Connecting Delta Cities

RESILIENT CITIES AND
CLIMATE ADAPTATION STRATEGIES

RESILIENT CITIES AND
CLIMATE ADAPTATION STRATEGIES

Connecting Delta Cities

ARNOUD MOLENAAR, *City of Rotterdam*
JEROEN AERTS, *VU University Amsterdam*
PIET DIRCKE, *Rotterdam University of Applied Sciences*
MANDY IKERT, *C40 initiative*

Colophon

Authors
We would like to thank all the authors who contributed to this third CDC book and others that helped us to make this a success. In particular we would like to thank:

Corjan Gebraad (City of Rotterdam), Chantal Oudkerk Pool (City of Rotterdam), Daniel A. Zarrilli (Resiliency New York City), Philip Ward (VU University Amsterdam), Muh Aris Marfai (Faculty of Geography, Gadjah Mada University, Yogyakarta), Aisa Tobing (Jakarta Research Council), David Waggonner (Waggonner & Ball Architects), Cedric Grant (Vice Mayor of the City of New Orleans),Alex Nickson (Greater London Authority), Fedrick Y. F. Kan (Hong Kong Drainage Services Department), T. C. Lee (Hong Kong Observatory), Vincent S. C. Mak (Hong Kong Water Supplies Department), Yasumasa Kanai (Tokyo Metropolitan Government), Arata Ichihashi (Tokyo Metropolitan Government), Kanako Sakai (Tokyo Metropolitan Government), Nguyen Van Nga (Department of Natural Resources and Environment, Ho Chi Minh City), Steven Slabbers (Bosch Slabbers), Enrico Moens (Grontmij), Beth McLachlan (City of Melbourne), Lykke Leonardsen (City of Copenhagen), Eui-suk Hong (Environmental Capital Dept, City of Changwon) Kyung-hoon, Lee, (Environmental Capital Dept. City of Changwon), Mi-kyung, Moon (Environmental Capital Dept. City of Changwon), Rodrigo Rosa (City of Rio de Janeiro), Luciana Nery (City of Rio de Janeiro), Pedro Junqueira (City of Rio de Janeiro), Fabio Riva (Safeguarding Venice Department of the Venice Water Authority), Simone Tola (AGIRE - Venice Energy Agency), Paula Verhoeven (City of Rotterdam).

Sponsors
This book has been sponsored by the City of Rotterdam, the Rotterdam Climate Proof Initiative, the Dutch Partners for Water programme, VU University Amsterdam, Rotterdam University of Applied Sciences and ARCADIS. The CDC knowledge networks are suported by the FP7 ENHANCE, FP7 TURAS and FP7 RISES projects. The Connecting Delta Cities network has been addressed as a joint action under the C40 initiative, a group of the world's largest cities and a number of affiliated cities committed to taking action on climate change. For more information on these initiatives and their relation to Connecting Delta Cities, see: ***www.deltacities.com***.

Acknowledgements
We gratefully acknowledge the generous support and participation of Charles Allen III (City of New Orleans), Andy Sternad (Waggonner & Ball Architects), Ronald Siu (City of Hong Kong), Edwin S.C. Lau (City of Hong Kong), Annisa Triyanti (Faculty of Geography Universitas Gadjah Mada, Yogyakarta), Welmoed Visser (Grontmij), Stijn Koole (Bosch Slabbers), and the C40 team. We would also like to thank everyone who contributed in so many ways to make this third Connecting Delta Cities book a success. In particular we would like to thank, Maarten de Vries, Nicolien Wirschell, Rik Heikoop, Tanya Huizer, Nick Parrot (TextualHealing) and Marco van Bodegom (Beau-Design) for their support.

 ISBN 978-90-72498-00-7

Contents

Preface


A. Aboutaleb


M.R. Bloomberg

Cities around the world are on the front lines in the battle against climate change. Delta cities, however, confront a particularly urgent challenge, as Hurricanes Katrina (New Orleans) and Sandy (New York), the flash flood in Buenos Aires, the cloudburst in Copenhagen, and the annual flooding inundation in Ho Chi Minh and Jakarta have shown. Situated where rivers meet larger bodies of water, delta cities must safeguard urban populations and infrastructure from the potentially devastating impacts of climate change and severe weather, such as storm surge, flooding, and sea level rise.

These urgent challenges sparked the first conversations between Rotterdam and other megacities during a 2007 C40 Cities Climate Leadership Group meeting in Tokyo, leading to the formation of the C40 Connecting Delta Cities (CDC) network. Today there are ten global cities in the CDC network: Ho Chi Minh City, Hong Kong Jakarta, London, Melbourne, New Orleans, New York, Rotterdam, Copenhagen and Tokyo – all committed to sharing knowledge about policies, planning measures, and technologies that reduce the impact of climate risks.

The success of the CDC network has become a proof point for what is now an organizing principle of C40: the formation of working groups of cities focused on common challenges and opportunities. But CDC's success was not built overnight. The first step was for member cities to exchange information on our climate-related challenges – this was the focus of our first book, published in 2008. Next, we needed to identify and share best practices – the topic of our second book, published in 2010.

We are pleased now to present our third book, which features our member cities' climate adaptation strategies, and highlights the urban leaders, experts and professionals whose collaborations have been so essential in advancing urban action. Whether helping a city in crisis following an extreme weather event; working bilaterally to transfer specific knowledge; or together assessing the benefits and limits of grey or green infrastructure responses and stakeholder engagement approaches and tools, the CDC network is about pioneering solutions – collaboratively. Together, we have made great strides in tackling the unique set of issues delta cities face and have forged strong bonds among city officials throughout the world. These bonds have also underscored the shared mission of all C40 leaders to take actions locally that can have impacts globally.

On behalf of all CDC network mayors, we hope that readers of this book will find ideas to borrow – as well as cause for hope that, whatever the climate risks we face, cities are building a foundation of preparedness that will serve their populations for generations to come.

A. Aboutaleb
Mayor of Rotterdam,
The Netherlands

M.R. Bloomberg
Mayor of New York City,
USA

1

Delta cities in times of global changes

by Arnoud Molenaar, Jeroen Aerts, Piet Dircke, Mandy Ikert

1 Introduction

Recent projections show that by the middle of this century, the majority of the world's population will live in low-lying cities in or near deltas, flood plains or coastal zones, resulting in even more people living in highly exposed areas. Such socioeconomic trends, combined with ongoing subsidence in most deltas, further amplify the possible consequences of future floods and other extreme climatic events, as more people move towards urban delta areas and capital is continuously invested in ports, industrial centres and financial businesses in flood-prone areas.[1,2]

In August 2013 the World Bank published the report 'Future flood losses in major coastal cities'. It states that average global flood losses in 2005 are estimated to have reached approximately US$6 billion per year, increasing to US$52 billion by 2050 with projected socioeconomic change alone. And taking climate change and land subsidence into account, present protection will need to be upgraded to avoid unacceptable losses of US$1 trillion or more per year.

In September 2013 the IPCC launched their fifth global climate report 'Climate Change 2013: The Physical Science Basis'. One of the main conclusions of the report is that continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. This century the sea level will keep on rising and the contrast in precipitation between wet and dry regions and between wet and dry seasons will increase. According to the IPCC, extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this century.

Furthermore, the IPCC expects that the frequency, intensity and duration of extreme precipitation events will increase, as well as the frequency and duration of droughts. At the same time, many delta cities suffer from severe land subsidence. As a consequence of these urban developments, and projections for land subsidence and climate change, the vulnerability of our delta cities is expected to increase in the decades to come.

All this may well be the future scenario, but climate change is already occurring, with extreme events happening more frequently and cities already facing flood losses. New Orleans, New York, Bangkok, Manila, Jakarta and many others all faced severe flooding, losses and damage in recent years. The current climate risks and the projected increase in climate risk and other trends create an urgency for cities to act. Hence, the question is no longer if delta cities should act, but when and how delta cities should act and invest in adaptation and flood protection. It is for this reason that in 2008 several delta cities joined forces and, initiated by the City of Rotterdam, set up the network called Connecting Delta Cities (CDC).

Connecting Delta Cities (CDC)

CDC is a sub network within the framework of the C40 Cities Climate Leadership Group (C40), a network of the world's mega cities committed to addressing climate change. C40 was created in 2005 by former Mayor of London Ken Livingstone, and forged a partnership in 2006 with the Cities Programme of President Clinton's Climate Initiative (CCI). Sharing knowledge and working together on adaptation to climate change is what these cities practise within the CDC-network. Cities play an important role in the climate adaptation process since they have already developed the ability to adapt continuously to change and attract economic activity and investment. One could say cities have already been adapting to changing conditions for many years or even centuries, and climate change is an additional challenge that needs to be addressed in cities' planning, investments and regulations. With the CDC network, the member cities have shown for five years now leadership in the field of adaptation to climate change. More about the CDC network, its ambitions, goals and action plan can be found in chapter 2.

1.2 Connecting Delta Cities - Book part III

This book explores the different aspects of climate adaptation in delta cities with a special focus on the climate adaptation strategies contributing to the resiliency of delta cities. It gives an overview of comparable adaptation challenges, strategies and progress in implementation and investments in the 10 Connecting Delta Cities (CDC) cities - Rotterdam, New York, Jakarta, London, New Orleans, Hong Kong, Tokyo, Ho Chi Minh City, Melbourne and Copenhagen. Three potential new members are also introduced: Changwon, Rio de Janeiro and Venice.

The book is the third in a series of CDC books (Figure 1.1). The first CDC book, launched during the Henry Hudson 400 celebrations in New York, was published in 2009 and described climate adaptation challenges in New York, Rotterdam and Jakarta. The second CDC book was launched at the international conference, Deltas in Times of Climate Change, in 2010 in Rotterdam. This second edition described the best practices in the eight CDC cities at that time - Rotterdam, New York, Jakarta, London, New Orleans, Hong Kong, Tokyo and Ho Chi Minh City. The Connecting Delta Cities network used this second book to focus on the best practices of urban climate adaptation and the experiences and lessons learned of coastal cities on the topic of climate adaptation and flood risk. While cities will follow adaptation paths that may differ, sometimes substantially, each city can learn from other cities. Moreover, while the second book focused largely on coastal flooding, it is important to note that each of the CDC cities is also affected by climate change in other ways, including impacts that occur away from the coast.

Figure 1.1 The first (above) and second (left) Connecting Delta Cities Book.

1.3 Climate Adaptation Strategies

Figure 1.2 Community involvement.

The series of CDC books give an interesting overview of the development of the CDC network and the progress delta cities have made for developing and implementing adaptation (-pathways). This third book describes state-of-the-art urban climate adaptation, as these cities are the leading cities in this field.
All connected delta cities somehow succeeded in addressing climate adaptation and getting it on the political agenda. In addition, most cities have started to take action by implementing no- and low-regret measures. And, in the meantime, a lot of research has been done. Now, most cities have reached the phase that they have developed a knowledge-based Climate Adaptation Strategy (CAS).

Adaptation strategies are needed at all levels of administration: at the local, regional, national, continental and also the international level. These strategies serve as important framework for governments to promote greater coordination and information sharing between stakeholders. They give a comprehensive overview of climate effects, vulnerabilities, risks, and solutions. Moreover, cities can use their Climate Adaptation Strategies to create commitment and to develop well-founded applications for financial support by (international) financial institutes.

While the CDC cities' strategies differ from one to another and are tailor made, they all roughly consist of the same ingredients, such as: an overview of climate changes and local effects, risk assessments, vulnerability maps, adaptation pathways, short-term measures and long-term solution directions. Ideally,

Figure 1.3 Often the city's poor live in the vulnerable areas.

a CAS is supported by tools like a social cost-benefit analysis, an information system and monitoring plans. A CAS is not the end of a process, but an important marking point in the process of adapting to climate change and the beginning of a dialogue with stakeholders and a strong base for new coalitions. The role of stakeholders in the development and implementation of adaptation measures is a key ingredient. A participative approach ensures that stakeholders can express their objectives, concerns and visions, and stimulates the development and implementation of innovative ideas in the adaptation process.

Community resilience and adaptation

In this third CDC book, the cities give an insight into their stage of developing a climate adaptation strategy. Their best practices are described and also knowledge gaps are addressed. A prominent topic on the agendas of the delta cities nowadays is community resilience. As climate change often effects the vulnerable and poor, the most focused attention should be paid to improve their resiliency and get the adaptation plans connected to the people and local communities involved by raising awareness, improving communication and facilitating communities to act autonomously. Often the city's poor live in the most vulnerable areas (Figure 1.3) and potentially are most affected by natural hazards related to flooding and heat. Additionally these groups are most vulnerable to increase in housing costs, caused by rising energy prices, in combination with the economic crisis. This is why adaptation to climate change cannot be seen separate from social resiliency. Urban adaptation is strongly related to social adaptation.

Adaptation and financing

Many delta cities are gradually taking on the issue of climate adaptation and there is a growing interest in sharing and exchanging experience and knowledge between cities. Since the choices made today will influence vulnerability to climate risks in the future, it is important to link adaptation measures to ongoing investments in infrastructure and spatial planning, and to draw up detailed estimates of the benefits of adaptation. In this way, adaptation becomes a challenge rather than a threat, and climate adaptation may initiate opportunities and innovations for investors and spatial planners. Due to the economic crisis right now there is a growing need for new investors and new financial arrangements. This is the second new topic on the agenda of the connecting delta cities network.

Green adaptation

A third upcoming topic is the so-called 'green adaptation'. Several cities have incorporated different types of green measures as an important part of their adaptation strategies. Most delta cities are now highly urbanised and densely populated areas, while in the early day's marshes and mangroves were often part of the system and contributed to the resiliency of deltas and delta cities. These natural climate buffers gradually disappeared during the urbanisation of these delta cities. Now these ecosystem services are rediscovered as essential elements in building resilient cities and to serve the green growth of our delta cities.

by Chantal Oudkerk Pool, Mandy Ikert, Arnoud Molenaar

Introduction

1

2

The Connecting Delta Cities network of C40 cities brings together delta and coastal cities that are active in the field of climate-change related spatial development, water management and adaptation, in order to exchange knowledge on climate adaptation and share best practices that can support cities in developing and implementing their adaptation strategies.

History

Offering a confluence of agriculturally rich fluvial flood plains and port shipping opportunity, deltas have always been historically strategic centres of commerce and trade. Today, delta cities continue as hubs of economic and cultural activity while also now serving as home to many millions of people across the globe. Urban ports are more and more often displaced, allowing for redevelopment of once centrally located docklands, further increasing population densities. These great opportunities are also the root of the challenges facing delta cities. The combination of coastal and riverside location paired with extremely high densities of people and assets make delta cities vulnerable to extreme weather events and sea level rise, and consequently very vulnerable to climate change.

The Connecting Delta Cities (CDC) network was founded in 2008 when the world's leading cities gathered in Tokyo for a C40 workshop on climate change adaptation. In response to a call to action from Tokyo, Rotterdam took the initiative to form and lead this network, because, -having just started the ambitious Rotterdam Climate Proof programme, it saw great opportunities in sharing experiences with other delta cities facing similar climate-change related challenges. Rotterdam sought partners in delta cities that showed leadership in climate change adaptation and water management, in order to exchange knowledge on climate adaptation and share best practices that can support cities in developing and implementing their adaptation strategies.

CDC today

Since its foundation, much knowledge has been

Figure 2.1 Roofpark opening, Rotterdam July 2013.

gained and exchanged between the cities. The effects of climate change have become clearer and many cities have made progress in the development of a climate adaptation strategy or have even moved to the next phase: implementation.

In the meantime, climate adaptation has climbed up political agendas. CDC cities have raised awareness among regional and national government bodies and international institutions. They have stressed that, in addition to the relatively abstract regional and national policies, practical solutions at local level are required. Moreover, they have reminded policymakers to take into account the characteristics and particular needs of highly vulnerable delta cities. Together, CDC cities have a stronger voice.

CDC cities in international media

CDC cities' leadership in climate change adaptation is increasingly recognised and showcased in international media, which helps raise awareness among policymakers, decision makers and other important stakeholders all around the world. To mention a few examples:

- CNN item in November 2012 highlighting Tokyo's giant water-discharge tunnels that protect Tokyo from flood threat.[5]
- CNN item featuring mayor Bloomberg of New York City "Why Sandy forced cities to take lead on climate change" in which he states that "Mayors are pragmatists, not partisans; innovators, not ideologues. We are responsible for delivering results, not debating politics. And as the world becomes increasingly more urban, the importance of bold local action – particularly on climate change – will continue to grow.[3]
- National Geographic's September 2013 issue on Rising Seas featuring Rotterdam's approach and solutions to protect the city from sea level rise and ways of living with water.[4]

The CDC network is constantly evolving based on such developments. Presently most member cities already have – or are in the process of developing – a local coalition that can be divided into three layers. Since the CDC network is carried by local governments, the core of each member consists of government contacts. The second layer consists of knowledge institutes that provide the cities with the latest insights on the local effects of climate change, possible measures and its effectiveness. The third layer is formed by the private sector, both consultancies and private parties that help the cities in becoming resilient. The local city contacts can help their partners in the second and third layer connect and cooperate with their counterparts in other member cities.

The CDC network currently consists of ten cities: Copenhagen, Ho Chi Minh City, Hong Kong, Jakarta, London, Melbourne, New Orleans, New York, Rotterdam and Tokyo. Together, these cities constitute the CDC board. The CDC secretariat is based in Rotterdam (hosted by the Rotterdam Climate Proof programme).

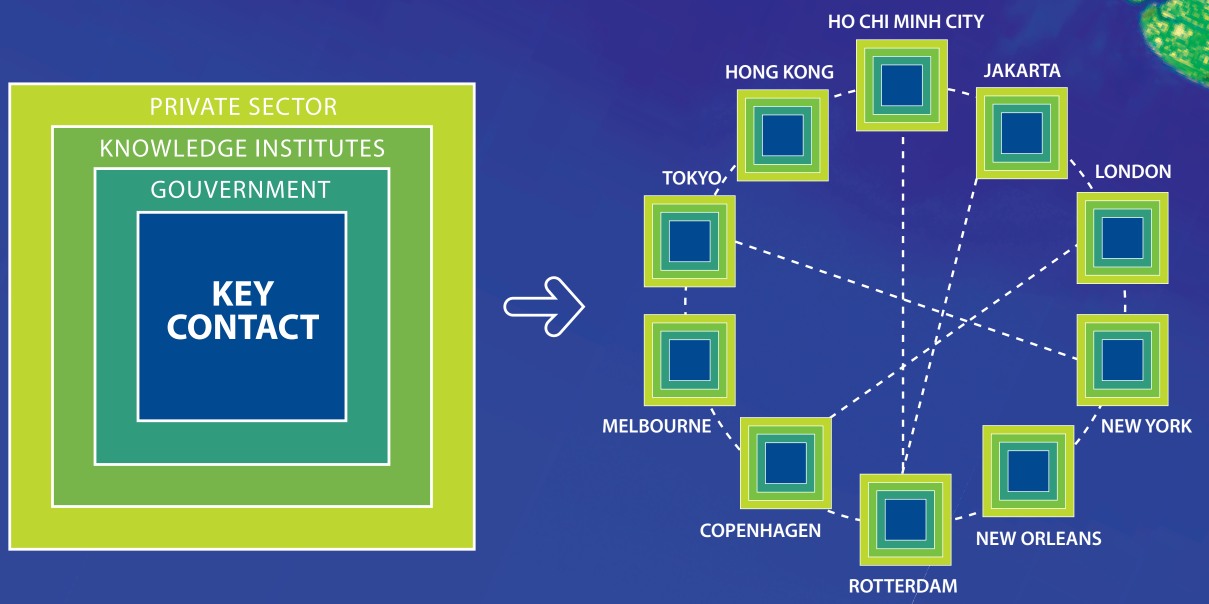


Figure 2.2 CDC Board members. Each city has its own network of partners or coalition with knowledge institutes and the private sector.

Development of the CDC network

2

For the network itself there have also been developments. New cities have shown interest in CDC, new topics have come up, new partners have shown interest in cooperating with CDC, such as non-governmental organisations, international financial institutions and knowledge institutes, and new C40 networks on adaptation have emerged. Melbourne and Copenhagen enriched the CDC network in 2012 and joined the CDC board. CDC members can learn from these two cities especially because of their experiences about respectively heat stress and cloudbursts. More and more cities have expressed interest in participating in the network. The CDC board decided in June 2013 to allow the network to grow and create a wider community for knowledge exchange. New members are able to join the network and participate in CDC activities, and the board will be the steering body of the network.

Figure 2.3 The current cities of the CDC initiative (orange: CDC board members and yellow potential members).

Potential near future members are: Changwon, Rio de Janeiro, Venice, Singapore, Vancouver, Dhaka, Buenos Aires, Shanghai, Mumbai and Bangkok. The world map shows the current situation of the CDC-network (Figure 2.3). So, in just five years the CDC grew from a joint action of a few delta cities, to a network comprised of a directing board of ten cities with another ten cities expressing interest to join. The C40 organisation is also strongly encouraging this network to continue and expand its activities, and in early 2013 started to facilitate the network with support of a C40 director on adaptation and water.
In chapter 13, Rio de Janeiro, Venice and Changwon present their work on climate change adaptation, enriching the book with topics such as community resilience, world heritage and measures to prevent flooding from typhoons.

Figure 2.4 The new CDC website allows easier searches and knowledge exchange.

Working method
City officials and staff are already very busy, many support networks and initiatives exist, and therefore CDC wants to create an efficient way of operating. Hence it follows a 'minimum effort maximum results' approach, by providing easy access to the latest information on the website www.deltacities.com, through an online C40 exchange portal, and by linking to larger international conferences that target member cities as much as possible. C40 events in particular are ideal places to meet and exchange the latest news on adaptation.

The main activities are:

1. Knowledge exchange
Initiating symposia, workshops, student exchanges, and meetings where students, scientists, engineers and policymakers can exchange expertise and ideas.

2. Documentation
Supporting the publication of reports, films, publications and books on climate adaptation in delta cities.

3. Project support
Mobilising experts for projects and support the development of projects and proposals relating to climate adaptation research and implementation.

Examples of CDC network activities
Since the release of the second CDC book a wide variety of activities have taken place. *To mention a few:*
2010: Deltas in times of Climate Change conference organised by the Dutch Knowledge for Climate Programme and the City of Rotterdam: 1,200

visitors from around the world participated in this international conference at the interface of science and practice. It included 30 workshops tailored to policymakers and practitioners, showcasing best practices from CDC member cities. Almost all CDC cities attended, plus other C40 cities such as Johannesburg and Dhaka.
2011: World summit Jakarta: organised by the Indonesian Institute of Sciences (LIPI) and Delta Alliance Indonesia Wing enabled participants to share a common but differentiated responsibility on securing the deltas' functionality for our survivability and address the challenges and create new opportunities as well while reducing the disaster risks and properly alleviating the poverty under the changing climate.[6]
2012: Brand new website which allows for easier search by city or topic.
2013: Workshop on climate adaptation strategies and risk assessment in which 23 C40 cities shared their experiences of barriers and solutions to common challenges. The three-day workshop was hosted by Rotterdam and the CDC network discussions were

Figure 2.5 Three-day workshop in Rotterdam, 2013.

focused on adaptation strategies, grey and green infrastructure for flood management, and lessons learned from extreme weather events.
2014: Deltas in Times of Climate Change II: an international conference at the interface of science and practice, focussing on the implementation of climate adaptation strategies and measures and related issues such as mainstreaming, costs and benefits of adaptation, financing and innovations.

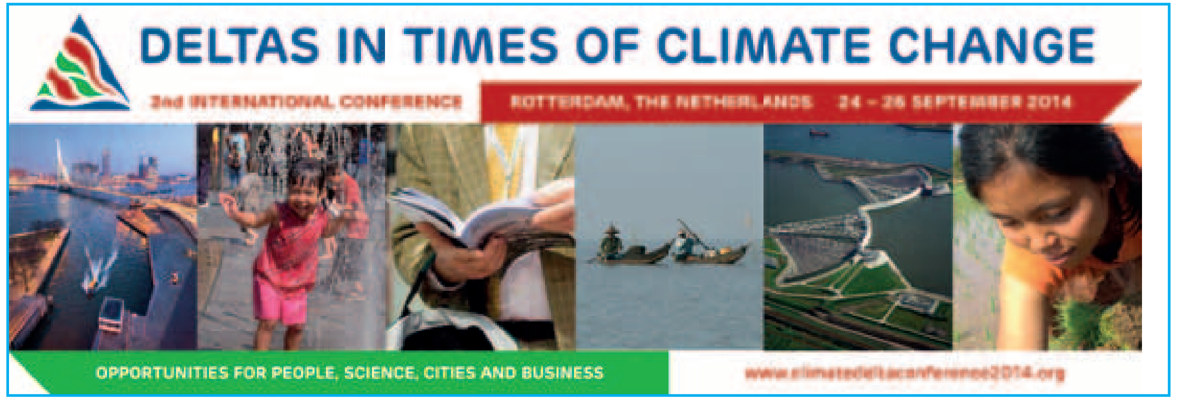


Figure 2.6 Delta in Times of Climate Change II will combine practice and science.

Examples of cooperation between CDC cities

Ho Chi Minh City & Rotterdam
The cooperation on adaptation between the two cities started of with the signing of a Letter of Intent in 2009. Ever since, cooperation intensified with a major milestone in 2013: the launch of the Climate Change Adaptation Strategy (CAS) for Ho Chi Minh City. Chapter 10 will elaborate more on the process and contents of this strategy. The next phase in this partnership focuses on capacity building and raising awareness of all stakeholders that are key to an adaptive Ho Chi Minh City, including the private sector. The partnership is funded by the Partners for Water programme of the Dutch government in the framework of its Global Water Programme.

Figure 2.7 The signing ceremony CAS launch Ho Chi Minh City.

Cooperation in EU-funded projects
CDC and C40 cities also jointly apply for and participate in climate change adaptation projects that are funded by the European Union. For example, Rotterdam and London participate in the FP7 TURAS project for increasing flood risk resilience. London, New York and Rio participate in the RAMSES project that aims to develop new concepts for damage and adaptation cost assessment for European agglomerations and cities abroad.[7] London, Rotterdam and Paris cooperate in RainGain, a transnational project aimed at improving the prediction of pluvial floods in our cities, developing and testing innovative tools and practices based on the use of high resolution radars in the pilots.[8] The three aforementioned cities and Berlin also cooperate in the Blue Green Dream. This project aims to enhance the synergy of urban blue (water) and green (vegetated) systems and provide effective, multifunctional blue-green adaptation solutions.[9]

Other bilateral cooperation and meetings
On a smaller scale, cities directly contact each other for specific queries. Moreover, cities organise city tours and presentations for incoming delegations from partner cities, highlighting flood management, green infrastructure and adaptation interventions.

The C40 umbrella
In 2013, C40 formally established a Water and Adaptation Initiative to expand its support to member cities in these areas from its original focus on greenhouse gas reduction and climate change mitigation. In addition to supporting the continued growth of CDC, C40 has recently launched complimentary new adaptation networks specifically

focused on heat vulnerability and climate risk assessment. CDC is working in close alignment with these new networks and serves as a model for their development and as an incubator for new topics. For example, CDC hosted the first brainstorming session for the climate risk assessment network. A number of cities within CDC also participate in this new network (and also the Cool Cities network), ensuring transfer of best practices in city-to-city cooperation even wider than the delta city context.

Future Topics

So far, CDC has focused on climate change challenges, best practices and Climate Adaptation Strategies (CAS). In the Rotterdam meeting in June 2013 new potential CDC topics were discussed. The prioritised topics additional to the three topics mentioned in

chapter 1 – community resilience, financing adaptation and green adaptation – are also: implementation of CAS, green and grey adaptation solutions and urban design and planning. CDC activities will focus on these topics in the next few years. In chapter 13 'Future Outlook' some of these topics are addressed more explicitly and especially the development of the so-called knowledge-to-knowledge layer is worked out in more detail.

Other topics that were mentioned and will be kept in mind for webinars, meetings and workshops are: infrastructure resilience; environmental risks: port related vulnerabilities; world heritage and adaptation to salinisation.

Rotterdam

3

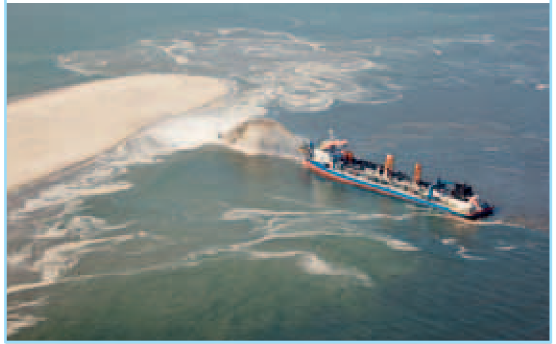
by Arnoud Molenaar, Piet Dircke, Corjan Gebraad

Introduction

3.1

Rotterdam, often known as the Gateway to Europe, is a port city of international stature, located just in the heart of the Dutch delta. It is Europe's largest port and offers inland shipping links that stretch to Germany, Switzerland and France. With a population of just over 600,000 it is the second largest city in the Netherlands. Nearly 80 percent of the city lies below sea level (some parts by up to 6 m). The city and the surrounding region (known as Rijnmond) are protected from the sea by a complex and extensive system of dikes, closure dams and storm surge barriers, all part of the famous Dutch Delta Plan. In May 2013, the seaward port extension called 'Maasvlakte 2' was officially opened, adding another 20 percent to the port area that now stretches out over a length of 40 km.

Figure 3.1 Map of Rotterdam.



3.2

The Adaptation Programme ‘Rotterdam Climate Proof’

Within the Rotterdam Climate Initiative, Rotterdam addresses the entire field of climate change, both reducing the causes of climate change (mitigation) and adaptation. Its adaptation programme, Rotterdam Climate Proof (RCP), was launched in 2008 and aims to ensure that Rotterdam is fully climate resilient by the year 2025.[10]

The approach adopted in Rotterdam’s adaptation strategy is that of ‘connecting water and adaptation with opportunities’. In practical terms this involves applying innovative solutions that enhance the safety and the quality of life in the city while, at the same time, offering substantial economic potential for the entire region. The programme is based on three pillars: **(1)** knowledge; **(2)** implementation; and **(3)** exposure and spin-off.

Knowledge
Rotterdam is able to draw on specific knowledge generated through the national Knowledge for Climate Research Programme. Crucial knowledge about regional and national flood risk management has been (and continues to be) developed through the National Delta Programme and its regional sub-programme, ‘Rijnmond Drechtsteden’, which is chaired by the Mayor of Rotterdam.[11]

On an international level, Rotterdam established the Connecting Delta Cities (CDC) network to share knowledge, experiences and best practices. This third CDC book is just one example of this process of knowledge sharing.

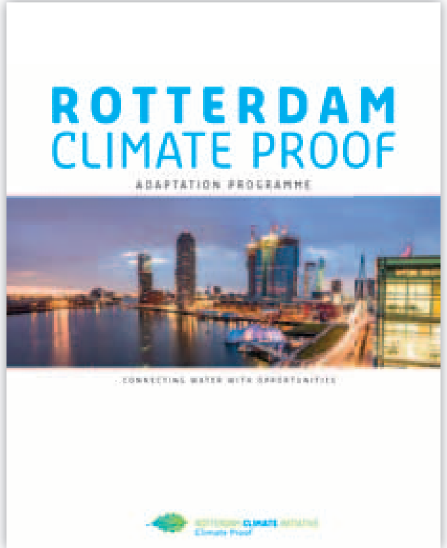


Figure 3.2 Rotterdam Climate Proof adaptation programme.

Implementation
Rotterdam develops innovations and knowledge and applies these in practice. In recent years several innovative pilot schemes have been implemented including: water squares, underground water storage below a car parking garage, a rowing course annex water storage and a floating pavilion.

Exposure and spin-off
Rotterdam’s leading position in this field is now creating new alliances and programmes, which further support the implementation of tsshe climate adaptation strategy. Additionally Rotterdam’s reputation also brings new projects for knowledge institutes, consultancies and other knowledge-driven businesses in the region, creating high quality jobs and attracting motivated and talented students.

Challenges

3

3

The water in Rotterdam comes from four sides: the sea, river, sky (precipitation) and from below (ground water). For this reason Rotterdam, like many other delta cities, is vulnerable to the consequences of climate change in many ways.

Rising sea levels and changing river discharges
With higher sea and river levels, the risk and frequency of flooding in the outer-dike areas of Rotterdam will increase, as will depth of flood inundations. Figures 3.4a and 3.4b illustrate the predicted flooding of outer-dike Rotterdam in 2015 and 2100 (W+) with a probability of 1 in 1,000 years. A scenario of extreme climate change (W+), with rises in sea level of 85 cm would mean that, by 2100, the City Harbours and some post-war harbour areas would join the already vulnerable outer-dike areas in the heart of the city, such as Noordereiland, in being susceptible to flooding. Even if sea levels rise by 60 cm, the frequency of flooding in these areas will increase from once every 50 years to an average of once every year.

Flooding of the outer-dike areas in Rotterdam can cause considerable damage in the affected areas. The disruption of business activities and services as well as the temporary inaccessibility of the area will cause economic losses. Yet it is very unlikely that casualties will occur as a direct result of flooding of outer-dike Rotterdam. The river zone area has a relatively high elevation (Figure 3.3) and this will limit the floodwater flow rates and flood depths during periods of flooding. However vital infrastructure within the outer-dike areas, such as power stations, electricity

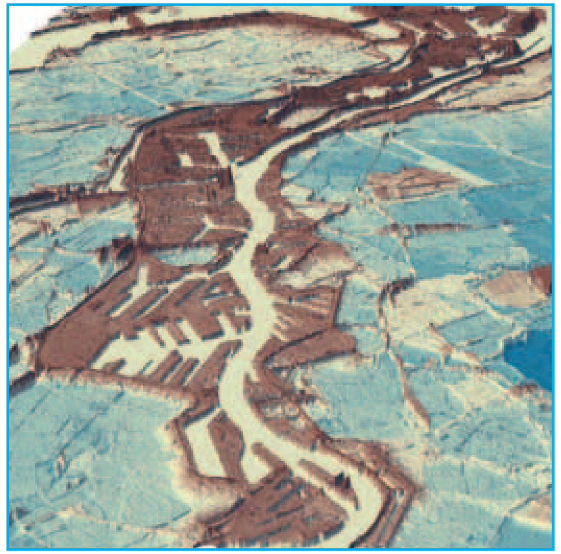


Figure 3.3 Rotterdam 3D elevation model: the inner-dike areas (blue) are below sea level. The river zone area (outer-dike area: brown) is above sea level.

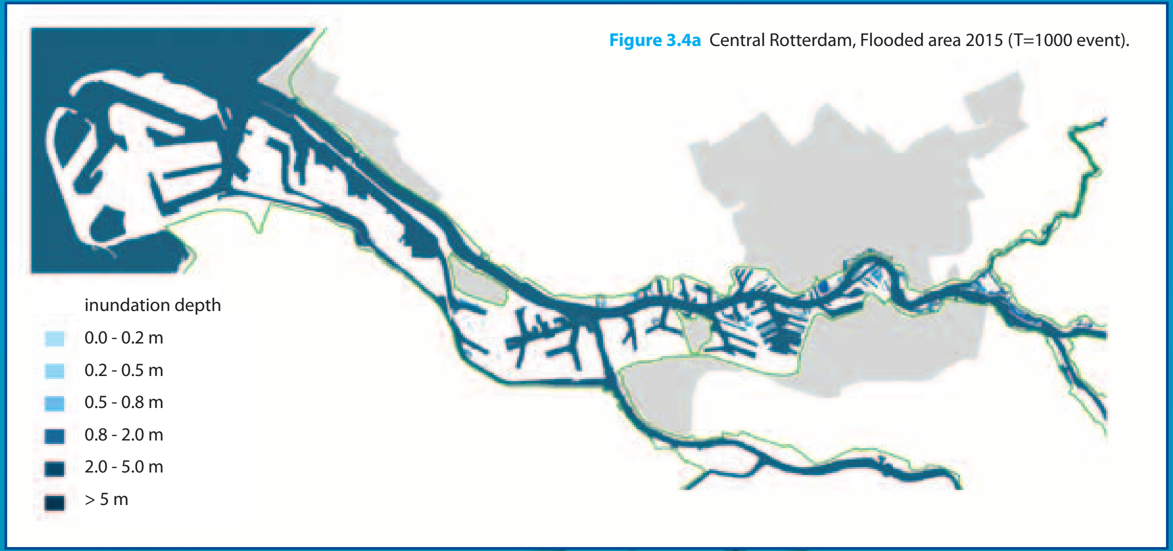


Figure 3.4a Central Rotterdam, Flooded area 2015 (T=1000 event).

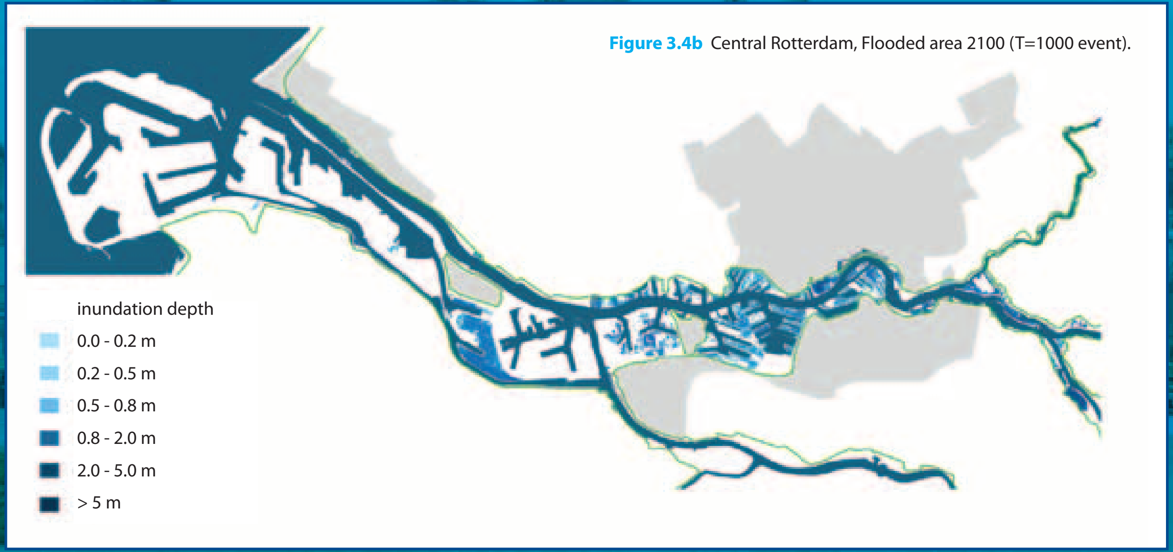


Figure 3.4b Central Rotterdam, Flooded area 2100 (T=1000 event).

Figure 3.5 The Maeslant Storm Surge Barrier.

supplies, water purification plants, motorways, major roads, railways, the gas distribution network, sewers and ICT facilities will be vulnerable. In Rotterdam, the level of protection for the inner-dike areas (the polders) varies from an average of 1:4,000 years in the south of Rotterdam (dike ring 17) to an average of 1:10,000 years for the North Bank (dike ring 14).

Rising sea levels and increased variations in river flows will lead to an increased frequency of high river levels. If no measures are taken, the risk of inner-dike Rotterdam flooding will increase. Rising water levels will also mean that the Maeslant storm surge barrier (see Figure 3.5) will have to close more frequently. This barrier is designed to cope with rises in sea level of up to 50 cm. In the extreme climate change scenario (W+), the barrier will be able to fulfil its function until about 2070, after which it will need to be upgraded. If no measures are taken, sections of the dikes will not be high enough in both the scenarios W+ and G (sea level rise 15-to-35 cm). In scenario W+, by 2100 the areas susceptible to flooding will extend to Merwe-Vierhavens, the Maasboulevard and the City of Hoek van Holland.

Changing rainfall patterns

During extreme rainfall, the vulnerability of the drainage system becomes apparent. Peak downpours are already causing disruption and damage as water floods the streets, cellars become inundated and sewer overflows discharge directly into the canals and waterways. In recent years the city has made extra room for water, both within the robust system (for example, the underground water storage facility under the Museum Park) and also in additional surface water, as in Zuiderpark. Climate change is expected to cause these downpours to not only become more frequent but also more intensive. The Royal Dutch Meteorological Institute (KNMI) has calculated that for each degree centigrade rise in temperature, the average intensity of the rainfall will increase by 14 percent. The probability of flooding is increased by the fact that the low-lying peat on which many areas of Rotterdam are built is still settling and compacting. This problem will increase as a result of climate change because longer periods of drought are likely to occur and this will increase subsidence and destabilise and weaken dikes.[12]

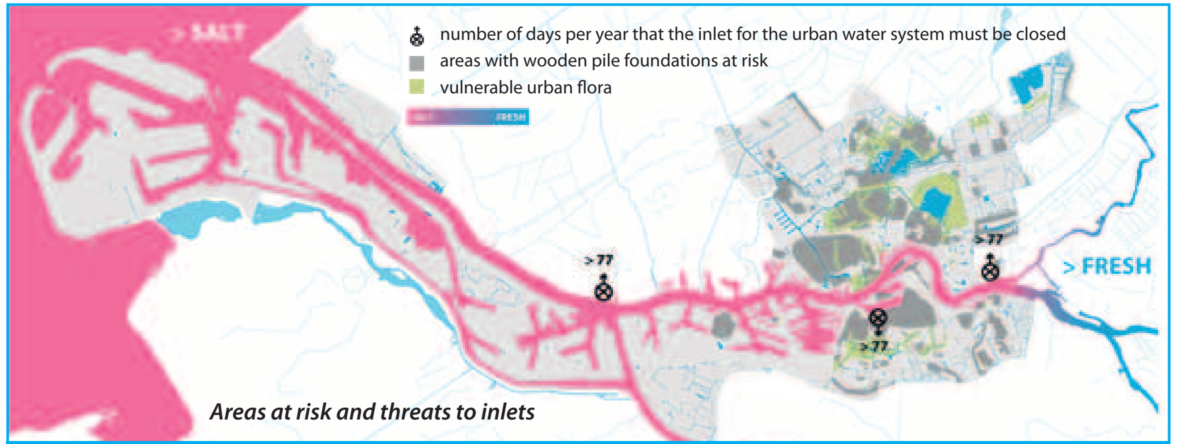
Drought

As a result of climate change, longer periods of drought and shortages of rainfall will also occur more frequently, especially in the W+ scenario. One direct effect of this is that drought will lead to a groundwater deficit and lower water tables. A second consequence is that longer dry periods in the river catchment areas will lead to lower river levels. The drying up of the sub-soil in certain areas will lead to further compacting and subsidence. Subsidence and lower groundwater levels in turn also pose a threat to buildings on wooden pile foundations. A further direct result of lower river levels will be the increase of salt intrusion (Figure 3.6) This will have an impact on drinking water supplies and the ecology of the river. Finally, the lower river levels will obstruct shipping as the navigable depths decrease.

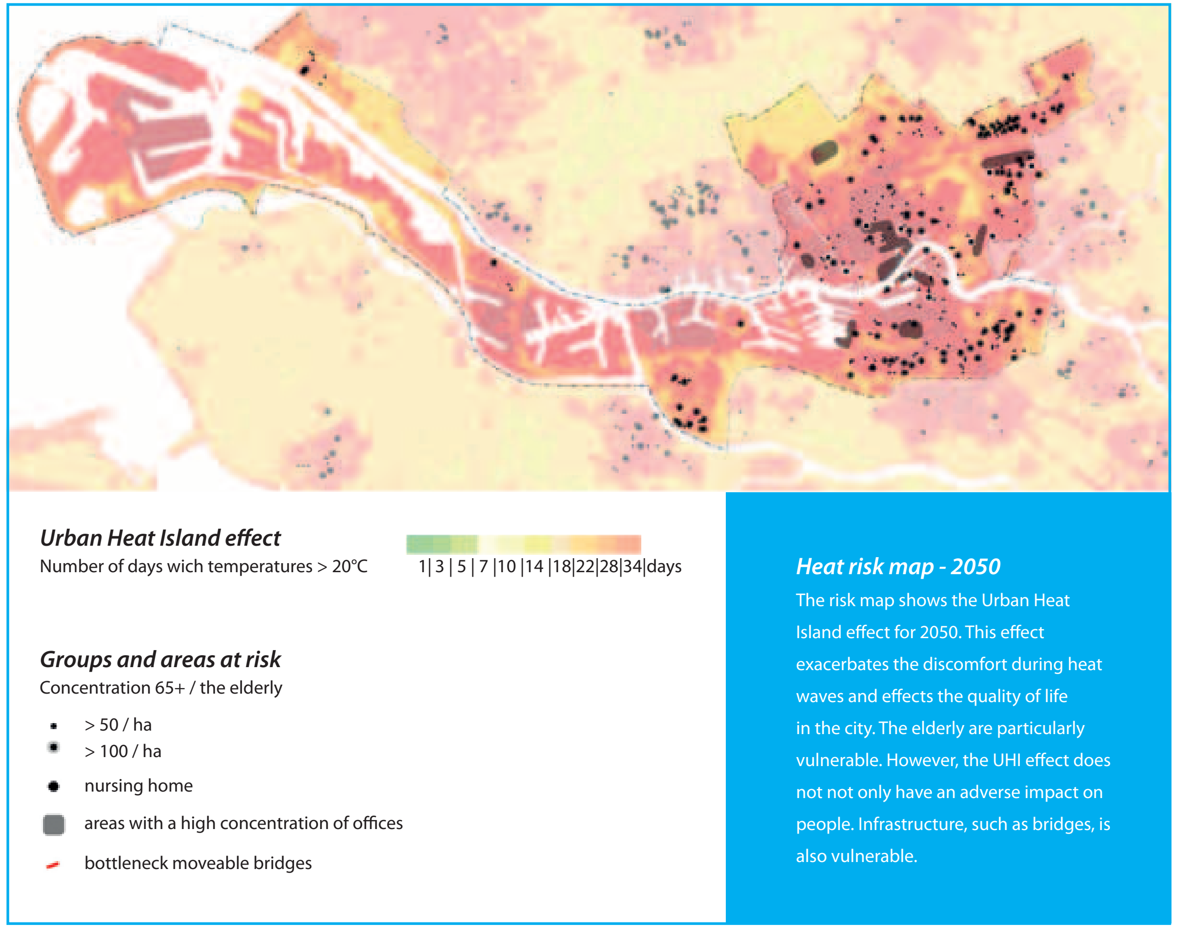
Heat Stress

Climate change will also increase the number of tropical days (hotter than 30 °C) and the likelihood of heatwaves. These changes will be magnified by the Urban Heat Island (UHI) effect. The difference in temperature between the city centre and surrounding countryside can be as high as 8 °C. Measurements have shown that the coolest areas of Rotterdam are those districts with low buildings and plenty of vegetation. The warmest areas are the city centre, the urban districts directly neighbouring it and the industrial areas. The combination of the UHI effect together with a warmer climate is likely to have an impact on the city and its inhabitants. The UHI effect exacerbates discomfort during heatwaves. The elderly and people suffering from respiratory diseases are the most

Figure 3.6 Saltwater intrusion in 2050 (W+ climate scenario).



Drought risk map - 2050 The risk map depicts the salt water intrusion in 2050 (W+climate scenario). During long periods of drought, when river levels are low, the salt water will intrude further and further into the delta. This can cause problems for freshwater inlets, wooden pile foundations, water quality and urban flora.



Heat risk map - 2050

The risk map shows the Urban Heat Island effect for 2050. This effect exacerbates the discomfort during heat waves and effects the quality of life in the city. The elderly are particularly vulnerable. However, the UHI effect does not not only have an adverse impact on people. Infrastructure, such as bridges, is also vulnerable.

Figure 3.7 Risk map showing the Urban Heat Island effect for 2050.

vulnerable groups and there is a significant increase in mortality rates among these groups during heatwaves, partly due to heat stress, but partly to poorer air quality. Malfunctioning of essential structures in the road network, such as bridges not opening or closing properly due to heat stress or melting asphalt on major roads, can disrupt the traffic in the city and damage the economy.

4

3

Rotterdam's Climate Change Adaptation Strategy

The challenges that Rotterdam faces as a result of climate change are not acutely critical. The city does have enough time to adjust to and evolve with the 'delta dynamics'. It should be able to adapt to the effects of a changing climate on a changing urban environment. These are the basic pillars of Rotterdam's Climate Change Adaptation Strategy[13]:

1. Rotterdam can continue to rely on the current robust system, which consists of storm surge barriers and dikes, of canals and lakes, outlets, sewers and pumping stations. The City Government will continue to keep this system in good shape, to maintain it and to improve it where necessary.

2. This, however, is not enough. Rotterdam has to adapt by introducing additional measures across the entire city. This will generally involve a wide-scale application of small-scale measures. With new measures in the public and private area and on top of buildings an additional 'layer' of measures will be added to the more traditional solutions related to the sewer system.

3. These measures need to be done together with new partners and stakeholders and to be linked with projects and maintenance programmes.

4. All measures should generate added value to the living environment, communities, economy and ecology. Wherever possible these measures should involve ecologically sound solutions.

Figure 3.8 The Rotterdam Climate Change Adaptation Strategy scheme.

The following objectives have been set and are to be met through the Climate Change Adaptation Strategy:

- The city and the port are protected against flooding;
- Rotterdam is a comfortable, liveable and attractive city;
- Rotterdam is an accessible port city, facing minimal risk of disruption;
- The city and its residents are affected as little as possible by a lack, or surplus, of precipitation;
- The residents of Rotterdam are aware of the consequences of climate change and of what they can do themselves to adapt to them;
- Climate adaptation strengthens the city economically and enhances its strong delta city image;

In densely built-up urban areas there is a lot of pressure on public areas and very little available space. Here, the focus is on combining urban functions, such as including space for underground water storage underneath or on top of a car parking garage as has been done at Museum Park and Kruisplein, and water squares such as the Bellamyplein. In addition, green and blue roofs, the removal of paving, the planting of trees and bushes in the streets, the provision of more open areas and 'waterproof design' all contribute to increased resilience. In the post-war urban districts there is more potential for creating additional stretches of open water, such as canals and lakes.

In the outer-dike areas the strategy focuses on a combination of prevention and adaptation. New building codes will be developed. Over the coming years, the City Harbours will provide a location for floating communities. A first step has already been realised in the Rijnhaven: The Floating Pavilion (Figure 3.10).

Figure 3.9 Community involvement on new Dakpark.

Figure 3.10 The Floating Pavilion in the Rijnhaven.

Figure 3.11 Levee reinforcement will be linked to local development.

Adjustments of the dike at the Merwe-Vierhavens are already necessary in order to meet current dike safety standards. In the long-term, higher high-water levels will mean that the dikes in the City of Hoek van Holland and along the Maasboulevard will need to be reinforced. These measures will be linked to specific local area development (Figure 3.11).
A sound and effective measure to combat the effects of drought is to create extra surface water in the city. It is possible to achieve this at city level by expanding and constructing green-blue networks. Another issue currently being discussed is the establishment of 'climate buffers', which can be fed by regional water connections. Ideas in this respect include the creation of rain gardens and pavement gardens on privately owned land while, in the public domain, the effectiveness of linear green areas where water can infiltrate is being investigated. These might include sidewalk planters and bio-swales. In addition to these measures, water squares (see below) will also make a contribution.

Rotterdam has, as yet, not decided to take active measures to prevent heat stress, but rather to participate in the movement to make the city greener and to enlarge its sponge capacity. This means promoting green roofs, green facades, small parks and the planting of trees. In addition, residents and companies – and in particular, specific target groups such as senior citizens – will be made aware of the dangers of extreme heat. They will also be made aware of what they can do themselves to contribute to a healthy and pleasant living environment during periods of hot weather. In addition, it is important to implement plans to promote greenery to the public.

Figure 3.13 Green roof at the Maasstad Hospital.

Figure 3.12 Picknick in Rotterdam community green.

Figure 3.14
Water storage on top of Kruisplein Car Park using Water Shells.

Inspiring Solutions

Water storage on top of Kruisplein Car Park

Additional water storage has been created on the top of a new car park near Rotterdam Central Station. This is another innovative example of a multifunctional construction, in which the creation of water storage has piggybacked with the development of the construction of an underground parking garage. Through the use of so called 'Water Shells' a strong light-weight water storage construction has been created, which adds 2,400 m^3 of additional water storage.

Benthemplein water square

The Bethemplein water square has a capacity to store 1,800 m^3 of rainwater. It was completed in December 2013. Benthemplein is the world's first large water square, designed by Rotterdam-based architects (De Urbanisten). It is an example of both a multifunctional solution and a true participatory approach. The rainwater that falls on to the square runs into large stainless steel gutters, which carry the water into the basins. When it is dry, these basins are suitable for use by everybody on wheels and are a focal and meeting point. The rainwater is collected in three basins: two shallow ones for the immediate surroundings will receive water whenever it rains, one deeper basin will only receive water after heavy rainfall. As part of the design process the designers consulted extensively with local residents and other stakeholders. The final design involved collaboration with students and teachers of the nearby Zadkine College and the Graphic Lyceum, members of the adjacent church, youth theatre and the David Lloyd Gym, well as inhabitants of the Agniese neighbourhood. During three workshops, they discussed possible uses, desired atmospheres and how the storm water could influence the square (Figure 3.16, next page) .

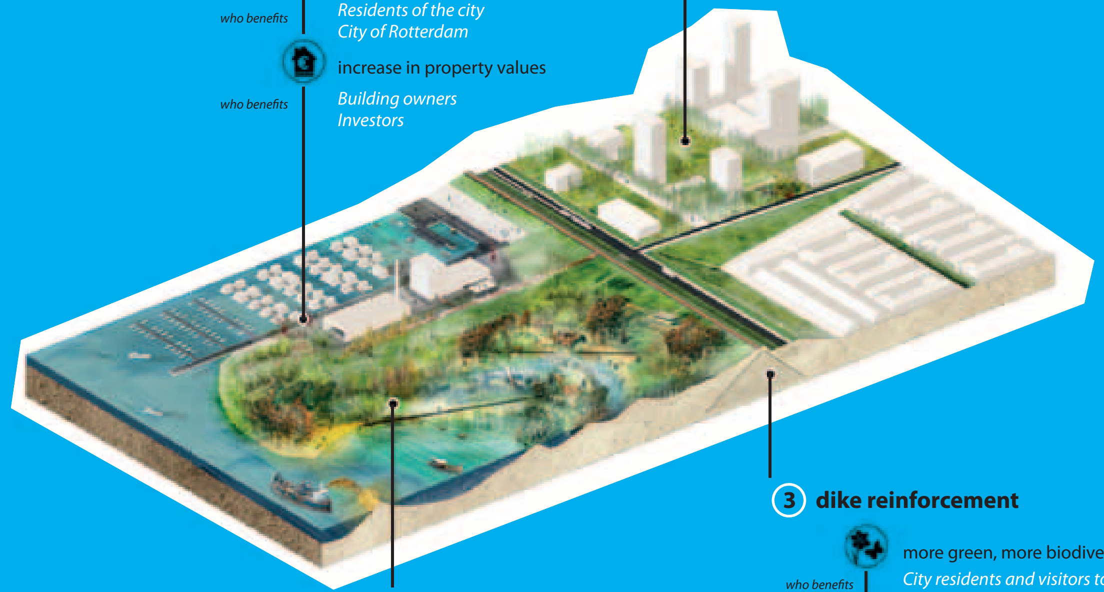
Perspectives for the climate-proof delta city

To strengthen the adaptation strategy descriptions of six typical Rotterdam landscapes have been put together to illustrate which adaptive measures will be most effective in different parts of the city and how these measures will contribute to improving the environment, society, economy and ecology. These six urban landscapes cover: the commercial port, city port, outer-dike urban districts, compact city centre, inner-dike urban districts and post-war suburbs with their parks and gardens. The most effective measures to promote a climate-proof city port area are illustrated in figure 3.17 (next page).

Figure 3.15 Reinforced urban levee.

Figure 3.16 Benthemplein water square.

Figure 3.17 Creating a climate-proof City Port area.



Rotterdam, the Smart Delta City

Rotterdam's strategy does not just involve developing and implementing adaptation measures, but also the development of innovative smart tools that will enhance the climate proofing of the city. One of the methods used is to integrate IT technology into the most modern and innovative adaptive flood control science and development. This strategy, which marries implementation and research, has led to Rotterdam becoming increasingly recognised as an innovative centre for water management and climate change – a truly smart delta city.

Smart flood control and climate adaptation is not just about technology and innovation; it is also about human capital. Rotterdam needs a future generation of engineers, civil servants and scientists to deal with the ongoing challenges of climate change and to develop the next generation of innovative solutions. Young talents need to be attracted to start a career in the water sector and, recognising this, the city cooperates with research institutions, businesses, the Rotterdam University of Applied Sciences and its students, in what the Dutch call a 'golden triangle'.

A number of smart climate adaptation tools has already been developed and are in use, including the Rotterdam Climate Atlas, the Adaptation Design Toolkit, the Rotterdam Climate Societal Cost Benefit Analysis and the Rotterdam Climate Game (to the right).

Figure 3.18a Climate Atlas.

Figure 3.18b Adaptation Design Toolkit.

Figure 3.18c SCBA.

Figure 3.18d Rotterdam Climate Game.

Attractive City and Added Economic Value

Rotterdam Climate Proof connects water with opportunities. Adaptation to climate change is more than just a necessity for Rotterdam. Equally, and perhaps even more importantly, it also offers economic opportunities. In recent years, Rotterdam has already started to harvest the benefits from this approach. New partnerships and coalitions have been set up helping to start and finance pilots in the city. New innovation and valorisation programmes have been started. Usually Rotterdam welcomes 20-to-25 delegations, who visit the city every year to experience at first hand our approach to climate adaptation. This is creating new business, jobs and research programmes. Also the 'Peer City' status Rotterdam had within the European Adaptive City Project, contributed to building our reputation.

Figure 3.20 Mayor Aboutaleb being interviewed by CNN in Rotterdam.

Part of the spin-off was that Mayor Aboutaleb received an invitation from Mayor Bloomberg of New York and former President Clinton to participate in round-table talks about Climate Resilient Cities in May 2013. Later that year, Mayor Aboutaleb was interviewed by CNN about Rotterdam's approach to climate adaptation.

Figure 3.19

A delegation visiting the underground water storage facility.

People and Partnerships
The city and its inhabitants are at the heart of Rotterdam's Adaptation Strategy. So one key aspect of the strategy is to raise awareness, so that people realise what needs to be done and what must be given priority. Many of the measures (such as underground water storage) will be invisible to citizens, while others (such as water squares) will affect them directly. Careful participation is therefore important, as exemplified in the design and construction of Benthemplein water square. On the other hand, residents can also help to create a climate-proof environment, and the concept of community resilience is becoming more widespread in the Netherlands. The 'paving out and plants in' campaign is a good example of how residents can take an active part in the process. It's never too early to raise awareness.

Educational campaigns aimed at schoolchildren and a global water college for students are two examples of involving younger people. Student involvement in these processes is positive for the city. Residents will also play a pivotal role, and partnerships with them are needed if the city is to achieve all that it plans to. Rotterdam is working together at all levels – local, regional, national and international – to draw up and implement its adaptation strategy.

"Rotterdam strives to combine improvements in the city's public spaces with smart maintenance and improvements in the city's facilities. In this way, Rotterdam is shouldering its present and future responsibilities as a low-lying delta metropolis. Rotterdam serves as a living showcase of climate change adaptation. And we will continue to develop smart innovations, to improve water safety in the city and port area and to create business opportunities worldwide. Networks such as Connecting Delta Cities help promote innovation and safety on a global scale."

Alexandra van Huffelen (sustainability, city centre and public space), Vice-Mayor Rotterdam

4 New York

by Daniel A. Zarrilli, Piet Dircke

4.1 The growth of the city

New York City is a coastal city and has thrived in large part due to its waterfront – first as a source of sustenance, then later as a venue for commerce and transportation, and ultimately serving as a destination for living and recreation.

The Italian explorer Giovanni da Verrazano is believed to have been the first European to explore the area now known as New York Harbor in 1524. However, it was Henry Hudson who claimed Manhattan for the Dutch Government in 1609 and sailed his ship, The Half Moon, 275 km (171 miles) up the river, which now bears his name, to the modern location of the state capital of Albany. Over the next twenty years, many Dutch and other Europeans settled in New Amsterdam, the principal city and port of New Netherlands.

The Dutch continued to control New Amsterdam until 1664, when the British took over and renamed the city New York, after James, Duke of York. In 1783, New York became the first capital of the newly independent United States of America. New York City experienced

Figure 4.1 Map of New York City.

an exceptional period of growth during the 19th century. In 1800, when the city still consisted primarily of Manhattan, it had a mere 60,000 inhabitants; by 1898, the population of the city, now including Brooklyn, Queens, Staten Island and the West Bronx had grown to over three million inhabitants.

The opening of the Erie Canal in 1825 boosted the economic development of the city by providing an efficient transportation network for Midwestern grain and other commodities for domestic use and for export through New York Harbor. In addition, the opening of the Croton water system in 1842 brought clean water to the city's population for the first time and improved public health, further facilitating the growth of the city. The population has now grown to over 8 million inhabitants.

Figure 4.2 Great Kills Harbor, Staten Island.

4.2 New York City's diverse waterfront

New York City's physical coastline, which stretches a total of 830 km (520 miles) and is longer than the coastlines of Miami, Boston, Los Angeles, and San Francisco combined, has changed dramatically since the 17th century. Bordering the ocean, as well as rivers, bays and inlets - it is both diverse and complex.[14]

To understand the coastline, it is critical to understand its geomorphology – the combination of its natural landforms, underlying geological conditions, and built condition. The geomorphology of today's city is largely the result of a colossal glacier that moved across what is now New York City over 20,000 years ago, combined with the coastal modifications that inhabitants have made in more recent times. This complexity is amplified not only by the diverse uses and multiple property owners found today along the city's coastline, but also by the many regulators with the responsibility to protect it.

The inhabitants of New York City have altered its topology in many ways, dredging waterways to ease the way for shipping, constructing piers and bulkheads, and even using fill to shape the contours of the coastline. While some of the historic natural features that once protected New York City have been lost in the process, the man-made changes that have enabled commerce and industry to flourish, neighborhoods to thrive, and infrastructure to perform critical functions.

Notwithstanding the important role played by the city's waterfront through most of its history, during the last decades of the 20th century, large sections of the coastline fell into disuse and disrepair due to the decline of manufacturing and water-dependent industry. In recent years however, the city began to reconnect with this critical asset as it has sought to meet the needs of a growing population and expanding economy. Nevertheless, proximity to water comes with certain challenges especially as global climate change advances.

4 3

Flood risks

Storm surges, winter storms and hurricanes
Storm surges along the east coast of the United States are associated with either late summer/early fall hurricanes or extra tropical cyclones in the winter period, the so-called 'nor'easters'. The effects of nor'easters' can be significant, in part because their relatively long durations (as compared to hurricanes) can lead to extended periods of high winds and high water. The height of the surge is amplified if it coincides with the astronomical high tide and particularly if it occurs at the time of a new or full moon (spring tides). Although hurricanes strike New York City infrequently, when they do, generally between June and October, they can produce large storm surges as well as wind and rain damage inland. A period characterized by many severe hurricanes (Saffir-Simpson categories 3-5) in the 1940s to 1960s was followed by relative quiescence during the 1970s to the early 1990s, thought, greater activity has again occurred since the late 1990s.[15]

History of flood events
In 1821, a hurricane made a direct strike on New York City, bringing winds of about 75 mph and a reported 13-foot storm surge that flooded Lower Manhattan as far north as Canal Street. In 1938, a storm known as the Long Island Express – because the fast-moving eye passed over Long Island – hit with no warning, leading to over 600 deaths, including 10 in New York City, while 100-mph wind gusts knocked out electricity north of 59th Street in Manhattan. In 1960, Hurricane Donna had wind gusts of up to 90 mph and a 10-food storm surge that caused expensive pier damage. Major storms have been showing up in the North Atlantic with greater frequency in the last few decades. Examples of recent storms having significant impacts to New York City include: Agnes in 1972, Belle in 1976, Gloria in 1985, a nor'easter in 1992, Bertha in 1996, Floyd in 1999, Isabel in 2003, Ernesto in 2006, a nor'easter in 2007, and Irene and Lee in 2011 – which made back-to-back appearances just 14 months prior to Sandy.

4 4

New York after Sandy

Sandy
Hurricane Sandy was a meteorological event of colossal size and impact. It was a convergence of a number of weather systems that came together in a way that was disastrous for the New York area. Sandy scoured the city's beach communities along the ocean-facing coastline and lower New York Bay, damaging buildings and infrastructure, flooding neighborhoods, causing dangerous erosion, and most seriously, killing 44 people, the vast majority of whom perished from drowning in areas where waters rose rapidly as a result of the surge.

When Sandy struck, a new urgency was added to the climate change conversation that had been occurring in the city. No longer was it reasonable to wait—it was time to more quickly act to protect the city from the current and future impacts of these changes, and in doing so, to emerge stronger and more resilient.

Impact of climate change
Over the last century, sea levels around New York City have risen more than 30 cm (1 ft.). Temperatures are also climbing. In fact, the National Weather Service and National Oceanic and Atmospheric Administration labeled 2012 the warmest year on record in New York City and the contiguous United States, with average temperatures at 1.8 degrees Celcius (3.2 degrees Fahrenheit) above normal and a full degree higher than the previous warmest year ever recorded. Long-term changes in climate mean that when extreme weather events strike, they are likely to be increasingly severe and damaging. As sea levels rise, coastal storms are likely to cause flooding over a larger area and to cause areas already at risk to flood more frequently than today. As temperatures get warmer, heat waves are expected to become more frequent, last longer and intensify – posing a serious threat to the city's power grid and New Yorkers' health.

Figure 4.3 Battery Park Underpass in Lower Manhattan, flooded from floor to ceiling during Sandy.

Flood Risk Maps
Since 1983, New York's vulnerability to coastal storms has been reflected in Flood Insurance Rate Maps (FIRMs) produced by the Federal Emergency Management Agency (FEMA), which describe the Federal government's assessment of flood risk.

Sandy demonstrated the importance of regular coastal updates to FEMA's maps because, in many neighborhoods, the areas that flooded were several times larger than the 100-year floodplain outlined on these maps.[16] Meanwhile, about 60 percent of all buildings and more than half of all residential units in areas that Sandy inundated were outside the 100-year floodplain, as were approximately 25 percent of the buildings tagged as having been seriously damaged or destroyed as of December 2012. In these areas, not only were residents unaware of the risks that they faced, but the buildings in which they lived and worked had also not been subject to the flood-protective construction standards that generally apply within the floodplain.

Eight months after Sandy, in June 2013, FEMA issued updated flood maps for New York City. The new 100-year floodplain includes larger portions of all five boroughs, with significant expansion in Brooklyn and Queens. Citywide, there are now 67,700 buildings in the floodplain (an increase of 90 percent over the 1983 FIRMs) encompassing over 534 million square feet of floor area (up 42 percent). Almost 400,000 New Yorkers now live in the floodplain (up 83 percent) – more than in any other American city (though some cities, such as New Orleans, have a much higher share of their populations in the 100-year floodplain) and that number is expected to double by the 2050s given our projections of sea level rise.

While Sandy was historic, it was not a worst-case scenario for New York City. As climate changes, raising the prospect of stronger and more frequent storms, the risks that New York City faces will intensify. Furthermore, the city is vulnerable to other 'extreme' events, such as heavy downpours, heat waves, droughts and high winds. Chronic conditions, such as rising sea levels, higher average temperatures and increased annual precipitation, also have direct impacts on the city and can worsen the effects of extreme events.
For this reason, even as the city organized unprecedented relief operations following Sandy, Mayor Bloomberg convened the Special Initiative for Rebuilding and Resiliency, and charged it with analyzing the impacts of the storm on the city's buildings, infrastructure and people; assessing the risks the city faces from climate change in the medium term (2020s) and long term (2050s); and outlining ambitious, comprehensive, but achievable strategies for increasing resiliency city wide. The product of that effort is the groundbreaking A Stronger, More Resilient New York, described below.

Comparison of 100-Year Floodplain in 1983 FIRMs and Sandy Inundation Area

1983 FIRMs 100-Year Floodplan
Sandy Inundation Area

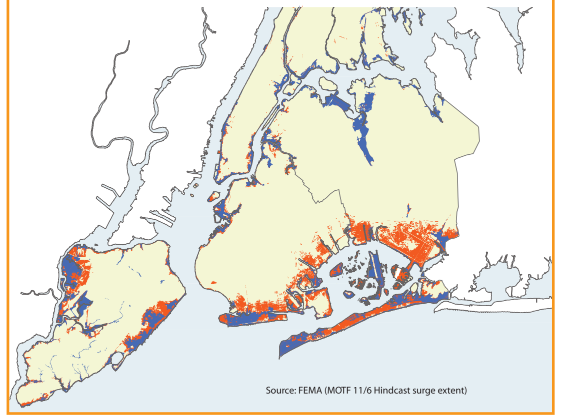


Figure 4.4 Comparison of 100-Year Floodplain in 1983 FIRMs and Sandy Inundation Area.

4.5 Climate Adaptation Strategies

A Greener, Greater New York
The launching of PlaNYC in 2007 was Mayor Michael R. Bloomberg's pioneering effort to accommodate a growing population, enhance the quality life for all New Yorkers, and address climate change. A Greener, Greater New York laid out the City's ambitious goals.[17]

As part of PlaNYC, the Bloomberg Administration sought to understand New York's climate risks. For example, the New York City Panel on Climate Change (NPCC) was established, consisting of leading climate and social scientists charged with advising the city on future climate projections based on the best available science. Moreover, the city began working with the Federal Emergency Management Agency to produce updated Federal flood maps that would provide more accurate information about New York's risks from coastal storms. In 2011, the city updated A Greener, Greater New York, with new initiatives that placed an even greater emphasis on climate resiliency in response to changes in weather that were already taking place.

Hurricane Sandy's force, however, made two things devastatingly clear. First, New York City had been right to invest in planning and protections against extreme weather. The City's resiliency investments performed well during Sandy. Nevertheless, the storm's magnitude, its effects on so many parts of the city, and the threat of even greater risks from climate change also taught a second lesson: efforts need to redouble.

A Stronger, More Resilient New York
Following Sandy, Mayor Bloomberg released A Stronger, More Resilient New York. The nearly US$20-billion plan includes over 250 initiatives. Together, these initiatives will further protect the coastline – the city's first defense against storms and rising sea levels – as well as strengthen the buildings in which New Yorkers live and work, and all the vital systems that support the life of the city, including the energy grid, transportation systems, parks, telecommunications networks, the healthcare system, and water and food supplies. Meanwhile, for the areas of New York that Sandy hit especially hard, the plan outlines local rebuilding initiatives that will help these communities emerge safer, stronger and better than ever.[18]

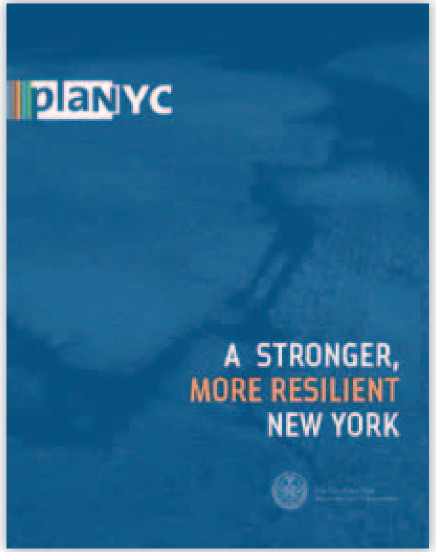


Figure 4.5 Mayor Bloomberg's plan towards a more resilient New York City.

The underlying goal of the plan is resiliency. A resilient city is not one that is shielded from climate change all of the time – because when it comes to nature's powerful forces, that is simply not possible. But a resilient city is one that is: first, protected by effective defenses and adapted to mitigate most climate impacts; and second, able to bounce back more quickly when those defenses are breached from time to time. It is based on these convictions that the following goals were formulated to guide the development of A Stronger, More Resilient New York: the plan is ambitious but achievable; the plan acknowledges limited resources but seeks to stretch those resources to achieve maximum impact; and the plan is multi-layered and seeks to reduce impacts where possible, while allowing the city to recover from impacts faster, when they do occur.

The threats of climate change are significant and growing. Some have said that the only answer to these threats – rising sea levels, powerful storms, and other chronic and extreme events – is to wall the city in or to retreat from the shore. But for the City Administration, the lessons drawn from the storm – including many examples across the five boroughs and from around the world – make clear that it is possible to build a more resilient New York.

Resiliency Principles

4 6

New York City has formulated the following resiliency principles – principles that underlie all aspects of the city's plan.

These are the principles that should also guide the city in the years and decades ahead as the work is done to create a stronger, more resilient New York:

■ The city can embrace its coastline

A strong coastline – with vibrant waterfront neighborhoods, critical infrastructure, and cherished natural and cultural resources – is essential to New York's present and future. The city can fight for and rebuild what was lost, fortify the shoreline, and develop waterfront areas for the benefit of all New Yorkers. The city cannot, and will not, retreat.

■ The city must plan ambitiously

Even with limited resources, the city must make investments in smart, effective protections for the city, modifying and expanding strategies as more is learned about the threats, and piloting projects that can be scaled up over time.

■ New York must be a stronger, more resilient city

The city must be able to withstand the forces of climate change and bounce back quickly when extreme weather strikes. Climate change affects all New Yorkers; not just those whose homes or businesses were flooded during Sandy. In this vision of a stronger, more resilient city, many vulnerable neighborhoods will sit behind an array of coastal defenses. Waves rushing toward the coastline will, in some places, be weakened by offshore breakwaters or wetlands, while waves that do reach the shore will find more nourished beaches and dunes that will shield inland communities. In other areas, permanent and temporary floodwalls will hold back rising waters, and storm surge will meet raised and reinforced bulkheads, tide gates and other protections.

Water that makes its way inland will find hardened and, in some cases, elevated homes, making it more difficult to knock buildings off their foundations or knock out mechanical and electrical systems. And it will be absorbed by expanded green infrastructure, or diverted into new high-level sewers. Meanwhile, power, liquid fuels, telecommunications, transportation, water and wastewater, healthcare and other networks will operate largely without interruption, or will return to service quickly when preventative shutdowns or localized interruptions occur.

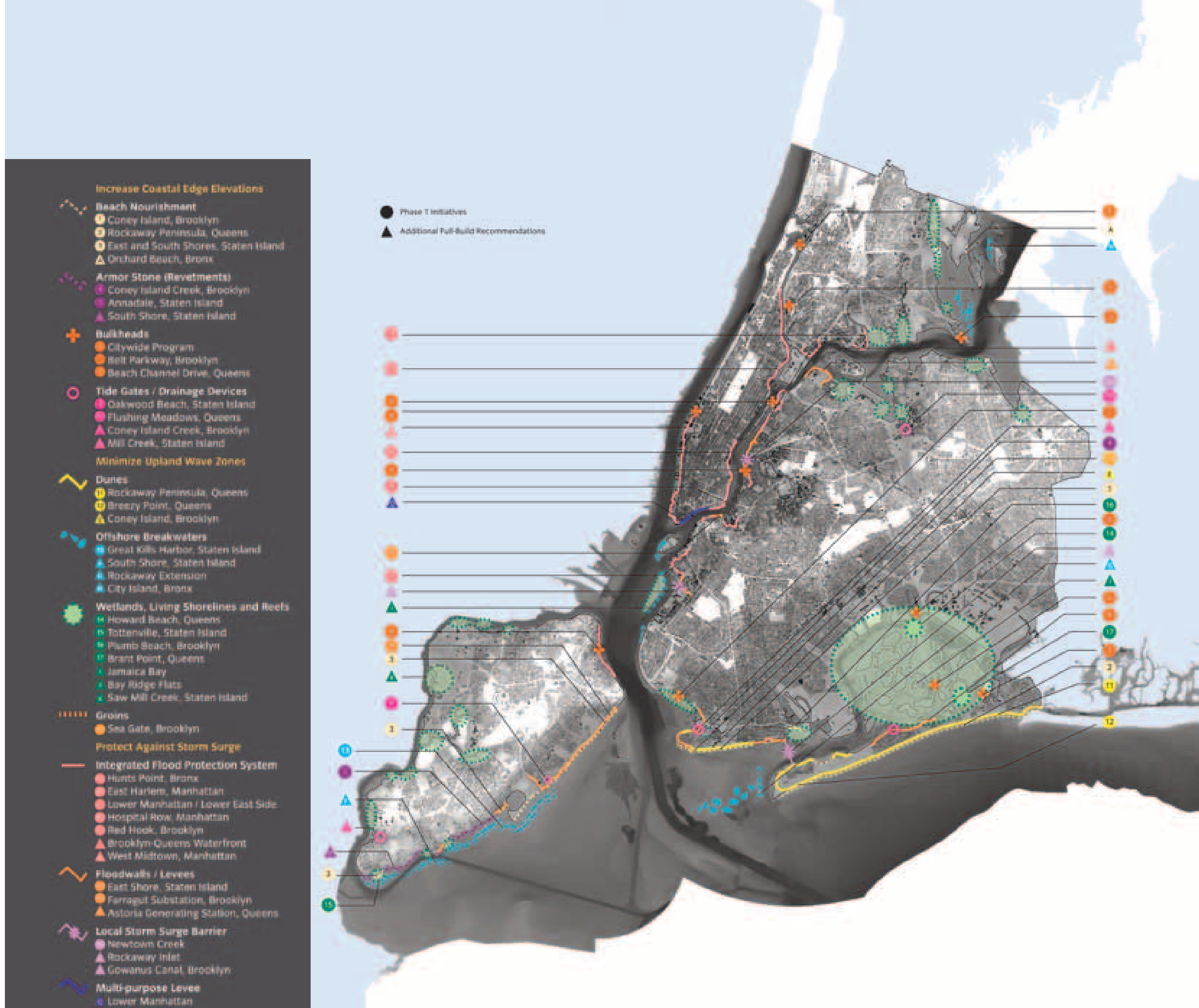


Figure 4.6 Comprehensive Coastal Protection Plan: Full-Build Recommendations.

4.7 Future Outlook

Of course, New York City will not be completely 'climate-change proof' – an impossible goal – but it will be far safer and more resilient than it is today. Implementation of A Stronger, More Resilient New York addresses many of the risks that a coastal city like New York may face and we will measure its success by protecting residents most vulnerable to the impacts of acute and chronic weather events and maintaining community cohesion and economic resiliency in at-risk areas. Individual measures of success will include fewer and shorter power outages during heat waves and after severe weather, fewer people with damaged or destroyed property after acute weather events, the incorporation of resiliency planning measures into the day-to-day operations of City agencies, and an increase in the public's understanding and embrace of resiliency goals. Large resiliency infrastructure projects will also provide relief from chronic challenges, such as tidal flooding and combined sewer overflows.

While no one can say with certainty exactly how much safer the city will be, the rigorous analysis performed during the development of the plan shows that the recommended investments will be worthwhile. Lives will be saved and many catastrophic losses avoided. For example, while Sandy caused about US$19 billion in losses for the city, rising sea levels and ocean temperatures mean that by the 2050s, a storm like Sandy could cause an estimated US$90 billion in losses (in current dollars) – almost five times as much. However, by taking the first phase of coastal protection measures and major power infrastructure and building protections recommended in the plan into account, the economic outlook changes dramatically. Pursuing just these measures could reduce expected losses in the 2050s by up to 25 percent, or more than US$22 billion. Implementing all of the measures in the plan would result in an even larger reduction, and smart investments by other authorities could reduce losses further still.
This economic analysis only quantifies the value of losses avoided due to future coastal storms, but New York City's resiliency plan will also help avoid losses as a result of other extreme weather events, such as the heavy downpours and heat waves that can cause damage and threaten public health, and which are predicted to grow in intensity as the climate changes. Over time, implementation of this plan would address many of the risks that a coastal city like New York faces. By hardening our coastline, by making our building stock stronger, by creating a more durable infrastructure network, and so much more, the city can be better prepared for anything the future holds.

Henry Hudson H_2O9: Building Climate Resilient Communities in New York City and Rotterdam.

On 9 and 10 September 2013, Dutch, American and international resiliency experts gathered in New York and New Jersey at the Henry Hudson H_2O9 Conference to discuss solutions to 21st century water challenges facing coastal cities. One of the topics was 'Building Climate Resilient Communities'. A resilient waterfront community is one that is: first, protected by effective defences and adapted to mitigate most climate impacts; and second able to bounce back more quickly when those defences are breached. Resiliency involves multiple dimensions, including physical, social, and economic, as well as technical capacity.

The goal of this session was to compare opportunities for improving resiliency of waterfront communities in New York and Rotterdam. The long-term objective is to continue the dialogue and knowledge-sharing between New York City and Rotterdam (and other comparable cities), universities and knowledge institutions. This dialogue and knowledge-sharing could function as part of the CDC Connecting Delta Cities Network.

"We are a coastal city, and we cannot, and will not, abandon our waterfront. Instead, we must build a stronger, more resilient city – and this plan [A Stronger, More Resilient New York] puts us on a path to do just that. It will not be easy, and it will take time; but as New Yorkers we are more than up to the task."

Michael R. Bloomberg
Mayor of New York City

5 Jakarta

by Muh Aris Marfai, Philip Ward, Aisa Tobing, Annisa Triyanti

5.1 Introduction

Jakarta is the capital city of Indonesia, as well as its largest city. It is located in the northern part of the coastal area of Java Island. Jakarta covers a low-lying area of about 662 km^2, with 40 percent below sea level. Thirteen rivers flow through the city towards Jakarta Bay, with the main drainage occurring through the Ciliwung River (Figure 5.1). The population in Jakarta reached 9.59 million people in the year 2010, which is a sharp increase from 2.7 million in 1960 and 8.4 million in the year 2000. The population in Jakarta will continue to increase and is expected to reach 12.5 million in 2030.[19]

The first recorded flooding occurred in 1621, during the Dutch colonial time. One of the largest floods took place in the year 2007, and another major flood occurred in early 2013, both causing large societal disruptions, and millions of euros of economic losses. In February 2007, Jakarta was hit by one of the worst floods ever experienced, covering 70 percent of the metropolitan area. Total financial loss was estimated to be around 8 Trillion Indonesian Rupiah (US $ 879 million), 79 lives were lost, and the number of people displaced was 223,203 However, the flood in 2013 is considered to be even more damaging than the one in 2007. The flood waters in 2013, which inundated 90 percent of the city, reached up to the HI statue in Central Jakarta, whereas this important landmark of Jakarta was not flooded in 2007 (Figure 5.2), and financial losses were estimated to be close to 30 trillion

Figure 5.1 Map of Jakarta.

Figure 5.2 Flooding event in 2013 inundated the heart of Jakarta.

Rupiah.[20] One of the factors that caused the severe flooding in 2013 was the breach of the Latuharhary embankment (Figure 5.3 a and b).

Many factors exacerbate flood disasters in Jakarta. The low-lying elevation, the presence of land subsidence, climate change, intense rainfall and low drainage capacity are the main causes of the increase in flood hazards.[21] Jakarta is sinking rapidly due to land subsidence, and the subsidence rate in northern Jakarta is on average 7.5 cm annually.[22] [23] Furthermore, climate change and the melting of ice sheets cause the sea level to rise, and it appears that the sea level in Jakarta Bay is already rising by 0.5 cm per year.[24] Furthermore, flood exposure has increased due to population growth and urbanisation.[25]

The drainage capacity in Jakarta is continually being reduced due to the existence of illegal slum settlements that are narrowing the river body and retention basins, as well as the presence of a large amount of solid waste and sediments in the river. Moreover, there have been large-scale changes in the ratio of green spaces to settlements and industries, which also decreases the buffer capacity for rain events. During the period of 1984 to 2012, the percentage of green area decreased from 28.8 percent to only 10 percent.

Figure 5.3a/b Latuharhary Embankment was damaged (top) and repaired (bottom) in 2013.

5.2

Climate adaptation strategies

The government of Jakarta, with support from the central government and the Public Works Agency, is developing adaptation strategies to overcome the problems of flooding. Structural and non-structural adaptation measures have been developed in order to save the city from worse floods in the future. Increased cooperation between institutions is also being stimulated in order to improve water management in the city.

Improve evacuation capacity: MRT (Mass Rapid Transit) Development Planning in Jakarta
In May 2013, the government of Jakarta launched the development of a new infrastructure plan to reduce traffic jams, called MRT (Mass Rapid Transit). This transportation development project has been decided on in order to overcome traffic congestion, which causes considerable problems in Jakarta during evacuation due to floods. The MRT track will be 110.8 km long, and is supported by the Japan International Cooperation Agency (JICA). The first phase is expected to be finished in 2017. Consisting of a partially elevated and partially underground railway system, the MRT project is expected to solve most of the traffic problems but this remains a challenge, since at least 1,000 new cars appear every day on Jakarta's streets. On the up side, however, the MRT might contribute to reduce air pollution caused by Jakarta's traffic.

Structural Adaptation Measures
Flood control management will be carried out using the following basic principle: hold as much water as possible in the upstream area in reservoirs, water retention areas, and recharge wells, while in the center area allow water to flow naturally downstream through the river and canal. In the lower area the flow of water will be assisted by the polder pump system.

Several structural strategies have been developed and have been planned by the government. The on-going measures include the development, rejuvenation, and maintenance of polder systems in Jakarta. Polder systems consist of an urban drainage system, retention basins, embankments and dikes, and water pumps, as well as water gates, and are spread throughout Jakarta. Recently, the government repaired the damage to the Latuharhary embankment that occurred during the flooding event in 2013. Another initiative by the government is the revitalisation of the Pluit retention basin in order to enlarge storage capacity (Figure 5.4). The opening of the Banjir Kanal Timur channel (BKT-Eastern Flood Channel), now allows for a balanced distribution of water drainage paired together with the Banjir Kanal Barat (BKB-Western Flood Channel). To reduce the rate of land subsidence, an aquifer storage system is also under development by the Public Work Agency, which optimises existing wells and adds an artificial aquifer. Besides the sophisticated technologies, more simple efforts are being developed to enhance rain infiltration, and water conservation on a local scale; for example by using bio-phore (small infiltration holes, filled with organic waste) to increase water infiltration or by using zeolite and gravel.

A dredging strategy is also planned and being implemented in collaboration with the Jakarta Urgent Flood Mitigation Project (JUFMP), supported by the World Bank, and state and local government (APBN and APBD). The dredging initiative is particularly important, considering the fact that every day 300 tons of garbage are thrown into the rivers of Jakarta, blocking the runoff of rainwater (below). In addition, the Ministry of Environment noted that 70,000 tons of garbage are flushed annually into the Ciliwung River alone[26], 70 percent of which comes from domestic waste.

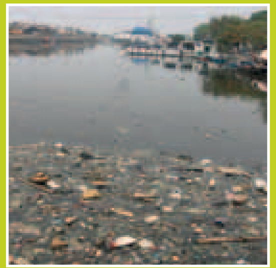


Figure 5.4 Satellite Image of Pluit Retention Basin.

Figure 5.5 Construction of Low Cost Housing in Marunda Area to reduce the vulnerability of slum dwellers (Adisukma, 2011).

Zoning and spatial planning
The narrowing of river bodies and retention basins is one of the main problems caused by large scale slum areas in these low-lying areas. This causes difficulties in implementing spatial planning and other measures to reduce flood risks (e.g. dredging and dam construction). Therefore, the government relocates slum dwellers living on the rivers' embankments to higher-ground, low-cost housing. Although the relocation program was originally difficult, several local housing areas have already been built and others are still under construction. The low-cost housing is also aimed to help the slum dwellers to gain a better housing environment and quality of life (Figure 5.5).

NCICD National Capital Integrated Coastal Development
The National Capital Integrated Coastal Development (NCICD) strategy focuses on both structural and non-structural measures, and aims to improve the quality of the whole waterfront of northern Jakarta over a distance of 32 km, including 5,000 new hectares (ha) of land reclamation.

The plan aims at reducing groundwater extraction to reduce land subsidence and to reclaim land. Furthermore, the plan includes the construction of a giant sea wall in combination with new land reclamation with urban development and other investment opportunities. The NCICD concept offers a breakthrough solution that not only provides protection to northern Jakarta from flooding, but also serves as a fresh water reservoir. Flood protection, combined with land reclamation, infrastructure development and urban renewal, is expected to transform northern Jakarta into a more attractive place for investment, living and working. The NCICD initiative has been developed in collaboration with Dutch institutions.

In principle, the sea dike development would open new opportunities for other economic activities, which could be used to finance the construction of the dam itself. Potential revenue could be obtained from land reclamation and investment opportunities for the private sector, such as highway construction, the construction of a deep-sea port, and the development of railways. The government plans to build facilities for water supply, waste management, and sewage.

5.3 Community based adaptation

Several programs to enhance non-structural flood mitigation and preparedness measures have been developed in Jakarta, either by the government or other private institutions. People living in small settlements, especially in the northern part of Jakarta, have implemented local indigenous strategies to face floods, such as small dams surrounding their settlement areas, the building of special storage places in the second storey of buildings, and the heightening of houses to prevent flood waters from entering. Furthermore, several non-structural measures have been developed, such as the strengthening of law enforcement, early warning systems, and community capacity enhancement, as well as watershed planning and management, which mainly focus on the upper stream area.

Challenges and opportunities
The recent development of the Pluit retention basin (see Figure 5.4) as one of the flood protection strategies in Jakarta originally brought up social conflicts. A number of inhabitants living on the bank and encroaching into the basin opposed relocation. However, since flooding issues should be solved at the root of the problem, the government increased its activities to raise the awareness of the people living near the retention basins and riverbanks, and to increase stakeholder participation in order to gain support from the inhabitants, and after direct discussions between the people and the Governor and Vice Governor, the people have accepted the proposals to relocate and are awaiting the completion of their new government-provided housing.

However, huge investments from local and international institutions are available to enhance the resilience of Jakarta to climate change. This could be an advantage and opportunity for Jakarta to further develop both the structural and non-structural adaptation measures, in particular those related to flooding.

Jakarta as a delta city is facing a huge issue of flooding. Several factors contributing to this issue are the bad waste management, lack of water recharge area, slum areas near the river and embankments, and ineffective river management. The national and local government have made many efforts, both through structural and non-structural adaptation. However, the major challenge is how to involve the community in order to support the government program. In fact, public awareness to cooperate with the government in tackling floods is still limited. Therefore, the approach to the community and community development has become the main focus of the government in order to deal with flooding. Although establishing cooperation in order to overcome the flooding is undeniably crucial, the cooperation itself should be carefully planned and executed to avoid being a burden to the government and community. Furthermore, sharing knowledge and cooperation development at local, regional and international level is urgently needed in order to overcome the issue of flooding.

Ir. Basuki Tjahaja Purnama - Mayor of Jakarta, MM (Vice Governor of Jakarta)

The world deltas have been the focus of great civilizations and more than half of the world's population lives at the mercy of deltas. The dual and peculiar characteristics of world deltas are their enormous natural blessing and gifted richness and, currently, their alarming vulnerabilities due to severe environmental devastation and the aggravating impacts of climate change. These have compelled the world community to a new era of wise, smart and visionary governance of this critical piece of our Earth's heritage through the use of the power of nature and clear knowledge-driven insights. Indonesian deltas, most notably the Jakarta urban delta, have undergone some latent, chronic and typical megacity diseases and increasing climate change risks through frequent and ever damaging floods and spring tides, as well as poor drinking water supply. The sharing of worldwide experience, knowledge and wisdom are keys to address the restoration and retainment of healthy delta features in order within the realm of sustainable and resilient deltas.

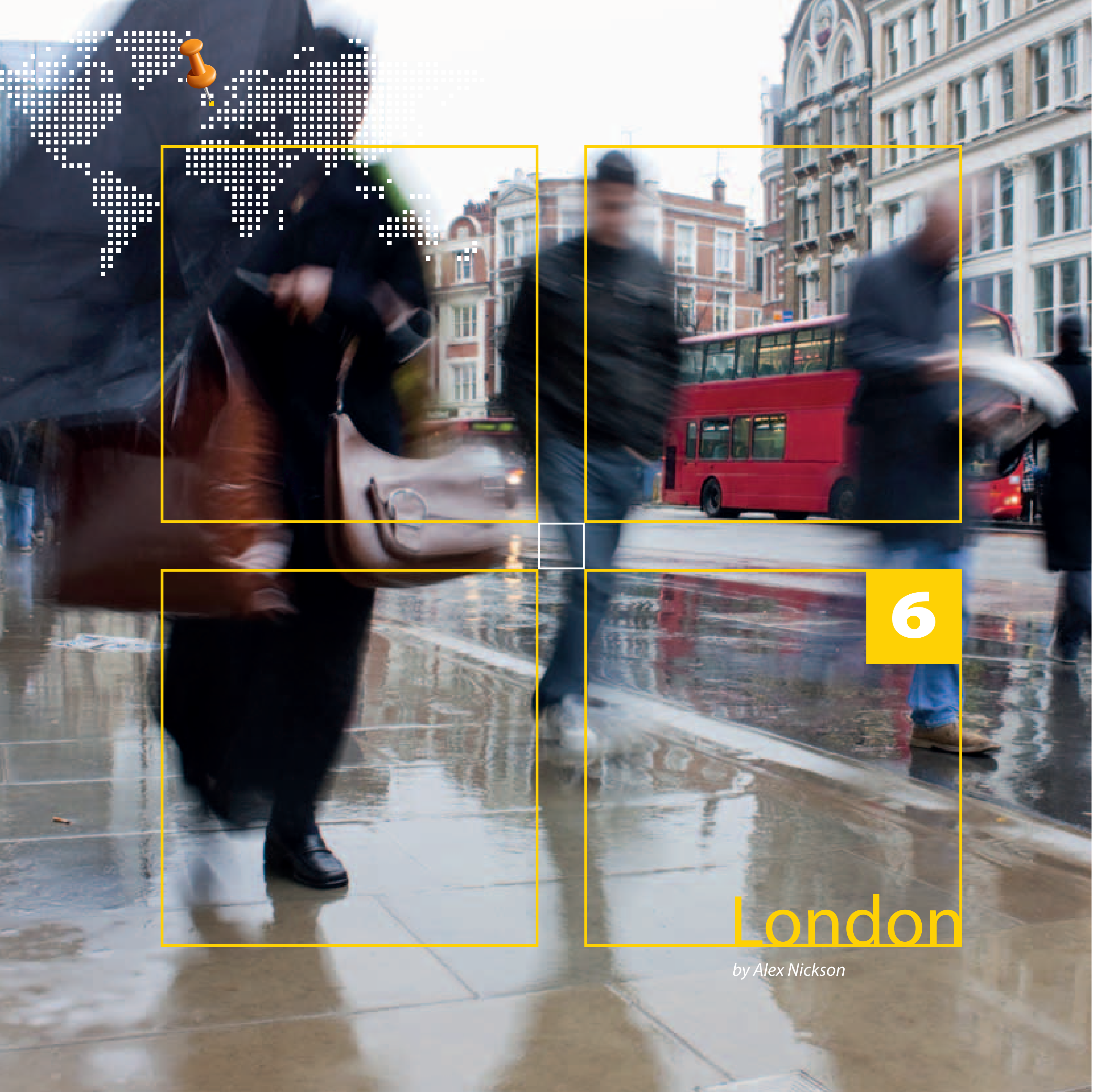
Prof. Dr. Jan Sopaheluwakan, (Initiator and Chairman Organizing Committee of the World Delta Summit, Jakarta, Indonesia, 2011 Delta Alliance International, Coordinator Indonesia Wing)

Jakarta Climate Adaptation Tools (JCAT)

In 2011, the project, 'Jakarta Climate Adaptation Tools' (JCAT), was initiated (Figure 5.6a). The project has played an important role in promoting the concept of flood-risk assessment and management in Jakarta. The overarching objective of the project is to contribute to the development of tools to assess, compare, and optimise options for climate adaptation in Jakarta and other delta cities. These tools are available to decision-makers and stakeholders in Jakarta, for assessing flood-risk, and assessing both the costs and benefits of adaptation measures.
As part of the project, two young Indonesian PhD students are being trained in Indonesia and the Netherlands in climate change adaptation and flood risk management – developing vital skills that they can use in their professional lives to help address the flood problems faced by Jakarta.
The project is an example of how working together – between countries, disciplines and institutes – can help Jakarta face future challenges. Connecting Delta Cities plays an important role in the project, with many of the important contacts first being made in CDC meetings and workshops. The project is funded and supported by the Delta Alliance and Knowledge for Climate.
The work is being carried out by universities from Indonesia (Gadjah Mada University in Yogyakarta and Bogor Agricultural University) and the Netherlands (VU University Amsterdam and Wageningen University). But importantly, it is being carried out in close collaboration with different research institutes in Indonesia (e.g. the Indonesian Institute of Sciences and the Agency for the Assessment and Application of Technology), local governments (e.g. DKI Jakarta) and consulting firms working in Jakarta. In October 2012 JCAT contributed to the 5th Asian Ministerial Conference on Disaster Risk Reduction in Yogyakarta (Figure 5.6b).

Figure 5.6a JCAT kick-off workshop in Jakarta, bringing together stakeholders to discuss flood problems in Jakarta and focus research.

Figure 5.6b JCAT contribute to the 5th Asian Ministerial Conference on Disaster Risk Reduction in Yogyakarta, Indonesia, in October 2012.



6 London

by Alex Nickson

6.1 Introduction

Figure 6.1 Map of London.

From a peak of 8.8 million in 1939, London's population steadily declined to 6.7 million in 1988. Since then, the population has grown steadily to 7.6 million today and is expected to keep growing. Nearly all of this growth will be accommodated on brownfield sites, or further densification of development around high transport accessibility nodes. This approach leads to a compact, dense city, but also intensifies vulnerability by concentrating a high number of people and assets within a relatively small area. London sits astride the River Thames. While not a traditional delta, England's capital city is further bisected by 12 tributaries and the tidal influence of the North Sea extends almost entirely through the city. London, as with much of the United Kingdom, is buffered from the continental climate by the Gulf Stream, and thus has a marine climate. This means that winters are less cold and summers are less hot. This reduced seasonal variation is one of the key reasons why much of the UK is poorly adapted to extreme weather, as wide seasonal variations are very uncommon and generally short-lived.

There is growing awareness that the resilience of a city to extreme weather is an important component of its international reputation. Climate resilience will become as important as a city's business laws, taxation system and the skills of its workforce in attracting and retaining business and investment. London's status as a world financial centre is partly built upon its reputation as a safe place to do business and invest in. Investing in maintaining and increasing this resilience is therefore an important part of the economic development of the city, but with the added benefit of improving the quality of life for its residents and reducing social inequality.

The Greater London Authority (GLA) is the regional city government for London. It is the strategic authority for London with particular responsibility for spatial planning, transport, economic development, emergency planning, health inequalities and the environment. The GLA consists of a directly elected executive Mayor and Assembly, which have powers to scrutinise the Mayor and his policies and programmes. The Mayor works with the 33 London boroughs, which have local responsibility for planning, development control, waste management, social services and environmental issues.

"Since the Mayor came to power, London has experienced a succession of extreme weather events that have rewritten the record books. The 2010 winter was the coldest in a century; the period April 2010 to March 2012 was the equal-driest since 1910, and 2012 saw the wettest summer in over a century. These events caused economic, social and environmental impacts that affected Londoners and diverted limited resources away from other priorities. Reducing our vulnerability to extreme weather is therefore a sound investment as it not only reduces the likelihood and scale of future impacts, but creates jobs and attracts investment to support our economic recovery".

Matthew Pencharz – Senior Adviser - Environment and Energy to the Mayor of London

6.2

Future impacts of climate change

The recent UK census provided stark evidence that London's population is growing even more quickly than expected. Since 2008, at least 330,000 more people have come to call London home[27] and by 2016 the population is projected to top its all-time peak of 8.8 million and to keep on growing to reach nearly 10 million by 2030.[28]

This level of growth presents a number of challenges: firstly, housing people in a city where a shortage of homes has led to an average house price that is 15 times the average national income and 200,000 families living in overcrowded homes.[29] To meet this demand, London is going to have to construct 400,000 new homes over the next 10 years. Secondly, to provide gainful employment, London will have to facilitate the creation of 450,000 new jobs. London's transport, water and energy infrastructure needs huge investment to meet the demographic challenge. The city cannot indefinitely increase the demands on its existing infrastructure that is, in the case of the London Underground, the water distribution and combined sewer networks, already 150 years old. London will have to improve and increase its transport, utilities, social and 'green' infrastructure.

This growth means that, even without climate change, the impact of extreme weather in London would increase simply by virtue of the number of additional people and assets at risk. The City has been fortunate to avoid some of the extreme weather that has affected other CDC cities, however this luck will not hold forever and crossing one's fingers is considered not an acceptable resilience strategy.

London is already now vulnerable to extreme weather – its usually mild climate has meant that the city has become adapted to quite a narrow 'window' of weather. This in turn means that 'extremes' of weather well within other cities' average climates sometimes causes problems. *The benefits of this position are:*

- that London needs to take early action to increase its resilience;
- that London will be able to plan for further climate change in new developments;
- these actions will benefit the quality of life of current and future Londoners,
- that they will attract and secure investment in London; and
- that they will enable the city to sell its skills and experiences on the international stage to other cities and organisations.

Figure 6.2 Thames Barrier.

3

6 Climate risks

The key climate risks to London are flooding, water shortages and heatwaves.

Flooding

The capital is located on a former marshy area at the point farthest east where the River Thames could be bridged. The marshes were gradually drained and the river corridors defined by docks and floodwalls. This process has led to the position today where approximately 15 percent of the city by area is located on the former floodplains of its rivers and 80 percent of the rivers are heavily modified.

London is vulnerable to flooding from three key sources: 'tidal' flooding when tidal surges combine with high tides and onshore winds; 'fluvial' flooding from the freshwater rivers in London; and 'surface water' flooding, when heavy rainfall overcomes the drainage system.

An analysis of 'who and what' is at flood risk today, shows that a significant proportion of London's critical infrastructure lies in areas of flood risk and also that some of the poorest Londoners are living in areas of tidal flood risk. This is important because it underlines that much of the infrastructure London would rely on in the event of a flood is at risk and that the most vulnerable part of the population also lives in at risk areas. The 125 km^2 area protected from flooding is also the most intensively developed part of the city, with 1.25 million people living and working at managed flood risk. London is also vulnerable to surface water flooding when heavy rainfall overcomes the drainage system. The city is protected from tidal flooding by the Thames tidal defences, which include the Thames Barrier and more than 337 km of floodwalls and floodgates in total, of which 225 km is in London. This integrated system provides a high standard of protection and is expected to continue to do so for several decades to come.

The UK Environment Agency has undertaken a study, called Thames Estuary 2100 (TE2100), to identify the flood risk management options for protecting London and the Thames Estuary from tidal flooding to the end of the century. The project has identified a range of possible options – from raising the height of existing defences to constructing a second Thames Barrier – and assesses the level of protection that each option can provide. The thresholds for protection against rising sea levels provided by each of the options are then plotted against sea level rise. This approach helps decision makers to understand the suite of options open to them, and how they can be combined into a 'decision pathway' to create a portfolio of measures through the century.

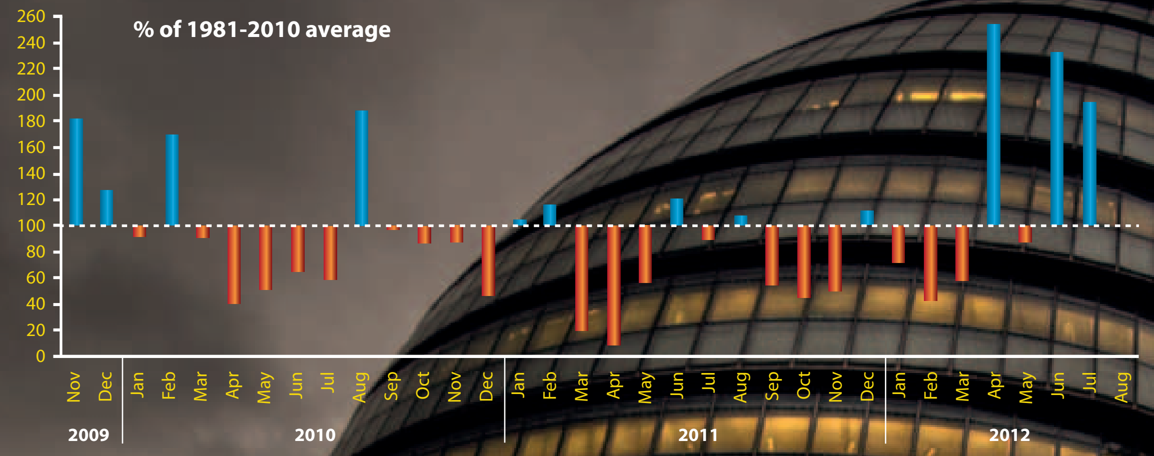


Figure 6.3 Rainfall over 2010-2012.

Drought

Eighty percent of London's water comes from the River Thames and River Lea and 20 percent from the confined chalk aquifer under the city. The Thames Basin is the largest river basin in the southeast of England. As such, it offers a more dependable supply of water during droughts than other catchments in the southeast, as it is able to collect more water. The Thames Basin receives an average of 690 mm of rainfall per year. Of this, two-thirds is lost to evaporation or transpired by plants; 55 percent of the remaining 'effective rainfall' is then abstracted for use, one of the highest amounts in the country. Eighty-two percent of the abstracted water is for public supply, with half of this supplied to households and a quarter to non-households. The remainder is lost in leakage.

London is usually fairly resilient to periods of low rainfall as its location, where the Thames and its tributaries meet the sea, allows significant volumes of fresh water to be abstracted from the rivers with minimal environmental impact. High river flows are pumped into reservoirs during the winter to provide back-up supply for when river levels are low. However in 2012, after two successive 'dry' winters, London's watershed had received only 60 per cent of its normal rainfall and was experiencing one of the worst droughts on record. Using projections based on previous droughts, it was clear that if the drought continued, London would face severe water restrictions in late summer, potentially affecting the London 2012 Olympic Games. Most of the water companies in the southeast of England introduced 'Temporary Use Bans' in March 2012, which restricted water use for many non-essential purposes. Fortunately, the rain started to fall in April and what became the wettest summer in over a century rapidly restored groundwater levels and allowed the water use restrictions to be lifted in time for the Games and before any major economic impacts were felt.

Heatwaves

Summers in London are rarely hot enough to cause a significant health impact. However, it is this rare exposure to high temperatures in combination with the poor ability of much of London's housing stock to maintain comfortable temperatures that causes Londoners' vulnerability to high temperatures. The August 2003 heatwave caused the deaths of 600 Londoners. An analysis level 3 of the health impact of the heatwave across all the UK regions showed that while London did not experience the highest temperatures, it did result in the highest number of deaths when averaged over the population. It is proposed that the urban heat island (UHI) effect was a key factor in this excess mortality, as the UHI prevented the city from cooling off overnight and maintained temperatures at a threshold too high for vulnerable people to recover sufficiently from the heat of the day.

A recent epidemiological study of Londoners' response to heat showed that rising temperatures start to affect Londoners from 24.7 degrees Celsius with mortality increasing by 3.8 percent for every degree above this threshold.[30] High temperatures also affect London's infrastructure, for example, through increasing energy demand for air-conditioning leading to brownouts and railway tracks buckling.
Climate change is projected to bring more frequent and intense extreme weather as well as long-term changes to the baseline climate, both of which are expected to further challenge London's technical, cultural and financial responses.

6.4

Increasing resilience and managing risks

The London Climate Change Adaptation Strategy[31] was published by the Mayor in late 2011. The Strategy identifies the key climate risks to London, proposes a range of adaptation measures to manage these risks and focuses on where the Mayor is uniquely placed to lead by example and co-ordinate actions with others. The strategy can be subdivided under four activities (the actions provided below under each of these activities do not represent all that London is doing, but are thought to be the most informative for and transferrable to other cities):

1. Identifying and better understanding climate risks

The Greater London Authority (GLA) has been working with London's 33 boroughs and the UK Environment Agency to map surface water flood risk in London. The map has been used to identify areas where flooding could present a risk to people and property. This has enabled the Mayor to identify and target strategic risks (for example, critical infrastructure) and help each London borough develop their own surface water management plan in coherence with one another.

The GLA has been working with academic partners through the LUCID project[32] to develop a 'surface energy balance model for London'. This model represents the heat exchanges between the atmosphere, the city's surfaces and heat sources (energy use) in the city. Effectively the model allows the GLA to understand how climate change is likely to affect the urban heat island (UHI); to test the impact of different land cover types (for example green and white roofs); and energy usage (for example air conditioning) in managing or exacerbating the UHI.

The GLA has also been working with academic partners[33] to develop a 'triple jeopardy' heat risk map for London. The map will help identify overheating 'hotspots' where there is a combination of areas with high temperatures in the urban heat island, buildings likely to overheat and a concentration of people vulnerable to high temperatures, creating the conditions for higher risk. This tool will help prioritise where and how to tackle overheating risk.

2. Raising awareness and building capacity

There are areas of London that have experienced flooding and where there are limited physical measures to manage flood risk in the short to medium term. The GLA has been working with a number of communities facing higher flood risk to develop Community Flood Plans (CFPs). The CFP is a plan that

Figure 6.4 London Underground entrance.

is developed and owned by the community. It sets out what the community will do before, during and after a flood to increase its resilience and how community leaders will work with their local government and emergency services to ensure more effective mutual cooperation.

The Mayor has set a target to increase greencover in the centre of the city by five per cent by 2025 to help manage climate risks and improve the quality of life in the city. As much of the centre of the city is privately owned, this means working with private landowners and their tenants. The Mayor has worked with 11 central London Business Improvement Districts (BIDs) to undertake 'Green Infrastructure Audits', which identify opportunities to 'green' the local area. These audits have identified opportunities for 300 raingardens, 200 greenwalls and 100 ha of green roofs. The GLA is now working with the BIDS to deliver some of these opportunities.

3. Ensuring to lead by example

London Underground (responsible for the city's metro system) is undertaking a £490,000 (€570,000) flood risk assessment of its 3,000 assets – this includes stations, tunnels, signalling system, etc. The assessment will inform its capital investment programme and identify opportunities to use routine maintenance programmes to deliver greater flood resilience.
The Mayor is responsible for the London Fire and Emergency Planning Authority. The GLA is undertaking a flood risk assessment of all of London's emergency services (fire, police and ambulance) to understand the risk to emergency services and how flooding may affect an emergency response.

4 Implementing win-win solutions

The Mayor has set a target of reducing London's carbon emissions by 20 percent by 2015 and 60 percent by 2025 from a 1990 baseline. To deliver these ambitions, the GLA has developed a number of carbon reduction programmes, targeting public sector buildings, social housing and small to medium-sized businesses. Given that about 20-to-25 percent of a building's energy use is in heating water for washing and cleaning, improving the water efficiency can both help improve London's water security and reduce carbon emissions.

6 London 2012 Olympic Games case study

The 2012 Olympic Games provided a once-in-a-century opportunity to regenerate an undervalued part of London. A key commitment in the capital's Olympic bid, and to Londoners, was the creation of high-quality, vibrant and climate-resilient new quarter for London.

The area for the Olympic Park presented a number of environmental challenges – the site is bisected by the River Lea and a network of lesser rivers (collectively known as the Bow Back Rivers), many with poor water quality and low standards of flood protection. Much of the land and groundwater was heavily contaminated by previous industrial landuses and the Park is located in the South East of England, where there is little new water available.

The flood defences in the Park are designed to maintain a standard of protection equivalent to 1 in 100 years, with an allowance for climate change, over the lifetime of the development. Managing flood risk was used to inspire the design of the waterfront of the Park. Where possible, flood defences were set back to give the rivers room to flood, create valuable wetland habitat, improve accessibility to the water and enable easy future access and maintenance.

Water Supply
The Olympic Delivery Authority's (ODA) Sustainable Water Strategy aimed to reduce potable water use by 40 per cent through creating water efficient venues, drought resilient planting schemes and using rainwater and treated sewage where possible as alternatives to treated (potable) water. The combined effect of these water-saving measures achieved a 58 per cent reduction against a business-as-usual approach. Critical to the success of achieving this target was the site-wide non-potable network and the 'Old Ford' wastewater recycling plant.[ii]

Flood Risk
There are 8.35 km of waterways in and around the Olympic Park. Many of the waterways travel north to south through the heart of the Park and discharge into the tidal River Thames. The flood risk management strategy for the Park needed to help reduce flood risk up and downstream of the Park, as well as managing flood risk to the Olympic venues and the further redevelopment that would follow the Games. A new tidal lock was constructed to enable construction barges to enter the heart of the Park, to regulate water levels in the rivers and to 'lock out' the tide.

Over 30,000 tonnes of silt, gravel and rubbish were dredged from the rivers and recycled or reused in construction works. More than 5 kms of riverbanks were replaced or enhanced to manage flood risk. The multimillion pound dredging and riverbank enhancement works have revitalised the Olympic Park waterways, improving water quality and allowing both commercial freight barges and leisure boats to take to the water once again in east London.

Old Ford wastewater reclycling

The Old Ford wastewater recycling is the UK's largest community wastewater recycling plant. It treats wastewater from the Northern Outfall Sewer and feeds in to a non-potable network that connects to the Olympic Park for toilet flushing and irrigation, and to the Energy Centre for cooling water. The plant cost £5 million to build and uses Membrane Bioreactor technology to produce over half a million litres of water a day.

Figure 6.5 Thames Water's effluent treatment plant at Olympic Park.

Sustainable drainage strategy

Much of London is drained by a combined sewer, where sewage and rainwater flow into the same sewers to sewage treatment works. Recent studies by Thames Water (responsible for London's sewerage system) have highlighted that in some areas of London, the combined sewer can be up to 80 per cent full with sewage, leaving little space for rainfall. This means that even comparatively light rainfall can lead to combined sewer overflows where diluted, but untreated, sewage is released into the Thames. In one particular drainage catchment, during heavy rainfall, the lack of sewer capacity, combined with the construction of habitable rooms below the level of the sewer, means that 30,000 homes are at risk of sewer flooding[34] Drainage systems in the UK are usually designed to drain away rainwater from a storm event of up to a 1-in-30 year intensity. Climate modelling suggests that what is a 1-in-30 year event today increases in frequency to a 1-in-15 year event by mid-century and that what is a 1-in-100 year event today increases in frequency to a 1-in-30 year event by the end of the century. This may mean that London may need to adapt to a 1-in-100 year event by the end of the century to maintain the current standard of protection through the century.

To tackle these challenges, the GLA, Thames Water and the UK Environment Agency are jointly working on a sustainable drainage strategy for London. The aim of the strategy is to understand the capacity of London's drainage system to manage current and future challenges and to develop short and long-term actions to manage surface water and sewer flood risk.

The project is in its early stages, but it will:

- Subdivide London into a number of drainage catchments;
- Assess the capacity of the drainage network in each drainage catchment to deal with current challenges;
- Model future challenges to the drainage networks in each catchment from population growth, 'urban creep'[35] and climate change to determine if the current 'headroom' is sufficient to maintain an acceptable level of service, or how much it is exceeded by;
- Identify a range of options for each catchment, including water efficiency (to reduce the volume of sewage produced) sustainable drainage (to keep more of the rain out of the drains) and flood resilience (managing flood risk where a residual risk still exists) to ensure an acceptable level of risk through the century;
- Develop an action plan to co-ordinate and facilitate the implementation of these measures.

7 New Orleans

by David Wagonner, Cedric Grant

7.1 Introduction

In August 2012, Hurricane Isaac struck the Mississippi Delta and tested the brand new Hurricane Risk Reduction System protecting New Orleans, constructed by the US Army Corps of Engineers after Katrina and built in 4 years. All storm surge barriers were closed, all pumps worked, all flood walls held: New Orleans was safe. But only for now. With rising seas and sinking land, a place integral to American history and world culture struggling to reinvent itself and reverse its decline, still faces an uncertain future.

New Orleans was founded along the Mississippi River near Lake Pontchartrain almost 300 years ago to take advantage of waterways and water resources. Now the Crescent City faces new challenges, from a changing climate to the sinking and regular flooding of the land. Developing and implementing the Urban

New Orleans is the present-day test case for world delta cities. In 2005, Hurricane Katrina brought about the failure of the levee system, flooding 80 percent of the city and forcing prolonged evacuation of almost the entire population. Five years later, BP's Deepwater Horizon oil rig exploded south of the city, unleashing a torrent of oil from the reservoir beneath the ocean floor, threatening fragile, protective wetlands critical to the region's economy, culture and storm protection.

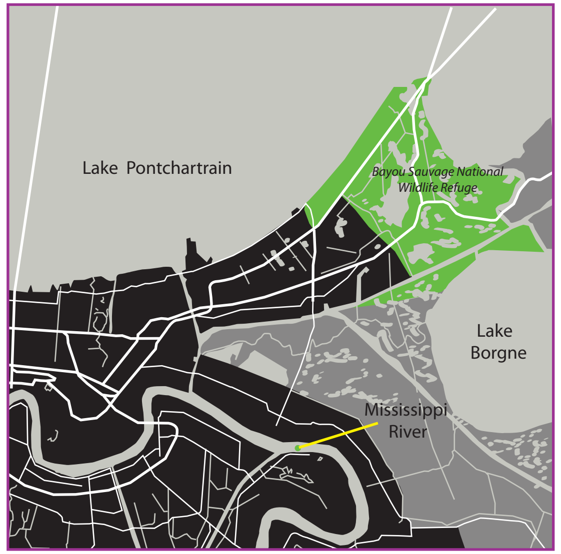


Figure 7.1 Map of New Orleans.

Water Plan[36] for America's first great water city requires a new approach to water – Greater New Orleans' most abundant natural asset – to create a safer, more prosperous, and more beautiful environment as a leading global example of a city in balance with nature The disasters that have severely disrupted life in New Orleans throughout its three centuries of existence have served as grim reminders of the city's geography, which has been both the source of its wealth and a bane to those seeking opportunities in its waters and soils. The city has always fought to overcome the limitations of its geography, to limit the risk of inhabiting low ground surrounded by high waters in order to realize the benefits of occupying the mouth of the Mississippi and the rich soils of the delta.

7 2 Katrina

Katrina in August 2005 was maybe not only the worst Hurricane in the city's history but certainly the most costly ever to occur in the United States. Damage estimates reached US$125 billion in economic losses on the Gulf Coast, and US$30 billion in the city of New Orleans alone. The city lost 70 percent of its urban canopy, an estimated number of 100,000 trees. More than 160,000 homes were destroyed or heavily damaged and 1,500 lives were lost. Katrina forced the evacuation of 1.36 million people, creating a New Orleans diaspora across the continent. The suburban developments on former back swamp areas suffered most, and subsidence of six to seven feet below sea level in some places worsened the flood's effect. The older neighborhoods on high ground on the river's edge and ridges suffered little or minor flooding.
In response to the storm, the US Army Corps redoubled its levee strengthening efforts. The US Congress released US$14.45 billion for the levees and floodwalls, storm surge barriers, outfall canal repairs and closure structures; and pump stations and storm proofing. With unprecedented speed the Corps set a world record in constructing the Hurricane Protection System within approximately 4 years, around ten times faster than the Dutch built their Delta Plan in about 40 years after the floods of 1953.

Full protection from a 100-year storm, equating to a one percent chance of failure in given year, is projected since June 2011. The system within the levees remains unchanged: pumps can handle one inch of rainfall in the first hour and 0.5 inches in each subsequent hour. When combined, Orleans Parish's three outfall canals can discharge 16,000 cubic feet of water per second. Although impressive, this system, practically devoid of storage capacity, can still be overwhelmed by recurring rainstorms that can produce two to four inches of rain an hour.

The use of engineered solutions for narrowly defined problems has in recent times proven insufficient to combat the complex, intertwined challenges confronting modern delta living. Considering the fact that climate change and continued subsidence will increase the challenges further, New Orleans may need to embrace a more holistic, ecologically-based thinking, with the cultivation of nature's own lines of defence, not just to sustain the city's future but also to avoid the continuous increase of the adaptation cost, which will perhaps eventually outweigh the incredible cultural and economic value of habitation on the Mississippi Delta.

7 3

Challenges

New Orleans is first and foremost a city in the delta, founded between the Mississippi River and Lake Pontchartrain. The construction of navigation channels, such as the Inner Harbor Navigation Channel and the Gulf Intracoastal Waterway, along with the land reclamation project of the lakefront in 1930 have determined the hydrological characteristics of the city today: three distinct polders bounded on each side by levees and water.

The areas within the levees consist of fine gradations of alluvial soils, deposited over millennia by the Mississippi and its distributaries. These deposits formed areas of high ground and low ground. Because this is a relatively flat city with an average elevation of 1.8 meters below sea level, the elevation that does exist is of even greater significance than in other landscapes. In Hurricane Katrina's wake, slight elevation changes were the difference between disaster and giddy good fortune. Indeed, topography has shaped the geography of each disaster: where one could retreat from rising waters, whose homes and businesses were flooded, how long floodwaters remained, and where one might live next if forced to rebuild.

Even as the river and lakefront levees are lifted ever higher to counteract the effects of land subsidence and to provide additional factors of safety in the face of rising sea levels, the low ground has sunken lower and lower. River levees prevent the Mississippi from replenishing the ground with fresh sediments, and the extraction of groundwater has greatly increased the rate of natural subsidence. Once kept plump with river water, rainfall and fresh sediments as a spongy but stable matrix of earth, water and vegetation, the low ground has been squeezed of its liquids and cut off from river-borne nourishment. It is in slow collapse. A sinking city already burdened with dilapidated infrastructural systems and the compounding effects of climate change and coastal instability faces dire economic prospects. Without significant changes to the city's water and soil management regimes, costs due to flooding and subsidence are estimated to exceed US$10 billion over the next fifty years. These costs are borne not just by public entities that are already strapped for cash, but by each citizen and business that makes their home in New Orleans. Receiving over 60 inches of rain each year, New Orleans possesses in abundance one of the 21st century's most important natural resources. For reasons of safety, quality of life and economic opportunity, the city must develop its ability to better manage its water resources. This is imperative not just in terms of incurred costs, but also because access to water, in a time of growing scarcity for many regions, will be one of the factors that determines the ability of entire industries, cities and regions to thrive.

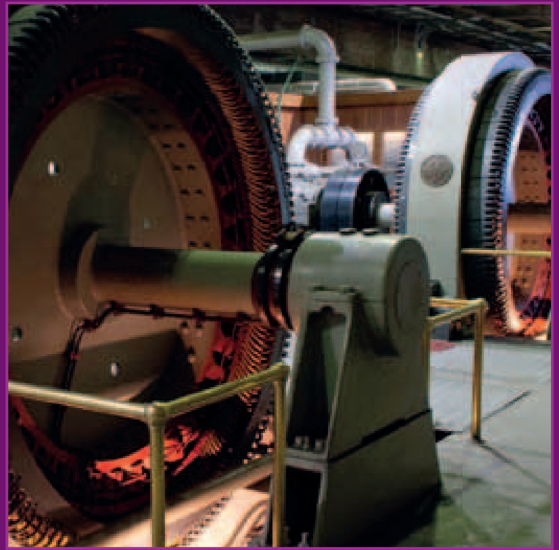
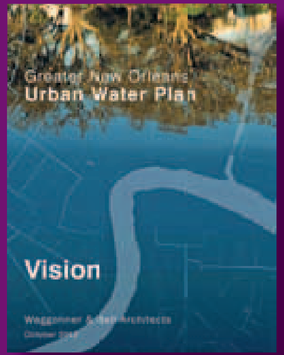


Figure 7.2 Pumps are a necessity in this low-lying region.



4

7 Climate Adaptation Strategies

The New Orleans Urban Water Plan is a holistic first-of-its-kind plan for an American city, and draws from international best practices and New Orleans' own history. The strategy grew directly out of and builds upon the Dutch Dialogues, a partnership born after Hurricane Katrina and facilitated by the Royal Netherlands Embassy, the American Planning Association and Waggonner & Ball to re-think not only the shape of the city but the planning process itself. The Water City plan begins with the soft soils underlying the city, and overlays the infrastructure, communities, and culture above. This ground-up approach provides the means for achieving long-term resilience and sustainability.

Adaptation begins with a new operational paradigm. The current approach to managing stormwater says that every drop of water that falls must be pumped out. In the Water City, water must be viewed as a resource and asset rather than as a nuisance to be removed at all costs. This approach takes root at every level, from the management of stormwater in individual yards and streets up to the level of entire canal networks and the operations of our many pump stations. Phased retrofits of existing systems emphasize visible stormwater infrastructure, with natural elements and ecological processes incorporated throughout the system design in order to enhance overall function and safety.

Smart retrofits build towards a total transformation of existing systems. Phasing strategies strike a balance between incremental patches to the old system and integrating new components, in order to capitalize on opportunities that already exist within the system while generating economic development, reinvestment and other near-term and long-term public benefits as a result of each step.

To allow us to continue to inhabit the Mississippi Delta, the water systems within the levees must sustain a landscape that requires proper soil saturation in order to remain stable. The existing single-purpose drainage system should be transformed to manage water comprehensively every day, during both wet and dry periods, rather than simply pumping when it rains.

Natural flows characterize a healthy delta landscape, and the elements and processes at work outside the levees also underlie the urban area within. A new circulating, living, water system based on natural principles aligns the city with the fundamentals of its place. Flowing water supports healthy

Figure 7.3 The Urban Water Plan team.


Figure 7.4 Clockwise, from top, left: Orleans Avenue, canal rowing, Palmetto Canal and the Dutch-American team observe the open canal.


ecosystems with populations of species that feed on mosquitoes, like fish and frogs, and moving water limits the breeding of mosquitoes. Low volume siphons operate under gravity to let water in, and small constant duty pumps already exist at many pump stations to induce flow through the system. The same water sources that charge the circulating system also provide water to raise operating levels in the city's canals in order to facilitate groundwater recharge. The existing networks of pipes, canals, and pumps can distribute water to areas most at risk for subsidence and most in need of groundwater balance.

Despite the need for new day to day systems, intense rainfall remains a major challenge. The functional limits of a 'pump first' system have already been surpassed by the rainfall the city sees today. As climate change brings even greater intensity and unpredictability to climate and weather, a transition is needed to a storage-based system. At every stage, steps should be taken to reduce and slow surges of water into the system during peak rainfall. At its most basic, New Orleans needs to make space for water. The already low-lying city needs to dig.

Catching water as soon as it falls, before drops combine into a rushing stream, is essential to limiting localized flooding and giving water time to infiltrate into the ground. Solutions to slow the flow of water will be distributed across all properties and land uses. Excess runoff cannot be properly managed without holding water at every possible point. Many green solutions, like planting trees and creating raingardens, provide benefits to the city even when it's not raining, such as providing much-needed shade on sunny days. Water storage within the system is available through widened canals, parks and overflow areas – all between the catch basin and the pump. These spaces allow the pumps to catch up and can be used for other public activities in dry weather. Extra storage space also compensates for storage volume lost to higher water levels, a necessary step to limit subsidence. Finally, storage in key locations reduces drainage bottlenecks and relieves pressure on the downstream components.

In a city below sea level surrounded by high levees, pumping will always be part of the equation. Pumping, however, should be a last resort, not the solitary solution. The development of the existing drainage system overlooks the relationships between high and low ground. The living water system must align with the landscape and use even the slightest slope to its advantage. Wherever possible, water should be moved to the nearest perimeter point of discharge, including the Mississippi River, the Industrial Canal and the wetlands that surround the city, rather than always to the lake.

Perhaps more important than physical adaptations to the water system are the cultural and societal shifts that must take place to support them. New Orleans must develop a water-literate culture, with a populace engaged in the science and management of soils and water; systems managers dedicated to the monitoring and revitalization of the landscape; and civic leaders and elected officials engaged in realizing a shared vision of a stronger, more beautiful water city.

The Mirabeau Water Garden

As witnessed in August 2012 during Hurricane Isaac, storm surges approaching twenty feet are possible in Lake Pontchartrain, and the newly completed hurricane protection system is capable of managing these levels. Internally, however, new structures are needed to balance surface and groundwater levels that change with heavy rainfall and drought.

Twenty-five acres of land rest unused on Mirabeau Avenue in the heart of the Filmore neighborhood between Bayou St. John and the London Avenue Canal. Oak trees line the northern edge of the site culminating in a live oak grove in the northwestern corner. Looking to the south, one can see the downtown New Orleans skyline beyond the neighborhood.
The proposal aims to slow and store stormwater from the Mirabeau Avenue S&WB storm drainage trunk line. Under this proposal, water from the neutral ground subsurface pipe enters a forebay, an open concrete-lined box only several inches deep, five feet beneath the ground. Passersby notice both the volume of water and the sound of water flowing. As one enters the site, water cascades into a deeper forebay where it collects before pumps raise the water into a sequential filtration "train." Water winds through the first in a series of vegetated filtration terraces planted with lily pads to filter nutrients, petroleum and toxins from the water. As the lily bed fills to capacity, water falls into a constructed bed filled with tall reeds and grasses, filtering even more of the toxins. The third and final bed contains cypress trees, both filtering the water and soaking up the water which can evaporate through transpiration. Channels connected to the filtration beds cut laterally across the site and fill when the beds overflow, creating a gridded network across the property.

The filtration sequence will culminate in a fresh-water swimming pool. In this final step of the cleansing cycle, one can look towards the lake and understand how the water is pumped then

Figure 7.5 Dry. Water features and fields that serve a local university and the neighborhood.

Figure 7.6 Wet. Rain gardens, boiswales and low-lying athletic fields provide storage during the heaviest rain events.

cleansed and filtered. Leaving the fresh-water swimming pool, one faces a tree-lined pedestrian boulevard leading toward the memorial to the Congregation of St. Joseph, longtime owners of the tract.

As the pool fills, water will fall into a willow and cypress grove. Inspired by the Chinampas in Mexico, willow-lined vegetated beds alternate with navigable canals, providing space for water recreation such as kayaking or paddle boarding. The willow grove collects water from the southern edge of the site before overflowing to the wooded wash. Winding around the foot of the foundation fill, the woodland wash collects water from the rest of the site as well as exposing the groundwater. Shaded by existing and newly planted trees, one can walk along the woodland wash and catch glimpses of buildings toward the lake and athletic fields towards the river. As water nears the end of the woodland wash, it winds around the CSJ memorial. A weir allows excess water to pass through the existing oak grove and re-enter the subsurface drainage system through a pipe on the northeastern corner of the site. The excavated southern half of the site is used as storage in extreme rainfall, designed to flood and infiltrate through a sand layer.

Figure 7.7 Existing situation.

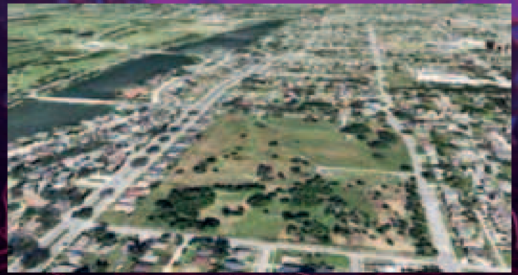


Figure 7.8 Potential situation of Mirabeau water garden.

On the site, buildings are arranged along a series of gridded channels, which catch runoff and convey the water to the woodland wash. The water garden becomes an educational experience and neighborhood amenity.

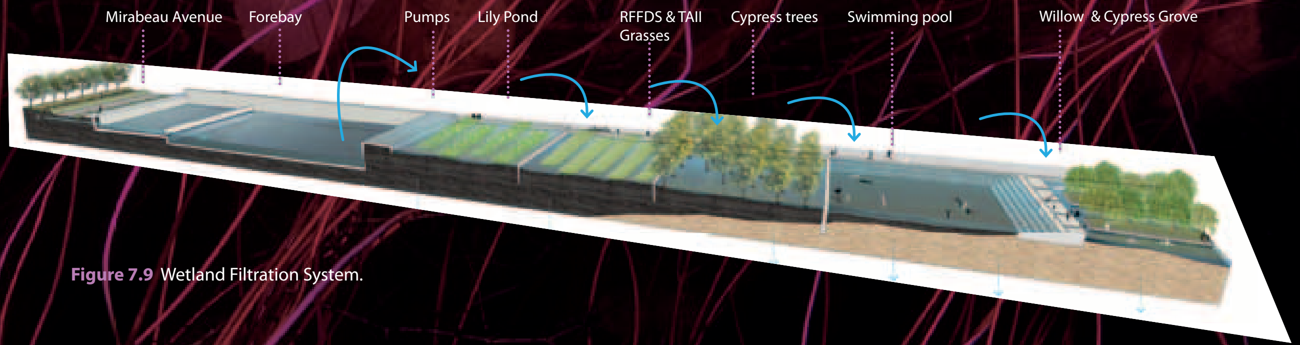


Figure 7.9 Wetland Filtration System.

"Every day the current course is maintained, the region's lands and levees sink, pipes break, streets decay, building foundations weaken. Even investments in repairs and improvements made by one community will produce little lasting value if not coordinated and supported by those across the region. The Greater New Orleans Urban Water Plan reconnects communities with water and with each other to enhance the prospects and wellbeing of all. It is based upon economies of scale, hydrologic and demographic reality, and the tenet that water sustainability will be a key driver of community success and vitality in the coming years."

Professor Mark Davis, Director of the Institute on Water Resources Law and Policy at Tulane University

Looking to the future, we must prepare for the unpredictable impact climate change will have on coastal communities like New Orleans. It is because the dangers are so clear and present that coastal communities like New Orleans are uniquely poised to chart a new way forward. We must be the ones to set the standard for community renewal and sustainable development. We who live in the world's deltas or on the edges of great oceans are the most immediate laboratory for innovation and change, and our success or failure will be the symbol for the world's ability to accomplish great things, or not.
But for all coastal cities our future is not just about survival. It's about sustainability. It's about redemption. It's about getting this right, for now and for the generations to come.

Cedric Grant,
Vice Mayor of the City of New Orleans

8 Hong Kong

by Fedrick Y.F. Kan, T. C. Lee, Vincent S. C. Mak , et al[37]

8.1 Introduction

Thanks to its favourable location, Hong Kong has continued to expand over the years as a leading international economic hub, particularly for trade with China. With the fast-growing tourism industry, the territory records a vast improvement in communication, together with an increasing number of people entering mainland China each year from or through Hong Kong, the natural gateway. However, with the increasing trend of having more extreme precipitation, the threat from tropical cyclones and higher mean sea level, Hong Kong is facing new challenges in adaptation for climate change.

Hong Kong is a highly urbanised coastal city, which is usually subject to severe rainstorms between April and October each year. Hong Kong, situated at the southeastern coast of China, is composed of Hong Kong Island, Kowloon Peninsula, the New Territories and 262 outlying islands (Figure 8.1). With the presence of a natural deep-water Victoria Harbour lying between Hong Kong Island and Kowloon Peninsula, Hong Kong continues to be an important entrepôt in the world and a popular gateway to China.

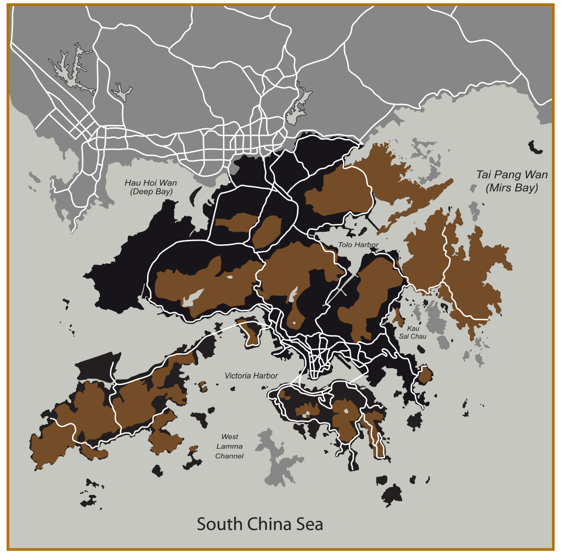


Figure 8.1 Map of Hong Kong.

8 2

General city characteristics

The total area of Hong Kong is around 1,104 km^2, but owing to its mountainous topography, less than 25 percent of the land is developed. Around 40 percent of the undeveloped land is country parks and nature reserves. From 1981 to 2012, the population of the territory increased from 5.18 million to 7.15 million at an average growth rate of 1.05 percent per annum. Hong Kong is a vibrant metropolitan city and has strong economic links with mainland China and the rest of the Asia-Pacific region. To keep pace with developments, the Government places strong emphasis on improving and expanding infrastructure. As a result, Hong Kong has been transformed into a modern city with efficient road and rail links, and first-class port and airport facilities. Its economy is characterised by free trade, low taxation and minimum government intervention, facilitating the territory to become the world's 9th largest trading economy. In 2012, the GDP per capita was HK$285,403, in which the total GDP was HK$2,041.9 billion.

Climate and flood risks

Hong Kong has a sub-tropical climate. Approximately 80 percent of Hong Kong's average annual rainfall of about 2,400 mm occurs between May and September [38], with June and August being the wettest months. In the months between June and October, passages of tropical cyclones over the northern part of the South China Sea can bring high winds and widespread heavy rain. Landslides and flooding sometimes cause considerably more damage than the winds. During severe rainstorms, flooding may occur in the rural low-lying areas and the natural flood-plain over the northern part of the territory, as well as in parts of the old urban areas.

Against the background of global climate change and local urbanisation, significant changes in the climate in Hong Kong have been observed in the last 130 years (Figure 8.2), including an increase in average temperature and total rainfall as well as a rise in the mean sea level.[39 40] Studies of past occurrences of extreme temperature and rainfall in Hong Kong have revealed that cold episodes are becoming rarer while very hot days, hot nights and heavy rain events are becoming more frequent. The annual total precipitation due to extreme rainfall events has also increased, indicating an increasing contribution of heavy rain to annual rainfall figures.[41]

The trends in temperature extremes that have been observed during the 20th century are expected to continue into the 21st century with a significant increase in the number of hot nights and very hot days, as well as a significant decrease in the number of cold days.[42] Rainfall in Hong Kong in the 21st century may become more variable and extreme. While the number of rainy days is expected to decrease, the number of days with extreme rainfall and daily rainfall intensity will increase.[43]

Typhoons and floods are recurring threats that have brought catastrophic consequences throughout the history of Hong Kong[44]:

- An unnamed typhoon in 1906 caused vast damage in Hong Kong and resulted in a death toll of over 10,000 (among them 90 percent were boat people), a shocking figure for a population of less than 450,000 people at the time.
- The villages along the coast of Tolo Harbour were severely flooded by the storm surge of the Great Hong Kong Typhoon in 1937. Again over 10,000 lives were lost. The surge was about 3.8 m.

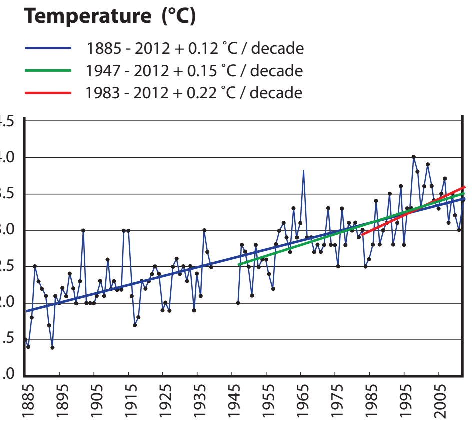


Figure 8.2 Annual mean temperature recorded at the Hong Kong Observatory Headquarters (1885-2012). Data not available from 1940 to 1946.

- Typhoon Wanda (1962) coinciding with a high tide brought tidal waves as high as 7 m. The effect was devastating, with over 130 people dead and 72,000 people left homeless.
- Typhoon Rose came with an extreme rainfall of 288 mm on 17 August 1971, resulting in flooding and landslides. 110 people were killed and 5,644 left homeless.
- June 2008 brought a record-breaking monthly rainfall total of 1,346 mm. A Black Rainstorm Signal was issued on June 7, when 301 mm fell within a day. The damage on this day alone was estimated at EUR55 million (US$75 million).
- During the passage of Typhoon Hagupit in September 2008, there was severe property damage, land erosion and coastal flooding in Hong Kong.

Water supply risks

Hong Kong has no significant groundwater owing to the hard granite base and absence of sizable lakes and rivers. Nowadays, Hong Kong's two main sources of fresh water are rainfall from natural catchment (accounting for 20-to-30 percent of the city's water supply) and Dongjiang water imported from Guangdong in China (accounting for 70-to-80 percent of the city's water supply). Although it is anticipated that the current arrangement of water supply is able to meet the projected demand up to 2030, acute climate changes may bring about adverse impact on the city's water resources.

8.3 Climate adaptation strategies

Drainage Services Department (DSD) has been actively commissioning drainage studies and implementing flood prevention projects to expand and improve the existing drainage system - undertake river training works; construct storm water tunnels for interception at upland catchment; and provide storm water storage facilities, a pumping scheme and a village flood protection scheme at flood prone areas to upkeep the excellence of the existing drainage system in Hong Kong. Since its establishment in 1989, DSD has completed eleven Drainage Master Plan (DMP) studies for the whole territory (Figure 8.4, next page). Following the recommendations of the DMP Studies, diversion of storm water at upstream catchment or storage at its downstream area have been promoted to relieve the load to the existing drainage pipes due to extreme rainfall.

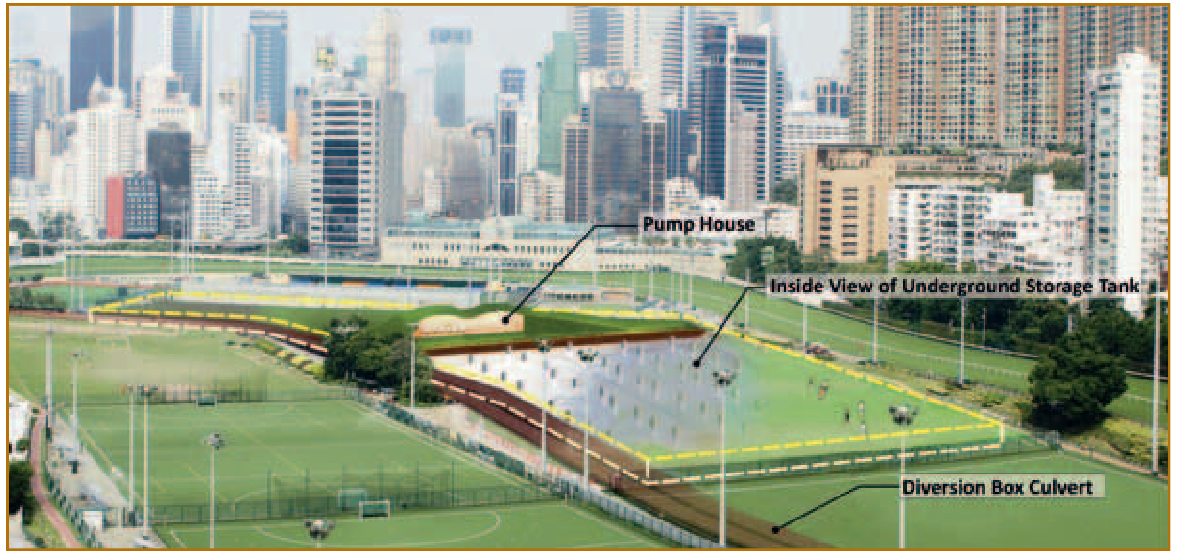
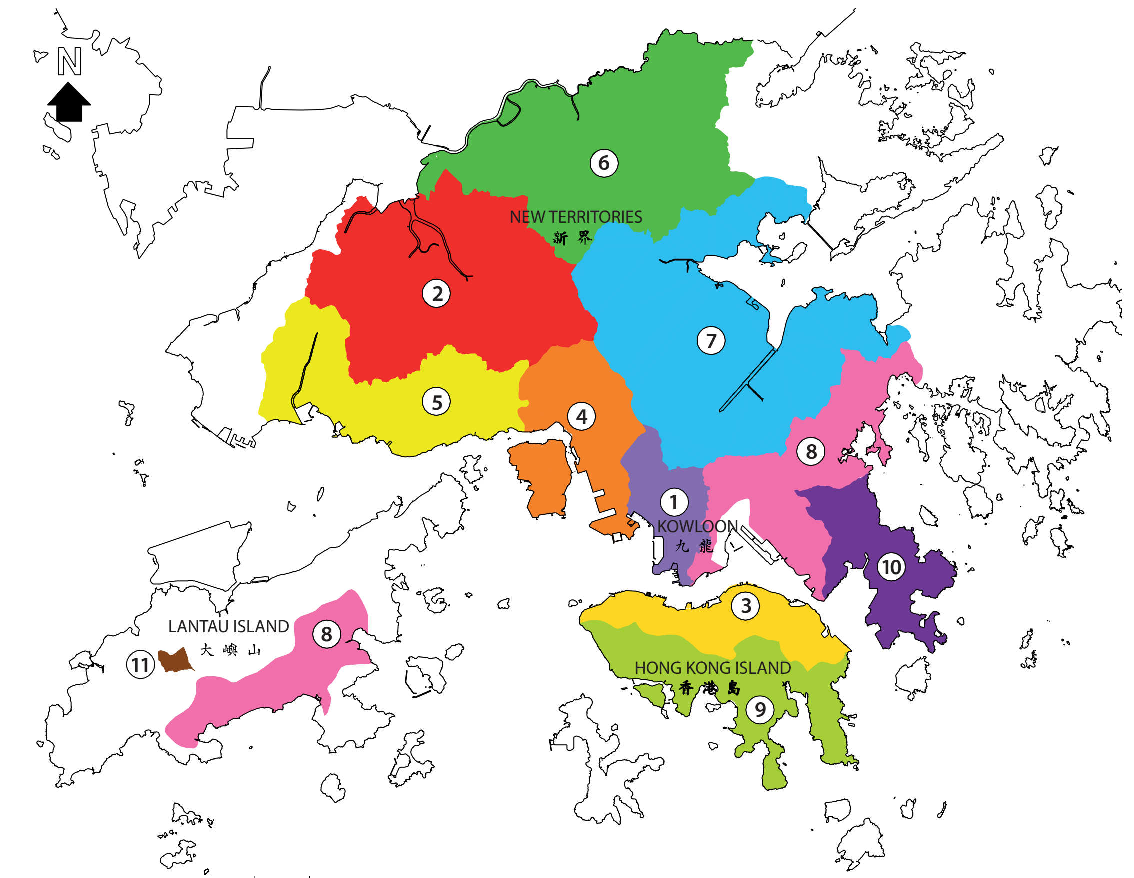


Figure 8.3 Happy Valley Underground Storm water Storage Scheme 2012 IWA Project Innovation Awards (East Asia Regional Award).



Study Areas 研究地區	START DATE 開始	COMP. DATE 完結
1. West Kowloon 西九龍	6/94	12/95
2. Yuen Long, Kam Tin, Ngau Tam Mei & Tin Shui Wai 元朗、錦田、牛潭尾及天水圍	1/96	12/98
3. Northern Hong Kong Island 香港島北部	5/96	2/99
4. Tsuen Wan, Kwai Chung & Tsing Yi 荃灣、葵湧及青衣	9/96	7/99
5. Tuen Mun, Sham Tseng 屯門及深井	3/97	3/99
6. Northern New Territories 新界北部	10/97	10/99
7. Sha Tin & Tai Po 沙田及大埔	1/98	10/99
8. Sai Kung, East Kowloon & Southern Lantau 西貢、九龍東部及南大嶼山	9/98	9/00
9. Southern Hong Kong Island 香港島南部	9/02	9/04
10. Tseung Kwan O 將軍澳	8/06	8/09
11. Ngong Ping 昂坪	12/08	7/10

Figure 8.4 Drainage Master Plan Studies.

Runoff interception at uphill catchments has proven to be an effective and sustainable means for flood prevention. Four drainage tunnels were built (Figure 8.5) in Tsuen Wan, Lai Chi Kok, Kai Tak and Hong Kong West, in which the newly commissioned Hong Kong West Drainage Tunnel in August 2012 is one of the world-class projects delivered by DSD in relieving the flooding risk in Hong Kong Island and won the top prize at the Tunnelling Project of the Year of the 2011 International Tunnelling Awards.

The building of retention tanks is another sustainable contribution for flood prevention in Hong Kong. Apart from the Tai Hang Tung Storage Scheme and Sheung Wan Storage and Pumping Scheme completed in 2004 and 2009 with a flood storage capacity of 100,000 and 9,000 m³ respectively, the Happy Valley Underground Stormwater Storage Scheme, with a capacity of 60,000 m³,currently under construction, gives due attention to the flooding issue in this developed urban area, culminating in international recognition of the project.

Figure 8.5 Drainage Tunnels in Hong Kong.

From 1989 to 2013, the Hong Kong Government spent an average of US$128 million per year for improving the drainage system in Hong Kong, leading to a substantial reduction in the number of flooding blackspots in the territory, from 90 in 1995 to 13 in 2013. With the new bearing of drainage sustainability, DSD aims to uplift the existing drainage system to a new phase and remove more flooding blackspots by 2016. Despite the achievement made so far, the drainage system in Hong Kong keeps facing challenges from sea level rises and extreme rainfall events resulting from climate change.

Coping with the latest developments in the community, changes in land use, drainage network, geomorphology, computing technology and weather pattern, together with their effects on the drainage system, DSD continuously reviews and updates the completed DMP studies of different regions in phases. The first review of DMP studies in Yuen Long and North Districts was completed in 2011, followed by another two DMP review studies in West Kowloon and East Kowloon, which were started in 2012 for completion in 2014. Other reviews of DMP studies have recently been launched in Tai Po, Shatin and Sai Kung in 2013 for completion in 2015. Through continuing assessment on climate change and the comprehensiveness of the drainage system, the DMP review studies devise new strategies to meet the city's increasing expectation on drainage service.

Eco-city concept

To meet contemporary public aspirations in respect of the natural environment and protection of the local culture and rural lifestyle, a more adaptable form of urbanisation with the concept of building an eco-city in the future new town development project is being explored in Hong Kong. Various measures, including the integration of land use with flood prevention measures, eco-hydraulics designed for rivers and sustainable urban drainage design under the eco-city concept, have been derived and recommended for further study in the future new town development project.

Integration of land use

By integration of land use with the planning of 'blue-green' infrastructure to cater for future urban development, this new form of urbanisation will result in medium- to high-density developments intermingled with the rural environment comprising active agricultural land, with potential for rehabilitation and rural settlements.

Delineation of land use will be adopted for flood protection and re-use of treated effluent to reduce the amount of effluent in compliance with the environmental policy of 'no net increase in pollution load'. Flood retention lakes and interception measures will be adopted whilst the existing rivers will be upgraded with a green and eco-hydraulic approach for integration with the overall land use planning. Sustainable urban drainage concepts, including green roofs, porous pavements and rainwater harvesting, will be promoted to reduce the rainwater runoff. Caverns will be used to house additional sewerage treatment works, fresh water/treated effluent service reservoirs and a refuse transfer station.

Eco-hydraulics design for rivers

Maintaining the good ecological value of the rivers before and after the implementation of flood mitigation works is of prime importance. DSD works with other departments and counterparts to incorporate various green and species-friendly features in and around the river to ensure the maintenance of wildlife habitat. Recommendations of regular post-construction monitoring have been made and a digital ecological management system is being established to record the change of river ecology. The whole concept will be considered in the design of the current new town development projects and eventually will contribute an essential part to the success of an eco-city in the territory.

Sustainable urban drainage system

Instead of enlarging the existing drainage pipe system, the developed source control technique and sustainable drainage design measures in DSD will be injected into the overall design of an eco-city. Studies of at-source attenuation of surface runoff and pollutants, like porous pavements, bioswales, rain gardens and green roofs are progressing well. Intensive reviews and site trials on vertical greening and riparian vegetation are also being conducted, targeting the reduction of the carbon footprints at drainage facilities. To utilise rainfall, DSD has introduced rainwater harvesting concepts (Figure 8.6) in current drainage design to reuse the water for irrigation or toilet flushing.

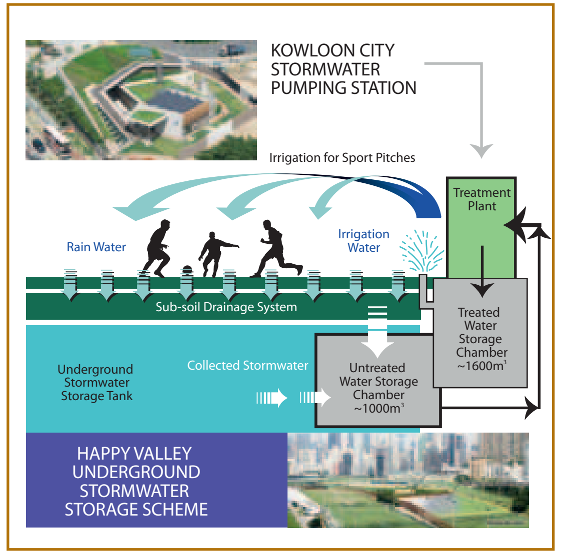


Figure 8.6 Rainwater Harvesting.

Figure 8.7 Approach for Green Works in Sha Tin Sewerage Treatment Works.

Total water management for the sustainable use of water[45]

Hong Kong Observatory (HKO) has projected that it is likely for Hong Kong to have more drought events in the coming one or two decades, with more uneven distributions of wet and dry periods and an increased number of extremely wet and dry years in the 21st century.

To better prepare Hong Kong for adverse impacts on water resources from acute climate changes, the Government pledged the implementation of Total Water Management (TWM) in 2003 and has since then put forward different studies, trials and schemes to enhance water conservation and to explore new water resources. Hong Kong's first TWM strategy, promulgated in 2008, put emphasis on containing growth of water demand and strengthening water supply management by an array of TWM measures. It sought to achieve an optimal balance between water demand and water supply to ensure sustainable use of water resources.

The key initiatives under the strategy are:

Water Demand Management

- To enhance public education on water conservation;
- To promote use of water saving devices;
- To enhance active leakage control;
- To extend the use of seawater for flushing.

Water Supply Management

- To strengthen the protection of water resources;
- To actively consider water reclamation;
- To develop seawater desalination.

Water Supplies Department (WSD) will continue to explore new sources of water which are less sensitive to the impacts of climate change, including reclaimed water and seawater desalination (Figure 8.8); and study the feasibility of using the surface runoff collected by storm drains and tunnels for different applications to promote water harvesting.

Figure 8.8 Planning and Investigation of Desalination Plant at Tseung Kwan O.

Flood prevention

To combat intense rainfall and sea level rises brought on by climate change, DSD takes a proactive and pragmatic approach to implement holistic flood mitigation measures. From forward planning for territory-wide storm water drainage systems to implementing various sizable and innovative drainage improvement works (river training, village flood protection schemes, drainage tunnels, underground storage tanks), DSD's target is to provide world-class storm water drainage services enabling the sustainable development of Hong Kong in a cost-effective and environmentally responsible manner.

River training works for the effective discharge of rainfall has been executed for decades. For low-lying rural areas, a village flood protection scheme, comprising a periphery road embankment and a storm water pumping station, has been widely implemented with successful results. By introducing innovative and massive drainage tunnels and underground storm water storage facilities in urban areas of Hong Kong (Figure 8.9), intercepted storm flow from upland catchment is then diverted or temporarily stored respectively to attenuate the peak runoff loading to the downstream drainage system.

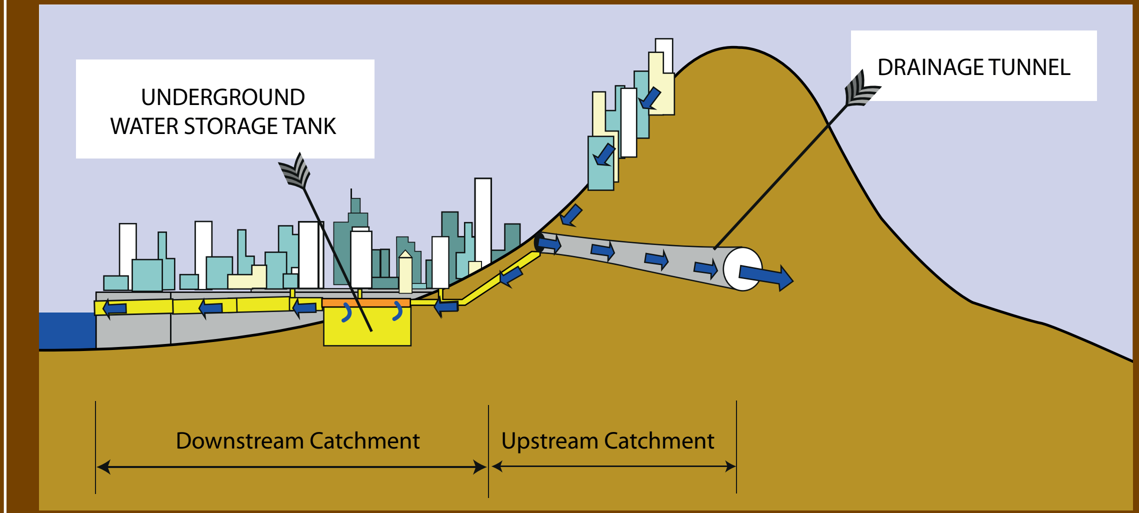


Figure 8.9 Conceptual Layout of Drainage Tunnel and Underground Storm water Storage Tank at Tai Hang Tung, Kowloon (Source: Drainage Services Department)

As well as the sophisticated drainage system in the territory, DSD has set up an Emergency and Storm Damage Organisation (ESDO) and provides round-the-clock services to handle urgent flooding incidents. The Emergency Control Centre (ECC) under ESDO will be activated during specified inclement weather conditions. For water levels and crucial hydraulic structures at major channels including flood pumping stations and inflatable dams, they are being closely monitored by real-time telemetric system and video surveillance. When necessary, ECC will alert other departments to prepare for rescue, evacuation and opening of flood shelters as appropriate.

Figure 8.10 Emergency Control Centre in operation.

Climate change study
Environmental Protection Department (EPD) completed in 2010 a comprehensive consultancy study to provide the basis for implementing strategies and measures for addressing climate change in Hong Kong (Figure 8.11).

On adaptation to climate risks, the report has identified the following areas that are most vulnerable to climate change impacts in Hong Kong:

- Biodiversity and nature conservation – including terrestrial, aquatic and marine biodiversity, and nature conservation;

Figure 8.11 A study of Climate Change in Hong Kong.

- Built environment and infrastructure – including construction and maintenance, building stock, transport infrastructure, communications infrastructure, drainage and sewage infrastructure;
- Business and industry – including trading and logistics, manufacturing, professional services and producer services;
- Energy supply – including electricity generation, electricity distribution and transmission, primary fuel imports and supply;
- Financial services – including banking, financial trading, brokerage and speculation, asset management, insurance, reinsurance and other financial services;
- Food resources – including agriculture, aquaculture and fisheries in Hong Kong, overseas food imports and food wholesale and retail trade;
- Human health – including healthcare infrastructure, changes to mortality and morbidity due to accidents, chronic health conditions, etc;
- Water resources – including local yield and treatment, and Dongjiang imports.

The report suggests that Hong Kong possesses significant adaptive capacity to climate change impacts and has many systems in place that could be used to adapt to the physical impacts of climate change. For example, the Security Bureau is responsible for the Government's overall contingency plan in coping with different disasters or emergency situations. Various government departments and service providers have also developed monitoring or emergency response mechanisms to deal with landslides, flooding, or handle matters related to dangerous buildings, banking, telecommunications, public transport services, and energy and food supply in times of severe weather. In addition, the relevant authorities have been closely monitoring the ecosystem or species, pest situation under their monitoring programmes.

Nevertheless, the report suggests that it is likely that some of the policies and facilities may need to be up-scaled in the following aspects:

- Monitoring – creation of monitoring infrastructure which enhances knowledge pertaining to the status of key sectors, as well as enhancement of current efforts for the purpose of reviewing and revising current programmes;
- Institutional strengthening and capacity building – enhancing the ability of institutions to respond and adapt to adverse impacts brought about by climate changes;
- Disaster management and emergency planning – improvement of the planning and systems which are responsible for responding to emergencies;
- Research and investigation – expanding current knowledge regarding vulnerable sectors such as establishing priorities for improvement measures and identifying local high-risk areas;
- Education and public awareness – increasing the level of public awareness amongst the population such that they can take appropriate actions to combat climate change impacts.

Civil Engineering and Development Department (CEDD) completed a consultancy study to review the implications of climate change on the design of coastal structures in June 2013.

With reference to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and recent studies by the Hong Kong Observatory (HKO), Hong Kong will probably be subject to more extreme weather conditions due to climate change. So far, there has been no significant increase in the annual number of tropical cyclones affecting the South China Sea and the vicinity of Hong Kong in the last 50 years or so.[46] But against the background of global climate change, most of the available model simulations suggest an increase in tropical cyclone intensity and precipitation rates in the 21st century over the western North Pacific basin.[47] Although the vulnerability of coastal regions to storm surge flooding will ultimately depend on storm characteristics, future sea-level rise is likely to accentuate such vulnerability. Figure 8.14 illustrates coastal flooding areas in Hong Kong under different sea level conditions.

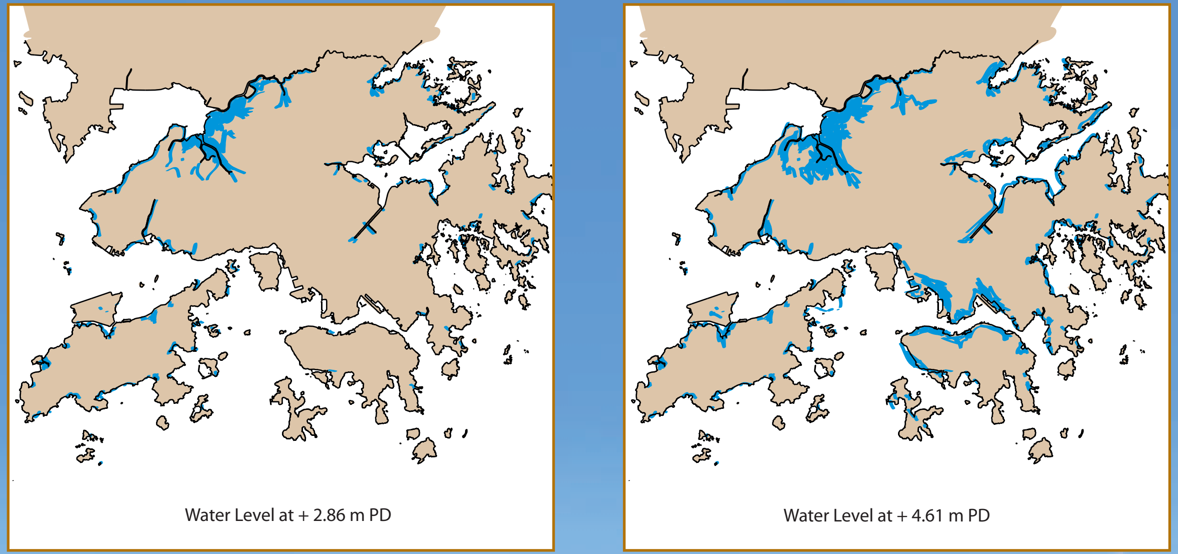


Figure 8.12 Illustrations of coastal flooding areas in Hong Kong under different sea level conditions.

Climate Change Public Education and Outreaching Activities

To keep the public informed of and enhance their awareness on climate change impacts, HKO proactively communicates the information to the public via various channels, including media interviews, press conferences, TV documentaries, a climate change web portal and various stakeholder engagement activities[48] HKO has also produced an educational package for free distribution to schools and libraries in Hong Kong. Furthermore, a team of professional meteorologists from HKO regularly gives free public lectures and school talks on climate change.

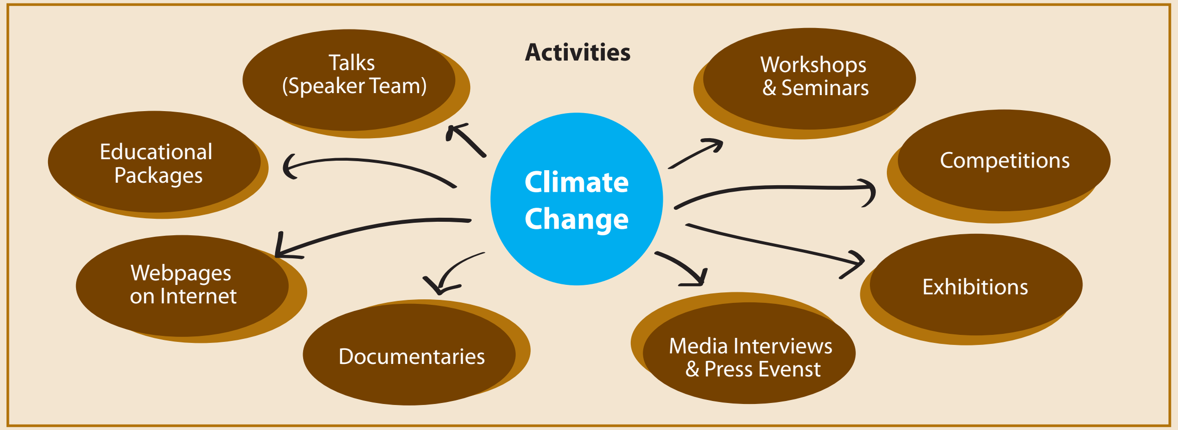


Figure 8.13 HKO's climate change public education and outreaching activities.

Hong Kong attaches significant importance to combating climate change. It is a global challenge that calls for concerted action from all people. In Hong Kong, we have been working closely with all major stakeholders to cope with the impact of climate change and mitigate greenhouse gas emissions in a bid to promote low-carbon living and create a green community with our partner cities in the region. We will continue our efforts to rise to the challenge.

Mr KS Wong,
Secretary for the Environment,
Hong Kong Special Administrative Region Government

9

Tokyo

by Yasumasa Kanai, Arata Ichihashi, Kanako Sakai et al

9.1 Introduction

Tokyo is the capital of Japan and is situated in the Kanto region of Central Honshu, next to Tokyo Bay on the floodplain of three large rivers. Tokyo is densely populated and is one of the world's largest cities, with a population in excess of 13 million people. Large parts of the city are below the flood level of its main rivers. Japan has high annual rainfall and is prone to floods, earthquakes and tsunamis.

Present situation

The Metropolitan Area of Tokyo stretches for about 100 km east to west, containing a mountainous district in the west and lowlands in the east (Figure 9.2). The lowlands in the east are located at the mouth of three large rivers: the Sumida River, the Ara River and the Edo River. The Sumida River flows through the centre of the city, the Edo and Ara Rivers are located in the outer districts.

Tokyo has annual precipitation of 1,621 mm (63.8 inches), more than two-and-half times that of London. Heavy precipitation occurs during the rainy season (in June and July), during the typhoon season (in September and October), and there is winter snowfall mainly on the higher ground. Japan is a narrow and mountainous country, so the rivers are

Figure 9.1 Map of Tokyo.

short and steep, and flow rapidly. After high rainfall events, the discharge can be a hundred times higher than the minimum discharge. As a result, the water levels in the rivers running through Tokyo can rise very quickly, sometimes by as much as 3-to-5 metres in 30 minutes.

Tokyo has improved many diversion channels by making use of spaces, for example, under highways so that they help drain these rapid pulses of water. These rivers help to drain excess water and are valuable assets to this historic low-lying city. In some cases, underground regulating reservoirs have been built to capture excess flows.

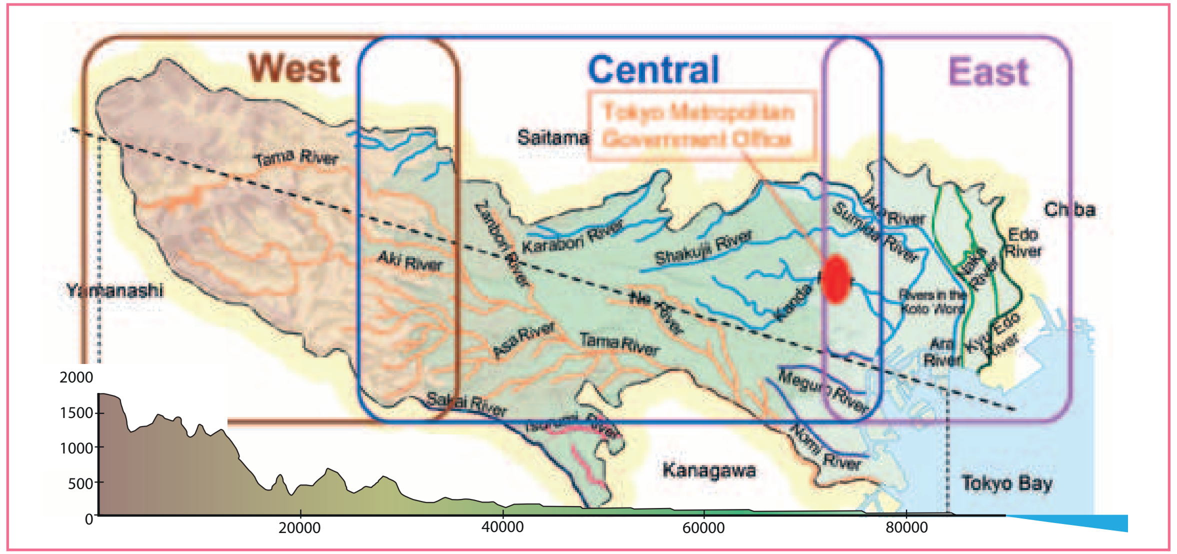


Figure 9.2 Map of Tokyo with elevation chart.

9.2 Urbanisation

Tokyo has experienced rapid urbanisation over the last century. The built up area within the Kanda River Basin increased from 60 percent to 96 percent between 1945 and 2005. Areas that used to be forest, paddy fields and ponds have now largely been covered by houses, other buildings and infrastructure. This further decreases the ability of the land to absorb intense periods of rain (Figure 9.3).

The population of the metropolitan area has risen rapidly, from some 7.4 million inhabitants in 1940 to approximately 13.3 million inhabitants (some 10 percent of Japan's total population) in 2013. With a population density of 6,029 persons per square-kilometer, Tokyo is the most densely populated prefecture in Japan and one of the most densely populated cities in the world. The outwards spread

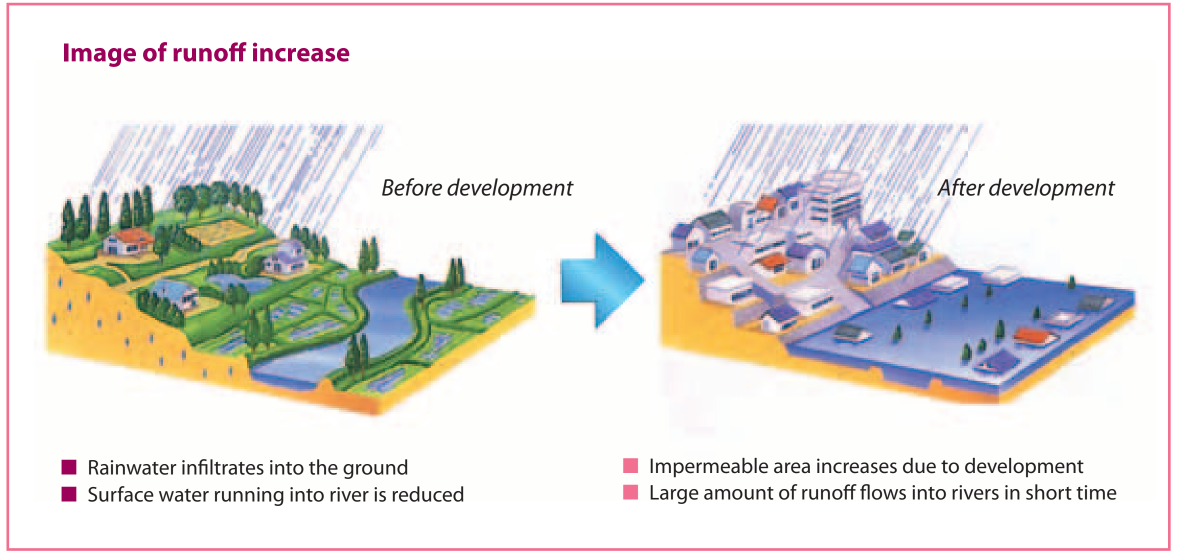
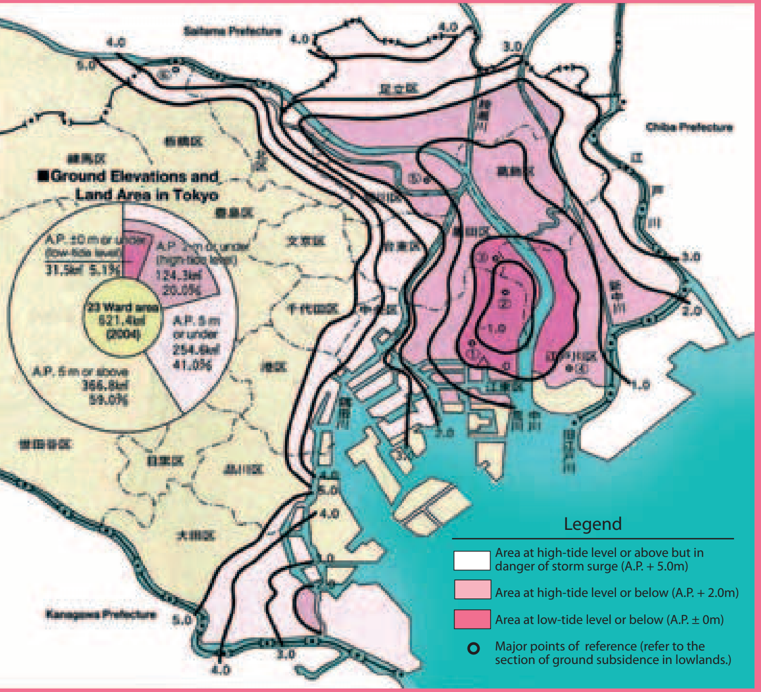


Figure 9.3 Urbanisation causes a decrease in water storage capacity.



* A.P. refers to Arakawa Peil, indicating A.P. ±1.134 m when the T.P. (Tokyo Peil) is 0 m.

Figure 9.4 Planimetric map of ground elevations in the lowlands, Tokyo.

of residential and commercial areas towards the more-elevated western region and the flood-prone eastern area is further increasing the number of people and properties vulnerable to flooding and increasing the intensity of runoff of rainwater into rivers. As more land is covered and unable to absorb rain, the frequency of flooding has been increasing. Most of the lowland area is below the mean high tide level in Tokyo Bay (Figure 9.4). The land in these areas subsided as a result of the excessive pumping of groundwater during the era of rapid economic growth.

These low-lying areas have a history of being prone to flood damage caused by high tides and typhoons. For example, during Typhoon Kitty in 1949, more than 130,000 houses were submerged and 122 people were killed or injured. Typhoon Kanogawa in 1958 caused the worst damage ever seen along Tokyo's small and medium rivers, damaging 16,743 homes, killing 1,269 people and leaving 12,000 homeless. The overall damage was estimated at US$50 million or 20.6 billion yen.

Much has already been done to reduce the damage from high tides and typhoons. For example, on 11 September 2001, Tokyo was struck by Typhoon No. 15; one of the largest typhoons since WWII. The resultant tide level was A.P. + 3.15 m, about the same level as that of Typhoon Kitty in August 1949. However, due to the completion of levees along the main rivers and storm gates, there was no major storm surge up the rivers and serious loss of life and damage to property was avoided.

9 3 Climate change and adaptation

Precipitation in summer and winter are predicted to be likely to increase in East Asia over the coming decades. It is also thought that the frequency of intense precipitation events and high winds (particularly associated with tropical cyclones) in the region will increase. Tokyo is now introducing a number of adaptive projects to reduce flooding and the damage it causes. River improvement measures are being implemented, according to the local geographical and rainfall characteristics. These measures can be grouped into three main categories:

- projects for rivers in the eastern lowlands to prevent damage from storm surges and earthquakes, including the construction of tide embankments and seismic reinforcement;
- projects for small and medium-sized rivers (central area and west area) to prevent damage from flooding, including broadening river courses and improvement of retention basins;
- projects in the mountainous western area to prevent sediment disasters, including landslide prevention projects on steep slopes, and designating areas as high-risk areas, for example, by designating vulnerable areas as erosion control areas.

All of these projects also involve improving the riverside environment, for example, the greening of revetments (sloping structures placed on banks or cliffs in such a way as to absorb the energy of incoming water) to create green corridors and to improve environmental amenities for Tokyo's citizens (Figure 9.5). For each categorie examples of measures are described in the following paragraphs.

Figure 9.5 Green corridors in Tokyo.

Measures against storm surges and earthquakes

Tokyo has been further improving its tide embankments and installing more water gates. These gates and other tidal defenses are designed to withstand surges one metre higher than the highest level experienced to date. Most of these flood defenses are now complete.

Super levees

Super levees are designed to protect dense urban areas from extreme flood events (Figure 9.6 and 9.7). Essentially a super levee is a wide river embankment that can with-stand overflowing and thereby prevent destruction. They have a shallower slope than a conventional dike at around 1:30: a super levee with a height of 10 m will be about 300 m wide. Super levee projects are always implemented in conjunction with urban redevelopment, land rezoning or other urban planning projects. They are multifunctional structures that provide both flood control and usable land and space for dwellings.

The super levees constructed today are better than their predecessors in two respects: first, they are seismically reinforced to prevent them being destroyed by earthquakes; and second, they are designed with the clear objective of allowing the public access to and enjoyment of the water. Unlike conventional tidal defense walls, which block views of the river, super levees positively enhance the environment. Just over a quarter of the existing 50 km of Sumida River wall has been replaced by a super levee. This super levee improves defenses against high tides and earthquakes and has also created excellent views with an improved river area. This super levee project will continue in the coming years. These levees were one of the main reasons for averting the loss of human life when Typhoon No. 15 hit Tokyo in September 2001.

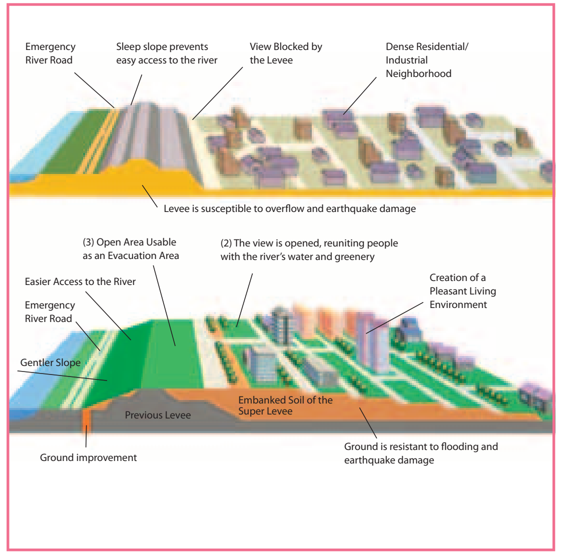


Figure 9.6 Principles of a super levee.

Figure 9.7 A Tokyo super levee.

Earthquake resistance

After the Great East Japan Earthquake (Richter scale: 9.0) occurred on 11 March 2011, Tokyo's authorities reconsidered the measures in place for earthquakes and tidal waves in the city's eastern lowland area and made a plan to improve river facilities. The Improvement Plan of River Facilities in Eastern Lowland Area in Tokyo was completed in December 2012. The aim is that all necessary facilities should remain operational in the case of tsunamis triggered by potential future maximum magnitude earthquakes. All the recommended improvement measures to floodgates, pump stations and levees will be implemented by 2020.

Floodgate management system

Tokyo's authorities operate a centralised management system that controls the sluice gates and drainage pump stations that defend the city against floods (Figure 9.8).

The Sluice Gate Management Centre enables rapid integrated and remote operation. There is a back-up system at Kinoshitagawa Centre in case the Sluice Gate Management Centre is out of operation for any reason. A dual loop system of fibre-optic cables is used for communications.

Figure 9.8 Flood gate.

Small and Medium-Sized Rivers

While existing design standard embankments and control reservoirs are resistant to rainfall of up to 50 mm per hour, flood damage accompanied by typhoons with rainfall of more than 50 mm per hour or localised torrential rains are increasing. To respond to this Tokyo's authorities have held a series of review meetings with specialists since June 2011, which led to the completion of the Improved Policy of Small and Medium-Sized Rivers in Tokyo in November 2012. This policy has resulted in raising the design target standards up to 75 mm per hour maximum in the eastwards areas and 65 mm per hour in the west Tama area. Such standards, when all planned improvements are completed, would ensure security for intensive rainfall on the scale of the Kanogawa Typhoon, which caused the worst flood damage in history, or localised torrential rainfall of 100 mm per hour.

River improvement measures

One common method of re-engineering urban rivers is to secure a wider flow area by developing a revetment (a sloping structure placed along the riverbank to absorb the energy of incoming water).

Figure 9.9 Tennis courts as temporary runoff storage.

Another method is to construct a separate channel alongside the river (for example, under an adjacent highway). This has the same effect of expanding the capacity of the river channel.

Regulating reservoirs

When it is difficult to develop a separate channel, an underground regulating reservoir can be constructed to store excess water. The Meguro River Ebara Regulating Reservoir is a large underground structure[49] spanning four tiers that was built to protect the city from the floods caused by overflow from the Meguro River. It holds the same amount of water as about 800 25-metre swimming pools.

Another example is the Kanda River Loop Road No.7 Underground Regulating Reservoir, constructed under Loop Road No. 7, one of Tokyo's highways. It is 4.5 km long, has an inner diameter of 12.5 m, and a storage capacity of 540,000 m^3, which makes it the biggest regulating reservoir in Tokyo. It takes flood water from the Kanda, Zenpukuji and Myoshoji Rivers.

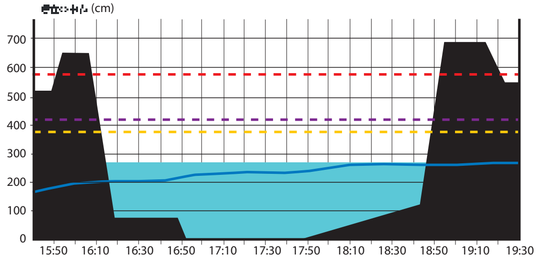
Tokyo also makes use of smaller, more limited spaces for water storage and infiltration facilities. These in part compensate for the loss of natural water retaining structures brought about by intense urbanisation. They include features such as permeable pavements and infiltration inlets in parks, schoolyards and houses that can absorb rainfall. Figure 9.9 shows a temporary runoff storage installation. In normal conditions, it is used as tennis courts but when there is heavy rainfall, it temporarily stores runoff and slows down its flow to the river.

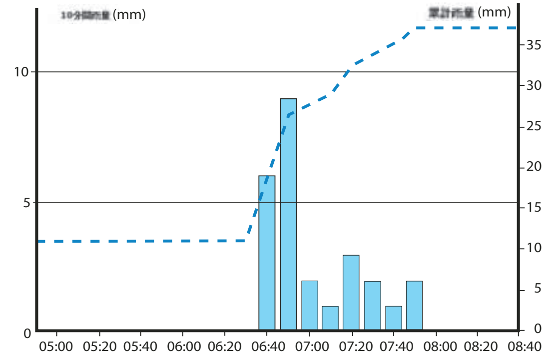
Figure 9.10 The Metropolitan Area Outer Underground Discharge Channel (Kasukabe, Saitama , Japan).

9.4 Public awareness

While infrastructure plays a vital role in Tokyo's flood defense plans, Tokyo municipality uses the internet, mobile phone and e-mail services to provide the city's inhabitants with information on various topics such as rainfall and river water level. This information is constantly updated and searchable. Hazard maps are extremely useful in showing which areas are likely to be submerged when a river floods, and places where residents can take refuge from rising waters (Figure 9.11). Individual municipalities each create a flood hazard map for their areas based on an area map produced by the Tokyo Metropolitan Government or the national government and make this available to their residents.

Figure 9.11 Flood and Rain Information System.





Collaborative research on impacts of climate change in Tokyo and adaptation

9 5

Tokyo has already taken a variety of measures to address climate risks, and, as a result, has a high response capacity. But the city now has to respond to risks exacerbated by the changing climate. To this end, the 'Investigation and Analysis Team for Adaptation to Global Warming', a task force consisting of 11 bureaus from the Tokyo Metropolitan Government, was established. Along with representatives of national government and research institutes, it took 4 years – until March 2013 – to complete a climate change impact assessment. It assessed as quantitatively as possible how the future climate change will influence five sectors: water resources, disaster prevention, ecosystems, health, and agriculture, forestry and fisheries through using the results of the Innovative Programme of Climate Change Projection for the 21st Century[50 51], the latest projections of climate change (Figure 9.12).

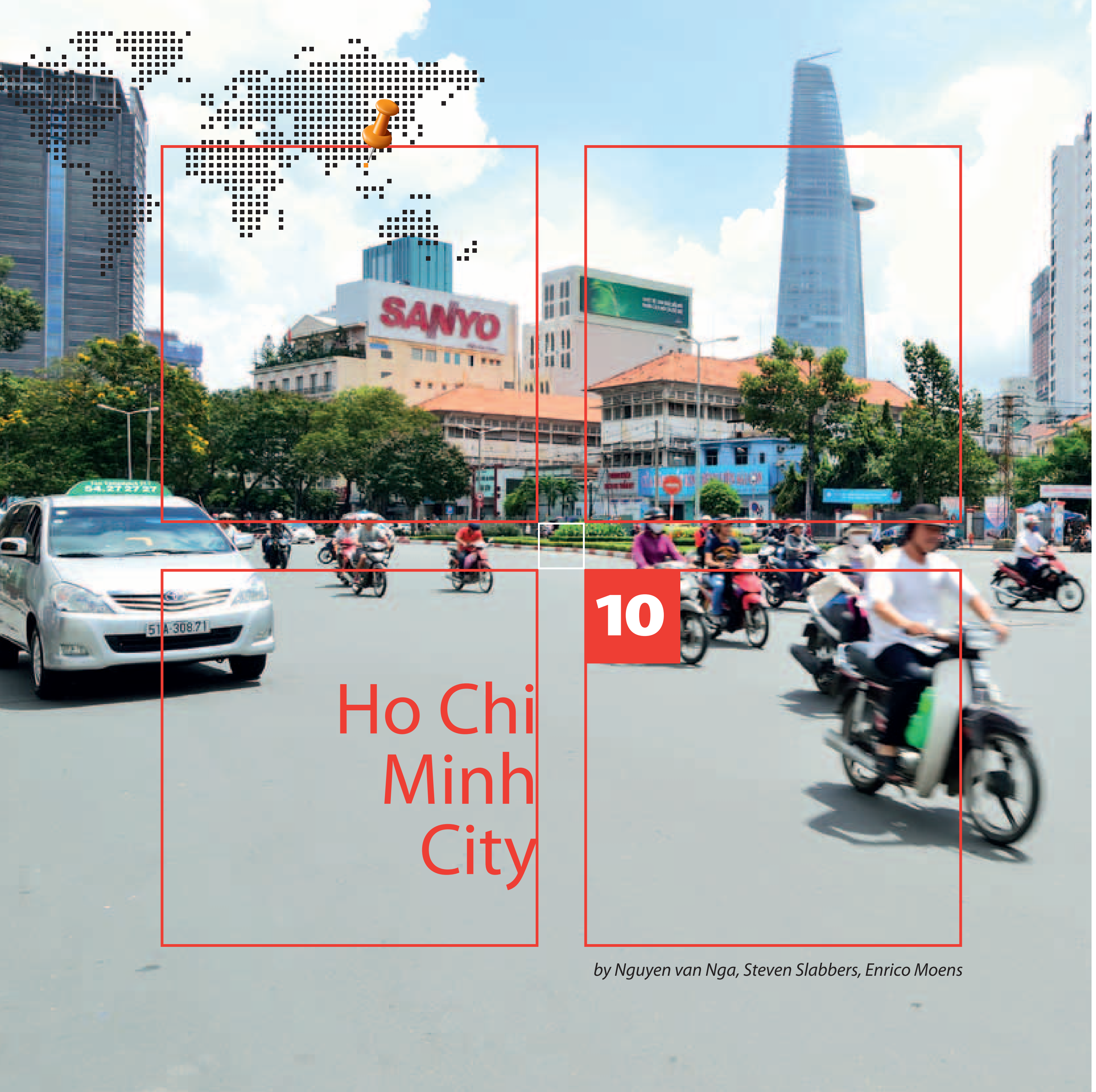
This research is the first scientific impact assessments using computer simulation by local governments, and it is possible to conduct further individualisation and refinement for the model that has been constructed this time. Thus, it can be considered that actions towards adaptation measures in Tokyo have moved forward. Also, this is the first research specifically showing impacts of climate change comprehensively and sector by sector, and it is expected to be used as basic data for planning adaptation measures in the future.

Impact Sector	Target	Impact Index
Water resources	River water	River flows
	Groundwater	Amount of water
Disaster prevention	River water	Large river floods
		Small and medium-sized rivers and sewer overflow
	Soil and sand	Mudslide
	Coastal areas	Storm surge floods
Agriculture, forestry and fisheries	Agriculture	Fruit trees
		Tea and vegetables
	Livestock industry	Meat
	Forestry	Artificially-established forests
	Fisheries	Migratory fish
		Coastal fish and algae
		Suitable cultivation area
Ecosystems	Terrestrial ecosystem	Natural forests
	Coastal ecosystem	Coral reefs
	Multidisciplinary fields	Changes of vegetation seasonality
		Changes of animal seasonality
Health	Heat stress	Death toll, number of people hospitalized due to heat stroke
		Sleep disorders
	Infectious diseases	Water-borne diseases
		Vector-borne diseases
	Other	Air pollution
		Allergy

Figure 9.12 List of Sectors for Impact Assessments.

Impacts of climate change have already begun to emerge in various ways around the world, and Tokyo is no exception. While various mitigation measures, including the world's first urban cap-and-trade programme, have been taken in Tokyo, we have also implemented many advanced measures against storm surges and flooding.
This year, an impact assessment of climate change in Tokyo has been completed as the initial step towards implementing adaptation measures. We will continue further discussion on adaptation measures and evaluate their potential effectiveness.

Mr. Akira Hasegawa,
Director General, Bureau of Environment,
Tokyo Metropolitan Government



10

Ho Chi Minh City

by Nguyen van Nga, Steven Slabbers, Enrico Moens

10.1

Introduction

Ho Chi Minh City (HCMC), located in the delta area of the Sai Gon and Dong Nai rivers is Vietnam's largest city and an important economic, trade, cultural and research centre of the country. With its seaport lying at an important intersection of international maritime routes, HCMC is situated at the heart of Southeast Asia and has become a traffic hub for the region and an international gateway.

HCMC has a diversified topography, ranging from mainly agricultural and rural areas in the north to a widespread system of rivers, canals and dense mangrove forest to the south. The urban areas are located approximately 50 km inland from the Pacific Ocean (also called East Sea by Vietnam) at the banks of the Sai Gon River. Early settlements date back to the 17^{th} century and were developed close to the Sai Gon River on slightly higher grounds and thus very favourable areas. Annual rainfall, temperature and sunshine are visualized in Figure 10.2 (next page).

Ho Chi Minh City (HCMC) is one of the fastest growing cities in the world. However, on-going subsidence, and the high-density urban housing in which people live make HCMC extremely vulnerable to climate change.

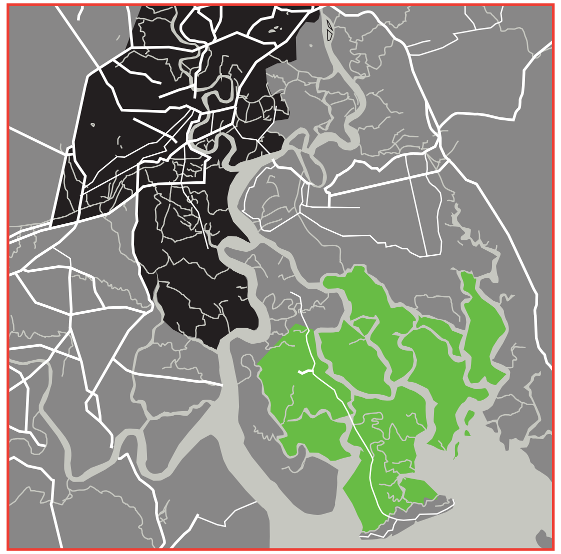


Figure 10.1 Map of Ho Chi Minh City.

The adaptation challenge for HCMC

10.2

Ho Chi Minh City is a vibrant metropolis with its own characteristics. It has a mixture of western and eastern influences, traditional architecture next to modern developments, small-scale enterprises versus megalopolitan developments and neighbourhood markets next to metropolitan economics. The fast growing economy, increasing population (7.5 m) and the existence of numerous social and cultural institutions characterize a city that is changing and expanding rapidly.

However two slower and subtler processes are becoming increasingly important for the city's future. The first is climate change, which leads to rising sea levels, changing rain patterns and increasing average temperatures. The second is subsidence in parts of the city making these areas more vulnerable to flooding. Today, approximately 60 percent of the urban area is located less than 1.5 m above sea level, making it highly vulnerable to projected sea-level rise.

Since the mid 1990s, the magnitude, frequencies and duration of floods are steadily increasing. Rising pressure on space has another drawback: available space for urban green areas decreases, which causes more frequent inundations by rainfall and high river flows. These changes will have a large impact on the economy of HCMC and the quality of life of its inhabitants if no immediate action is taken. Figure 10.3 gives an overview of the climate change related challenges in HCMC.

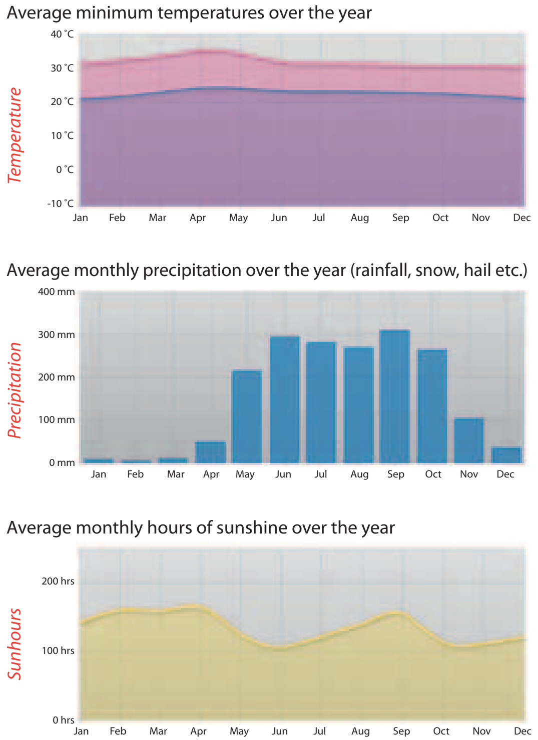


Figure 10.2 Temperatures and rainfall HCMC.

The urban development of HCMC is guided by the Spatial Master Plan 2025.[52] Since publication of the plan it was recognised that the impact of climate change on the development of HCMC is considerable and that there is a need to develop a Climate Adaptation Strategy. In 2010 the cooperation between the City of Rotterdam and HCMC on the development of a strategy began. This cooperation is part of a broader framework of cooperation between the Netherlands and Vietnam. Vietnam is a partner of the Netherlands' Global Water Programme, financed by Partners for Water Netherlands. This partnership was formalized when the Prime Ministers of Vietnam and the Netherlands signed a Strategic Partnership Agreement in October 2010.

A Dutch private consortium was contracted to assist HCMC to shape the Climate Adaptation Strategy in the project, 'HCMC Moving towards the sea with Climate Change Adaptation'.[53] The Vietnamese and Dutch team worked on one integrated strategy, which consists of six strategic directions within three different timeframes. Together they can transform Ho Chi Minh City into a unique climate-proof Delta city. After a very successful and inspiring process that took 1.5 years to complete, the strategy has been presented to the Peoples Committee in April 2013 and was approved in May the same year.

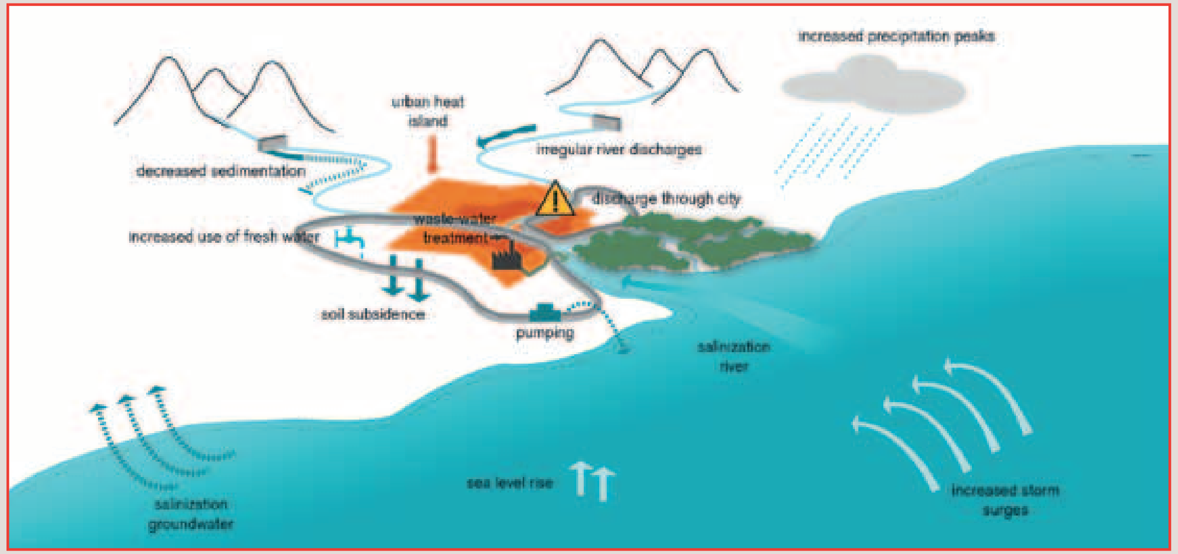


Figure 10.3 Climate change related challenges HCMC.

10

3

Development process

The development of the Climate Adaptation Strategy followed the Triple-A method for Strategic Planning. First an Atlas was developed including all readily available relevant facts, trends and underlying factors for climate-proof city planning. This Atlas forms the joint common reference for rational spatial planning. The first version of the Atlas was presented and handed to Mr. Kiet, Vice-Chairman of the HCMC Climate Change Steering Board, and Mr. Aboutaleb, Mayor of Rotterdam (May 2012).

Second, the Adaptation Strategy itself was developed, which presents the strategic development -direction for climate proofing HCMC. It integrates spatial, technical and additional interventions, and at the same time, adds quality to the city. The strategy was developed using a series of charrettes (see city focus box): on long term perspectives for the city, on the strategy itself and in the design of two pilot projects (District 4 and Nha Be) to test the possibilities of the step-by-step approach.

The third planning tool is an Action Plan detailing the mechanisms of implementation of the strategy for the short, medium and long term. The strategy and the action plan were presented to the People's Committee in May 2013.

To conduct day-to-day project activities, working groups were formed consisting both of Vietnamese staff from city government departments and Dutch experts. This stimulated the collaboration between the involved city departments and made it possible to develop an integrated plan.

Figure 10.4 Artist impressions/plans HCMC.

Strategic Directions and Strategic Interventions contribute to climate change adaptation because they:

- are low or no-regret measures that are justified in all plausible future scenarios;
- create win-win situations by matching climate change adaptation and benefits in other fields;
- increase flexibility, leaving room for future adjustment;
- include safety margins in case the less favourable scenarios become reality;
- delay action until really necessary and therefore are more cost-effective;
- reduce decision time by preparing future.

10 4

Result

The adaptation strategy consists of six Strategic Directions that, together, constitute a guide towards a climate-proof future for HCMC. Implementing the strategy will make HCMC a 'Unique Delta City' in which the urgency to adapt to climate change provides the opportunity to make the city a safe and attractive place to work and live.

Direction 1

Create urban density, make smart use of the space within the existing city, before developing new areas outside the city. Then, base the urban development on flood risk and the soil and water system. Industrial and harbour development will move towards the sea and new residential areas will move towards the northwest and east. This requires seamless connections between the living and working areas.

Direction 2

Develop a step-by-step flood protection by storing water upstream of the city and make space for the river where flooding does not cause much damage. Apply multi-scale flood protection measures combining large scale infrastructure (Figure 10.5), a central ring dike, small scale adaptation measures in the districts, and support and stimulate the adaptation capacity of the residents in unprotected areas.

Direction 3

Avoid local flooding due to excessive rainfall by enlarging drainage systems and creating more water storage. The redevelopment of large parts of the city will also offer opportunities for waterproofing houses and elevating new urban and harbour developments (Figure 10.6).

Figure 10.5 Flood protection measures.

Direction 4

Reduce salinisation problems. Drinking water intakes should be relocated upstream and resistant vegetation in flood prone areas should be used. Also, reservoir management, decreasing groundwater extraction and smart dredging are useful measures.

Direction 5

Reduce subsidence by avoiding uncontrolled expansion of groundwater abstraction. A programme is needed for sanitation and surface water quality improvement so the water can be used for industrial and agricultural purposes and for drinking water. This should be combined with regulation and enforcement on groundwater abstraction.

Direction 6

Reduce urban heat stress, bring coolness into the city. Interventions to reduce heat stress could strengthen the green-blue network in the city by developing a central park and district parks combined with water storage. Transform the main roads to green avenues, implement green building codes and improve natural ventilation. These six Strategic Directions combined result in integral climate adaptation measures that add spatial quality to the city. New icons will attract tourists from all over the world and negative effects of climate change will no longer have such a strong impact on daily life. The essence lies in preservation and strengthening the city's own identity, rather than a 'total make-over'. Therefore HCMC 2100 will become an improved version of HCMC 2013, and one of the most attractive cities in Asia in which to live and work.

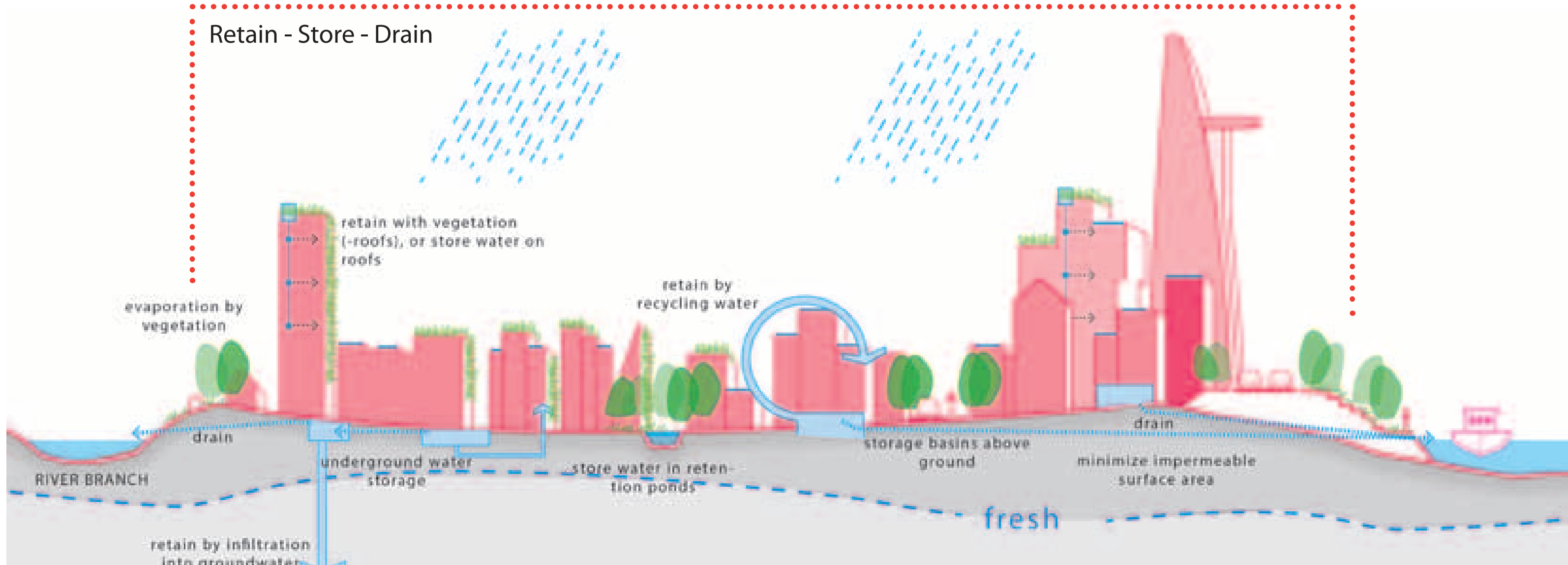


Figure 10.6 Enlarge drainage systems and create more water storage.

Charrettes

When developing an integrated strategy for climate change in such a complex environment as an evolving mega-city, integrating information and ideas from multiple stakeholders, disciplines, geographical scales and time scales is of crucial importance. Not one person or discipline has the complete overview of issues at stake and facilitating cooperation is vital. Therefore, 'charrettes' have been introduced as a working method, which is based on research by design. Drawing has been used as the Esperanto between languages, cultures and disciplines and was the pre-eminent means to bring different disciplines together in conversation and consolidate ideas into form.

Throughout the development process of the Climate Adaptation Strategy of HCMC stakeholders from many sectors, experts and architects where brought together in several charrettes. Two or three-day sessions were organised to discuss problems and opportunities covering a range of topics. This led to concrete ideas which were then worked out. First sessions focussed more on research and coming to a shared understanding of the most pressing issues. Later in the process, the sessions worked towards solutions and integrating these solutions into a strategy. During these sessions, working groups regularly zoomed in and out to interlink the measures on each spatial scale.

Different time scales were also an important issue in charrette development: developing a long term perspective and translating this back to short-term and mid-term actions.

Both pilot areas demonstrated: the proof of the pudding is in the eating! For example, a stepped levee along the Sai Gon River and an iconic bridge over the Sai Gon River as a logo for the city were proposed for District 4. By building a ring dike towards the river in Nha Be, both the existing residential areas and the ones that have to be developed will be protected. Sluices in the levee connect the old creeks with the river. The natural water system is almost entirely maintained, which means that new developments need to be elevated.

Charrettes made room for shared discoveries, resulted in concrete proposals and speeded up the process. The key success factor was that it facilitated communication and helped to create mutual understanding in cross-cultural settings. The co-production resulted in an approved Climate Adaptation Strategy and will be a strong basis to enable and guide the long-term sustainable socio-economic development of Ho Chi Minh City towards the sea, taking into account the effects of climate change.

To fulfil the Climate Adaptation Strategy, follow-up steps have to be taken such as implementing procedures found in the strategy's principles and developing an Integrated Water Resources Management Plan for Ho Chi Minh City in which climate change is taken into account. Increasing awareness and capacity building of city government departments' staff on climate change adaptation are also important steps to be taken.

"Ho Chi Minh City is a major centre of economic, cultural, education and training, science and technology. And the leading economic city of the country and the southern key economic region. Ho Chi Minh City faces many challenges with regard to climate change, which directly threatens social life, damages the economy and degrades the quality of the living environment of the city. The jointly developed Adaptation Strategy is the basis for further developing the city towards a climate-proof future."

Professor Mr. Nguyen Huu Tin,
Mayor of Ho Chi Minh City,
HCMC Vice Chairman

Introduction

11 1

The municipality of Melbourne (the City) managed by Melbourne City Council faces significant flood, heat and drought challenges under changing climate conditions. The City's 2009 Climate Change Adaptation Strategy[54] outlined these risks and defined the municipalities' approach to managing these risks and developing a resilient community. Four years into the implementation of the strategy, the City has led and invested in extensive research, infrastructure upgrades, planning amendments and community engagement to drive a resilient city.

It has also embedded climate change adaptation into its corporate risk management framework to drive cultural change across the organisation.

The municipality of Melbourne covers the central areas of the broader city of Melbourne, in the Australian state of Victoria. Melbourne is Australia's second largest city with a population of around four million people. Europeans settled in and named Melbourne in 1835, and the built environment increased significantly during the 1850s and 1860s due the substantial wealth acquired through the Victorian gold rush era.

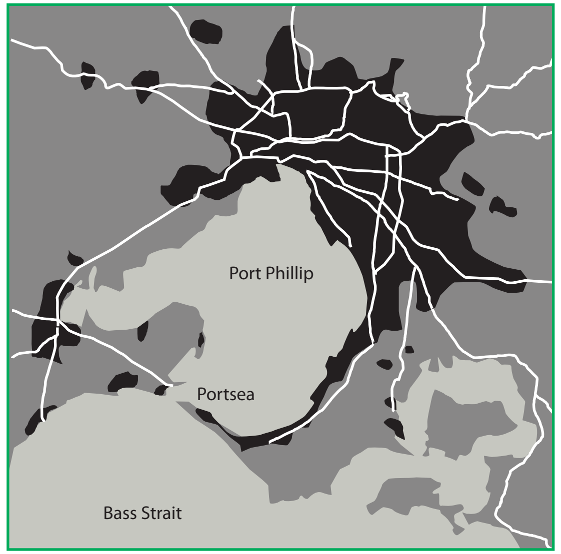


Figure 11.1 Map of Melbourne.

The City covers 37.7 km^2 and encompasses the central business district and a number of inner Melbourne regions including Carlton, Southbank, Docklands, East Melbourne, North Melbourne, Kensington and Flemington. The municipality is home to just over 100,000 residents, but has a day-time population of around 800,000 people with many people commuting into the city for work, shopping and leisure. Melbourne has a highly multicultural population with 47.5 percent of residents born overseas. Over the next 20 years its residential population is expected to grow at a rate of 2.88 percent per year.

Season	mm
Annual average	864
Summer	166
Autumn	213
Winter	245
Spring	152

Figure 11.2 Melbourne's seasonal rainfall averages.

Geographically, the City sits at the head of the Yarra River and Port Phillip Bay. A number of areas of Melbourne are relatively low-lying and are already subject to flooding due to high rainfall and king tides. The climate in Melbourne is temperate, with an average annual maximum temperature of 18.7 degrees Celsius and average annual minimum of 8.3 degrees Celsius. Melbourne's rainfall is shown in the table above.

Melbourne City Council is charged with managing parks and gardens, local parking and local roads, drainage infrastructure, community services such as libraries and sports grounds, and planning, and plays a key role in the city's emergency management system. Victorian State Government entities manage water and sewer systems for the City and greater Melbourne. Melbourne's public transport system is operated by private organisations licensed by the State Government. The operation of energy provision infrastructure is regulated by the State Government.

11.2 Climate Adaptation Strategy

In 2010, the City of Melbourne developed its first Climate Change Adaptation Action Plan.[56] This plan outlined the steps Council would take to manage the specific risks facing the city. Since the release of this action plan, Council has undertaken a number of activities to minimise climate change risks associated with heat, drought and flood. These issues are being faced now, while sea level rise is an issue which needs to be considered in a longer term way. Sea level rise is expected to be between 5 and 15 cm by 2030, between 26 and – 59 cm by 2070 and up to 1 m by 2100.

The development of Melbourne's Adaptation Strategy in 2009 was in response to a clear indication from the City's community that this was a priority. This advice was obtained through the development of Melbourne's Future Melbourne Strategy, Melbourne's long-term plan for the future direction of all aspects of city life. In 2009, Melbourne City Council (Council) released its Climate Change Adaptation Strategy, encompassing a thorough risk assessment (based on the AUS/NZ Standard 4360:2004)[55], which identified four key high-level risks facing the Municipality of Melbourne.

- Extreme Heat and Bushfire;
- Drought and Water Scarcity;
- Extreme Storm Event and Flash Flooding;
- Sea Level Rise.

11

3

Heat

Case example

More than 500,000 Melbourne residents lost power during a heatwave on 30 January 2009. The estimated cost to the Victorian economy are AUS$100 million and 1,300 train services were cancelled. During Black Saturday, on 7 February 2009, 173 persons died, 414 were injured and 400 individual fires occurred.

Melbourne's urban forest and green spaces play an important role in managing heat impacts in the city. The release of our Urban Forest Strategy in 2012 outlines Melbourne's approach to enhancing the resilience of our urban forest and double our canopy cover by 2040. Council is also developing guidance on the installation of green roofs and facades to further encourage green spaces in the City.

The City currently experiences heatwaves and urban heat island effect that have significant impact on Melbourne's community and infrastructure. Figure 11.3 shows the annual mean temperature of Australia from 1910 to 2012. Melbourne is expecting an increase in temperature of around 2.6 degrees centigrade by 2070. To better understand heat impacts, solar mapping of the municipality with a 'hot and cool spot' analysis was undertaken. This analysis compared like-for-like infrastructure, which either heated or remained cool under heat conditions and established characteristics of infrastructure types that best suited the Melbourne climate. Council has also undertaken economic analysis[57] to understand the cost to society of current and future heat impacts and research to understand the benefits of installing green and white roofs in the City (Figure 11.4).

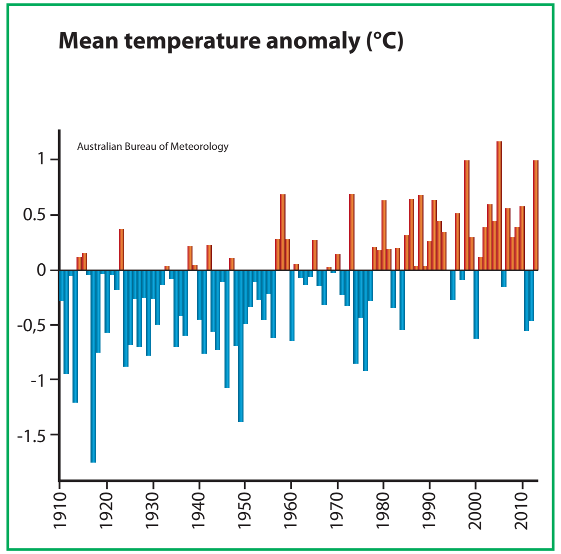


Figure 11.3 Annual mean temperature Australia (1910-2012).

Heat: Economic Costs

Heat Impacts (Present Values Discounted @ 3%)					
Category	Impact	Heatwave costs ($)	Single hot day costs ($)	Total heat costs ($)	% of impact
Health	Ambulance & ED (64+ years)	1,594,800	894,800	2,489,600	0.13%
Mortality	Mortality	476,009,900	1,124,965,800	1,600,975,700	86.05%
Transport	Delayed travel time	2,978,000	6,958,500	9,936,500	0.53%
Energy	Increase energy demand and faults	2,852,000	106,090,700	108,942,700	5.85%
Anti-social behaviour	Costs of assault	24,481,900	73,890,800	98,372,700	5.29%
Trees and Animals	Tree deaths and irrigation	462,100	39,232,900	39,695,000	2.13%
Total Impacts		508,378,700	1,352,033,500	1,860,412,200	

Figure 11.4 Overview of economic costs of heat (CDC Workshop June 2013).

Drought and water scarcity

4

11

Victoria is expected to become drier with annual average rainfall decreasing by 4 percent by 2030 and 11percent by 2070. Most of that decrease is expected in spring.

In order to reduce Council's operational water use, a variety of new Water Sensitive Urban Design technologies have been installed in our parks and gardens to reduce the reliance on mains water. Actions have also been taken to reduce the water consumption of Council's own buildings. For example, Council has:

- Implemented several large storm-water harvesting schemes including those in Fitzroy Gardens and East Melbourne. This has reduced storm-water pollutants such as suspended solids by 23 percent and decreased reliance on mains water by 267 million litres per year.
- Reduced water use in Council-owned buildings through efficient fittings and toilets, improving fire sprinkler testing regimes, cooling tower efficiencies and rainwater harvesting.
- Council has made changes to the planning scheme to ensure all new commercial buildings met water efficiency standards.

Flood

In order to understand the future risks of flooding in the City, a GIS model of water movement through the broader catchment and city has been developed, along with detailed modelling of at-risk areas in the City.[58] While more modelling and research is still required, the work to-date gives a clear indication of which areas are at risk and what kinds of flooding intensity and frequency can be expected. This allows for designing future research projects and considering flooding in future planning for these at-risk areas.

Council has begun work on managing flood risk through drainage upgrades, permeable pavements, water sensitive urban design and planning scheme requirements for flood risk regions.

Community and engagement

Since 2009 Council has worked with a variety of organisations throughout the City to manage climate change risks. Council recognised the need to connect these organisations, their programmes, knowledge and messages, and created the Inner Melbourne Climate Adaptation Network to address this need.

The network, made up of 30 organisations and 79 individual members, brings together conversations to ensure a consistent understanding of what is happening across the sector.

Engagement with the City's broader community about adaptation risks is at its early stages. Council undertook social research in 2010 to establish how residents, visitors and businesses of Melbourne view climate change risks and their own vulnerability to them. Using this information, community education has begun and a broad community engagement programme is under development.

Challenges and Opportunities

5

11

The City is already experiencing changes to weather patterns, having just come out of a decade of drought, and experiencing a number of recent extreme floods and heatwaves. It is therefore imperative for Council to enhance its infrastructure and community resilience.

A key challenge faced by the City, and many cities around the world, is enhancing resilience in an uncertain context. While future impacts in the City can be predicted, making planning and infrastructure decisions without a high level of certainty of future risks is an ongoing challenge, as is funding research to fill these information gaps. An example of this challenge is enhancing the planning process to ensure buildings and infrastructure built today will be able to withstand future conditions. This challenge carries with it an opportunity to develop new decision-making processes, which allow for uncertainty and flexibility into the future.

Funding of adaptation initiatives continues to be a key challenge for the City, and the development of new funding models and approaches is essential to adapting the City.

The opportunities of a better adapted city: human health and safety (and the broader benefits which go along with this - economic, cultural, etc), making risk mitigation investments at the right time, broader economic benefits (including fewer insurance claims, reduction in business time losses, less infrastructure and building damage, etc) attracting more visitors and investment to Melbourne.

Urban Forest Strategy

Melbourne's urban forest and green spaces play an important role in managing heat impacts in the city. However, after more than a decade of drought, severe water restrictions and periods of extreme heat, combined with an aging tree stock, Melbourne's trees are under immense stress and many are now in a state of accelerated decline. As a result of this and a changing climate, 27 percent of the City's current tree population is expected to be lost in the next decade and 44 percent in the next 20 years. Urban forests have proven to be one of the most effective methods for mitigating heat impacts in urban areas, particularly central business districts.

The urban heat island effect is common world-wide, as cities become warmer than nearby suburban and regional areas, particularly at night. After a hot day, parts of the city can be four to seven degrees hotter than surrounding rural areas. This phenomenon occurs all year round, but it becomes a problem during hot weather. It exacerbates heat stress, particularly for vulnerable people such as the elderly, the very young and those with pre-existing medical conditions. Heatwaves already kill more Australians than any other natural disasters.

The release of the Urban Forest Strategy in 2012 outlines Council's approach to enhancing the resilience of the urban forest and double the canopy cover by 2040. Council is also developing guidance on the installation of green roofs and facades to further encourage green spaces in the City.[59]

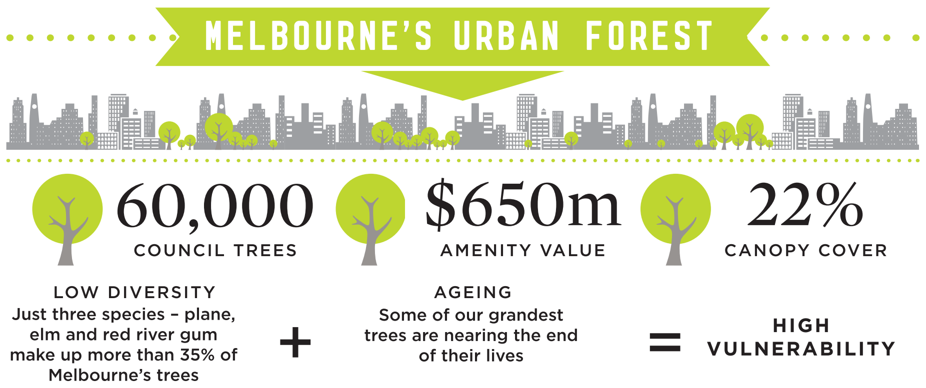


Figure 11.5 Melbourne's Urban Forrest Strategy summarised.

"Melbourne is proud to be one of the world's most liveable cities. But we understand liveability, prosperity and sustainability are closely linked, which is why we're also aiming to become one of the world's most sustainable cities.

Our city faces significant challenges from a changing climate, including sea level rise, extreme heat and bushfire, drought and water scarcity, and extreme storm events and flash flooding.

We are working closely with residents, businesses and partners to develop a united response to these risks. Since setting out our vision in 2009, the City of Melbourne has led and invested in extensive research, infrastructure upgrades, planning amendments and community engagement to make our city more resilient.

We have embedded climate change adaptation into our work to drive cultural change across our organisation. We are taking action today to ensure that our city and landscapes are flourishing in 10, 20 and even 100 years' time. Our Urban Forest Strategy sets a target to increase the city's tree canopy cover from 22 percent to 40 percent so that the city is greener and cooler in summer, reducing the heat island effect and improving conditions for residents, visitors and workers."

Lord Robert Doyle,
Mayor City of Melbourne

12 Copenhagen

by Lykke Leonardsen

12

1 Introduction

During the past 20 years Copenhagen (Figure 12.1) has undergone tremendous development. From a city with a very bad economy and declining population it has been transformed into a vibrant city with a growing population, a strong economy, an international reputation for implementing green solutions and for being one of the world's most liveable cities.

With only 550,000 inhabitants Copenhagen is a small capital city. But, being a part of the Øresund region (Greater Copenhagen and Southern Sweden), it is the capital of a region of more than 2.5 million people. And currently the city is growing at a rate with 1,000 new residents every month and, by 2025, the city will have more than 100,000 new residents. The city has undergone a very positive development from the early 1990s, where it was literally bankrupt, until today with a growing economy, growing population and a local government economy that has enough tax income not just to provide for basic services, but also to invest in the development of the city.
The city has set ambitious climate action goals and aims to be carbon neutral by 2025, but recent weather events have also raised awareness for the need of climate change adaptation.

Figure 12.1 Map of Copenhagen.

12 2

Climate challenges

Climate challenges

Copenhagen is relatively well protected against climate change with a location where tidal water is not an issue and with a well-functioning combined sewer system. The city today has a typical Northern European climate with summer daytime temperatures averaging 20 degrees Celsius and winter daytime temperatures just above zero degrees Celsius, and annual precipitation of just over 600 mm.
Despite this generally moderate climate and protected location, the city will face challenges that the present level of protection cannot handle. The climate challenge that Copenhagen is facing is mainly an increase in precipitation. It is estimated that general rainfall will increase by about 30 percent and heavy thunder storms – especially during the summer – will also increase. The city has already had a taste of what the future will bring. A massive cloudburst in 2011 showed the vulnerability of the city to the future climate. Massive traffic disruption with closed roads, power cuts at hospitals, etc, showed the need for action.

Located by the sound separating Denmark and Sweden, the city will eventually also face the problem of rising sea levels. The narrow entrance to the sound limits the effects of tidal water for the city – and with a general location at 1.5 m above sea level this makes the city relatively well protected. But with rising sea levels the risk and frequency of storm surges will increase – as storms can press large amounts of water into the Baltic and out again. Storm surges like this have hit the city during its history but with the increased economic activity and greater density of the city, future storm surges will have a great impact on the city – especially in the older districts with their cultural, economic and historical values, located on the harbour front. And as the city is growing it is also expanding into the former harbour areas. New residential districts are being planned and built, and the city needs to make sure that these areas will be protected against storm surges (Figure 12.2).

Figure 12.2 Copenhagen port area.

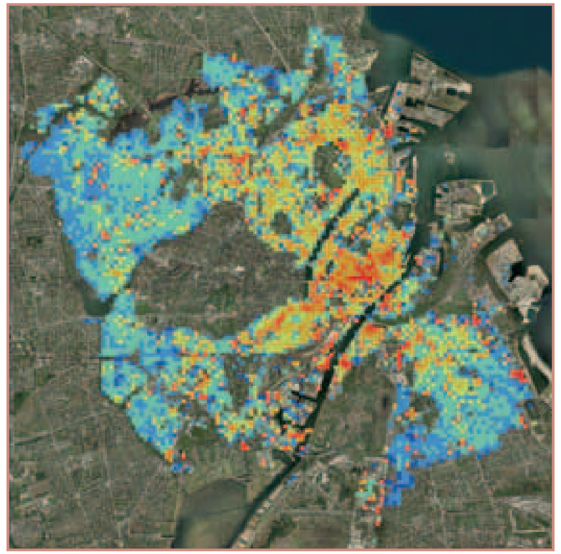
The Climate Adaptation Plan

In 2009 the city in its annual budget agreement decided to start working on a Climate Adaptation Plan to prepare for a future with a warmer, wetter climate with an increase in extreme weather events. Originally this was intended just to be a small fragment of the Climate Mitigation plan, but cooperation with other cities within the C40 network like Rotterdam and London demonstrated the need for more comprehensive work. The plan mapped the risks that the city could expect to be facing given the various scenarios and sets the strategy for the work that has to be carried out over the next 30-to-50 years to make sure that Copenhagen despite the changing climate continues to be a great place to live, work and invest in (Figure 12.4).

Figure 12.3 Copenhagen Climate Adaptation Plan Cover.

The main purpose of the plan is to map the risks for the future with regards to precipitation, heat, storm surges and water supply – and to define the strategy on adaptation, which is not only focussing on the process to solve the problem, but also looking for opportunities for the city. The plan sets the roadmap for a flexible adaptation that can be expanded if climate changes turn out to be more severe than the current scenarios show.

The plan does not plan for a specific climate change scenario, according to the Intergovernmental Panel on Climate Change (IPCC). In general these scenarios are very unclear – and are also changing, as the climate models improve. But most models have the same development over the next 30-to-50 years – and when it comes to urban planning, that is a very long time. Instead it was decided to have a plan that could be flexible – both with regards to the size of the measurements but also with regards to multi-functionality. And the plan itself also has to be flexible – it will be revised every four years. This way there is time to increase or decrease the adaptation measures as the climate scenarios develop over time.

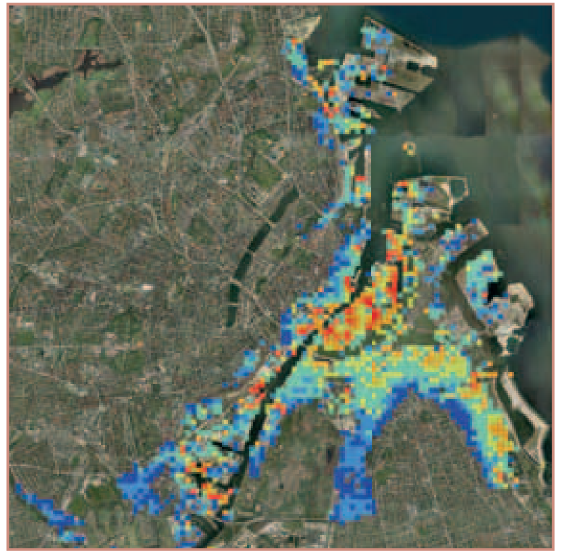


Flooding from rain / Risk in Krone

51 - 1418
1419 - 8553
8554 - 23175
23176 - 40963
40964 - 91771
91772 - 50000000

The basic philosophy behind the Adaptation Plan is to make adaptation a precondition in the future for urban development in the city. Resilience must be a part of all the work that will be undertaken – and not just from a negative, problem fixated point of view. No, the idea is to look for synergies and possibilities, and develop solutions that will improve the recreational qualities of the city – and the quality of life for Copenhageners.

Another important issue is to use the adaptation work as an innovation platform for creating jobs and growth in the city. New technology, new solutions and the construction work will have a significant impact on the city's economy over the coming years.



Flooding from sea / Risk in Krone

24 - 7920
7921 - 42728
42729 - 386232
386233 - 1063542
1063543 - 4293557
4293558 - 55000000

Figure 12.4 a/b Risk map for flooding caused by rain (top) and storm surges (bottom) from the sea in 2100.

The cloudburst in 2011 – and the Cloudburst Management Plan[60]

12 3

Originally the city planned to implement the adaptation plan gradually over a period of between 30-to-50 years. But on 2 July 2011 a massive cloudburst hit Copenhagen. More than 150 mm of rain fell over the city in less than 2 hours causing massive flooding, disruption of traffic, breakdown of communication infrastructure, and even threatened the two main hospitals in the city because of power cuts. The cloudburst cost more than 800 million Euros in insurance claims alone.

This one event was a game changer both on a local and a national level. The city allocated money for adaptation and emergency measures and has already implemented the first cloudburst management projects, especially in the inner city.

Another critical problem was the financing of cloudburst measures, especially since the city wanted to work with a mixture of traditional storm water management measures (underground pipes and reservoirs) and surface solutions. In Denmark storm water management is handled by the water companies and paid through water fees. But mixing urban infrastructure with storm water management was not possible within national legislation. The city lobbied hard and finally managed to push for a change of national legislation to enable financing of new types of adaptation measures.

The Cloudburst Management Plan was prepared in 2012. This plan sets up the future service level for storm water management in the city. Basically business case models showed that, if cloudburst water management was combined with normal storm water management, it gave the most effective and economically viable results. And the analyses also showed that economically it would make most sense to develop a storm water management system that could handle a 100-year event – even as far into the future as 2110 (Figure 12.6). But Copenhageners will have to accept water in streets in these situations. Up to 10 cm is an acceptable level that will make it possible for the city to continue to function in these situations.

The cloudburst plan divides the city into 7 water catchment areas, and detailed plans for each area will give the basis for the future work, and the local dialogue with the citizens and stakeholders over the coming year.

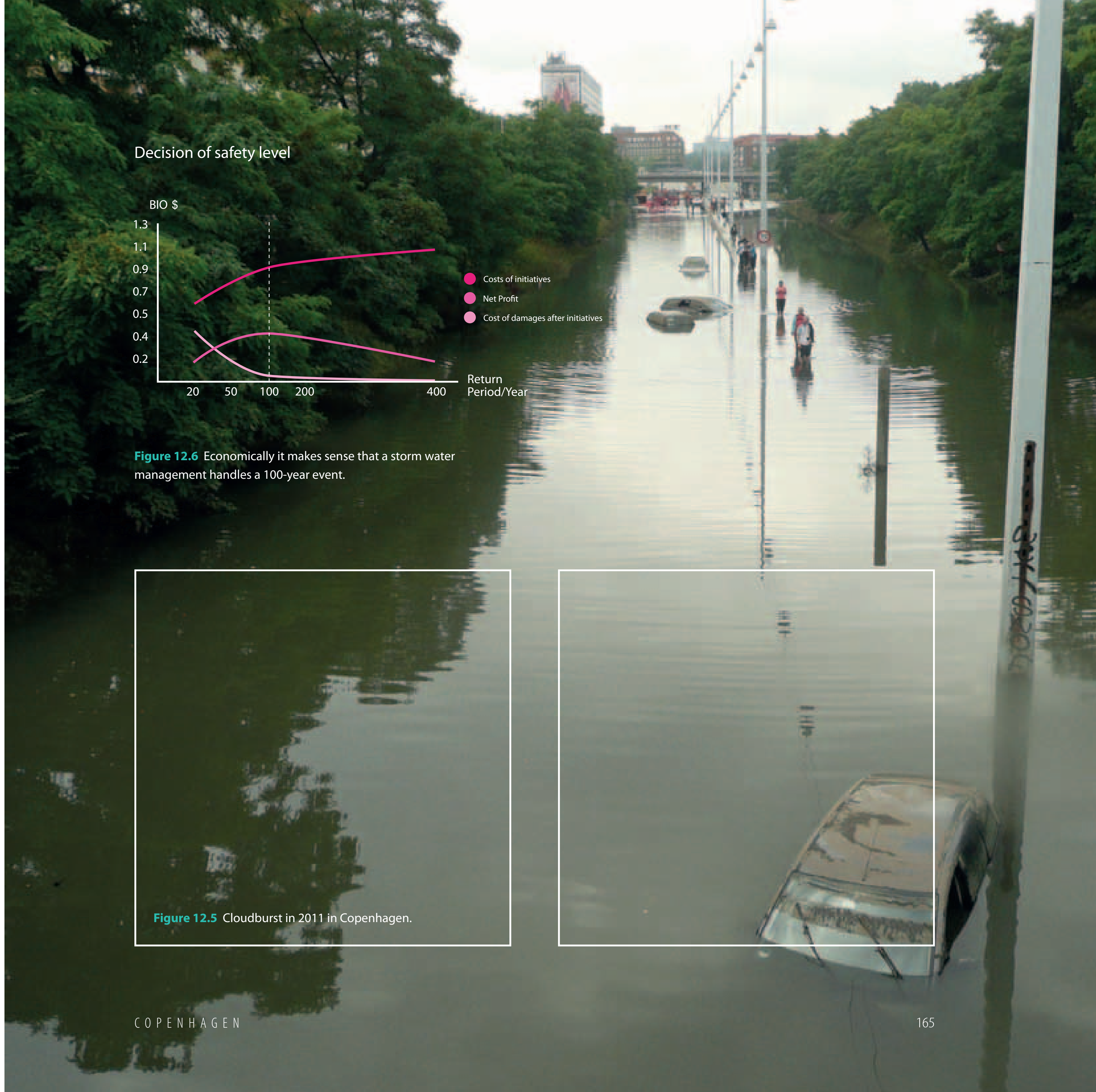


Figure 12.6 Economically it makes sense that a storm water management handles a 100-year event.

Figure 12.5 Cloudburst in 2011 in Copenhagen.

One of the challenges of the cloudburst management plan is to put in a new layer of storm water infrastructure in the city. Mostly based on green and blue surface solutions, it gives the city a unique opportunity to improve the quality of life for Copenhageners by creating green and blue recreational areas and a more diverse city.

But the surface solutions also take up space in the city – space that is also wanted for bicycles, parking and cars. So over the next years, as the implementation is put into motion, there will be a continuous discussion on how to prioritize the use of urban space in the city. And, at the same time, there is a strong demand that the environmental standard in Copenhagen will not suffer from the adaptation measures. The aim is that the sewer that overflows to streams, lakes and the sea will be further reduced by the climate adaptation measures when the rain water is separated from the sewers. So, in the future, Copenhageners will still have the opportunity to swim in the harbour and enjoy the clean water in lakes and streams (Figure 12.7).

Figure 12.7 Copenhagen harbour swimming pool.

"When Copenhagen was hit by the worst cloudburst ever in 2011 it signalled a change for the city. We had already made an adaptation plan, but none of us had expected that a cloudburst like that would happen so soon. I am proud to say that we have risen to the challenge. We have decided to ensure the safety of the whole of Copenhagen within 20 years. The aim is to use the climate adaptation plan as a precondition to approach our vision of being a modern liveable capital. And we want to involve the Copenhageners in this transformation. It proves to me that Copenhagen is at the forefront when it comes to finding solutions to future challenges."

Ayfer Baykal,
Mayor of Copenhagen

Showcase neighbourhood Skt. Kjelds

It is difficult to imagine what a climate proof Copenhagen will look like – and it also has to be acknowledged that not all the solutions are in place. How will the new storm water infrastructure interact with the existing city and how can it be used to improve urban life in the city?

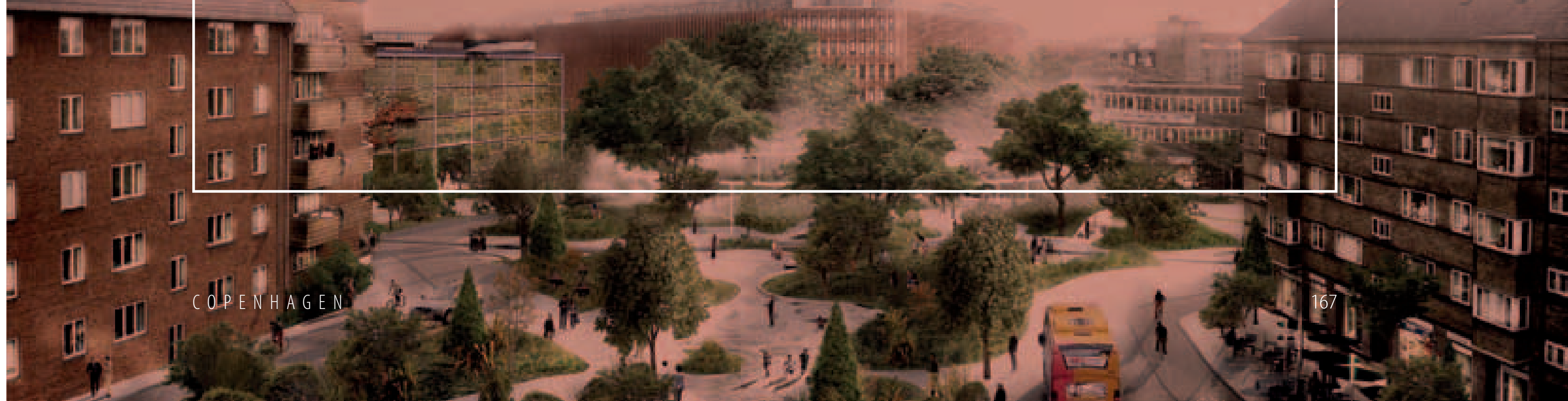
This is one of the reasons why Copenhagen has selected a local neighbourhood in the city as its 1:1 laboratory. Planned to be finished in 2016 this neighbourhood will demonstrate the ideas behind the adaptation work and serve as an inspiration, a laboratory for new types of solutions. How can Copenhagen use climate adaptation to create a more green and blue city, with higher biodiversity and more recreational space for Copenhageners?

The neighbourhood selected was Skt. Kjelds, located in the north-eastern part of Copenhagen, and is in population, flooding risk and structure very much a typical city district. It is part of the neighbourhood regeneration area, but it also houses the current prime minister of Denmark. The entire neighbourhood has 24,000 residents and 10,500 workplaces, but only a section of the neighbourhood will be subject to the climate proof measures.

Over the next years, local stakeholders, citizens and the city will work on implementing a number of projects, such as local water boulevards and water squares that will demonstrate the ideas and possibilities of the climate adaptation plan. It is also intended that the projects will explore new types of solutions, and identify and develop new products for storing and managing water that need to be undertaken by consultants and manufacturers in order to meet the challenges of a changing climate.

A detailed plan for the neighbourhood has been prepared and the first construction work on a water square at Tåsinge Plads will start in the late summer of 2013. An important part of this work has been the involvement by local residents who have participated in workshops where they have had the opportunity to influence the projects.

When the work is done the neighbourhood will be a showcase for other Copenhagen neighbourhoods, and an international exhibition for how Copenhagen tackles the challenge of climate change. And Copenhagen will have valuable information on how to proceed with other neighbourhoods.



Observations and Future Outlook

13

by Arnoud Molenaar, Mandy Ikert, Chantal Oudkerk Pool

13.1 Observations

This third CDC book presents the state of the art with respect to climate adaptation in delta cities. Together, the sequence of CDC books so far tells the story of how CDC cities have advanced from identifying challenges (book 1), to experimenting with innovative solutions (book 2), towards the development and implementation of integrated adaptation strategies (book 3). This rapid development – which took place over five years only – would not have been possible without the knowledge exchange and cooperation between this strong coalition of leading delta cities. Please note that the strategies and actions mentioned in this book do not represent all the knowledge and best practices that these delta cities have to offer. The selection in this book is thought to be the most informative or transferable to other cities worldwide. Based on the previous chapters, a few general and more specific observations can be made.

Figure 13.1 CDC Workshop, June 2013.

Strategies and tools
In general the city chapters show that adaptation strategies, although tailor made, roughly all consist of a few key ingredients, such as an overview of climate changes and local effects, risk assessments, vulnerability maps, adaptation pathways, short-term measures and a range of long-term solution directions. In some cities, climate adaptation strategies are supported by tools such as societal cost benefit analyses, city specific climate data systems, and monitoring plans. In the coming years, the exchange of experiences with the development and application of these instruments will be very relevant for the CDC members.

New coalitions
In a world of changing responsibilities and economic crisis, and with new solutions for urban challenges, cities seek new coalitions with new public/private partners and financial arrangements. This identification and involvement of stakeholders is a key ingredient in the operationalisation and financing of the adaptation strategies and will allow CDC cities to take the big steps towards becoming truly resilient delta cities.

Specific Key Observations

■ **Adaptation covers the entire city**
One can see a trend that cities are complementing large infrastructural works with small-scale measures across their entire city. Some cities have accelerated this process by adding adaptation to general maintenance programmes. With small measures, such as permeable pavements, cities like Copenhagen and Rotterdam added a new 'layer' of solutions – in both public and private areas – to the more traditional robust urban water system consisting of canals and sewer systems. Other cities, like Ho Chi Minh City and Jakarta, with more acute problems, are at the beginning of a period of large infrastructure interventions in combination with adaptive measures for new urban development.

■ **Cities are embracing green measures**
Such as parks, green roofs and green facades. These measures help cities to create an urban sponge function to collect and absorb water. London's green cover plans and Green Infrastructure Audits are good examples of how to set this up in a structural way. Another popular new element in New Orleans, Ho Chi Minh City and Jakarta is to explicitly use ecosystem services to become more adaptive, such as using mangroves and wetlands for their protective functions. The important protective function of wetlands and mangroves should be taken into account when delta cities develop towards the sea. With A Stronger, More Resilient New York, New York City plans to use wetlands to weaken the impact of storm surges on certain areas of the coastline. Small 'Building with Nature' solutions can also add ecological value to cities at the same time. Rotterdam will experiment with new aquatic sediment habitats to strengthen existing levees. Hong Kong introduces eco-hydraulics in the framework of their eco-city programme. And last but not least, Melbourne's Tree Policy plan helps to make the city more livable during heatwaves.
Although several cities took initiatives it can be concluded that 'green adaptation' stll is in a premature and experimental fase. More research and more pilots are needed. That's why this topic will be on the agenda for the coming years.

■ **Urban catchments as an area-oriented approach**
Urban catchments, to capture the water as soon as it falls, are an area-oriented approach to scale comprehensive measures. For example, London will be subdivided into a number of drainage catchments. New Orleans switches to the so-called Water City Approach in which water is viewed more as a resource to be preserved rather than as a nuisance to be removed at all costs. Copenhagen – as part of its Cloudburst plan – divided the city into eight catchments with tailor-made plans. Tokyo and Hong Kong have also found that runoff interception at uphill urban catchments has been a proven and effective means for flood prevention.

■ **Adaptation and financing**
As mentioned in chapters 1 and 2 the search for new financial arrangements to operationelise adaptive urban development is high on the agenda of the CDC members. The observation is that there are still few examples of new financial constructions. Rotterdam now starts to experiment with the involvement of new stakeholders in a water front development based on the outcome of a cost benefit analyses. Also New York will closely look for new arrangements to finance post Sandy measures in Manhatten. However more pilots are needed and it is clear that the search for creative financial solutions and other tools to get the strategies implemented will go on for the coming years.

Community Resilience

■ Delta cities have become increasingly aware of the fact that a resilient community is not only about physical protective measures against floods and other extreme weather events. Resilient communities are also capable of accepting, dealing with and recovering from a disaster, in case parts of the defense system fail. This requires physical, social, environmental and economic capacities. A resilient community is well aware of the risks and likelihood of extreme weather events, knows how to mitigate the effects, and participates on an equal basis in the dialogue on issues of climate change with governments, businesses and NGOs. On the short term the CDC cities will intensify the exchange of ideas and best practices on this important topic.

■ In New Orleans, after Katrina hit, there were lessons to be learned with regards to different recovery of neighborhoods after the water was gone and the Hurricane Protection system was constructed.

The Dutch Dialogues contributed significantly to the change in mindset of the people, that they have to accept certain risks of living near the water, act more pro-actively, improve their quality of life; and increase their resilience in order to be better prepared for the next event.

- In Rotterdam, the redeveloped RDM campus, a former dry-dock in the old City Port area is retrofitted into a centre of sustainable development and education. New York has comparable issues in the Brooklyn Port area and is exchanging ideas and comparing opportunities with Rotterdam for improving the resilience of waterfront communities. The long- term objective of this cooperation is to continue the dialogue and knowledge-sharing between New York City and Rotterdam (and other comparable cities), universities and other knowledge institutions. This dialogue and knowledge sharing could function as part of the CDC Connecting Delta Cities network and can open up the opportunity for other cites to join.

Smart Delta Cities

- Delta cities become increasingly smart in their adaptation by using the latest IT and communication technologies for climate adaptation, not only to improve the performance of flood protection or mitigation systems, but also for monitoring and communication purposes, and to enhance public and political support and awareness. In Rotterdam a whole range of smart tools were developed and applied, including serious games that can be used for both communication to increase awareness and training of students and professionals.

- In New Orleans a smart flood control system to improve performance of the flood protection system is under development, combining state-of-the-art models, IT technology, sensor technology, forecasting and decision-support systems.

- In Rotterdam a smartphone app was launched to inform citizens and visitors about the latest developments in climate adaptation in Delta City Rotterdam. Also in Jakarta an app was developed that informs citizens on their smartphones online about actual water levels and the risks of flooding in their city, and also giving recommendations and information on how to act and where to go.

Figure 13.2 The Rotterdam Delta City smartphone app.

13

2

Future outlook

Topics and Trends

In this book it has become clear that despite the considerable progress member cities have made in the past couple of years, a lot still needs to be done. Cities that completed a thorough risk assessment are now facing the challenge to turn this into an integrated long-term strategy. Cities that do have an adaptation strategy are struggling to convince key partners to jointly act and invest.

The current worldwide economic crisis is making this even harder. Projects that were underway and seemed perfect opportunities to link with the implementation of adaptation measures (thereby saving costs) are delayed or even put on hold. Moreover, stakeholders need to be more certain than ever that the benefits of adaptation cover the costs. But how to monetise these benefits and which mechanisms can turn the payers into beneficiaries? And how to create resilient communities?

In addition, getting it on the agendas of newly elected politicians, often with only four to five year administrations to go and thus with short-time horizons, is a recurring challenge. And related to that: how to measure the progress and success of all the effort that is put into adaptation?

The list of questions and challenges faced by the CDC members is much longer than the issues mentioned above. This is why the CDC board decided to focus on the following topics for the next few years:

1. ***Implementation of climate adaptation strategies:*** covering topics such as governance, finance, decision support instruments, monitoring and evaluation.

2. ***Green adaptation solutions:*** green infrastructure, ecosystem services and building with nature.

3. ***Grey adaptation measures:*** including evaluation criteria for big infrastructural works.

4. ***Community resilience:*** emergency preparedness, awareness, public involvement and communication.

5. ***Urban design and planning:*** adaptation solutions that enhance urban quality and risk management in rapidly growing cities.

Towards Resilient Cities

Over the past couple of years, CDC cities have taken important steps in becoming resilient. Together, we succeeded in getting adaptation on the political agenda. And, equally important, we gained a tremendous amount of knowledge which we used for the development and implementation of our integrated adaptation strategies. These are major achievements we should be proud of.

However, there's more to resilience. I believe there are more opportunities for synergy between mitigation and adaptation. Therefore, I fully support C40's decision to address both energy savings and adaptation to climate change. Mitigation and adaptation can strengthen each other. For example, energy management programmes should not focus on energy saving only, but also on creating a robust system that is able to withstand an extreme weather event. Moreover, resilience concerns social vulnerability. Especially in the present economic situation, more attention should be paid to creating resilient communities, inclusive of vulnerable residents. Lastly, new financial arrangements and multifunctional solutions require new coalitions. New stakeholders will join the adaptation arena.

Therefore, new partnerships and a participatory approach will be the key to a successful implementation. Although each city has its specific challenges and circumstances and adaptation requires tailor-made solutions, cities can learn from each other about the aforementioned topics. And reframing climate adaptation to resilience will help us keep this topic on the political agendas and create awareness and commitment among our communities.

Paula Verhoeven
Director Sustainability and Climate Change,
City of Rotterdam

Cooperation
Aware of the fact that the list above is still quite extensive, CDC seeks cooperation and knowledge exchange with other networks, events and partners. The Deltas in Times of Climate Change II conference in Rotterdam in 2014 has been designed to address the above topics to a large extent in around 70 scientific and applied workshops, which is a good learning opportunity for CDC and a good way to share with the academic and practitioner communities.
C40 supports CDC in organising conference calls, webinars and workshops on topics of shared interest to members and facilitating interaction between cities. Increased staff capacity with C40 for adaptation and resilience allows for intensified knowledge exchange between CDC cities and with other C40 cities. CDC will also explore opportunities of working together with new partners that are very active in certain adaptation areas, such as The Nature Conservancy, ICOMOS and the Rockefeller Foundation.

Joint Projects and Direct Exchange
Members partake in joint research and advocacy projects. For example, discussions are underway to expand a smartphone APP that Rotterdam has developed to showcase and map its urban adaptation interventions throughout all cities in the group. This APP also helps to create awareness among (young) citizens and helps students and professionals to guide them along cities the city's adaptation highlights. Furthermore, cities collaborate on press, awareness building, and advocacy opportunities since collectively the concerted voice of 10+ delta cities, consisting of some of the largest cities in the world alongside some global innovators, is a powerful tool for advocacy both in countries domestically and at international forums.
Continuously, city representatives partake in city-to-city exchanges and study visits to learn directly how a city has implemented an adaptation measure. This has grown into bilateral assistance programmes – often funded through national government support – a trend which is expected to grow further in coming years. For example, Rotterdam will facilitate Jakarta with its capacity building by organising training programmes.

K2K
Apart from the abovementioned increase in cooperation, CDC will also try to facilitate the cooperation between the knowledge institutes the cities work with. On the one hand, this could lead to useful comparative research of CDC case studies and to successful joint applications for research that can provide useful inputs for the update of adaptation strategies.

On the other hand, it will allow the next generation of water management and adaptation experts to be trained on the latest insights, knowledge, experiences and best practices. In some cases it will even allow them to gain international experience due to student exchange programmes and short international working visits in which they meet and work with students. These activities will not only build capacity worldwide, they will also lay the basis for future international relations and cooperation.

That is why the CDC board decided in June 2013 to activate the knowledge layer of the existing network of city representatives, which is referred to as the 'K2K' layer, Knowledge to Knowledge (Figure 13.3).

Knowledge is needed in the various phases of climate adaptation: such as assessing climate risks, identifying measures, assessing the effectiveness of these measures, developing decision support tools and exploring new financial and legal arrangements. In each phase, universities and knowledge institutes can support policy makers, with data, modelling simulations, etc. A stronger cooperation between city government, universities and knowledge institutes within and between the cities will contribute to more resilient delta cities.

In the coming period, beyond Johannesburg 2014, CDC aims to further develop the K2K layer through the following activities:

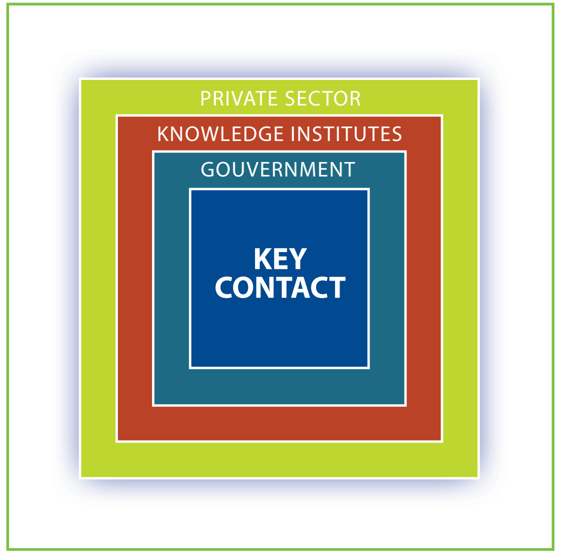


Figure 13.3 Development of the K2K layer in the CDC network.

- **Scientific symposia**
(Co-) organise sessions at scientific-oriented conferences that respond to cities' needs in terms of database and scientific methods, which can be used to support policy making and adaptation decision making questions. An important conference will be the 'Deltas in Times of Climate Change' conference in Rotterdam 2014.

- **Student exchange and internships**
With students working on research topics that are identified and prioritised by CDC member Cities. Those students may conduct the research in cooperation with city agencies and international institutes.

- **Knowledge coalitions in cities**
Some CDC city agencies have already established relations with knowledge institutes in their region. These local and regional coalitions regularly meet to exchange ideas and jointly work on developing solutions to anticipate future change. For example, scientific information and methods can be used by policy makers to show the effectiveness of developing new green infrastructure in cities in terms of storing rainwater, and can also show its costs and benefits.

- **Exchange between knowledge institutes and coalitions in various CDC Cities**
The Rotterdam University for Applied Sciences now closely cooperates with counterparts in New York, Jakarta and Ho Chi Minh City. Similarly, Columbia University in New York has established eight Global Centres around the world.[61] 'The centers encourage new relationships across schools, institutes and academic departments at Columbia. In addition, webinars will stimulate knowledge exchange between cities and its scientific institutes. C-40 already plays a facilitation role in these exchanges.

Network expansion and promising cities
More and more cities are aware of the need of climate change adaptation and have shown interest in participating in the CDC network. In order to accommodate this interest and potential growth, the 10-city CDC group as it exists now has been established to serve as a core direction setting board for a larger network. In June 2013, this new board of cities decided to allow new cities to participate in the network. Rio de Janeiro, Venice and Changwon are very promising new potential members of CDC that have very interesting experiences in the field of community resilience, cultural heritage protection and green infrastructure. Therefore, this book ends with a sneak preview of the inspiring work of these three cities. Other delta cities are also in discussion with CDC, including Shanghai, Singapore, Mumbai, Dhaka, and Buenos Aires.

Figure 13.4 Participants of the 2013 CDC Workshops in Rotterdam.

13

3

Changwon

by Eui-suk Hon, Kyung-hoon Lee, Mi-kyung Moon

Introduction

Changwon is the capital of Gyeongsangnam-do, located in the mid-southern part of Gyeongsangnam-do in the southeast of South Korea. Changwon was merged with its neighbouring cities of Masan and Jinhae, and now has 1.1 million residents. It is the first planned city in Korea developed through the industrialisation embarked upon in the 1970s. It has a strong industrial sector, which rapidly advanced with the construction of the national industrial complex in 1983. Changwon is a marine city, with Masan Bay at the centre and Jinhae Bay on its southeastern tip, and has around 321 km of coastline. North of the city are Moohaksan Mountain, Jeongbyungsan Mountain and Bieumsan Mountain, while flowing from west to east, the Nakdonggang River forms its northern border.

Climate conditions

Located on the southern coast of South Korea, Changwon has relatively minor temperature fluctuations on both a daily and an annual basis. The average temperature of the coldest day in January is 2.8 degrees Celsius considered mild compared to other regions in Korea. The annual average temperature is 14.9 degrees Celsius. Its annual precipitation is 1,545 mm, with heavier rainfall in the summer season. Changwon lies in the path of typhoons, generated by the hot and humid North Pacific high-pressure system. This geographical feature causes significant asset losses and casualties in Changwon. The typhoon Maemi, which hit Changwon in September 2003, caused asset losses worth 4.7 trillion South Korean won, leaving Changwon designated as a natural disaster-prone area under the management of the nation (National Emergency Management Agency).

Figure 13.5 Map of Changwon.

Figure 13.6 City Roundable Plaza.

Typhoon Maemi was recorded as the strongest ever to hit the Changwon area since records began. It caused 32 casualties (including 18 dead), left 765 people of 311 households homeless, and damaged 94 factories and 1,790 stores, making the typhoon the worst natural disaster in regional history. In 2007, the National Emergency Management Agency designated the 59,100 m^2 wide Guhang district in the Masan Bay area of Changwon as a low-lying coastal area with a danger of inundation if hit by tidal wave or typhoon. The agency also set up plans to establish and repair facilities to better adapt to various climate conditions.

Representative industrial city

Bordering the sea, Changwon has enjoyed a well-developed maritime trade. As a hilly district, it has good access to both water and land. Thanks to such geographical conditions, the Bronze Age and Iron Age civilisations blossomed in Changwon. It was once a centre of military and economy, and since the establishment of the Korean government in modern history, Changwon has grown to be a representative industrial city and the southeastern hub of the Korean Peninsula. As part of the government's policy to foster the heavy and chemical industries, Changwon National Industrial Complex was established in 1974. Its geographical advantage of having a port has attracted around 4,000 companies, including LG Electronics, Samsung, Doosan Heavy Industries & Construction, and other representative companies in heavy equipment machinery, auto manufacturing, electronics industries, etc. This also shows that Changwon is one of the cities in Korea that is well equipped with financial and environmental amenities. However, such rapid economic development has caused environmental pollution as a side effect, having both direct and indirect influences on citizens' lives. As a consequence of this pollution, a new agenda to improve the environment was developed by different interested parties in the city.

Declaration of 'Environmental Capital'

Acknowledging that 'Changwon will never become a global city without an environmental mindset', the city, along with the public and other experts from academic, industrial and administrative areas, declared itself an environmental capital with economically sound and sustainable development.

The environmental capital project aims to create a pleasant urban environment where clean air and water are provided to improve the life quality of citizens. Through a campaign to plant 10 million trees in parks

Figure 13.7 Changwon a mecca for Machinery Industry.

Figure 13.8 Park In Changwon.

and green lands along with building a green land network, Changwon became a city with the largest number of parks and forests in Korea (per capita green land: 34.9 m^2). The riverside filtered water development system has provided Changwon citizens with clean and safe drinking water. The city has promoted four major strategies along with eight grand goals such as the introduction of a public bicycle system 'Nubija' (Figure 13.9) and the establishment of a comprehensive public transportation system.

Especially because of the public bicycle system 'Nubija' - introduced as a low-carbon, green growth city initiative – bicycles now account for 7 percent of transportation. More than one-tenth of the city population is registered as members of the 'Nubija' system, making Changwon a representative bicycle city in Korea.

Changwon held the EcoMobility & World Bike Festival in October 2011, where the EcoMobility Alliance was launched with the aim of building sustainable future transportation cities. As the chair city, Changwon is doing its best to lead by example in building an exemplary green transportation city. In the international area, it has also acted as environmental leader in the building of a sustainable city by holding global events such as the Ramsar Convention, the UN Convention to Combat Desertification, the International Congress of Education Cities, and the East Asian Seas Congress.

Actions for Climate Change Adaptation

The National Emergency Management Agency designated the 59,100 m wide Guhang district in the Masan Bay area of Changwon as a 'Ga' grade of tidal wave danger zone. In order to protect the assets and lives of its citizens from various natural disasters such as tidal waves, typhoons and rising sea level, the agency has established and worked on a plan to build a prevention hill. The city is also promoting various disaster prevention projects such as the establishment of a migration policy for the people from disaster-prone districts, building an undercurrent tank and planting 10 million trees. Based on recent climate change scenarios, Changwon City decided to establish a 3 m high, 1,250 m long and 30-to-70 m wide prevention levee with the project expenditure of 60 billion South Korean won (Figure 13.10).

The levee will be used not only to prevent damage from tidal waves and typhoons but also to provide a water-friendly environment for the city's population. The city also prepared a migration policy for those living in low-lying areas prone to frequent inundation.

Figure 13.9 Public bicycle system 'Nubija'.

In addition, Changwon is working on a project to turn an urban stream (35 km long) into an ecostream. The city established a comprehensive plan to reduce damage from storms and floods in 2011. It designated 104 districts and categorised them depending on the 11 disaster types. Changwon is expected to set up and operate necessary prevention measures such as river improvement, building undercurrent tanks to ensure safety from disasters caused by landslide, wind and tides, improving pipes and installing simple water supply facilities.
Changwon will set up a climate change adaptation plan by 2014 to prepare itself for various climate conditions including not only typhoons and floods but also heatwaves, abnormal precipitation and rising sea level. It is also preparing to receive safe city accreditation by WHO.

Figure 13.10 Levee to prevent damage from tidal waves and typhoons.

"Changwon developed the vision to become an "Environmental Capital of Korea" in 2006. The vision was made out of the philosophy that the city's competitiveness in the 21st century should be enhanced, by securing amenities that ensure environmental sustainability. With joint efforts from the public, academia, experts and businesses, Changwon has strengthened its status as an environmental capital of Korea. With a preemptive response to the current climate change, I will dedicate my passion and determination to make Changwon a global environmental city with dignity.I hope Connecting Delta Cities (CDC), the network of cities around the world with advanced water management, will serve as a venue to exchange information necessary to build an environmental city."

Park, Wan-su, Mayor of Changwon

"Recently the world has suffered significant damages from climate change and natural disasters such as heatwaves, heavy snowfall and rainfall. According to the most recent climate change scenarios announced by the Korea Meteorological Administration in 2012, the sea level of the southeastern sea of Korea will rise by 70 cm by 2100. In addition, the average temperature will go up by 2.5 degrees Celsius, and precipitation will increase by 30-to-45 percent by 2100.As Changwon borders the sea and the river, I believe that proper water management according to climate change is important. Therefore, we will actively provide support and assistance for efficient responses to various issues arising from climate change. I am confident that the solidarity by advanced cities to share information on efficient and systemic water management will be an indispensable choice."

Bae, Jong-cheon, Chairman of Changwon City Council

13

4

Rio de Janeiro

by Rodrigo Rosa, Luciana Nery, Pedro Junqueira et al

Introduction

Located on the coast of South America, Rio de Janeiro is a densely populated metropolis, with 6.4 million inhabitants, and has a tropical climate. Since its foundation in 1565, urban occupation has allowed the city to develop but also interfered with the environment, often altering the course of rivers, coastlines, hills, marshes and lakes. Despite these changes Rio de Janeiro still retains much of its natural wealth – 43 percent of the territory is covered by green areas, including two of the largest urban forests in the world and over 197 km of coastline.

Rio is preparing a comprehensive long-term plan 'Rio Resilient', to mitigate the effects of its recurrent summer floods and the human tragedy that they entail. The perception is that climate change will make floods more frequent and deadly, thus increasing the need to expand current efforts for flood prevention and to prepare the city for sea level rise.

Tropical storms and extreme rainfall events

Tropical storms have always been a natural event with high potential harm, often resulting in landslides and flooding, mostly in summertime. Rapid urbanisation and the expansion of slums on steep areas ('favelas') have aggravated the damage potential of these events. Most weather-related fatalities happen as a result of landslides in the favelas. Favalas can be defined as high-density settlements with poor infrastructure, occupied by low-income residents. In Rio, most of the favelas are located on the slopes of mountains. This is where nearly one million people currently reside, which is about 18 percent of the total population of the city.

Figure 13.11 Map of Rio de Janeiro.

Figure 13.12 Consequences of a landslide.

Figure 13.13 a/b Water flooding the streets of Rio de Janeiro.

In 2010 record-breaking rainfall paralysed the city, resulting in 2,600 homeless and 42 fatalities. It was the heaviest rainfall since 1965, but its consequences were worse because of the increased population density, especially in the hillside favelas.

For many decades the municipal governments have been erecting contention walls in the favelas, but the extreme rain event in 2010 demonstrated that this measure was insufficient, particularly to protect from landslide damage.

Transition to prevention, knowledge development and human training

After 2010, it was clear that Rio had to completely redesign policy and actions on managing the consequences of natural disasters and emergency situations. The city had to improve its resilience to extreme weather events and reorganise its actions based on three pillars of action: prevention, intelligence and human training.

Figure 13.14 Centre of Operations Rio (COR).

Prevention: Centre of Operations Rio (COR)

The first measure was the installment of the Centre of Operations, a high-end technology situation room. The Centre of Operations centralises all actions from municipal departments, and was a joint initiative of Rio de Janeiro Municipality with help of private partners, such as IBM and Cisco. The centre is one of the most advanced operation centres in the world. New technology has been incorporated in the facility, including a modern weather radar and a high-resolution weather forecasting and hydrological modelling system (PMAR), entirely customised to Rio's geography. The technology allows Rio to predict strong storms 48 hours in advance. The system is constantly being perfected and adapted, incorporating new data, as Rio recognises the need for constant vigilance due to climate change.

Today the Centre of Operations (COR, left page) coordinates operations from 30 different departments, mostly municipal, but also from utilities companies and other services that impact the city. The pressroom is situated right above the situation room, so that the media can report occurrences right away, which is not only a vehicle for transparency but also a means of informing as many residents as possible in the shortest space of time.

COR also manages traffic in an effort to reduce congestion and the resulting carbon emissions. It can control remotely the traffic signs, deploy traffic agents and dispatch emergency vehicles. It has recently developed a partnership with Google in order to use Waze's capability to detect road accidents and other traffic bottlenecks.

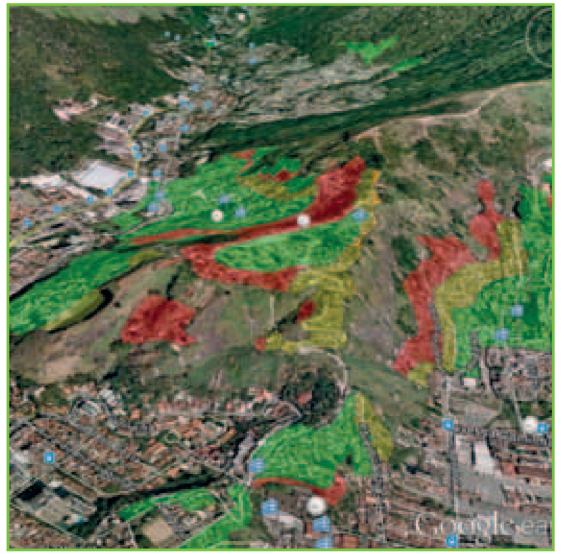


Figure 13.15 Geotechnical maps of risk areas .

Human training: COR

COR has also already proven its worth during emergencies. When the rain reaches a certain level in a specific part of the city, as determined by the local rain gauges, COR can activate the loudspeakers installed in 122 favelas and order their evacuation. It can also deploy civil defense teams and send other city staff, such as street cleaners and social workers, to the affected areas. City staff can also be informed about the location of people with special needs, and those who might need extra help during evacuation because their names, condition and the name of their caretakers have already been documented by health agents. In this way it is possible to know whether a person with severe hearing problems, a newborn baby or an elderly citizen might need special assistance in the evacuation process. It can also remotely clear roads for the passage of civil defense teams and ambulances, as well as empty the emergency room of hospitals in case of catastrophe.

Residents from more than 100 favelas are periodically drilled on what to do in the case of an emergency, where to go and who to contact. Classes on the principles of civil defense are being taught to schoolchildren and simulations are carried out inside the schools close to the high-risk areas.
Those three pillars of action – prevention, intelligence and human training – are the basis of the project, 'Rio Resilient', which incorporates academic knowledge and the experiences of other cities, mostly attained among those of C40. The next steps on the plan are to evaluate in more detail the impacts of climate change and predict its repercussions on the city and its infrastructure.

Infrastructural works
For 2020, the city aims to reurbanise all the favelas in Rio de Janeiro, with an investment of US$5 billion. Favelas are currently being renovated at their core, with entirely new infrastructure of water, sewage, energy, public lighting, garbage collection, schools, health clinics and recreation and sports areas. Rio's objective is to provide better than adequate living conditions and reduce considerably the risks of fatalities due to weather-related events. Despite being first and foremost a social policy, it will also make Rio a much more resilient city.

Figure 13.16 Rio's Port Area is being renovated.

The renovation of Rio's Port Area since 2010 is also proving to be a unique opportunity to build large-scale resilient infrastructure. The municipality identified the region's potential for growth, as a new space for tourism, and for commercial and residential buildings close to the financial center of the city. One of the objectives of the project is to bring people closer to their workplaces.

The Port Area's renewal entails a complete upgrade of its water, rainwater and sewage system, built to withstand a 0.50-to-1 m elevation of the sea level. In an effort to avoid the appearance of an urban heat island, 15,000 new trees will be planted, so that 10 percent of the area will be under a green coverage. To minimise carbon emissions, the city will reduce the number of buses circulating, build

17 km of cycle lanes and implement 26 km of light rail tracks connecting the area to the domestic airport and to a Bus Rapid Transit line. The solid waste will be recycled and transformed into energy by a plant located in the area. Still at the planning stages, innovative guidelines for sustainable construction and standards for new buildings are being established by law, thus ensuring that the best sustainable practices will be pursued.

Green initiatives
Green initiatives are indeed taking over the whole city. From 2009 to 2016 Rio expects to expand 1,700 hectares of green area and plant 500,000 trees in squares, parks and conservation areas. Rio is also implementing a Low Carbon City Development Programme, a partnership between the Municipality and the World Bank, and preliminary findings estimate that Rio has 12.5 million tons of carbon dioxide stored in the forests. The city aims to sequestrate as much carbon as possible, while also reducing local temperature, avoiding soil erosion (and thus landslides) and preserving our biodiversity.
Prior to the Rio +20 Conference, C40 Mayors announced the commitment to reduce their combined emissions by up to 1.3 gigaton of carbon dioxide by 2030. That commitment was internationally recognised as one of the most significant outcomes of the global agenda around Rio+20. Rio de Janeiro has set targets to reduce greenhouse gase emissions by 8 percent in 2012, 16 percent in 2016 and 20 percent in 2020 from the 2005 baseline, despite already having one of the lowest levels of greenhouse gas emissions per capita among metropolises.

13 Venice

by Fabio Riva, Simone Tola[62]

Introduction

The City of Venice is the capital of the Veneto Region and the largest town in the region in terms of both population and surface area. The detail that makes Venice unique in Italy is its surface area, which consists of 61 percent water (25.7 km^2 of water against 15.7 km^2 of land). The total surface of the municipality is divided into three major areas: the old town, the estuary and the mainland. The total population of the municipality is approximately 270,000 inhabitants of which 60,000 live in the ancient city.

The historic centre corresponds to the ancient city of Venice, made up of an archipelago of 118 islands with 177 channels crossed by 355 bridges. The estuary includes all other main islands of the lagoon (Burano, Murano, Torcello, and Sant'Erasmo), while the lagoon

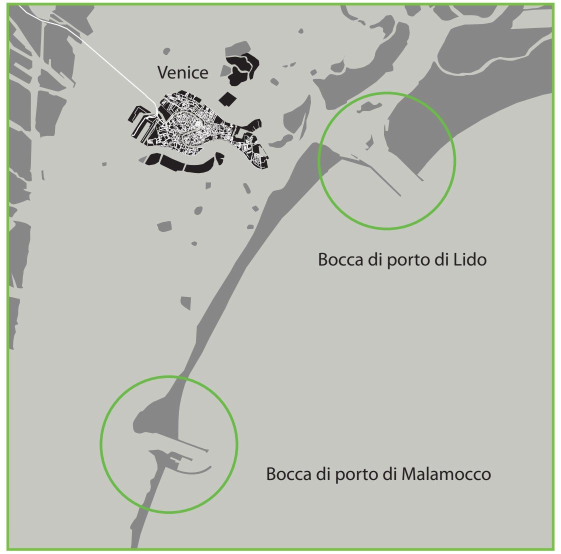


Figure 13.17 Map of Venice.

Figure 13.18 Piazza San Marco flooded.

is separated from the sea through the barriers formed by the Venice Lido and Pellestrina. The lagoon is fed by several rivers and sea water exchanges with the Adriatic Sea through three inlets. The position of Venice is also strategic for transport and housing. The most important port in northeast Italy, with over 30 million tons of traffic, covers an area of 2,045 acres. Marco Polo Airport is the third-largest in Italy with about eight million passengers a year.

About 20 million tourists visit Venice every year, while daily commuters to the city (students, workers), total 30,000. This results in a situation where, in addition to the 60,000 residents in the ancient city, there are about 85,000 other people who spend on average their whole day in the city (although not as residents), more than doubling the load on the city's infrastructure.

Challenges

Venice is located in the middle of a lagoon that UNESCO has rated as a World Heritage Site. The lagoon of Venice is one of the few parts of the lagoon that remains from Roman times; through the infrastructural projects of the past centuries, Venetians were able to prevent the accumulation of sediments , thereby making the lagoon sustainable. For this reason, it is also said that the lagoon of Venice is a partially man-made environment. Added to the intrinsic fragility of the lagoon of Venice are now the new challenges presented by climate change.

Examples of historic human intervention in the lagoon are the diversion of rivers (since 1300), embankments (end of 1700), changes to the

Figure 13.19 A flooded Piazza San Marco covered in snow.

Figure 13.20 Venice Arsenale hosts the forecasting and decision making system.

lagoon boundary (1791), dams (1840 to 1934), porto Marghera and digging channels (since 1917), agricultural reclamation (since 1924), stemming the fish farms (1950s), landfills and the construction of the airport (1960s) and MOSE, artificial mobile barriers (since 2000).

A Climate Change Action Plan for Venice

In the Mediterranean area, the scientific community envisages a gradual increase in average temperatures in summer and winter, rising sea level, intensification of heavy rain events and the simultaneous reduction of rainfall that will replenish aquifers. These processes have already caused major flooding, such as in September 2007. Therefore, in 2012, the City Council of the City of Venice decided to adopt a Plan of Action to Climate Change.[63]

The plan is divided into four thematic areas:

the first area, the ***Green City***, will address the relationship between climate change and land use with consideration also related to the risk of flooding due to the simultaneous increase of extreme events with the reduction of permeable surfaces of the land. Also, the risk from heatwaves will be analysed in this area.

The action plan related to the risks posed by climate change can be summed up by:

- the increase of green multifunctional areas;
- the elimination of land use;
- urban regeneration;
- improved quality of settlements;
- solutions to the phenomenon of heat islands.

The second area, the ***Blue City***, covers the relationship between the city and the water, the lagoon, and all the infrastructures that may be threatened by phenomena such as the rise of the tides and flooding of watercourses. This field of action is primarily aimed at increasing the resilience of natural and man-made structures in the city, in order to preserve the integrity, completeness and usability, as well as ensuring the existence and functionality of social productive activities and the integrity of the city's cultural heritage. The Climate Plan will assess risks and analyse scenarios for the evolution of key impacts and make them available to support future choices for tidal safety, maintenance of the lagoon morphology, biodiversity conservation and management of water resources.

The objectives to be pursued in this field of action can therefore be summed up by:

- the safety of the ancient city by the tides and the mainland from flooding;
- the maintenance of the lagoon morphology;
- the conservation of biodiversity;
- the improvement of the water cycle.

The third theme focuses on ***Energy & Mobility*** through the inclusion of the mitigation strategy outlined in the Sustainable Energy Action Plan (SEAP) within the Covenant of Mayors EC Initiative.[64] It may also include evaluations of those sectors previously excluded like industry, transport crossing, ships and planes, and power generation). The objectives of SEAP are: to reduce greenhouse gas emissions from residential and commercial buildings; to reduce dependence on fossil fuels; and to increase the use of public transport or bicycle usage. It is envisaged that the SEAP will be absorbed into the action plan for climate change.

The last theme will be dedicated to the ***green economy***, including all matters related to the reduction of the impact of productive activities, whether industrial, tourism or even related to the food chain. Venice also intends to set goals for medium and long-term sustainability, for example, to secure tourism activities, which are very important to Venice. Climate change could change the tourist season and Venice is devising strategies to meet this challenge, such as to create a closed cycle of waste that maximises the share of recycling and reuse of materials, and an increased recovery of materials and energy.

Figure 13.21 High water on 1st November 2012. The tide reached a height of 143 cm.

The MOSE [65]

To meet the objective of a complete defence of the inhabited lagoon from high waters of any level, an integrated system of storm-surge barriers, known as MOSE, has been developed to be implemented at the three inlets. MOSE is able to isolate the lagoon from the sea during high tide events over a designated area. Complementary works such as new cliffs outside the inlets and the rise of the banks and floor might help to mitigate more frequent tide levels. The integration of these operations defines a highly functional defence system that reduces the closures of MOSE barriers 3-to-5 times a year with the current tide level. This will guarantee the quality of water, the protection of the lagoon morphology and landscape and the maintenance of the port. Currently, the gates are activated when the water is 110 cm above normal levels (according to the sea level meter placed in Venice, Punta della Salute). This level is not, therefore, a functional limit of the defence system and may be revised and lowered if necessary.
The storm surge barriers are made up of lines of flap-gates built into the inlet canal beds. They are 'movable' because in normal tide conditions they are full of water and lie flat in their housings built into the inlet canal bed. When, however, there is a tide higher than the predetermined safety level (tide gauge at Punta della Salute) the gates are emptied of water by injecting compressed air. In this way, they are raised, rotating around the axis of the hinges, to enable them to emerge from the water's surface. In this way, it is possible to temporarily isolate the lagoon from the sea and to block the flow of the tide. The mouths of the lagoons remain closed for the duration of the high water and the operating times of the gates (on average, 4.5 hours in total). In the future, the phenomenon of high waters could be further aggravated by the predicted rise in sea levels produced by climate change. With regard to this problem, MOSE (with the reinforcement of the coastal strip) has been designed on the basis of a precautionary criterion to cope with an increase of up to 60 cm in sea level. The management of MOSE is flexible enough to cope with an increase in high waters in various ways, depending on the characteristics and scale of the tidal event. Depending on the situation, the defence strategies can involve simultaneous closure of all three inlets, closure of one inlet at a time, or partial closure of each inlet, as the gates are all independent.

Figure 13.22 Malamocco inlet. The temorary site equipped to construct the gate housing caissons.

Facts & Figures:

- 4 the number of mobile barriers being constructed at the lagoon inlets (2 at the Lido inlet, 1 at Malamocco and 1 at Chioggia);
- 78 the total number of gates. The gates are disappearing, oscillating, buoyancy flap gates;
- 18.5 m x 20 m x 3.6 m length, width and thickness of the smallest gate (Lido – Treporti row);
- 29.6 m x 20 m x 4.5 m length, width and thickness of the largest gate (Malamocco row);
- 1 lock for large shipping at the Malamocco inlet enabling port activities to continue when the gates are in operation;
- 3 small locks (2 at Chioggia and 1 at Lido-Treporti) to allow the transit of fishing boats and other smaller vessels when the gates are in operation;
- 3 m the maximum tide which the gates can withstand (to date, the highest tide has been 1.94 m);
- 60 cm the increase in sea level the MOSE System has been designed to cope with;
- 3,000 people currently directly or indirectly employed;
- 9,000 m of rock-fill already completed out of the 9,850 required to complete the visible structures such as the small craft harbours, jetty reinforcement and breakwaters;
- 4,100 m of vertical wall already completed out of the 4,590 required to complete the visible structures such as locks and the 'abutments' for the row of gates;
- 398,700 m^2 of bed protection and underwater structures out of the 597,000 required for completion.

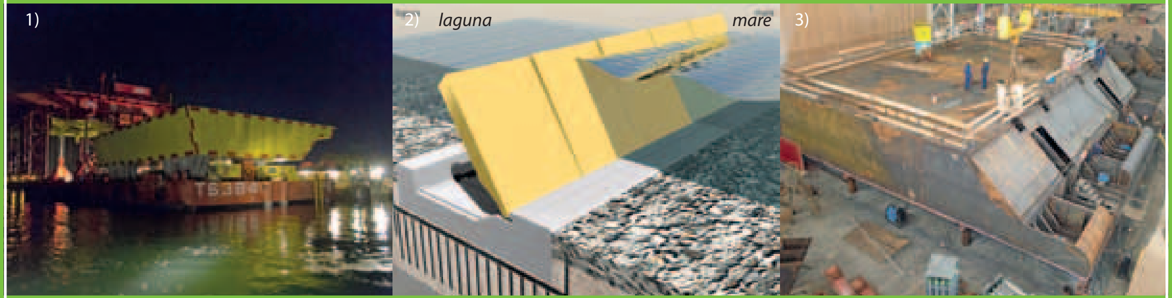


Figure 13.23 1) The gate (yellow) just arrived at the Lido inlet and the special craft (red) for the launch and the installation of the gates. 2) The MOSE - 3) The mobile gates in construction in Monfalcone to be installed at the Lido Treporti inlet.

References

The following list of references consist of climate adaptation plans, relevant projects and institutes. The content of this book is mainly based on the contribution of the delta cities. More background information could be found in the reference list of previous Connecting Delta Cities books vol. I and vol. II or by contacting Rotterdam Climate Initiative via www.rotterdamclimateinitiative.nl/en

Delta cities in times of global changes

1 Aerts, J.C.J.H., Molenaar A. and P. Dircke (2008) Connecting Delta Cities, vol. I. Coastal Cities, Flood Risk Management and Adaptation to Climate Change'. Rotterdam: Connecting Delta Cities.

2 Dircke, P., Aerts, J.C.J.H. & A. Molenaar (eds.) (2010), Connecting Delta Cities, vol. II. Sharing knowledge and working on adaptation to climate change. Rotterdam: Connecting Delta Cities.

CDC update

3 CNN (the city) Bloomberg: Why Sandy forced cities to take lead on climate change, August 2013. ***http://edition.cnn.com/2013/08/21/world/europe/bloomberg-why-sandy-force-cities/index.html***

4 National Geographic USA, September 2013, p. 54.

5 CNN (2013), How giant tunnels protect Tokyo from flood threat, ***http://edition.cnn.com/2012/10/31/world/asia/japan-flood-tunnel/***

6 Antaranews (2011) Jakarta to host world Delta Summit, October 2011. ***www.antaranews.com/en/news/76308/jakarta-to-host-world-delta-summit***

7 Potsdam Institute for Climate Impact Research (2012), Five year Project on Cities (RAMSES) coordinated by PIK, November 2012. ***www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/news-events-rd2/five-year-project-on-cities-ramses-coordinated-by-pik***

8 Raingain (2013) ***www.raingain.eu/en/four-cities-gain-rain***.

9 Blue Green Dream (2013) ***http://bgd.org.uk/***

Rotterdam

10 Rotterdam Climate Initiative (2010), Rotterdam Climate Proof (RCP) Programme.

11 National Delta Programme, regional sub-programme 'Rijnmond Drechtsteden' (2013).

12 The Royal Dutch Meteorological Institute (KNMI).

13 City of Rotterdam (2013), Rotterdam's Climate Adaptation Strategy.

New York

14 NYC Department of Planning (2011) Vision 2020: New York City Comprehensive Waterfront.

15 Coch, N.K. (1994). Hurricane hazards in the Northeast US Journal of Coastal Research, 12, 115-147.

16 Federal Emergency Management Agency (FEMA) (2013) Flood Insurance Rate Maps (FIRMs) for New York City.

17 New York City; PlaNYC (2007) A Greener, Greater New York.

18 New York City; PlaNYC (2011) A Stronger, More Resilient New York.

Jakarta

19 City of Jakarta.

20 Jakarta Globe (2013), Total Losses for Jakarta Flooding Hit Rp 32 Trillion ***www.thejakartaglobe.com/archive/total-losses-for-jakarta-flooding-hit-rp-32-trillion/***

21 Ward, P.J., Marfai, M.A., Tobing, A. & Elings, C. (2010). Jakarta flood risk. In Dircke, P., Aerts, J.C.J.H. & Molenaar, A. (eds.), Connecting Delta Cities. Sharing knowledge and working on adaptation to climate change. (pp. 60-67). Rotterdam: Connecting Delta Cities.

22 Abidin, H.Z., Andreas, H., Gumilar, I., Gamal, M., Susanti, P.Fukuda., Deguchi, T. (2010), Land Subsidence in the Jakarta Basin (Indonesia): characteristics, causes and impacts. IAHS book series. Groundwater system response to a changing climate. CRC Press/Balkema, in press.

23 Model Implementation, National Capital Integrated Coastal Development Implementation Model study, August 30, 2013.

24 Pribadi, K.S.(2008), Climate change adaptation research in Indonesia. Asian Universities for Environment and Disaster Management. 28-29 July 2008, Kyoto, Japan.

25 Marfai, M.A. (2011), Bencana Banjir Jakarta Dan Peran Masyarakat Pada Fase Kesiap-Siagaan Bencana. Presented in the conference of 'Menuju Masyarakat Siap Bencana', 9-10 Maret 2011. Gedung Pasca Sarjana UGM. Yogyakarta.

26 Rista Rama Dhany (2012), Waduh! 70.000 Ton Sampah Pertahun Dibuang ke Ciliwung, detikNews, February 2012 ***http://news.detik.com/read/2012/02/18/143014/1845816/10/waduh-70000-ton-sampah-tiap-hari-dibuang-ke-ciliwung***

London

27 Office for National Statistics (2011) Census.

28 Greater London Authority (2012) Population Projections (2012, Round SHLAA based.

29 Greater London Authority (2011), Crowded-Houses-Overcrowding-in-London-Social-Rented-Housing, ***http://glaconservatives.co.uk/wp-content/uploads/2013/04/Crowded-Houses-Overcrowding-in-London-Social-Rented-Housing.pdf***

30 Armstrong B.G., Chalabi Z., Fenn B., et al. (2009), Association of mortality with high temperatures in a temperate climate: England and Wales. J Epidemiol Community Health 2009;65(4):340-5.

31 Greater London Authority (2011) Managing risks and increasing resilience. The London Climate Change Adaptation Strategy.

32 The Development of a Local Urban Climate Model and its Application to the Intelligent Design of Cities (2007-2010), LUCID project.

33 Air pollution and WEather-related health impacts (2011-2014), AWESOME project, by Natural Environment Research Council (NE/I007938/1).

34 Thames Water (2013), Our proposed Counters Creek scheme ***www.thameswater.co.uk/about-us/9344.htm***

35 'urban creep' refers to incremental loss of permeable land through development and use of impermeable surfaces.

New Orleans

36 City of New Orleans (2013), The Greater New Orleans Urban Water Plan.

Hong Kong

37 Acknowledgement of contributions from Fedrick Y F Kan of Drainage Services Department, T C Lee of Hong Kong Observatory, Vincent S C Mak of Water Supplies Department and from the Environmental Protection Department, Civil Engineering and Development Department, and Census and Statistics Department.

38 Hong Kong Observatory (2012). Climate of Hong Kong. ***www.hko.gov.hk/cis/climahk_e.htm***

39 Ginn, W.L., Lee, T.C. & Chan, K.Y. (2010). Past and Future Changes in the Climate of Hong Kong. ACTA Meteorologica Sinica, 24(2), 163-175. (English Edition)

40 Li, K.W. & Mok, H.Y. (2011). Long term trends of the regional sea level changes in Hong Kong and the adjacent waters. Presented in the 6th International Conference on Asian and Pacific Coasts (APAC2011), Hong Kong, China, 14 December 2011, HKO Reprint No. 990.

41 Wong, M.C., Mok, H.Y. & Lee, T.C. (2011). Observed Changes in Extreme Weather Indices in Hong Kong. International Journal of Climatology, 31, 2300–2311, DOI: 10.1002/joc.2238.

42 Lee, T.C., Chan, K.Y. & Ginn, E.W.L. (2011). Projections for extreme temperatures in Hong Kong in the 21st Century. Acta Meteorologica Sinica, 25(1):1-20. (English Edition)

43 Lee, T.C., Chan, K.Y., Chan, H.S. & Kok, M.H. (2011). Projections for Extreme Rainfall in Hong Kong in the 21st Century. Acta Meteorologica Sinica 25(6): 691-709. (English Edition)

44 Sin, C.Y., Fung K.W. & Lau Y.W., 2008 : Sewerage and Flood Protection – Drainage Services 1841 - 2008. Drainage Services Department, p.84-90.

45 Lee, T.C., Leung, W.H. & Ginn, E.W.L. (2008). Rainfall projections for Hong Kong based on the IPCC Fourth Assessment Report. Hong Kong Meteorological Society Bulletin, 18, HKO Reprint No. 798.

46 Lee, T. C., Leung, Y. Y., Kok, M. H., & Chan, H. S. (2012). The Long Term Variations of Tropical Cyclone Activity in the South China Sea and the Vicinity of Hong Kong. Tropical Cyclone Research and Review, 1(3): 277-292.

47 Ying, M., Knutson, T. R., Kamahori, H., and Lee, T. C. (2012). Impacts of Climate Change on Tropical Cyclones in the Western North Pacific Basin. Part II: Late 21st Century Projections. Tropical Cyclone Research and Review, 1, 231-241.

48 Lam, H. & Lee, T. C., 2012 : Climate services in Hong Kong - Accomplishment through partnership and outreaching, Climate ExChange. WMO, ISBN 978-0-9568561-3-5, Tudor Rose, p.212-215.

Tokyo

49 Asian Human Network Databank (2013), Tokyo Metropolitan Government Flood, Storm Surge and Tsunami Control Workshop carried out by the TMG ***www.asianhumannet.org/english/newsletter/201303/4.html ;Tokyo Metropolitan Government***

50 Innovative Programme of Climate Change Projection for the 21st Century (KAKUSHIN) (2012).

51 The latest climate change projection research was conducted by making the best use of the Earth Simulator, a world-class supercomputer. The latest research results are expected to contribute to the formulation of the Fifth Assessment Report (2013-2014) of the Intergovernmental Panel on Climate Change (IPCC).

Ho Chi Minh City

52 Ho Chi Minh City (2013), Ho Chi Minh City Spatial Master Plan 2025.

53 Vietnam Climate Adaptation Partnership (2013)'HCMC Moving towards the sea with Climate Change Adaptation' - ***www.vcaps.org*** Atlas and Climate Adaptation Strategy of HCMC.

Melbourne

54 City of Melbourne (2009) Climate Change Adaptation Strategy.

55 Joint Australian/New Zealand Standard, risk management AS/NZS 4360:2004.

56 City of Melbourne (2010), 1st Climate Change Adaptation Action Plan.

57 City of Melbourne (2012), Economic Assessment of the Urban Heat Island Effect, summary p. 44-45 ***www.melbourne.vic.gov.au/Sustainability/AdaptingClimateChange/Documents/UHI_Report_AECOM.pdf***

58 Association of Bayside Municipalities (ABM) (2013), Southbank case study ***www.abm.org.au/adaptationproject/isitsb.html***

59 City of Melbourne (2012), Urban Forest Strategy.

Copenhagen

60 City of Copenhagen (2012), Cloudburst Management Plan.

Observations and future outlook

61 Columbia University website (2013), ***http://globalcenters.columbia.edu/content/about-1***

Venice

62 Acknowledgement of contributions from Ministry of Infrastructure and Transport - Magistrato alle Acque di Venezia, concessionary Consorzio Venezia Nuova.

63 City of Venice (2012), Plan of Action to Climate Change.

64 Covenant of Mayors - Sustainable Energy Action Plan (SEAP).

65 Ministero delle Infrastrutture e dei Trasporti Magistrato delle Acque di Venezia (2013), MOSE ***www.salve.it/***

Photos and illustrations

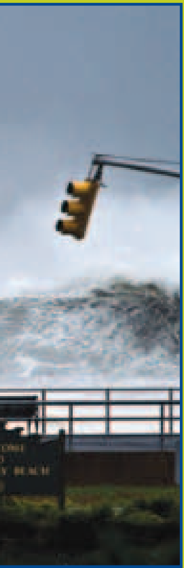
This book contains photos and illustrations by all cities involved and Adisukma, Aji Putra, Allyn Baum/The New York Times, Beau Design, Bosch Slabbers, BPS, Deltares, DE URBANISTEN, Eric Fecken, Google Earth (2013), Hong Kong Observatory, I. Bobbink (Delft Technical University), Ibnu Affiano, London 2012, NYCDOT, Paul Martens, RNW Conceptdesign (app development), Rotterdam Images, Ursula Bach, Stefan Klaas, Tulane University. If you are not credited here, please notify the secretariat.

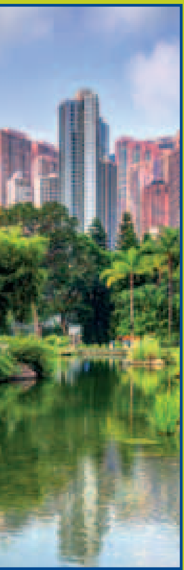
Contact Information CDC secretariat
Ms. Chantal Oudkerk Pool

Address
Galvanistraat 15, 3029 AD Rotterdam,
PO Box 6575, 3002 AN Rotterdam,
the Netherlands

E-mail
info@deltacities.com

Website
www.deltacities.com





Socioeconomic trends, combined with ongoing subsidence in most deltas, further amplify the possible consequences of future floods and other extreme climatic events, as more people move towards urban delta areas and capital is continuously invested in ports, industrial centres and financial businesses in flood-prone areas. In 2013 the World Bank stated that taking climate change and land subsidence into account, present protection will need to be upgraded to avoid unacceptable losses of US$1 trillion or more per year.

This third CDC book goes beyond exploration of the challenges delta cities face around the world. This volume shows the recent progress made in Rotterdam, New York, Jakarta, London, New Orleans, Hong Kong, Tokyo, Ho Chi Minh City, Melbourne and Copenhagen. Progress many cities make in close collaboration, enabled by the international networks like CDC. As many cities have entered a new phase in developing and implementing their adaptation strategies, knowledge exchange will prove crucial in the next few years.

ISBN: 9789072498007

9 789072 498007