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ARUP

THE CITY WATER RESILIENCE APPROACH

CITY CHARACTERISATION REPORT

ROTTERDAM

ACKNOWLEDGEMENTS

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CONTENTS

EXECUTIVE SUMMARY

The City Water Resilience Approach (CWRA) helps cities plan and implement actions to build resilient urban water systems. A critical first step in this process is understanding the local water system, and the factors that contribute to or detract from resilience.

This report details research undertaken in Rotterdam with the goals to:

1. Define the city water basin including natural basin(s), the urban water system and its governance structure, and the interdependencies with other systems; and
2. Identify the factors contributing to the resilience of the city water system and those increasing its vulnerability.

In developing this characterisation report, the Arup team collected desktop data on the biophysical characteristics of the basin and key actors in the water system.

WATER GOVERNANCE IN ROTTERDAM

Rotterdam is located southwest of Amsterdam in South Holland in the Netherlands. Built mostly behind dykes, large parts of Rotterdam are below sea level, with the lowest point 6.76 metres below sea level. As of 2017, Rotterdam has a population of 633,471, making it the second largest city in the Netherlands. Rotterdam is Europe's largest port with the rivers Rhine, Meuse and Schelt giving waterway access from the North Sea to the heart of Western Europe. The port is a major logistic and economic centre.

Rijkswaterstaat, the Ministry of Infrastructure and Water Management, is responsible for providing effective water management to protect the country against flooding. The City of Rotterdam manages all open water bodies in the city and all sewer systems. The city consists of 14 sub-municipalities.

The drinking water supply for Rotterdam is largely sourced from the Maas River. It has an extensive drainage system. Wastewater is treated then discharged into the Nieuwe Maas River. With large parts lying below sea level, Rotterdam has extensive flood protection infrastructure including dams, pumping stations, dykes, levees and storm surge barriers.

KEY STAKEHOLDERS

Evides Waterbedrijf is the public water utility while the City of Rotterdam is a government body responsible for resources and sewer systems. Rijkswaterstaat, the Netherlands' Ministry of Infrastructure and Water Management, is responsible for the execution of water management and flood protection and prevention. The Waterboard of Delfland, Province of South Holland government, and the Waterboard of Holland Delta maintain the dykes and dams, water level control and water quality. DCMR Environmental Protection Agency Rijnmond (DCMR) is the joint environmental protection agency for the Province of South Holland. The Port of Rotterdam Authority is responsible for the sustainable development, management and commercial operation of the port.

SHOCKS AND STRESSES

The key interdependencies between the water system and city systems in Rotterdam are the economy, transport and housing systems. This is mostly due to the impact of severe flooding on each of them.

Key shocks and stresses impacting Rotterdam are flooding, drought, subsidence, groundwater depletion and heatwaves. Flooding is rife throughout Rotterdam in all forms – pluvial, fluvial and coastal. Sea level rise from climate change puts the Port of Rotterdam at risk.

Failure of climate change mitigation, inadequate governance, ageing infrastructure and lack of investment all inhibit the resilience of Rotterdam.

BUILDING RESILIENCE

Through engagement with Rotterdam's stakeholders, it was identified that water storage, increasing community participation / awareness and improved governance and strategy are positive factors of resilience for Rotterdam's urban water system.

1

BACKGROUND

Rotterdam is located southwest of Amsterdam in South Holland in the Netherlands. The city dates back to 1270 when the first dam was constructed in the Rotte River (Wikipedia, n.d.). Built mostly behind dykes, large parts of Rotterdam are below sea level, with the lowest point 6.76 metres below sea level (RCI, 2013). Rotterdam continues the Dutch tradition of learning how to live below sea level with very active in knowledge collaboration with Erasmus University Rotterdam (EUR), TU Delft, UNESCO-IHE, and Deltares and the Rotterdam University for Applied Sciences (water management) (RCI, 2013).

Erasmusbrug (Erasmus bridge) nicknamed 'the swan' on the Nieuwe Maas river, Rotterdam

Central Rotterdam

POPULATION

As of 2017, Rotterdam has a population of 633,471, making it the second largest city in the Netherlands. It is a densely populated city and continues to grow. Just over half of the population has non-Dutch origins or at least one parent who is not Dutch (Wikipedia, n.d.).

ECONOMY

Rotterdam is Europe's largest port with the rivers Rhine, Meuse and Schelt giving waterway access from the North Sea to the heart of Western Europe. The port is a major logistic and economic centre, and the port's main activities are in the petrochemical industries and general cargo handling and transhipment (Wikipedia, n.d.). There is also a significant railway line that links the port to other parts of Europe. In 2011, at 12% Rotterdam actually had twice the national average of unemployment (Wikipedia, n.d.). However, Rotterdam also accounts for 17% of production for the whole country (RCI, 2013).

GOVERNANCE

Rijkswaterstaat, the Ministry of Infrastructure and Water Management, is responsible for providing effective water management to protect the country against flooding. The Netherlands has a unique system of local Dutch Water Boards (waterschappen), which govern water barriers, waterways, water levels, water quality and sewage treatment in their respective regions (Wikipedia, n.d.). The City of Rotterdam manages all open water bodies in the city and all sewer systems. The city consists of 14 sub-municipalities.

2

RESEARCH METHODOLOGY

The remote engagement with Rotterdam was comprised of three parts:

PART 1	A desktop study aimed at understanding the city's water basin, identifying shocks and stresses that impact the city's water system, and understanding the system vulnerabilities.
PART 2	Survey and Key Informant Interviews – Wave 2 cities used a stakeholder organogram created during the desk study to identify key stakeholders within their cities. These stakeholders completed a survey or interview to share their insights about the urban water system.
PART 3	While the number of surveys completed for Rotterdam was small (6), those who filled it out have unique insights and perspectives into the water system in Rotterdam and do represent six of the organisations who are decision-makers in the Rotterdam Stakeholder Organogram. Insights from the survey have been backed up by the desktop study with references listed here as relevant.

Engagement with 'Wave 1' cities included a two week field mission, where workshops, focus groups and interviews were conducted.

Engagement with 'Wave 2' cities included remote support to city partners where surveys and interviews were conducted.

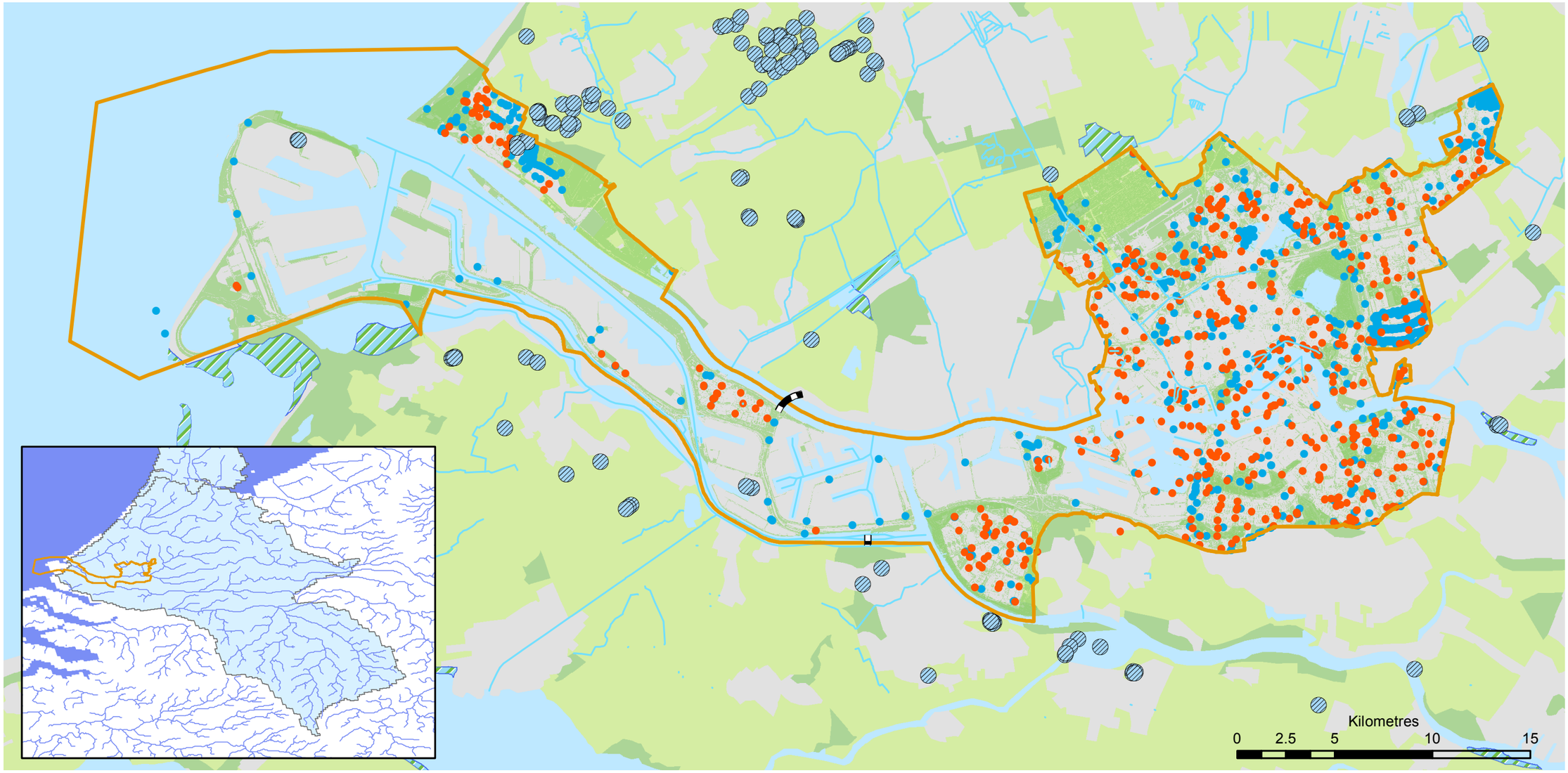
3

UNDERSTANDING ROTTERDAM'S WATER SYSTEM

The city is located at the end of the Nieuwe Maas channel and within the Rhine-Meuse-Scheldt River Delta at the North Sea. The rivers connect Rotterdam with much of Europe, and its port and rail system connect it to the rest of the world. The Rotte River no longer directly connects to the Nieuwe Maas channel; it was pumped in the early 1980s to make way for a second subway line (Wikipedia, n.d.).

Overlooking Rotterdam city

Figure 1:
Greater Rotterdam Basin Map



The drinking water supply for Rotterdam is largely sourced from the Maas River (Evides, n.d.). The city has an extensive drainage system, consisting of sewage pipelines, pumping stations and pressurized pipelines. Wastewater is transported to treatment plants before being discharged into the Nieuwe Maas River. Much of the city is highly urbanised with strategic 'green spaces' to compensate for pluvial flooding within the city.

With large parts lying below sea level, Rotterdam has extensive flood protection infrastructure including dams, pumping stations, dykes, levees and storm surge barriers. The outer dykes' regions are directly exposed to the river and the sea on much higher ground, so flooding tends to be less severe. The potential threat of a storm surge from the North Sea has been managed through a series of construction projects like the Europoortkering. The Europoortkering is includes both the Maeslantkering and the Hartelkering (both storm surge barriers) and the dyke fortifications in the lower river area (The Keringhuis, n.d.).

4

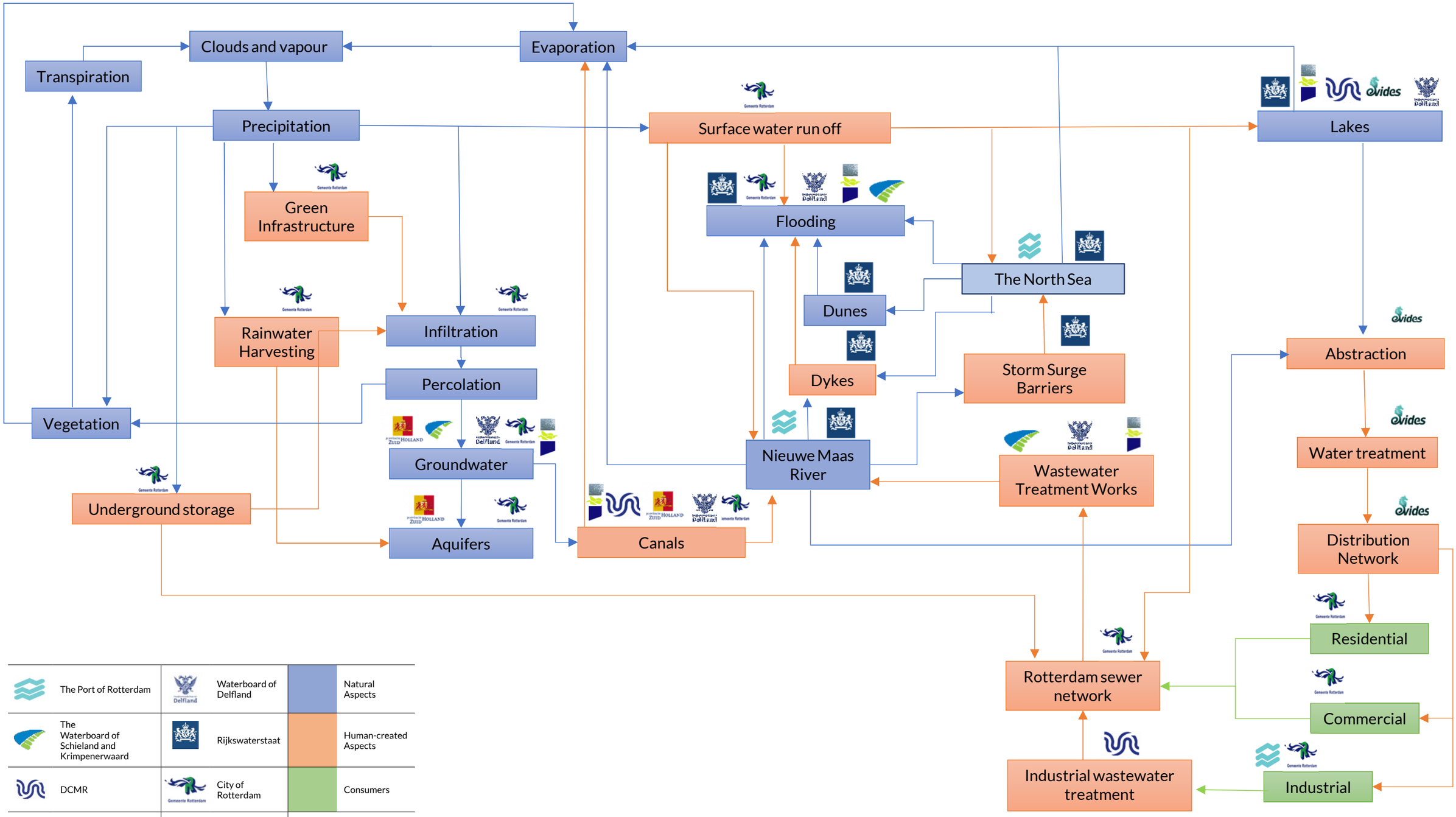
ENGAGEMENT WITH KEY STAKEHOLDERS

The following organogram describes the Great Rotterdam water system with the logos of decision-making stakeholders where appropriate. Another way of denoting stakeholder responsibility for these categories is visualized in Figure 2, which describes how different organisations work within specific functions.

Canal in Rotterdam

GREATER ROTTERDAM WATER CYCLE GOVERNANCE DIAGRAM

Figure 2:
Rotterdam's Water cycle governance diagram



STAKEHOLDER COMMENTARY

BASIC SERVICE PROVISION

Evides Waterbedrijf, the public water utility, is responsible for the provision of potable water, and the City of Rotterdam is a government body managing all open water bodies and sewer systems in the city. Rijkswaterstaat, the Netherlands' Ministry of Infrastructure and Water Management, is responsible for the practical execution of water management and flood protection and prevention. The Waterboard of Delfland, Province of South Holland government, and the Waterboard of Hollandse Delta manage the maintenance of dykes and dams, water level control and water quality.

RISK MANAGEMENT

The Port of Rotterdam Authority is responsible for protecting the port against flooding. To tackle the risk of a storm surge from the North Sea, Rijkswaterstaat funded the construction of a storm surge barrier, the Maeslantkering, which was part of the Europoortkering and the Delta Works to improve flood defences in Rotterdam (Wikipedia, n.d.). Investment in green infrastructure has raised water awareness, including green roofs, floating house developments, water squares, and underground water storage.

ENVIRONMENT

DCMR Environmental Protection Agency Rijnmond (DCMR) is the joint environmental protection agency for the Province of South Holland and its 15 municipalities, a heavily industrialised and densely populated region. Its fundamental tasks include imposing environmental rules, monitoring environmental quality, and advising on environment and safety. It works with local and regional authorities on these issues.

ECONOMIC AND SOCIO-CULTURAL

The port of Rotterdam is the largest port in Europe, and the **Port of Rotterdam Authority** is responsible for the sustainable development, management and commercial operation of the port. Within the port, the Botlek area is of major economic importance, is home to numerous chemical companies, and is aided by an extensive network of pipelines (Deltacommissaris, n.d.).

BASIC SERVICE PROVISION	Evides	DCMR	City of Rotterdam	Rijkswaterstaat	Waterboard of Hollandse Delta	Waterboard of Delfland	Province of South Holland
FLOOD RISK	The Port of Rotterdam	City of Rotterdam	Rijkswaterstaat	Waterboard of Hollandse Delta	The Waterboard of Schieland and Krimpener-waard	Waterboard of Delfland	
ENVIRONMENT	DCMR	Waterboard of Hollandse Delta	Waterboard of Delfland	Province of South Holland			
ECONOMIC	The Port of Rotterdam	City of Rotterdam					
SOCIO-CULTURAL	The Port of Rotterdam	Rijkswaterstaat					

Figure 3: Key actors and water functions

KEY PROGRAMMES

Rotterdam's history is marked by its citizens' work towards resilience. Challenges were overcome in water management, trade, fighting cholera, and reconstructing the city after the Second World War. With rising sea levels and the constant threats of flooding, Rotterdam has developed many programmes to improve and innovate their water system. Water management and climate change lie at the heart of the city's resilience efforts.

1. Delta Works

Programmes developed to protect the city against flooding include the Delta Works—consisting of thirteen sections—forming the largest flood protection system in the world. The national programme demands collaboration from the national government, provincial authorities, municipal authorities and the water boards. It has continued with the Delta Programme for the Rijnmond-Dretchsteden area of Greater Rotterdam (Deltacommissaris, n.d.).

2. Rotterdam Climate Proof Programme

This programme was set up in 2008 to ensure the city was climate proof by 2025, focussing particularly on adaptation. This programme stated that Rotterdam is vulnerable to climate change and the primary objectives include protecting inhabitants from the rivers and seas, ensuring minimal disruption from too much or too little rainfall and guaranteeing the Port of Rotterdam remains safe and accessible.

3. Climate Change Adaptation Strategy

In 2013, Rotterdam released its Climate Change Adaptation Strategy with the goal to be climate proof by 2025 through a series of critical programmes and actions (RCI, 2013). This strategy takes into account a variety of innovative options to enhance resilience and examines how to climate proof the city across all systems.

4. 100 Resilient Cities

In 2016, the City of Rotterdam became one of the first cities in the 100 Resilient Cities network to release its resilience strategy. Through this strategy, Rotterdam has been taken an honest and proactive view of its resilience challenges and opportunities, recognising that it has to become resilient not just by fortifying its defences to a changing climate and rising seas, but also by building a more cohesive and inclusive society and ensuring security from cyber-attacks and weather extremes (100RC, 2016).

Maasvlakte, Rotterdam

5

CHARACTERISING RESILIENCE

One of the important aspects of this Snapshot was reaching out to key stakeholders identified in the organogram above to see how they thought about the shocks and stresses of their area and about what was happening with resilience. This information is framed using the City Water Resilience Framework (CWRF). The Appendix provides additional details on CWRF, its shock/stress tags, goals, and dimensions.

These inputs were shared through surveys as indicated in the Wave 2 Methodology. Survey participants were 72% Government, 14% Private Business, and 14% Academic as shown in Figure 4. Most survey responses related to the City Water Resilience Framework (CWRF) dimensions of Infrastructure & Ecosystems and Governance & Strategy (Figure 5) though there is also interest in Health & Wellbeing and Economy & Society. The main point to draw from Figure 5 is how different types of stakeholders are involved or focused on all the different dimensions—the exception being that academic participants did not reference Economy & Society.

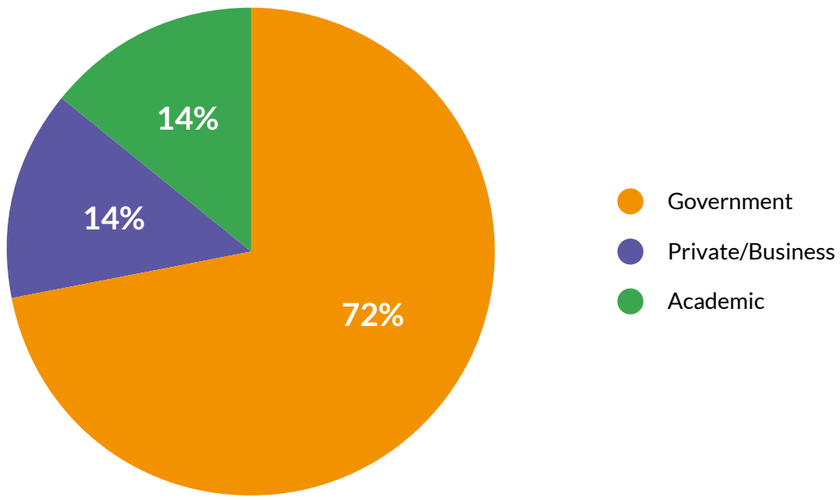


Figure 4:
Stakeholder Type of Survey Respondents

CRITICAL INTERDEPENDENCIES

The urban water system does not exist in a vacuum. In fact, one of the main focuses of the City Water Resilience Framework is how the water system within the city engages not just with the full basin it belongs to but also the other sectors that rely on water and that influence the use of water.

ECONOMY

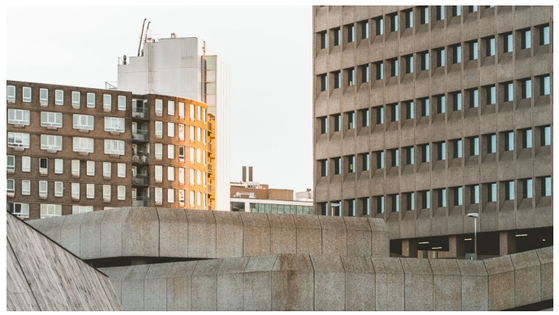
Various water stresses and shocks could negatively influence the economy of the port. Some of these, such as cyber concerns, are described in the Rotterdam Resilience Strategy.

TRANSPORT

Severe flooding can impact the transport sector through delays and damage to infrastructure. Transport includes the rail lines that connect the port to Europe and, of course, the port itself. Not to mention the normal roads and public transport for citizens and other businesses.

HOUSING

The damage to people's well-being and safety during flooding was marked in both the survey and desktop research. It was noted that flooding can lead to subsidence in the housing, which can make it dangerous to live there. In extreme rainfall with inadequate sewers, sewage water can enter homes through toilets and basins.



KEY SHOCKS AND STRESSES

All of the shocks or stresses to the Rotterdam water system mentioned in the desktop research and the survey responses were tagged with one of the shock/stress tags from the CWRF (see Appendix). Figure 6 shows the tags for shocks and stresses mentioned in the surveys broken out by stakeholder type. Figures 7 and 8 highlight the top shocks and stresses and identify how they each fit within the twelve CWRF goals (see Appendix). Figure 7 looks specifically at which shocks and stresses were highlighted in the survey results. Due to the small sample size of the survey, Figure 8 examines the same questions but including the information obtained during the desktop study.

The most frequently mentioned shocks and stresses included flooding, drought, climate change, and shortfall of critical infrastructure. Critically and unsurprisingly, each shock or stress fits under multiple goals, highlighting how interdependent aspects of the urban water system are to the different dimensions of city water resilience.

Flooding

The threat of pluvial, fluvial and coastal flooding has always put pressure on the resilience of the city's water system. All three types of flooding were prevalent in the desktop study research. Survey participants mentioned flooding impacts beyond infrastructure damage such as the health and wellbeing of citizens.

Pluvial flooding is the combined result of heavy rainfall and impervious surfaces as urbanisation continues within the city. This was the top concern for Greater Rotterdam. As well as putting citizens at risk, respondents conveyed that it can have secondary effects on accessibility and economy due to major traffic issues.

Fluvial flooding has been known to have a negative impact on local ecosystems due to repeated flooding. In some places, regulations are not in place to restrict building on floodplains resulting in the flooding of infrastructure and private homes.

Coastal flooding in the form of a potential sea surge from the North Sea puts the port at risk to flooding. Always stated as a stress, coastal flooding is most likely to fit within the context of rising sea level due to climate change.

Drought

Drought was, and perhaps surprisingly to some, the second most important concern from both Figures 7 & 8. In survey responses, drought was mentioned in the context of climate change and its effect on water quality, ecosystems, and the economy due to low river levels obstructing shipments coming through the port. Periods of drought might become a routine reality for Rotterdam. Already with the 2018 summer drought in drier parts of the Netherlands, rats were entering streets from pipes in search of water (De Telegraph, 2018). The Netherlands has a policy during droughts that top priority for water allocation will go to the dykes and other flood defences even before human consumption (Rijkswaterstaat, 2011). Given droughts will require a new type of strategy, it is clear this issue is being taken seriously now.

Failure of climate change mitigation and adaptation

Climate change is one of the top concerns and is the reason behind the possible droughts and some of the flooding already mentioned. For Rotterdam, climate change could bring rising sea levels, more extreme weather events including heavier rainfall with potential flooding, and longer periods of drought. It. Despite the good work that has been completed or begun to mitigate climate change, survey respondents were fundamentally concerned about ensuring suitable risk management to mitigate the effect of climate change.

Inadequate governance / urban planning

Governance issues were mentioned within the survey responses and the research. Concerns included the complexity of government functions including different policy departments and diverse disciplines. Lack of continuity and lack of focus on long-term challenges was another concern of survey participants. It was noted that the sheer number of stakeholders involved slows down the process from decision-making to implementation, which might be connected to concerns about the lack of urgency regarding shocks/stresses within the government. The difficulties in integrating water issues into urban development given the different types of infrastructure above and below the ground was also mentioned.

Shortfall of critical infrastructure / ageing infrastructure

In some places within Rotterdam, traditional infrastructure such as canals and sewers lack the capacity to cope with an increase in stormwater especially in dense urban areas. Blockages to the drainage system, ageing infrastructure, and a decline in effective flow capacity mean that the system cannot flow at its design capacity, which is an issue during significant rainfall (Bouwens, Christian et. al. , 2018).

Ageing infrastructure was also a common stress given by respondents. Such infrastructure resulted in flooding within the city due to sewage overflows. Respondents were also unhappy about the costs and the delays due to maintenance and other construction work to try and improve ageing infrastructure.

Lack of investment

Another broad concern of survey participants was a lack of investment to adequately meet the needs of combatting shocks and stresses. Creating separate sewer and stormwater systems is a significant investment as is fixing ageing infrastructure. It was felt that adaptation measures were trying to be implemented on too tight a budget.

Groundwater depletion

Groundwater abstraction can endanger the portability of the ground water due to saline intrusion. Therefore, it is not used as a potable source in Rotterdam. Groundwater levels can fluctuate with short term and long-term impacts as a result. In the short-term, basements can flood, while on the longer term, wooden pole foundations of houses are affected. Groundwater is also leaked due to aged infrastructure.

Subsidence

While not a strong factor mentioned in the survey, subsidence is another issue that Rotterdam faces. Subsidence can occur through subsoil drying out during a drought and then result in more flooding when the rains come. Heavy rainfall can particularly damage areas with uneven subsidence within the city. The issue of subsidence applies not just to homes, buildings, and pipelines but also to the dykes that protect Greater Rotterdam (RCI, 2013). Another subsidence issue has occurred from draining peat areas too deeply to make the land in the western Netherlands suitable for agriculture (Hanssen & Cuenca, 2008).

Heat waves

While not a strong factor mentioned in the survey results, the urban heat island effect could become a problem for Rotterdam due to the anticipated heat waves from climate change (RCI, 2013). The urban heat island (UHI) effect occurs when the lack of green space in a city, results in that area having higher temperatures than the surrounding countryside. Some concerns include issues with the malfunction of bridges, dykes, and main roads as well as health of residents, particularly vulnerable groups such as the elderly and small children. Currently, there are only a few days a year where the temperature is over 20□C, but by 2050 it could be over a month of the year (RCI, 2013). This summer (2018) involved a significant heat wave.

Figure 6:
Shocks and stresses by stakeholder type

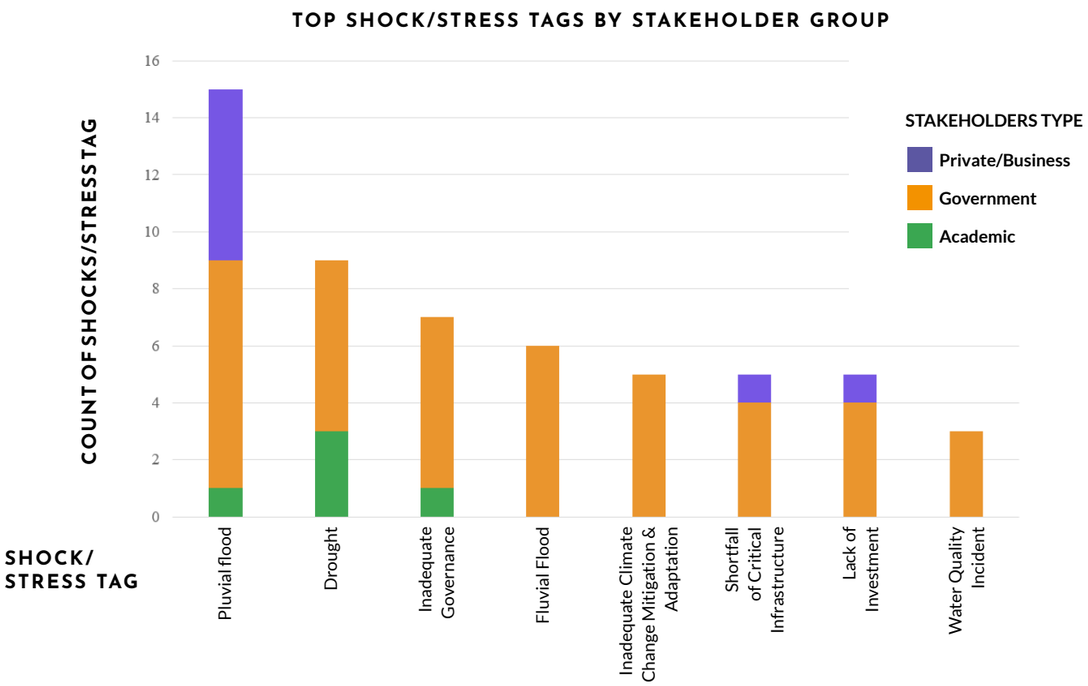


Figure 7:
Shocks and stresses by CWRF V.0 Goals based on survey responses

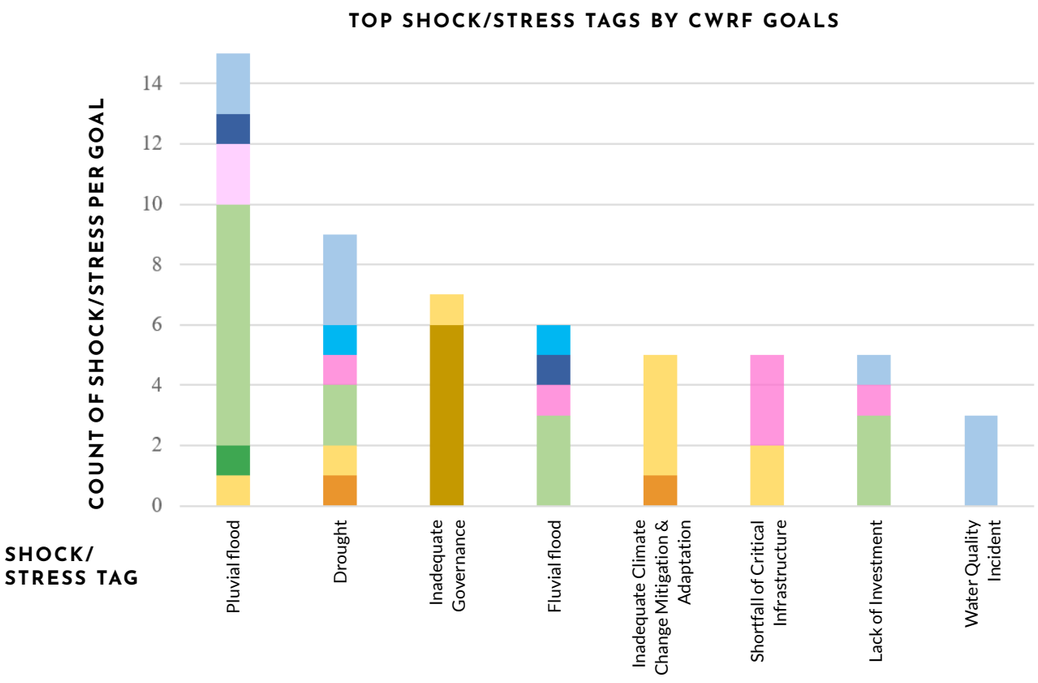
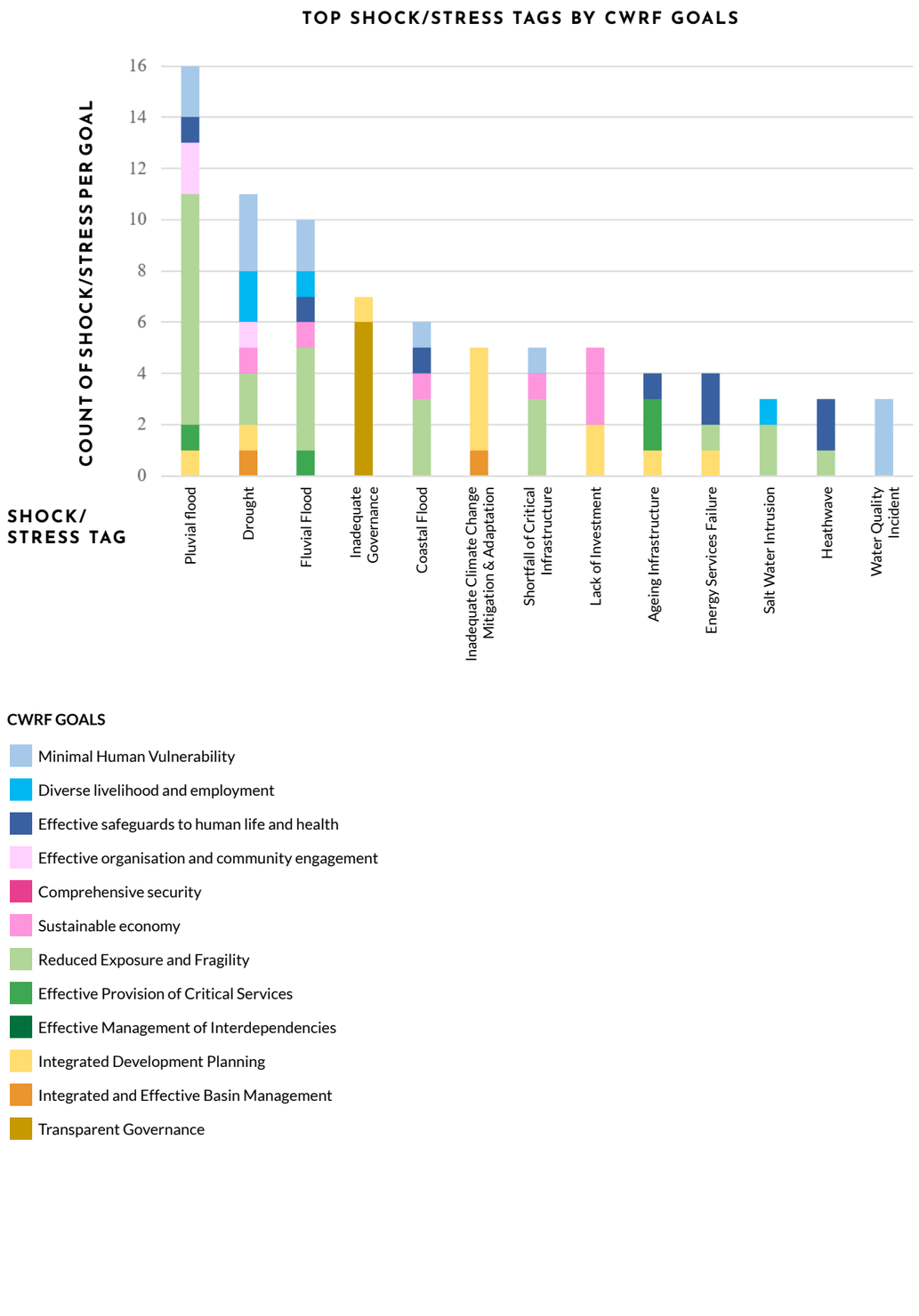


Figure 8:
Shocks and stresses by CWRF V.0 goals based on survey responses & wider research



KEY FACTORS OF RESILIENCE

The City of Rotterdam has a proactive Climate Change Adaptation Strategy with the goal to make Rotterdam climate-proof by 2025 (RCI, 2013). From participating in the 100 Resilient Cities to other Key Programmes mentioned, it is clear that resilience is an important target for Rotterdam. Therefore, it is no surprise that the desktop study and survey highlighted strong factors of resilience.

Top three resilience factors from the surveys were the value/importance of Water Storage, Regulations, and Public Awareness. Figure 9 shows the factors identified by survey participants of both (current) resilience and the proposed resilience categorised by their dimension within the CWRF (see Appendix). Figure 10 brings together all the factors of resilience (proposed and current) to examine how they break out across the twelve CWRF goals.

The data shows that Governance & Strategy was a strong focus for the current and proposed city resilience factors.

WATER STORAGE

Water storage is an important way to be resilient during floods. Some of the options mentioned here have already been implemented in Rotterdam. Others are ideas from the survey or planned through programmes mentioned above. Green roofs, facades and green spaces are all good ways to help alleviate runoff during flooding. Additionally, green spaces can also be an excellent way to bring the community together and increase awareness of the water system. Water squares, water plazas, and infiltration zones could help compensate for the increasing urban infrastructure and allow surface water to seep back into the ground. Floating pavilions were mentioned to help create climate-proof buildings and would decrease the amount of pavement used to house buildings (RCI, 2013). Underground water storage like the Museumpark car park, which has a capacity of 10 million litres, is another option (RCI, 2013).

INCREASING COMMUNITY PARTICIPATION/AWARENESS

The only proposed factor resilience was to increase public awareness of the water system and the work being done on climate resilience. While growing such awareness is part of the Rotterdam Climate Change Strategy, other aspects of the city may benefit from more community engagement.

IMPROVED GOVERNANCE AND STRATEGY

Participants cited several importance aspects of resilience that are already part of the government and urban planning. One was the commitment and knowledge of city's water management department. Other participants lauded the collaboration with business and knowledge institutes as well as the good long-term vision for climate adaptation.

Suggestions for enhancing governance included actions at the city level and more broadly. There was a focus on increasing transparency of decision-related information, using data to drive decision-making, and monitoring progress on adaptation going forward. Suggestions for how future spending could be used included regulations, increased cooperation among departments, and working towards a more circular water system—including water recycling.

Factors that could improve resilience included the need for better city planning, ways to monitor progress on adaptation, better cooperation between departments, and working towards a more circular water system. One of the survey responses suggested a network of sensors across the water system to simultaneously measure rainfall, water levels, and water quality.

Figure 9:
Factors of resilience in Rotterdam within CRWF V.0 dimensions

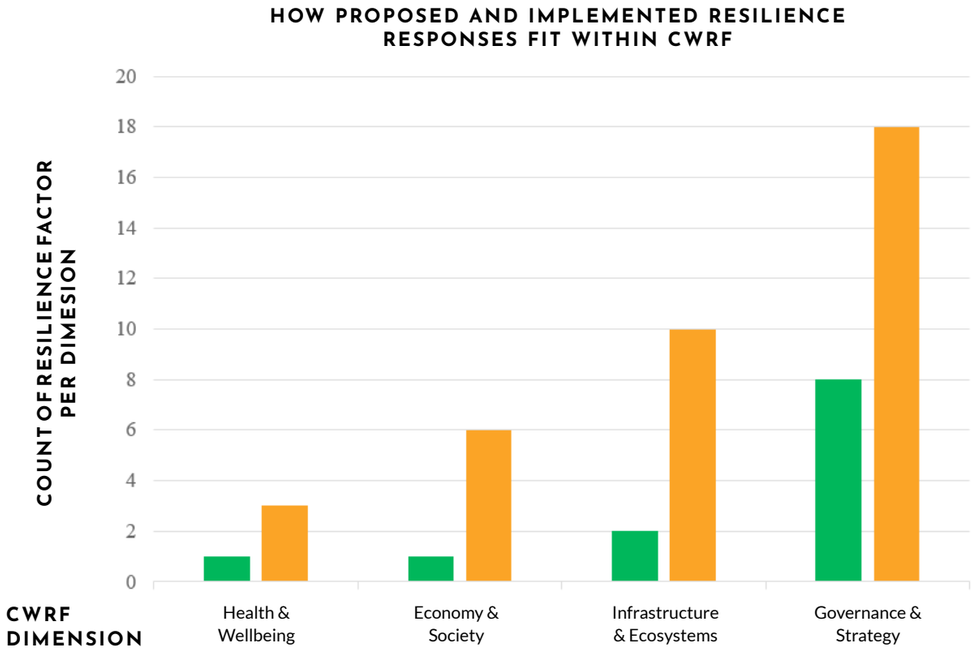
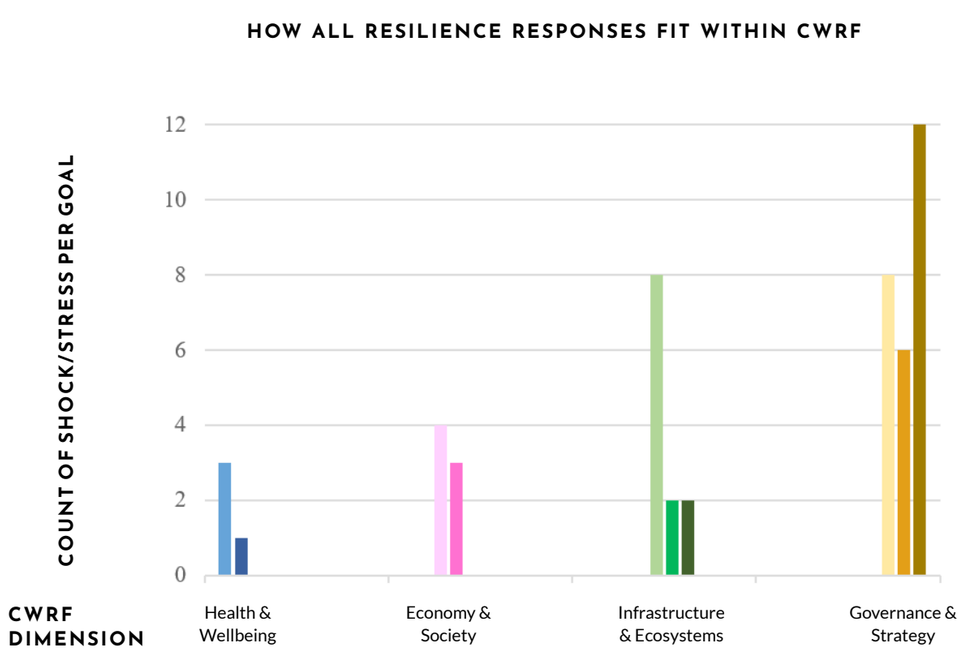


Figure 10:
Examining how all resilience factors fit within CWRF V.0 goals and dimensions



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