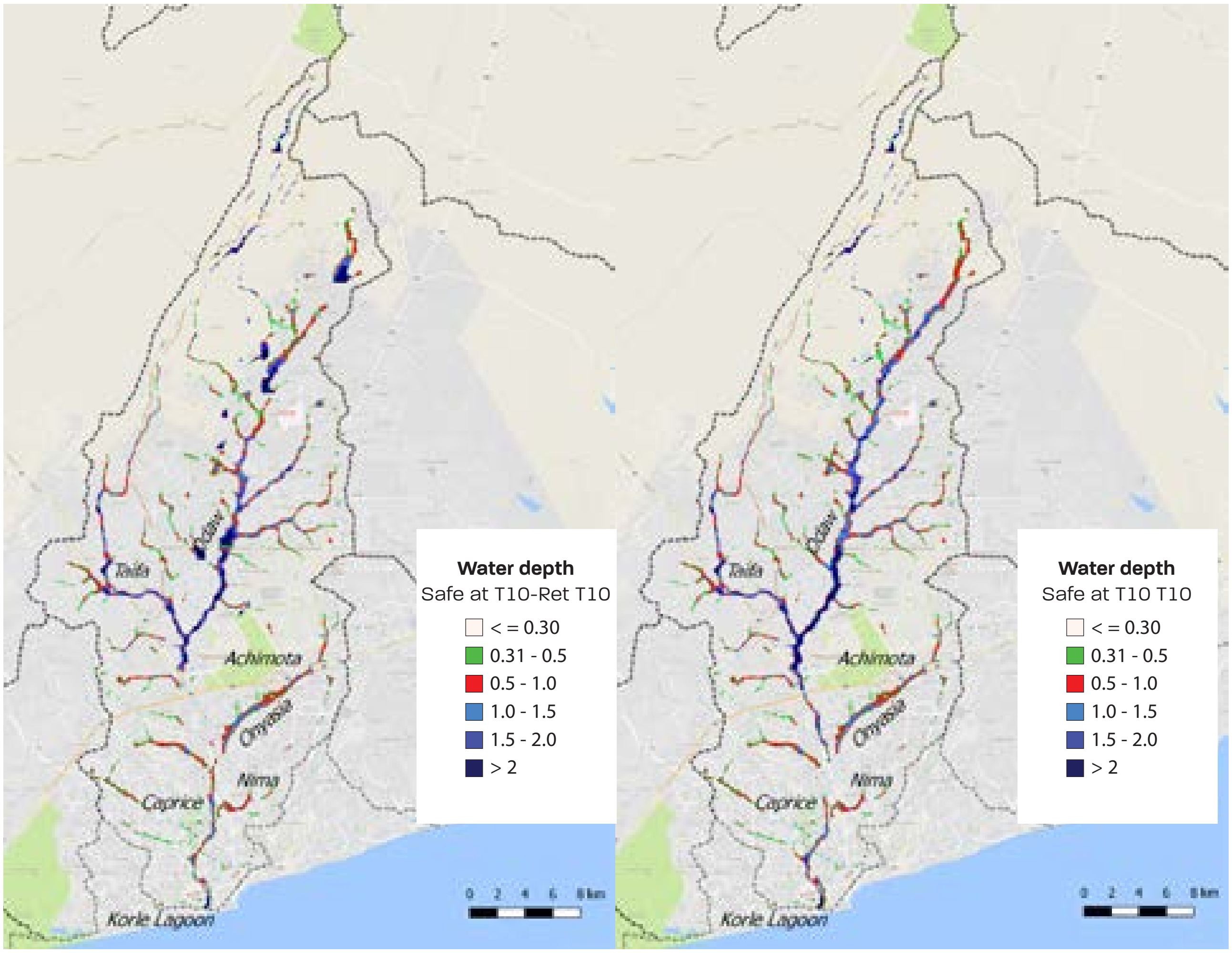
The individual measures, as described earlier, are combined into flood risk mitigation investment alternatives. All alternatives include the nonstructural measures. The same applies for wadis, which are especially important for mitigation of the additional risks due to future climate change and urbanization. Below the investment alternatives are summarized looking at the measures and their effect on flood hazard.

Baseline. The "baseline," or "maintenance," investment alternative assumes "no-regret" measures, as summarized earlier under the "Priority 1: Maintenance" structural flood mitigation measures. These measures do not lead to complete flood safety for a T10 flood (map 3.7).

Safe at T10 A. This alternative, also described as "Safe at T10 Retention," includes the maintenance measures plus implementation of retention ponds (map 3.8, panel a). Under this alternative, there is hardly any flood hazard between Caprice and the sea for a flood situation with a return period of 10 years.

Map 3.8 Flood Hazard in the Odaw Basin under the "Safe at T10" Investment Alternatives

a. Safe at T10 A: water retention measures **b. Safe at T10 B: widening of Odaw drain**



Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
a. The hazard map illustrates the estimated inundation under a "T10A" investment alternative
b. The hazard map illustrates the estimated inundation under a "T10B" investment alternative

Safe at T10 B. This investment alternative focuses on widening of the Odaw in combination with the maintenance measures (map 3.8, panel b). Retention is not needed in that case. The flood hazard is similar to Safe at T10 A.

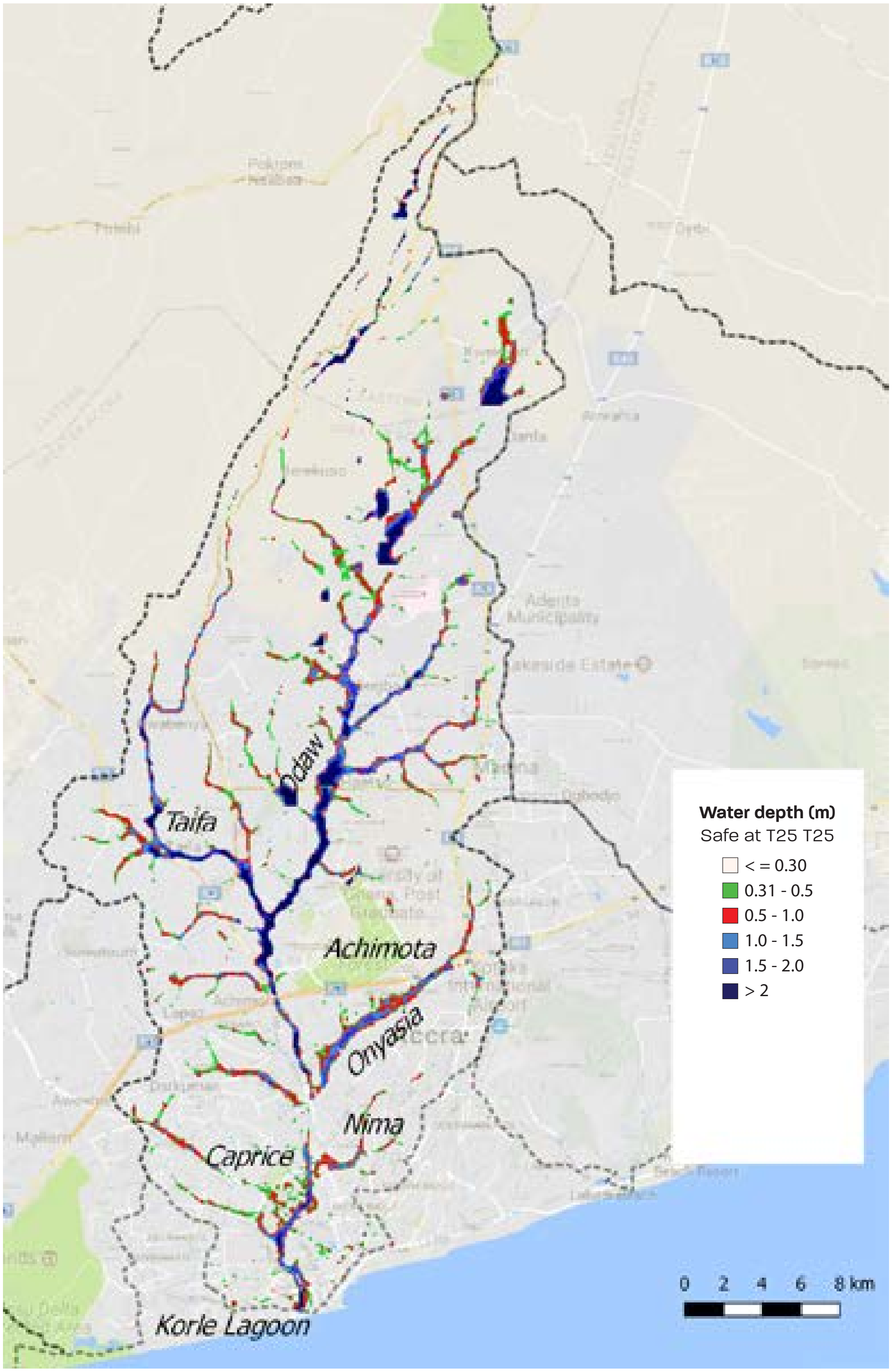
Safe at T25 A. The "Safe at T25 A" alternative combines the measures from the Baseline, Safe at T10 A, and Safe at T10 B investment alternatives (map 3.9, panel a). It thus includes both retention and widening of the Odaw on top of maintenance measures. The flood hazard is almost completely removed for a flood with a return period of 25 years.

Safe at T25 B. Compared with Safe at T25 A, the "Safe at T25 B" investment alternative omits retention areas and instead adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls (map 3.9, panel b). This leads to a flood hazard between Caprice and Abossay-Okai Bridge similar to Safe at T25 A.

Safe at T50. The "Safe at T50" alternative includes all measures from the previous alternatives; in fact, this is equivalent to Safe at T25 B plus retention (map 3.10). Under this alternative, the resulting flood hazard for a flood with a 50-year return period is strongly reduced but not removed completely.

Map 3.9A Flood Hazard in the Odaw Basin under the "Safe at T25 A" and "Safe at T25 B" Investment Alternatives

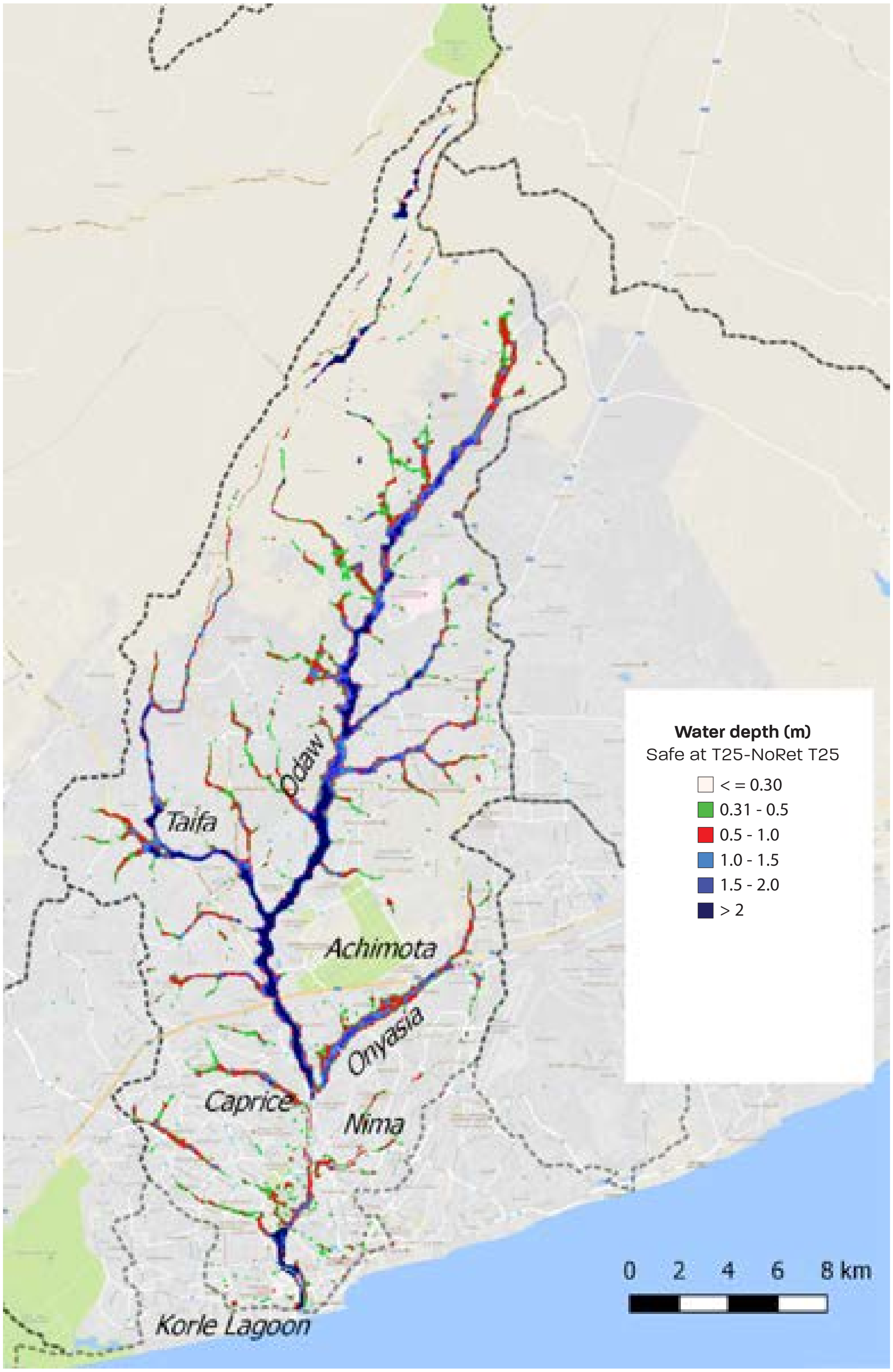
a. Safe at T25A



Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
a. The hazard map illustrates the estimated inundation under a "T25A" investment alternative
b. The hazard map illustrates the estimated inundation under a "T25B" investment alternative

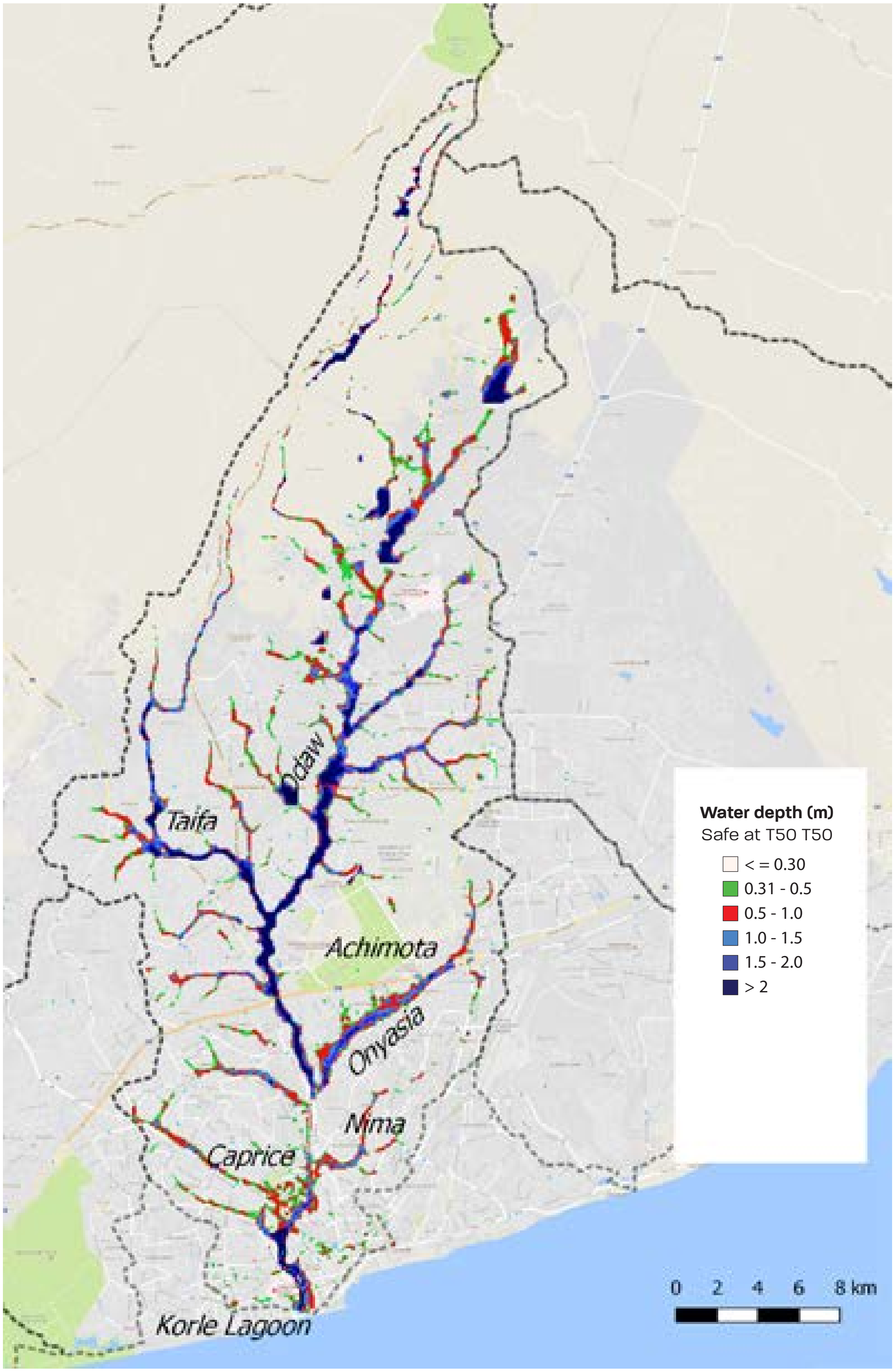
Map 3.9B **Flood Hazard in the Odaw Basin under the "Safe at T25 A" and "Safe at T25 B" Investment Alternatives**

b. Safe at T25B



Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
a. The hazard map illustrates the estimated inundation under a "T25A" investment alternative
b. The hazard map illustrates the estimated inundation under a "T25B" investment alternative

Map 3.10 Flood Hazard in the Odaw Basin under the "Safe at T50" Investment Alternative



Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
a. The hazard map illustrates the estimated inundation under a "T25A" investment alternative

Box 3.2 Creating Urban Space and Developing Revenues by Covering the Odaw Drain

Different options for developing the urban areas around the Odaw drain were discussed during the planning sessions with stakeholders in Ghana. One option was the covering or partial covering of the Odaw drain to generate urban space and possibly income through land value capture and property development (figure B3.2.1).

Figure B3.2.1 Impression of Development around the Odaw Channel

a. Widened Odaw with limited property development

b. Widened and partially covered Odaw with property development

Source: Bosch+Slabbers. ©World Bank. Further permission required for reuse.

Figure B3.2.2 Rendering of Possible Urban Renewal and Land Development above the Odaw

Source: Bosch+Slabbers. ©World Bank. Further permission required for reuse.

To assess the economic feasibility of widening and covering the Odaw, the economic costs and benefits were compared (as summarized in table B3.2.1). The costs equals the costs of construction, land acquisition, and compensation for resettlement. The benefits can be both direct and indirect and can either be priced (monetary) or nonpriced (externalities).

Table B3.2.1 Overview of Potential Benefits from Widening and Covering the Odaw for Land Development

Benefit category	Direct benefits	Indirect benefits
Priced (monetary)	• Land revenues (land sales) • Producer surplus (rents) real estate developers • Benefits users of housing, buildings, and so on (consumer surplus)	Competitive position
Nonpriced (externalities)	• Recreation value • Green and biodiversity (spatial quality) • Economic spillovers	Income distribution

This assessment focuses solely on the direct priced effects and land revenues in particular because there is either (a) a lack of insight regarding what the other effects could entail (being dependent on the use of the developed land); or (b) a lack of information.

In this cost-benefit analysis, the developers' company profits are not included given the insight concerning the investment and capital costs to establish commercial real estate in the area and what the precise potential real estate revenues would be. The land revenues, however, are derived from the potential land development from covering the Odaw drain, as follows: The *area of net land* created for development of real estate (assuming 33 percent of gross land) is multiplied by the *average land price* for residential and commercial real estate in the area. Assuming a well-functioning real estate land market in the area, the *land price (per square meter)* is an appropriate measure to capture the total economic value of the land considering all associated aspects.

The land price in the Odaw area varies between US$150 and US$300 per square meter. A best-case scenario was assumed, with high-end real estate development for this area and multifloor buildings (on average, three stories for the whole zone, although five to six stories are well possible, too). This would result in a land sales price of US$300 per square meter for the net buildable area. The financial benefits would, in this case, be US$71 million (present value). The additional costs to cover the (widened) Odaw drain are estimated at US$128 million and outweigh these financial benefits.

From a commercial point of view, then, covering the Odaw drain is not financially feasible (given these assumptions). However, other impacts like spatial quality and social and green improvements should also be considered as well as a scenario in which five- to six-story buildings are developed at higher density. A more detailed business case and cost estimate is needed for a final assessment of the economic feasibility of covering the Odaw drain.

3.5 Comparison and Evaluation of Investment Alternatives for the Odaw Basin

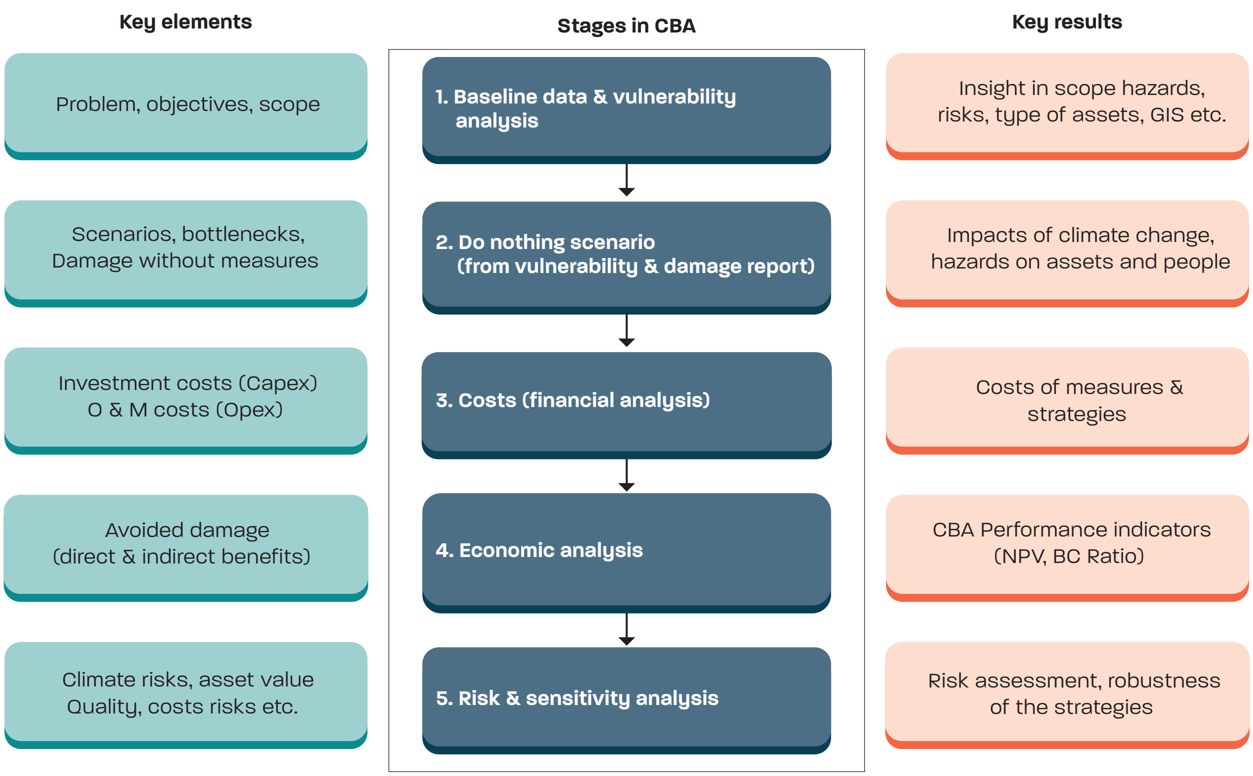
The different investment alternatives (combinations of individual flood mitigation measures) designed to achieve certain design safety levels have been compared and evaluated against economic costs and benefits and a broader qualitative comparison considering a wide range of environmental, social, and financial criteria. The two tools used for the evaluation and comparison are accordingly the economic cost-benefit analysis (CBA) and a multicriteria analysis (MCA).

In an economic CBA, the costs and benefits of alternatives are analyzed from a broad welfare perspective. Not only are direct costs and revenues considered but also all other possible positive and negative impacts on the economy. A CBA principally involves the identification of all the effects (economic, financial, social, and environmental) that the investment alternatives will have on the welfare of all members of society (either population or business). In a CBA, the effects to society are quantified and also translated into monetary units (Ghana cedis or U.S. dollars). Nonetheless, some impacts cannot be expressed in monetary units (intangibles) and therefore remain outside the scope of the CBA. This is the case here for environmental and social impacts. To still take such impacts into account, they are assessed in the MCA. The CBA and MCA methods complement each other, and the outcomes of the CBA have been used as input in one of the criteria in the MCA.

3.5.1 Methodology and Key Assumptions in the Cost-Benefit Analysis

The key ingredients and steps in CBA are summarized in the figure 3.11. In the CBA approach, effects are defined as changes (costs or benefits) that may be attributed to an investment alternative. Effects are determined by investigating the difference between the future situation—both "with" and "without" implementing the investment alternatives (the "do nothing" scenario). The CBA thus analyzes the societal returns of taking additional action. Table 3.2 lists the key indicators and assumptions in the CBA.

Figure 3.11 Key Elements and Steps in the Cost-Benefit Analysis



Source: ECORYS ©World Bank. Further permission required for reuse.
Note: BC ratio = benefit-cost ratio. CBA = cost-benefit analysis. GIS = geographic information system. NPV = net present value. O&M = operations and maintenance.

Table 3.2 Key Indicators and Assumptions Applied in the Cost-Benefit Analysis

Indicator	Assumptions	References
Total costs	• Initial construction costs • Yearly costs of operations and maintenance • Initial costs of land acquisition • Initial costs of resettlement • A provision for contingencies, design studies, and supervision	Agreed upon during stakeholder discussions and workshops
Benefits	Flood risk reduction from implementation of flood mitigation measures as reduced risk	Based on damage model
Population growth	Yearly population growth of 3 percent	GSS 2012
Real economic growth rate	Average real economic growth rate of 2.8 percent through 2060	The real economic growth in GAR in 1991–2016 was, on average, 2.8 percent (World Bank 2017).
Time horizon	40 years	For this project, 2020–60 (40 years) is the chosen and agreed-upon time span, assuming 10 years for full implementation of the flood mitigation interventions and an additional 30 years as the lifetime.
Discount rate	6 percent	The opportunity cost of capital method based upon alternative investments. The real interest rate in Ghana is about 4.5 percent (22 percent nominal rate – 17.5 percent inflation). If a risk premium of 2.5 percent is added, the total real rate is 7 percent. The social time preference method based upon long-term GDP growth. The real GDP growth rate was 7.8 percent in 2016 and 6.1 percent in 2017. A World Bank study on the "Economics of Adaptation to Climate Change" in Ghana used a real discount rate of 5 percent (World Bank 2010), and the International Union for Conservation of Nature (IUCN) CBA for a forest in Ghana also used a discount rate of 5 percent (IUCN 2016).
Climate change	10 percent gradual increase of rainfall until 2050	World Bank 2018b

Note: CBA = cost-benefit analysis.

3.5.2 Cost-Benefit Analysis of Investment Alternatives

The investment alternatives were defined together with national stakeholders and compared with the support of a CBA and an MCA. Table 3.3 provides an overview of the nominal costs for each of the investment alternatives, excluding indirect costs and contingencies (26 percent).

3.5.2.1 Costs of Flood Mitigation Measures

The costs of measures consist of investment costs (capex) and yearly operations and maintenance costs (opex). Investment costs include the following components:

- *Land acquisition costs* are especially important for the measures involving retention areas and widening of the Odaw.
- *Resettlement costs* (compensation and the like) have been estimated separately for the relevant measures and are included as a separate cost category in the CBA. Resettlement costs are based on maximum direct damages, assuming this is a reasonable estimation of structures that need to be removed and rebuilt. Resettlement costs for informal settlements are based on maximum indirect damages. This leads to the following results for resettlement costs:
  - Eight retention areas: US$36.7 million
  - Odaw widening: US$28.9 million
  - Floodplain lowering (informal settlements): US$0.3 million.
- *Construction costs* have been assessed at the level of a conceptual design, using a bottom-up method. Measures were broken down by cost items, which were quantified based on bills of quantity and unit prices as known from recent construction works in Accra.
- *Indirect costs* of studies, management, and supervision (assuming 11 percent of the land acquisition and construction costs)

Table 3.3 Nominal Costs of Flood Mitigation Measures in the Odaw Basin, by Investment Alternative

Measure	Investment alternatives					
	Baseline[a]	Safe at 10A[b]	Safe at T10B[c]	Safe at T25A[d]	Safe at T25B[e]	Safe at T50[f]
A. Maintenance and repair	X	X	X	X	X	X
B. Flood Retention Pond	—	X	—	X	—	X
C. Widening of Odaw Drain	—	—	X	X	X	X
D. Floodplain lowering, Agbogbloshie to Old Fadama	—	—	—	—	X	X
E. Floodwalls (1 meter high), Circle to Kaneshie	—	—	—	—	X	X
F. Widening of the Outlet to the Sea	—	—	—	—	X	X
G. Micro water retention and new drain design	(X)	(X)	(X)	(X)	(X)	(X)
Nominal costs (US$, millions)						
Initial construction costs	43	47	83	88	121	125
Yearly operations and maintenance	0.5	0.63	0.50	0.63	0.50	0.63
Land acquisition	—	134	29	162	29	162
Resettlement	—	37	29	66	29	66

Note: "X" means measure is included in the designated alternative. "(X)" means the measure included in the alternative but not in the CBA, because these measures are included in all alternatives and the additional costs are low. — = not applicable.
a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

- Contingencies (15 percent of land acquisition and construction costs have been assumed); and
- Indirect taxes such as value added tax (VAT) are *not* included (regarded instead as transfers in CBA literature).

The operations and maintenance (O&M) costs include the following:

- *Dredging of the Odaw* needs to be repeated every five years, at an average annual estimated cost of US$0.5 million.
- *Dredging of the retention ponds* is estimated at a yearly cost of US$0.13 million.

The O&M costs are considered to be constant for the entire time horizon. Measures other than dredging of the Odaw itself and the retention ponds do not require extra maintenance.

3.5.2.2 Timing of Costs and Benefits

The present value of the benefits (flood risk reduction) of flood mitigation measures depends on the timing of the measures' implementation. The CBA only books the risk reduction of an alternative once its measures are realized. Table 3.4 shows an overview of the timing (as discussed with national stakeholders and experts) and the construction costs of the flood mitigation measures.

The implementation of the retention measures and of the widening of the Odaw will take several years. It is assumed that the costs of these multiyear investments are equally spread between the commencement and finalization of the measure. The measures for floodwalls and floodplain lowering are implemented within a single year, but their implementation is foreseen to start only in seven and two years' time, respectively.

3.5.2.3 Benefits of the Investment Alternatives

Benefits considered in the CBA are direct and indirect flood risk reduction benefits of the investment alternatives (compared with the "do nothing" scenario). The direct benefits consist of asset damage reduction (based upon the damage model) for the following:

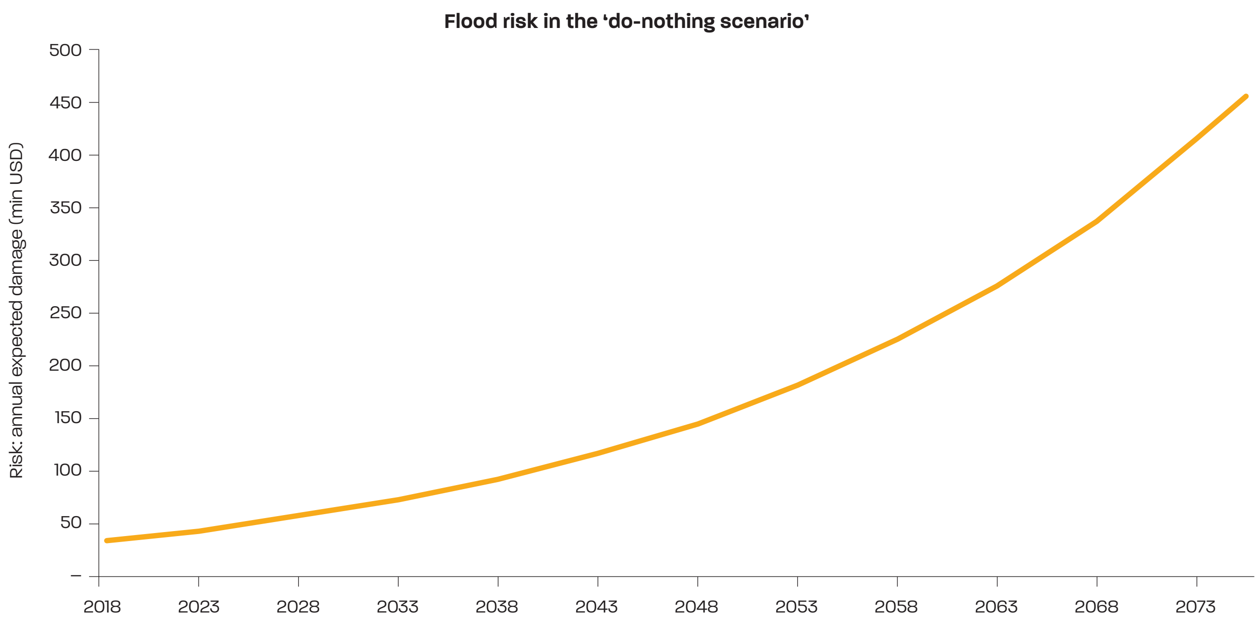
- Residential assets
- Commercial and industrial assets

Table 3.4 Costs and Timing of Construction Measures, 2017

Measure	Investment cost (US$, millions)	Timing
1. Dredging and sand traps	35.7	Implemented in year 1
2. Remove or clean interceptor weir[a]	< 0.1	Implemented in year 1
3. Retention ponds	174.5	Implemented year 1 to year 5
4a. Widening Odaw from 50 meters to 100 meters	97.7	Implemented year 1 to year 7
4b. Widening Odaw from 50 meters to 100 meters (covered drain)	226.5	Implemented year 1 to year 7
5. Floodplain lowering	17.5	Implemented in year 2
6. Floodwalls (at Nima and Odaw)	18.2	Implemented in year 7
7. Widen outlet to sea	0.5	Implemented in year 1
8. Repair major bottlenecks	9.3	Implemented in year 1

Note: The costs of construction measures exclude resettlement, contingencies, and indirect costs.
a. The cost-benefit analysis (CBA) assumed costs for removal of the interceptor weir. When (partially) rehabilitated, maintenance and operational costs will be substantial. This is not considered in the CBA here.

Figure 3.12 Annual Expected Increase in Flood Damage in the Odaw Basin under a "Do Nothing" Scenario, 2018–75



- Agricultural assets (set at zero for Odaw)
- Infrastructure assets.

Indirect benefits are all other damage reductions based upon asset damage reductions such as transport and business interruption, and so on. These are estimated as mark-ups on the direct asset damages in the damage model.

3.5.2.4 "Do Nothing" Scenario

First of all, the do-nothing scenario is presented, showing how flood risks will develop without any intervention. Assets (including content values) at risk will increase over time because of volume and quality changes. The volume will increase because of population growth and growth of economic activities over time. The quality of the assets and content will improve over time because of income growth. As stated above, for economic or income growth, 2.8 percent annual real growth was applied.

Overall, this implies for the do-nothing scenario that the potential yearly average flood damage will increase over time by a factor of 12 (figure 3.12). This implies that there is substantial potential for flood mitigation measures to prevent future damages.

Table 3.5 B-C Ratio and NPV, by Investment Alternative, Relative to "Do Nothing" Scenario, 2015

US$, millions

Item	Investment alternative					
	Baseline, T10A,	T10-A[b]	T10-B[c]	T25-A[d]	T25-B[e]	T50[f]
Total costs	62	260	166	364	206	404
Investment costs	54	251	159	355	198	395
O&M costs	8	9	8	9	8	9
Total benefits	275	674	443	748	514	780
Risk reduction	275	674	443	748	514	780
Net present value	213	414	276	384	308	376
Benefit-cost ratio	4.40	2.59	2.66	2.00	2.50	1.90

Note: O&M = operations and maintenance. NPV = net present value.
a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

3.5.2.5 Cost-Benefit Analysis: Results

Table 3.5 shows the discounted total investment costs, O&M costs, and risk reduced by an investment alternative compared with the do-nothing scenario (situation in the reference year 2015). The two bottom rows illustrate the benefit-cost ratio (B-C ratio) and net present value (NPV) for each alternative relative to the do-nothing scenario.

As table 3.5 makes clear, all investment alternatives have a B-C ratio that is higher than 1 and positive NPVs. This shows that the (discounted) benefits of all investment alternatives outweigh the (discounted) costs. This in turn implies that, in principle, a choice for a high safety level is justifiable from a societal welfare perspective. As also can be seen, the B-C ratio is highest for the baseline alternative. From an efficiency point of view solely, the baseline alternative is thus favorable. In terms of absolute benefits and costs, the baseline alternative scores lowest because it reduces the risk significantly less than the other alternatives. This said, notwithstanding the relatively high costs of retention ponds, the NPV is highest for investment alternative T10 A because of the significant risk reduction realized by the retention ponds. From an absolute risk (damage) reduction perspective, alternatives T25 A and T50 outperform the other alternatives.

3.5.3 Sensitivity Analysis

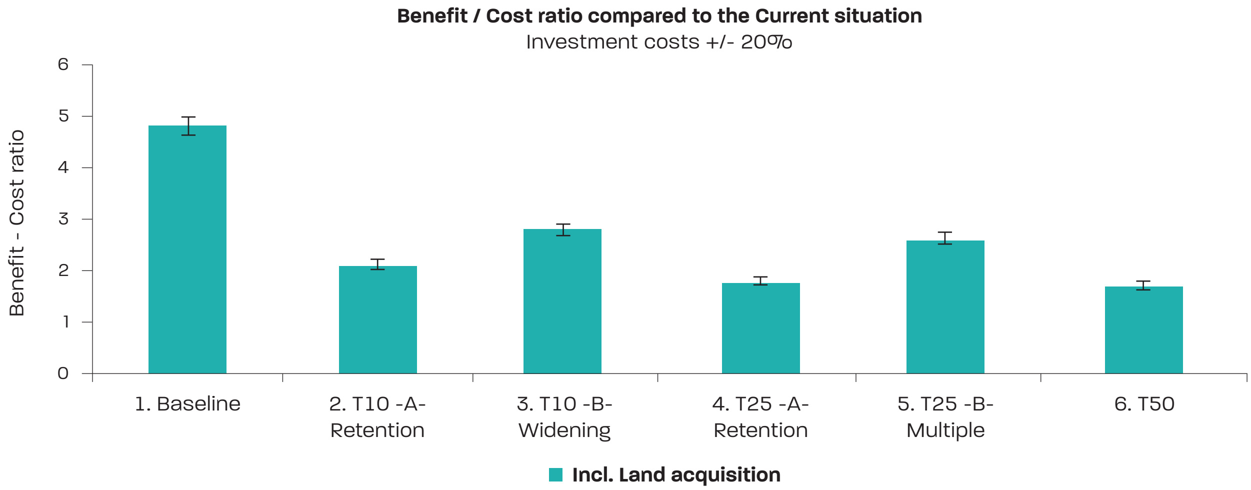
Any CBA deals with uncertainties regarding key (input) assumptions and future developments. For this CBA, several factors are uncertain and important for the results of the CBA:

- *The future economic growth rate* (income growth) as a determining factor of the future size of the assets at risk
- *The discount rate*, assumed at 6 percent based upon current real interest rate and economic growth assumptions
- *Investment costs,* assuming that higher costs are possible
- *Investment costs* without land acquisition.

Some estimations of the B-C ratio at different assumptions regarding the above variables are provided (figures 3.13, 3.14, and 3.15). The black bars in the figures denote the B-C ratio for the sensitivity analysis. The upper end of the bars represent values for the figures' respective variables of +20 percent, 5 percent, and 4 percent.

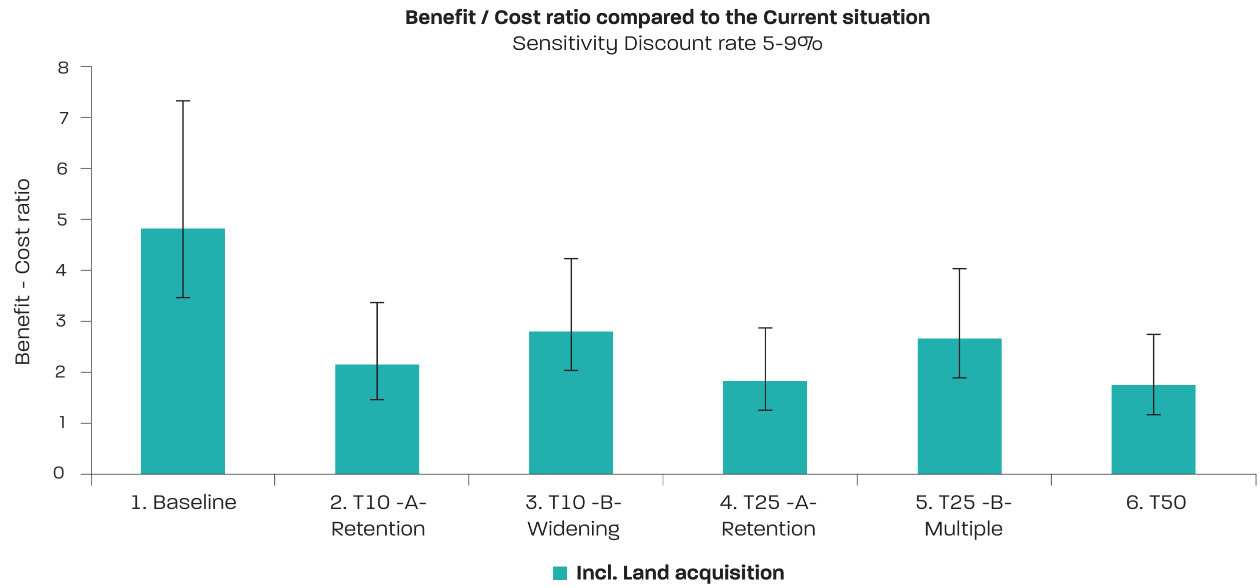
As the figures show, the variations in the investment costs barely affect the B-C ratio because the risk reduction realized by each of the alternatives significantly outweighs the costs of the alternatives. The figures also show that the discount rate does affect the B-C ratio, albeit not to an extent that one of the alternatives cannot be considered economically viable anymore. Moreover, no relatively large variations are observed, which follows from the costs and the benefits being booked relatively early in time. The figures show that variations in the economic growth or asset value growth rate will influence the B-C ratio of the alternatives—but, again, not to the extent that an alternative's cost would outweigh its benefits.

Figure 3.13 B-C Ratio Sensitivity to Investment Costs of +/–20 Percent, by Investment Alternative



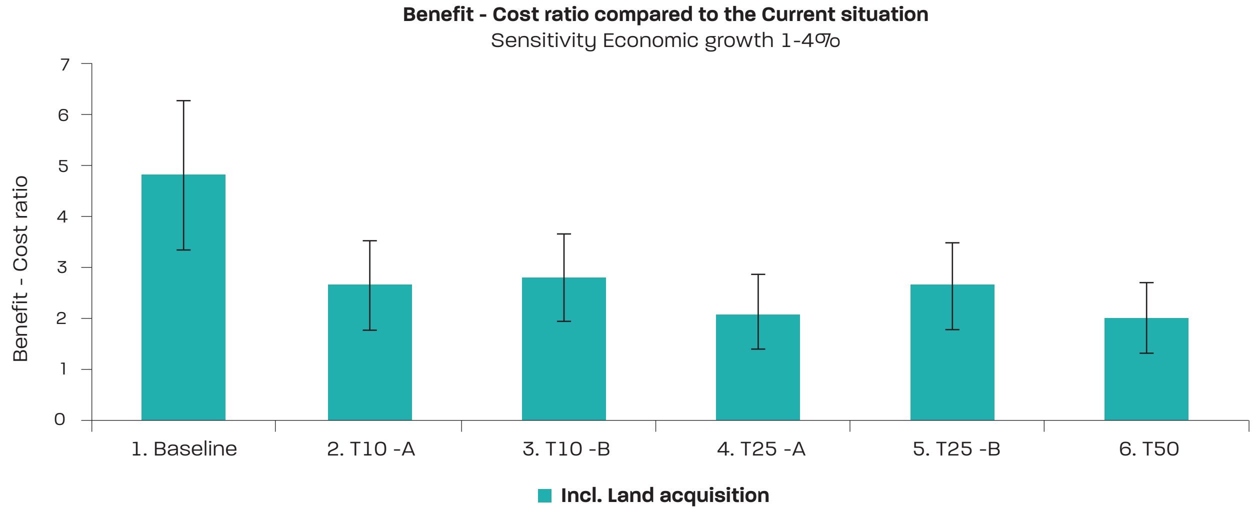
Note: The benefit-cost ratio (B-C ratio) for each alternative is compared with the current situation. Costs include land acquisition. Black bars denote the B-C ratio.
a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

Figure 3.14 B-C Ratio Sensitivity to Discount Rate of 5–9 Percent, by Investment Alternative



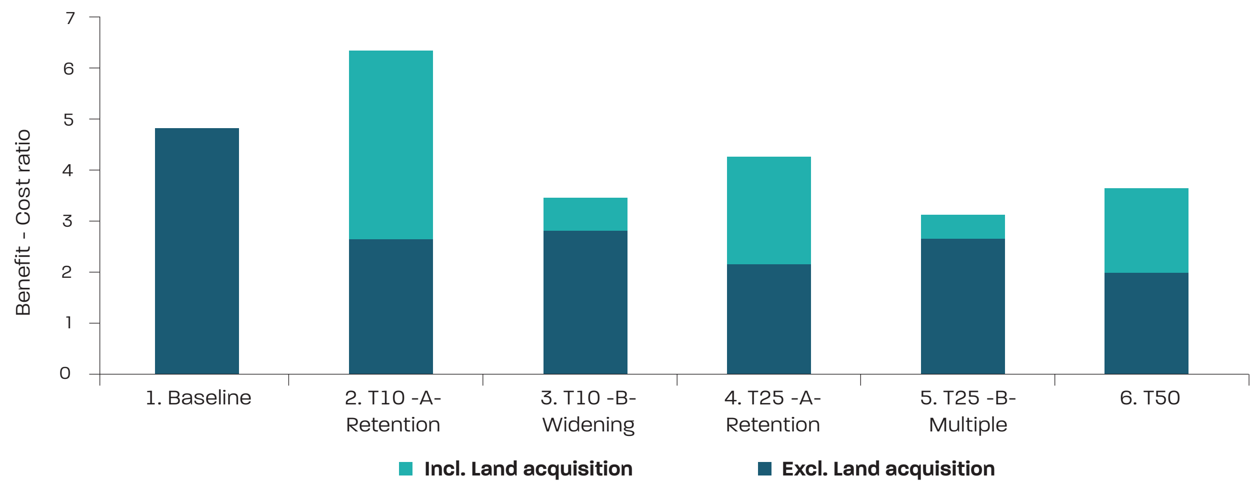
Note: The benefit-cost ratio (B-C ratio) for each alternative is compared with the current situation. Costs include land acquisition. Black bars denote the B-C ratio.
a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

Figure 3.15 B-C Ratio Sensitivity to Economic Growth of 1–4 Percent, by Investment Alternative



Note: Costs include land acquisition. Black bars denote the B-C ratio
a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

Figure 3.16 Comparison of B-C Ratios, by Investment Alternative, With and Without Land Acquisition Costs



a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

In determining the cost per measure, there remained uncertainty around the land price data in Accra. Because the costs of some measures (Odaw drain widening and retention ponds) are largely determined by the price of land, the B-C ratios of the alternatives when land acquisition costs are not considered are also presented. Figure 3.16 shows that the B-C ratios for the T10-A, T25-A, and T50 investment alternatives substantially improve when land acquisition costs are not considered. The NPV and B-C ratios are also summarized in table 3.6.

Table 3.6 B-C Ratio and NPV of Investment Alternatives Compared with Do-Nothing Scenario without Land Acquisition Costs

US$, millions

Item	Investment alternatives					
	Baseline[a]	T10 A[b]	T10 B[c]	T25 A[d]	T25 B[e]	T50[f]
Total costs	62	112	138	187	176	227
Investment costs	54	103	130	178	168	218
O&M costs	8	9	8	9	8	9
Total benefits	275	674	443	748	514	780
Risk reduction	275	674	443	748	514	780
Net present value	213	562	305	561	338	553
Benefit-cost ratio	4.4	6.0	3.2	4.0	2.9	3.4

Note: B-C ratio = benefit-cost ratio. O&M = operations and maintenance. NPV = net present value.
a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

3.5.4 Conclusions of the Cost-Benefit Analysis

The following can be concluded from the CBA and the related sensitivity analysis (as presented in table 3.6):

- For all investment alternatives, the B-C ratios are larger than 1 and NPVs are positive. (Discounted) benefits of all alternatives outweigh the (discounted) costs. This implies that, in principle, a choice for a high safety level is justifiable from a society welfare point of view.
- The B-C ratio is highest for the baseline alternative. From an efficiency point of view, the baseline alternative is favorable. Investment alternative T10 B scores the second highest ratio.
- The NPV is highest for investment alternative T10 A because of the higher absolute benefits (of combined measures) and relative lower costs than the alternatives, with a higher safety level due to absence of the Odaw widening measure. From an absolute risk (damage) reduction perspective, alternative T25 A outperforms the other alternatives.
- For all investment alternatives, the B-C ratio stays larger than 1 at a discount rate of 9 percent. The baseline, T10 B, and T25 B alternatives are especially robust because they do not or marginally include land acquisition costs.

3.5.5 Methodology and Indicators Used in the Multicriteria Analysis

The objective of the MCA is to assess and prioritize the measures and investment alternatives in a more comprehensive way—"more comprehensive" in the sense that the tool not only focuses on costs and benefits (damage reduction) but also provides insights on more intangible impacts (such as social and environmental impacts) and on aspects such as political acceptance and the institutional feasibility and sustainability of the measures and alternatives. The main criteria have been ranked in order of importance by the participants in that meeting. The resulting main criteria and subcriteria, for which the impact assessment of the investment alternatives is executed, are presented in table 3.7.

Table 3.8 describes the indicators in the MCA "scorecard." All measures have been scored on the main criteria and subcriteria by participants in the workshop and by the national experts. The financial-economic criteria, reduction of people affected, and spatial impact (land use) of measures in hectares by floods have been derived from the CBA and flood-damage model.

The scoring grid uses "++" for "very positive"; "+" for "positive"; "0" for "neutral"; "-" for "negative"; and "--" for "very negative." These scores have been translated to numerical values ranging from +5 (very positive) to –5 (very negative). The negative score values are introduced for aggregating

Table 3.7 Impact Assessment Criteria for the Flood Risk Mitigation Investment Alternatives

Main criteria	Subcriteria	Assessment
1. Institutional feasibility and sustainability and legal impacts	1.1 Clear organizational responsibilities 1.2 Capacity of the implementing institution (technical, maintenance, and financial) 1.3 New legislation needed 1.4 Enforcement ease	Qualitative scores
2. Political acceptance	2.1 Acceptance by political levels	Qualitative scores
3. Environmental impacts	3.1 Pollution impact (waste, sludge, water quality, smells, and so on) 3.2 Impact on biodiversity and green city	Qualitative scores
4. Readiness	4.1 Time needed to implement the measure (and strategy)	Qualitative scores
5. Social impacts	5.1 Number of people affected by floods 5.2 Number of people temporarily displaced 5.3 Number people to be resettled 5.4 Impacts on cultural heritage or traditions	Quantitative and qualitative scores
6. Financial-economic impacts	6.1 Net present value from cost-benefit analysis	Quantitative scores
7. Spatial impacts	7.1 Land area needed (in square meters) 7.2 Spatial quality impact	Quantitative and qualitative scores

impacts from measures to alternatives (small positive scores for negative impacts could by aggregation be incorrect at alternative level). The subcriteria have been allocated an equal share in the overall main criteria. Tables 3.8 and 3.9 present the scores of the individual measures on the criteria.

The scores have been translated to the numerical scores and have been aggregated to the main criteria. The assessment of the individual measures was not possible at the financial-economic (CBA) and reduction of affected people criteria, because the effects depend on the combination of certain measures and therefore can only be presented on an investment alternative level. Table 3.9 presents the scoring outcomes for the measures (unweighted; weights have only been discussed at investment alternative level for all criteria).

From table 3.9, it is concluded that the best-scoring measures overall are the repair of major bottlenecks, dredging and sand traps, and removing or cleaning the interceptor weir. Widening the Odaw scores lowest (relating to the lack of expected political acceptance, social issues [especially resettlement], and spatial impact [land use]). Furthermore, retention has a lower score because of a lower enforcement score and negative scores on readiness and social impacts (resettlement).

Table 3.8 Institutional and Legal Assessment of Flood Risk Mitigation Measures

Measure	Institutional and legal impacts					
	Organization responsibilities	Technical capacity	Maintenance capacity	Financial capacity	Legal framework	Enforcement
1. Dredging and sand traps	++	++	-	- -	+	+
2. Remove or clean interceptor weir	++	++	-	-	+	+
3. Retention ponds	0	++	-	- -	+	0
4. Widening Odaw from 50 meters to 100 meters	++	+	- -	- -	+	+
5. Floodplain lowering	++	++	0	-	+	+
6. Floodwalls (at Nima and Odaw)	++	++	0	-	+	+
7. Widen outlet to sea	++	++	0	-	+	+
8. Repair major bottlenecks	++	++	0	-	+	+

Note: + = positive. ++ = very positive. 0 = neutral. - = negative. -- = very negative.

Table 3.9 Scores of Flood Risk Mitigation Measures (Totals, Unweighted)

Measure	Institutional	Environment	Readiness	Political acceptance	Social impacts	Spatial impacts	Unweighted total score
1. Dredging and sand traps	++	++	-	- -	+	+	12.92
2. Remove or clean interceptor weir	++	++	-	-	+	+	12.50
3. Retention ponds	0	++	-	- -	+	++	−5.00
4. Widening Odaw from 50 meters to 100 meters	++	+	- -	- -	+	+	−13.33
5. Floodplain lowering	++	++	0	-	+	+	7.08
6. Floodwalls (at Nima and Odaw)	++	++	0	-	+	+	12.08
7. Widen outlet to sea	++	++	0	-	+	+	12.08
8. Repair major bottlenecks	++	++	0	-	+	+	14.17

Note: + = positive. ++ = very positive. 0 = neutral. - = negative. -- = very negative.

3.5.6 Results of the Multicriteria Analysis

Based upon the assessment of measures and scores highlighted in tables 3.8 and 3.9, the scores have been aggregated by investment alternative. In the aggregation, there is a complexity: Some impacts can be aggregated (spatial, environmental, and social). For some others (readiness and institutional), straightforward aggregation could be questionable (as when positive more measures would result automatically in a higher strategy score). For this reason, the scores per investment alternative based upon the averages (alternative score divided by the number of measures in the strategy) are presented in the table 3.10.

The weights of the main criteria were defined in a workshop with the key stakeholders on February 12, 2018. All workshop participants were asked to rank the criteria group with a figure of 1–7 (1 being top priority, 7 being lowest rank). Based upon this ranking, the criteria were categorized as most important (25–30 percent weight), of medium importance (15 percent weight), and of low importance (5 percent weight). Based on this session, the institutional and spatial impact criteria were regarded as most important while social, economic, and readiness criteria were regarded as least important (table 3.11).

As table 3.11 indicates, the "Baseline" and "Safe at T25 B" investment alternatives have the highest scores. The

Table 3.10 Quantitative Information on Financial-Economic Criteria and Reduction of Flood-Affected People, by Investment Alternative

Indicator	Investment alternative					
	Baseline[a]	T10 A[b]	T10 B[c]	T25 A[d]	T25 B[e]	T50[f]
Economic: NPV from CBA (US$, millions)	213	414	276	384	308	376
Social: reduction of affected people in 2050	−33,924	−49,348	−41,324	−53,143	−50,435	−63,277
Social: minimum number of houses resettled	Possibly some	342: Retention	300: Odaw widening	642: Retention Odaw widening	400: Odaw widening Floodplain lowering	742: Retention Odaw widening Floodplain lowering

Note: CBA = cost-benefit analysis. NPV = net present value. Numbers follow directly from the analysis and are not rounded to a realistic accuracy.
a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

Table 3.11 Outcomes Weighting and Scoring, by Investment Alternative

Scores per category (average)	Investment alternative						Weights (%)
	Baseline[a]	T10 A[b]	T10 B[c]	T25 A[d]	T25 B[e]	T50[f]	
Institutional feasibility and sustainability	1.39	1.04	1.15	1.04	2.17	1.81	30
Environmental impacts	1.67	1.56	1.88	1.56	2.75	2.50	15
Readiness	4.17	1.88	1.88	1.56	3.00	1.67	5
Political acceptance	5.00	4.38	2.50	1.88	4.50	4.17	15
Social impacts	0.46	−0.12	−0.28	−0.04	−0.25	−0.42	5
Financial-economic impact	2.76	5.00	3.49	4.75	3.93	4.69	5
Spatial impact	3.75	1.25	2.50	1.25	0.75	0.83	25
Total score (unweighted)	19.20	14.99	13.11	12.00	16.84	15.25	100
Total score weighted	2.72	1.85	1.88	1.45	2.26	2.05	

a. "Baseline" includes maintenance measures for flood mitigation.
b. "T10 A" includes the maintenance measures plus implementation of retention ponds for a flood with a return period of 10 years.
c. "T10 B" includes widening of the Odaw plus the maintenance measures, but not the retention ponds, for a flood with a return period of 10 years.
d. "T25 A" combines the baseline maintenance measures, retention ponds, and widening of the Odaw Channel for a flood with a return period of 25 years.
e. "T25 B" omits retention areas but adds floodplain lowering, widening of the outlet to the sea, and placement of floodwalls for a flood with a return period of 25 years.
f. "T50" refers to a design safety level of protection from a 1-in-50-year flood, combining baseline maintenance measures, retention ponds, widening of the Odaw Channel, floodplain lowering, widening of the outlet to the sea, and placement of floodwalls.

baseline alternative performs well because of the high scores on readiness, political acceptance, economic impact, and low spatial impact (land use). Investment alternative T25 B scores very well on readiness, political acceptance, and environmental impacts compared with the other alternatives. Alternatives that score relatively low are T25 A and T10 A. They perform lower than the B alternatives because of the retention measure and the absence of the other measures with positive impacts. This is in turn owing to the lower overall score of the flood retention measure and more positive scores of the other measures.

Apart from this assessment at the level of the investment alternatives, the MCA makes very clear that the measures that require land acquisition (widening of the Odaw and retention basins located on land not owned by the government) are considered less favorably by national stakeholders. The reasons for this are that (a) the land ownership is not very clear, (b) land acquisition is complicated and takes a long time, (c) it causes resettlement issues, and (d) it is expensive. The political acceptance is also far less for alternatives that require the widening of the Odaw drain, not only because of the necessary land acquisition but also because of the long-lasting hindrance in an area with high economic activity.

3.5.7 Overall Conclusions from the Analysis

The main conclusions from the assessment of the investment alternatives to inform the government of Ghana's decisions about (a) the desired flood safety level for the Odaw basin, and (b) the contours of the pilot investment plan, are as follows:

- *All investment alternatives show a very clear positive benefit-cost balance.* The (discounted) benefits of all investment alternatives outweigh the (discounted) costs. The highest value of the NPV is found for the "Safe at T10 A" investment alternative, but differences with "Safe at T25 A" and "Safe at T50" are small. This implies that in principle a choice for a high safety level is justifiable from a society welfare point of view.
- *The discounted investment costs vary* from US$62 million for the "Baseline" alternative to either (a) US$404 million for the "Safe at T50" investment alternative (when all land needs to be acquired), or (b) US$227 million for the "Safe at T50" (if no land needs to be acquired).
- *The reduction of the affected people (yearly average) varies* from 30,000 for the "Baseline" alternative to 60,000 for the "Safe at T50" alternative (rounded numbers).
- *The number or houses to be resettled varies* from possibly "some" in the "Baseline" alternative to more than 750 in the "Safe at T50" investment alternative. However, the situation on the ground in Accra changes rapidly, and

no accurate data are available, so the actual numbers may be considerably different.

- *National stakeholders are least favorable toward measures requiring land acquisition* (widening of Odaw and retention basins located on land not owned by the government) because (a) the land ownership is not very clear, (b) land acquisition is complicated and takes a long time, (c) it causes resettlement issues, and (d) it is expensive.
- *There is far less political acceptance for alternatives that require the widening of Odaw drain,* not only because of the necessary land acquisition but also because of the long-lasting hindrance it will cause in an area with high economic activity.
- *However, a safety level of T25 or T50* probably cannot be obtained without measures that require land acquisition.

3.6 Flood Risk Management Strategy for Greater Accra

The Odaw Basin represents one of the 19 river basins of Greater Accra. To provide a more global analysis for the entire greater Accra region, the analysis for the Odaw Basin was extrapolated to estimate the flood risk for the entire GAR. The objective is to reflect on the results of the GAR flood risk analysis and provide quantitative indications for potential flood risk measures.

To that end, this section discusses

- The results of the flood risk analyses for the entire GAR;
- Lower and upper ranges for the maximum investment levels (investment ceilings) that are expected to be economically feasible; and
- Indicators for potential cost-effectiveness of flood mitigation measures.

This information can be used to prioritize specific basins when further elaborating flood interventions at the basin level.

3.6.1 Flood Risk Analysis for Greater Accra

This section discusses the results of this flood risk analysis. As before, flood risk is expressed as the expected annual damage. This figure is an average of annual direct and indirect flood damages on agricultural, commercial, industrial, and residential assets. It is a weighted average; in reality, some years have significantly lower and other years significantly higher flood damages. The total damages are presented as the NPV for the period up to 2060 (figure 3.17).

Map 3.11 presents the spatial distribution of flood risk across the GAR. The figures show that the damages are highest in areas near the main rivers and in urban areas. In general, low-lying, downstream coastal regions suffer from higher damage than more inland (upstream) areas. Urbanization and climate change cause the projected damage in 2050 to be significantly higher than in 2018.

The total damage per basin is presented as NPV (figure 3.17). The largest damages are observed in the Koluedor and Densu Basins, where flood damage values exceed US$500 million. In contrast, the total flood risk is low in the Lower Volta, Chemu, Songo, and Tema Basins, in some cases below US$1 million. Note that only the damage in GAR has been considered. For example, the flood damage in the upstream parts of the Densu Basin in the Central Region is not included.

3.6.2 Investment Ceilings for Flood Risk Measures

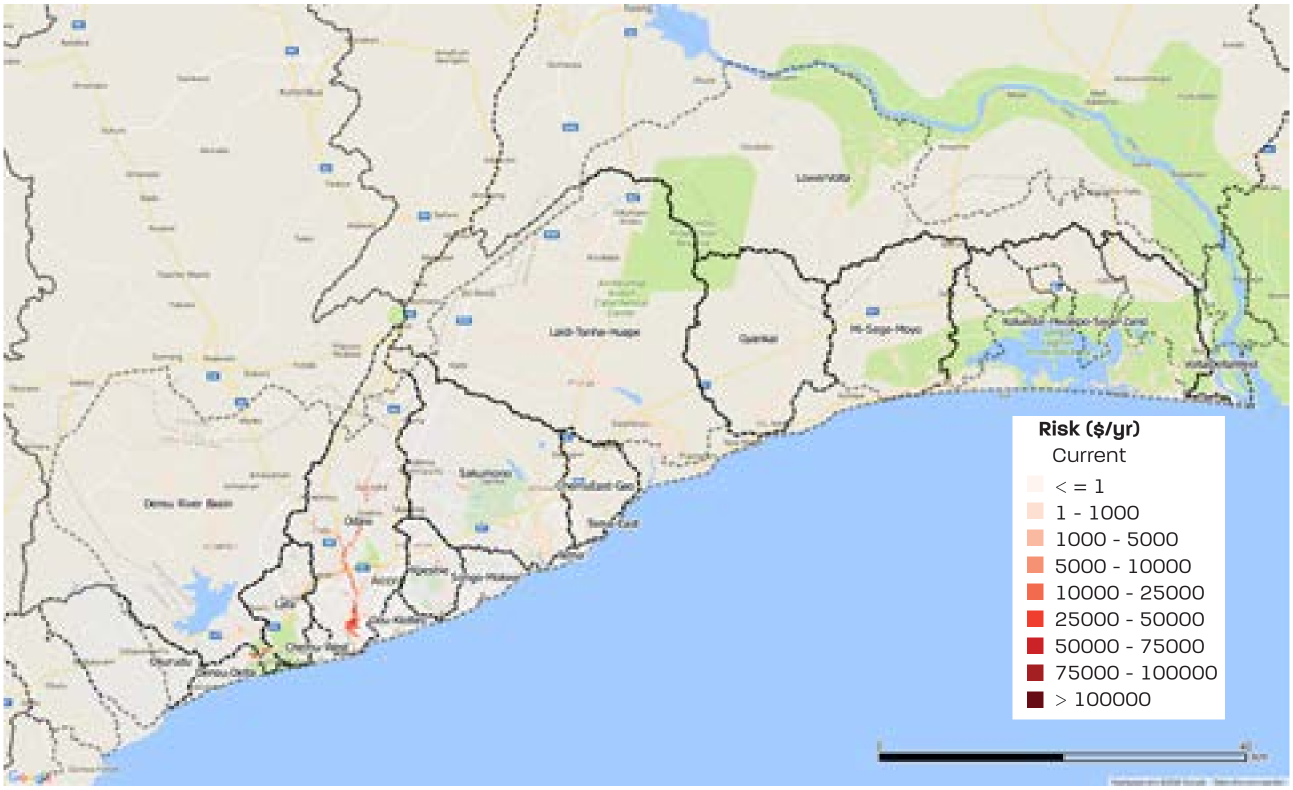
The flood risk analysis identified investment ceilings for flood mitigation measures in Greater Accra, providing an indication of the economic scope of the investments. Map 3.11 shows the expected flood risk across the Greater Accra basins. Considering that flood risk measures aim to reduce flood risk, the absolute maximum benefit of flood risk mitigation measures equals the total flood damage that can be avoided.

Following this rationale, the total flood risk thus represents the absolute maximum investment ceiling to address flood risks. In reality, flood risk mitigation measures can of course be much more cost-effective. This implies that for each ¢1 spent, more than ¢1 of flood damage is avoided. The high B-C ratio of the investment alternatives presented for the Odaw Basin also show this effect. In other words, the maximum investment ceilings presented here are upper-range estimates.

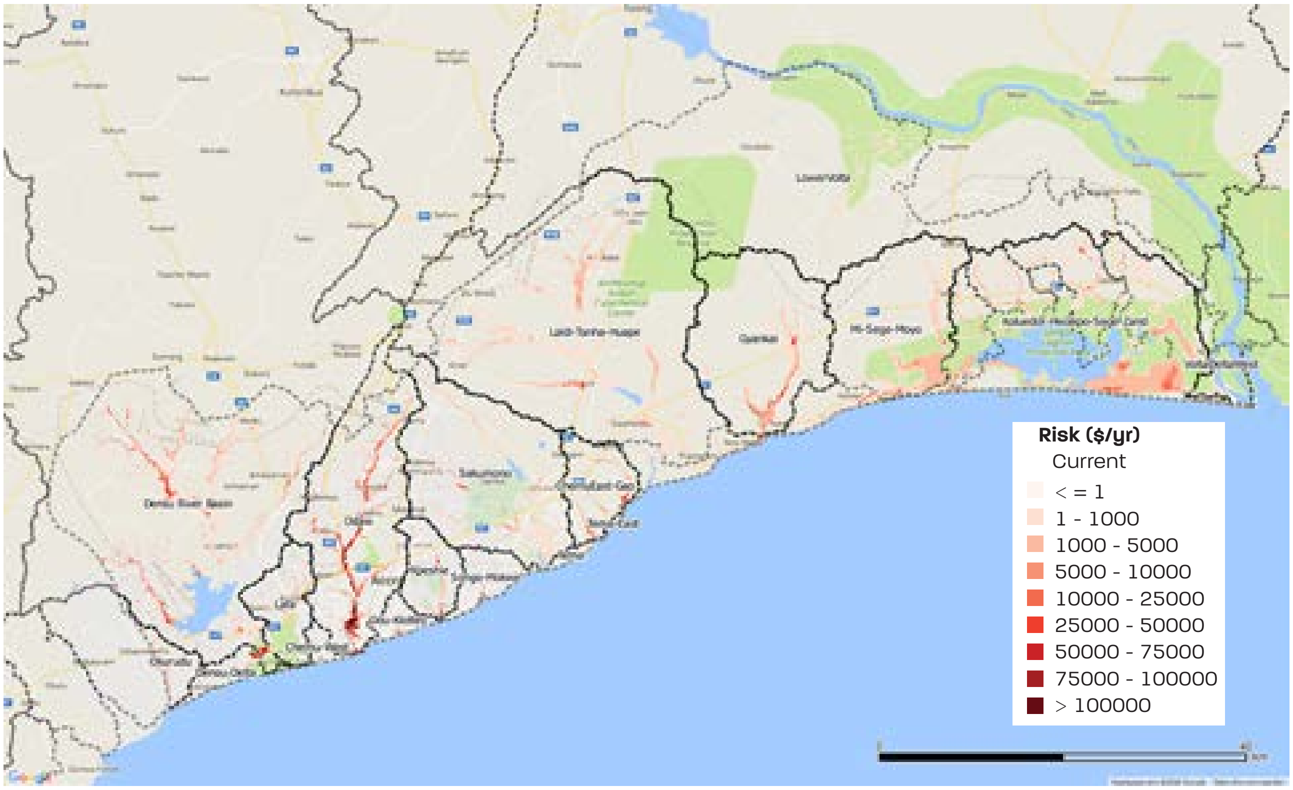
To account for this potentially higher cost-effectiveness of flood mitigation measures, the investment ceiling is assessed under an assumed higher cost-effectiveness. For this purpose, the analysis assumes a cost-effectiveness of

Map 3.11 Overview of Flood Risk (Expected Annual Flood Damage) in the Greater Accra Region, 2015 and 2050

a. Flood damages in 2015, US$

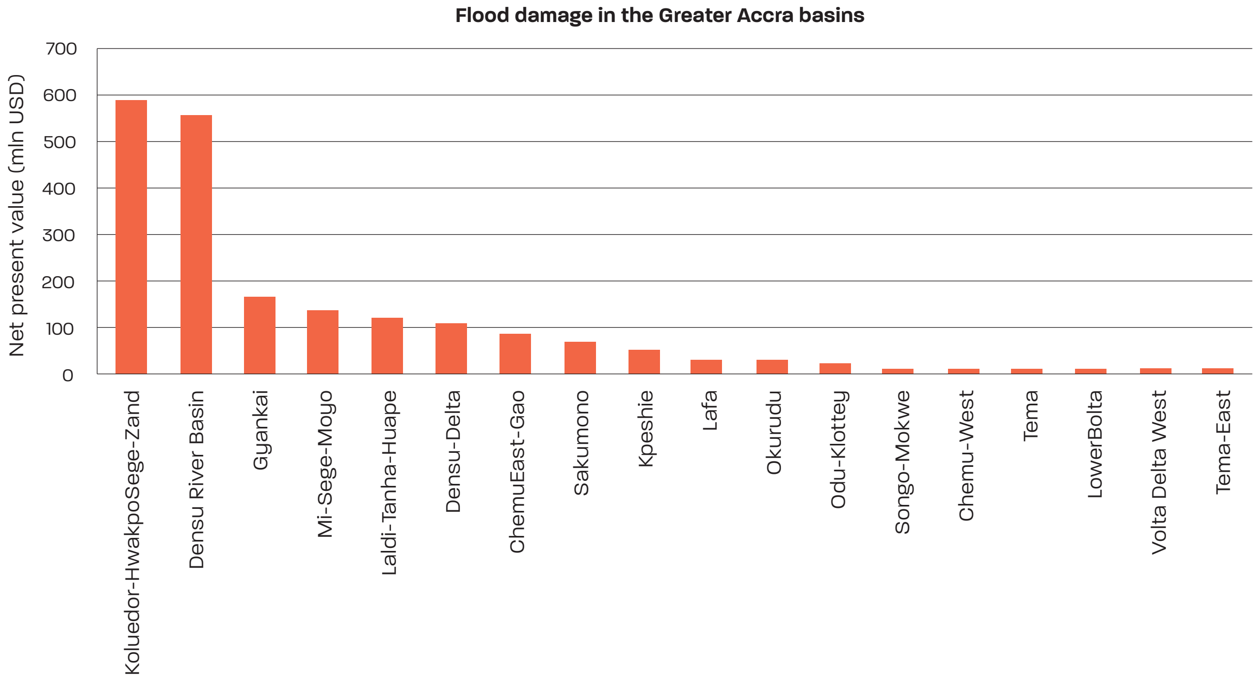


b. Flood damages in 2050, US$



Note: Background based on Google Earth. ©World Bank. Further permission required for reuse.

Figure 3.17 **Total Flood Risk, as Net Present Value, for the Greater Accra Basins, 2020–60**



Note: NPV = net present value. Wetlands are not accurately defined in the land-use database for areas in Greater Accra East. Because the land use is the basis of the urbanization model, this leads to an anomaly for the 2050 projections in Greater Accra East (especially in the Kolueder, Hwapka, Sege, and Zand Basins), resulting in overestimated flood damage.

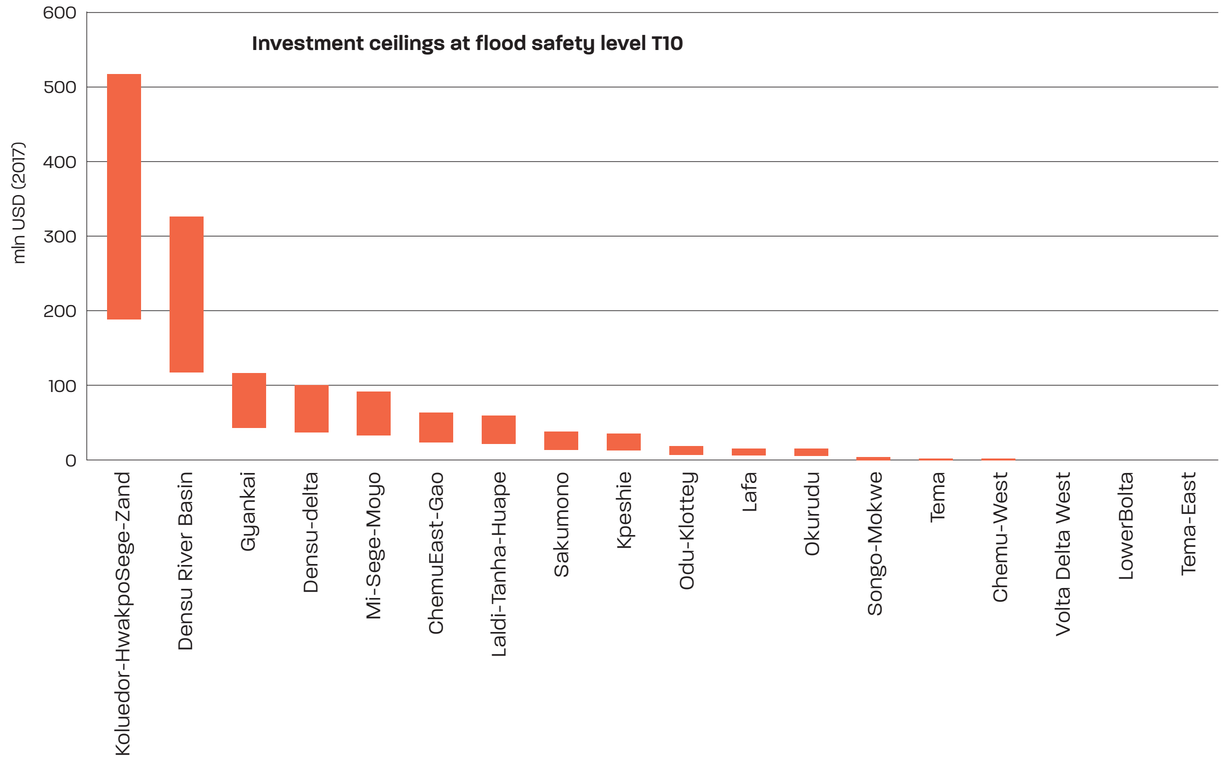
flood mitigation measures identical to that observed in the Odaw Basin. This represents the lower range of the investment ceiling, because it reduces the budget needed to address all flood risks. This approach is operationalized in figure 3.18 for a hypothetical investment package that guarantees a T10 safety level. (This means that all flood events that are expected to occur *more often* than once every 10 years do not cause any damage.) The upper range shows the investment needs based on the estimated avoided damage. The lower range shows the investment needs, assuming the same cost-effectiveness as estimated in the Odaw Basin.

The implementation of flood mitigation packages for floods occurring once per 10 years (T10) does imply that not all risks are reduced. Damage of floods caused by events that occur once every 25 or 50 years are not prevented by such measures. For some basins, most of the flood damage is caused by frequent low-intensity floods, while for other basins, flood damage is mainly caused by intensive but rare floods. Therefore, both upper- and lower-bandwidth investment ceilings are multiplied by the percentage of risk reduction at T10. Figure 3.18 presents the resulting lower and upper estimates for investment ceilings per basin.

Figure 3.18 shows that the range of investment ceilings is still quite high. At the same time, it shows that even in the lower range estimate, the investment ceiling varies between US$30 million and US$180 million in the five most affected basins. The total lower range estimate reaches a figure of roughly US$500 million. This implies that there is sufficient scope to further elaborate the potential of flood mitigation measures, especially in the most vulnerable basins.

The lower bandwidth of the investment ceiling assumes an identical cost-effectiveness of measures as observed in the Odaw Basin. This is, of course, a simplification, considering that the Odaw is a densely populated area around the main Odaw River, which is not the case for most of the other basins in the GAR. Moreover, many areas within GAR have larger shares of natural and agricultural land use than in the Odaw Basin. In addition, the geography of the Odaw Basin is different from many upstream basins. Therefore, both the applicability and cost-effectiveness of different types of flood mitigation measures may differ between the Odaw and the other basins. For a more accurate overview of investment ceilings, detailed assessment of assets and suitable investment packages should be executed in a similar way as has been done for the Odaw Basin.

Figure 3.18 Bandwidth of Investment Ceilings for Flood Safety Level T10, by Greater Accra Basin



Note: Figure shows ranges of a hypothetical investment package that guarantees a T10 safety level—that is, safety from a flood occurring once every 10 years. The upper range shows the investment needs if 1 USD invested avoids 1 USD of flood damage. The lower range shows the investment needs assuming the same cost-effectiveness as estimated in the Odaw Basin.

3.6.3 Cost-Effectiveness of Flood Risk Mitigation Investments for Greater Accra

Through more careful inspection of the flood risk analysis results, indicators on the potential cost-effectiveness of measures across the Greater Accra basins have been developed. This should facilitate a targeted approach when further operationalizing flood risk mitigation strategies across the GAR.

Generally speaking, the cost-effectiveness of flood mitigation investments depends on variations in land use, population densities, required safety levels, and other variables. For some regions, low investments may be sufficient to mitigate floods, while other basins may require expensive interventions. To provide an indication on the potential cost-effectiveness of measures, three indicators have been developed:

- *Total absolute risk:* Direct and indirect damage (US$). Basins with high damage values indicate a potential for cost-effective measures because of scale advantages. Furthermore, even low investments may significantly reduce damage (low-hanging fruit) and thus would likely be cost-effective. In contrast, flood protection investments in basins with low damage values are more likely to be inefficient because the costs of measures may be higher than the flood damage costs.
- *Relative risk:* Damages per affected area (US$ per hectare). Flood protection investments are most likely more cost-effective when the flood damage per hectare is high because of economies of scope advantages. Usually, high flood damage per hectare indicates the presence of high-value assets (such as buildings and agriculture) for that location. When such areas are protected from floods, the prevented flood damage (in monetary value) is high.
- *Percentage of risk reduction at flood safety level T10:* The share of flood damages that occur up to once per 10 years (T10) as part of the total damage. A high percentage value indicates that most of the damage occurs from frequent, less-intense floods. In general, lower investments are required to prevent floods with high intervals compared with rare but intensive floods. Thus, flood mitigation investments for basins with a high percentage of risk reduction at T10 are most likely cost-effective.

The 18 basins are ranked and compared with each other for the three indicators mentioned above (table 3.12). The

Table 3.12 Categorization of Greater Accra Basins for Cost-Effectiveness of Flood Mitigation Measures

Most cost-effectiveness	Average cost-effectiveness	Least cost-effectiveness
1. (In)direct flood damage: US$14 million	1. (In)direct flood damage: US$16 million	1. (In)direct flood damage: US$4 million
2. Flood damage per area: US$3.4 per hectare	2. Flood damage per area: US$2 per hectare	2. Flood damage per area: US$0.9 per hectare
3. Risk reduction of total damage at T10 measures: 90%	3. Risk reduction of total damage at T10 measures: 70%	3. Risk reduction of total damage at T10 measures: 60%
Basins: Osu Klottey, Chemu East Gao, Koluedor Hwakpo Sege Zand, Densu Delta	Basins: Kpeshie, Mi Sege Moyo, Gyankai, Densu River Basin	Basins: Sakumono, Lafa, Okurudu, Laldi Tanka Huape

Note: "T10" refers to 1-in-10-year flood event.

top 6 basins are characterized as "high-effective" and receive a score of 3 points per indicator. The middle 6 basins are characterized as "middle-effective" and receive a score of 2 points. The lower 6 basins are characterized as "low-effective" and receive 1 point. The points are added for the three indicators to define a total score (with a maximum of 9 and a minimum of 3 points).

Based on the above analysis, table 3.12 categorizes the basins for cost-effectiveness of implementing flood mitigation measures. It is found that, for some basins, the relative flood risk and risk reduction indicators were not reliable because the absolute risk was too low. This holds for the Volta Delta West, Tema East, Tema, Songo Mokwe, Chemu West, and Lower Volta Basins. These basins were therefore not included in table 3.12.

Decision makers can use table 3.12 to assess which basins should be prioritized in addressing the flood risks from an economic point of view.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CHAPTER 4

Investment Plan for Flood Risk Mitigation in the Odaw River Basin

Introduction

The flood management strategy described in the previous chapters compares different investment alternatives, or packages, of individual measures that can achieve the design safety levels of T10, T25, and T50—corresponding to protection from 1-in-10-year, 1-in-25-year, and 1-in-50-year floods. The cost-benefit analysis and multicriteria analysis provide an objective comparison of the different investment alternatives according to financial, social, and environmental criteria.

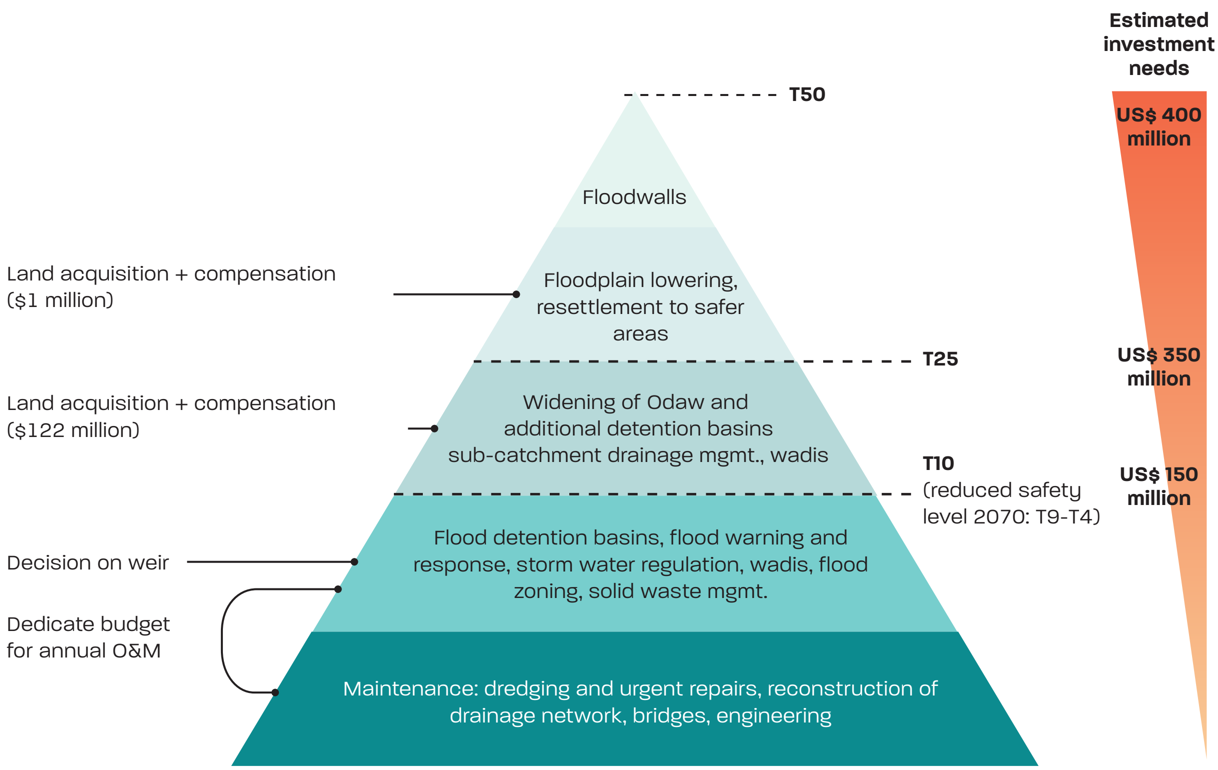
Considering the magnitude and complexity of the flood management issues and interrelation of different measures, it is obvious that a single set of measures may not be readily available (for example, because of constraints on the availability of public land or unclear land titles). Therefore, the steering committee agreed to proceed instead with a phased approach. This approach will ensure a basic safety level (T10) for the most flood-affected areas in the Odaw Basin in the short term while allowing additional time to address, for example, land issues and toincrease safety levels to T25 and T50 for the Odaw Basin and the remaining parts of Greater Accra in phases 2 and 3 (figure 4.1).

For the first phase of financing (box 4.1), the project steering committee agreed to apply the following criteria for the selection of the final investment alternative:

- Avoid the need for land acquisitions, implementing measures only on government-owned land to reduce any (involuntary) resettlement, limit land acquisition costs, and have ample time to address unclear land rights and acquisition of private land following participatory, global good practice for land acquisitions
- Design and implement measures flexibly enough to ensure that they can be extended to increase safety levels in subsequent phases
- Achieve at least a T10 flood safety level in the entire Odaw Basin
- Realize the measures within a maximum budget of US$100 million.

This chapter presents a detailed investment plan adopted by the steering committee to achieve a T10 flood safety level in the Odaw Basin.

Figure 4.1 Phased Approach for Increasing Safety Levels through Flood Mitigation Measures in GAR



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Note: GAR = Greater Accra Region. O&M = operations and maintenance. "T10" refers to a design safety level of protection from a 1-in-10-year flood; "T25" to protection from a 1-in-25-year flood; and "T50" to protection from a 1-in-50-year flood.

4.1 Investment Plan for T10 Safety Level

The investment plan focuses on implementing a safety level that corresponds with a 1-in-10-year flood and that can be constructed within three years while not exceeding the maximum available budget of US$100 million. This T10 investment plan includes the following measures (map 4.1):

- Two retention ponds on land already owned by the government: Atomic East (at the Odaw itself) and Atomic West (at an unnamed tributary of the Odaw)
- Dredging of the Odaw as defined in all investment alternatives but at a lower cost by implementing a performance-based dredging contract
- Construction and regular maintenance of a sand trap
- Reconstruction of critical obstructive bridges over the Odaw Channel between Caprice and Abossey-Okai Bridge
- Repair of broken drainage channel sections at the Odaw main channel and Nima drain
- Increase of Nima drain capacity from Paloma Bridge to the downstream underground section
- Regular cleaning of the interceptor weir
- Reconfiguration of the Odaw outlet to the sea.

The different individual measures are described in detail in this chapter. Within the final investment plan, two alternatives have been compared considering different designs and locations of the detention ponds. A cost-benefit analysis of these two versions is also presented to inform the final choices made within the project.

4.1.1 Priority 1: Maintain—Performance-Based Dredging and Sand Traps

The Odaw Channel and Korle Lagoon, from Caprice to the sea, need to be dredged, both (a) initially to *restore* the design flow capacity (referred to as deferred dredging), and (b) annually to *maintain* the design flow capacity (referred to as maintenance dredging). The channel and part of the lagoon were dredged between 2016 and 2017, but observations show that the sediment layers have already substantially increased, again reducing the flow capacity (map 4.2). National experts estimate a sedimentation rate of around 20–25 centimeters per year. This rate leads to the dredging volumes presented below, by location.

4.1.1.1 Deferred Dredging

The following sections of the Odaw Basin require deferred dredging under the T10 investment plan:

- *From Caprice to Abossey-Okai Road (Bridge)* is more than 3.8 kilometers in length. As noted above, this section was recently dredged (in 2016–17). Assuming the dredging restarts in 2020, the deferred dredging volume will be 70,000–100,000 cubic meters.
- *From Abossey-Okai Road (Bridge) to the interceptor weir* exceeds 1.5 kilometers. The main channel of this section was dredged over a width of 20 meters in 2016–17, but the original channel alignment between the riverbanks is 60 meters wide. It is recommended to dredge at least 2 meters deep throughout the entire width to the original banks. This means additional dredging over a width of 40 meters and a length of 1.5 kilometers, resulting in a dredged volume of 120,000 cubic meters. Sediment accumulated in the main channel since the previous dredging campaign is estimated at a volume of 30,000 cubic meters. Thus, the total deferred dredging volume for this section adds up to 150,000 cubic meters.

The Korle Lagoon area, from the interceptor weir to the sea, has channels to be cleared exceeding 60 meters wide and 1.5 kilometers long. The sediment currently built up in this section is not exactly clear. The best estimate is an average dredging depth of 1 meter, resulting in 90,000 cubic meters of dredged volume.

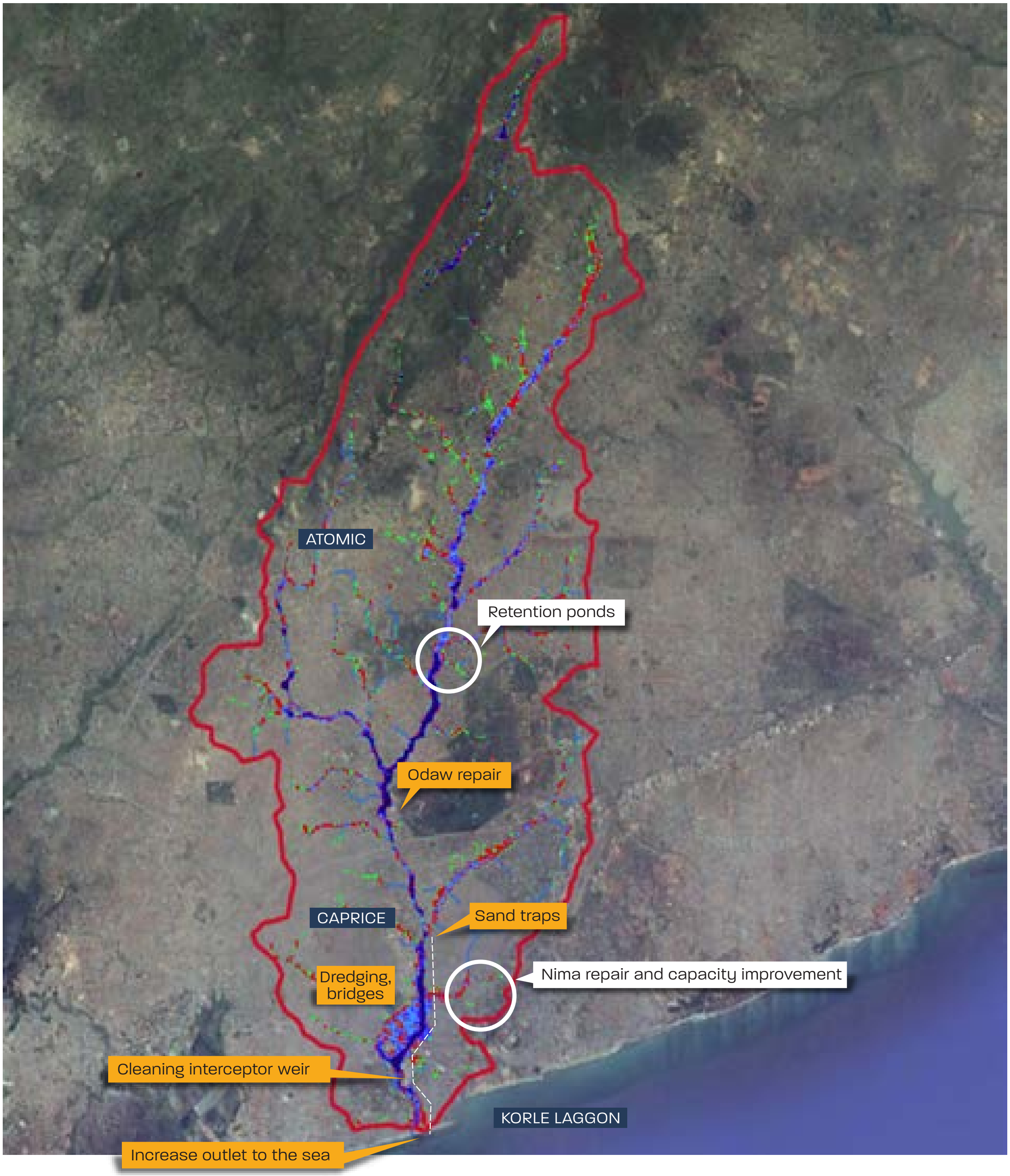
South Kaneshie drain has not been dredged in the past. Deferred dredging is estimated at 900 meters in length, 20 meters in width, and 2 meters in depth, which totals 36,000 cubic meters in dredged volume.

Agbogbloshie drain is 825 meters in length, 20 meters in width, and 2 meters in depth, which totals 33,000 cubic meters in dredged volume.

4.1.1.2 Maintenance Dredging

Downstream Caprice, the channel slope reduces significantly, and flow velocities drop, resulting in sedimentation. It is therefore recommended to construct a sand trap directly downstream of Caprice Bridge, where one existed in the past. National experts estimate that this sand trap will reduce the sedimentation of the Odaw downstream by 50 percent, leading to a residual sedimentation rate of 10–12.5 centimeters per year. The estimated dredging surface is 350,000 square meters, resulting in 35,000–43,750 cubic meters dredged material annually.

Map 4.1 Locations of Proposed Flood Risk Mitigation Measures in the T10 Investment Plan



Note: Background based on Google Earth. Red border designates Odaw catchment. ©World Bank. Further permission required for reuse.

Map 4.2 Sections of Odaw Basin that Need Dredging

Note: Background based on Google Earth. ©World Bank. Further permission required for reuse.

4.1.2 Priority 2 and 3: Retain and Store – Route Floodwater into Retention Ponds

Of all the potential retention pond locations considered in the chapter 3, only two are located on government-owned land and require no land acquisition and little or no resettlement. These areas are in the Atomic area and called "Atomic East" and "Atomic West." Atomic East is storing water from the Odaw itself; Atomic West is in the catchment of an unnamed tributary of the Odaw.

Retention ponds can be implemented as either

- *In-line retention:* retention regulated by a dam in the river, creating a lake with a variable size, dependent on the inflow; or
- *Off-line retention:* retention in an area connected with the river by a weir, inundating only when floods occur.

Atomic West can only be implemented as in-line retention pond. Atomic East can be implemented as either an in-line or off-line retention pond.

4.1.2.1 In-Line Retention Options

Map 4.3, panel a, shows the in-line retention options for both Atomic West and Atomic East. The dam storing the water is shown in brown. The Atomic West retention pond stores the entire volume of a 1-in-10-year flood wave in the tributary. Atomic East captures part of the 1-in-10-year flood volume originating from the upstream part of the Odaw Basin. Because the volume of Atomic East retention pond is the highest, the flood-level reduction downstream is higher than that of Atomic West.

The dam in Atomic East leads to inundation of some nearby houses (map 4.3, panel b). These houses are on government-owned land, as stated by national specialists. The people living there should be resettled, or a protective levee constructed, to prevent these dwellings from flooding.

The budget necessary for resettlement is considered in the cost assessment (presented in appendix A). In the case of in-line retention, an outlet at the bottom of the dam is necessary to release the water after the flood has receded. Another necessary item is a spillway to release excess water and prevent the dam from overtopping.

4.1.2.2 Off-Line Retention Option

Map 4.4 shows the off-line retention option for Atomic East. The brown line shows the levees around the pond. The west side of the retention pond is impounded by higher grounds. Because the surface area is smaller than in the in-line retention design, excavation is needed to create the necessary storage volume. The white arrow and dotted line indicate the inflow direction and weir location of the retention pond, respectively (map 4.4, panel b).

The challenge is to maximize the inflow into the retention pond during extreme flow conditions. This can be done not only by maximizing the weir width but also by raising local water levels to increase the head difference over the weir. The latter is effectuated by placing levees downstream of the inlet, creating a backwater effect during extreme flows, resulting in increased flow into the retention pond (the levees indicated by yellow lines in map 4.4, panel b). Simulations have shown that the levees downstream of the inlet do not increase the flood hazard outside the retention ponds for a 1-in-10-year and a 1-in-100-year flood. Finally, an outflow structure is needed to release the water once the flood wave is passed (indicated by the white outgoing arrow).

The retention options (described in table 4.1) reduce the peak discharge of a 1-in-10-year flood wave of the Odaw directly downstream of the Atomic area by approximately 80 cubic meters per second (figure 4.2).

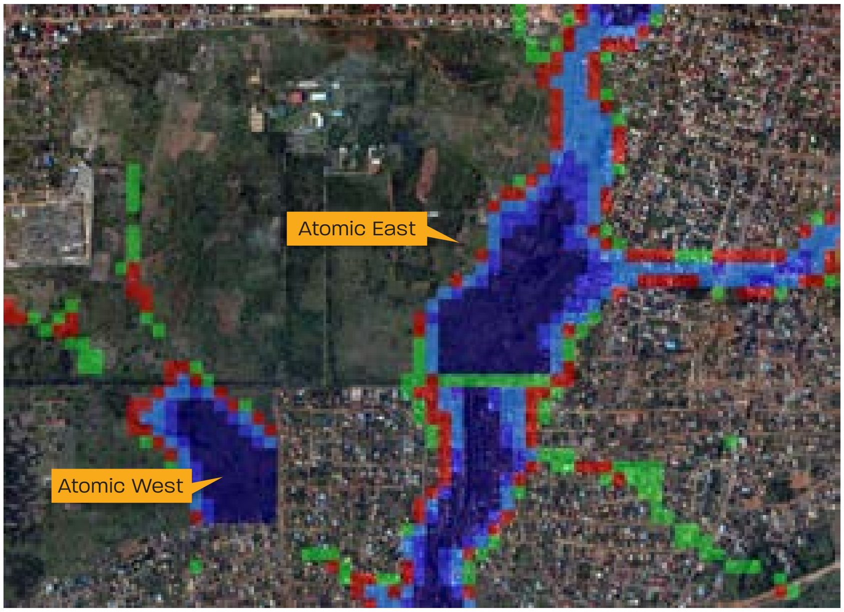
Table 4.1 Characteristics of Retention Pond Options in the Atomic Area, Odaw Basin

Retention pond location and typea	Area (ha)	Volume (m^3, millions)	Stored T10 (m^3, millions)	Excavation (m^3, thousands)	Dam volume (m^3) and height (m)
West Atomic, in-line	50	0.8	0.6	20	20,000 / 5.5
East Atomic, in-line	75	1.0	1.0	10	10,000 / 4.5
East Atomic, off-line	15	0.4–0.5	0.5	400–500	25,000 / 4.0

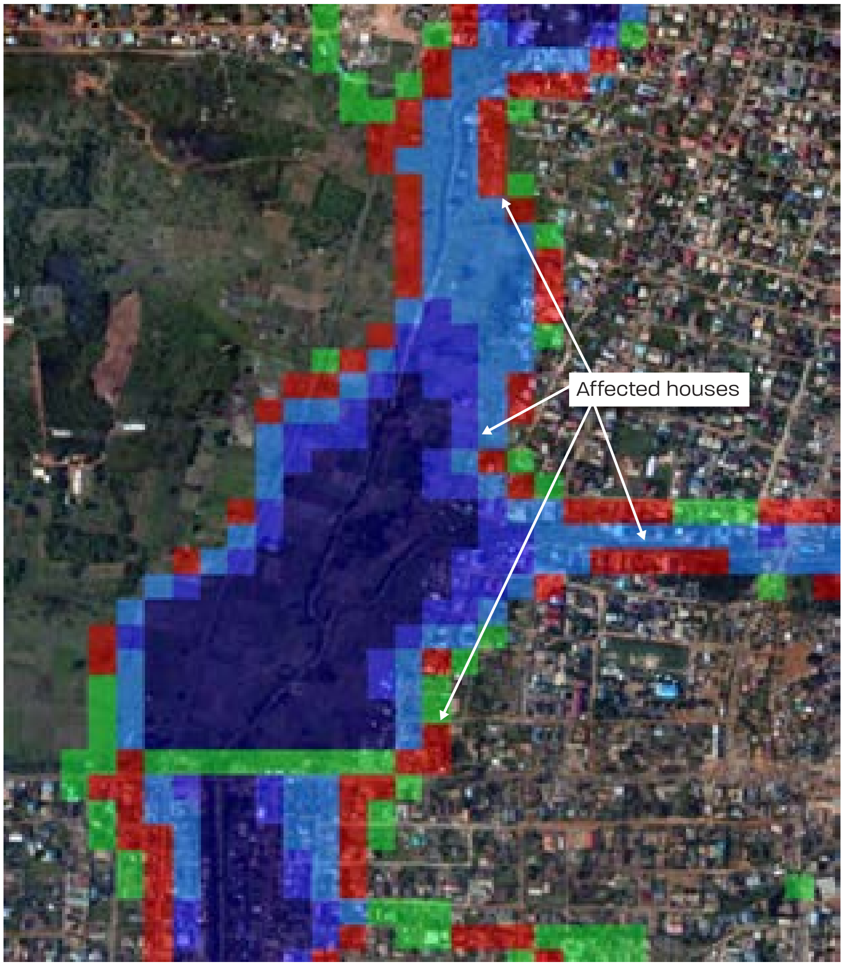
Note: ha = hectares. m = meters. m^3 = cubic meters. T10 = water storage from a 1-in-10-year flood.
a. An in-line retention pond retains water using a dam in the river, creating a lake with a variable size, dependent on the inflow. An off-line retention pond retains water in an area connected with the river by a weir, inundating only when floods occur.

Map 4.3 In-Line Retention Pond Options in the Atomic Area, Odaw Basin

a. In-line retention ponds, Atomic West and Atomic East



b. In-line retention detail, Atomic East



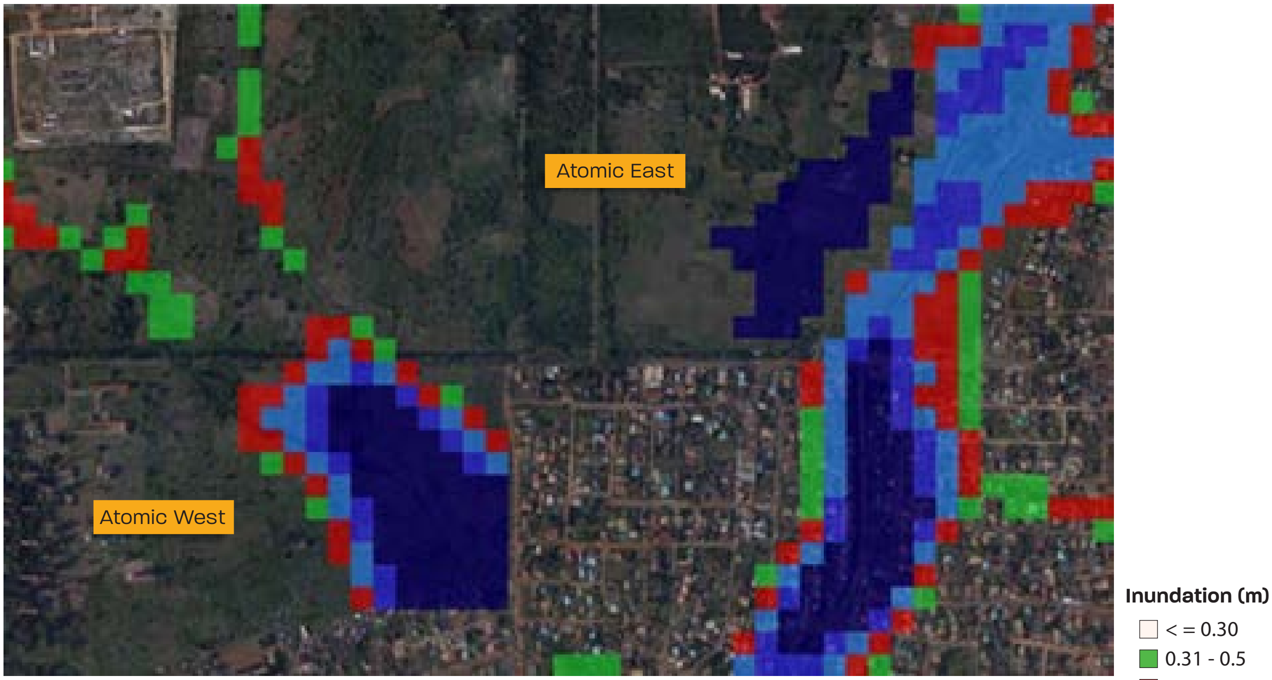
Inundation (m)

- < = 0.30
- 0.31 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2

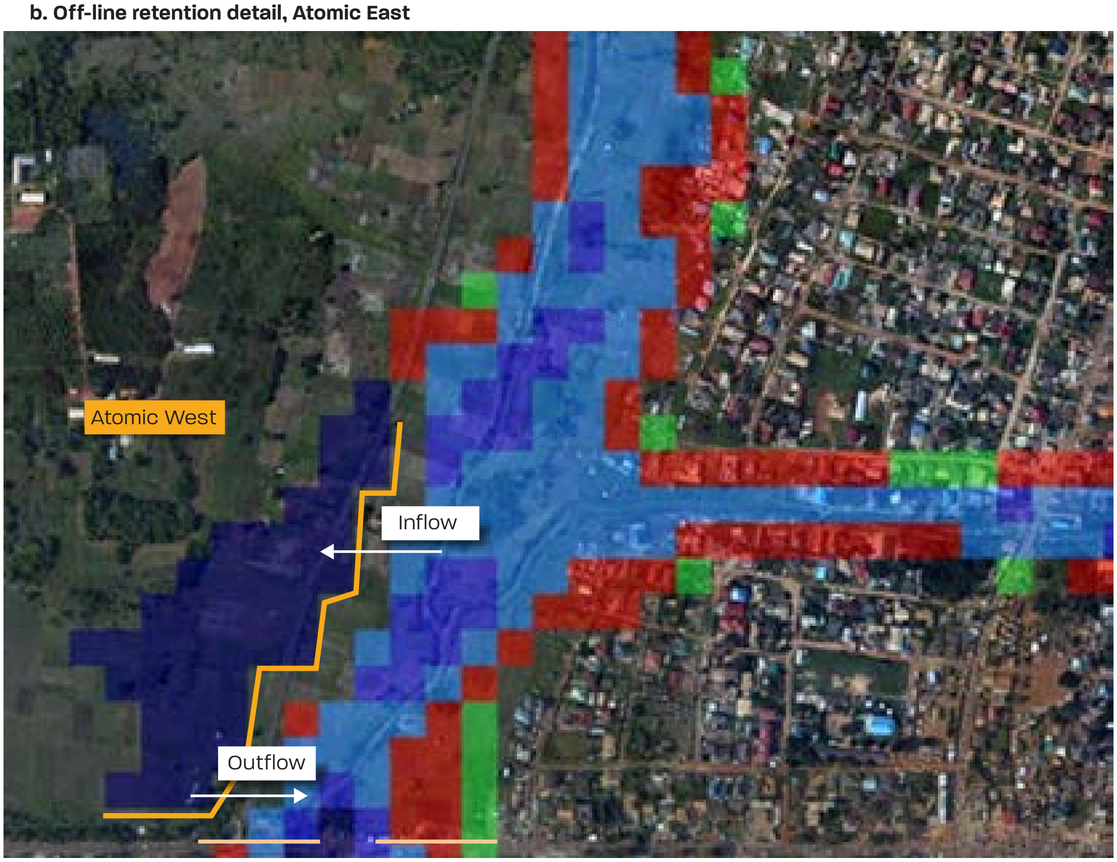
Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
Brown lines indicate the dams storing water for in-line retention. "Affected houses" are those that may be affected by the in-line retention option.

Map 4.4 Off-Line Option for Atomic East Retention Pond, Odaw Basin

a. Atomic East location relative to Atomic Westv

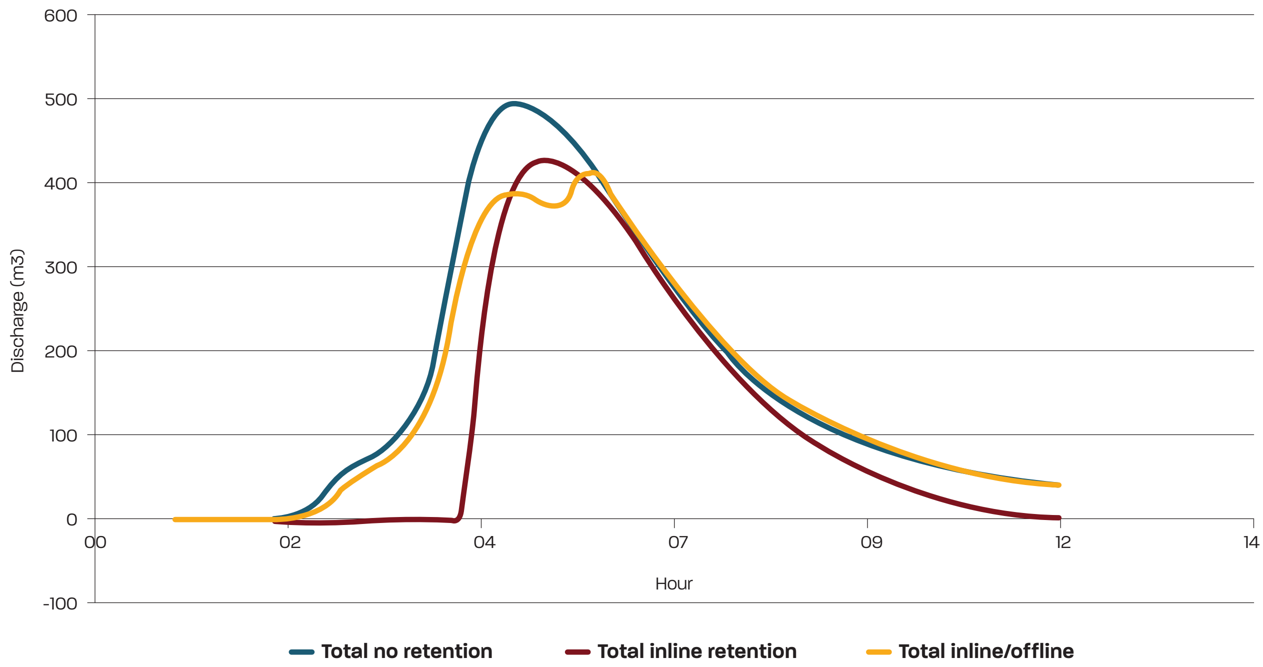


b. Off-line retention detail, Atomic East



Notes: Background based on Google Earth. Brown lines indicate the dams storing water for in-line retention. ©World Bank. Further permission required for reuse.
a. Brown lines at Atomic West indicate the dams storing water for in-line retention. Brown lines at Atomic East designate levees around the retention pond.
b. Brown lines designate levees around the retention pond. The upper white arrow and dotted line indicate the inflow direction and weir location of the retention pond, respectively. The lower white arrow indicates the location of the outflow structure needed to release the water. Horizontal yellow lines indicate the levees downstream of the inlet, which, during extreme flows, increase the flow into the retention pond.

Figure 4.2 **Reduction of 1-in-10-Year Flood Discharge in Atomic Area of the Odaw Basin, by Retention Pond Option**



4.1.3 Priority 4: Drain—Repair Broken Drains and Widen Outlet to the Sea

4.1.3.1 Reconstruction of Critical Bridges

Some bridges over the Odaw cause a significant backwater effect during floods. The potential backwater effect was assessed in a field survey, covering all bridges from Caprice to the Abossey-Okai Bridge (map 4.5).

The field survey concluded as follows:

- The bridges over Korle Lagoon (the interceptor weir and Guggisburg Avenue Bridge) need to be dredged and cleaned (solid waste removal).
- The bridge at the outlet to the sea also needs to be dredged and realigned as a separate measure.
- Three bridges need to be raised: Railroad Bridge, Graphic Road Bridge, and Abossey-Okai Bridge.
- Removal of two small bridges at Kwame Nkrumah Circle is proposed.
- The other bridges in the area have limited or no negative impact on flood levels when properly dredged and need no further action.

4.1.3.2 Rehabilitation of Broken Drain Sections of the Odaw

The embankments of the Odaw Channel at the Abofu-Achimota and Nima drains need to be repaired (photo 4.1). The collapsed concrete lining needs to be removed and rebuilt.

4.1.3.3 Increase of Nima Drain Capacity

The Kwame Nkrumah Circle area floods from inundations of the Nima drain where the drain goes underground. This underground section is too small, obstructing water flow when the Odaw level is high and causing a backwater effect. Water overflows in the direction of Kwame Nkrumah Circle (photo 4.2, panel a) and in another section goes underground (photo 4.2, panel b).

It is recommended to increase the Nima drain's channel capacity between Paloma Bridge and the Nima underground section by changing the trapezoid cross-section into a rectangular section over a length of almost 900 meters. While reconstructing the Nima drain, current damages to the concrete lining can be repaired. The measure also includes construction of a floodwall 1 meter high along the channel banks.

4.1.3.4 Reconfiguration of Outlet to the Sea

The Odaw River's outlet to the sea is relatively small because of siltation under the bridge ("1" in photo 4.3) and the rock foundations of the old bridge ("2" in photo 4.3).

The outlet will be reconfigured by

- Dredging the channel under the bridge;
- Removing the old bridge foundation;
- Realigning the coastline eastward (red line); and
- Realigning the groin (red dotted line).

Map 4.5 Overview of Odaw River Bridges between Caprice and Outlet to the Sea

Notes: Background based on Google Earth, ©World Bank. Further permission required for reuse.
The red line designates Odaw catchment Brown lines indicate the dams storing water for in-line retention.

Photo 4.1 Broken Drain Sections of Odaw Channel in Need of Repair

a. Abofu-Achimota drain

Source: Google Earth images

b. Nima drain

Source: HKV Consultants

Photo 4.2 Critical Sections of Nima Drain for Capacity Increase

a. Section of overflow toward Kwame Nkrumah Circle[a]

b. Underground section[b]

Source: HKV Consultants ©World Bank. Further permission required for reuse.
Notes: a. Arrow indicates direction of water overflow toward Kwame Nkrumah Circle.
b. Arrow indicates where the Nima drain goes underground.

Photo 4.3 Aerial View of Planned Reconfiguration of Odaw Outlet to the Sea

Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
"1" indicates the area of siltation under the bridge. "2" indicates rock foundations of the old bridge. The red solid line indicates the proposed coastline realignment. The red dashed line indicates proposed groin realignment.

4.2 Evaluation of Investment Plan for T10 Safety Level

The flood hazard for a 1-in-10-year (T10) flood in the current situation is shown in map 4.6, panel a. When measures as defined in the T10 investment plan are implemented, excluding the retention ponds, a safety level of T5 can be achieved (map 4.6, panel b). A safety level of T10 is achieved when the retention ponds are included (map 4.6, panels c and d). The remaining flood hazard is presented for both (a) the in-line retention ponds option in the Atomic area (map 4.6, panel e); and (b) the in-line (Atomic West) and off-line (Atomic East) option (map 4.6, panel f), which show similar flood hazard results. Map 4.6 shows that after implementation of the full T10 investment plan, the flood hazard for a 1-in-10-year flood is restricted to the riverbed itself and large-scale inundations downstream of Caprice have diminished.

4.2.1 Cost-Benefit Analysis

The costs and benefits are derived for two options for the T10 investment plan for the Odaw Basin:

- *T10 investment plan, Option A:* Atomic East and West are both designed as in-line retention ponds.
- *T10 investment plan, Option B:* Atomic East is designed as an off-line retention pond, while Atomic West is an in-line retention pond.

The costs and benefits of each option (table 4.2) are calculated in full accordance with the methodology described in the previous chapters. For the breakdown of the costs of the T10 investment plan, see appendix A (excluding 26 percent contingencies and indirect costs).

The benefit-cost ratio of the T10 investment plan is high—two to three times higher than the investment alternatives for the Odaw presented in chapter 5. The main reasons are that the dredging costs are lower (owing to the "performance-based" contracting method) and costly land acquisitions are avoided. Also the net present value is highly positive, clearly showing a sound business case from a welfare point of view.

Looking into the details of the T10 investment plan, Option A has a slightly higher benefit-cost ratio than Option B. This is because the in-line retention pond at Atomic East has a higher mitigating effect on extreme floods than the off-line retention pond. However, the in-line retention pond should be further assessed in terms of resettlement and additional safety level measures, especially related to the Ghanaian dam safety regulations. It is strongly recommended to assess in a feasibility study, together with the Water Resources Commission, which dam classification within the dam safety regulations is applicable for the in-line and off-line retention options. This assessment will lead to a set of requirements, including a safety level based on the spillway or other safety measures.

Table 4.2 Cost-Benefit Analysis of the T10 Investment Plan for Flood Mitigation in the Odaw Basin

Costs, benefits, risk reduction, and NPV all in US$, millions

Item	T10 Investment Plan	
	Option A (in-line retention)a	Option B (off-line retention)b
Total costs (US$, millions)	53	59
Investment costs (US$, millions)	45	49
O&M costs (US$, millions)	8	10
Total benefits (US$, millions)	396	417
Risk reduction (US$, millions)	396	417
Net present value (US$, millions)	343	358
Benefit-cost ratio	7.51	7.06

Note: O&M = operations and maintenance. NPV = net present value. T10 indicates protection for a 1-in-10-year flood.
a. In Option A, Atomic East and West are both designed as in-line retention ponds (retaining water using a dam in the river, creating a lake with a variable size, dependent on the inflow).
b. In Option B, Atomic West is an in-line retention pond, while Atomic East is designed as an off-line retention pond (retaining water in an area connected with the river by a weir, inundating only when floods occur).

Table 4.3 Beneficiaries of the T10 Investment Plan in the Odaw Basin, 2015 and 2050

Number of affected people, annual average

Time horizon	Do nothing	T10 investment plan	Beneficiaries
2015	100,000	70,000	30,000
2050	150,000	100,000	50,000

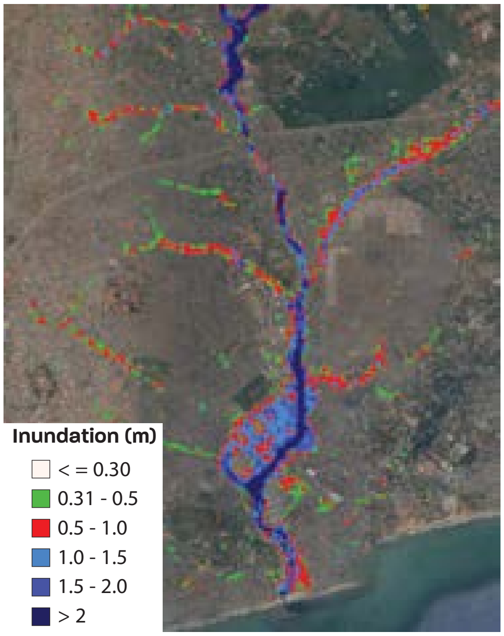
Note: The T10 investment plan provides for flood risk mitigation measures to protect against a 1-in-10-year flood in the Odaw Basin.

4.2.2 Estimation of Beneficiaries

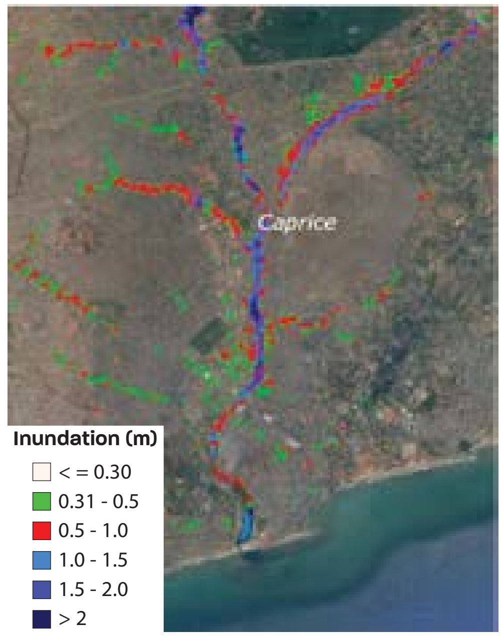
Besides expressing the benefit-cost analysis in monetary terms, the impact of the flood risk measures are evaluated in terms of affected people. The number of beneficiaries—people no longer affected by flooding—is estimated by comparing the average numbers of annually affected

Map 4.6 Flood Hazard in the Odaw Basin after Implementation of T10 Investment Plan, by Water Retention Option

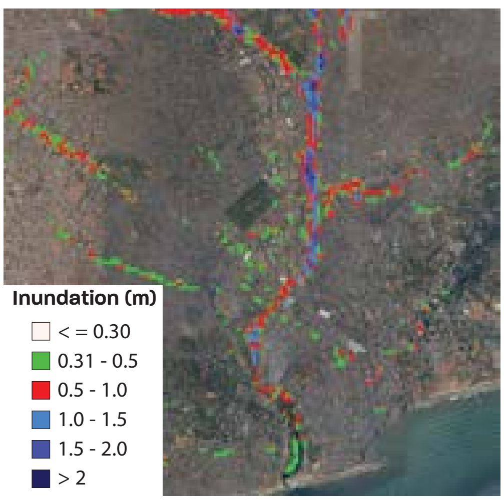
a. T10 current situation: no measures



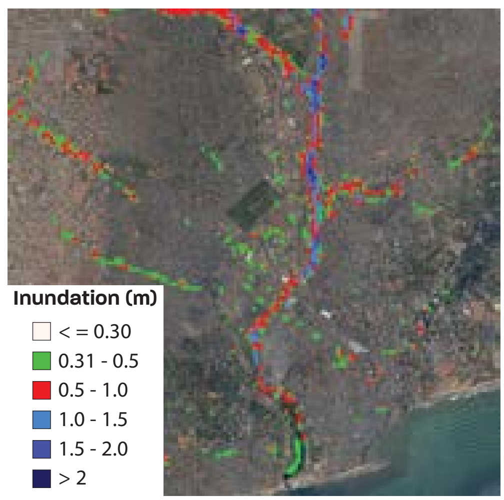
b. T10 investment plan: no retention



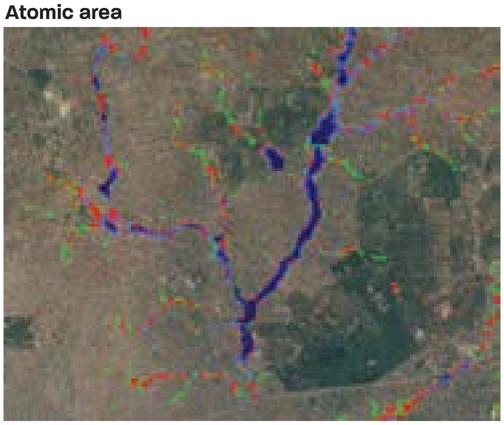
c. T10 investment plan: in-line retention



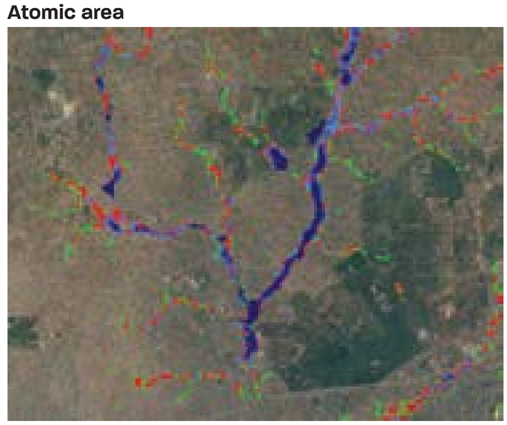
d. T10 investment plan: off-line retention



e. T10 investment plan: in-line retention, Atomic area



f. T10 investment plan: off-line retention, Atomic area



Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
T10 indicates protection for a 1-in-10-year flood. An in-line retention pond retains water using a dam in the river, creating a lake with a variable size, dependent on the inflow. An off-line retention pond retains water in an area connected with the river by a weir, inundating only when floods occur. .

people in the Odaw Basin in the current situation (that is, doing nothing) and after implementation of the T10 investment plan.

Beyond this definition of beneficiaries, there is a vulnerable floating population of approximately 1 million who pass through the flood-prone Kwame Nkrumah Circle every day. The transport terminals provide daily services to all regions of Ghana, which accounts for the large transient population. Experts suggest that a minimum of 10 percent of the transient population will be affected by flood intervention measures. Hence, 100,000 transient beneficiaries could be included in the number of people benefiting from the T10 investment plan in the current situation. The number of transient beneficiaries in 2050 is more difficult to predict given the spatial limitations on the number of people who could possibly pass through this area.

4.3 Estimation of Climate Change Adaptation Needs for T10 Safety Level Investment Plan

With projected climate change and continued rapid urbanization—Accra's population being expected to reach 11 million in 2050—it will be important to assess the impacts of these factors on the safety levels and, if necessary, propose additional measures to ensure that the same levels of safety can be guaranteed by 2070. The potential impacts of climate change will require adaptation of infrastructure designs—notably, of drainage and flood management infrastructure—as well as additional measures (for example, additional widening of bridges and additional or larger retention ponds).

When those measures are implemented in a timely manner (at the time of construction or when enough public space is available for placing additional measures), costs can be kept reasonable and impacts on the affected population can be limited, in contrast to costly retrofitting of infrastructure in a few years or decades. The timing and appropriate planning of climate change adaption measures will thus be of particular importance, which has led the government of Ghana to request (a) identification of additional measures to ensure that the same safety levels can be guaranteed by 2070, and (b) a determination of the costs of those additional climate change adaptation measures.

The term "climate additionality" originates from the discussion on the additionality of climate finance to "traditional" development finance (Brown et. al. 2010). In the context of this project and report, the term "additionality" refers to the additional measures and costs to cover the potential impacts of climate change. The "traditional" IDA and government financing of the Greater Accra Resilient and Integrated Development Project (GARID) refers to the financing of urban drainage, solid waste management, and community development infrastructure—thus barriers and issues—that would occur with or without the effects of climate change and are inherent urban development challenges. Nevertheless, a clear distinction between urbanization challenges and climate change challenges, even with the support of the best models, is not always possible.

In addition, climate change adaptation, combined with the challenges of rapid urbanization, now provide momentum for a paradigm shift toward climate-resilient, water-inclusive urban development of Greater Accra. Because the city is rapidly developing, areas for additional flood mitigation measures need to be identified while ensuring that the urbanization is implemented in a climate-resilient and water-inclusive manner following appropriate policies and planning guidelines. Below, this chapter first estimates the potential impact of climate change and urbanization on the safety levels for the selected T10 investment alternative for IDA financing. It then determines suitable measures to adapt under different climate and urbanization scenarios.

4.3.1 Identification and Costs of Additional Climate Change Adaptation Measures

The identification of potentially required additional measures for climate change adaptation departs from the investment alternative presented in chapter 3, which will be implemented in the first phase. However, the same constraints apply to the implementation of these additional measures, as follows:

- *Avoid need for land acquisition land acquisitions*, implementing measures only on government-owned land to reduce any (involuntary) resettlement, limit land acquisition costs, and have ample time to address unclear land rights and acquisition of private land following participatory, global good practice for land acquisitions
- *Design and implement measures flexibly enough* to ensure that they can be extended to increase safety levels in consequent phases
- *Maintain at least a T10 flood safety level* in the entire Odaw Basin under projected climate change scenarios for 2070

- *Promote a paradigm shift* toward climate-resilient, water-inclusive urban development of Greater Accra
- *Ensure that the measures are cost-effective, environmentally sustainable, and socially acceptable*.

The identification of additional measures follows the following steps and sequence:

- *Determine the set of future climate and urbanization scenarios*, including the combined effects of climate change and other autonomous developments (such as economic growth and urbanization)
- *Determine the hydraulic objective*, that is, the difference in water level between (a) the current investment alternative (T10) in the current situation, and (b) the future situation, including climate change and other autonomous development
- *Determine a set of measures to solve the hydraulic objectives* or, in other words, to mitigate the (future additional) flood risk for maintaining the current desired safety level (for a 1-in-10-year flood) in 2070
- *Determine a climate change adaptation investment alternative* for different climate change and urbanization scenarios
- *Identify the most suitable measures* that can be implemented in the context of climate finance.

Solving the three hydraulic objectives leads to a long list of scenarios (current and future climate scenarios with and without autonomous developments) for which investment alternatives (combination of measures) were identified. Whether these investment alternatives would lead to inundation between Caprice and the sea was assessed per scenario. The damage, number of affected people, and costs were also listed per scenario. The resulting matrix can be used to

- *Show climate additionality costs* for different climate scenarios;
- *Show the difference between flood effects* induced by climate change and those from autonomous developments; and
- *Support decision making* regarding flood management measures in the Odaw Basin.

4.3.2 Estimation of Climate Change Effects on the T10 Investment Plan

The estimation of the potential effects of climate change and urbanization commences with the analysis of relevant climate change scenarios. Because no single climate change scenario represents the potential future climate for West Africa or for the Greater Accra Region in particular, the analysis has applied a combination of different climate change scenarios (as summarized in chapter 1): a median scenario, a scenario representing the 10th percentile (P10), and a scenario representing the 90th percentile (P90). Table 4.4 summarizes the estimated percentage increase in precipitation by 2070 for those three scenarios. The calculations apply the annual sum of daily precipitation from T10 rainfall events. A sea level rise of +0.326 meters is the sea level boundary condition in the flood model for 2070.

Table 4.4 Estimated Precipitation Increase by 2070, by Climate Change Scenario, in the Greater Accra Region

Scenario	Precipitation increase by 2070 (%)
Median[a]	3
10th percentile[b]	−7
90th percentile[c]	19

Source: World Bank 2018b.
Note: Precipitation data were calculated as the sum of daily rainfall (in millimeters) from T10 (1-in-10-year) rainfall events in the Greater Accra Region. The 2070 flood model assumes a sea level rise boundary of +0.326 meters.
a. The "median" scenario represents the median results of all combinations of climate change scenarios and models for daily rainfall with a return period of 10 years.
b. The "10th percentile" scenario represents lowest 10 percent of results from the combined climate change scenarios and models.
c. The "90th percentile" scenario represents the highest 10 percent of results from the combined climate change scenarios and models.

The investment alternative (T10) leads to a safety level of protection from a 1-in-10-year flood in the current situation. The effective rainfall is 80.2 millimeters in 24 hours for this scenario. The safety level using a T10 rainfall scenario under the different climate scenarios (median, P10, and P90) is derived based on the respective effective rainfall numbers (table 4.5). For example, when the P90 climate change scenario and autonomous developments (urbanization) until 2070 are included, the Odaw Basin has a safety level (return period) of approximately four years (indicated in red).

The effect of autonomous developments and urbanization is derived based on the following: The urban fabric in the Odaw Basin for 2070 (percentage of area that is urban) is 100 percent using an urbanization increase of 3 percent per year (starting from 66 percent in 2015). The population increase is also 3 percent per year.

Table 4.5 Projected Effective Rainfall by 2070, by Return Period and Climate Change and Urbanization Scenario, in the Greater Accra Region

Millimeters in 24 hours

Return Period (years)	2015 Scenario (mm)	P10 with Urbanisation	P10 no Urbanisation	Medium with Urbanisation	Medium No Urbanisation	P90 with Urbanisation	P90 no Urbanisation
1	30.3	34.7	27.2	39.3	31.7	46.7	38.9
2	41.4	45.2	37.4	51.0	43.1	60.3	52.3
5	60.8	63.4	55.3	71.3	63.2	84.2	75.9
10	80.2	81.5	73.2	91.7	83.2	108.1	99.3
15	93.5	94.1	85.5	105.7	96.9	124.4	115.2
20	103.3	103.4	94.7	116.1	107.1	136.4	127.0
25	111.8	111.5	102.5	125.0	115.8	146.7	137.1
50	140.9	139.0	129.5	155.5	145.8	182.1	172.1

Note: "Median" represents the median results of all combinations of climate change scenarios and models for daily rainfall with a return period of 10 years. P10 = 10th percentile climate change scenario (lowest 10 percent of results). P90 = 90th percentile climate change scenario (highest 10 percent of results). Blue-shaded cells indicate the rainfall amounts similar to the current T10 and with climate outlook also more or less similar. The red cells show that the amount similar to the 1-in-10-years event under a P90 with urbanization scenario will have a return period shorter than 1 in 5 years. Red-shaded cells indicate the combined effect of both the P90 climate change scenario and urbanization in 2- to 5-year rainfall events.
a. The "return period" indicates the magnitude of a rainfall event in terms of the estimated frequency of, or average time between, such an event. For example, the effective rainfall for a T10 (1-in-10-year) rainfall scenario is 80.2 millimeters (mm) in 24 hours.

Using the same approach for each scenario, the safety levels (indicated as return periods) are estimated (table 4.6). For all scenarios, the estimated safety levels of the selected T10 investment plan are lower in 2070 than in 2015 except under the P10 climate scenario without urbanization.

To compensate for future adverse effects, the "hydraulic objective" was analyzed. This is the difference in water level between the T10 investment plan and future scenarios. This difference needs to be compensated for with additional measures. First, this hydraulic objective—termed "T10 2070"—was determined and assessed for the Odaw section between Caprice and the sea (figure 4.3). The P10 scenario without urbanization shows an increase in safety level. Flood mitigation measures are not needed in this case. The other scenarios all show an increase in water levels such that additional flood mitigation measures are needed (figure 4.3 and figure 4.4).

Table 4.6 Estimated Impacts of Climate Change and Urbanization Scenarios on Safety Levels of Flood Mitigation Measures in Greater Accra

Scenarioa	Safety level (return period, years)b
T10 Investment Plan (T10IP) 2015	10
(a) T10IP 2070 P10 with urbanization	9
(b) T10IP 2070 P10, no urbanization	13
(c) T10IP 2070 median with urbanization	7
(d) T10IP 2070 median, no urbanization	9
(e) T10IP 2070 P90 with urbanization	4
(f) T10IP 2070 P90, no urbanization	6

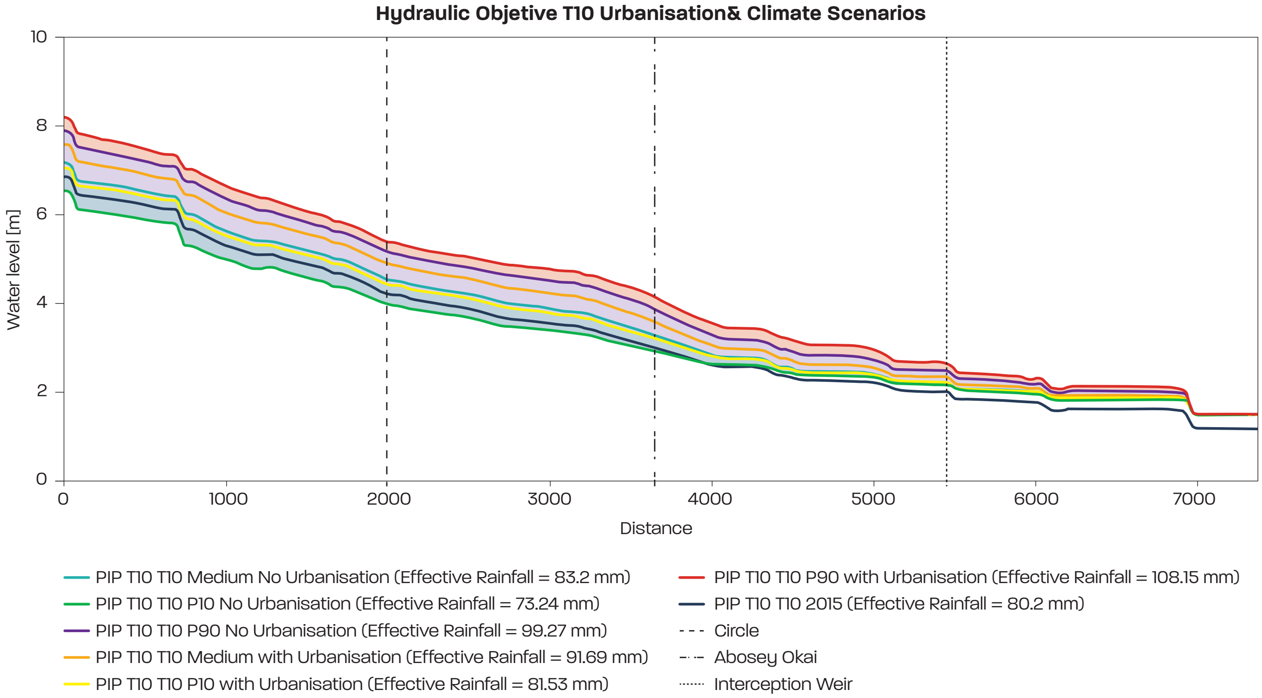
Note: T10IP = T10 investment plan.
a. "Median" represents the median results of all combinations of climate change scenarios and models for daily rainfall with a return period of 10 years. P10 = 10th percentile climate change scenario (lowest 10 percent of results). P90 = 90th percentile climate change scenario (highest 10 percent of results).
b. The safety level, expressed as a return period, refers to the extent of protection from an event of a given frequency. A safety level of 10 refers to protection from a 1-in-10-year flood event.

4.3.3 Proposed Climate Change Adaptation Measures

To adapt to potential climate change effects, additional structural and nonstructural measures are required to ensure the same safety levels in 2070 as the T10 investment plan would provide under the current condition. The following measures can be applied to mitigate the potential impacts of climate change:

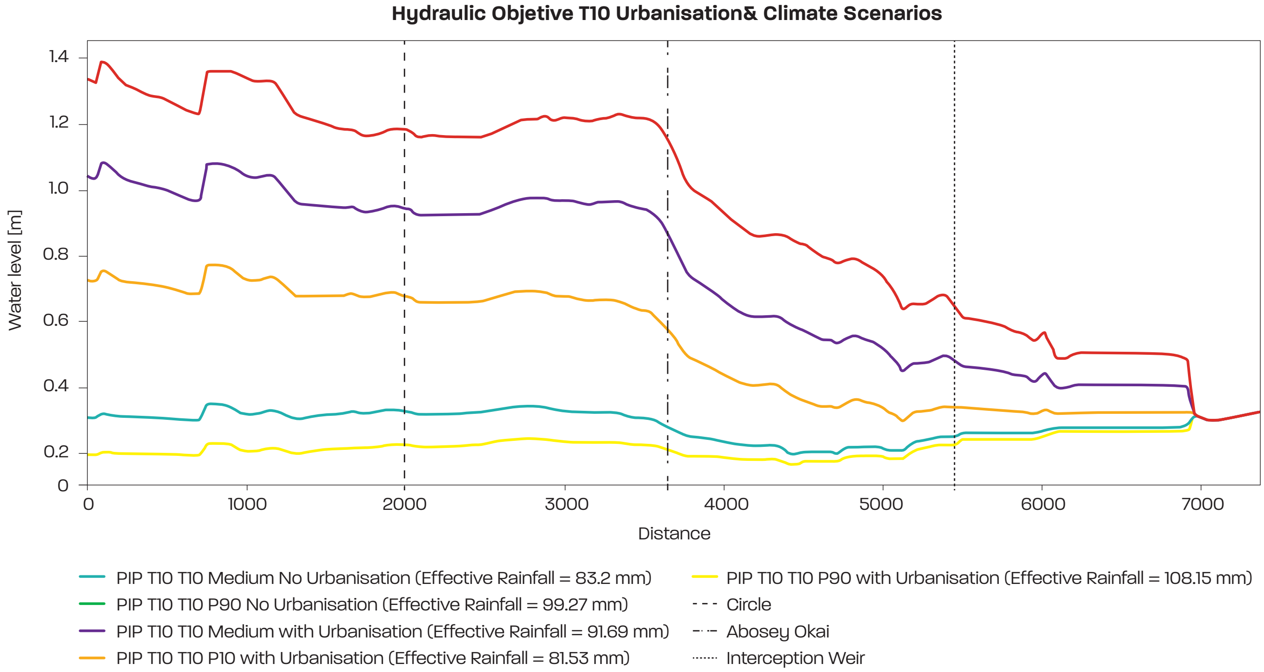
- Wadis (localized, nature-based micro detention areas)
- Redesigned drains
- Additional repairs of the drainage network
- Additional reconstruction of bridges
- Enlargement of planned retention ponds on government-owned land
- Implementation of retention ponds on privately owned land
- Floodplain lowering (limited effect on Kwame Nkrumah Circle area)

Figure 4.3 Impact of Climate Change and Urbanization Scenarios on the Water Level in the Odaw Basin, by Distance from Caprice



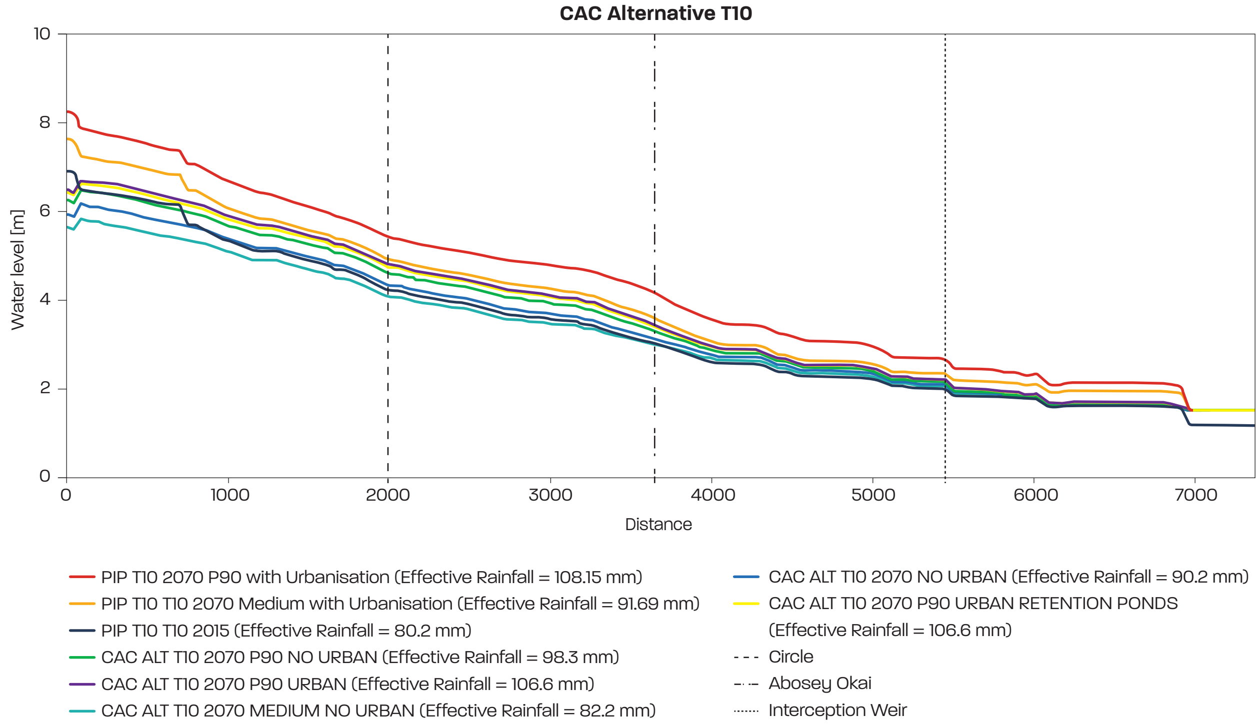
Note: Figure shows the "hydraulic objective" for the T10 flood risk mitigation investment plan in Greater Accra—that is, the difference between (a) the water level from a 1-in-10-year (T10) flood in 2015, and (b) the projected water level under various future climate and urbanization scenarios in 2070. The "effective rainfall" under each scenario is the estimated millimeters (mm) of rainfall per 24 hours during a T10 rainfall event.

Figure 4.4 Impact of Climate Change and Urbanization Scenarios on the Water Level in the Odaw Basin, expressed as change in water level compared to T10 Investment Plan, by Distance from Caprice,



Note: Figure shows the "hydraulic objective" for the T10 flood risk mitigation investment plan in Greater Accra—that is, the difference between (a) the water level from a 1-in-10-year (T10) flood in 2015, and (b) the projected water level under various future climate and urbanization scenarios. The "effective rainfall" under each scenario is the estimated millimeters (mm) of rainfall per 24 hours during a T10 rainfall event.

Figure 4.5 Impacts of Climate Change and Urbanization Scenarios on Water Level in the Odaw Basin, by Distance from Caprice



Note: Figure shows the "hydraulic objective" for the T10 flood risk mitigation investment plan in Greater Accra—that is, the difference between (a) the water level from a 1-in-10-year (T10) flood in 2015, and (b) the projected water level under various future climate and urbanization scenarios. PIP = T10 investment plan. CAC = climate change adaptation alternative. The "effective rainfall" under each scenario is the estimated millimeters (mm) of rainfall per 24 hours during a T10 rainfall event.

- Floodplain lowering north of Caprice along unlined sections (limited effect)
- Bypass construction between Nima and Odowna streams (limited effect and technically, economically, and socially difficult to support)
- Widening of the Odaw drain
- Construction of floodwalls
- Nonstructural measures, including flood zoning and enforcement and flood early warning systems.

Chapter 5 describes the combinations of different measures from this long list to form climate change investment alternatives. These alternatives are designed to compensate for the estimated climate change impacts of the different climate change and urbanization scenarios.

4.3.4 Hydraulic Effects of Proposed Climate Change Adaptation Measures

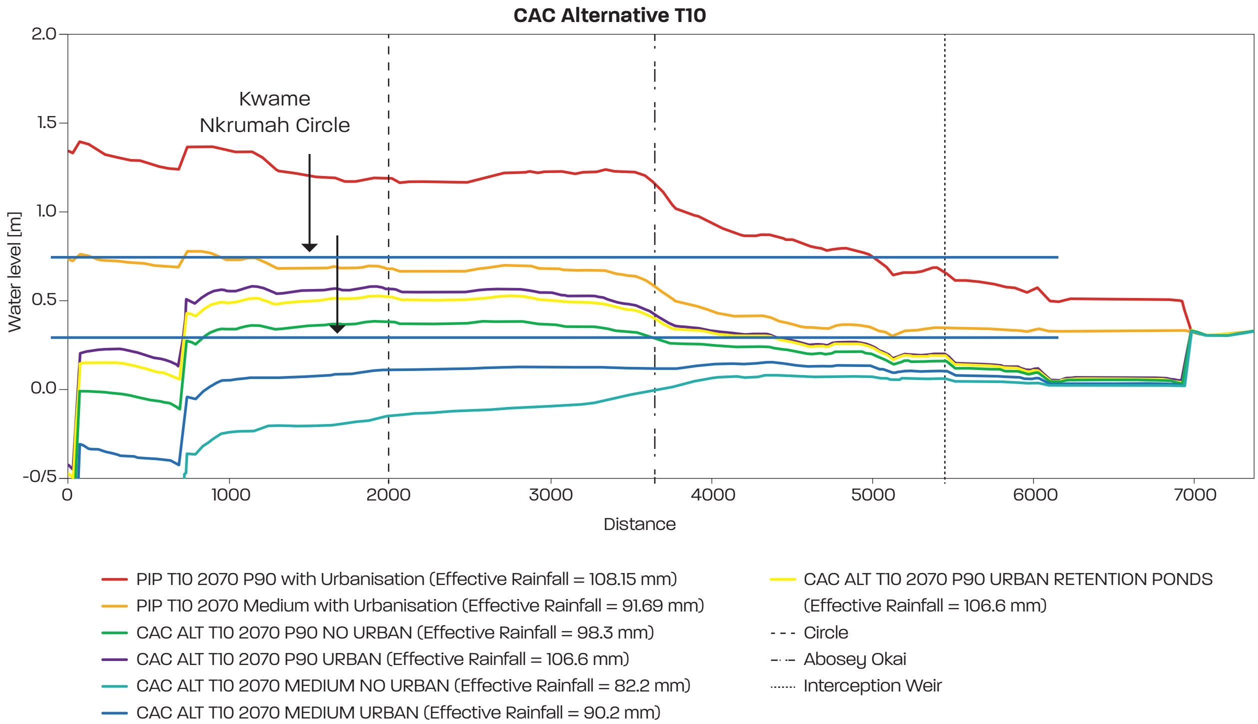
The climate change adaptation investment alternative (CAC alternative) meets the criteria listed earlier regarding land acquisition, budget, flexibility, and paradigm shift toward climate-resilient and water-inclusive urban development. The following measures meet these conditions:

- *Micro detention:* 1 millimeter storage (27.5 hectares)
- *New drain design:* 0.5 millimeter storage (70 kilometers of road)
- *Reconstruction of the bridges* at Caprice, Avenor, and the outlet to the sea
- *Construction of an additional in-line retention pond* on government-owned land (Atomic area)
- *Repairs on the Kaneshie drain*.

The combined climate change adaptation measures compensate for the effects of climate change under the median climate change scenario. They do not compensate all future adverse climate effects, as can be seen from the remaining hydraulic objective presented below:

- *The P90 climate scenario*, with urbanization effects, shows a maximum increased water level of 0.55 meters at Kwame Nkrumah Circle. Without urbanization, the maximum increased water level is 0.4 meters.

Figure 4.6 Impacts of Proposed Structural Climate Change Adaptation Measures on 2070 Water Levels in the Odaw Basin, by Distance from Caprice



Note: Figure shows the impact on 2070 water levels in Greater Accra from both the the T10 flood risk mitigation investment plan (T10 2070) and the climate change adaptation alternative (CAC ALT) under various future climate and urbanization scenarios. For example, under the P90 (90th percentile) climate scenario, water levels would fall from 1.4 meters to 0.55 meters. Under the median climate scenario, water levels would fall from 0.7 meters to 0.15 meters. PIP = T10 investment plan. The "effective rainfall" under each scenario is the estimated millimeters (mm) of rainfall per 24 hours during a T10 (1-in-10-year) rainfall event.

- *The median climate scenario*, with urbanization, shows a maximum of increased water level of 0.15 meters at Kwame Nkrumah Circle.
- *The P10 climate scenarios*, with and without urbanization, lead to lower water levels than the investment alternatives in the current situation and are not shown in the figures below.

The effects of the climate change adaptation investment alternatives on the hydraulic objective, or water level, can compensate for the climate change effects of a 1-in-10-year return period flood for a median climate change scenario *without* additional effects of urbanization. For a median climate change scenario *with* the effects of urbanization, a hydraulic objective of 15 centimeters remains (table 4.7). Under more extreme climate change scenarios, further measures would be required to meet the hydraulic objective. Map 4.7 illustrates the areas that would still be inundated under a P90 climate change scenario and the implementation of the climate change adaptation investment alternative.

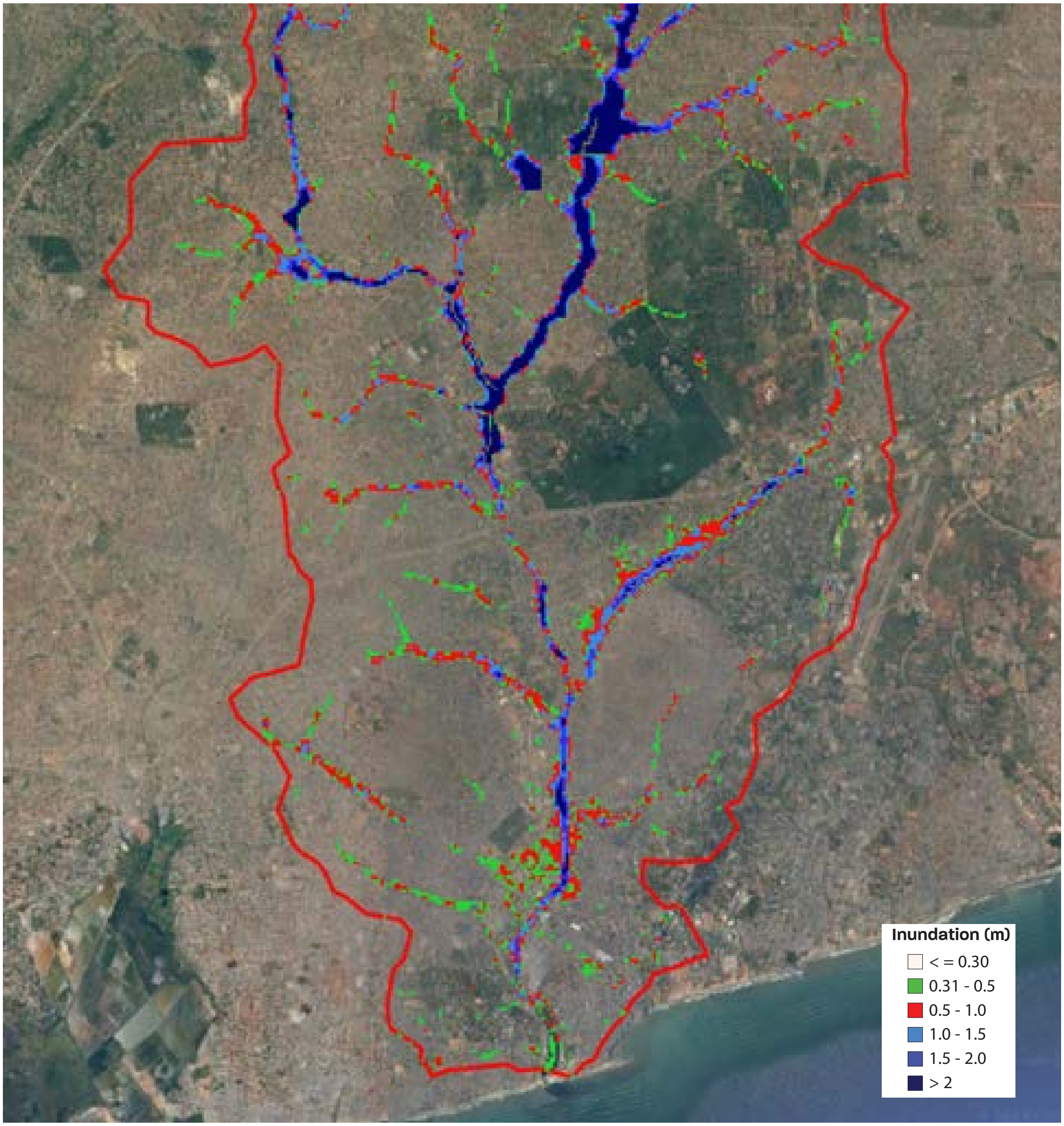
Table 4.7 Remaining Hydraulic Objective of Flood Risk Mitigation in 2070 at Kwame Nkrumah Circle, with Climate Change Adaptation Measures, by Scenario

Scenario[a]	Remaining hydraulic objective at Kwame Nkrumah Circle, centimeters[b]
(d) 2070 T10 median, no urbanization	n.a.
(c) 2070 T10 median with urbanization	0.15
(f) 2070 T10 P90, no urbanization	0.40
(e) 2070 T10 P90 with urbanization	0.55

a. "2070 T10" refers to the hydraulic objective for a 1-in-10-year flood in 2070. The "median" scenario represents the median results of all combinations of climate change scenarios and models for daily rainfall with a return period of 10 years. "P90" refers to the 90th percentile climate change scenario (that is, the highest 10 percent of results).
b. The "hydraulic objective" refers to the difference between (a) the water level from a 1-in-10-year (T10) flood in 2015, and (b) the projected water level under a given future climate and urbanization scenario. n.a. = not applicable.

In an iterative process, measures were added to identify further investment alternatives to the climate change investment alternative described earlier—which, as noted, compensates for the effects of climate change under the

Map 4.7 **Inundated Areas of the Odaw Basin under the P90 Climate Scenario with Urbanization, 2070**



Notes: Background based on Google Earth. ©World Bank. Further permission required for reuse.
Red border designates Odaw catchment. The "P90" scenario represents the 90th percentile (or highest 10 percent) of results of all combinations of climate change scenarios and models for daily rainfall with a return period of 10 years. "Urbanization" assumes that the urban fabric in the Odaw Basin in 2070 (percentage of area that is urban) will be 100 percent, based on an estimated urbanization increase of 3 percent per year (starting from 66 percent in 2015). The population increase is also 3 percent per year.

median climate change scenario but not for all future adverse climate effects (figure 4.6). In a next iteration to solve the hydraulic objective T10 2070, retention ponds on privately owned lands were added to the model. This resulted in only a 7 centimeter decrease of the maximum water levels between Caprice and the sea. The reason is that the retention ponds are all located upstream of the Odaw Basin and can only store part of the flood wave that inundates the downstream Odaw section. A large part of the Odaw flood wave originates from the lower Odaw sub-basins like Onyasia. For some future scenarios, runoff from lower sub-basins leads to inundation on Odaw between

Table 4.8 Projected Effects of Micro Retention Measures to Manage Additional Rainfall in 2070 in the Odaw Basin, by Climate and Urbanization Scenario

Scenario[a]	Effective rainfall (mm)[b]	Managed rainfall (above 80.2 mm)[c]	Measures[d]
(d) 2070 T10 median, no urbanization	82.2	2.0	No added measures needed
(c) 2070 T10 median with urbanization	90.2	10.0	• 272 ha wadis (1 percent of urban area)
(f) 2070 T10 P90, no urbanization	98.3	18.1	• 272 ha wadis (1 percent of urban area) • 1,400 km new roadside drains
(e) 2070 T10 P90 with urbanization	106.6	26.4	• 408 ha wadis (1.5 percent of urban area) • 1,500 km roads with new drain design

a. "2070 T10" refers to the hydraulic objective for a 1-in-10-year flood in 2070. The "median" scenario represents the median results of all combinations of climate change scenarios and models for daily rainfall with a return period of 10 years. "P90" refers to the 90th percentile climate change scenario (that is, the highest 10 percent of results). "Urbanization" assumes that the urban fabric in the Odaw Basin in 2070 (percentage of area that is urban) will be 100 percent, based on an estimated urbanization increase of 3 percent per year (starting from 66 percent in 2015). The population increase is also 3 percent per year.
b. "Effective rainfall" under each scenario is the estimated millimeters (mm) of rainfall per 24 hours during a T10 (1-in-10-year) rainfall event.
c. "Managed rainfall" refers to the amount of rainfall that needs to be stored to reach a safety level of T10. It is equal to the estimated amount of rainfall exceeding 80.2 millimeters (that is, the effective rainfall during a 2015 T10 rainfall event managed under the T10 investment plan).
d. The measures are those estimated to achieve the specified "managed rainfall" under each scenario if added to the climate change investment alternative for flood risk mitigation in 2070. ha = hectares. km = kilometers.

Table 4.9 Projected Effects of Widening the Odaw Channel to Manage Additional Floodwaters in 2070, by Climate and Urbanization Scenario

Scenario[a]	Hydraulic objective at Kwame Nkrumah Circle[b]	Measure[c]
(d) 2070 T10 median, no urbanization	0.00	No added measures needed
(c) 2070 T10 median with urbanization	0.15	Widen Odaw by 40 meters
(f) 2070 T10 P90, no urbanization	0.40	Widen Odaw by 50–55 meters
(e) 2070 T10 P90 with urbanization	0.55	Widen Odaw by 55–60 meters

a. "2070 T10" refers to the hydraulic objective for a 1-in-10-year flood in 2070. The "median" scenario represents the median results of all combinations of climate change scenarios and models for daily rainfall with a return period of 10 years. "P90" refers to the 90th percentile climate change scenario (that is, the highest 10 percent of results). "Urbanization" assumes that the urban fabric in the Odaw Basin in 2070 (percentage of area that is urban) will be 100 percent, based on an estimated urbanization increase of 3 percent per year (starting from 66 percent in 2015). The population increase is also 3 percent per year.
b. "Hydraulic objective" refers to the amount of floodwater to be managed to reach a safety level of T10. It is the difference between between (a) the water level from a 1-in-10-year (T10) flood in 2015, and (b) the projected water level under a specified 2070 climate and urbanization scenarios.
c. The measures refer to widening of the Odaw Channel at Kwame Nkrumah Circle to achieve the hydraulic objective under each scenario if added to the climate change adaptation investment alternative.

Caprice and sea without significant inflow from the upper Odaw basin. Retention in the lower Odaw sub-basins is not possible because lands are not available.

Because of the limited effects of the upstream retention ponds, it is difficult to compensate for these effects without other high-impact flood mitigation measures like (a) further development of micro detention and new drain design (table 4.8), or (b) widening of the lower Odaw River section (table 4.9).

Although the above estimations clearly indicate that additional measures would be required to compensate for the effects of climate change and urbanization under all scenarios, the choice of these additional measures is not straightforward. On the one hand, there are the lighter structural measures, such as the implementation of nature-based, localized retention and micro retention. On the other hand, structural measures such as widening the Odaw drain can be considered. Both types of measures have different implications on budget, social impacts (including land acquisition and resettlement), and environmental effects. The effects of both types of measures on the hydraulic objective are described below.

Table 4.8 expresses the climate and urbanization scenarios in millimeters of effective rainfall. The amount of rainfall that needs to be stored to reach a safety level of T10 is indicated in the "managed rainfall" column. The "measures" column shows the required extent of micro retention measures to store the excess rainfall.

Table 4.9 presents the hydraulic objective of the climate and urbanization scenarios at Kwame Nkrumah Circle. The widening of the Odaw is a high-impact flood mitigation measure to solve the hydraulic objective.

Table 4.10 **Estimated Impacts of Flood Mitigation Investment Alternatives, by Climate Change and Urbanization Scenario, in the Odaw Basin, 2070**

Alternative and scenario (a)	Additional measures (b)	Safe?	Damage (US$, millions)	Damage reduction (US$, millions)	Total affected people	Reduction of total affected people	Affected people low income areas	Reduction of affected people in low income areas	Flooded area (ha)	Costs (US$, million)
T10 IP *		y	37		114,000		10,000		1,470	0
T10 IP P10NU		y	28		187,000		17,000		1,350	0
T10 IP P10U		n	62		217,000		21,000		2,120	0
T10 IP MEDNU		n	49		233,000		22,000		1,690	0
T10 IP MEDU		n	100		268,000		28,000		2,430	0
T10 IP P90NU		n	110		307,000		33,000		2,010	0
T10 IP P90U		n	180		331,000		37,000		2,860	0
CAC T10 P10U		y	43	-19	152,000	-66,000	14,000	-6,000	1,480	97
CAC T10 MEDNU		y	38	-11	179,000	-54,000	17,000	-5,000	1,300	97
CAC T10 MEDU		n	67	-33	180,000	-88,000	19,000	-9,000	1,640	97
CAC T10 P90NU		n	61	-49	170,000	-137,000	18,000	-15,000	1,110	97
CAC T10 P90U		n	108	-72	198,000	-133,000	22,000	-15,000	1,710	97
CAC T10 P90NU	Wadi 10mm, drain design 8.5mm	y	37	-73	103,000	-204,000	11,000	-22,000	670	1013
CAC T10 P90U	Wadi 15mm, drain design 11.8mm	y	64	-116	118,000	-213,000	13,000	-24,000	1,020	1429
CAC T10 MEDU	Odaw widening by 40m	y	88	-12	235,000	-33,000	24,000	-3,000	2,140	110
CAC T10 P90NU	Odaw widening by 50 to 55m	y	79	-31	221,000	-86,000	24,000	-9,000	1,450	116
CAC T10 P90U	Odaw widening by 55 to 60m	y	107	-73	196,000	-135,000	22,000	-15,000	1,700	129

Note: T10 = safety level for a 1-in-10-year event. MED = median climate change scenario. P10 = 10th percentile climate change scenario. P90 = 90th percentile climate change scenario. U = with urbanization. NU = without urbanization. ha = hectares. m = meters. mm = millimeters. n.a. = not applicable.
a. The investment alternatives are either "PIP T10" (T10 Investment Plan, which is meant to achieve a safety level of protection from a 1-in-10-year flood under the current situation) or "CAC T10" (climate change adaptation measures to achieve a T10 level of safety in 2070). "Urbanization" assumes that the urban fabric in the Odaw Basin in 2070 (percentage of area that is urban) will be 100 percent, based on an estimated urbanization increase of 3 percent per year (starting from 66 percent in 2015) and a population increase of 3 percent per year.
b. "Additional measures" are those needed, beyond the climate change alternative investment plan, to compensate for climate change effects in 2070.

4.3.5 Estimated Impacts of Climate Change Adaptation Alternative

A series of current and future climate scenarios with and without autonomous developments and investment alternatives (combinations of measures) have been assessed. Different hydraulic objectives were set and solved step by step, with a combination of measures depending on the climate and urbanization scenario. Whether the investment alternatives lead to inundation between Caprice and the sea per scenario was assessed. The damages and number of affected people are also listed per scenario.

The proposed alternatives that solve the hydraulic objectives are presented in table 4.9. As noted earlier, the climate change adaptation investment alternative (CAC alternative) mitigates future flooding to a large extent but not for every climate and urbanization scenario. Additional measures may therefore be required, such as widening the Odaw drain by an additional 55–60 meters or covering 1.5 percent of the urban fabric of Accra with nature-based,

Table 4.11 **Estimated Additionality Costs of Climate Change Adaptation Measures under the "Safe at T10" Investment Alternative**

Climate Scenario	Alternative and Scenario	Additional Measures	Damage ($)	Damage reduction (US$ millions)	Total Affected people	Total Affected people reduction	Total affected slum/low income	Total affected people slum/ low income reduction	Flooded area (ha)	Costs ($M)
P10 No Urbanisation	PIP T10 P10NU		28		187,000		17,000		1,350	0
P10 Urbanisation	CAC T10 P10U		43	-19	152,000	-66,000	14,000	-6,000	1,480	97
Medium No Urbanisation	CAC T10 MEDNU		38	-11	179,000	-54,000	17,000	-5,000	1,300	97
Medium Urbanisation	CAC T10 MEDU	Odaw Widening 40m	88	-12	235,000	-33,000	24,000	-3,000	2,140	110
P90 NO Urbanisation	CAC T10 P90NU	Wadi 10mm, Drain Design 8.5mm	37	-73	103,000	-204,000	11,000	-22,000	670	1013
	CAC T10 P90NU	Odaw Widening 50-55m	79	-31	221,000	-86,000	24,000	-9,000	1,450	116
P90 Urbanisation	CAC T10 P90U	Wadi 15mm, Drain Design 11.8mm	64	-116	118,000	-213,000	13,000	-24,000	1,020	1429
	CAC T10 P90U	Odaw Widening 55-60m	107	-73	196,000	-135,000	22,000	-15,000	1,700	129

Note: T10 = safety level for a 1-in-10-year event. MED = median climate change scenario. P10 = 10th percentile climate change scenario. P90 = 90th percentile climate change scenario. U = with urbanization. NU = without urbanization. ha = hectares. m = meters. mm = millimeters. n.a. = not applicable.
a. "Urbanization" assumes that the urban fabric in the Odaw Basin in 2070 (percentage of area that is urban) will be 100 percent, based on an estimated urbanization increase of 3 percent per year (starting from 66 percent in 2015). The population increase is also 3 percent per year.
b. The investment alternatives are either "PIP T10" (T10 investment plan to achieve a safety level of protection from a 1-in-10-year flood under the current situation) or "CAC T10" (climate change adaptation measures to achieve a T10 level of safety in 2070).
c. "Additional measures" are those needed, beyond either the T10 or CAC investment plans, to compensate for climate change effects in 2070.

localized micro retention and 1,500 kilometers of new roadside drains.

Table 4.10 lists the damages, total affected people, affected people in low-income areas, and flooded hectares under each scenario. It also presents the reductions in damages and affected people (beneficiaries) for the scenarios. For example, the climate change adaptation investment alternative can compensate for the climate change effects under a median climate change scenario *without* the effects of urbanization (CAC T10 MedNU). Under this scenario, an additional 54,000 people would benefit. Implementing additional measures to compensate for a P90 climate change scenario *with* the effects of urbanization (CAC T10 P90U) would cost between US$129 million and US$1.4 billion, depending on the type of infrastructure measures chosen and land acquisition costs considered.

4.3.6 Estimated Costs of Climate Change Adaptation

The estimation of climate additionality costs involves many factors and are here described in a simplified manner. The additional costs are estimated for different climate change and urbanization scenarios considering either (a) soft structural measures (nature-based, localized drains and water detention); or (b) hard structural measures (widening of the Odaw drain) as follows:

- Costs with scenario code "NU" (no urbanization effects considered) are climate additionality costs, because they include only the effects of climate change.
- Costs with "U" (with urbanization effects) are costs for climate additionality and autonomous development.
- Costs vary according to the types of additional measures chosen. In general, widening the Odaw is less costly than micro detention and new drain design.

Depending on the climate change scenario and climate change adaptation measures, the cost can range from US$97 million for compensating the median climate change scenario *without* urbanization effects to between US$129 million for hard structural measures and US$1.4 billion for soft structural measures to compensate for the effects of a P90 climate change scenario *with* urbanization effects. It should be noted that the land acquisition costs for widening the Odaw drain are not included in the cost estimates, whereas costs for nature-based, localized drains are estimated as full construction costs. Going forward, different policy choices (land acquisition to widen the Odaw or implementing strong stormwater management policies) are therefore unavoidable for the government to ensure a proper adaptation to climate change.

An extrapolation from the Odaw Basin to all basins in Greater Accra indicates that additional measures would cost between US$100 million (Odaw widening) and US$1 billion (micro detention and new drain design), depending on the type of measure to completely mitigate the T10 climate effects. When autonomous development (urbanization) is taken into account, the additionality costs are between US$130 million and US$1.43 billion. Climate additionality costs for a T25 rainfall event are between US$115 million (Odaw widening) and US$1.1 billion (micro detention and new drain design), depending on the type of measure. When autonomous development is taken into account, the additionality costs are between US$240 million and US$1.62 billion.

4.4 Conclusions Related to the T10 Investment Plan

The T10 investment plan results in a 1-in-1-year flood safety level for the Odaw Basin while the investment costs are well below US$100 million, and the benefits well outperform the investment costs. No complicated, time-consuming, and costly land acquisitions are necessary in this investment plan. Although the T10 investment plan is developed with the aim of a short implementation period, important steps still must be taken to reach a full understanding of the plan's feasibility. In a feasibility study, a technical design of the flood mitigation measures is to be developed, and the assessment of the impact should be broadened to social and environmental impacts as well. Important issues to be resolved include the following:

- How many people would need to be resettled who now live on the borders of the planned retention ponds? Based on the aerial photography used for this report, the number of houses affected is not high, but the situation on the ground in Accra changes almost daily. A field survey is required to obtain an accurate estimate.
- The dams that are necessary for the retention ponds have to be designed in accordance with the dam regulations of the government of Ghana and global best practices, including the World Bank Policy on Safety of Dams (World Bank 2001).
- The retention ponds may negatively affect people's health if they turn into perfect breeding conditions for mosquitoes.

The conclusion therefore is that a feasibility study needs to be executed as the next step toward the implementation of the T10 investment plan.

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CHAPTER 5

Policy Choices and Proposed Short-, Medium-, and Long-Term Actions for Implementation

Introduction

The previous chapters provide a detailed analysis of the different structural and nonstructural measures for flood mitigation in the Greater Accra Region. The implementation of those measures will require various short-, medium-, and long-term policy choices and may offer a unique opportunity to seize the momentum for a more transformational shift toward resilient urban development in Greater Accra.

The process followed for this study created a journey of joint discoveries toward flood resilience and created a strong momentum among stakeholders and decision makers to find lasting solutions to the perennial floods in Greater Accra following years and decades of short-term recovery instead of preventive measures. The study can support evidence-based decision making but cannot replace political decision making itself. This chapter therefore not only summarizes the study's key findings but also explores the remaining challenges and opportunities in achieving flood-resilient urban development in Greater Accra and highlights actions and next steps for its implementation. Regarding implementation, the report introduces the priority actions that have been set for the International Development Association (IDA)[22]-financed Greater Accra Resilient and Integrated Development Project (GARID).[23]

5.1 Key Findings and Policy Choices

5.1.1 Summary of Key Findings

Investments in flood mitigation measures for all safety levels (T10, T25, and T50) are highly beneficial and economically feasible but would require, depending on the safety level, choices on budget, operations, maintenance, land acquisition, spatial planning, and environmental issues. The T10 investment plan, presented in chapter 4, results in a 1-in-10-year flood safety level for the Odaw Basin at an investment cost well below US$100 million, and the benefits well outperform the investment costs. No complicated, time-consuming, and costly land acquisitions are necessary for the T10 investment plan, making it a feasible alternative or investment plan that can be implemented in the short term. An estimated 30,000 people living in the most flood-affected areas of the Odaw Basin would be the direct beneficiaries, whereas the total number of beneficiaries may be substantially higher given that up to 1 million people are estimated to pass through central Accra daily.

The study highlights that, whatever measures are chosen, the effective operations and maintenance (O&M) of the existing drainage system is of utmost importance. Without O&M—which also includes the frequent dredging of the Korle Lagoon, management of sand traps, and operation of hydraulic infrastructure—none of the other measures would make sense. The failure of the interceptor weir during the floods of June 3, 2015, demonstrated the potential negative impacts of a failing flood management infrastructure.

It is feasible to achieve a safety level of T10 (protection against floods with an average return period of 10 years) without land acquisition and with minimal resettlements at this stage. However, any substantial increase in the safety level—for example, to T25 or T50—would require at some points additional space for widening waterways, for retention ponds, or other measures. Climate change and progressing urbanization will have further substantial impacts on the safety levels. In most cases, additional measures would be required to guarantee the same safety levels for future generations.

In sum, the flood risk management strategy for Greater Accra requires the combination of structural measures with nonstructural measures and should be part of an urban design and development vision that spearheads a transformational shift toward flood-resilient urban development.

5.1.2 Policy Choices

In the short to medium term, the government administration, stakeholders, and decision makers at Ghana's local, regional, and national levels need to make policy choices and political decisions to agree on the final flood risk mitigation strategy and its effective implementation.

Flood mitigation strategy. The flood mitigation strategy should be part of a larger conceptual framework toward a water-inclusive resilient development of Greater Accra. The strategy could also open new opportunities for urban development and, as part of an urban planning and

22 IDA is part of the World Bank Group.

23 For more information, see the World Bank's GARID Project website: https://projects.worldbank.org/en/projects-operations/project-detail/P164330?lang=en.

development vision, could be an opportunity to create new urban space. However, this requires an urban planning vision, detailed study, and a careful approach in addressing the concerns of affected people. Nature-based solutions and the localized management of stormwater through wadis and new roadside drains would be important elements of water-inclusive, climate-resilient urban development. The promotion of these localized and new drains will require getting private landowners on board and drafting and implementing adequate stormwater management policies and regulations.

Land acquisition and resettlement. The remaining open space—notably, government-owned open space—where flood mitigation measures can be implemented is rapidly built up or used for other purposes. Many of the flood mitigation measures such as retention ponds and widening of the Odaw drain require land acquisition, whereas ownership and current habitation on the land may not be clear. Clarifying land ownership, conducting spatial planning, and holding consultations with the affected owners would therefore be advisable. Any planning of land acquisition and resettlement of the affected population should be guided by good global practice and standards and related national laws and practice.[24]

Widening of Odaw drain. The widening of the Odaw drain is one of the potential measures of protection against higher-return-period floods in the area downstream of Caprice. This widening is difficult to implement because of the dense population of the affected areas and the hindrance of economic activities in the area as well as the loss of precious and scarce space. A more tailored, differentiated, and phased widening approach may be less difficult and less costly to realize while still substantially reducing flood risks. Moreover, by covering the drain, instead of losing space, additional space becomes available that can be used to generate additional economic activities and income. A feasibility study, including the business case for widening and (partly) covering the Odaw drain between Caprice and Abossey-Okai Bridge is necessary to make a final decision.

Options for the interceptor weir. Regarding the interceptor weir in Korle Lagoon, options might include partial rehabilitation (for example, of the gates) and daily cleaning of the weir. Notably, the weir can still cause obstruction during a flash flood because debris will block the weir even when it had been cleaned before. Options for the interceptor weir include the following:

- *Cleaning the weir daily.* As noted, however, the weir can still cause a major obstruction during a flash flood because debris will block the weir.
- *Providing for waste collection.* The interceptor weir is a location where most of the waste from the main drains in the basin ends up. It is a perfect place for a waste or plastic collector, including a recycling facility. A pedestrian bridge could also be considered.
- *Removing the weir.* The most logical measure, from a flood safety point of view, is to remove the weir completely and prevent obstruction of flow.
- *Rehabilitating the weir.* Fully rehabilitate the weir and pump installation after a thorough feasibility study focusing on sustainability aspects.

Nonstructural measures. Effective nonstructural measures, including the following, should be planned and implemented:

- *An early warning system* is a cost-effective measure to further decrease the risk of loss of life. Such a system, in simple form, can already be realized in 2020, using the model developed in this study and rainfall records from the Ghana Meteorological Agency's (GMet) satellite and ground stations.
- *Flood zoning,* properly enforced, is part of a paradigm shift toward climate-resilient, water-inclusive urban development. This means that where flood zoning has not yet been adopted, it should be realized as soon as possible with the support of the metropolitan, municipal, and district assemblies (MMDAs); the Land Use and Spatial Planning Authority; and the Water Resources Commission. The flood hazard maps provided by this study give a clear picture of the areas that are at risk and should be protected from encroachment. Furthermore, it is of utmost importance that the enforcement of the ban on building in the flood zones be taken seriously and that human resources and budgets be organized to increase the enforcement capacity.
- *Solid waste management* is a known problem in Accra. Especially on the tertiary drain level, the lack of solid waste management causes inundations due to blocking of the drains. Accra deserves a solution for the solid waste.

24 Regarding the World Bank's resettlement policies, see "Operational Policy (OP) 4.12: Involuntary Resettlement." Operational Manual, World Bank, Washington DC. https://policies.worldbank.org/sites/ppf3/PPFDocuments/090224b0822f89db.pdf.

5.1.3 Phased Approach

Complex issues such as flood management in Greater Accra require substantial financial resources; often the acquisition of land; and a combination of structural, non-structural, and policy measures. Because these issues are complex and adequate resources may not be available at once, a phased approach for the implementation of the flood management strategy has been proposed. This would allow an increase in the safety level over different phases and extend flood protection coverage from the Odaw Basin to other basins. The first phase of GARID will implement the T10 investment plan for the Odaw, while subsequent phases will increase safety levels and spatial coverage beyond the Odaw Basin.

5.1.3.1 Short to Medium Term

In the short to medium term, the T10 investment plan will be implemented and an operational early warning system set up while policy changes initiate resilient spatial planning, municipal financing, stormwater regulation, and O&M of infrastructure. Feasibility studies can support the subsequent phases by, for example, identifying land issues and designating available open space for flood management infrastructure and technical design studies.

The short-term analytical work would also need to improve participatory mapping coverage, data collection, and monitoring and evaluation while capturing lessons learned and maintaining momentum with stakeholders and the affected population. A delayed or haphazard implementation may lose the trust of the affected population and local decision makers, which could consequently further increase flood risks.

5.1.3.2 Medium to Long Term

In the medium to long term, additional measures will be designed and implemented to increase the safety level in the Odaw Basin to T25 or T50. Appropriate flood management measures will also be implemented for the remaining basins in Greater Accra. These measures will be supported by a policy shift toward a resilient, decentralized stormwater management policy and implementation of an overall vision for resilient urban development.

The long-term perspective allows the government not only to identify and acquire land to implement measures but also to develop a plan to benefit from income-generating opportunities through land value capture. The long-term measures also include adequate municipal budgeting for O&M, metropolitan governance, and capacity building for national government experts as well as for an operational and well-functioning solid waste management system as part of an effective flood management strategy. In addition, the long-term perspective enables the exploration of risk financing instruments for homeowner flood insurance and municipal-level risk transfer mechanisms.

Other long-term questions concern the management of Greater Accra's rapid growth. These include how areas with a high flood risk can be preserved from settling and how Accra can sustainably develop toward an urban area of 11 million people where no one needs to live in vulnerable areas and informal settlements. In addition, the effects of climate change in a highly urbanized context need to be addressed.

5.2 Road Map for Implementation of Investment Alternatives

As already noted, the implementation of an effective flood risk mitigation strategy requires a phased approach that substantially increases Greater Accra's flood safety levels in the short term (to at least a T10 safety level) while allowing ample time to address complex issues such as land acquisition, urban planning, and budgetary and policy-related decision making. Implementing measures to achieve safety levels of T25 or even T50 for all parts of the Greater Accra Region will require substantial financial resources (estimated at US$700 million to US$1 billion).

5.2.1 Gradual Increase in Spatial Coverage and Safety Levels

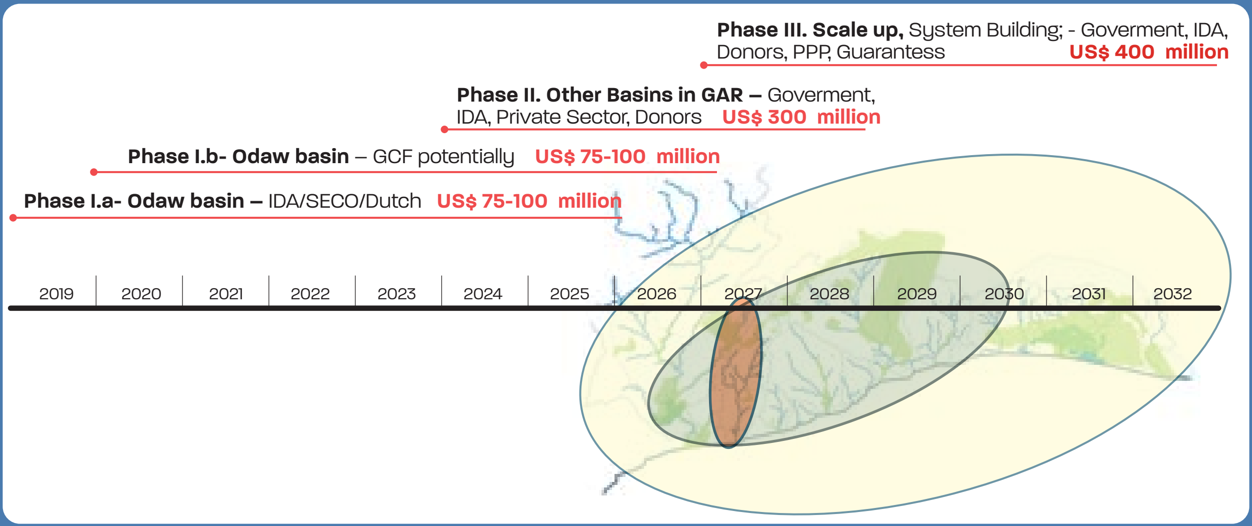
For implementation that gradually increases the safety levels and spatial coverage, a phased approach has therefore been proposed. Figure B5.1.1 illustrates the proposed approach for (a) increasing safety levels over two to three project phases, and (b) increasing the spatial coverage, targeting the Odaw Basin at a T10 safety level in the first phase and targeting other basins within Greater Accra in consecutive phases.

The baseline (maintenance and repair) investment alternative should be realized as soon as possible. This alternative scored highest on the cost-benefit analysis (CBA) and multicriteria analysis (MCA) and is a condition for

Box 5.1 The Greater Accra Resilient and Integrated Development Project (GARID)

In May 2019, the International Development Association (IDA) Board approved the first phase of the Greater Accra Resilient and Integrated Development Project (GARID) for US$200 million. GARID is based on the findings of this report, the Greater Accra Climate Risk Mitigation Study. Given the magnitude and complexity of the challenges, the project is designed as the first in a series of projects (SOP) supporting a gradual improvement of integrated flood risk management, starting from the Odaw River Basin in Phase I and rolling out to other priority basins within the Greater Accra Region (GAR) in subsequent phases (figure B5.1.1). The SOP approach provides a framework for coordination between the urban flood management programs developed by the government of Ghana and those of donors.

Figure B5.1.1 Financing Framework for Increasing Spatial Coverage of Flood Risk Mitigation Measures in the Greater Accra Region, 2019–32



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Note: IDA = International Development Association (of the World Bank Group). GAR = Greater Accra Region. GCF = Green Climate Fund. PPP = public-private partnership. SECO = Swiss State Secretariat for Economic Affairs.

The Phase I project development objectives are to improve flood risk management and solid waste management in GAR's Odaw River Basin and to improve access to basic infrastructure and services in the targeted communities within the Odaw River Basin. GARID focuses on mitigating the flood risk for a 10-year flood within the Odaw River Basin through performance-based dredging, the construction of flood detention basins, and the repair and reconstruction of critical drainage channels and bridges. It includes the scaling up and modernization of the existing flood forecasting, warning, and emergency response systems for the entire GAR.

Additionally, GARID supports

- *Reduction of solid waste* entering the Odaw primary channel and key tributaries through a community-based solid waste management approach, development of waste transfer stations, capping of old dump sites, and improvements in final solid waste disposal capacity;
- *Basic infrastructure and services* through participatory urban upgrading in targeted low-income communities; and
- *Improvements in metropolitan planning and coordination, stormwater regulation, and flood zoning* as well as local governments' operations and maintenance (O&M) capacity.

The project will directly benefit approximately 2.5 million people living within the Odaw River Basin.

the other investment alternatives to be implemented. However, aiming for higher safety levels (T25 and T50) is justifiable from the perspective of maximizing welfare and minimizing risks (damage). From that standpoint, the highest-scoring option on the CBA and MCA was the "Safe at T25 B" option (baseline alternative + widening of Odaw drain and rebuilding of bridges + floodwalls + floodplain lowering at Korle Lagoon + widening of the outlet + wadis and nonstructural measures but no retention ponds). It is therefore recommended to create the necessary political space that enables an implementation of this T25 safety level for the Odaw Basin and addresses budgetary issues, land acquisition, and effective participation of the affected communities and stakeholders.

In the short term and within the context of GARID, the financing of structural and nonstructural measures—which have been outlined as the pilot investment plan—will be realized. Box 5.1 provides an overview of the investment plan, which was agreed upon in 2019 for the GARID project and will be implemented starting in 2020.

5.2.2 Next Steps

For the implementation of the abovementioned structural and nonstructural measures, several next steps need to be addressed.

Step 1: Completion of feasibility study and assessment of potential environmental and social impacts of the pilot investment plan. A technical feasibility study should be rolled out to plan, dimension, and design the different interventions; get a full cost estimate; and identify the O&M costs. Social and environmental impacts need to be studied in detail and fully understood and should be summarized in an independent environmental and social impact assessment (ESIA). The social and environmental issues to be assessed also include the following:

- *Number of people to be resettled* who live now on the borders of the planned retention ponds. Develop the necessary safeguard documents for resettlement.
- *Dam safety regulations* for the design and management of the retention ponds. These regulations should be in accordance with the dam regulations of the government of Ghana and the World Bank.
- *Potential health impacts* on the affected population. Retention ponds may have a negative impact on people's health if they turn into perfect breeding grounds for mosquitoes.

Step 2: Development of funding plan and agreements with donors and government. Based upon more in-depth cost estimations and funding options, a final funding plan is to be developed and agreed upon by potential donors and the government of Ghana.

Step 3: Development of detailed design and tender dossier. Detailed designs for the important measures should be drafted. A full tender dossier needs to be developed for works and services. It is advisable to include the services next to construction management and supervision. Part of this step would be to define an optimal procurement strategy for the components of the pilot investment plan (packages of works and services, equipment, timing, and so on).

Step 4: Procurement and contracting. The final step would be the implementation of procurement and contracting the key works, services, and supply contracts. Improving the flood protection of the Greater Accra Region does not stop after implementation of the pilot investment plan for the Odaw. In the next phases, additional measures will be considered to achieve a higher safety level for the Odaw Basin.

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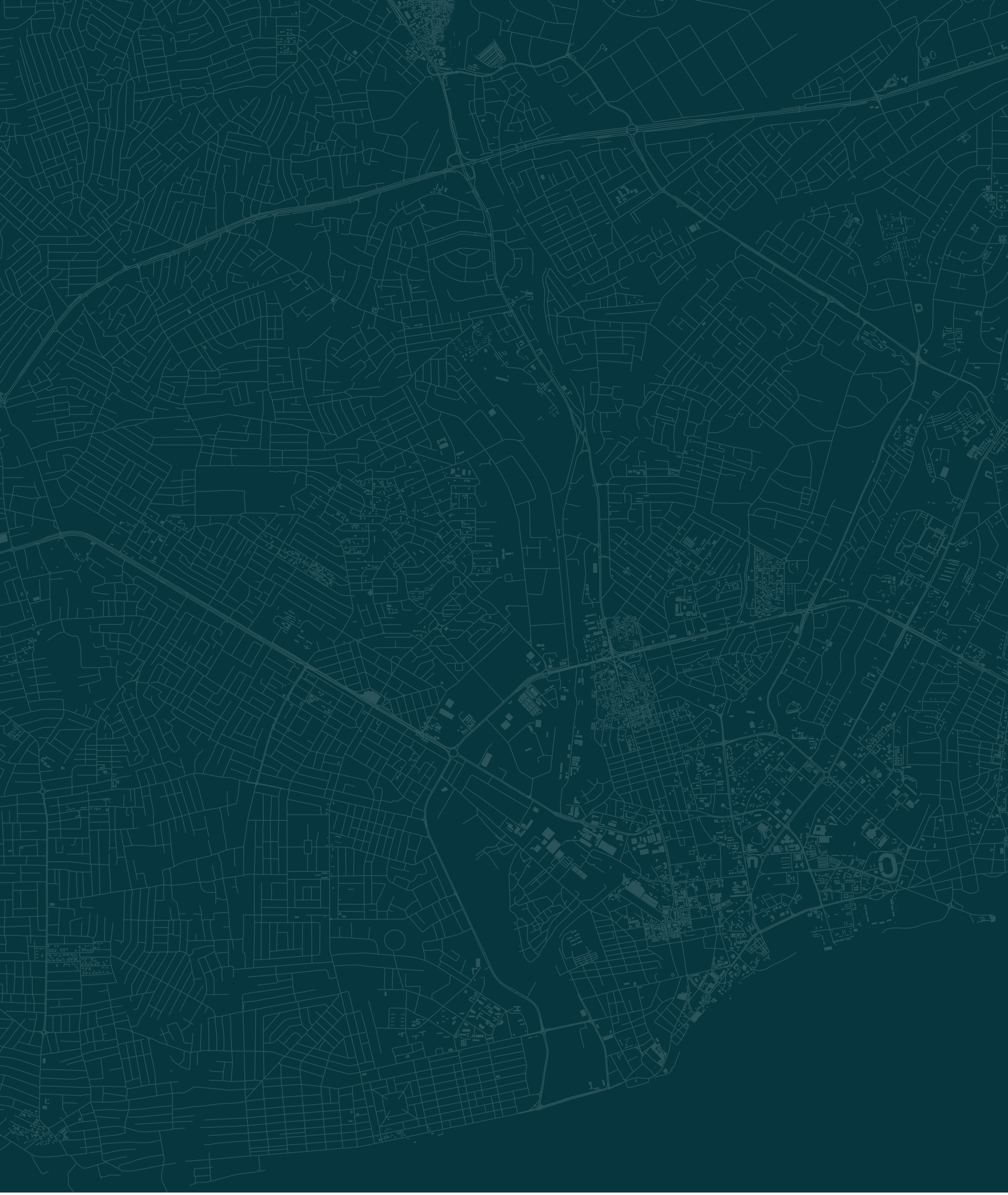

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