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Enabling Delta Life

Exploratory study of pluvial flood impacts in Dutch urban areas

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Title
Exploratory study of pluvial flood impacts in Dutch urban areas

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Summary
Urban delta areas, such as cities in the Netherlands, are vulnerable to flooding due to extreme local precipitation (pluvial flooding). In order to mitigate consequences of pluvial flooding, measures are implemented to increase drainage and storage capacity of the urban system. The efficiency of these measures is determined based on the presence and height of floodwater levels on streets. Yet, in order to fully determine the efficiency of these measures, an additional step should be taken, going further than determining whether water is present on the streets. This calls for a vulnerability approach for the implementation of pluvial flood adaptation measures. Yet, hardly any knowledge is currently available about pluvial flood impacts, making it almost impossible to adopt a vulnerability approach. This approach calls for consideration of a broad range of impacts induced by water on streets, classified as material damages, economic impacts, health impacts, costs for emergency services and social discomfort. Since little knowledge of pluvial flood impacts is available, the goal of this study is to explore impacts and the quantification of those impacts of pluvial flooding in Dutch urban areas. First, a literature review combines all relevant pluvial flood impacts for Dutch urban areas. Secondly, several aspects of this literature review are assessed in more detail in three case studies. Based on the literature review, a 'long list' of pluvial flood impacts is compiled, which forms a framework for further research. From this framework, pluvial flood impacts on inhabitants, traffic and sewer system management are assessed in more detail. Pluvial flood impacts on inhabitants are assessed by the use of surveys. Traffic delays are assessed by the use of municipal traffic data. Costs for sewer system management services are assessed by use or municipal data of citizens' complaints regarding problems with urban drainage. The overall results form a first overview of currently available knowledge of pluvial flooding that could form building blocks for a vulnerability approach in urban flood management. Though the results are promising, the study reveals a large knowledge gap in the field of urban flood risk management. Not only are we unable to approximate the overall risk of pluvial flooding, consequently, deciding on the implementation of measures could even be inadequate. This emphasizes the need for comprehensive knowledge about pluvial flood events and impacts, combining knowledge and skills of inhabitants, municipalities and research agencies.

References
Van Riel, W. (2011), Exploratory study of pluvial flood impacts in Dutch urban areas, Deltares, Delft, The Netherlands

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1 Introduction

This report is the final product of the fulfillment of the MSc degree for the studies 'environmental sciences', specialization 'integrated water management' at Wageningen University. This study is conducted for the 'Knowledge for Climate' program (second line), consortium 'Climate Proof Cities', in which Deltares is consortium partner. One of the sub projects in the Climate Proof Cities consortium is 'Project 2.3: Sensitivity, Vulnerability and Impacts', which this master thesis study is part of.

1.1 Research context

The Knowledge for Climate program aims at generating knowledge on making the Netherlands more resilient to effects of climate change. This is referred to as climate adaptation or, as mentioned by Kabat et al. (2005), 'climate proofing'. A separate consortium, Climate Proof Cities, is set up within Knowledge for Climate, which primarily focuses on climate adaptation research in Dutch urban areas. Adaptation to effects of climate change is commonly approached through the concept of vulnerability. Through assessment of vulnerability, policies could be formulated addressing measures to adapt to potential negative effects of climate change. This is visualized in figure 1.1.

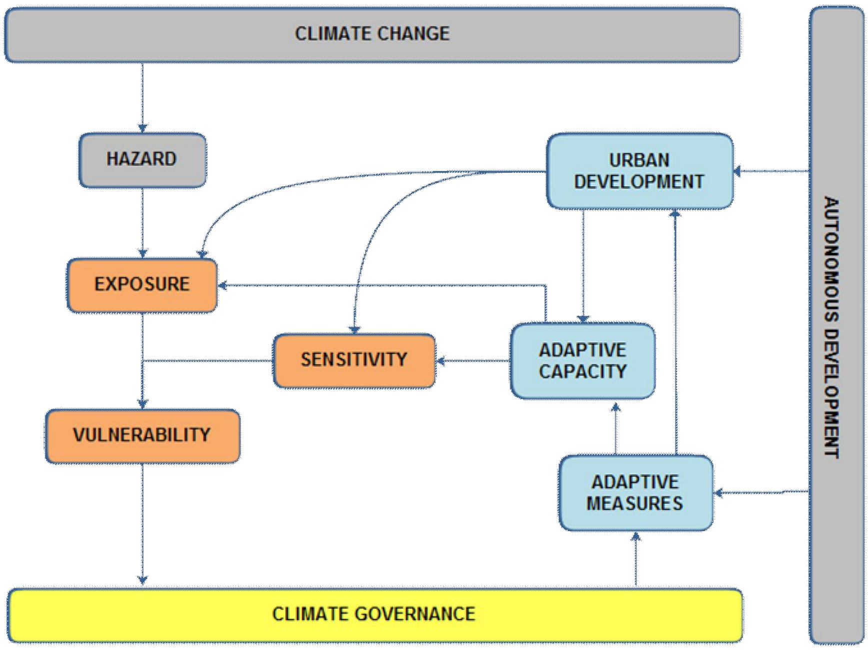


Figure 1.1 Schematic overview of climate adaptation and related concepts (Van de Ven et al., in press)

This study focuses on determining an area's sensitivity. Sensitivity is defined as the level to which exposure to a climate related effect leads to impacts (Van de Ven et al., in press). The remainder of the concepts in figure 1.1 are described in appendix F.

This study focuses on exploration of impacts due to extreme local precipitation, leading to (pluvial) flooding. This is a first step in determining an area's sensitivity and ultimately its vulnerability to pluvial flooding.

1.2 Problem analysis

Particularly densely populated delta areas, such as the Netherlands, are vulnerable to effects of climate change. Delta areas contain high value economic activities and a relatively large and increasing population. Yet, these areas are subject to problems due to subsidence, rising sea level and an increase in precipitation extremes. In urban areas in these deltas, these issues are further converged, which makes these areas even more vulnerable. In order to prepare for and adapt to effects of climate change, the Knowledge for Climate program is set up.

Not only the climate and subsequent effects will change in the coming decades. Urban areas will also undergo many changes and cycles of renewal and expansion. To investigate the vulnerability of urban areas to climate change and determine adaptation strategies, one should consider not only the physical effects of climate change but also urban developments and socio-economic changes. To summarize, vulnerability of urban areas to effects of climate change is driven by a combination of (Van de Ven et al., in press):

- climate changes;
- socio-economic growth and development;
- urbanization rate.

As indicated by KNMI (2006), effects of climate change for the Netherlands are predicted through four climate scenarios for the years 2050 and 2100. While the predicted amount of change in climate effects per scenario can differ, the four climate scenarios have the following commonalities:

- the average temperature increases;
- during winter, average precipitation and extreme precipitation increases;
- during summer, the severity of extreme precipitation events increases, while the number of rainy days decreases;
- changes in wind circulation patterns are relatively small, compared to the natural variability;
- the average sea level rises.

This study focuses on extreme precipitation and the related effects of that on people, objects and activities in Dutch urban areas.

Due to intense local precipitation events (extreme precipitation), Dutch urban areas are flooded occasionally, potentially causing damage to people, object and activities. This is caused by precipitation that hits the surface does not enter the sewer system or the precipitation intensity overwhelms the sewer system storage capacity. This type of events are defined as ‘urban pluvial flooding’ (Ten Veldhuis, 2010). Since this flooding mostly occurs only in urban areas, the term pluvial flooding is used from here on.

In order to prevent or mitigate impacts of pluvial flood events, urban water managers search for measures to do so. A decision maker assesses whether or not to implement measures on pluvial flood prevention or mitigation. To weigh this decision, the decision maker needs information about:

- the risk the measure covers, for floods defined as a product of probability and impact;
- benefits of the measure;
- costs of the measure;
- other possible relevant aspects, e.g. moral aspects, responsibility and governance strategies.

Considering a risk based approach for the implementation of adaptation measures, it is important to identify to what extent flood impacts are prevented or mitigated. Yet, little is documented on the topic of impacts caused by pluvial flooding. Consequently, decisions, based on risk evaluation, for future adequate measures on climate adaptation cannot be taken properly.

Hardly any research is performed on the topic of pluvial flood consequences. This study contributes to the development of scientific knowledge on damage assessment of low frequent (extreme) precipitation events (probability smaller than once per two years) leading to pluvial flood events. This creates an opportunity for the development of damage assessment tools or models that can be used for predicting flood impacts and testing of efficiency of flood prevention and mitigation measures. These tools and models are used to support decision-making.

1.3 Objective and research questions

Since current knowledge on urban pluvial flood impacts is limited, this study aims to explore pluvial flood impacts in Dutch urban areas, by analyzing actors' interests and relevant additional data. The knowledge produced by this study should provide input for the set up of a model (quantitative or qualitative) to estimate impacts of pluvial flooding in a certain area. This model aims at providing decision-makers information about flood impacts, so they can properly weigh decisions on adequate measures to prevent or mitigate flood impacts.

The main research question is stated as:

Which knowledge can be generated about pluvial flood impacts in Dutch urban areas, by analyzing actors' interests and relevant additional data?

The research objective and main research question is separated into five sub questions.

1. Which actors are affected by pluvial flooding in Dutch urban areas?
2. How are the actors affected?
3. Which pluvial flood impacts can be quantified, based on literature and an actor analysis?
4. Which data sources are available to generate new knowledge about pluvial flood impacts?
5. Which knowledge can be generated from these additional data sources that quantifies impacts of pluvial flooding?

1.4 Research design and data collection

1.4.1 Research design and perspective

The design of this research is an exploratory case study. The rationale for this research design is that little is known of pluvial flood impacts and exploration of the topic is relevant. The case study provides the opportunity for detailed analysis of specific details of the research's subject, while the exploratory character provides a broad perspective that is needed in this study.

A possible disadvantage of a case study approach is that it might be difficult to generalize the research results and conclusions (Kumar, 2005). Flyvbjerg (2006) states that a careful case choice provides the opportunity to generalize from a single case. The addition of a second or third case adds even more strength to generalizations of the research results and conclusions. Three cases are selected:

- Amsterdam: Stadsdeel Oost;
- Rotterdam: Oude Noorden;

- Gouda

Amsterdam and Rotterdam are involved in the Knowledge for Climate program. Gouda is added as an extra case. At the start of this study, Watergraafsmeer (part of Stadsdeel Oost) was selected as a study area. However, the applied methods of data collection forced the study to scale up the area to Stadsdeel Oost.

Impacts of pluvial floods are assessed through the perspective of a potentially affected stakeholder, where the inhabitant's perspective is most important. That is because inhabitants could be the most valuable data source in assessing pluvial flood impacts. In the context of assessing an urban area's vulnerability to pluvial flooding, it is important to adopt a holistic approach in the assessment of flood impacts. The rationale for this is that little knowledge is available about the topic of interest and therefore broad exploration is needed. For this study, the holistic approach starts with an analysis of the (potentially) involved stakeholders in a pluvial flood event.

1.4.2 Data collection

Three methods for data collection are applied: analyzing documents, taking interviews and administering surveys.

The following documents are used for analysis:

- Academic literature. Literature is used to identify the current state of knowledge about pluvial flood impacts.
- News bulletins. Severe pluvial flood events are featured on national television and in newspapers. These news bulletins illustrate the severity of the flood event.
- Registered data. Registered data is analyzed in order to assess potential impacts of a pluvial flood event.

Interviewing is used for the collection of information from people in the case studies. Expert judgment is accounted as unstructured interviewing.

Surveys are administered to citizens in the case areas. The goal of the surveys is to explore the experience and opinion of inhabitants about pluvial flooding. The rationale for administering a survey is that the study population is distributed over a large area and the number of respondents should be as high as possible, which is not achieved by taking intervies. In Gouda, administration of surveys is the single research method applied in that case.

1.5 Thesis overview

Figure 1.2 depicts the thesis overview in which per process the necessary input and the generated output is described.

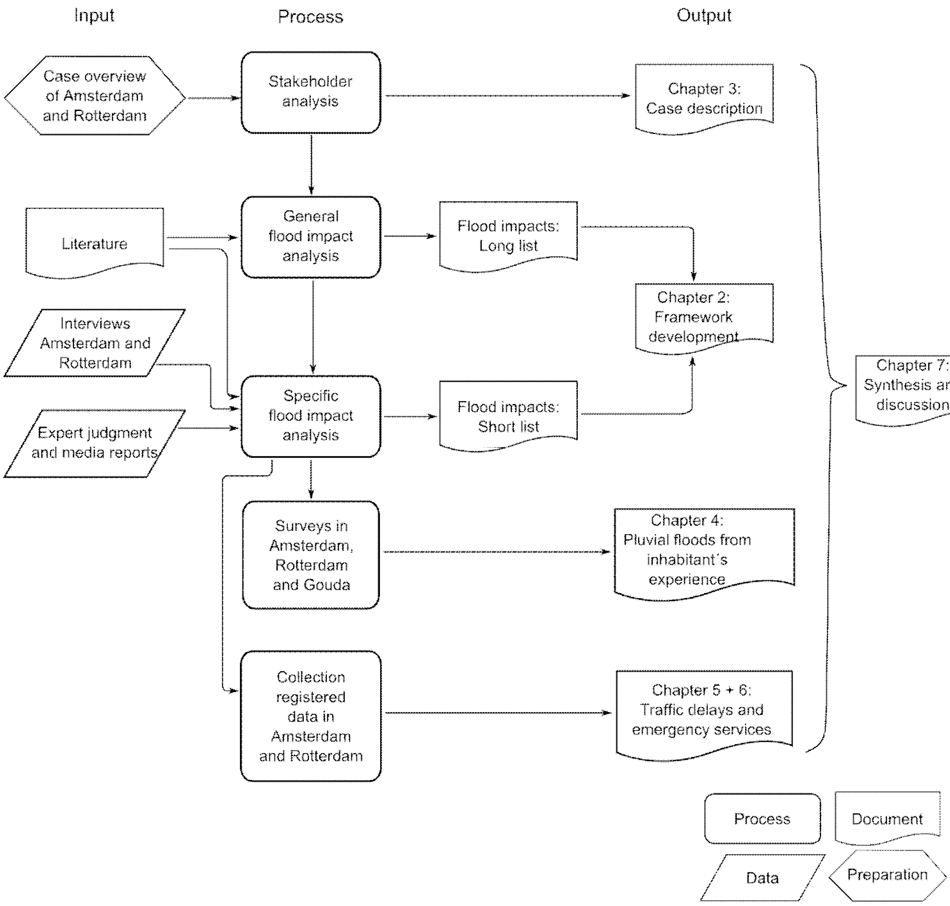


Figure 1.2 Thesis overview

Chapter 2 describes a framework of general and specific pluvial flood impacts based on the stakeholder analysis and literature, interview results, expert judgment and media reports. This chapter is a mixture of a literature review and the research delineation. It depicts the current state of knowledge about pluvial flood impacts and demarcates the remainder of the study.

Chapter 3 sets out basic elements of the selected case areas together with a stakeholder analysis.

In chapter 4, pluvial flooding from an inhabitant's perspective is described based on surveys in Amsterdam, Rotterdam and Gouda. In this chapter, causes, effects and flood perception are described.

Chapter 5 and 6 respectively describe the potential pluvial flood impact on traffic delays and emergency assistance.

Chapter 7 forms the synthesis of the presented results and describes the promising results that could lead to adoption of a risk-based approach in pluvial flood management.

2 Framework for pluvial flooding and its impacts

In this chapter, concepts of flooding in urban areas are described together with a framework that sets out the current state of knowledge about pluvial flood impacts. From this framework, a short list is extracted that composes of pluvial flood impacts that will be investigated in more detail.

2.1 The context of urban flooding

Five types of urban flooding can be distinguished (modified from Zevenbergen et al., 2010).

- Coastal flooding caused by failure of coastal defenses.
- Fluvial flooding caused by failure of river defenses, often caused by heavy precipitation upstream.
- Pluvial flooding caused by local heavy precipitation exceeding drainage capacity.
- Groundwater flooding, caused by extensive periods of precipitation (weeks or months) that lead to a slow move of groundwater to low-laying areas where the groundwater table breaks the ground surface.
- Flooding due to failure of pipes or pumping stations (e.g. drinking water flooding or flooding due to failure of ground water pumping station).

Specific definitions for pluvial flooding are stated in CEN (1996), Terpstra et al. (2006) and Falconer et al. (2009). The European Standard EN 752 (Drain and Sewer Systems Outside Buildings – Part 2: Performance requirements) defines flooding as “a condition where wastewater and/or surface water escapes from or cannot enter a drain or sewer system and either remains on the surface or enters buildings” (CEN, 1996). A similar definition is stated by Terpstra et al. (2006): “abnormal amounts of water in the streets or on the land due to heavy rain fall, maximum a few decimeters”. Falconer et al. (2009) describes pluvial flooding as “the result of rainfall-generated overland flow and ponding before the runoff enters any watercourse, drainage system or sewer, or cannot enter it because the network is full to capacity”. These definitions have in common that rainwater ponds on streets and cannot enter a drain point.

In the Netherlands, a further distinction is made by differentiating pluvial flooding in three categories, based on the severity of the potential impacts caused by the flood (RIONED, 2006).

1 Water hindrance: relatively small volume of water on street, time span of approximately 15 – 30 minutes.
2 Severe water hindrance: relatively large volume of water on streets, flooded tunnels, risen manhole lits, time span of approximately 30 – 120 minutes.
3 Water nuisance: relatively large-scale water on street, flooded shops, damage to private properties, possibly severe disruption of (economic) infrastructure, long time span.

The first two flood categories have in common that water stays within the boundaries of the street with the possibility of several flooded cellars, unlike the third flood category. These first two flood categories can both be considered as in Dutch called ‘water on streets’, causing mostly inconvenience and traffic hindrance. The third flood category implies significant property damage. Yet, there is no clear quantitative distinction between these flood categories. Next to that, a flood event probably cannot be allocated to one flood category, since the severity of the flood can vary over an area. Due to these two reasons, it is questionable whether this categorization of flood events is useful.

Generally, scientific literature on assessment of urban flood impacts focuses on material damages due to coastal and fluvial floods (e.g. Apel et al., 2009; Dutta et al., 2003; Gersonius et al., 2006 and Thieken et al., 2005). In these studies, the studied water depths vary from 0.5 to several meters, where flood damage is described as a function of water depth. It is expected that the water depth-damage relations (referred to as stage-damage curves) in these studies are not appropriate for events of pluvial flooding in the Netherlands, where the water depth is not likely to exceed 0.5 meter. While considerable water depths associated to coastal and fluvial flooding leads to a generalization of stage-damage curves, stage-damage curves for pluvial flooding are extremely sensitive to specific characteristics of urban assets (e.g. height of doorstep or presence of ventilation gaps in brick walls). This was shown my Merz and Thieken (2005) and Apel et al. (2004, 2006, 2008 and 2009) who stated that uncertainty in depth-damage functions dominate all other uncertainties for frequent flooding, i.e. floods with low water depths (Stone et al., in press).

Ten Veldhuis (2010) is probably the only researcher who specifically assessed pluvial flood impacts in Dutch urban areas, partly based on stage-damage functions for fluvial flooding.

2.2 Pluvial flood impact categories

In order to create an overview of a large variety of pluvial flood impacts, categories of impacts are defined, based on a stakeholder analysis and literature from Parker et al. (1987) and Balmforth et al. (2006).

Identification of the key stakeholders is performed based on expert judgment of Deltares flood experts and in collaboration with research contributors. The results of the stakeholder analysis, depicted in appendix B, form the basis for categorizing pluvial flood impacts. In table 2.1 , a summary of the stakeholder analysis is depicted.

Table 2.1 Summary of stakeholder analysis for pluvial flood impacts

Stakeholder	Impact
Citizens	Flooding of property and content, inconvenience
Businesses	Flooding of property and content, turnover loss
Traffic	Flooding of infrastructure
Emergency services	Provision of emergency assistance
Municipality	Flooding of public space, responsible for drainage network
Water board	Interaction with surface water, surface water flooding public space

Though the affected stakeholders could vary per area, the presented stakeholders in table 2.1 are considered most relevant.

Literature from Parker et al. (1987) and Balmforth et al. (2006) provide two classifications of flood impacts. Parker et al. (1987) approach flood impacts from a rather theoretical perspective. They categorize flood impacts in direct and indirect impacts, which are both split into tangible and intangible impacts. Direct and indirect impacts relate to whether the impact is induced by physical contact with water or by indirect consequences of material impacts. Tangible impacts are impacts that can be expressed in costs, while intangible impacts are difficult to express in costs. Balmforth et al. (2006) adopt a rather practical perspective in their categorization of flood impacts into damage to properties, health and safety, loss of facility/business, emergency services and social implications.

Combining the stakeholder analysis in appendix B and the flood loss typology in Parker et al. (1987) and Balmforth et al. (2006), five categories of flood impacts are presented here and used for analysis in this study.

1 Material impacts: defined as damage to physical objects caused by direct contact with rainwater.
2 Economic impacts: defined as induced costs caused by interruption of economic activities or sectors. It could be defined as the value of lost time. Examples are interruption to business activities, traffic, communication or electricity supply.
3 Health impacts: defined as impacts to physical health and associated social costs resulting from contact with floodwater directly or potential effects of damp houses in combination with fungi. Mental health impacts are assumed negligible.
4 Emergency assistance impacts: defined as induced costs resulting from the provision of emergency assistance by police, fire department or municipality in case of a flood event. This includes costs for labor, training and capacity building, maintenance of equipment and hardware for rescue operations.
5 Discomfort: defined as overall inconvenience due to a combination of multiple pluvial flood impacts.

2.3 Pluvial flood impacts: long list

Based on the presented categories in the previous paragraph and the stakeholder analysis, a long list is composed that grasps all relevant potential pluvial flood impacts.

Table 2.2 depicts this long list. All impacts in table 2.2 can be expressed in costs, health risk or level of discomfort, yet to be quantified.

Table 2.2. Potential pluvial flood impacts: long list

Material impacts	Economic impacts	Health impacts	Emergency assistance impacts	Discomfort
Residential and commercial building and content	Disruption of electricity network	Health impacts due to contact with flood water	Fire department services	Inhabitants' experience of all relevant impacts in a flood event
Public building and content: – schools – child care – hospital – etc.	Disruption of communication network	Health impacts due to damp house and associated fungi	Police department services	
Traffic infrastructure: – Roads, including tunnels – Bicycle lanes – Sidewalks	Disruption of traffic: motor vehicles public transport bicycles, emergency services		Sewer system management services Water board services	
Public space (parks, parking lots)	Turnover loss of businesses			
Public utility objects and networks (electricity, communication, gas, water)				
Other vulnerable objects: – gas stations				

– historical buildings – etc.				

Below, for each flood impact category, a description is added of its literary background, data availability and expectation of relevancy.

2.3.1 Material impacts

Most data of the presented five categories is about material impacts.

In contrary to damage due to coastal and fluvial floods, material damage due to pluvial flooding in the Netherlands is relatively small per event, because of small water depths in the order of 20 cm or less (local depressions excluded). However, due to the relatively high frequency of occurrence, the cumulative material damage could be considerable (Ten Veldhuis, 2010). Pluvial flooding generally causes material damages composed of cleaning costs, repair costs and might induce replacement costs (Stone et al., in press).

The extent of material damage in the Netherlands follows from the water depth, duration of flooding and water quality. In coastal or fluvial flood events, flow velocity and turbulence also determine the extent of material damage. Yet, for pluvial flood events in the Netherlands, the effect of high flow velocity is rather limited, because of small water depths, in combination with small surface gradients.

Assessment of costs of material damage is often undertaken by the use of stage-damage functions, in which an inundation depth is related to monetary damage. The stage-damage functions origin from fluvial flood damage assessments in Apel et al. (2009), Dutta et al. (2003), Gersonius et al. (2006) and Thieken et al. (2005). However, as indicated by Merz et al. (2004), stage-damage functions are highly uncertain, as stated in paragraph 2.1. Merz et al. (2004) indicate that stage-damage functions for pluvial flooding are highly sensitive to specific characteristics of urban assets. This can be illustrated easily. For example, the height of the doorstep or air vents is a crucial factor for occurrence of material damage when the flood stage is only several centimeters, as shown in photo 2.1 (Stone et al., in press). As such, it is expected that material damage due to pluvial flooding cannot be expressed as a function of water level or precipitation intensity.

Photo 2.1 Height of air vents and door steps making properties susceptible for material damage

Little is written on the topic of costs or damages resulting from pluvial flooding in the Netherlands. Current available figures are extracted from data of fluvial floods in Germany and the Netherlands, as executed by Ten Veldhuis (2010). Assuming a flood depth of 10 cm, the material damage to flooded residential buildings range from 1,000 to 30,000 Euro per flooded building, while for commercial buildings damage ranges from 2,000 to 30,000 Euro per flooded building, as stated by Ten Veldhuis (2010).

Material impacts due to water damage are insurable. Generally, inhabitants and businesses can claim compensation for the inflicted damage at insurance companies. Spekkers et al. (2011) used Dutch insurers' data aiming at quantifying damages as a function of precipitation intensity. Insurers' data could provide valuable information regarding damages for flooded properties. Average costs per flooded property for content damage is 817 Euro, while the average costs for property damage is 1229 Euro for the period of July 1 2004 to September 30 2004. However, the results show no clear correlation between damage costs per day and precipitation intensity. Partly this is caused by the fact that damage records in the used database could not be directly linked to precipitation, i.e. other water related causes were also influential for inducing damages.

Another approach is to administer surveys among inhabitants to retrieve information of material damages to residential buildings.

Damage to commercial buildings and possessions could be considerable. Next to direct damage to the properties, possessions or stock could be partly lost. Photo 2.2 depicts the flooding of a shopping mall in Hamburg resulting from extreme precipitation on June 6 2011.

Photo 2.2 Flooding of a shopping mall in Hamburg after pluvial flooding on June 6 2011 (Bild, 2011)

Little is known about Identifying the associated costs for the flooding of commercial building. Since presence and distribution of commercial buildings, as well as precipitation intensity, could vary considerably per area in a city, costs for material damage should be assessed case dependent.

Since most literary and media attention of flood impacts goes to material impacts to residential buildings, it is expected that a sufficient amount of data is available to quantify material impacts in costs. Material damages to public space, roads and other traffic infrastructure due to pluvial flooding are expected to be rather small, due to small water depths, and have limited social or economic consequences. No newspaper articles are found reporting about damages to public transport networks in the Netherlands. Vulnerable objects, such as public buildings and public utility objects are expected to suffer from material impacts only in rare occasions. However, social impacts (and costs) could be considerable, since many people depend on these buildings and objects. Yet, the costs are difficult to estimate since they are rather intangible. Estimation of these social costs is not reported about in literature.

Compton et al. (2002) described three cases (Boston, Seoul and Taipei) of flooding of underground subway networks, causing direct damage ranging from $1.3 million/km to $4 million/km of track length repair costs for the case of Boston, which resembles most to Amsterdam in terms of population size and density. This corresponds to approximately 0.9 to 2.8 million Euro per km of track length repair costs (assuming a currency ratio of EUR/USD = 0.7). Though conditions in Boston are different from those in Amsterdam, the figures indicate substantial (direct damage) costs are induced due to flooding of subway networks. No figures are reported about the economic consequences, in terms of business loss.

2.3.2 Economic impacts

A basic principle in interruption of economic activities is that induced losses represent lost opportunities, which can never be recovered (Parker et al., 1987). The cost of interruption of economic activities by a flood event is defined as the value of lost time in that activity.

Fluvial and coastal floods could cause significant economic damage. Economic damage induced by pluvial floods is expected to be limited due to small water depths and relatively short flood durations. The potential associated impacts are business interruption, traffic disruption and the possibility of utility service interruption (communication and electricity).

2.3.2.1 Business interruption

In the Netherlands, businesses have the opportunity to get insurance for loss of business activities due to flooding or other types of calamities. Therefore, the costs for business interruption could be retrieved from insurance companies. Yet, actual costs are difficult to estimate due to human behavioral aspects, e.g. employees might work a few hours extra for compensation, therefore limiting turnover loss (Stone et al., in press).

2.3.2.2 Traffic interruption

No literature is found that assesses economic impacts of pluvial flooding on traffic. Available literature in Parker et al. (1987) and Penning-Roswell et al. (2005) suggest methods to quantify potential costs due to traffic interruption. No empirical data is found on this topic.

The costs of travel time have been described by various researchers, serving as input for cost-benefit analyses in transport infrastructure projects. Travel delays could be perceived as the extra delay on top of the average travel time. Detailed costs for travel delays are computed in the Netherlands as well as the UK, including vehicle operation costs for multiple vehicle types. Instigated by the former Dutch Ministry of Transport, Public Works and Water Management instigated, costs for traffic delays are described by the ‘unreliability of travel time’ (Hamer et al., 2005). It is the unexpected delay in traveling between two points. This approach assumes travelers already account for some delay they perceive as inevitable. Assessing the costs of traffic delays due to pluvial flooding has not been reported about so far. Costs for travel time for multiple vehicle types have been reported by the British Department for Transport (DfT), as depicted in table 2.3.

Table 2.3 Market price values of time per vehicle in 2002 based on distance traveled in Euro per hour (converted with currency rate EUR/GBP = 1.56); LGV = light goods vehicle, OGV = other goods vehicle, PSV = public service vehicle (modified from DfT, 2011)

Vehicle type and journey purpose	**Weekday**					**Weekend**	**All week**
	7.00 – 10.00	**10.00 – 16.00**	**16.00 – 19.00**	**19.00 – 7.00**	**Average weekday**		
Car	17.11	18.80	15.44	15.24	17.00	14.38	16.32
Light goods vehicle	18.02	18.02	18.02	18.02	18.02	19.36	18.14
Other goods vehicle	15.88	15.88	15.88	15.88	15.88	15.88	15.88

Public service vehicle	115.77	107.95	116.50	122.07	113.77	105.88	111.73

These presented figures, together with the vehicle type proportions, results in an average price of time of 17.60 Euro per hour (converted with currency rate EUR/GBP = 1.56 in 2002 prices) (DfT, 2011). In the Netherlands, a regularly used figure is 15 Euro per hour for the average vehicle delay costs.

Photo 2.3 depicts two pluvial flood events resulting in disruption of traffic. The left photo depicts the flooding of a tunnel in Arnhem on June 5 2011, blocking any form of traffic and even posing the risk of drowning. The right photo depicts a less severe disruption of traffic in Amsterdam due to pluvial flooding on August 26 2010.

(Nu, 2011)

(Waternet, 2010)

Photo 2.3 Pluvial flooding influencing traffic in local depressions in infrastructure

Municipal traffic data could be acquired in order to examine the potential relation between traffic flow and precipitation. Traffic models might be of use to estimate delays on road segments.

Especially in large Dutch cities (> 100,000 inhabitants), public transport is an important form of transport many people depend on. Disruption of public transport services due to pluvial flooding could lead to significant costs. No figures are found that describe economic impacts due to disruption of public transport.

Data of delays in public transport could be obtained from public transportation companies. Yet, results from interviews with people from municipal traffic departments (Blankert and Sturm in appendix A) showed it would be difficult to obtain data about delays in public transport and related costs.

2.3.2.3 *Utility services interruption*

Other than Parker et al. (1987) and Penning-Roswell et al. (2005), no literature is found that describes flood damage to electricity and communication networks. Parker et al. (1987) suggest a vulnerability analysis for utility services, assessing physical susceptibility, consumer dependency and transferability or redundancy. Penning-Roswell et al. (2005) adopted this approach. No data is added of induced economic losses due to outage of utility services.

Huizinga et al. (2011) developed a method through expert judgment to estimate the level of social disruption due to fluvial flooding in flood prone areas in the Netherlands. Outage of utility functions is included in this assessment of social disruption. The description describes the potential time needed for repairs and replacements.

Though outage to utility functions seems an important economic impact due to flooding, remarkably little is known about this topic. Though, the physical susceptibility to water damage of utility object might be low, social and economic dependency is very high. This could lead to considerable economic or social impacts due to outage of utility functions.

Based on Huizinga et al. (2011) it is expected that underground utility networks (drinking water, electricity and gas) do not suffer from interruptions due to pluvial flooding. For drinking water systems, damage is only expected when soil is flushed away. Outage of drinking water is not expected, since the drinking water pipe network is highly redundant. Next to that, even if electricity fails, drinking water companies are legally obligated to supply drinking water for ten days by using back-up power units. Outage of electricity could occur when flood levels exceed 50 centimeters. Replacement of the electricity network takes approximately four days. Replacement of electricity substations takes approximately twelve weeks to two years. Outage of gas supply seems also unrealistic, because gas pipes are able to cope with a flood level of one meter, assuming a pipe depth of 80 centimeters below surface level.

2.3.3 Health impacts

The source of potential health impacts is faecally contaminated floodwater, in which pathogens could be present from roofs, streets and sidewalks or the combined sewer system. Sterk et al. (2008) show a gastrointestinal illness risk of 10 % and a respiratory illness risk of 3.9 % when being exposed to the floodwater. They conclude that the magnitude of the public health risk posed by urban flooding is significant.

Based on a theoretical approach, De Man and Leenen (2010) indicate the risk for sickness due to contact with storm water on street is over 11 %.

Empirical data of analyses of health effects associated with urban pluvial floods is scarce. According to De Man et al. (2011), people do indeed get sick due to contact with storm water on streets. On September 10 2005, pluvial flooding in Hardinxveld-Giessendam lead to 33 people getting sick after contact with the storm water on streets. At the event, houses were flooded and children played in the storm water.

Surveys among inhabitants could provide more information of potential health effects to inhabitants.

The health impacts to people due to contact with storm water also induce social costs, which could be considerable. People might visit the doctor, take medication or are unable to go to work. In the Netherlands, a regular doctor visit costs approximately 25 Euro (Nederlandse Zorgautoriteit, 2010), which is paid by health insurance companies. Costs for being unable to work are indirect economic costs, but might be negligible for one day because workers can compensate lost time.

The risk for health impacts is currently addressed in another subproject of Climate Proof Cities.

2.3.4 Emergency assistance impacts

Little is written on the topic of emergency assistance during or after floods and its related costs. Literature on this topic is found in Parker et al. (1987) and Penning-Roswell et al. (2005), in which data is documented following from flood events in the early eighties and the autumn of 2000 respectively.

Parker et al. (1987) provided standard emergency costs per flooded property in British urban areas for a range of flood scenarios and durations. The related costs for emergency assistance per flooded property in British residential areas vary from £166.7 to £295.5 in January 1985, representing approximately 520 to 920 Euro net present value (interest rate of 4 % and translated to Euro with a currency rate of GBP/EUR = 1.12). Yet, these figures are not representative for Dutch pluvial flood events, because the emergency services included in these costs cover a wide range of emergency services, such as cost for the military and authorities for the district and county.

Penning-Roswell et al. (2005) indicate a clear relation between emergency assistance costs and the number of flooded properties, resulting in a factor of scale. The costs for emergency assistance per flooded property decrease with increasing amount of flooded properties. However, Penning-Roswell et al. (2005) do not support scaling of such costs, since a substantial part of their recorded costs are induced by flood prevention, e.g. sandbagging.

2.3.4.1 Police department services

In the context of flooding, police departments assist only in crisis situations, as described by the Ministry of the Interior and Kingdom Relations (2008) (in Dutch: Ministerie van Binnelandse Zaken en Koninkrijkrelaties). Pluvial flood event are not formally entitled as crisis situations, leading to little or no police department assistance during pluvial flood events.

2.3.4.2 Fire department services

Fire department services during pluvial floods consist mostly of draining flooded tunnels and basements. It is expected that the major part of emergency service costs is induced by the fire department, since this is often featured in media after extreme precipitation events.

Parker et al. (1987) described costs for fire department services based on data of floods in 1982 and 1983. No description is included of the type of assistance provided. They state the average costs per flooded property are £8.4, assuming a 7.5 ratio of properties flooded/calls attended, representing 2.8 to 5.0 % of the total emergency assistance costs.

2.3.4.3 Municipal sewer system management department services

Citizens have the opportunity to call the sewer system management department in case of a potential problem with urban drainage. The municipal sewer system management department is there to solve these citizens’ complaints. This service is not provided specifically in extreme precipitation events. However, it is expected that the labor and related costs for system management department services increase with increasing precipitation intensity.

As shown by Ten Veldhuis (2010), municipal call data registered by sewer system management departments provides information about causes, locations and consequences of urban drainage problems. As such, adding precipitation intensities to these data could provide knowledge of the assistance costs provided by the municipality due to (extreme) precipitation.

2.3.5 Discomfort

Discomfort is an important flood impact not represented in the previously described flood impacts. Discomfort goes beyond the measurable impacts and grasps the associated perceived severity of various flood impacts, and should therefore be included in an assessment of pluvial flood impacts. Factors or pluvial flood impacts influencing discomfort of people could be:

- damage to property and content;
- clean up efforts;
- overflowing toilet;
- health impacts;
- stench;

- loss of mobility;
- traffic disruption;
- loss of electricity;
- loss of communication;
- closure of schools;
- closure of child care;
- limited access to shops.

Balmforth et al. (2006) argue that flooding can cause significant stress to individuals, particularly where loss is not insured. Next to that, impact on stress may be greater in poorer areas of society. Discomfort is likely to be influenced by flood frequency, flood duration and extent of the flood. Frequent minor flood events can lead to long-term psychological effects though this can often be overlooked when compared with the less frequent but greater impact of coastal and fluvial flooding. Generally, the response to and impact of flooding will depend on the social and economic background of the people affected (Balmforth et al., 2006).

A social impact assessment tool is developed by Huizinga et al. (2011) for Dutch flood prone areas. In their methodology, social disruption is assessed by evaluating the number of affected people, disruption duration, severity of impacts and water depth. The following objects and functions are assessed:

- housing;
- offices and educational buildings;
- public utility services (water, electricity, sewer system and gas);
- accessibility (roads and public transport);
- medical care;
- public event locations (soccer stadiums, theaters, etc.);
- industry and businesses;
- catering services and shops.

Unlike material damage, discomfort is difficult to quantify, because it depends on the nature of the flood event and behavioral characteristics of citizens. Discomfort per person could be quantified by (experienced) severity of a flood impact multiplied with the time of experiencing the flood impact as suggested by Huizinga et al. (2011). Surveys among citizens could be distributed to quantify the level of discomfort due to pluvial flooding.

2.4 Conclusions of current state of knowledge

As described in the previous paragraph, many different types of pluvial flood impacts can be distinguished. While some impacts are described in more detail, e.g. material impacts, recorded data about quantifying impacts is scarce, making quantification of impacts difficult. However, potential sources of data are identified per impact that could provide valuable information.

Material impacts to buildings are described most in various literary sources. Though the term economic impacts might suggest otherwise, economic impacts is rather intangible, since it is difficult to determine the consequence of material damages for economic activities. Costs for traffic delays are expressed rather detailed, while the relation with floods is still rather unknown. Outage of utility services seems luckily unrealistic in pluvial flood events, based on expert judgment in Huizinga et al. (2011), but could lead to considerable damages. Data about services provided by emergency assistance is scarce, although much media attention is given to this topic. Though discomfort of people seems a subjective impact that cannot be quantified, Huizinga et al. (2011) provide a basis to do so.

Overall, most of the described pluvial flood impacts are treated separately in the described literature. No study has been conducted so far that combines all impacts.

2.5 Pluvial flood impacts: short list

Based on expected relevancy of impacts, data availability and time availability, a short list is extracted from the previously described long list. This short list, in table 2.4, depicts the pluvial floods impacts that are examined further in this study.

Based on experience with pluvial floods and media attention, it is expected material damage to traffic infrastructure and public space is limited. Vulnerable objects as public buildings and public utility objects are expected to suffer from material impacts only in rare occasions, but could lead to substantial social and economic costs. Yet, interviews with relevant stakeholders (see appendix A) did not provide any knowledge of damages to infrastructure, public space or vulnerable objects. For this reason, it is excluded from further investigation.

Turnover losses and business interruption for businesses are expected to be limited due to small water depths and relatively short flood durations. Material damages could be considerable, as potentially shown in photo 2.2. Workers could compensate lost hours. Therefore, economic impacts of business interruption are excluded from further investigation.

Due to the expectation that material damages to public transport networks are small and obtaining data for assessment of economic impacts would be difficult, material and economic impacts to public transport are excluded from further investigation.

Health impact assessment is a research topic that goes beyond the scope of this research. Yet, it is likely that a 11 % risk of sickness could lead to substantial social costs. Research on this topic has just started. Since little data is available on the topic of health impacts, it is excluded from further investigation.

Since police departments do not provide assistance during pluvial flood events, these services are excluded from further investigation.

The remaining pluvial flood impacts in the short list seem relevant for Dutch urban areas, and sufficient data is expected to be available per impact.

Table 2.4 Potential pluvial flood impacts: short list

Material impacts	**Economic impacts**	**Health impacts**	**Emergency assistance impacts**	**Discomfort**
Residential building and content	– Disruption of traffic network – Disruption of communication network – Disruption of electricity network	Not considered	– Sewer system management services – Fire department services	Inhabitants' experience of all relevant impacts in a flood event

3 Case description: Stadsdeel Oost, Oude Noorden and Gouda

This chapter describes the selected cases. The cases are selected based on pragmatic choices for access to study population, cooperation of authorities and expected data availability. Several basic features are described, as well as an overview of the relevant stakeholders in the cases, whom to obtain data from.

3.1 Amsterdam, Stadsdeel Oost case description

Amsterdam is one of the research areas in the Knowledge for Climate research program. As mentioned in paragraph 1.4.1, the selected study area in Amsterdam was Watergraafsmeer. However, the applied methods for the survey distribution and data collection of sewer system management were only applicable for the bigger scale of Stadsdeel Oost. Therefore, the research was forced to scale up from Watergraafsmeer to Stadsdeel Oost.

3.1.1 Basic features

The location of Stadsdeel Oost is depicted in figure 3.1.

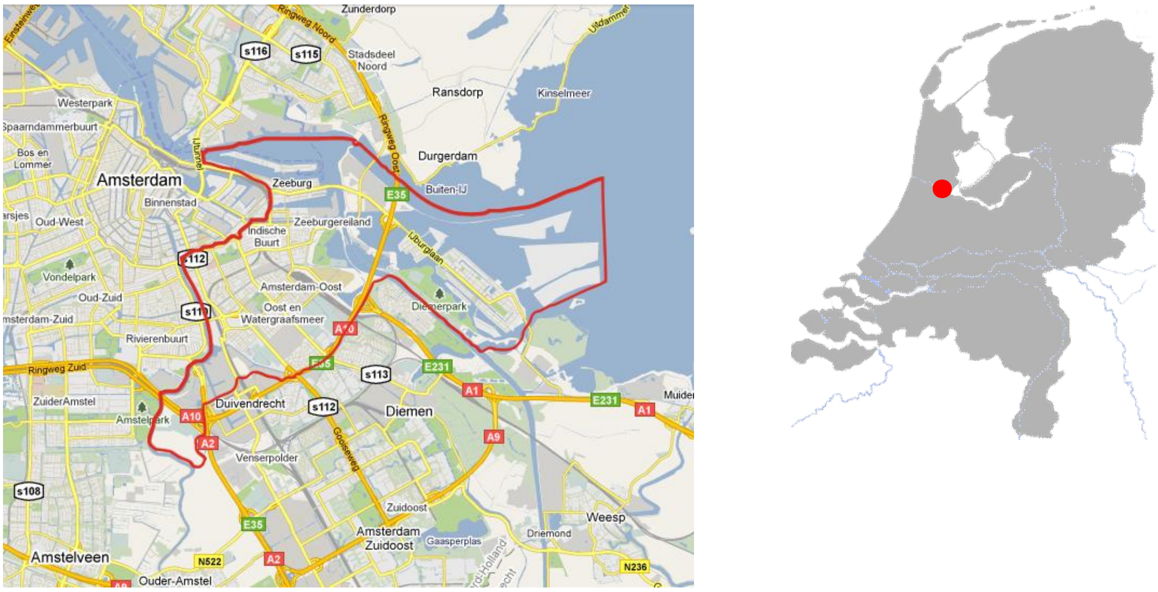
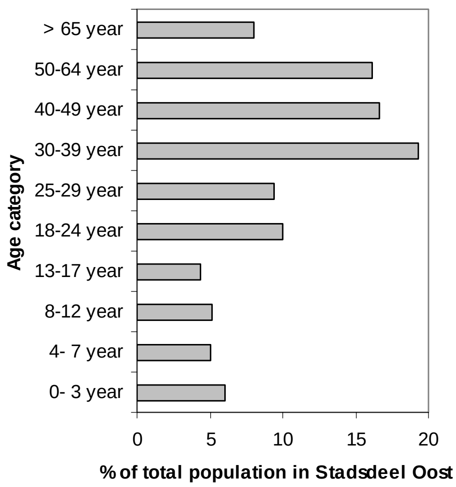


Figure 3.1 Location of Stadsdeel Oost in Amsterdam (Google, 2011)

Prior to May 1 2010, Amsterdam was split in fifteen city districts. Due to aimed improvement of municipal governance, the fifteen city districts were rearranged into seven city districts, one of which is Stadsdeel Oost (Joosten, 2009).

In 2010, Stadsdeel Oost had a population size of 116,615 inhabitants (Dienst Onderzoek en Statistiek, 2011), with a population density of 6,565 inhabitants per km^2 of land. The total surface area is approximately 31 km^2, of which approximately 18 km^2 is occupied by land.

In figure 3.2, several demographic characteristics of the population of Stadsdeel Oost are depicted.



Private properties (% of total housing stock)	26 – 28 %
Rental properties (% of total housing stock)	62 – 64 %
Mean yearly income per working citizen	28,000 – 32,000 Euro
Number of households (households per km^2 of land)	61,582 (3,421 per km^2)

Figure 3.2 Population pyramid and demographic characteristics of Stadsdeel Oost in 2010 (Dienst Onderzoek en Statistiek, 2011)

Media reports are used to determine when pluvial flood events occurred in Amsterdam. Table 3.1 shows several 'water nuisance events' in Amsterdam according to different internet sources. Note that the reliability of these sources reporting about pluvial flooding is debatable.

Table 3.1 Reported pluvial flood events with corresponding precipitation intensities from the KNMI measurement station Amsterdam

Reported period	Maximum registered precipitation intensity (mm day^{-1})
Autumn 2005	33 (September 16) 34.6 (November 25)
August 2006	24.2 (August 29) 46 (sum of August 11 and 12)
January 2007	32.7 (January 18)
April 2009	10.3 (April 11)
November 2009	26 (November 5)
August 23 2010	34
August 26 2010	52.8

Since the pluvial flood event in August 2010 is most recent and rather severe, most of the media attention is about this is event. For some pluvial flood events, media report headlines indicate flooding of streets and adjacent buildings. Precipitation figures do not show extreme intensities (< 30 mm day^{-1}). This is caused by the high variability in space and time of precipitation.

A large part of Stadsdeel Oost has a separated sewer system, which transports wastewater and storm water in separate pipe networks. The storm water is discharged onto surface water directly or after minor treatment. The advantage of a separate sewer system is that no sewage is discharged onto surface water or streets in case of heavy precipitation events. Yet, distances to surface water (distance between storm water collection and discharge points) should be small to prevent build up of water pressure in the pipe network.

The total land area of unpaved surface is approximately 6.7 km^2 (38 % of land surface area), in which precipitation is able to infiltrate the subsurface. This is a relatively large portion of the surface area. By comparison, in the city centre of Amsterdam 6 % of the land surface area is unpaved (Dienst Onderzoek en Statistiek, 2011). In the context of pluvial flooding, a larger portion of unpaved area results in a decrease in chances for pluvial flooding.

According to Waternet, Amsterdam's houses and streets are built while taking into account floods. This means that a certain height is kept between street level and doorstep level, by the use of sidewalk curbs. This decreases the chance of flooded buildings.

Though Stadsdeel Oost has a large portion of unpaved area and takes into account a certain difference in height between street level and doorsteps, pluvial floods occur, which is inevitable.

3.1.2 Stakeholder analysis

A stakeholder analysis is performed to categorize flood impacts and to determine which actors could provide data to gain insight in the topic of pluvial flood impacts.

Identification of the key stakeholders is performed based on expert judgment of Deltares flood experts and in collaboration with Waternet, Amsterdam. A full overview of the identified stakeholders and impacts per stakeholder is depicted in appendix B. Table 3.2 shows an overview of the most relevant affected stakeholder based on the short list of pluvial flood impacts in paragraph 2.5.

Table 3.2. Stakeholders potentially affected by pluvial flooding

Stakeholder group	**Stakeholder**	**Impact**	**Source**
Citizens	Inhabitants	Flooded house, cellar and garden	Media reports, Dutch Association of Insurers, 2010 (Verbond van verzekeraars)
		Overflowing toilets and sinks	Experience
		Contact with flood water	Sterk (2008)
		Temporarily moving out (because of drying time)	Unknown
		Stench	Experience
		Inconvenience (e.g. loss of mobility, not walking dog)	Media reports
		Loss of electricity	Unknown
		Loss of communication services	Unknown
Traffic	Motor vehicles	Road blockage, including tunnels	Media reports and experience
Emergency services	Fire department	Remove water by pumps	Media reports
Municipality and water board: Waternet	Sewer system management department	Handling and solving complaint calls	Ten Veldhuis (2010)

Interviews with Waternet and Stadsdeel Oost (see appendix A) showed that pluvial flooding generally does not lead to flooding of properties. Based on their expert judgment, this is caused by the historical understanding to avoid flooding of properties by building properties higher than street level. Next to that, Waternet and Stadsdeel Oost state that their intensive management of street refuse, gutter and gully pots results in increased storm water drainage capacity.

Inhabitants form a key stakeholder in this study for the assessment of several pluvial flood impacts. In order to gain access to experience and knowledge of inhabitants in Stadsdeel Oost, a survey is distributed through the local newspaper 'Stadsdeelkrant Oost' and several websites (see appendix E).

A dense traffic network is situated in Amsterdam, in which motor vehicles and public transport networks cross the urban area. Extreme precipitation resulting in flooded roads could cause disruption of traffic flows, especially in local depressions. One example of traffic disruption due to pluvial flooding was the flooding of the Mr. Treublaan under the overpass at the Amsterdam Amstel station. At August 26 2010, this busy secondary road under the overpass was flooded (see the right photo in photo 2.3), resulting in closure of this part of the road. Data of traffic flows is available at the municipal Department of Infrastructure Traffic and Transport in Amsterdam (in Dutch: Dienst Infrastructuur Verkeer en Vervoer, DIVV).

3.2 Rotterdam, Oude Noorden case description

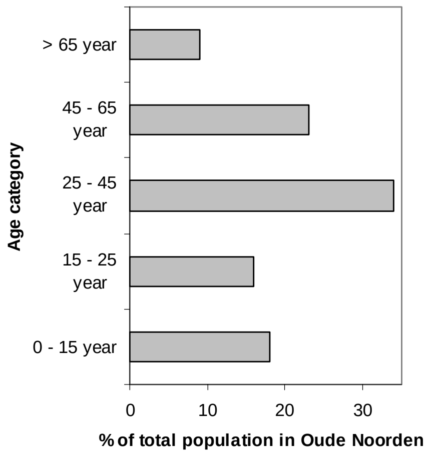
Rotterdam is one of the research areas in the Knowledge for Climate research program. The neighborhood 'Oude Noorden' in Rotterdam is selected as a study area.

3.2.1 Basic features

The location of Oude Noorden in Rotterdam is depicted in figure 3.3.

Figure 3.3   Location of Oude Noorden in Rotterdam

In 2009, Oude Noorden had a population size of 16,750 inhabitants (CBS, 2009), with a population density of 16.604 inhabitants per km^2. Figure 3.4 depicts several demographic characteristics of Oude Noorden..



Mean yearly income per working citizen	15,700 Euro
Number of households	8,600
Private properties (% of total housing stock)	14 %
Rental properties (% of total housing stock)	86 %

Figure 3.4 Population pyramid and demographic characteristics of Oude Noorden in 2009 (CBS, 2009)

One extreme precipitation event (May 2009) is found when searching internet for pluvial flooding in Rotterdam Yet, no newspaper headlines are found reporting about pluvial floods.

According to the municipality of Rotterdam, Oude Noorden is almost fully paved (approximately 70 %), resulting in a large fraction of storm water being unable to infiltrate the soil. The unpaved areas are mostly private gardens, resulting in a little amount of public green space. Almost the complete sewer system in Oude Noorden is of the combined type, because little surface water is present in the area. Excess storm water is discharged onto a ditch (Noordsingel) via overflows.

The stakeholder analysis for Oude Noorden is comparable to the analysis for Stadsdeel Oost. The same stakeholders are involved, except Waternet.

A dense traffic network is situated in Rotterdam, in which motor vehicles and public transport networks cross the urban area. Extreme precipitation resulting in flooded roads could cause disruption of traffic flows, especially in local depressions. Data of traffic flows is available at the municipal Department of Urban Planning and Public Housing, sub department of Traffic and Transport (in Dutch: Dienst Stedenbouw en Volkshuisvesting, afdeling Verkeer en Vervoer) in Rotterdam.

3.3 Gouda case description

Gouda is added as an extra study area for the distribution of digital surveys. Inhabitants are offered a digital survey through news letters and websites of neighborhoods in Gouda. Three neighborhoods positively reacted to the request of placing an article leading to the digital survey:

- Binnenstad (city center);
- Stolwijkersluis;
- Wervenbuurt.

3.3.1 Basic features

Figure 3.5 depicts the location of the three city districts in Gouda.

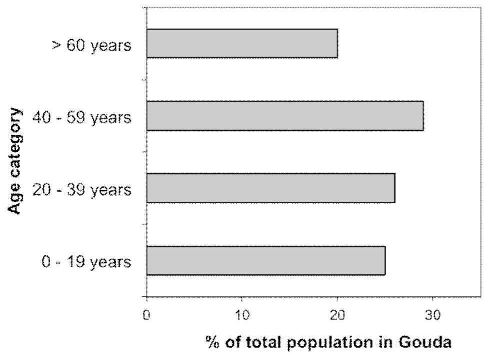
Figure 3.5 Location of Binnenstad, Wervenbuurt and Stolwijkersluis in Gouda

Table 3.3 depicts the population size and density of the three selected city districts in Gouda.

Table 3.3 Population size and density of three city districts in Gouda (source CBS, 2008 and 2011)

Name city district	**Population size**	**Total area (km^2)**	**Population density (# km^{-2})**
Binnenstad (2008)	3,621	0.45	8,046
Stolwijkersluis (2008)	420	0.95	442
Wervenbuurt (2008)	860	0.06	14,333
Gouda total (April 2011)	71,096	18	3,950

In figure 3.6 several demographic characteristics of Gouda are shown.



Yearly income per working citizen	33,900 Euro
Number of households	29,500
Private properties (% of total housing stock)	53 %
Rental properties (% of total housing stock)	47 %

Figure 3.6 Population pyramid and demographic characteristics of Gouda in 2009 (Municipality of Gouda, 2010)

4 Pluvial flooding through inhabitants' perspectives

This chapter describes the experiences of inhabitants in Amsterdam, Rotterdam and Gouda about the causes and effects of pluvial flood events. Data is obtained through municipal call data of citizens (paragraph 4.1) and analogue and digital questionnaires (paragraph 4.2).

4.1 Precipitation and pluvial flooding

It is expected that the magnitude of material impacts to houses or commercial buildings are correlated to precipitation intensity. This expectation is tested by the use of citizens' call data of Rotterdam. This data is described in appendix D. The registered complaints in the call data are separated in three classes: 'water on public space', 'water in gardens' and 'water in properties', representing an increase in the magnitude of material impacts. Per registered complaint, precipitation intensity of the corresponding day is plotted in a graph that is visualized in figure 4.1. The precipitation data in figure 4.1 is data of the KNMI precipitation measurement station Rotterdam Zestienhoven. Citizens' call data of Amsterdam was also obtained, but is not sufficiently detailed for the goal of this analysis, because no detailed descriptions of the complaint were available.

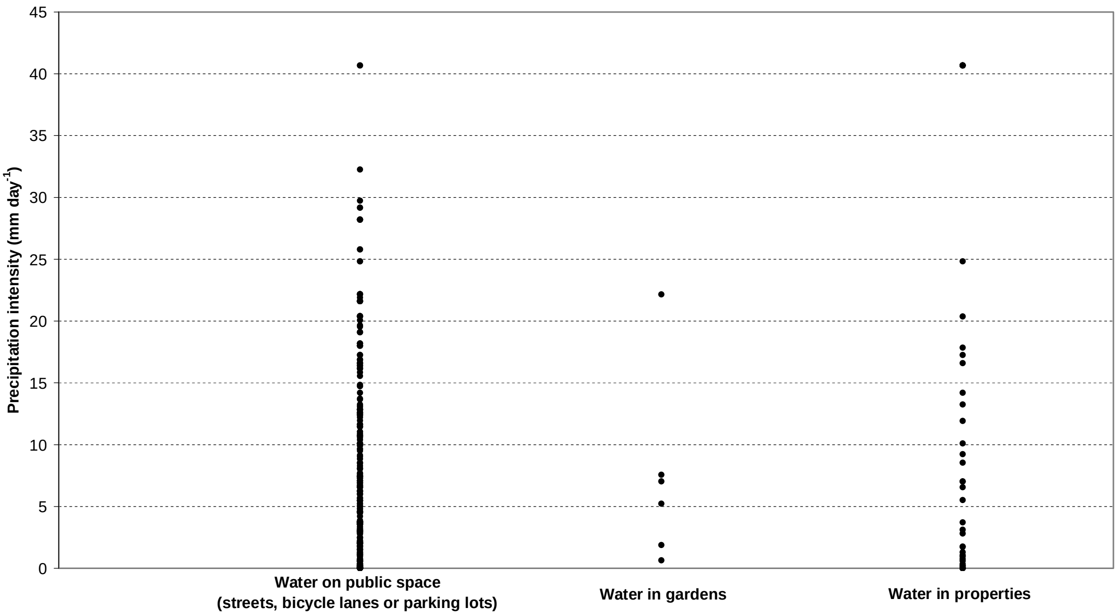


Figure 4.1 Complaint type per precipitation intensity in Oude Noorden Rotterdam, data of 10-2-2005 to 17-12-2005 (N = 387), each dot is one complaint

As shown by figure 4.1, water in gardens and properties, causing material damage, occurs at low as well as high intensity precipitation events. In several occasions, the call data registers report flooding of shops, while the KNMI measurement station reports hardly any precipitation. This result could be explained by the temporal and spatial variability of precipitation, which causes the precipitation data and assumed severity of flood impact not to be reflected in the registered call data. Substituting the KNMI precipitation data by average precipitation figures of a municipal measurement station and the KNMI Rotterdam Zestienhoven station does not change the data in figure 4.1.

In terms of a dose-response relation, the observed relation in this paragraph (precipitation – complaints), seems a horizontal line instead of the regular S-shaped curve, as shown in figure 4.2.

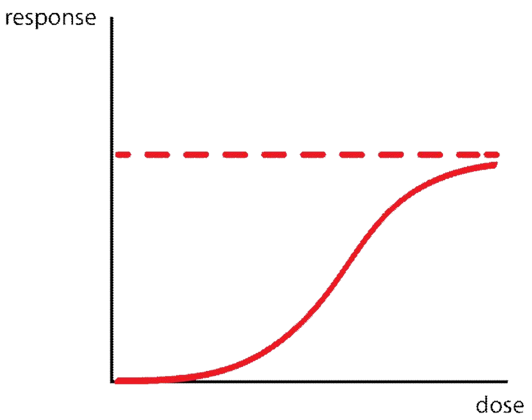


Figure 4.2 Regular S-shaped dose-response relation (solid line) and observed relation (dashed line)

Based on the presented data, it seems sensitivity to material damages does not increase with increasing precipitation intensity.

Yet, it seems unrealistic to conclude that severity of material damage is independent of the precipitation intensity. Flooding of houses and shops can only occur when sufficient precipitation falls down to enter buildings. In order to examine whether precipitation intensity is the driving influencing factor for material pluvial flood impacts, detailed radar precipitation data could be used to localize precipitation intensities on a smaller spatial and temporal resolution. Next to more detailed precipitation data, other areas could be assessed in a similar way to state a more representative conclusion.

On the other hand, 88 % of the call data complaints (n = 387) in figure 4.1, is about water on public space due to blockage of gully pots. This could lead to a conclusion that pluvial flooding (and related material impacts) has a higher probability to be caused by asset failure of the sewer system than by extreme precipitation. This conclusion is strengthened by Ten Veldhuis (2010), who states blockage of gully pots contributes to 71 % to the overall probability of flooding.

4.2 Pluvial flood experiences

In order to examine inhabitants' experiences with pluvial flood impacts, analogue and digital surveys are distributed in Amsterdam, Rotterdam en Gouda. The context and overview of the questionnaires are described in appendix E. A total of 90 inhabitants participated in the surveys, as depicted in table 4.1.

Table 4.1 Number of respondents per survey type and study area

Survey type	Amsterdam	Rotterdam	Gouda	Total
Analogue	50	5	-	55
Digital	12	1	22	35
Total	62	6	22	90
Response rate	0.05 %	0.04 %	0.28 %	

Since the response to the digital survey was relatively low, an analogue survey was distributed in Amsterdam and Rotterdam. By doing so, two separate samples are taken by the analogue and digital survey respondents. Due to a relatively low response rate (< 1 %), the results are not considered fully representative for the observed study areas.

The difference in samples is visible in the results of the experience pluvial flood impacts. 71 % of the analogue survey respondents (n = 55) stated they experienced a pluvial flood event between 2004 and 2010. 66 % of the digital survey respondents (n = 35) indicated they experienced a pluvial flood event between 2004 and 2010.

Table 4.1 depicts an overview of flood impacts experienced by inhabitants in the period of 2004 to 2010. In Amsterdam, approximately half of the 62 respondents indicated they experienced their worst flood event in August 2010. Yet, this result could be heavily influenced by cognitive remembrance.

Table 4.2 Urban pluvial flood impacts according to inhabitants' experience; the figures represent the number of respondents n; A = analogue survey, D = digital survey, T = A+D, blank cells represent a zero

Flood impact	**Amsterdam**		**Rotterdam**		**Gouda**	**Total**		
	A	D	A	D	D	A	D	T
Stench	17	5		1	8	17	14	31
Disruption of traffic, including bicycle	22	4			5	22	9	31
Water damage to house	2	7	1	1	8	3	16	19
Overflowing toilet	7	3			6	7	9	16
Water damage to garden	3	2	1		7	4	9	13
Water damage to possessions	2	4		1	4	2	9	11
Loss of electricity	1	2			1	1	3	4
Loss of mobility (not able to walk down the street)	2	1			1	2	2	4
Loss of internet	2	2				2	2	4
Flooded basement	2	2				2	2	4
Limited access to shops	1				2	1	2	3
Health impacts					1		1	1
Ruined wooden floor					1		1	1
Limitation of ability to walk the dog								
Temporary moving out, due to uninhabitable house								
Loss of school								
Loss of child care								
Total	61	32	2	3	44	63	79	142

The results in table 4.2 show that stench and disruption of traffic are experienced most by inhabitants. Limitation of walking the dog, moving out, loss of schools and loss of childcare is not experienced by the respondents. While water damage to houses seems to be experienced more than other described impacts, based on the total survey results, the analogue survey results prove otherwise.

While 16 % of the analogue survey flood impact experiences (n = 61) are material impacts (water damage to house, possessions and garden), 41 % of the digital survey flood impact experiences (n = 32) are material impacts. This indicates the results of the digital survey are biased towards the occurrence of pluvial flood impacts. This could be explained by the fact that the digital survey triggers more people that have actually experienced damages, they could perceive as inconvenient.

Due to a relatively low number of respondents per case, it is not possible to relate the results of the three cases to each other.

Based on the experiences of the 90 respondents, inconvenience is experienced most, resulting from stench, traffic disruption and overflowing toilets. Loss of utility services, health impacts and loss of public services are (almost) not experienced.

4.2.1 Costs of material impacts

Table 4.3 depicts the survey results indicating the costs for material damages induced by a pluvial flood event as experienced by the respondents. The respondents were asked to indicate a figure of the induced damage costs for their worst experienced flood event between 2005 and 2010. 20 % of 90 respondents stated they experienced material damage to their house, possessions and garden inducing costs.

Table 4.3 Induced damage costs by pluvial flooding according to inhabitants' experiences; the figures represent the number of respondents; A = analogue survey, D = digital survey, T = A+D, blank cells represent a zero

Cost range	**Amsterdam**		**Rotterdam**		**Gouda**	**Total**		
	A	D	A	D	D	A	D	T
0 Euro	33	3	1		6	34	9	43
1 to 500 Euro	1	4			1	1	5	6
501 to 2,000 Euro	1		2	1	2	3	3	6
2,001 to 5,000 Euro	1	1			1	1	2	3
> 5,000 Euro		2			1		3	3

The survey results indicate that for the majority of respondents in Stadsdeel Oost, Oude Noorden and Gouda no water damage costs are induced. When costs are induced due to material impacts, costs vary between 1 to over 5,000 Euro in several cases. It is unknown whether damage costs are induced to private home owners or housing corporations, since this was not part of the survey questions.

Again, the bias in the results of the digital surveys is visible for the results of Amsterdam. While 6 % of the analogue survey respondent (n = 50) were inflicted costs due to material damage, 58 % of the digital survey respondent were inflicted by costs due to material damage.

4.3 Pluvial flood acceptation

One of the survey's goals was to determine the acceptation of pluvial flooding and its consequences. The survey questions on this topic asked the respondents about their opinion in the context of "if they would experience a flood event". The addressed issues are acceptation of the pluvial flood frequency, perceived discomfort and willingness to pay to avoid pluvial flood impacts.

4.3.1 Pluvial flood frequency

Table 4.4 depicts the survey results, indicating the accepted pluvial flood frequency by the respondents.

Table 4.4 Acceptation of pluvial flood frequences; the figures represent the number of respondents; A = analogue survey, D = digital survey, T = A+D, blank cells represent a zero

Frequency	**Amsterdam**		**Rotterdam**		**Gouda**	**Total**		
	A	D	A	D	D	A	D	T
Once per year	2	1			7	2	8	10
Once per two years	3					3		3
Once per five years	5	2			4	5	6	11
Once per ten years	14	4			5	14	9	23
Never	26	5	5	1	6	31	12	43

As shown in table 4.4, most of the respondents have a tendency to not accept pluvial at all, or once per ten years. Respondents of Gouda accept a higher frequency of pluvial flooding (once per year) than in Rotterdam and Amsterdam.

The Dutch sewer system design standard is based on a pluvial flood frequency of once per two years. Yet, the acceptation of pluvial flooding of the respondents is, on average, lower than the design standard.

The current trend in Dutch water management practices is that people should accept and be aware of a certain flood risk (Ministry of Infrastructure and the Environment, 2005 and 2009). This tendency counts especially for fluvial floods, but could also be used for pluvial flooding. The presented social acceptation of pluvial flooding is the opposite of what is described in these national policy documents. Creation of awareness could improve this acceptation, for example by the creation of water squares as in Rotterdam.

4.3.2 Discomfort

One of the survey's goals is to determine the perceived severity of pluvial flood impacts based on "if inhabitants would experience a flood event". This is meant to mutually compare the level of discomfort per impact. In the survey, respondents are asked to rate the level of discomfort per impact in a top five (1 to 5 score), where number 1 represents their highest level of discomfort. As such, the level of discomfort per pluvial flood impact depends on 1) the number of respondents filling in a certain score and 2) the filled in scores (severity factor). In other words, discomfort per pluvial flood impact is quantified as the product of the response ratio per impact and the average score per impact.

$$\frac{\text{number of scores filled in}}{\text{number of respondents}} \times \frac{\text{total score per impact}}{\text{number of scores filled in}} = \frac{\text{total score per impact}}{\text{number of respondents}}$$

The filled in scores per impact are influenced by whether or not a respondent has actually experienced a certain pluvial flood impact. Table 4.5 depicts the levels of discomfort per flood impact. No distinction is made between the three different cases and analogue and digital survey respondents.

Table 4.5 Discomfort score per pluvial flood impact according to inhabitants' experiences

Flood impact	**Discomfort ranking**	**Perceived discomfort**
Loss of electricity	1	High
Health effects	2	
Water damage to possessions	3	
Stench	4	
Water damage to house	5	
Overflowing toilet	6	
Water damage to garden	7	
Disruption of traffic, including bicycle	8	
Temporary moving out, due to uninhabitable house	9	
Loss of mobility (not able to walk down the street)	10	
Loss of internet	11	
Time and energy for clean up	12	
Limited access to shops	13	
Loss of school	14	
Limitation of ability to walk the dog	15	
Loss of child care	16	Low

The presented figures in table 4.5 indicate that loss of electricity is experienced as causing the highest level of discomfort. Health effects and damage to possessions rank second and third respectively.

Though loss of electricity and health effects would be most discomfortable, these impacts are not experienced yet by the respondents, as described in paragraph 4.2. Water damage to possessions and stench is rated rather discomfortable and is also experienced more than other impacts.

4.3.3 Willingness to pay

Willingness to pay is a method to determine how much people are willing to pay for a change in quantity or quality (or both) of a particular commodity (Gunatilake et al., 2006). Though the appropriateness of this method is debated about among researchers, it is used here as a tool to approximate the valuation of pluvial flood impacts. Table 4.6 shows the results of the yearly amount respondents are willing to pay to avoid all possible pluvial flood impacts.

Table 4.6 Survey results willingness to pay to avoid all pluvial flood impacts, the numbers represent the number of respondents

Yearly payment	**Amsterdam**	**Rotterdam**	**Gouda**	**Total**
0 Euro	18	5	6	29
1 to 25 Euro	22		9	31
26 to 100 Euro	15	1	7	23
101 to 500 Euro	6			6
> 500 Euro	1			1
Total	62	6	22	90

The results in table 4.6 table show that approximately one third of the respondents is not willing to pay for avoiding pluvial flooding. Approximately 80 % of the respondents who are willing to pay, are willing to pay 1 to 100 Euro per year.

According to RIONED, the Dutch national platform on sewer systems and related urban water management, an average Dutch household pays approximately 150 Euro per year for all sewer system management costs (RIONED, 2009). Where the average household contains 2,2 persons (CBS, 2009), the yearly costs for sewer system management per person is 68 Euro. From this it can be concluded that a yearly payment of 100 Euro is much. It could generate large budgets for implementing measures to reduce pluvial flood risk.

4.4 Summary and discussion

Inhabitants' experiences are valuable sources of information for the assessment of pluvial flood impacts.

As shown by municipal call data of Rotterdam, no correlation between precipitation intensity and severity of pluvial flood impacts seems to exist. The associated dose-response relation is a horizontal line instead of a S-shaped curve. Yet, it seems unrealistic to conclude the severity of material damage is independent of precipitation intensity. On the other hand, the data suggest flooding is more likely to be caused by blockage of gully pots.

The results of the survey respondents are interesting. Surveys prove to be a useful source for obtaining data about pluvial flooding.

Based on the experiences of the 90 respondents, inconvenience is experienced most, resulting from stench, traffic disruption and overflowing toilets. Loss of utility services, health impacts and loss of public services are (almost) not experienced. The majority of respondents indicate no costs are induced due to material damage. When costs are induced due to material impacts, costs vary between 1 to over 5,000 Euro in several cases. The majority of respondents indicated they accept pluvial flooding once per ten years or never. This acceptation is lower than the sewer system design standard of once per two years. The presented social acceptation of pluvial flooding is the opposite of what is described in national water policy documents. The level of discomfort is introduced here as a pluvial flood impact that should not be neglected. Loss of electricity is perceived as causing the highest level of discomfort. Health effects and damage to possessions rank second and third respectively. However, these pluvial flood impacts are not experienced by the respondents. Approximately 80 % of the respondents who are willing to pay to avoid pluvial flood impacts, are willing to pay 1 to 100 Euro per year. A yearly payment of 100 Euro per person is higher than the current average costs for all sewer system management costs per person.

The survey response rates were rather low, which could be explained by the passive character of the digital survey. Although the digital survey was offered in several ways to inhabitants, the overall affection with the topic, or the medium the survey was presented in, seems low. The consequence of the low response rates is that the obtained survey results are not fully representative for the observed case studies. Yet, this study's goal is to explore the topic of pluvial flood impacts, not to exactly quantify them. In the digital survey results, bias is introduced, since the digital survey seemed to attract people with affection with the topic.

The obtained results could provide input for cost-benefit analyses for measures against pluvial flooding or the formation or adjustment of legal standards about sewer system management.

5 Economic impacts: traffic delays

The survey results indicate 31 of 90 respondents experienced some form of traffic disruption. Further assessment of the impact on traffic from extreme precipitation is undertaken by using traffic data from the municipality of Amsterdam and Rotterdam. The results are presented in this chapter.

5.1 Introduction

The main question this chapter tries to answer is: “is there a relation between precipitation intensity and traffic delays?”

The traffic flow rate, and related delays, is influenced by various factors, such as (modified from Turner and Harahab, 1993):

- the variety in vehicle types, including presence of public transport;
- roadside activities;
- road surface characteristics;
- speed limits;
- traffic density;
- road capacity;
- vehicle interaction;
- presence of junctions;
- weather conditions, including precipitation intensity.

Each of these factors influences drivers’ behavior, causing the traffic flow rate to fluctuate over time on a road segment. It is unknown to what degree each factor influences the flow rate. This study focuses on precipitation, which could be one of the traffic flow rate influencing factors.

5.2 Data description and approach

Traffic delays are computed by the use of traffic data acquired from the Department of Infrastructure Traffic and Transport in Amsterdam (in Dutch: Dienst Infrastructuur Verkeer en Vervoer, DIVV) and the Department of Urban Planning and Public Housing, sub department of Traffic and Transport (in Dutch: Dienst Stedenbouw en Volkshuisvesting, afdeling Verkeer en Vervoer) in Rotterdam. The acquired data are described in appendix C. The data consist of travel time and average speed between two fixed traffic registration cameras, i.e. road segments. In this study, five road segments are examined; four in Amsterdam and one in Rotterdam. The locations of the selected road segments are depicted in figure 5.1.

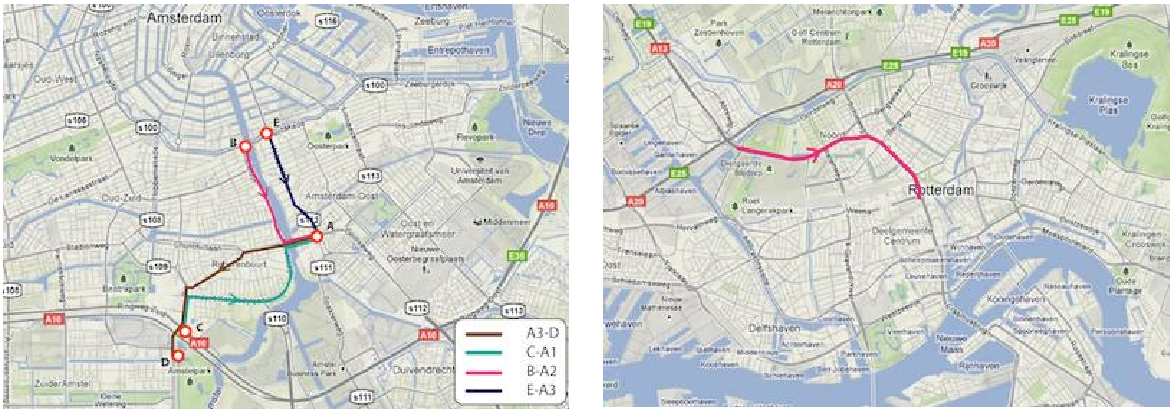


Figure 5.1 Location of examined road segments in Amsterdam (left) and Rotterdam (right); the arrow indicate the traffic flow direction measured by the traffic registration cameras (Google, 2011)

Three of the selected road segments in Amsterdam pass through the Mr. Treublaan under the overpass at the Amsterdam Amstel station. At August 26 2010, the road under the overpass was flooded, resulting in closure of this part of the road. Consequently, traffic delays could be expected on these road segments on August 26 2010. No heavy precipitation event occurred in Rotterdam in the corresponding period of the acquired dataset (see appendix C).

An overview of the distribution of travel time of the five selected road segments is depicted in figure 5.2.

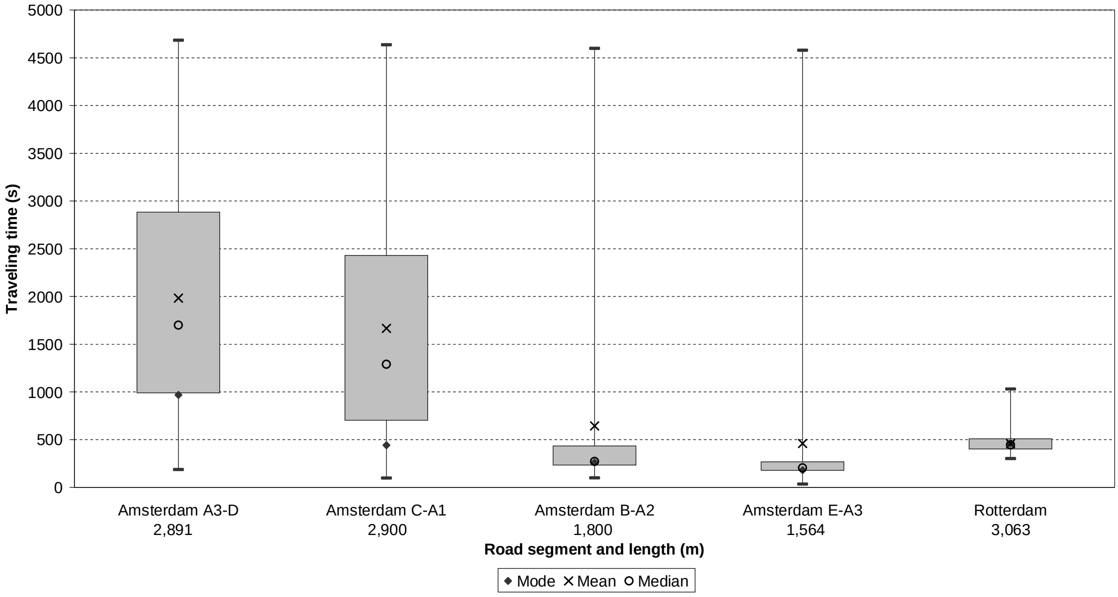


Figure 5.2 Box-plot of the travel time distribution for motor vehicles for five road segments. The box-plot depicts the minimum, first quartile, mode, median, mean, third quartile and maximum travel time.

The box-plot suggests that the distribution of travel time for the five road segments is positively skewed, because both the mode and the median for all four road segments are significantly lower than the mean.

The potential relation between precipitation and traffic flow rate is examined in a three step way.

1 Determination of a reference traffic flow rate
2 Calculation of the delay in traffic flow

3 Relate traffic delay to precipitation intensity

5.3 Determination of free flow

The travel delay per vehicle is computed by subtracting a reference value from the measured travel time. In traffic flow theories, this reference value is known as ‘free flow’. Free flow is the speed when there are no constraints placed on a driver by other vehicles on the road (Lieu, 1992). Free flow speed can be calculated as a function of traffic flow rate, traffic density and mean speed (Lieu, 1992). Since only travel time on road segments is available, free flow is calculated in an alternative way based on criteria setting. It is assumed that free flow occurs when the following criteria are met:

- travel time between 5th percentile and mode;
- 22:00 < t < 4:00 hours;
- no Saturday;
- precipitation < 2 mm;
- temperature > 0 °C.

Given these conditions, the mean free flow travel time for each of the four road segments in depicted in table 5.1.

Table 5.1 Mean free flow travel time for five selected segments

Road segment	Mean free flow travel time (s)	Standard deviation (s)
Amsterdam A3-D	743	131.1
Amsterdam C-A1	414	13.7
Amsterdam B-A2	227	19.8
Amsterdam E-A3	157	18.8
Rotterdam	401	39.3

5.4 Relation of travel delays and precipitation

Given the free flow travel time for each road segment, the travel delay for each registered vehicle can be computed and related to precipitation intensity.

The potential correlation between travel delay and precipitation is determined for road segments C-A1 and E-A3 in Amsterdam and heavy precipitation events on August 23 and August 26 2010. The other three road segments are not examined, since no heavy precipitation event in combination with sufficient amount of traffic data is available. The chosen time frame per precipitation event starts at precipitation > 2 mm and ends three hours after the maximum precipitation intensity.

5.4.1 Visual interpretation

Based on a visual interpretation in collaboration with the Department of Infrastructure Traffic and Transport in Amsterdam, the figures show a small peak in delay shortly after the precipitation peak. Next to that, an upward shift of the baseline can be seen in figure 5.3.

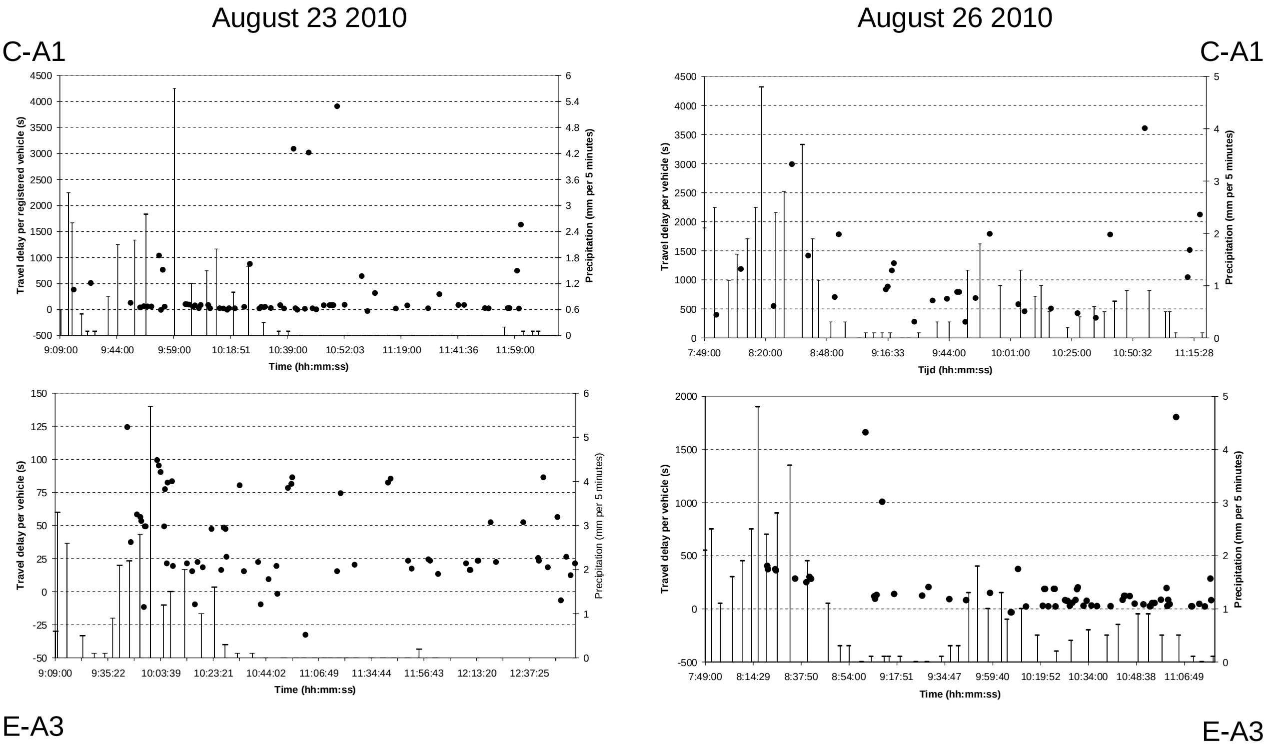


Figure 5.3 Travel delay per registered vehicle August 23 and August 26 2010 of road segments C-A1 and E-A3 in Amsterdam. Precipitation data are the municipality of Diemen's.

Following from the visual interpretation, it could be concluded that extreme precipitation leads to potential traffic delays. According to the Traffic Department, a delay increase of 5 minutes on top of the free flow is seen as problematic and in need for further attention.

5.4.2 Statistical analysis

A statistical analysis is performed to determine whether the measures traffic delays are caused by precipitation. A comparison is made between travel delays on six dry days (May 24, May 25, June 1, August 17, August 18 and September 10 2010) and August 23 and 26. This is shown in figure 5.4.

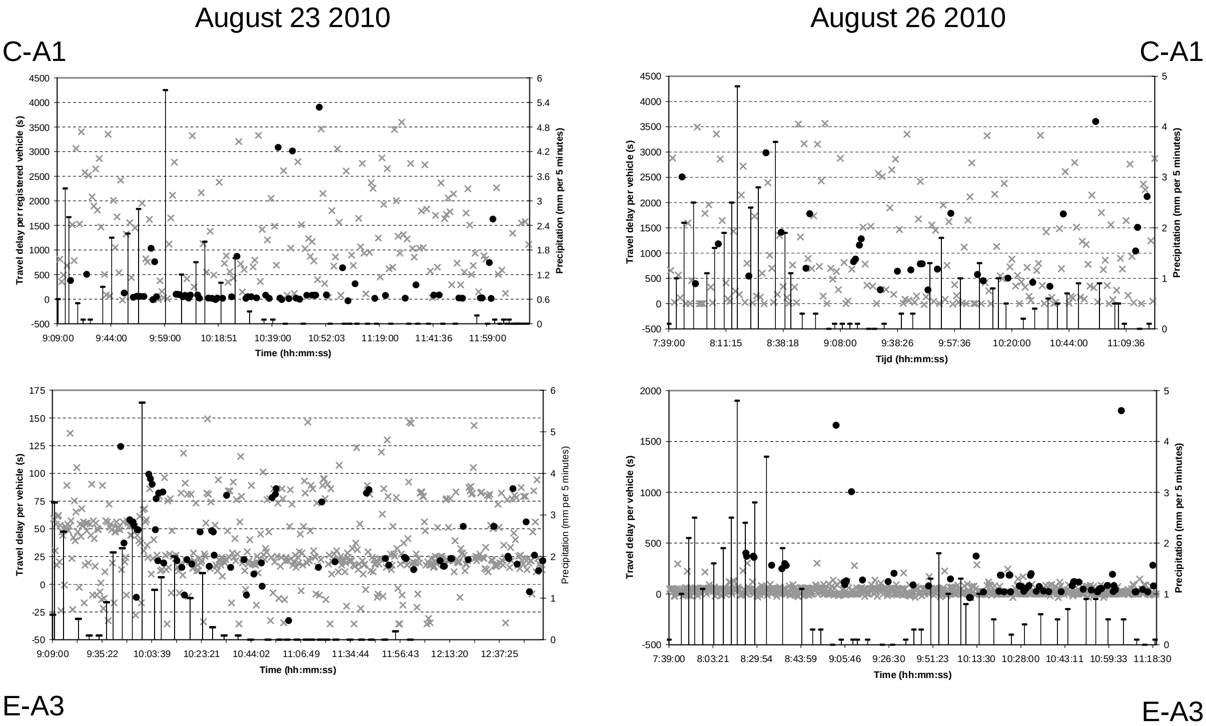


Figure 5.4 Travel delay per registered vehicle on six dry days, August 23 and August 26 2010 of road segments C-A1 and E-A3 in Amsterdam. For dry days, the 80th percentile is chosen as an upper boundary. Precipitation data are the municipality of Diemen's.

A two-sample z-test can be used in order to test the correlation of two samples of one population. As such, the two-sample z-test is used in order to determine the statistical correlation between travel delays on the six dry days and days with heavy precipitation. The z value following from the z-test is a number that represents the variance between the two samples in terms of the standard error of the difference between the sample means (normalization process). Due to normalization, the z-value corresponds to probability in the standard normal distribution. The z-value is described by:

$$z = \frac{(\bar{X}_1 - \bar{X}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Where,

z	=	z-value
$\bar{X}$	=	sample mean
μ	=	population mean
σ	=	standard deviation of sample
n	=	sample size

Null hypothesis H_0: $\mu_1 = \mu_2 \rightarrow \mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 > \mu_2 \rightarrow \mu_1 - \mu_2 > 0$

Decision rule: when probability of correlation is lower than 0.8 (standard normal probability of $-0.1 \leq P \leq 0.1$), reject H_0.

Extreme values are excluded by taking the 80th percentile as an upper boundary to exclude influences of traffic jams, car stops or accidents. In table 5.2, the corresponding data and results are depicted.

Table 5.2 Data and results of two-sample z-test for correlation between precipitation and travel delays on road segments C-A1 and E-A3; $\overline{X}_1$ = August 23 or 26, $\overline{X}_2$ = dry days

Road segment	Sample*	Sample mean (s)	Standard deviation (s)	Sample size*	z-score	Two tailed standard normal probability**	Rejection of H_0	Rejection of H_1
C-A1	Dry days	1216.0	822.0	148	-0,19	0,85	No	-
	Aug. 23	311.1	752.9	62				
	Dry days	930.0	896.0	148	0,03	0,98	No	-
	Aug. 26	1081.9	798.8	29				
E-A3	Dry days	35.0	34.0	496	0,48	0,63	No	-
	Aug. 23	38.0	32.0	65				
	Dry days	160.0	363.0	495	0,55	0,58	No	-
	Aug. 26	318.0	181.8	65				

* the dry days' sample mean and size vary due to different observed time frames

** figures retrieved from the 'unit normal table'

The figures in table 5.2 indicate the null hypotheses is accepted for all z-tests. One out of four z-scores is negative, indicating travel delays are significantly lower on August 23 than on dry days for road segment C-A1.

Based on the decision rule (correlation -0.1 ≤ P ≤ 0.1), the following conclusion can be drawn from the data presented in table 5.2. For each of the selected road segments and selected days, there is no statistical correlation between precipitation and travel delays.

Based on the results of the two-sample z-tests for the selected road segments and time frames, no significant increase in travel delay is found due to extreme precipitation. To a large part, this is caused by the great variety in travel time, which results in a higher mean traffic delay on dry days than on the selected rainy days. Consequently, two results of the two sample z-tests indicate a significant higher traffic delay on dry days than on the selected rainy days.

A possible explanation for this result is that traffic delay in general is subject to large variations caused by various sources. These sources influence the samples' mean travel time and standard deviations to a large part, leading to the presented conclusions. Though the method of a two-sample z-test is correctly used, the used data sets did not result in statistically satisfying results due to influences of other variables.

5.5 Summary and discussion

The relation between precipitation and traffic delays is assessed by the use of traffic data from the Department of Infrastructure Traffic and Transport in Amsterdam.

Based on a visual interpretation, extreme precipitation on August 23 and 26 2010 led to potential traffic delays on two observed road segments in Amsterdam.

When applying a two-sample z-test to determine the statistical correlation between precipitation and traffic delay, no correlation seems to exist. To a large part, this is caused by great variety in travel time over a measured road segment. Examples are rerouting or stops for numerous reasons. These variables could not be eliminated from the data set.

Traffic delays on rainy days fall well within the range of traffic delays on dry days. Therefore, it could be concluded that the influence of precipitation on traffic delays is rather small. This could be explained by the high redundancy of the traffic network. Due to numerous alternative routes along a registered road segment, drives could opt for alternative routes.

It could be concluded that redundancy reduces the possibility for traffic delay costs. Therefore, increasing network redundancy can reduce sensitivity of traffic to pluvial flooding, while exposure remains the same. A costs benefit analysis could identify an optimum between infrastructure investments (redundancy increase) and potential economic impacts due to traffic delays.

In order to further assess the relation between precipitation and traffic delays, the length of measured road segments could be decreased. By doing so, the chance other variables influence traffic delay can be decreased, or at least, monitored better. Next to that, data about accidents or other influences should be combined with the travel time measurements.

6 Emergency assistance: sewer system management

In the Netherlands, emergency assistance costs in urban pluvial flood events are induced by the fire department and the municipal sewer system management service. The costs for this latter service are described in this chapter in more.

6.1 Introduction and data description

The main question this chapter tries to answer is: "is there a relation between precipitation intensity and costs for sewer system management?" The costs for sewer system management come from solving citizens' complaint to the municipality regarding urban drainage. It is expected that an increase in daily precipitation intensity causes an increase in the number of daily citizens' complaints.

The call data from citizens' complaints are acquired from Waternet, for Stadsdeel Oost, and from Gemeentewerken Rotterdam for the case of Oude Noorden. Call data for both cases are available for the period of January 1 2005 to December 31 2010.

Registration of a citizen's complaint following a precipitation event is influenced by various variables, such as:

- characteristics of gully pot, adjacent sewer network and adjacent surface area, influencing the storm water inflow and drainage capacity;
- presence of objects in or surrounding a gully pot, managed by preventive cleaning of street surfaces, sidewalks and gutters by a municipal service;
- human behavior and response to the actual blockage of a gully pot leading to a potential call from a citizen to the municipal service for complaint registration and a potential registration by a municipal employee;
- weather conditions, including precipitation intensity.

This study focuses on precipitation intensity as one of the causes for costs for sewer system management costs.

6.2 Approach

The pragmatically chosen method to examine the potential relation is single linear regression. To approximate the costs, each complaint is multiplied by the average costs per complaint. For Amsterdam, the average costs for solving one complaint are 270 Euro (personal communication respondent Peter Nieuwenburg, 2011). These costs include costs for labor and equipment. For Rotterdam, costs could not be identified, because no straightforward knowledge and data is available to approximate costs for sewer system management. As such, the same costs as Amsterdam are applied to Rotterdam.

Two linear relations per case are examined: a day-to-day relation and a cumulative relation over multiple days. A day-to-day relation implies that the number of daily complaints depend on the daily precipitation intensity. It could be described by:

$$X_n = \alpha P_n + c + \varepsilon$$

Where:

X_n = Number of solved complaints on day *n* (# day^{-1})
α = Weight factor
P_n = Precipitation intensity on day *n* (mm day^{-1})
c = Constant: average number of solved complaint in dry periods

ε = Unexplained variance

A disadvantage of the above-described day-to-day relation is that precipitation shows great spatial and temporal variability, which might not be reflected in the call data. In order to decrease the effect of variability of precipitation in time and space, precipitation intensities can be summed over multiple days and related to the corresponding amount of registered complaints. So far, this different approach has hardly been reported about. The period over which to sum the precipitation and registered complaints is defined as a 'wet period'. A wet period is defined as an i-day wet period (i > 0), in which a wet period is a consecutive sequence of wet days preceded and followed by at least one dry day (Ison et al., 1971). A wet day is one during which at least 2 mm of precipitation falls.

$$\sum_{n(P>2)}^{n(P\leq 2)} P_n \,,\, X_n$$

A disadvantage of this method is that no distinction can be made between extreme precipitation events in summer and extended drizzle periods in fall. To avoid this, only summer months could be taken into account. In this study, all twelve months per year are considered.

6.3 Results

6.3.1 Amsterdam, Stadsdeel Oost

Figure 6.1 depicts the day-to-day relation between precipitation and induced costs for the department for sewer system management due to solving citizens' complaints. Every point represents a number of solved citizens' complaints per day, multiplied with a cost factor.

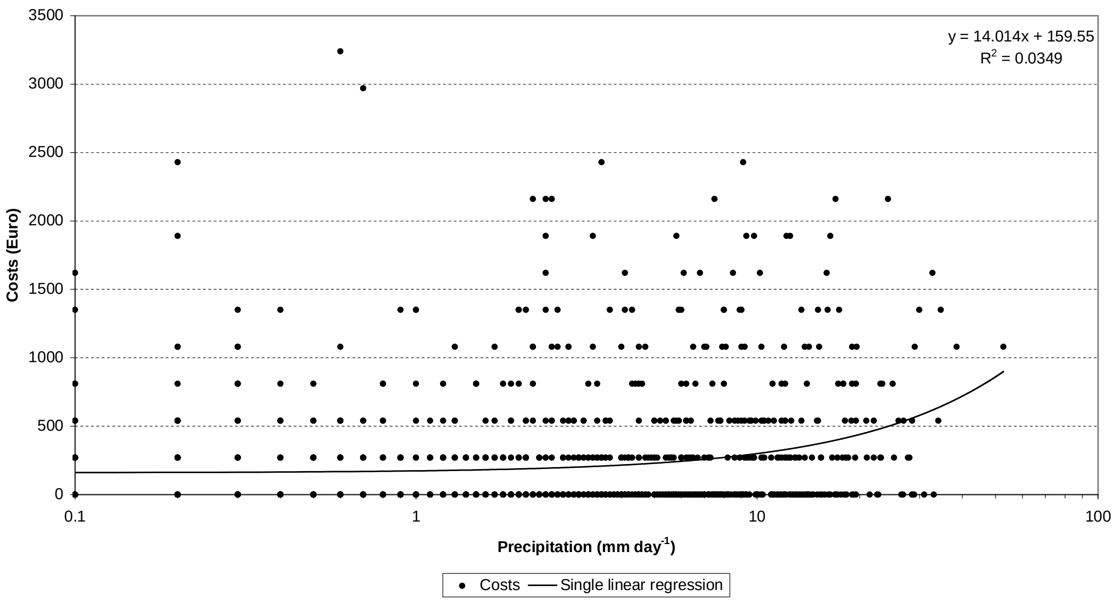


Figure 6.1 Correlation between precipitation and costs for sewer system management in Stadsdeel Oost; data of 2005 to 2010

Single linear regression in figure 6.1 shows a regression coefficient R^2 of 0.03, suggesting no significant correlation between the two variables on day-to-day basis. Figure 6.2 shows the relation between precipitation and induced costs, based on cumulated data over wet periods.

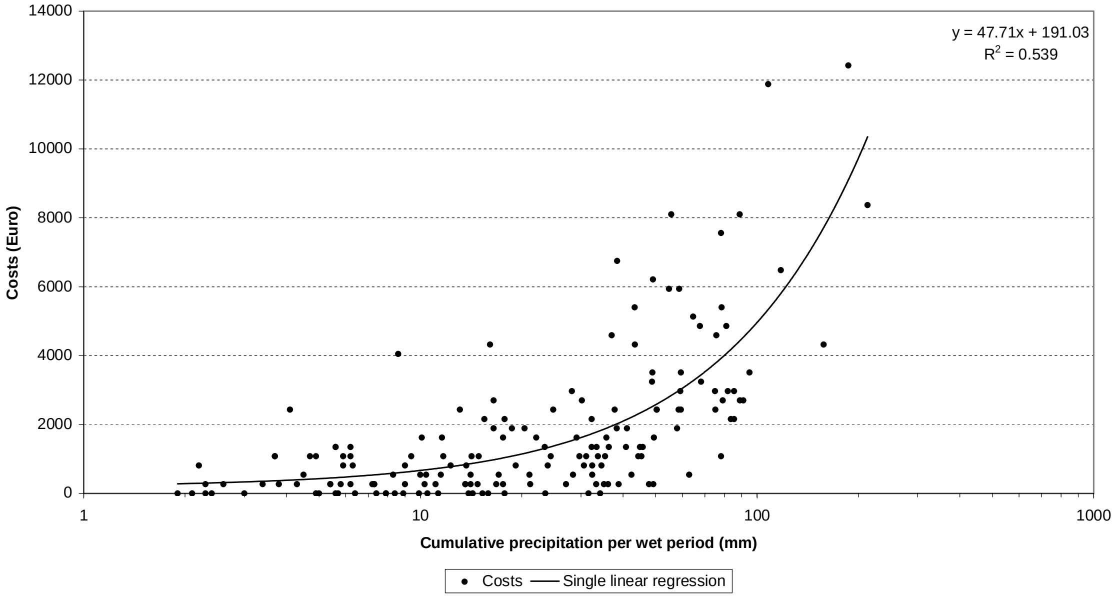


Figure 6.2 Correlation between precipitation and costs for sewer system management in Stadsdeel Oost, cumulated per wet period; data of 2005 to 2010

Single linear regression in figure 6.2 shows a regression coefficient R^2 of 0.54, indicating a higher correlation between the two variables than presented in the data in figure 6.1. The associated costs for sewer system management, as a one variable function of precipitation, could be described by:

$$\text{Costs per 10,000 inhabitants} = 4.10\,\text{Euro}\cdot\text{mm}^{-1} + 16.4$$

The number of complaints is described by:

$$\text{Complaints per 10,000 inhabitants} = 0.02\cdot\text{mm} + 0.06$$

6.3.2 Rotterdam, Oude Noorden

Figure 6.3 depicts the day-to-day relation between precipitation and induced costs for the department for sewer system management due to solving citizens' complaints.

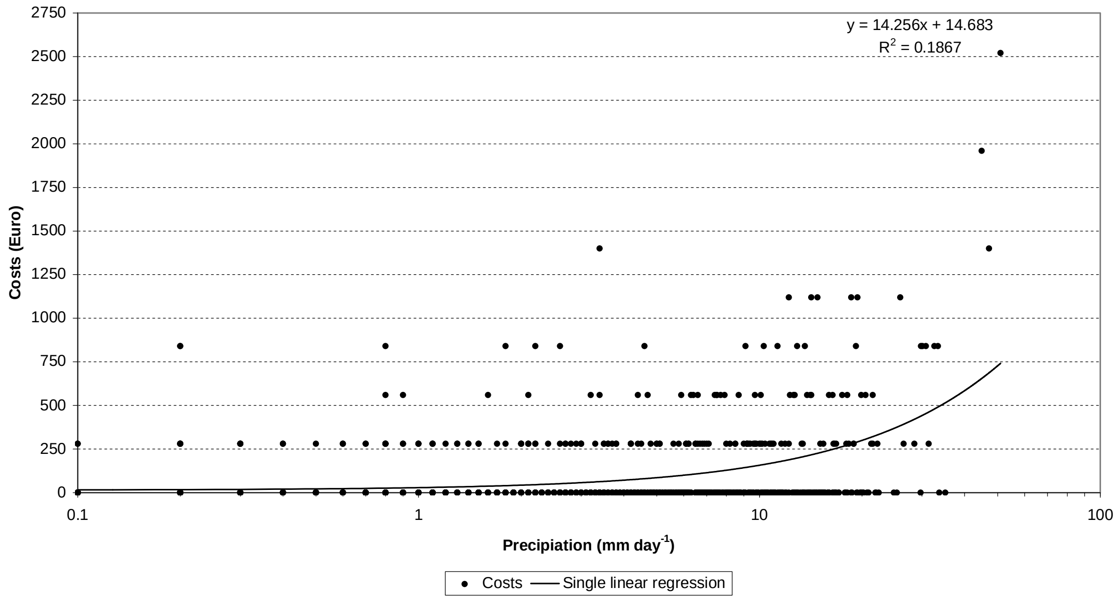


Figure 6.3 Correlation between precipitation and costs for sewer system management in Oude Noorden; data of 2005 – 2010

Similar to the day-to-day results of Amsterdam, figure 6.3 also shows no correlation between the precipitation intensity and costs associated to solving citizens' complaints. Figure 6.4 depicts the relation between precipitation and induced costs, based on cumulated data over wet periods.

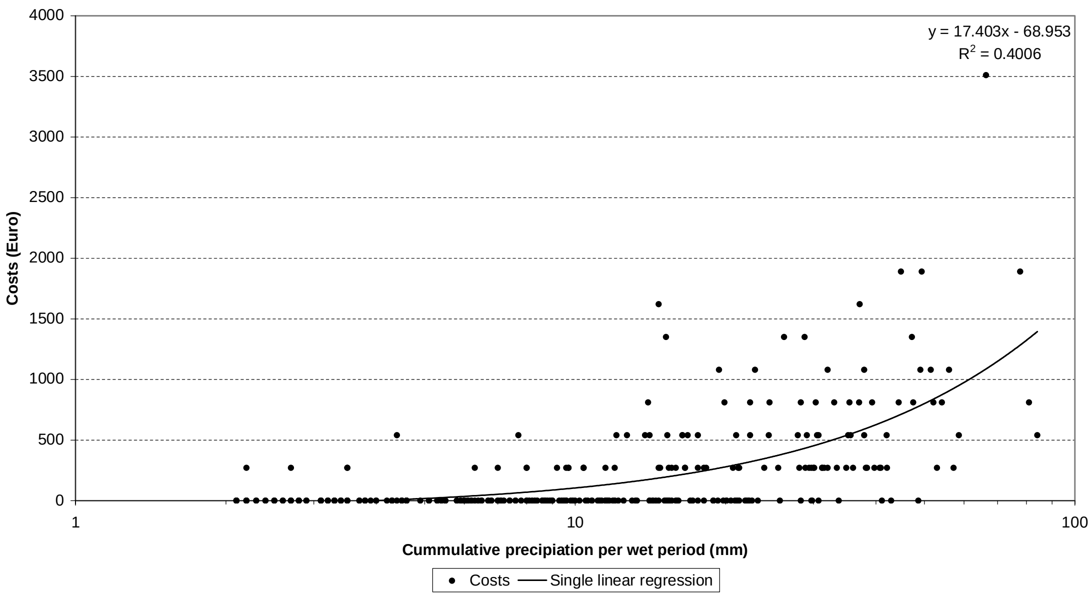


Figure 6.4 Correlation between precipitation and costs for sewer system management in Oude Noorden, cumulated per wet period; data of 2005 - 2010

As shown in figure 6.4, single linear regression shows a regression coefficient R^2 of 0.40, indicating a higher correlation between precipitation and costs for solving citizens' complaints than the correlation on a day-to-day basis.

The associated costs for sewer system management, as a one variable function of precipitation, could be described by:

$$\text{Costs per } 10,000 \text{ inhabitants} = 10.24\,\text{Euro} \cdot \text{mm}^{-1} - 41.15$$

The number of complaints is described by:

$$\text{Complaints per } 10,000 \text{ inhabitants} = 0.04 \cdot \text{mm} - 0.16$$

The results in the presented figures in this paragraph indicate that the day-to-day relation between precipitation and costs for the sewer system management department is weak. This can be explained by the fact that precipitation data coming from a single measurement station is not fully representative for the observed areas when assessing single days. Secondly, the influence of local conditions at micro scale on the occurrence of citizens' complaints, e.g. blocked gully pots or presence of air vents, is considered large. This results in discrepancy between precipitation intensity and expected amount of citizens' complaints. When data is summed over multiple days, the discrepancy decreases significantly as shown by the regression coefficients.

6.4 Summary and discussion

The main question of this chapter is to determine whether a relation is present between precipitation intensity and costs for sewer system management.

Municipal call data combined with precipitation figures provide information about this correlation. Where no correlation is found for single days, a (linear) correlation is found when cumulating precipitation and the number of complaints over wet periods. Costs for sewer system management per 10,000 inhabitants are approximately 4 Euro/mm and 10 Euro/mm for Amsterdam and Rotterdam respectively. Assuming similar average costs for solving one complaint, the costs for sewer system management in Rotterdam are higher than in Amsterdam. A potential explanation can be found in the fact that Amsterdam is almost fully equipped with separated sewer systems, while Rotterdam has a large portion of combined sewer system. This difference in sewer systems could lead to other (more costly) sewer system management approaches.

Unlike material damages to houses (paragraph 4.2), sensitivity to sewer system management assistance increases with increasing precipitation intensity.

The correlation between precipitation and sewer system management costs could be further improved by 1) using more detailed precipitation data to account for spatial variations and 2) using more detailed information about the actual costs for solving complaints.

7 Synthesis and discussion

In the previous chapters, potential consequences and associated costs of pluvial flooding in Dutch urban areas are described. This chapter forms the synthesis of the described pluvial impacts, discusses the results, answers the research questions and describes recommendations.

7.1 Synthesis: impacts of pluvial flooding

Table 7.1 depicts an overview of quantified flood impacts in this study. While some impacts and costs are elaborated on by the use of obtained data, the majority of pluvial flood impacts still have to be approximated by an educated guess.

Table 7.1 Overview of quantified pluvial flood impacts

Impact per category	Size of impact	Remarks
Material impacts		
• Damage to residential buildings, garden and possessions	1 to over 5,000 Euro per flooded property Average content damage: 817 Euro, average property damage: 1,229 Euro	Based on 12 survey respondents. Based on Spekker et al. (2011). No relation yet between precipitation intensity and damages.
• Damage to commercial buildings	2,000 to 30,000 Euro per flooded property	Based on Ten Veldhuis (2010).
• Damage to possessions and stock of commercial buildings	Unknown	Costs are case specific.
• Damage to underground subway	0.9 to 2.8 million Euro per track length	Based on figures from Boston (Compton, 2002).
• Damage to vulnerable objects (schools, hospitals, public utility objects, etc)	Unknown, not reported about	Individual costs might be low. However, the resulting social or economic costs could be considerable.
Economic impacts		
• Traffic delays	Motor vehicle delay costs of 15 Euro hour^{-1} per vehicle Low vulnerability of traffic disruption on busy inner city roads due to high redundancy.	Potential correlation between precipitation and traffic delays; however, not statistically proven.
• Business interruption	Low	Due to short flood durations, workers are able to compensate lost time.
• Outage of public utilities	Unknown	Costs could be considerable.
Health impacts	Risk for sickness due to	Costs for a doctor visit in the

	contact with storm water is approximately 11 %.	Netherlands are approximately 25 Euro.
Emergency assistance impacts		
• Fire department	Unknown	
• Sewer system management	Approximately 4 to 10 Euro per mm of precipitation per 10,000 inhabitants.	
Discomfort	Loss of electricity perceived as most inconvenient	However, not experienced by the respondents.

7.2 Discussion

Before this study started, no overview was available that combined knowledge of pluvial flooding and its associated impacts. Through literature review, stakeholder analysis, data acquisition and survey distribution this study framed the possible impacts of pluvial flooding in Dutch urban areas, and quantified some of these impacts as much as possible. Expressing the vulnerability of urban areas to pluvial flooding, which forms the main driver for this study, is extremely complex. However, the empirical results of this study reveals the tip of an iceberg.

The obtained results of damages, traffic delays, sewer system management, discomfort, etc. in table 7.1 offer knowledge for the creation of dose-response relations for future flood risk assessments. This is elaborated on in paragraph 7.4.

The literature review in chapter 2 provides an overview of the current state of knowledge about pluvial flooding. The results from this literature review indicated several topics that are relatively well-known, e.g. material impacts to properties, and revealed yet unknown territories, e.g. economic impacts.

The surveys results proved to be a good research method for this study. The results are promising. Inhabitants have valuable knowledge about pluvial flooding and its impacts. On top of that, inhabitants are the single source of information about social acceptation and inconvenience of pluvial flooding. Although this stakeholder group is large, it was difficult to reach them in an appropriate and efficient manner. This means, reaching many inhabitants at once and persuading them to participate. This difficulty is reflected in the relatively low response rates.

Municipal call data and traffic data provided knowledge on the one hand about the severity of pluvial flooding, on the other hand about the impact on sewer system management and traffic. Both are related to precipitation intensity coming from yet another data source (KNMI). Based on these data, potential correlations are approximated. Combining and relating the datasets was not at all straightforward, especially for the traffic data.

Three cases were selected, one of which is used only for survey distribution. Each of the cases is situated in the western part of the Netherlands, which are low-lying and have relatively low surface gradients compared to cities in the eastern part of the Netherlands. These areas in the west are less vulnerable to pluvial flooding, since hardly any horizontal water movement occurs. In the east, storm water is converted to depressions in the surface. Therefore, pluvial flood impacts in the eastern part of the Netherlands could be more severe, but are less spatially distributed. Unfortunately, due to the limited data availability and low survey response rates, combined with area characteristics, no similarities or differences between the selected study areas could be identified.

Overall, the amount of available knowledge and data at different stakeholders of pluvial flooding is low. Through this limitation in knowledge and data, it is by no means a straightforward task to define the impacts and costs of a pluvial flood event. In the context of urban flood risk management, the risk (in terms of probability multiplied by consequence) of pluvial flooding cannot be determined. Pluvial flooding does not seem to be perceived as a serious problem that needs to be tackled. Unlike coastal and fluvial flood, pluvial floods generally do not result in wide spread casualties or economic and social disruption (on a regional scale). Therefore, the need for registering knowledge or data about pluvial flood impacts could be low.

7.3 Concluding remarks

This study aimed to explore pluvial flood impacts in Dutch urban areas, by analyzing actors' interests and relevant additional data. Five research questions were set up:

1. Which actors are affected by pluvial flooding in Dutch urban areas?
2. How are the actors affected?
3. Which pluvial flood impacts can be defined, based on literature and an actor analysis?
4. Which data sources are available to generate new knowledge about pluvial flood impacts?
5. Which knowledge can be generated from these additional data sources that quantifies impacts of pluvial flooding?

A general stakeholder analysis provided insight in the affected stakeholders for a pluvial flood event. From this analysis, combined with literature, five categories of pluvial flood impacts are generated:

- material impacts;
- economic impacts;
- health impacts;
- emergency service impacts;
- discomfort.

The actor analysis offered a guide to determine which actors could provide relevant information for the assessment of pluvial flood impacts. This resulted in the distribution of surveys among inhabitants, obtaining data from municipal traffic departments and municipal sewer system management departments. Inhabitants proved to be a valuable source of information for the topic of pluvial flooding. The generated knowledge from these data sources is presented in table 7.1.

Although a first glance or building blocks of pluvial flooding are described, the exploration in this study reveals a large gap in knowledge in the field of urban flood risk management. Not only are we unable to quantify the risk of pluvial flooding, deciding on the implementation of measures could even be inadequate.

7.4 Recommendations

The conclusions emphasis the need for a comprehensive study on pluvial flood events and impacts combining knowledge and skills of inhabitants, municipalities and research agencies. This is needed to make better, or more adequate, decisions on implementing measures to mitigate pluvial flooding.

In several countries, such as the Netherlands and Germany, a trend emerged in flood management to convert from flood prevention to flood risk management. The latter adds the potential consequences of a flood event in taking measures (adopted from Te Linde, 2011, original from Plate, 2002; Merz et al. 2004; Büchele et al., 2006; Merz et al., 2008). This trend arose from awareness that socio-economic development behind flood defenses increases the flood risk.

A comprehensive study on pluvial flood events and impacts should focus on determination of dose-response curves for various types of pluvial flood impacts. For these curves, empirical results from this study can be used, combined with a theoretical approach. Based on these dose-response curves, efficiency of measures can be tested.

The current approach in Dutch urban water management is mostly focused on increasing drainage and storage capacity of sewer systems, which is extremely costly. In terms of dose-response relations, this is a horizontal extraction of the S-shaped curve, as shown in figure 7.1 by the horizontal arrow. This approach represents a certain retardation effect in the dose-response relationship. It simply takes a higher dose to reach the same responses.

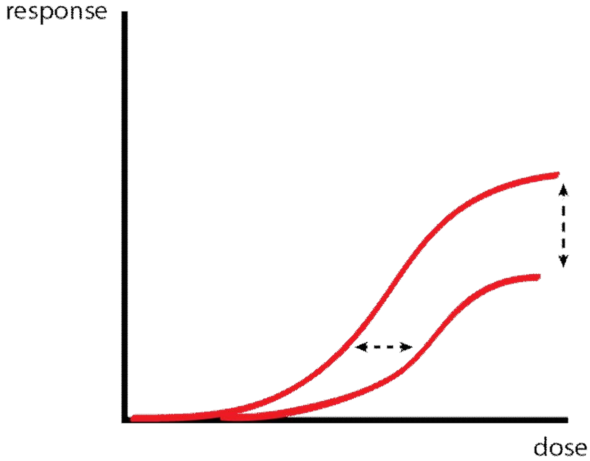


Figure 7.1 Two-way risk reduction in dose-response relations

Another type of risk reduction is present in the vertical contraction of the curve, shown by the vertical arrow in figure 7.1. This risk reduction addresses the responses, i.e. pluvial flood impacts. For example by increasing redundancy in the tram network, elevating vulnerable object of utility services, adjustment of building codes, etc. According to expert judgment within Deltares, addressing the responses is less costly than investing in the sewer system. Yet, the main challenge is to quantify the responses at a certain dose.

Addressing responses in taking measures to mitigate pluvial flooding is in line with the described ‘flood risk awareness and acceptation’ trend in the Dutch National Water plan 2009 - 2015 (Ministry of Infrastructure and the Environment, 2009).

Changes in our climate are expected to result in an increase of extreme precipitation events. This emphasizes even more the need for a shift in pluvial flood management, from a ‘flood safe’ to a ‘safe flood’ approach, where other types of measures are implemented.

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A List of interviewed persons

Name	Organization	Date
P. Hartog	Waternet, Amsterdam	23-02-2011
A. Fermont	Waternet, Amsterdam	23-02-2011
R. Nijman	Waternet, Amsterdam	01-03-2011
E. Koopman	Waternet, Amsterdam	01-03-2011
P. Nieuwenburg	Waternet, Amsterdam	14-03-2011 17-03-2011
R. Vogel	Waternet, Amsterdam	14-03-2011
B. Soolsma	Stadsdeel Oost, Amsterdam	14-03-2011
A. Blankert	Department of Infrastructure Traffic and Transport, Amsterdam	30-03-2011 16-05-2011
L. Plender	Municipality Rotterdam, department of	29-03-2011
J. Sturm	Department of Urban Planning and Public Housing, sub department Traffic and Transport, Rotterdam	05-04-2011
W. Paling	Municipality Rotterdam	10-06-2011
H. de Man-van der Vliet	Utrecht University	19-05-2011

B Stakeholder analysis

A general stakeholder analysis is performed that account relevant stakeholders potentially affected by a pluvial flood event in a Dutch city. Table B.1, the stakeholder analysis is depicted, combining the stakeholder, its impact and the rationale for including the stakeholder.

Table B.1 Stakeholder analysis for pluvial flooding in the Netherlands

Main stakeholder group	Stakeholder group	Stakeholder	Impact	Rationale
Directly affected	Citizens	Inhabitants	Flooded house, cellar and garden	News bulletins, Verbond van verzekeraars (2010)
			Overflowing toilets and sinks	Experience
			Contact with flood water	Sterk (2008)
			Temporarily moving out (because of drying time)	Unknown
			Stench	Experience
			Inconvenience (e.g. loss of mobility, not walking dog)	News bulletins
			Loss of electricity	Unknown
			Loss of communication services	Unknown
		Commuters	Travel delays	Expectation
	Public services	Schools, child care, sports club, community center, home for elderly, sheltered workshop public transport stations and stops	Flooded building	Schools: news bulletins
			Loss of service	Remainder: unknown
	Businesses	Public utility companies	Flooded utilities (objects)	Expectation
			Loss of utility services	Expectation
		Shops (retail and supermarkets)	Flooded stock and building	News bulletins
			Turnover loss (including due to decrease in access)	News bulletins
		Other businesses (non retail)	Flooded building and possessions	Unknown
			Turnover loss	Unknown
	Traffic	Public transport	Road or network blockage, including tunnels	News bulletins
		Cars and trucks	Road blockage, including tunnels	News bulletins and experience
		Cyclists & pedestrians	Road or sidewalk blockage	News bulletins and experience
			Contact with flood water	Sterk (2008)
	Housing corporation		Flooded houses	Expectation
	Municipality		Flooded public objects/services	News bulletins
Affected through response	Emergency services	Fire dept	Remove water by pumps	News bulletins
		Police dept	Control traffic and public order	Expectation
	Medical care	Municipal health service, hospitals	Illness of citizens	Sterk (2008)
	Municipality		Handling complaint calls	Ten Veldhuis (2010)
Affected through responsibility for recovery	Municipality		Flooded public objects/services	Expectation
			Drainage system management	Expectation
			Management pumping stations	Expectation
			Coordination emergency services	Expectation
			Communication to citizens	Expectation
			Trigger for adaptation measures	Expectation
	Water Board		Interaction with surface water (overflows, run off)	Expectation
			Management pumping stations	Expectation
	Insurance companies		Insurance claims from inhabitants	Verbond van Verzekeraars (2010)

For several stakeholders, it is unknown whether they are affected. Yet, based on expert judgment, they seem relevant to account for in the assessment of pluvial flood impacts.

C Traffic data

Traffic delays are computed by the use traffic data acquired from the Department of Infrastructure Traffic and Transport in Amsterdam (in Dutch: Dienst Infrastructuur Verkeer en Vervoer, DIVV) and the Department of Urban Planning and Public Housing, sub department of Traffic and Transport (in Dutch: Dienst Stedenbouw en Volkshuisvesting, afdeling Verkeer en Vervoer) in Rotterdam.

The data consist of travel time between two fixed traffic registration cameras, i.e. road segments.

Traffic registration cameras are distributed along major roads throughout the city in order to measure traffic flow rates on multiple road segments. The traffic registration cameras capture a vehicle's license plate, which is coded directly. When the vehicle passes a second camera, when is linked to the first camera, the travel time of that vehicle is registered. The purpose of measuring traffic flow rates is to direct traffic lights and to distribute traffic onto alternative routes if necessary, by using traffic models.

To eliminate variances in travel time, caused by alternative routing, stop-and-go or other influences, certain algorithms are applied to the raw travel time data.

C.1 Amsterdam data

Data is acquired of the total city of Amsterdam, for the period of April 1 2010 to March 27 2011.

Traffic data of Amsterdam is raw data from the traffic registration cameras. No algorithm is applied to the data, resulting in great variation of travel speed of approximately 1.2 to 28.0 km h^{-1}.

No distinction in the traffic data is made for the type of registered vehicles.

According to DIVV, a test for measurement error in February and March 2010 with 95 cameras showed an average registration percentage of 90.7 %.

C.2 Rotterdam data

Data is acquired of one road registered road segment in Rotterdam, for the periods of July 11 to July 17 2010 and August 15 to August 28 2010.

The traffic data is aggregated into average traffic speed per fifteen minutes, resulting in smaller variation in travel speed compared with the data of Amsterdam.

According the department of Traffic and Transport, the average registration percentage is 90 %.

D Citizens’ complaints call data

The call data from citizens’ complaints are acquired from Waternet, for Stadsdeel Oost, and from Gemeentewerken Rotterdam for the case of Oude Noorden. Call data for both cases are available for the period of January 1 2005 to December 31 2010.

D.1 Amsterdam data

The data acquired from Waternet consist of complaints of blocked gully pots, solved by the sewer system management department. The data consists of the following features per registered solved complaint:

- date of solving the complaint;
- complaint category code;
- corresponding location in terms of a code that refers to a city district
- remarks.

The registered solved complaints of blocked gully pots do not provide knowledge of the number of citizens’ calls per solved complaint and the cause of the complaints. For the area of Stadsdeel Oost in the period of 2005 to 2010, 1,590 solved complaints have been registered, which is 12 % of the amount of solved complaints for the total city of Amsterdam for that period.

D.2 Rotterdam data

The data acquired from Gemeentewerken Rotterdam consist of complaints (mostly) solved by the sewer system management department. The data consists of the following features per registered complaint:

- date of the complaint;
- date of the solving of the complaint;
- location in terms of the name of the city district;
- location in terms of the name of the neighborhood;
- location in terms of the name of the street;
- category of the type of complaint;
- description of the citizen’s complaint, written down by an employee of the municipality.

The total database acquired from Gemeentewerken Rotterdam consists of eleven categories of complaints:

- (blocked) culvert;
- groundwater;
- main sewer network;
- gully pot;
- gully pot general;
- blocked gully pot;
- no/poor drainage capacity;
- stench nuisance;
- malfunctioning of pumping station;
- water nuisance in houses;
- other water nuisance.

Filtering of the data is needed to exclude all complaints not related to nuisance caused by (heavy) precipitation. Table D.1 depicts the description and amount of the remaining complaints filtered from the total dataset.

Table D.1 Filtered registered complaints of Oude Noorden in the period 2005 – 2010, related to nuisance caused by (extreme) precipitation

Complaint description	Amount N
Blocked/full gully pot or manhole	341
Flooding of garden	6
Flooding of building	41
Total	387
Total unfiltered complaints for Oude Noorden	723
Total unfiltered complaints for Rotterdam	33,978

E Surveys

Surveys among inhabitants were distributed with the aim of obtaining information about inhabitants' experiences with pluvial floods. Since no ready to use data about urban pluvial flood experiences has been documented so far, people's experience is a valuable source of information.

In order to reach inhabitants, articles in media have been published that aimed at persuading people to go to a website to fill in a digital survey. Since the response to the digital survey was relatively low, an analogue survey was distributed in Amsterdam and Rotterdam. Table E.1 depicts the locations and means by which the digital survey was presented to inhabitants.

Table E.1 Means of survey distribution in Amsterdam, Rotterdam and Gouda

Amsterdam	Rotterdam	Gouda
Stadsdeelkrant Oost (newspaper of Stadsdeel Oost)	Newspaper Noorderzon (newspaper of Oude Noorden and adjacent Agniesebuurt)	Digital survey through publication on website of the city district of:
Website www.watergraafsmeer.org	Analogue survey through community center Mozaïek	– Binnenstad (city center) – Wervenbuurt – Stolwijkersluis
Linkedin weblink		
Twitter link		
Analogue survey through random sampling		

Below, each publication in the different media is depicted.

Stadsdeelkrant Oost of May 12 2011 (Dutch newspaper of Stadsdeel Oost)

Oost.
amsterdam.nl
Jaargang 4
nummer 18
12|05|11

Enquête over overlast door extreme regenval

Het kan iedere bewoner, en dus ook u overkomen; een extreme regenbui met als gevolg dat straten blank staan of zelfs regenwater in huis. Om schade en kosten door extreme regenbuien in de toekomst te kunnen beperken, doet het kennisinstituut Deltares samen met Waternet onderzoek naar extreme regenbuien en de gevolgen daarvan.

Stadsdeel Oost is in dit onderzoek aangewezen als onderzoeksgebied. Door uw ervaring en mening te delen kan gericht beleid worden ontwikkeld of bijgesteld om kosten en ongemak door extreme regenbuien te verminderen. Wilt u bijdragen aan dit onderzoek, ga dan naar de website: regenoverlast.deltares.nl en vul op deze website de enquête in.

Website WATERgraafsmeer

http://www.watergraafsmeer.org/projecten-en-activiteiten/enquete-regenwateroverlast

Water graafs meer

Enquête regenwateroverlast

Heeft u wel eens last gehad van wateroverlast in de straat of een ondergelopen kelder door extreme regenval? Het kan iedere bewoner, en dus ook u overkomen. Door veranderingen in het klimaat zal het vaker heviger gaan regenen. Het riool kan het regenwater in zo'n situatie niet meer afvoeren waardoor er regenwateroverlast kan ontstaan. Om schade en kosten in de toekomst te kunnen beperken, doet Deltares samen met Waternet onderzoek naar de gevolgen van extreme regenbuien. Met dit onderzoek willen we leren van de ervaringen van bewoners in Stadsdeel Oost. De resultaten van deze enquête worden gebruikt om een beter beeld te krijgen welke maatregelen getroffen kunnen worden om regenwateroverlast te verminderen. Uw ervaring en mening zijn hierbij erg belangrijk. Wilt u bijdragen aan dit onderzoek, vul dan deze enquête in.

Noorderzon edition May 2011 (newspaper of Oude Noorden and Agniesebuurt)

NOORDERZON

HUIS-AAN-HUISKRANT VOOR DE BEWONERS VAN HET OUDE NOORDEN / AGNIESEBUURT NUMMER 33 • MEI 2011

Overlast door extreme regenval: geef uw mening!

Heeft u wel eens last gehad van wateroverlast in de straat of een ondergelopen kelder door extreme regenval?

Het kan iedere bewoner, en dus ook u overkomen. Door veranderingen in het klimaat zal het vaker heviger gaan regenen. Het riool kan het regenwater in zo'n situatie niet meer afvoeren waardoor er wateroverlast ontstaat. Om schade en kosten in de toekomst te kunnen beperken, doet Deltares samen met de gemeente Rotterdam onderzoek naar de gevolgen van extreme regenbuien. Met dit onderzoek willen we leren van de ervaringen van bewoners in het Oude Noorden en de Agniesebuurt. De resultaten van deze enquête worden gebruikt om een beter beeld te krijgen welke maatregelen getroffen kunnen worden om regenwateroverlast te verminderen. Uw ervaring en mening over overlast door extreme regenbuien zijn hierbij erg belangrijk.

Wilt u bijdragen aan dit onderzoek, ga dan naar de website: noorderzonregenwater.deltares.nl en vul op deze website de enquête in.

Newsletter Binnenstad Gouda of May 4 2011 (City center of Gouda)

BINNENSTAD GOUDA

NIEUWSBRIEF

WIJKTEAM BINNENSTAD GOUDA | woensdag 4 mei 2011

Enquête over de gevolgen van wateroverlast

Door veranderingen in het klimaat zal het vaker heviger gaan regenen. Het riool kan het regenwater in zo'n situatie niet meer afvoeren waardoor er wateroverlast ontstaat. Om schade en kosten in de toekomst te kunnen beperken, doet Deltares in samenwerking met andere partijen onderzoek naar de gevolgen van extreme regenbuien. Met dit onderzoek willen we leren van de ervaringen van bewoners in de Binnenstad van Gouda. De resultaten van deze enquête worden gebruikt om een beter beeld te krijgen welke maatregelen gemeenten kunnen treffen om toekomstige regenwateroverlast te verminderen. Uw ervaring en mening over overlast door extreme regenbuien zijn hierbij erg belangrijk.

Wilt u bijdragen aan dit onderzoek, ga dan naar de website en vul hier de enquête in. Alvast bedankt voor uw medewerking!

Publication on website of Stolwijkersluis in Gouda on May 28 2011

http://www.stolwijkersluis.nl/index.php?limitstart=10

Wateroverlastenquête

Geschreven door Stichting Buurtschap Stolwijkersluis
zaterdag, 28 mei 2011 16:00

Beste Stolwijkersluizers,

In het kader van een nationaal klimaatonderzoek (Kennis voor Klimaat) is het verzoek gekomen om bewoners van Stolwijkersluis te laten deelnemen aan een enquête. Hierbij het vriendelijke verzoek aan u deze enquête in te vullen. Het ontvangen verzoek en de link naar de enquête staan hieronder.

Geachte bewoner van Buurtschap Stolwijkersluis,

Het kan iedere bewoner, en dus ook u overkomen; een extreme regenbui met als gevolg dat straten blank staan of zelfs regenwater in huis.

Om schade en kosten door extreme regenbuien in de toekomst te kunnen beperken, doet het kennisinstituut Deltares onderzoek naar extreme regenbuien en de gevolgen daarvan. Met dit onderzoek willen we leren van de ervaringen van de bewoners van Gouda. Door uw ervaring en mening te delen kan gericht beleid worden ontwikkeld of bijgesteld om kosten en ongemak door extreme regenbuien te verminderen. Wilt u bijdragen aan dit onderzoek, ga dan naar de website: http://regenoverlastgouda.deltares.nl en vul op deze website de enquête in.

Alvast bedankt voor uw medewerking.

Vriendelijke groet,

Wouter van Riel

The text of the (Dutch) surveys is depicted in the text box below. Per study area, the appropriate location and partner are filled in.

Geachte heer/ mevrouw,

Heeft u wel eens last gehad van wateroverlast in de straat of een ondergelopen kelder? Het zou iedere bewoner kunnen gebeuren. Door veranderingen in het klimaat zal het vaker heviger gaan regenen. Het riool kan het regenwater in zo een situatie niet meer afvoeren waardoor er wateroverlast ontstaat. We noemen dit ook wel "regenwateroverlast".

Deltares en [partner] doen onderzoek naar het optreden van extreme regenval en de gevolgen daarvan. Via deze enquête willen we leren van de ervaringen van bewoners die wonen in [locatie]. De resultaten van deze enquête worden gebruikt om een beter beeld te krijgen welke maatregelen getroffen kunnen worden om regenwateroverlast te verminderen. Denk bijvoorbeeld aan het vergroten van de riolering.

De enquête maakt deel uit van een onderzoek naar de gevolgen van regenwateroverlast in Nederlandse steden, dat uitgevoerd wordt door Deltares in samenwerking met [partner]. Zie voor meer informatie www.klimaatonderzoeknederland.nl.

De vragen zijn bedoeld om de ideeën en ervaringen die mensen hebben van regenwateroverlast in kaart te brengen. Kies daarom steeds voor het antwoord dat het beste bij uw mening of gevoel aansluit. Uw antwoorden zullen volledig anoniem worden verwerkt en zullen niet voor andere doeleinden worden gebruikt.

Het invullen van deze vragenlijst duurt ongeveer 10 minuten.

We hopen dat u tijd wilt vrijmaken om ons met dit onderzoek te helpen. Voor vragen kunt u contact opnemen met ondergetekende.

Wouter van Riel

Deltares
E.wouter.vanriel@deltares.nl
T. 088 - 335 7624

1. Heeft u in de afgelopen vijf jaar een situatie van regenwateroverlast meegemaakt?
   - o Ja, in [locatie].
   - o Ja, maar buiten [locatie].
   - o Nee, ik heb dit de afgelopen 5 jaar niet meegemaakt.

Als u vraag 1 met Nee beantwoord hebt, kunt u direct doorgaan naar vraag 9.

2. Wanneer en waar heeft u in de afgelopen vijf jaar een situatie van regenwateroverlast meegemaakt?

Vul in onderstaande tabel één of meerdere periodes in waar u als eerste aan denkt, met bijbehorende plaatsen.

Maand	Jaar	In [locatie]: ja of nee?	Indien nee: elders, namelijk in…

3. Hoe lang heeft de totale overlast voor u persoonlijk geduurd in uw genoemde situatie in vraag 2?

   Als u bij vraag 2 meerdere situaties heeft opgeschreven, ga dan uit van uw meest ernstige situatie in [locatie].
   - o 1 tot enkele uren
   - o Ongeveer 1 dag
   - o 2 tot 3 dagen
   - o 4 - 14 dagen
   - o Meer dan 2 weken

4. Welke gevolgen van regenwateroverlast heeft u meegemaakt in de afgelopen 5 jaar in [locatie] of daarbuiten? In onderstaande tabel kunt u voor ieder gevolg ja of nee aankruisen. Indien nodig kunt u zelf extra gevolgen invullen onderin de tabel.

Gevolg	**Ja, ik heb dit de afgelopen vijf jaar meegemaakt in [locatie]**	**Ja, ik heb dit de afgelopen vijf jaar meegemaakt, maar buiten [locatie]**	**Nee, ik heb dit de afgelopen vijf jaar niet meegemaakt**
Waterschade aan huis / onroerend goed			
Waterschade aan tuin			
Waterschade aan inboedel			
Overlopende toiletten			
Stank			
Gezondheidsklachten door contact met water			
Uitval of storing van elektriciteit			
Uitval of storing van internet			
Verstoring van verkeer, stremming vervoer, inclusief fietsverkeer			
Verlies van bewegingsvrijheid (niet de straat op kunnen)			
Hond niet kunnen uitlaten			
Tijdelijke verhuizing, omdat huis onbewoonbaar was			
Uitval van scholen			
Uitval van kinderopvang			
Geen toegang tot winkels			

Andere, namelijk…			
Andere, namelijk…			
Andere, namelijk…			

5. Waardoor zijn de gevolgen die u in bovenstaande tabel van vraag 4 heeft aangekruist veroorzaakt?
   - o Regenwater
   - o Grondwater
   - o Gesprongen waterleiding
   - o Een combinatie van bovengenoemde drie oorzaken
   - o Anders, namelijk...
   - o Ik weet het niet

6. Hoe erg of vervelend heeft u de verschillende gevolgen van regenwateroverlast ervaren die u in vraag 4 met 'ja' heeft beantwoord? Geef uw mening in onderstaande tabel door het voor u meest passende antwoord aan te kruisen. Indien nodig kunt u zelf extra gevolgen invullen onderin de tabel.

Gevolg	**Niet erg**	**Een beetje vervelend**	**Vervelend**	**Behoorlijk vervelend**	**Extreem vervelend**
Waterschade aan huis / onroerend goed					
Waterschade aan tuin					
Waterschade aan inboedel					
Overlopende toiletten					
Stank					
Gezondheidsklachten door contact met water					
Uitval of storing van elektriciteit					
Uitval of storing van internet					
Verstoring van verkeer, stremming vervoer, inclusief fietsverkeer					
Verlies van bewegingsvrijheid (niet de straat op kunnen)					
Hond niet kunnen uitlaten					
Tijdelijke verhuizing, omdat huis onbewoonbaar was					
Uitval van scholen					
Uitval van kinderopvang					
Geen toegang tot winkels					
Andere, namelijk…					
Andere, namelijk…					

Andere, namelijk…					

7. Indien u schade heeft ondervonden in uw genoemde situatie in vraag 2, wat waren de totale kosten van gevolgen van regenwateroverlast in Euro? Als u bij vraag 2 meerdere situaties heeft opgeschreven, ga dan uit van uw meest ernstige situatie van [locatie].
   o Geen schade: 0 Euro
   o 1 tot 500 Euro
   o 501 tot 2.000 Euro
   o 2.001 tot 5.000 Euro
   o meer dan 5.000 Euro

8. Zijn deze kosten uit vraag 7 door uw verzekeraar vergoed?
   o Ik heb de schade niet geclaimd.
   o Nee, ik was voor deze schade niet verzekerd.
   o Nee, ik was voor deze schade wel verzekerd, maar mijn verzekeraar heeft niets vergoed.
   o Ja, mijn verzekeraar heeft deze schade geheel of gedeeltelijk vergoed.

9. Hoe vaak vindt u dat regenwateroverlast zou mogen voorkomen?
   o Maximaal eens per jaar
   o Maximaal eens in twee jaar
   o Maximaal eens in vijf jaar
   o Maximaal eens in 10 jaar
   o Nooit

10. Kunt u aangeven welke gevolgen van regenwateroverlast voor u het meest vervelend zijn? Geef een top 5, waarin op nummer 1 het gevolg staat dat voor u het meest vervelend is.

Nummer	Gevolg
	Waterschade aan huis / onroerend goed
	Waterschade aan tuin
	Waterschade aan inboedel
	Overlopende toiletten
	Stank
	Gezondheidsklachten door contact met water
	Uitval of storing van elektriciteit
	Uitval of storing van internet
	Verstoring van verkeer, stremming vervoer, inclusief fietsverkeer
	Verlies van bewegingsvrijheid (niet de straat op kunnen)
	Hond niet kunnen uitlaten
	Tijdelijke verhuizing, omdat huis onbewoonbaar was
	Uitval van scholen
	Uitval van kinderopvang
	Geen toegang tot winkels
	Andere, namelijk…
	Andere, namelijk…
	Andere, namelijk…

11. Als u de keuze zou hebben om jaarlijks een extra bedrag te betalen zodat regenwateroverlast niet meer voorkomt, welk bedrag zou u dan bereid zijn jaarlijks te betalen?

Er is op dit moment geen regeling of verzekering beschikbaar, het gaat erom dat u aangeeft voor welk jaarlijks bedrag u regenwateroverlast zou willen vermijden.

- o Geen bijdrage
- o 1 - 25 Euro per jaar
- o 26 - 100 Euro per jaar
- o 101 - 500 Euro per jaar
- o Meer dan 500 Euro per jaar

12. Wat is uw geslacht?
    - o Man
    - o Vrouw

13. Wat is uw leeftijd?
    - o Jonger dan 21 jaar
    - o 21 tot 40 jaar
    - o 41 tot 60 jaar
    - o 61 jaar of ouder

14. Woont u op dit moment in [locatie]?
    - o Ja
    - o Nee

F Concepts of climate adaptation

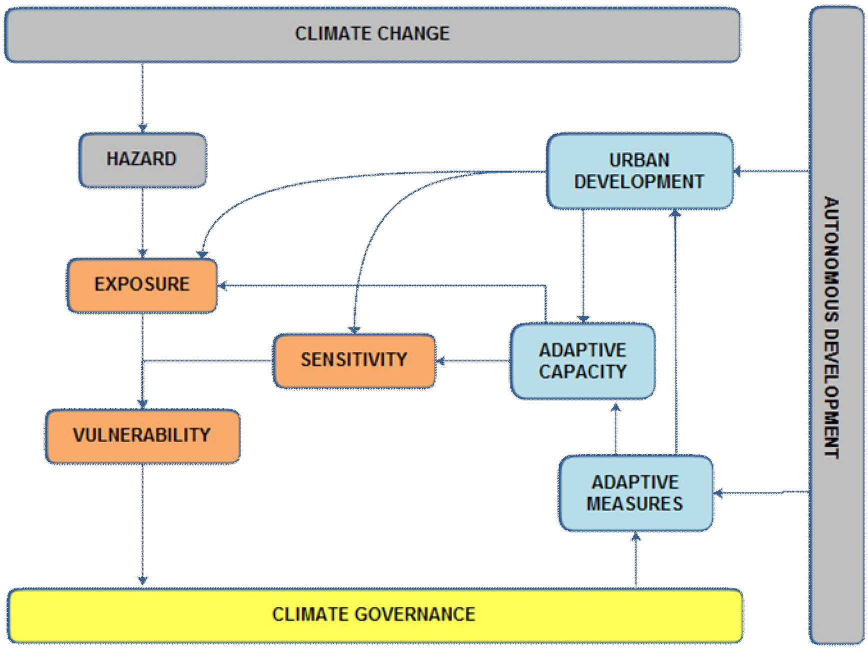

Figure F.1 Schematic overview of climate adaptation and related concepts (Van de Ven et al., in press)

- Climate change: climate change is a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or due to human activity (IPCC, 2007). The expected increase of extreme precipitation as one example of climate change is the subject of this study.
- Hazard: a physical event, phenomenon or human activity with the potential to result in harm. A hazard does not necessarily lead to harm (Gouldby and Samuels, 2005). Within Climate Proof Cities, a set of natural hazards are selected that seem applicable and important for Dutch urban areas. These comprehend (Van de Ven et al., in press):
  – water safety;
  – water nuisance (pluvial and groundwater flooding);
  – drought;
  – heat stress.

  From these four hazards, pluvial flooding is the topic of this study.
- Exposure: quantification of the receptors that may be influenced by a hazard (Gouldby and Samuels, 2005). Within Climate Proof Cities it is similarly defined as the extent and intensity where the hazard comes into contact with assets. Generally, the larger the distance of an area is towards open water (in which storm water drainage can discharge during extreme rainfall), the more exposed an area is to pluvial flooding (Van de Ven et al., in press). The number of inhabitants in a certain area could be one of the quantities to express exposure.
- Sensitivity: the level in which exposure to some climate related effect results in an impact (Van de Ven et al., in press). For pluvial flood for example, sensitivity could be determined for example by the sewer system storage capacity, the sidewalk curb height,

the doorstep height of houses or the presence of road junctions for alternative traffic routes.

- Vulnerability: characteristic of a system that describes its potential to be harmed (Gouldby and Samuels, 2005). De Graaf et al. (2009) defined vulnerability as a combination of:
  - threshold capacity, which is the capacity to prevent exposure to climate perturbations;
  - coping capacity, which is the capacity to deal with perturbations when they take place;
  - recovery capacity, which is the capacity to recover from perturbations after they have taken place;
  - adaptive capacity, which is the capacity to anticipate change of climate vulnerability on the long term.

  In Climate Proof Cities, vulnerability is the combination of exposure and sensitivity (Van de Ven et al., in press). Based on (Parker et al., 1987) vulnerability to interruption of economic impacts depends on three main aspects (Penning-Roswell et al., 2005):
  - the physical susceptibility to flooding of objects supporting an economic activity;
  - the dependency of stakeholders served by that economic activity;
  - the rate of transferability of activities to non-interrupted locations (redundancy).

  For pluvial flooding, vulnerability could be defined as the level to which extreme precipitation in an area leads to pluvial flood impacts.
- Climate governance: a policy framework in which climate related problems are addressed by formulation of incentives, guidelines and measures.
- Adaptation measures: actual responses to mitigate impacts of climate change on people, assets and activities (modified from Van de Ven et al., in press).
- Adaptive capacity: the ability to possess or to have access to physical/material, social and attitudinal responses to effects of climate change (adapted from Wisner et al., 2003; Anderson and Woodrow, 1989). Where this definition focuses on the human component in adaptive capacity related to natural disasters, the definition in Climate Proof Cities is reduced to ‘the ability to apply climate related responses’, including response capacity in the future (Van de Ven et al., in press). In Climate Proof Cities, it is used as a term to express the ‘room for potential change’ in spatial planning. As such, adaptive capacity is mainly determined by the expected end of lifespan of individual urban assets.
- Autonomous development: general societal changes not necessarily related to climate change, which to some extend influence the socio-economic conditions for adaptation response as well as the development of the urban environment (Van de Ven et al., in press).
- Urban development: the development in an urban area due to a combination of autonomous development and adaptive measures through climate governance, resulting in different levels of exposure and sensitivity towards effects of climate change (modified from Van de Ven et al., in press).