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## Supplementary material A: Actor analysis

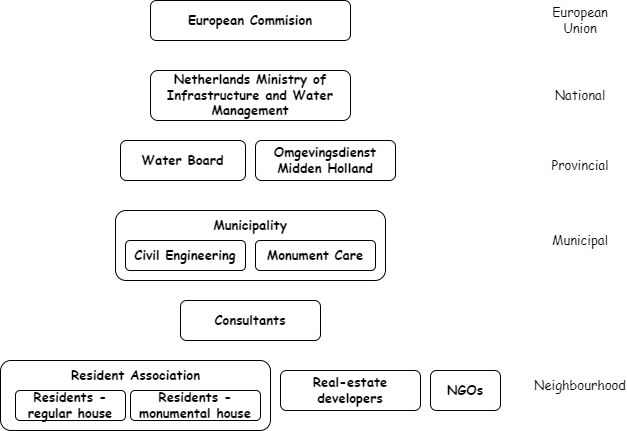


Figure 3: Map with list of actors at different levels of governance

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Stakeholder** | **Role** | **Resources** | **Actions** | **Objectives** | **Policies/regulations** |
| **European**  **Commission** | * Making policies for the EU | * Legal framework, regulations, policy * Budget | * Rules about permissible limits of e.g. micropollutants * Guidelines. monitoring requirements * Setting priorities of actions, e.g. preventive measures including green infrastructure * Subsidies for several policy portfolios | * Protect the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors * Ensure that domestic and industrial wastewater is effectively collected, treated and discharged * Climate mitigation and adaptation | * European Urban Wastewater directive * European Water Framework Directive * Groundwater directive * Nitrogen levels |
| **NL Ministry of Infrastructure and Environment** | * Making policies for the NL | * Legal framework, regulations, policy * Budget | * Standards regarding water quantity, water quality and fulfilment of functions * Subsidies related to policy portfolio | * Spatial adaptation: spatial planning is as climate-proof and water-robust as possible, eliminating any incidental flood-related risks of damage and victims, to the extent that this is reasonably feasible * Climate-robust design in area development, new construction, repurposing or renovation | * The Environmental Management Act provides the legal basis for the GRP, the discharge rules and the handling of urban waste water. * The municipal duties of care for rainwater and groundwater are laid down in the Water Act. * Procedures for granting permits follow from the Environmental Law General Provisions Act (Wabo). * Rules for spatial integration and the construction process follow from the Spatial Planning Act (Wro) and the Building Decree. |
| **Water Board** | * Treatment of wastewater * Surface water quality and water levels * Rues for what and what legal persons are (not) allowed to dump | * Policy – elected regional government body * Waterschapsebelasting (Water management tax) * . * Rules/penalties for surface water quality | * Limit or extend capacity of wastewater treatment * Maintain surface water quality * Administrative measures and fines for non-compliance * Provide subsidies for blue-green neighbourhoods | * Reduce amount of wastewater to be treated, reduce sewer overflows * Improve quality of surface water | * Roles and responsibilities defined by the Dutch Water Act |
| **Municipality – civil engineering** | * Collection and transport of rainwater (from public land) and wastewater (from private land) * Obliged to make an effort to collect rainwater if for a civilian it is unreasonable to do it (private land) * Make an effort to resolve structural GW problems * Spatial planning | * Regulation and policy via municipal council– elected local government body * Rioolheffing: sewer tax * Spatial planning rules * Urban drainage rules/decisions | * Upgrade sewer system * Decide UWM solutions to be implemented on public lands * Incentives for citizens * Spatial planning rules * Administrative measures and fines for non-compliance * Provide subsidies for green roofs and other “sustainability measures” | * Climate adaptation * Reduce flooding * Reduce heat stress * Reduce damage and casualties due to poor UWM | * Roles and responsibilities defined by the Dutch Water Act * Rainwater and Groundwater Discharge Ordinance are decisive for environmental management (and thus sewerage management) within the municipality. * At the level of the municipality, the Municipalities Act (the basis for the sewerage charge) – * Set rules for new developments and how they should treat their water, where to connect wastewater and what to do with stormwater * Environmental management Act * The Zoning Plan is decisive for spatial planning |
| **Municipality - Monument Care** | * Lay down rules for protecting the heritage value of the city remains intact | * Regulation and policy via municipal council – elected local government body | * Law down rules for what constitutes a monument and not * Provision of subsidies for renovations to monumental houses * List of allowed changes * Administrative measures and fines for non-compliance | * Protect the monumental value of the neighbourhoods and city * Make monuments more sustainable |  |
| **Residents – monumental houses** | * Decision makers as owners of private land | * Voting for the local municipality, water board, provincial government, national government and European government bodies (eligibility depending in nationality and residence status) * Sewer taxes * Private house ownership or tenancy rights | * Implement households SuDS | * Decrease living costs * Increase well being and liveability of the neighbourhoods * Live in a flood-poof area * Low impact of floods and corresponding damage/repair costs * Low nuisance (frequent construction activities, etc.) | * Responsible for water on their own land * Responsible for preserving the monumental value of the house they live-in * Regulations to abide by: Environmental permit laws under the Environmental Law General Provisions Act (“Wet algemene bepalingen omgevingsrecht” in Dutch): <https://wetten.overheid.nl/BWBR0024779/2018-07-28#Hoofdstuk1> * Guidelines to abide by: <https://www.monumenten.nl/gids> |
| **Residents – non - monumental houses** | * Pseudo decision-makers makers as owners of private land | * Voting for the local municipality, water board, provincial government, national government and European government bodies (eligibility depending in nationality and residence status) * Sewer taxes * Private house ownership or tenancy rights | * Implement households SuDS * Seek permits from OMDH for renovations and changes to the house | * Decrease living costs * Increase well-being and liveability of the neighbourhoods * Live in a flood-poof area * Low impact of floods and corresponding damage/repair costs * Low nuisance (frequent construction activities, etc.) * Low hassle of applications and permits for making changes to house | * Responsible for water on their own land * Regulations to abide by: Environmental permit laws under the Environmental Law General Provisions Act (“Wet algemene bepalingen omgevingsrecht” in Dutch): <https://wetten.overheid.nl/BWBR0024779/2018-07-28#Hoofdstuk1> * Guidelines to abide by: <https://www.monumenten.nl/gids> |
| **Real-estate developers** | * Develop housing and rent it out | * Land * Money (capital) * Own land and buildings (temporarily) | * Implement water retention/infiltration solutions * Rent control | * Profit (decrease cost to company) | * Responsible for water on their own land |
| **NGOs** | * Lobby for pro-environmental behaviours/policies | * Lobbying pressure * Gateway to media to influence public opinion | * Protests * Pro-environmental content/reports * Independent performance evaluation of institutions | * Ensure citizen welfare * Low environmental impact * Climate change adaptation * Mandatory green measures in housing construction |  |

## Supplementary material B: Interview protocol for building cognitive maps

***Interview with residents***

*Context/issue description:*

We are here to talk about the city of FloodCity. FloodCity has been experiencing frequent flooding due to intense rainwater showers. When it rains heavily, polluted water either goes to the canals or floods the streets. Different solutions exists, from replacing or upgrading the sewers to implementing sustainable blue-green solutions such as rooftop gardens or water barrels. This would require cooperation and converging to an acceptable solution for all stakeholders. Through today’s interview, I want to understand the perspective of a resident about the problem of flooding in FloodCity.

*Introduction*

1. Can you briefly introduce yourself? (Name, profession and organization/department) And the role of the sounding board?
2. Do you live in a monument building?
3. How much sewer/water taxes do you pay currently as a resident?

*Goals/objectives*

1. What’s the problem in FloodCity from your perspective with regards to flooding due to intense rainfall? [residents: How the issue of flooding directly or indirectly impact you?]
2. How does this impact you? Or why is this issue important to you?
3. What will an ideal situation look like to you? (optional)

*Actions*

1. What are you doing at the moment to cope with flooding?
2. What actions do you think can be taken to improve this situation? [Probe further about grey and blue-green solutions]
3. What challenges do you perceive in implementing this actions?

*Finances*

1. Who do you think should pay for these solutions? Willingness to pay as residents?

*Causal relations*

1. Why do you believe that this is a good solution? Why will it work?
2. Why has the problem not been resolved yet?

*Other actors*

1. Who should take these actions?
   1. Did you/someone in the neighborhood take any actions in the past with regards to this problem? Are you considering taking any actions? [residents]

*External factors (check if already answered w.r.t causal relations)*

1. What are the drivers or forces outside your (or your organization/department’s) control that contribute to this problem?

Cooperations

1. How would you like to be involved in the planning of the sewer system of the neighbourhood?

Snowballing: Can you suggest other people that are relevant to the problem and could be interviewed?

Well, I think that’s everything I wanted to talk about, is there anything that you’d like to ask me?

***Interview with the water board***

*Context/issue description:*

We are here to talk about the city of FloodCity. FloodCity has been experiencing frequent flooding due to intense rainwater showers. When it rains heavily, polluted water either goes to the canals or floods the streets. Different solutions exists, from replacing or upgrading the sewers to implementing sustainable blue-green solutions such as rooftop gardens or water barrels. This would require cooperation and converging to an acceptable solution for all stakeholders. Through today’s interview, I want to understand the perspective of the municipality about the problem of flooding in FloodCity.

*Introduction*

1. Can you briefly introduce yourself? (Name, profession and organization/department)
2. What is the role of the water board when it comes to urban flooding issues?
3. How is the governance of urban flooding structured with respect to other stakeholders – who and how do you collaborate with?
4. Policy on urban flooding?
5. How does the financing for flood-risk reduction work? How are the taxes collected and divided over flood risk reduction, upgrades? How much does it cost an average resident?
6. Are there any rules or regulations set by the water board? Monument buildings and city centre?

*Goals/objectives*

1. What’s the problem in FloodCity from your perspective with regards to flooding due to intense rainfall?
2. How does this impact the water board?
3. What will an ideal situation look like to you? (optional)

*Actions*

1. What are you doing at the moment to reduce the risk of flooding? What actions do you take currently?
2. What should be done in the future? What further actions should be taken to improve this situation? [Probe further about grey and blue-green solutions]
3. Do you prefer municipality extending the infrastructure or applying blue-green solutions?

*Causal relations*

1. Why do you believe that this solution/action will work?
2. Why has the problem not been resolved yet?

*Other actors*

1. Who is/should be involved in making this solution work?
2. Are there any plans to involve residents to figure out a solution to flooding by temporary storage of water on their land? Are there any apprehensions for such an approach?

*External factors (check if already answered w.r.t causal relations)*

1. What are the factors outside your (or your organization/department’s) control that contribute to this problem? E.g. climate change

Snowballing: Can you suggest other people that are relevant to the problem and could be interviewed?

Would you be willing to play a serious game to discuss the planning of sewers and blue-green systems with residents? What would you like to see in the game?

***For interviews with the municipality officials***

*Context/issue description:*

We are here to talk about the city of FloodCity. FloodCity has been experiencing frequent flooding due to intense rainwater showers. When it rains heavily, polluted water either goes to the canals or floods the streets. Different solutions exists, from replacing or upgrading the sewers to implementing sustainable blue-green solutions such as rooftop gardens or water barrels. This would require cooperation and converging to an acceptable solution for all stakeholders. Through today’s interview, I want to understand the perspective of the municipality about the problem of flooding in FloodCity.

*Introduction*

1. Can you briefly introduce yourself? (Name, profession and organization/department) What is the role of municipality when it comes to urban flooding issues?

*Goals/objectives*

1. What’s the problem in FloodCity from your perspective with regards to flooding due to intense rainfall?
2. How does this impact the municipality?
3. Why is this issue important to you? Or Why do you care?
4. What will an ideal situation look like to you? (optional)

*Actions*

1. What are you doing at the moment to reduce the risk of flooding? Do you prefer municipality extending the infrastructure or applying blue-green solutions?
2. What further actions should be taken to improve this situation? [Probe further about grey and blue-green solutions]

*Causal relations*

1. Why do you believe that this solution/action will work?
2. Why has the problem not been resolved yet?

*Financing*

1. How does the financing for flood-risk reduction work? How are the taxes collected and divided over flood risk reduction, upgrades? How much does it cost an average resident?

*Other actors*

1. Who is/should be involved in making this solution work?
2. Are there any plans to involve residents to figure out a solution to flooding by temporary storage of water on their land? Are there any apprehensions for such an approach?

*External factors (check if already answered w.r.t causal relations)*

1. What are the factors outside your (or your organization/department’s) control that contribute to this problem? E.g. climate change

Snowballing: Can you suggest other people that are relevant to the problem and could be interviewed?

Would you be willing to play a serious game to discuss the planning of sewers and blue-green systems with residents?

***Interview with City Council representative***

*Context/issue description:*

We are here to talk about the city of FloodCity. FloodCity has been experiencing frequent flooding due to intense rainwater showers. When it rains heavily, polluted water either goes to the canals or floods the streets. A range of solutions exists, from replacing or upgrading the sewers to implementing sustainable blue-green solutions such as rooftop gardens or water barrels. This would require cooperation between the residents and the municipality and converging to an acceptable solution. Through today’s interview, I want to understand your perspective about the problem of flooding in FloodCity.

1. Can you briefly introduce yourself and your role in issues related to urban flooding?
2. How is the governance of sewage and rainwater in FloodCity structured?
3. What’s the problem in FloodCity from your perspective with regards to flooding due to intense rainfall?
4. What is the goal with respect to urban flooding in FloodCity in the coming years?
5. What will an ideal situation look like to you?
6. What solutions are being considered to tackle the problem?
7. Which solutions can work within the current legal arrangements?
8. Do you foresee any uncertainty in implementing these solutions?
9. What arrangements or next steps would be needed to implement these solutions?
10. Why do you believe that this solution/action will work?
11. Who is/should be involved in making the solution work?
12. Can you suggest other people that are relevant to the problem and could be interviewed?
13. I am building a serious game to support the planning of sewers and blue-green systems with residents. What would you like to see in such a game?

## Supplementary material C: Consent form

**Delft University of Technology**

**HUMAN RESEARCH ETHICS**

**INFORMED CONSENT FORMS FOR THE STUDY:**

**Serious gaming to support urban stormwater management planning**

**Researcher: Aashna Mittal**

**Dear participant**,

You are being invited to participate in a research study titled “Serious gaming to support urban stormwater management planning”. This study is being done by Aashna Mittal, Lisa Scholten and Zoran Kapelan from the TU Delft in collaboration with the Municipality of FloodCity, Toekomst Sterk (represented by Koen Weytingh) and Luuk Jacobs Communicatieadvies.

**Study information:**

The purpose of this research study is to collect participant’s perceptions about flooding in FloodCity through an interview to understand the problem in detail, and will take you approximately 45-60 minutes to complete. The data will be used for building conceptual maps of the problem and developing a serious game intervention. The collected information will be pseudonymized and the results will be used for publication. We will be asking you to provide responses to your perception about the problem, actions to solve the problem and other stakeholders involved.

**Risk mitigation:**

The collected data will be stored in the laptop of the researcher as password protected files and uploaded to the project drive at TU Delft. As with any data collection activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by pseudonymizing the data collected and the information will not be attributed to the respondent. Personal identifiers will be removed from the interview data and only pseudonyms will be used, for example, “citizen”, “municipality representative”, or “consultant”.

**Voluntary participation:**

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions.

If you have any questions, remarks or concerns about the study, please feel free to contact me ([a.mittal@tudelft.nl](mailto:a.mittal@tudelft.nl))

With best regards,

Aashna Mittal

PhD researcher, Faculty of Civil Engineering and GeoSciences, TU Delft

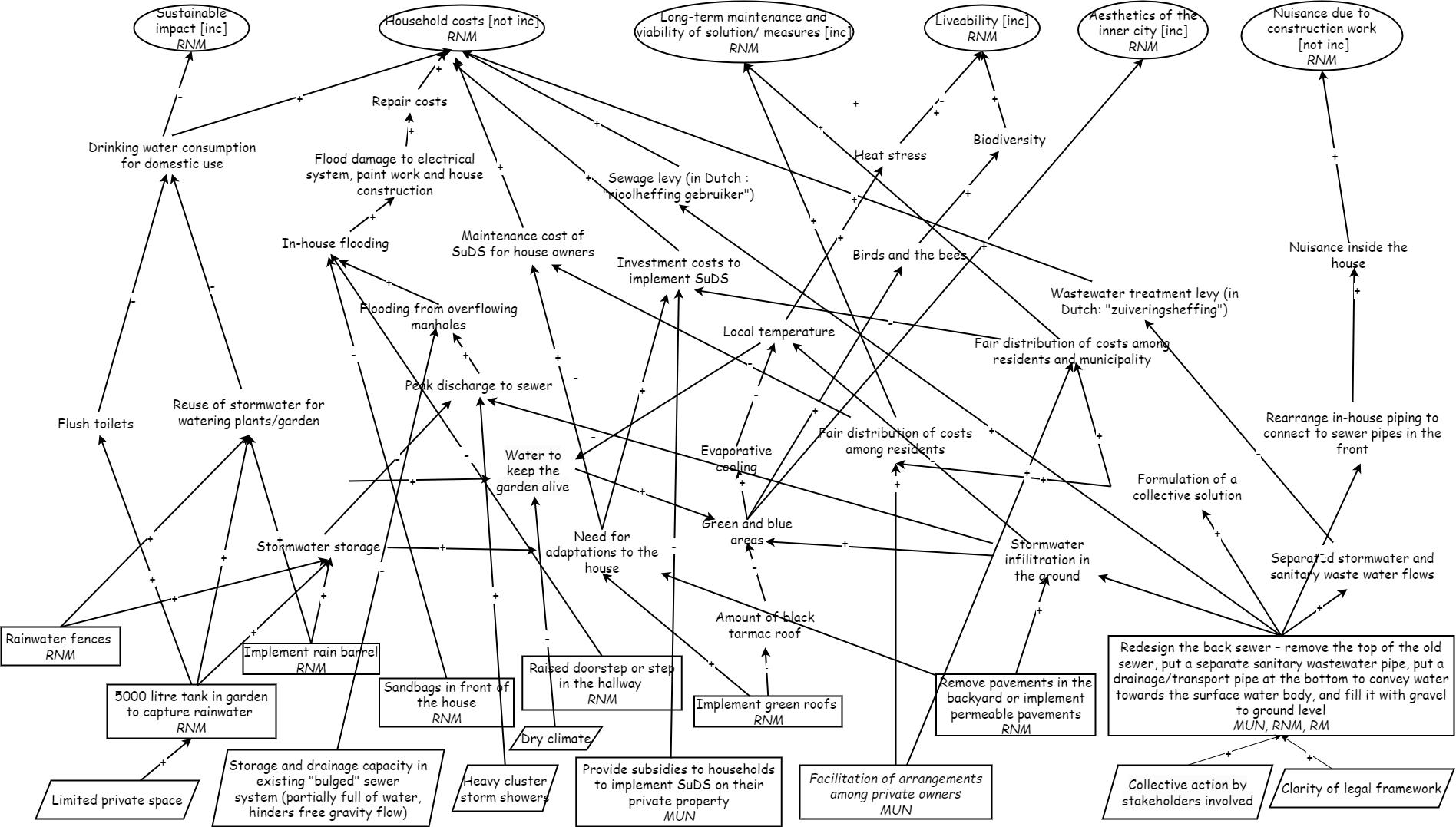
12th June 2023

| **PLEASE TICK THE APPROPRIATE BOXES** | **Yes** | **No** |
| --- | --- | --- |
| **A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION** |  |  |
| 1. I have read and understood the study information dated 12th June 2023, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction. |  |  |
| 2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason. |  |  |
| 3. I understand that taking part in the study involves:   * An audio-recorded interview along with written notes taken by the interviewer. Since this research is a qualitative study, it is important to ensure that there is minimal loss of data while conducting the interview. Hence, the audio recording will be used by the researcher to prepare a detailed transcript of the interview. The data collected in the audio recording will be transcribed into text by the researcher and the audio recording will be destroyed at the end of this research (June 2024). Any personal data in the transcripts will be removed to ensure that the interviewee is not identifiable. |  |  |
| 4. I understand that the study will end when the PHD project ends (June 2024) or when the corresponding research paper is published. |  |  |
| **B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)** |  |  |
| 6. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) such as name, designation, place of residence/work, and associated personally identifiable research data (PIRD) such as political opinion with the potential risk of my identity being revealed |  |  |
| 7. I understand that some of this PIRD is considered as sensitive data within GDPR legislation, specifically religious or political views |  |  |
| 8. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach by:   * anonymizing the data collected and using pseudonyms to refer to the interviewee for example “citizen”, “municipality representative”, or “consultant” * using password protected files to save the interview transcripts that are only accessible to the researchers involved in the study * validating the interview transcripts with the interviewee; transcripts of the interview will be shared with the participants upon request if they wish to validate the data they provided |  |  |
| 9. I understand that personal information collected about me that can identify me, such as name, designation, or where I live will not be shared beyond the study team. |  |  |
| 10. I understand that the (identifiable) personal data I provide will be destroyed when the research is finalized, anticipated to be in June 2024 |  |  |
| **C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION** |  |  |
| 11. I understand that after the research study the de-identified information I provide will be used for: |  |  |
| * Publications in academic journals and potentially policy reports for the local municipality * Name of the municipality/neighbourhood will not be used in the publications to avoid attribution and identification * Images taken during interviews and serious games will be anonymized by blurring the faces of the participants. * Pseudonymized quotes will be used in the publications and policy report. |  |  |
| 12. I agree that my responses, views or other input can be quoted anonymously in research outputs |  |  |
| **D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE** |  |  |
| 13. I give permission for the de-identified online survey questions and personal data that I provide to be used anonymously as statistical summary in the PhD thesis, potential research papers and will be archived in the TU Delft Repository and/ or 4TU.ResearchData so it can be used for future research and learning. |  |  |
| 14. I understand that access to the TU Delft repository and 4TU.ResearchData is open to everyone, and the potential research paper will be published for public access. |  |  |

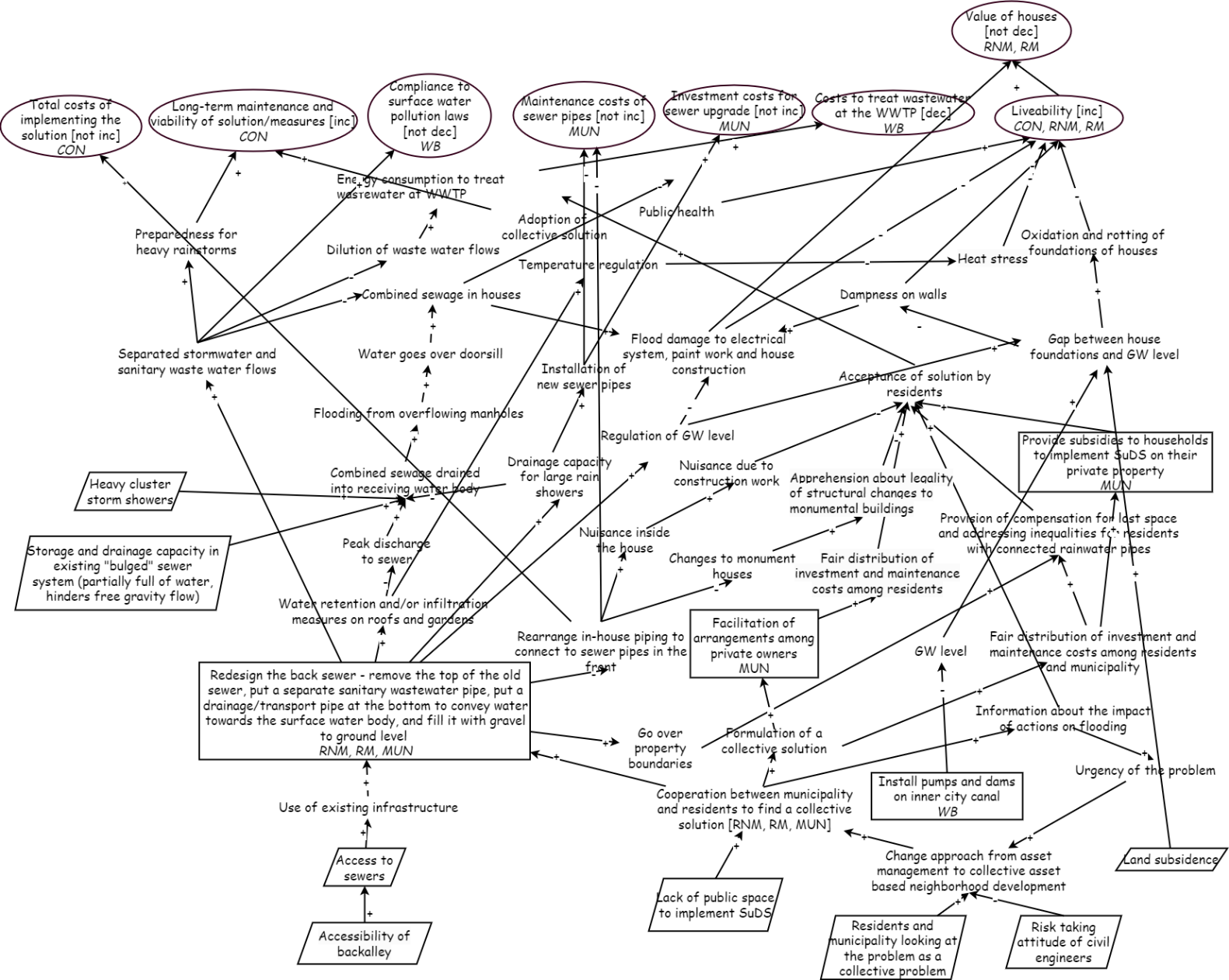
|  |  |  |  |
| --- | --- | --- | --- |
| |  | | --- | | **Signatures** | | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_  Name of participant [printed] Signature Date | | I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.  Aashna Mittal  Researcher name [printed] Signature Date  Study contact details for further information: *Aashna Mittal,* [a.mittal@tudelft.nl](mailto:a.mittal@tudelft.nl) | |

## Supplementary material D: Actor cognitive maps

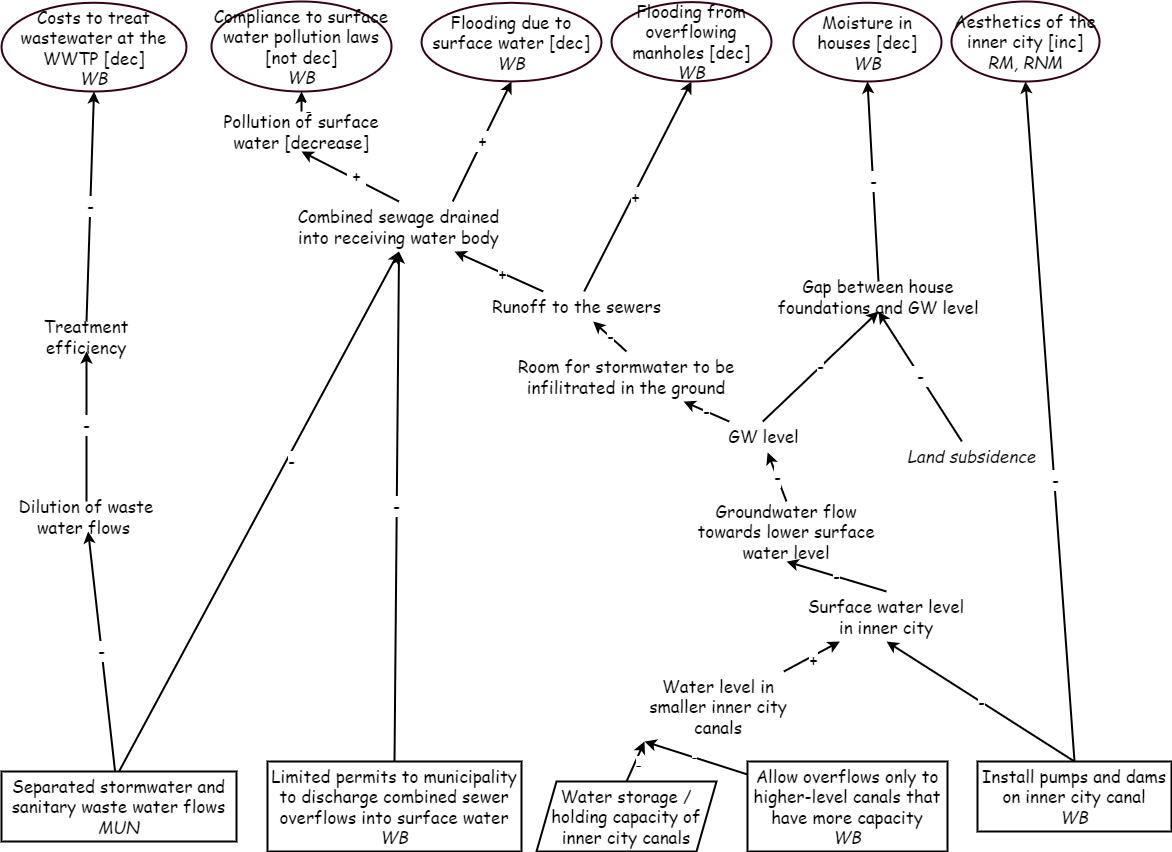
*Resident – non monumental house*

**

*Consultant*

**

*Water Board*

**

## Supplementary material E: Actor actions-goals consequences tables

Tables below present the action-goal consequence table for the actors resident non-monumental house (RNM), resident monumental house (RM), consultant (CON), and the water board (WB). Signs in the table represent the overall impact of the action on the goal (+ meaning increase and – meaning decrease). Actions that lead to desirable consequences on criteria are marked in green, undesirable consequences are marked in red, and uncertain consequences are marked in yellow

***Resident non-monumental house (RNM)***

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Goals**  **Actions** | Sustainable impact [inc] | Household costs [not inc] | Long-term maintenance and viability of solutions/ measures [inc] | Liveability [inc] | Aesthetics of the inner city [inc] | Nuisance due to construction work [not inc] |
| Rainwater fences [RNM] | + | -/+/+ |  | + | + |  |
| 5000 litre tank in garden to capture rainwater [RNM] | +/+ | -/-/+/+ |  | + | + |  |
| Implement rain barrel [RNM] | + | -/+/+ |  | + | + |  |
| Sandbags in front of the house [RNM] |  | - |  |  |  |  |
| Raised doorstep or step in the hallway [RNM] |  | - |  |  |  |  |
| Implement green roofs [RNM] |  | +/+ |  | +/+ | + |  |
| Remove pavement in the backyard and convert to green area [RNM] |  | -/+/+ |  | +/+ | + |  |
| Redesign the back sewer – remove the top of the old sewer, put a separate sanitary wastewater pipe, put a drainage/transport pipe at the bottom to convey water towards the surface water body, and fill it with gravel to ground level [MUN, RNM, RM] |  | -/-/-/+ | +/+ | + | + | - |
| Provide subsidies to households to implement SuDS on their private property [MUN] |  | - |  |  |  |  |
| Facilitation of arrangements among private owners [MUN] |  | - | +/+ |  |  |  |

***Resident monumental house (RM)***

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Goals**  **Actions** | Nuisance due to construction work [not inc] | Hassle of applications and permits for monumental houses [not inc] | Household costs [not inc] | Public health [not dec] | Liveability [inc] | Long-term maintenance and viability of solutions/ measures [inc] | Sustainable impact [inc] | Aesthetics of the inner city [inc] |
| Raised doorstep or step in the hallway [RM] |  |  | - | + | + |  |  |  |
| Implement green roofs [RM] |  | + | +/- |  | + |  |  | + |
| Implement green facades [RM] |  | + | +/- |  | + |  |  | + |
| Disconnect the downspout and channel water to canals through ditches [RM] |  | + | +/- | +/+ | +/+ |  |  |  |
| Implement rain barrel [RM] |  |  | +/+ | +/+ | +/+ |  | + |  |
| Remove pavements in the backyard or implement permeable pavements[RM] |  |  | +/- | +/+ | +/+ |  |  |  |
| Construct small gardens infront of the house [RM] |  | + | +/- | +/+ | +/+ |  |  | + |
| Water storage on roofs/terrace [RM] |  | + | +/- | +/+ | +/+ |  |  | + |
| Deepen the gutter that collects water from slanting roof to store water [RM] |  | + | +/- | +/+ | +/+ |  | + |  |
| Upgrade and install separated sewer system in the front street [MUN] | +/+/+ |  | +/-/- | +/+ | +/+ | + |  |  |
| Upgrade and install separated sewer system in back alley [MUN] | - |  | +/-/- | +/+ | +/+ | + |  |  |
| Facilitation of arrangements among private owners [MUN] |  |  | - |  |  | + |  |  |
| Pump out the canal [WB] |  |  | - | +/+ | +/+ |  |  |  |

***Consultants (CON)***

|  |  |  |  |
| --- | --- | --- | --- |
| **Goals**  **Actions** | Total costs of implementing the solution [not inc] | Long-term maintenance and viability of solution/measures [inc] | Liveability [inc] |
| Cooperation between municipality and residents to find a collective solution | - | +/+/+ | +/+/+/+ |

***Water Board (WB)***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Goals**  **Actions** | Costs to treat wastewater at the WWTP [dec] | Compliance to surface water pollution laws [not dec] | Flooding due to surface water [dec] | Moisture in houses [dec] |
| Limited permits to municipality to discharge combined sewer overflows into surface water [WB] |  | + | - |  |
| Allow overflows only to higher-level canals that have more capacity [WB] |  | + | - | - |
| Install pumps and dams on inner city canal [WB] |  | + | - | - |
| Separated stormwater and sanitary waste water flows [MUN] | - | + | - |  |

## Supplementary material F: Goal conflicts

Goal conflict occurs when two or more actors identify the same variables as goal but desire opposite changes in the goals. For instance, if an actor wants goal X to increase while another actor wants goal X to decrease, then there is a direct goal conflict. The table below lists all the goals mentioned by the actors considered for the analysis. Going through each rows, we see the actors who mentioned the goal and the desired change in that goal. Going through each row, we checked whether there is a conflict in direction of desired change for each goal and found no goal conflict. Additionally, summing across the row gives the number of actors that mentioned the goal.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Goals** | **WB** | | **MUN** | | **RM** | | **RNM** | | **CON** | | **Relevance** |
| **Present?** | **Desired change** | **Present?** | **Desired change** | **Present?** | **Desired change** | **Present?** | **Desired change** | **Present?** | **Desired change** |
| Sustainable impact |  |  |  |  | 1 | inc | 1 | inc |  |  | 2 |
| Household costs |  |  |  |  | 1 | not inc | 1 | not inc |  |  | 2 |
| Long-term maintenance and viability of the measures |  |  | 1 | inc | 1 | inc | 1 | inc | 1 | inc | 4 |
| Liveability |  |  |  |  | 1 | inc | 1 | inc | 1 | inc | 3 |
| Aesthetics of the inner city |  |  |  |  | 1 | inc | 1 | inc |  |  | 2 |
| Nuisance due to construction work |  |  |  |  | 1 | not inc | 1 | not inc |  |  | 2 |
| Hassle of applications and permits for monumental houses |  |  |  |  | 1 | not inc |  |  |  |  | 1 |
| Public health |  |  | 1 | not dec | 1 | not dec |  |  |  |  | 2 |
| Total costs of implementing the solution |  |  |  |  |  |  |  |  | 1 | not inc | 1 |
| Costs to treat wastewater at the WWTP | 1 | dec |  |  |  |  |  |  |  |  | 1 |
| Compliance to surface water pollution laws | 1 | not dec |  |  |  |  |  |  |  |  | 1 |
| Flooding due to surface water | 1 | not dec |  |  |  |  |  |  |  |  | 1 |
| Moisture in houses | 1 | dec |  |  |  |  |  |  |  |  | 1 |
| Land subsidence |  |  | 1 | not inc |  |  |  |  |  |  | 1 |
| Investment cost for sewer upgrade |  |  | 1 | not inc |  |  |  |  |  |  | 1 |
| Maintenance cost of sewer pipes |  |  | 1 | not inc |  |  |  |  |  |  | 1 |
| Monumental value of the inner city area |  |  | 1 | not dec |  |  |  |  |  |  | 1 |

## Supplementary material G: Action conflicts (shared actions)

To find out action conflicts, we first take a closer look at actions by counting their occurrence across the cognitive maps of different actors. Table below shows the list of all actions mentioned by actors. Summing across the rows provides the count of cognitive maps where the action was mentioned. We see that the action “Facilitation of arrangements among private owners” is most relevant as it is mentioned by 3 out of 5 actors.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Actions** | **Present?** | | | | | **Relevance** |
| **WB** | **MUN** | **RM** | **RNM** | **CON** |
| Rainwater fences |  |  |  | 1 |  | 1 |
| 5000 litre tank in garden to capture rainwater |  |  |  | 1 |  | 1 |
| Implement rain barrel |  |  | 1 | 1 |  | 2 |
| Sandbags in front of the house |  |  |  | 1 |  | 1 |
| Raised doorstep or step in the hallway |  |  | 1 | 1 |  | 2 |
| Implement green roofs |  |  | 1 | 1 |  | 2 |
| Remove pavement in the backyard and convert to green area |  |  | 1 | 1 |  | 2 |
| Redesign the back sewer – remove the top of the old sewer, put a separate sanitary wastewater pipe, put a drainage/transport pipe at the bottom to convey water towards the surface water body, and fill it with gravel to ground level |  |  |  | 1 |  | 1 |
| Provide subsidies to households to implement SuDS on their private property |  | 1 |  | 1 |  | 2 |
| Facilitation of arrangements among private owners |  | 1 | 1 | 1 |  | 3 |
| Implement green facades |  |  | 1 |  |  | 1 |
| Disconnect the downspout and channel water to canals through ditches |  |  | 1 |  |  | 1 |
| Construct small gardens infront of the house |  |  | 1 |  |  | 1 |
| Water storage on roofs/terrace |  |  | 1 |  |  | 1 |
| Deepen the gutter that collects water from slanting roof to store water |  |  | 1 |  |  | 1 |
| Upgrade and install separated sewer system in the front street |  | 1 | 1 |  |  | 2 |
| Upgrade and install separated sewer system in back alley |  | 1 | 1 |  |  | 2 |
| Pump out the canal |  |  | 1 |  |  | 1 |
| Cooperation between municipality and residents to find a collective solution |  |  |  |  | 1 | 1 |
| Limited permits to municipality to discharge combined sewer overflows into surface water | 1 |  |  |  |  | 1 |
| Allow overflows only to higher-level canals that have more capacity | 1 |  |  |  |  | 1 |
| Install pumps and dams on inner city canal | 1 |  |  |  |  | 1 |
| Separated stormwater and sanitary waste water flows | 1 |  |  |  |  | 1 |
| Planning rules necessitating measures for collecting and retaining rain water on private land |  | 1 |  |  |  | 1 |
| Put SUDS in the public area |  | 1 |  |  |  | 1 |

An action conflict occurs if two or more actors mention the same action in their maps but perceive conflicting impacts on their own goals, i.e., if the cognitive map of Actor A shows that the actor expects action X to have a desired effect on their goal (s), while actor B expects action X to have an undesirable effect on their goals (s), then the actors have conflicting preferences over action X and action X creates a conflict. In the table below, two actions “Upgrade and install separated sewer system in the front street”, and “Upgrade and install separated sewer system in back alley [MUN, RM]” create actions conflicts as they lead to desirable and undesirable consequences for both actors on different goals.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Actions** | **MUN** | | | | | | **RM** | | | | | | | | **RNM** | | | | | | **Remarks** |
| Land subsidence [not inc] | Investment cost for sewer upgrade [not inc] | Maintenance cost of sewer pipes [not inc] | Long-term maintenance and viability of solution/measures [inc] | Monumental value of the inner city area [not dec] | Public health [not dec] | Nuisance due to construction work [not inc] | Hassle of applications and permits for monumental houses [not inc] | Household costs [not inc] | Public health [not dec] | Liveability [inc] | Long-term viability of climate adaptation measures [inc] | Sustainable impact [inc] | Aesthetics of the inner city [inc] | Sustainable impact [inc] | Household costs [not inc] | Long-term maintenance and viability of the measures [inc] | Liveability [inc] | Aesthetics of the inner city [inc] | Nuisance due to construction work [not inc] |
| Implement rain barrel [RM, RNM] |  |  |  |  |  |  |  |  | +/- | +/+ | +/+ |  | + |  | + | -/+/+ |  | + | + |  | No conflicts |
| Raised doorstep or step in the hallway [RM, RNM] |  |  |  |  |  |  |  |  | - | + | + |  |  |  |  | - |  |  |  |  | No conflicts |
| Implement green roofs [RM, RNM] |  |  |  |  |  |  |  |  | +/+ | +/+ | +/+ |  | + |  |  | +/+ |  | +/+ | + |  | RNM and RM perceive similar impacts on household costs w.r.t green roofs. |
| Remove pavement in the backyard and convert to green area [RM, RNM] |  |  |  |  |  |  |  |  | +/- | +/+ | +/+ |  |  |  |  | -/+/+ |  | +/+ | + |  | No conflicts |
| Provide subsidies to households to implement SuDS on their private property [MUN, RNM] |  |  |  |  | +/-/+ | + |  |  |  |  |  |  |  |  |  | - |  |  |  |  | No conflicts |
| Facilitation of arrangements among private owners [MUN, RM, RNM] |  |  |  | +/+ | +/-/+ | + |  |  | - |  |  | + |  |  |  | - | +/+ |  |  |  | No conflicts |
| Upgrade and install separated sewer system in the front street [MUN, RM] | + | + | - | +/- | -/-/+ | + | +/+/+ |  | +/-/- | +/+ | +/+ | + |  |  |  |  |  |  |  |  | Goal conflict – same action has conflicting impacts on goals of MUN and RM |
| Upgrade and install separated sewer system in back alley [MUN, RM] |  | - | + | - | + | + | - |  | +/-/- | +/+ | +/+ | + |  |  |  |  |  |  |  |  | Goal conflict – same action has conflicting impacts on goals of MUN and RM |

## Supplementary material H: List of most frequent factors across all individual cognitive maps

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Factors | Water Board | Municipality | Resident – regular house | Resident-monument house | Consultants | Sum |
| Flooding from overflowing manholes [dec] | 1 | 1 | 1 | 1 | 1 | 5 |
| Separated stormwater and sanitary waste water flows | 1 | 1 | 1 | 1 | 1 | 5 |
| Aesthetics of the inner city [inc] | 1 | 1 | 1 | 1 |  | 4 |
| Long-term maintenance and viability of solution/measures [inc] |  | 1 | 1 | 1 | 1 | 4 |
| Nuisance due to construction work [not inc] |  | 1 | 1 | 1 | 1 | 4 |
| Land subsidence [not inc] | 1 | 1 |  | 1 | 1 | 4 |
| Facilitation of arrangements among private owners [MUN] |  | 1 | 1 | 1 | 1 | 4 |
| Provide subsidies to households to implement SuDS on their private property |  | 1 | 1 | 1 | 1 | 4 |
| Heat stress |  | 1 | 1 | 1 | 1 | 4 |
| Groundwater (GW) level | 1 | 1 |  | 1 | 1 | 4 |
| Rearrange in-house piping to connect to sewer pipes in the front |  | 1 | 1 | 1 | 1 | 4 |
| Storage and drainage capacity in existing “bulged” sewer system (partially full of water, hinders free gravity flow) |  | 1 | 1 | 1 | 1 | 4 |
| Nuisance inside the house |  | 1 | 1 | 1 | 1 | 4 |
| Costs to treat wastewater at the WWTP [dec] | 1 |  |  | 1 | 1 | 3 |
| Moisture in houses [dec] | 1 | 1 |  | 1 |  | 3 |
| Liveability [inc] |  |  | 1 | 1 | 1 | 3 |
| Public health [not dec] |  | 1 |  | 1 | 1 | 3 |
| Runoff to the sewers | 1 | 1 |  | 1 |  | 3 |
| Green and blue areas |  | 1 | 1 | 1 |  | 3 |
| Flood damage to electrical system, paint work and house construction |  |  | 1 | 1 | 1 | 3 |
| Stormwater infiltration in the ground |  | 1 | 1 | 1 |  | 3 |
| Heavy cluster storm showers |  |  | 1 | 1 | 1 | 3 |
| Fair distribution of investment and maintenance costs among residents |  | 1 | 1 |  | 1 | 3 |
| Changes to monument houses |  | 1 |  | 1 | 1 | 3 |
| Stormwater storage |  | 1 | 1 | 1 |  | 3 |
| Sustainable impact [inc] |  |  | 1 | 1 |  | 2 |
| Household costs [not inc] |  |  | 1 | 1 |  | 2 |
| Maintenance cost of sewer pipes [not inc] |  | 1 |  |  | 1 | 2 |
| Compliance to surface water pollution laws [not dec] | 1 |  |  |  | 1 | 2 |
| Install pumps and dams on inner city canal [WB] | 1 |  |  | 1 |  | 2 |
| Implement rain barrel |  |  | 1 | 1 |  | 2 |
| Raised doorstep or step in the hallway |  |  | 1 | 1 |  | 2 |
| Implement green roofs |  |  | 1 | 1 |  | 2 |
| Remove pavements in the backyard or implement permeable pavements |  |  | 1 | 1 |  | 2 |
| Redesign the back sewer – remove the top of the old sewer, put a separate sanitary wastewater pipe, put a drainage/transport pipe at the bottom to convey water towards the surface water body, and fill it with gravel to ground level |  |  | 1 |  | 1 | 2 |
| Upgrade and install separated sewer system in back alley [MUN] |  | 1 |  | 1 |  | 2 |
| Upgrade and install separated sewer system in the front street [MUN] |  | 1 |  | 1 |  | 2 |
| Room for stormwater to be infiltrated in the ground | 1 |  |  | 1 |  | 2 |
| Gap between house foundations and GW level | 1 |  |  |  | 1 | 2 |
| Water level in smaller inner city canals | 1 |  |  | 1 |  | 2 |
| Investment costs to implement SuDS |  |  | 1 | 1 |  | 2 |
| Maintenance cost of SuDS for house owners |  | 1 | 1 |  |  | 2 |
| Local temperature |  |  | 1 | 1 |  | 2 |
| Sewage levy (in Dutch: "rioolheffing gebruiker") |  |  | 1 | 1 |  | 2 |
| Peak discharge to sewer |  |  | 1 |  | 1 | 2 |
| Need for adaptations to the house |  |  | 1 | 1 |  | 2 |
| Wastewater treatment levy (in Dutch: "zuiveringsheffing") |  |  | 1 | 1 |  | 2 |
| Fair distribution of costs among residents and municipality |  |  | 1 |  | 1 | 2 |
| Absorption of water by walls |  | 1 |  | 1 |  | 2 |
| Ripping of floors |  | 1 |  | 1 |  | 2 |
| Limited public space to implement SuDS |  | 1 |  |  | 1 | 2 |
| Combined sewage drained into receiving water body | 1 |  |  |  | 1 | 2 |
| Repair costs |  |  | 1 | 1 |  | 2 |
| Formulation of a collective solution |  |  | 1 |  | 1 | 2 |
| Access to sewers |  | 1 |  |  | 1 | 2 |
| Nuisance outside the house |  | 1 |  | 1 |  | 2 |
| Combined sewage in houses |  |  |  | 1 | 1 | 2 |
| Dilution of waste water flows | 1 |  |  |  | 1 | 2 |
| Evaporative cooling |  |  | 1 | 1 |  | 2 |
| Investment costs for sewer upgrade [not inc] |  | 1 |  |  | 1 | 2 |
| Use of existing infrastructure |  | 1 |  |  | 1 | 2 |
| Installation of new sewer pipes |  | 1 |  |  | 1 | 2 |
| Flooding due to surface water [dec] | 1 |  |  |  |  | 1 |
| Monumental value of the inner city area [not dec] |  | 1 |  |  |  | 1 |
| Value of houses [not dec] |  |  |  |  | 1 | 1 |
| Hassle of applications and permits for monumental houses [not inc] |  |  |  | 1 |  | 1 |
| Limited permits to municipality to discharge combined sewer overflows into surface water [WB] | 1 |  |  |  |  | 1 |
| Allow overflows only to higher-level canals that have more capacity [WB] | 1 |  |  |  |  | 1 |
| Rainwater fences |  |  | 1 |  |  | 1 |
| 5000 litre tank in garden to capture rainwater |  |  | 1 |  |  | 1 |
| Sandbags in front of the house |  |  | 1 |  |  | 1 |
| Puts SuDS in the public area |  | 1 |  |  |  | 1 |
| Cooperation between municipality and residents to find a collective solution |  |  |  |  | 1 | 1 |
| Ensure succeeding owners maintain the infrastructure |  |  |  | 1 |  | 1 |
| Implement green facades |  |  |  | 1 |  | 1 |
| Disconnect the downspout and channel water to canals through ditches |  |  |  | 1 |  | 1 |
| Construct small gardens in front of the house |  |  |  | 1 |  | 1 |
| Water storage on roofs/terrace |  |  |  | 1 |  | 1 |
| Deepen the gutter that collects water from slanting roof to store water |  |  |  | 1 |  | 1 |
| Treatment efficiency | 1 |  |  |  |  | 1 |
| Groundwater flow towards lower surface water level | 1 |  |  |  |  | 1 |
| Surface water level in inner city | 1 |  |  |  |  | 1 |
| Flush toilets |  |  | 1 |  |  | 1 |
| Birds and the bees |  |  | 1 |  |  | 1 |
| Biodiversity |  |  | 1 |  |  | 1 |
| Dry climate |  |  | 1 |  |  | 1 |
| Amount of black tarmac roof |  |  | 1 |  |  | 1 |
| Drinking water consumption for domestic use |  |  | 1 |  |  | 1 |
| Water to keep the garden alive |  |  | 1 |  |  | 1 |
| Reuse of stormwater for watering plants/garden |  |  | 1 |  |  | 1 |
| Disruption of public area - roads, transport |  | 1 |  |  |  | 1 |
| Risk of extra subsidence (since monumental buildings are not found on pillars) |  | 1 |  |  |  | 1 |
| Risk of lung diseases such as asthma |  | 1 |  |  |  | 1 |
| Formalize responsibilities for maintenance of SuDS |  | 1 |  |  |  | 1 |
| Control of provision of public services |  | 1 |  |  |  | 1 |
| Continuous access for operation and maintenance |  | 1 |  |  |  | 1 |
| Ease of access with machines |  | 1 |  |  |  | 1 |
| Implementation of SuDS by residents on private property |  | 1 |  |  |  | 1 |
| Mandate collection and manage water falling on own property |  | 1 |  |  |  | 1 |
| Rotting of roots |  | 1 |  |  |  | 1 |
| Additional storage/drainage capacity |  | 1 |  |  |  | 1 |
| Lowering of GW level |  |  |  |  | 1 | 1 |
| Water goes over doorsill |  |  |  |  | 1 | 1 |
| Dampness on walls |  |  |  |  | 1 | 1 |
| Regulation of GW level |  |  |  |  | 1 | 1 |
| Temperature regulation |  |  |  |  | 1 | 1 |
| Provision of compensation for lost space and addressing inequalities for residents with connected rainwater pipes |  |  |  |  | 1 | 1 |
| Urgency of the problem |  |  |  |  | 1 | 1 |
| Change approach from asset management to collective asset based neighbourhood development |  |  |  |  | 1 | 1 |
| Adoption of collective solution |  |  |  |  | 1 | 1 |
| Information about the impact of actions on flooding |  |  |  |  | 1 | 1 |
| Oxidation and rotting of foundations of houses |  |  |  |  | 1 | 1 |
| Water retention and/or infiltration measures on roofs and gardens |  |  |  |  | 1 | 1 |
| Drainage capacity for large rain showers |  |  |  |  | 1 | 1 |
| Acceptance of solution by residents |  |  |  |  | 1 | 1 |
| Apprehension about legality of structural changes to monumental buildings |  |  |  |  | 1 | 1 |
| Go over property boundaries |  |  |  |  | 1 | 1 |
| Capacity for CSOs |  |  |  | 1 |  | 1 |
| Growth of fungi and moss |  |  |  | 1 |  | 1 |
| Pay permit fee |  |  |  | 1 |  | 1 |
| Amount of paved areas |  |  |  | 1 |  | 1 |
| Insurance for flooding and associated damages |  |  |  | 1 |  | 1 |
| Contractual/permit costs |  |  |  | 1 |  | 1 |
| Headache for inhabitants (dirt and construction workers everywhere) |  |  |  | 1 |  | 1 |
| Need for construction inside the house |  |  |  | 1 |  | 1 |
| Duration to implement the project relative to other solutions that use existing infrastructure |  |  |  | 1 |  | 1 |
| Need to hire engineer/contract for assessment/feasibility |  |  |  | 1 |  | 1 |
| Address permit and design/planning costs for small house improvements [OMDH and MUN] |  |  |  | 1 |  | 1 |
| Need to strengthen terrace foundation |  |  |  | 1 |  | 1 |
| Acknowledge the measures as part of the house in the ownership contract |  |  |  | 1 |  | 1 |
| Old sewer |  |  |  | 1 |  | 1 |
| Laying down new pipes in the front of the house |  |  |  | 1 |  | 1 |
| Evaporation and evapotranspiration |  |  |  | 1 |  | 1 |
| Sewer system durable for long-term |  |  |  | 1 |  | 1 |
| Request permit from OMDH |  |  |  | 1 |  | 1 |
| Costs for wastewater drainage |  |  |  | 1 |  | 1 |
| Water storage / holding capacity of inner city canals | 1 |  |  |  |  | 1 |
| Limited private space |  |  | 1 |  |  | 1 |
| Clarity of legal framework |  |  | 1 |  |  | 1 |
| Collective action by stakeholders involved |  |  | 1 |  |  | 1 |
| Green fund |  | 1 |  |  |  | 1 |
| Insufficient space in alleyways to upgrade sewer |  | 1 |  |  |  | 1 |
| Neighbours currently don't work together for rainwater management |  | 1 |  |  |  | 1 |
| Limited public space under street |  | 1 |  |  |  | 1 |
| Upgrade of underground heating system |  | 1 |  |  |  | 1 |
| Provision of sufficient parking space |  | 1 |  |  |  | 1 |
| Norms require separation of sanitary and storm sewage |  | 1 |  |  |  | 1 |
| Back alley is private property |  | 1 |  |  |  | 1 |
| Residents and municipality looking at the problem as a collective problem |  |  |  |  | 1 | 1 |
| Risk taking attitude of civil engineers |  |  |  |  | 1 | 1 |
| Accessibility of back alley |  |  |  |  | 1 | 1 |
| Unclear OMDH approval requirements |  |  |  | 1 |  | 1 |
| Unclear structural strength of roof |  |  |  | 1 |  | 1 |
| Unclear what changes are allowed or not |  |  |  | 1 |  | 1 |
| Runoff from the upstream neighbours |  |  |  | 1 |  | 1 |
| Cost sharing with neighbours where water crosses private boundaries |  |  |  | 1 |  | 1 |
| Checklist of renovations allowed or not |  |  |  | 1 |  | 1 |
| Number of trees in the area |  |  |  | 1 |  | 1 |
| Unclear what part of house qualifies as a monument or not |  |  |  | 1 |  | 1 |
| Total costs of implementing the solution |  |  |  |  | 1 | 1 |