TU Delft

Low-impact home in floodplains

Designing a land-bound, low-impact family home that is located in floodplains offering resilience against flooding.

Research plan

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Research plan

Student
Renée de Vries
5429978

Studio
Architectural engineering
Design tutor: Anne Snijders
Research tutor: Luca Iourio

Date
07-11-2022

Stage
Final

Preface

◀ **Picture front page**
Floodplains of the Waal river near Deest, the Netherlands.
Own image

Due to my own experience, living between two big rivers in the Netherlands, I have been able to see the great potential flood plains can have. In floodplains, nature is thriving (Schindler, et al., 2016). Besides livestock, Insects, birds, wild horses and cows can live there however they want. Showing a rich ecological environment for everyone to experience. The dikes surrounding these floodplains first and foremost protect against high river levels and thus floods. But in addition, serve as an entrance and simultaneously give an overview of the floodplains. On top of the dike immediately my eye falls on this rich green area which makes me want to live there. I think urbanized areas as we know them today would never be able to top this.

Besides my experience, of living in between rivers, there are other elements connected to architecture that interest me and plan to use in the eventual design project. Geometric shapes and the possibility of creating adaptability by dividing these shapes in a certain way. Others are self-sufficient, nature, daylight and tectonics. These are shown through a conceptual pavilion, and a compilation of several reference images, I made at the start of this project, see appendix 4 and 5.

Everything stated above contributes to the reason for choosing this graduation studio, Architectural Engineering. If I would like to make it possible to live in floodplains, in a sustainable and nature-inclusive way, choosing a studio that is a bit more angled at engineering would substantiate this project better. Because a building in this location is connected to a lot of technical factors besides architectural ones. In the end, being able to combine this technical knowledge into an architectural design for living in floodplain areas make it a good fit for the architectural engineering studio.

The graduation studio is part of the master Architecture at the BK faculty of the TU Delft. The studio is divided into two main parts. MSC3 where the thematic research and its preparations are conducted. And MSC4, the period where the thematic research is implemented into the design project. The MSC3 and MSC4 combined have a total duration of 42 weeks, with five main assessment moments. Hereinafter referred to as P1 through P5.

This document, the research plan, is part of the first 10 weeks until P1. The plan serves as a foundation for thematic research. It shows in context how the thematic research will support the overall design project.

Delft, 03 November 2022

Graduation project

◄ **Picture page 1**
Floodplains splitting of Rijn to Waal near Doornenburg, the Netherlands.
Own image

Introduction

Rivers are a big part of the Netherlands and its delta works (Hooimeijer, Meyer, & Nienhuis, 2009). Due to this, the landscape has been influenced, which is visible through several characteristics of delta works. For example, dikes and floodplains protect urbanized areas from fluvial floods from the rivers (Kok, Jongejan, Nieuwjaar, & Tánczos, 2017; Hooimeijer, Meyer, & Nienhuis, 2009; Pleijster & Veeken, 2014). The rising of river water levels is caused by heavy rainfall and depending on the origin of the river, also by snow melting (Blöschl, et al., 2015). Even though this was taken into account when creating the delta works, in some locations the river still does not have enough room to flow, and adaptations are made to give de river more space (Sijmons, Feddes, Luiten, & Feddes, 2017).

Figure 1 ►
Map of rivers and floodplains in the netherlands. Based on map rijkswaterstaat.
Own image.

Over the years floodplains have taken up more land. They are located along the big rivers, Ijssel, Maas, Neder-Rijn and Waal (Cohen, Amoldussen, Erkens, Popta, & Taal, 2014). Due to the flooding that happens several times a year on the floodplain, it has great biodiversity and fertile land (Schindler, et al., 2016; Bayley, 1995). This is visible when standing on top of a dike and looking over the floodplains. Floodplains along the Maas at Wijchen are one of the many floodplains in the Netherlands where vegetation like grass, plants and trees, and wild animals like birds, horses and cows live (Kurstjens & Peters, 2019).

Justifying building on floodplains, these being beautifully green and ecological areas with a high risk of flooding, is of utmost importance since human lives and the ecology of floodplains depend on it. But it is precisely

this dynamic location that can serve as an example for housing that can withstand repeated flooding of areas. Especially since it is expected that in western Europe river floods will occur more frequently and extremer in the future, due to global warming (Feyen, Dankers, Bódis, Salamon, & Barredo, 2012; Golz, Schinke, & Naumann, 2015). Therefore building in a floodplain area, where floods are a given, the project can present itself as an example of how to handle this. Not only for the Netherlands but for multiple locations over the world like Thailand, Suriname, Brazil, Australia, United Kingdom, France, United States, Belgium, Denmark, Germany, etc. that deal with river floods (Floodlist, 2022; Feyen, Dankers, Bódis, Salamon, & Barredo, 2012).

Despite the dangers rivers present, since ancient history, people have been attracted to water, as it was their source of life (Campanella, 2010; Hooimeijer, Meyer, & Nienhuis, 2009). To this century still, there is almost no difference, people still want to live near water (Harke, 2006). But creating housing in floodplains can pose a threat to the spatial quality (Braakhekke, Litjens, Winden, Berkum, & Hillebrand, 2007). This is why, when designing a house in this location it should be low-impact on the floodplains. Of course, when building on this location no impact would be better, but the moment anyone sets foot on this land it is already impacted on some level. So to be realistic, low-impact as possible is the aim. The moment a floodplain is under water and dried up again, a whole new ecosystem rises again making it a very dynamic and adaptable piece of land (Bayley, 1995). This would also mean that if for some reason a building in this location needs to be demolished and all the building residues are removed, after a new flood the floodplain should be as good as new. This does not count for only the visible things, but also the building component located underground, the structural foundation.

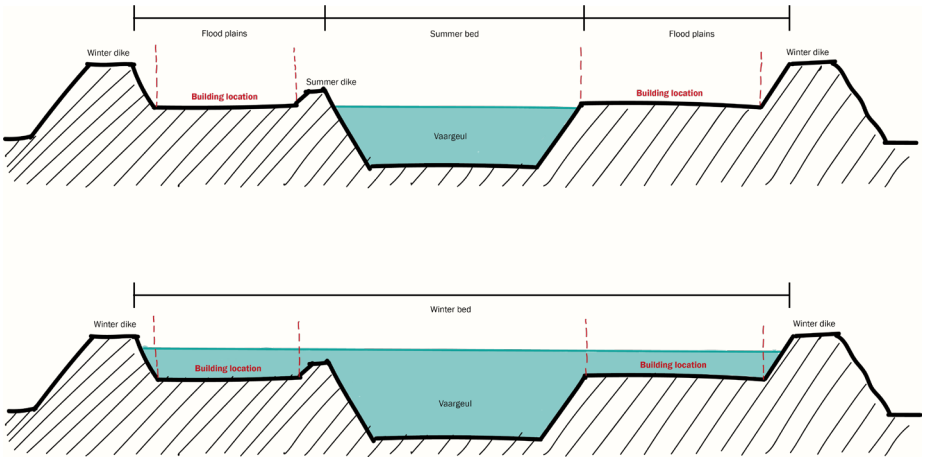
Keywords

Floodplains, foundations, housing, river, low-impact

Problem statement

The context of the graduation project revolves around the big rivers in the Netherlands and their floodplains. There are two channels in a river. The narrowest is the shipping channel and the widest is where the floodplains are filled with water, and sometimes up to the winter dikes, and become part of the main water body (Hooimeijer, Meyer, & Nienhuis, 2009). When looking at maps of the dikes in the Netherlands, floodplains themselves can be very narrow but there are also locations where they are widely spread (Pleijster & Veeken, 2014). This means that some areas have a bigger exposure risk of flooding than others. The location for this project must be flooding at least once a year with a minimal water level of 2 meters above ground level. Furthermore, the soil of the floodplains are very important for the type of foundation (Oosterhoff, 2013). Therefore the location for the graduation project should be placed on a composition that is most common in floodplains. These parameters for the flooding and soil composition are to ensure that the project stays relevant and can present itself as an example.

Figure 2 ►
Illustrative section of river, floodplain and dikes with building location.
Own image.



Program wise this building that will be constructed is will be a house. This building type is a great representative since there almost everybody all over the world lives in it. To specify a bit more this project will aim to design a family house as this is the most common house type in the Netherlands, around 65% of all houses is a family home (Oikonomou, 2019). The characteristics of these houses will be defined after careful investigation to create the best representative programme for the relevance of this project.

To be able to build this house in floodplain areas the thematic focus for this project lies on the foundation. Trying to find a better way to adapt them for floodplain soils. With the aim of it being a low-impact foundation. Because the foundation is a big part of the building it is not possible to justify building a low-impact house in this location if the foundation is not. Building a house in floodplains brings multiple risks to it as it is mostly composed of clay (Oosterhoff, 2013). The foundation therefore in this location should be able to account for big settlements as clay can swell when wetted and shrink when it dries out (Bell & Jermy, 2011). The risk is that the building can move around horizontally but also sink vertically into the soil lifted out of the soil when the water level rises and lifts the building from the topsoil layer.

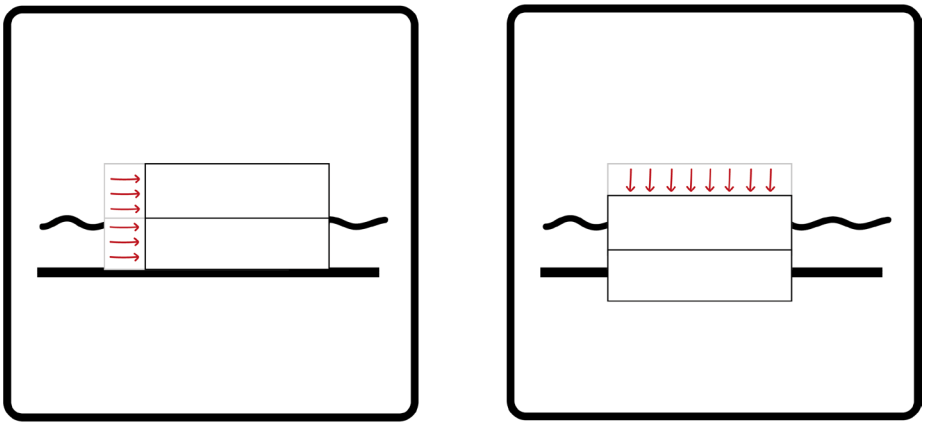
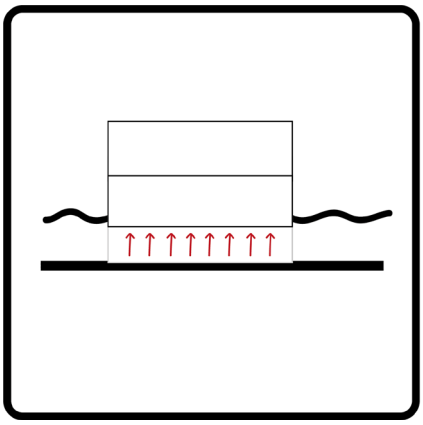


Figure 3a and b
Horizontal shifting (walking building)
Vertical shifting (sinking building)
Own image. ►

Figure 3c ►
Vertical shifting (floating building)
Own image.



There are two different types of foundations, shallow foundations and pile foundations (Oosterhoff, 2013). Though precast concrete pile foundations are often used in clay soils, they are not a desirable solution for building in floodplain areas. A pile foundation is relatively hard to remove (Chapman, Marsh, & Foster, 2001). Though recent studies show new methods for extracting precast concrete pile foundations by vibration techniques using heavy types of machinery (Inazumi, Kuwahara, Jotisankasa, & Chairprakaikeow, 2020; Kuwahara & Inazumi, 2019). These methods are implemented by multiple companies, also in the Netherlands (Jacobs, 2020; Sterk, 2021; Bentvelzen-jacobs, 2022). The re-use of prefab concrete piles is not possible to this date and the only option for these piles is to recycle them into concrete granulate (Dijken, 2021). This granulate can be used in new concrete mixtures or as road foundations (Velzing, Meijden, Vreeswijk, & Vrijhoef, 2021). To find a better low-impact solution for this problem research needs to be conducted.

Relevance

There are many interfaces with this subject compared to societal and environmental issues. For example overpopulation, in the Netherlands for multiple areas a housing shortage is expected (ABF Research, 2019). By making it possible to create safe housing in floodplains, which are relatively large areas could help solve this problem. In environmental relevance there are multiple issues that this project touches on. Loss of biodiversity is one of them. The ecology of floodplains are extremely biodiverse (Mulder, Pater, & Droogleever Fortuijn, 2019). By designing a low-impact house, nature and ecology are preserved as much as possible. Secondly, river floods are prone to happen more often and in more extreme forms in the upcoming years in places in Europe (Feyen, Dankers, Bódis, Salamon, & Barredo, 2012). Designing a building in a floodplain it can serve as an example for other locations dealing with the same issue. For example in Limburg, the Netherlands, where the Maas river flooded in 2021 because of high water levels in combination with local and extreme rainfall (Schyns, 2022). And lastly, droughts which are mentioned in current news topics. The extreme droughts in the soil are causing foundations to shift which can result in lots of damages to buildings (NOS nieuws, 2021). By searching for a low-impact foundation that can take in account these shifts it is possible to serve as an example for locations that are prone to shifting in the soil by droughts. All these issues can be

traced back to this graduation project, making it very relevant and actual research. Therefore even though this project will be placed in a specific location it will be able to present itself as a generic example.

Objective

The aim of this project is to design a land-bound, low-impact family home that is located in floodplains offering resilience against flooding. This will create an example project for locations that deal with partially or completely the same context.

Design question

What are the spatial consequences when designing a low-impact, land-bound family home on floodplains?

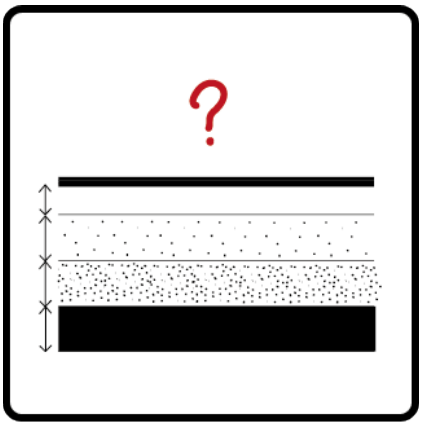
Thematic research

Research question

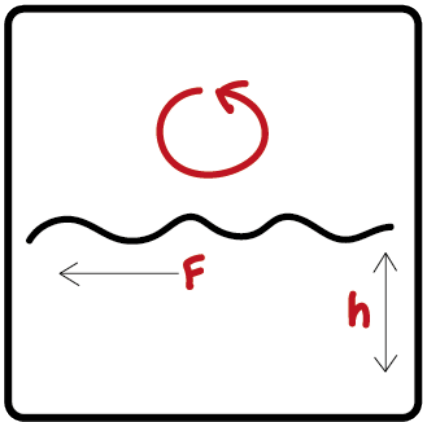
What foundation typology creates the lowest impact for land-bound housing in floodplains?

◄ **Picture page 7**
Floodplains of the Waal river near Deest the Netherlands.
Own image

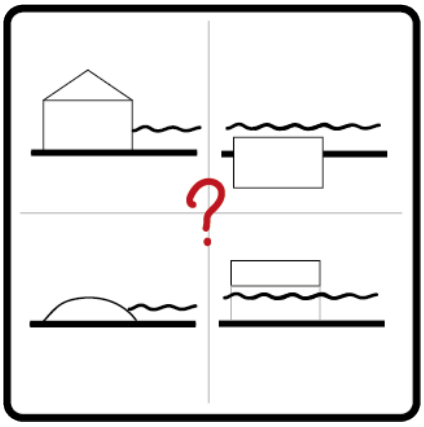
Subquestions



1. What are the dynamics of the soil in floodplains in relation to foundations?

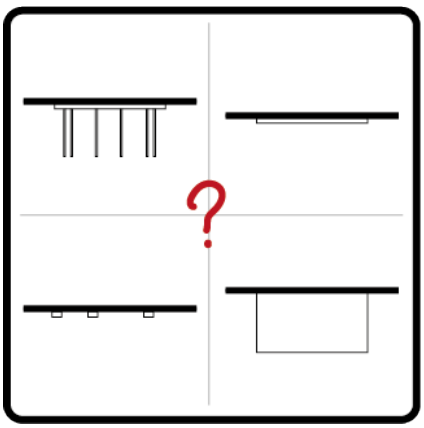


2. What are the characteristics of river floods in relation to foundations?



3. What building typology offers resilience to river floods?

Figure 4a, b and c
Illustrative image subquestion 1, 2 and 3
Own image. ►



4. What foundation typologies are there and what are their spatial qualities?

5. What is the impact of local foundation materials?

Figure 4d and e
Illustrative image subquestion 4 and 5
Own image. ►

Methods

By answering the sub-questions the answer can be given to the thematic research question. These questions will be researched with several different methods to create a diverse set of data and be able to substantiate the conclusion of the thematic research. The methods used are described below, together with the tools that will be used and the products they will result in.

Literature review

A literature review will serve as a base for the whole research. It will put the subjects of each sub-question in relation to existing information and academic content. This method therefore will be used for every research question. The tools I will be using for the literature review are online academic search engines, online libraries and physical libraries. I will be searching for academic research papers and books that will put the subject in context with existing studies and literature. The product is a review of the existing literature per sub-question. See appendix 1 for possible literature for the research paper.

Data analysis

The type of data analysis can be qualitative or quantitative based on the information needed for the sub-questions. The data needed per sub-question except for question 3 are described below. The data will be provided by the government, manufacturers, independent sources and connected parties. The quantitative analysis will result in a graphs and/ or tables that shows these data together. see appenidix 2 for the sources.

Case studies

The case studies are done based on primary and secondary data. Resulting in a descriptive set of data for sub-question three. The case studies on based on primary data collected by me taking pictures in floodplain areas and the secondary case studies are done on existing literature, drawings and images. The pictures, drawings, literature and images will be analysed by only looking at the specific element of that building that makes it possible to resist floods. And converting them into a type of a resilience by creating a visual graphical representation. These case studies involve housing but are not limited to offshore wind turbines and oil rigs.

Brainstorm sessions

Because the fields research lay for a big part out of my education area I want to involve experts that do have specific scientific knowledge about these fields, see appendix 3. These would be, Architecture for building design, engineering for building technologies, civil engineering for building on floodplains, urban design for designing in floodplains and geotechnical engineering for building foundations on certain soil composition. The way I want to do this is by organizing brainstorming sessions where an interactive discussion can take place about these subjects. These sessions will then be able to validate my initial findings and also purpose new insights. Into the different subjects. These sessions will be recorded and thereby contribute to the thematic research. And this makes it possible to the research where I am not able to gather all the knowledge by myself but use the knowledge of experts. These experts will involve lecturers, students, professors and also companies with relevant proficiency.

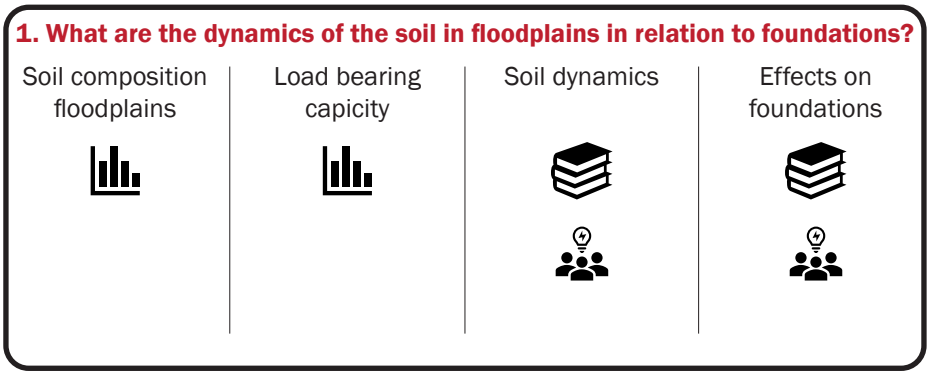
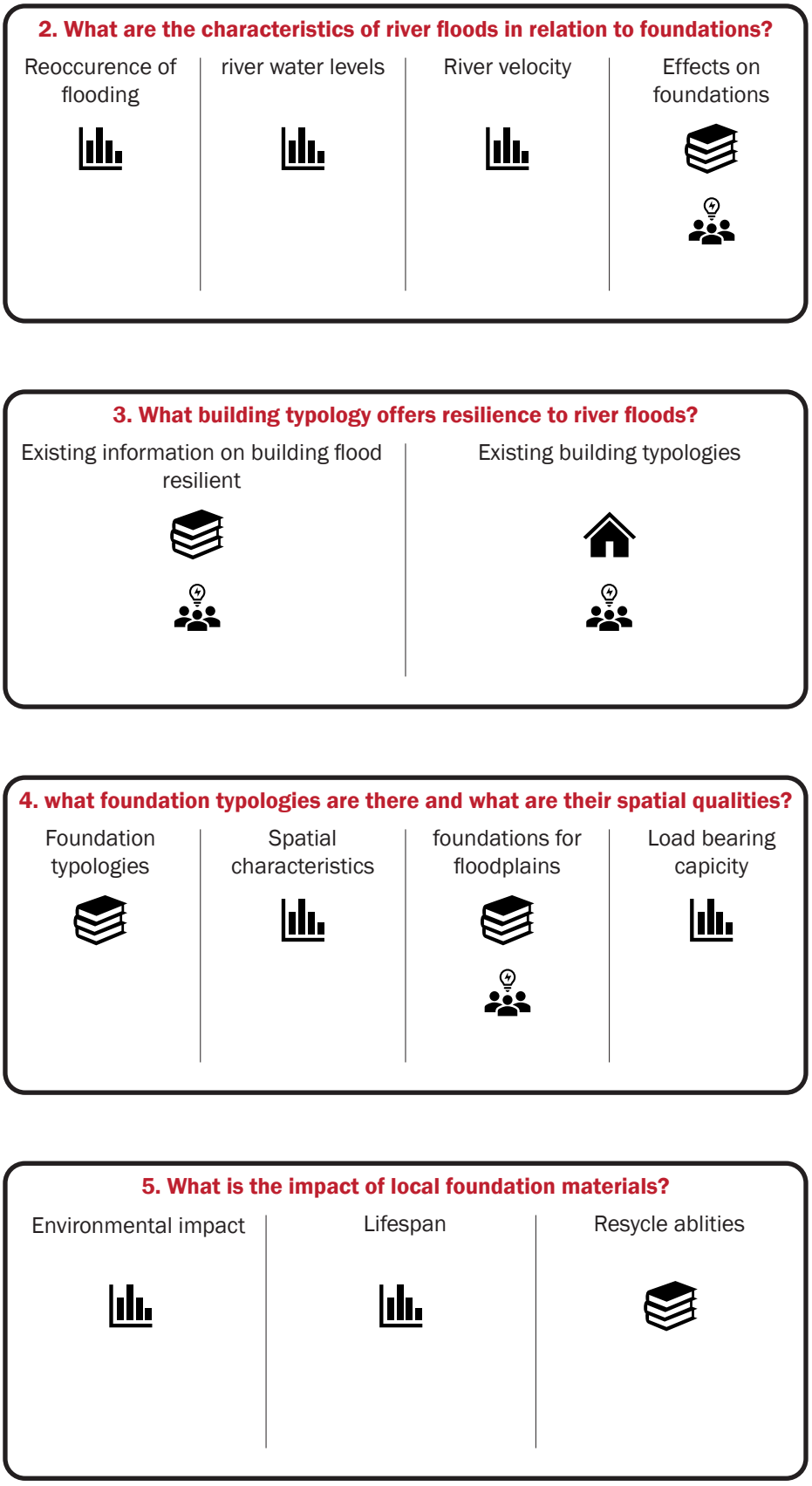


Figure 5a ►
Graphical representation of information needed per subquestion per method
Own image.

Figure 5b, c, d and e ►
Graphical representation of information needed per subquestion per method
Own image.



Planning

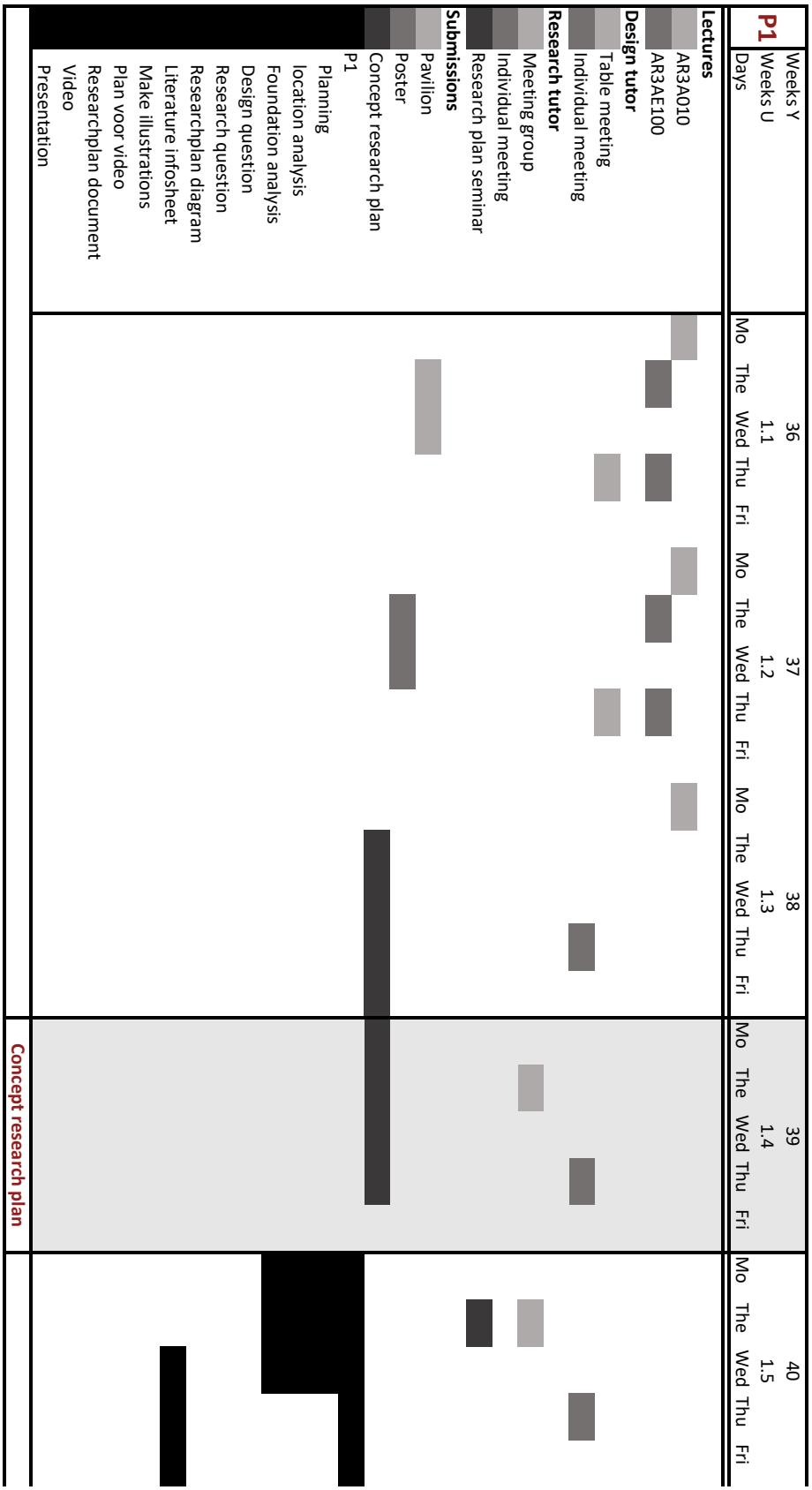
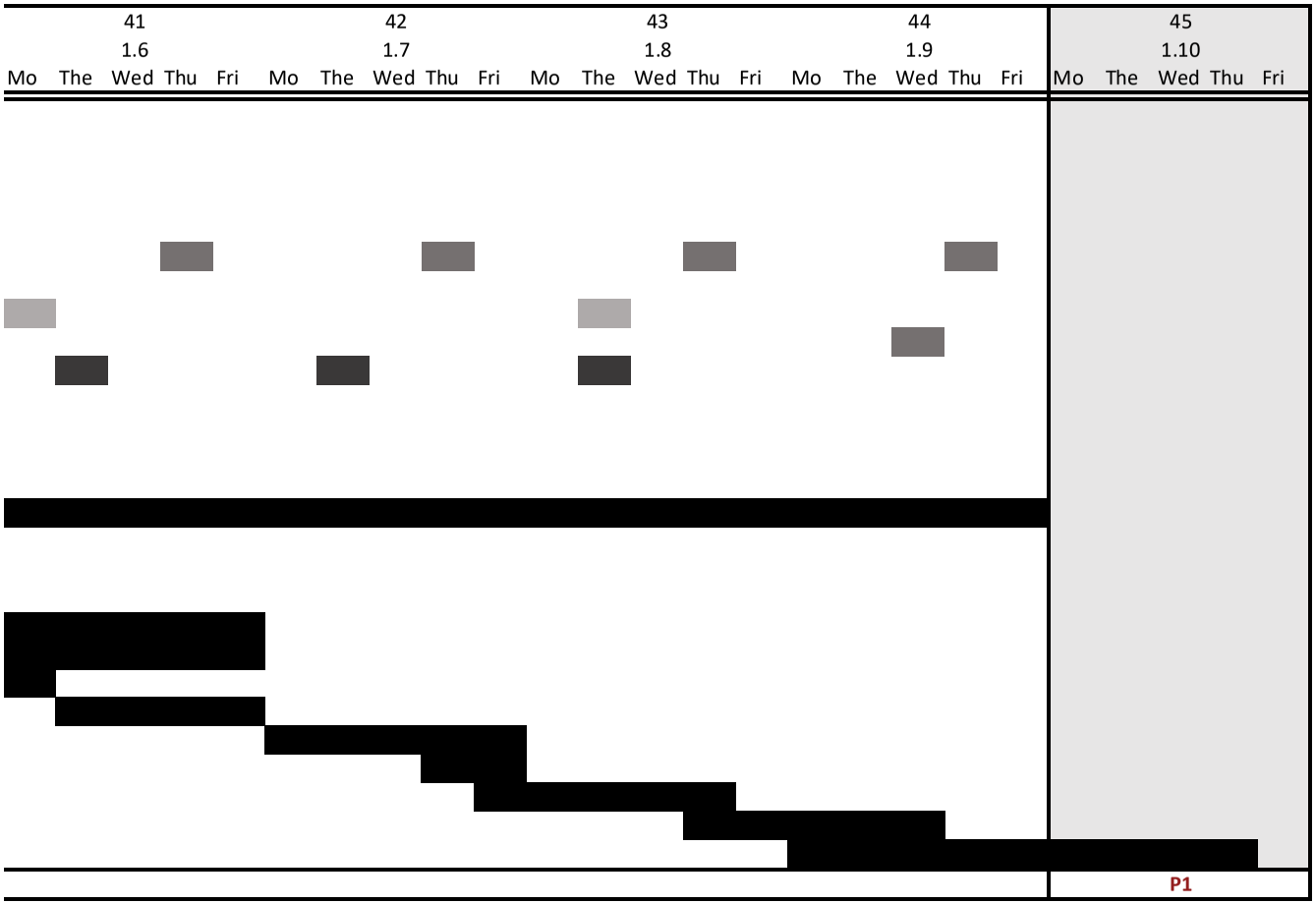


Figure 6a ►
Planning graduation P1
Own image.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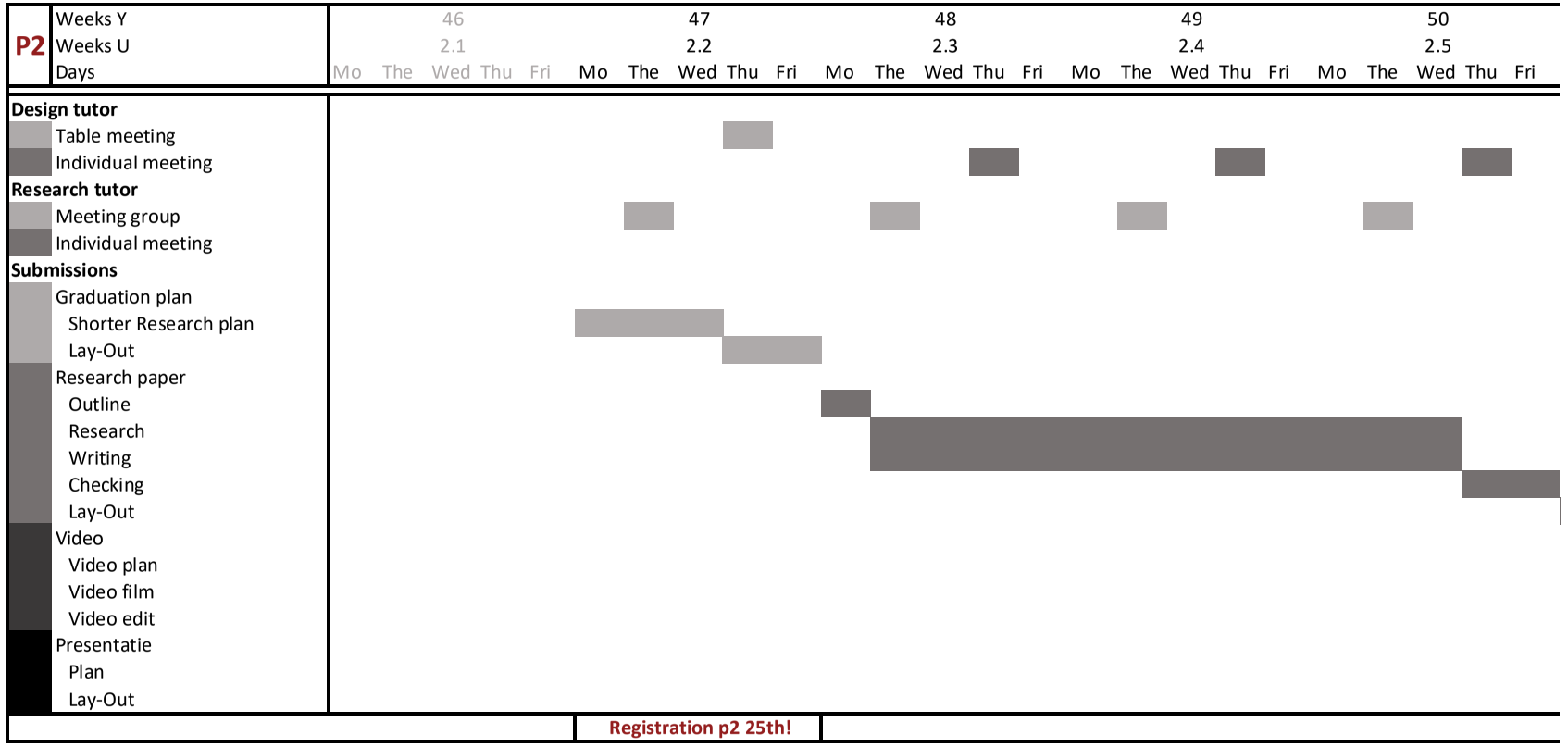
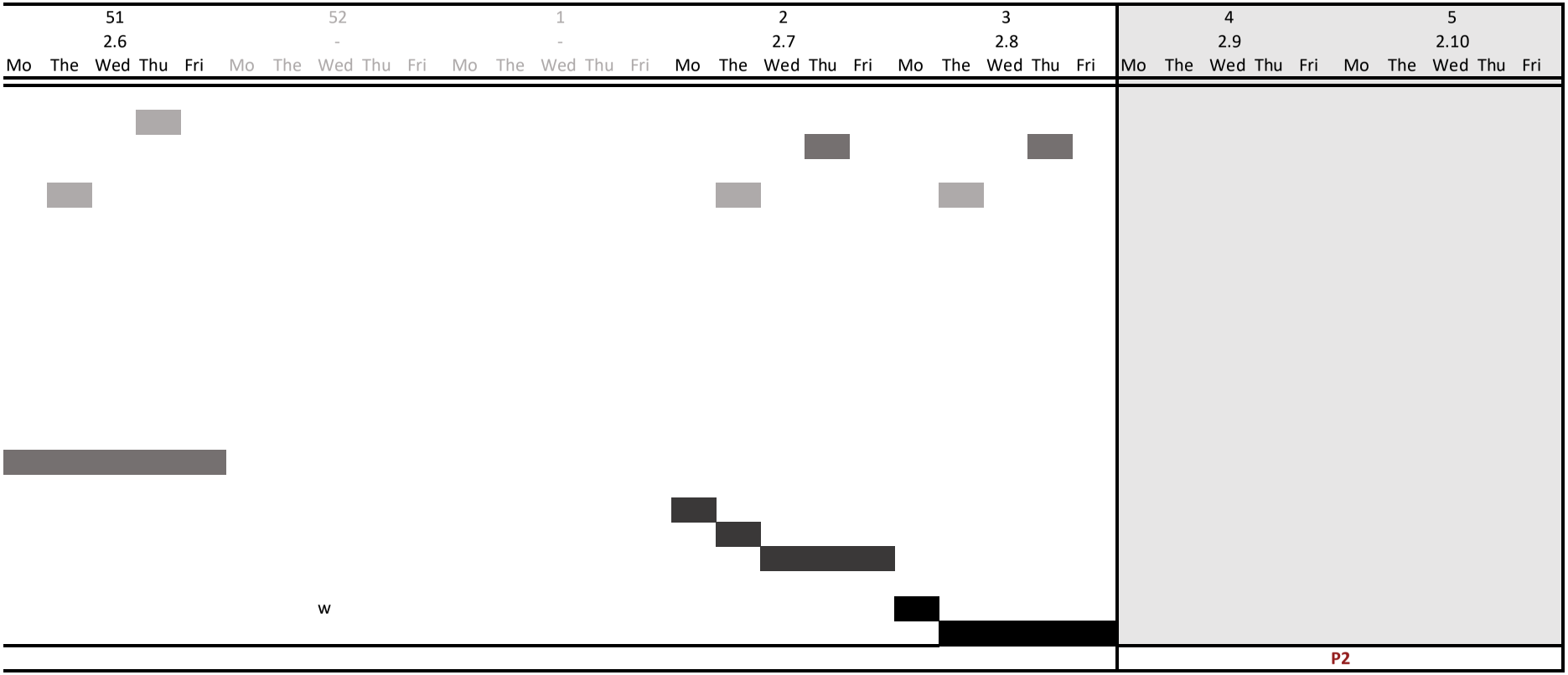


Figure 6b
Planning graduation P2
Own image.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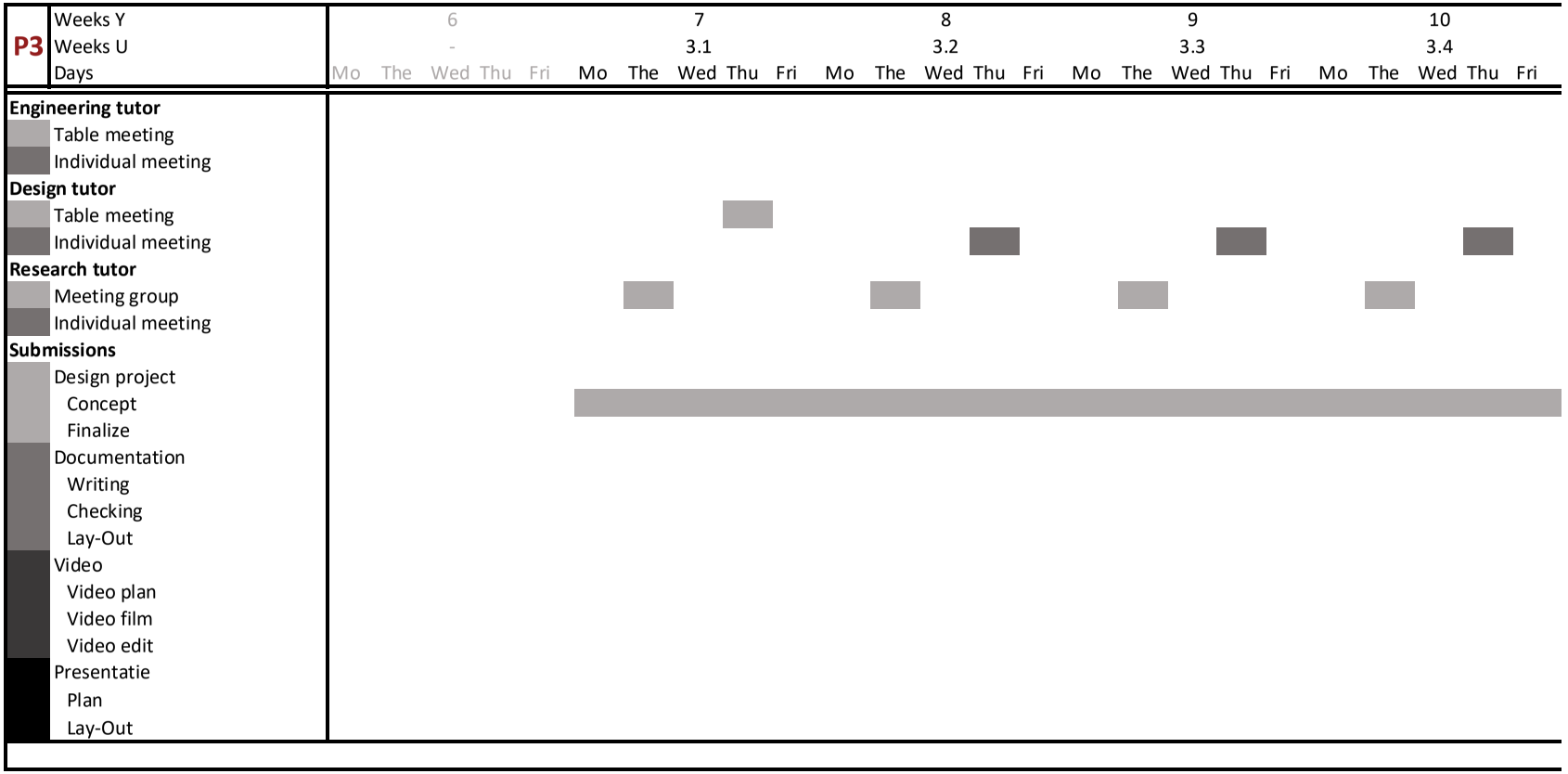
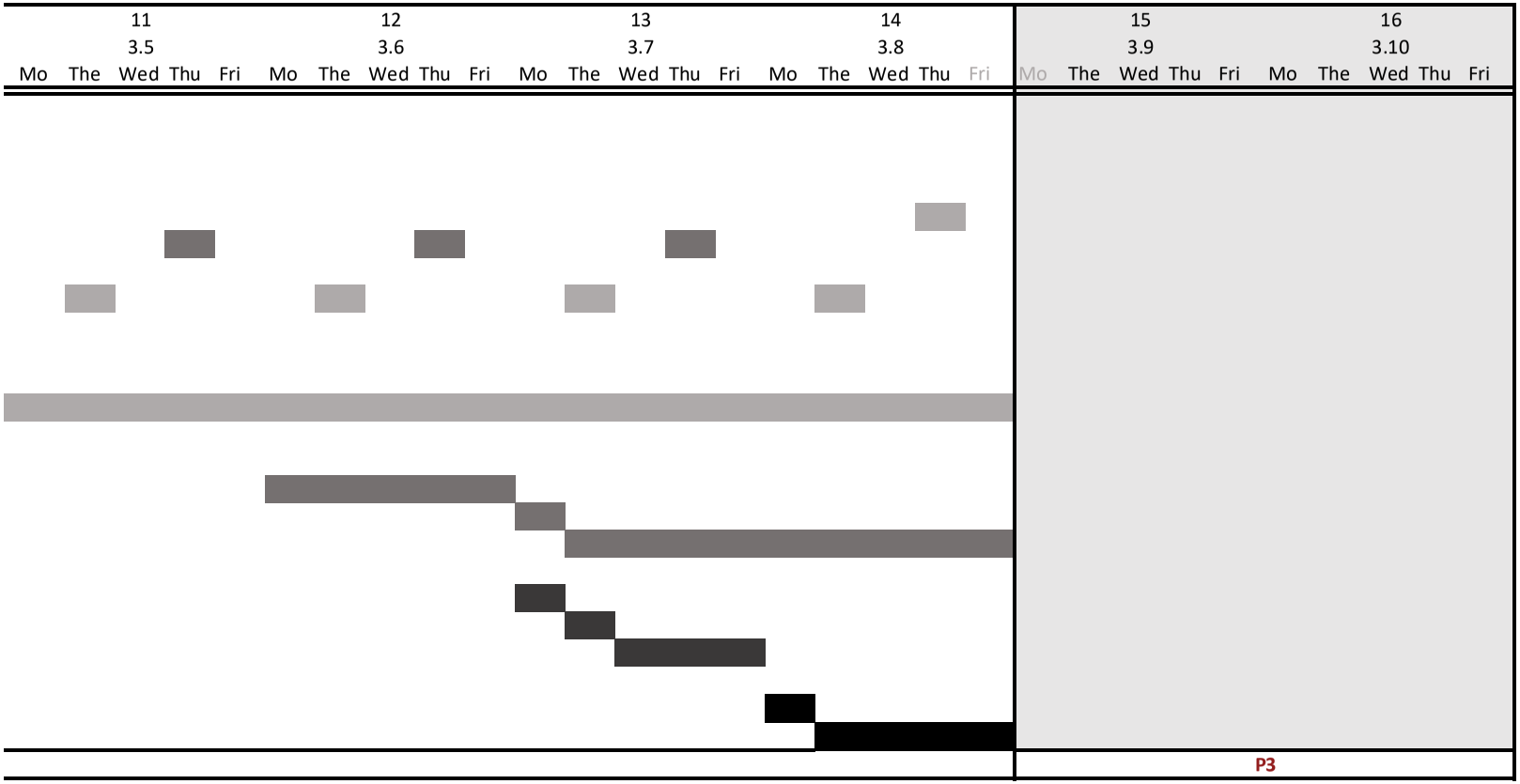


Figure 6c
Planning graduation P3
Own image.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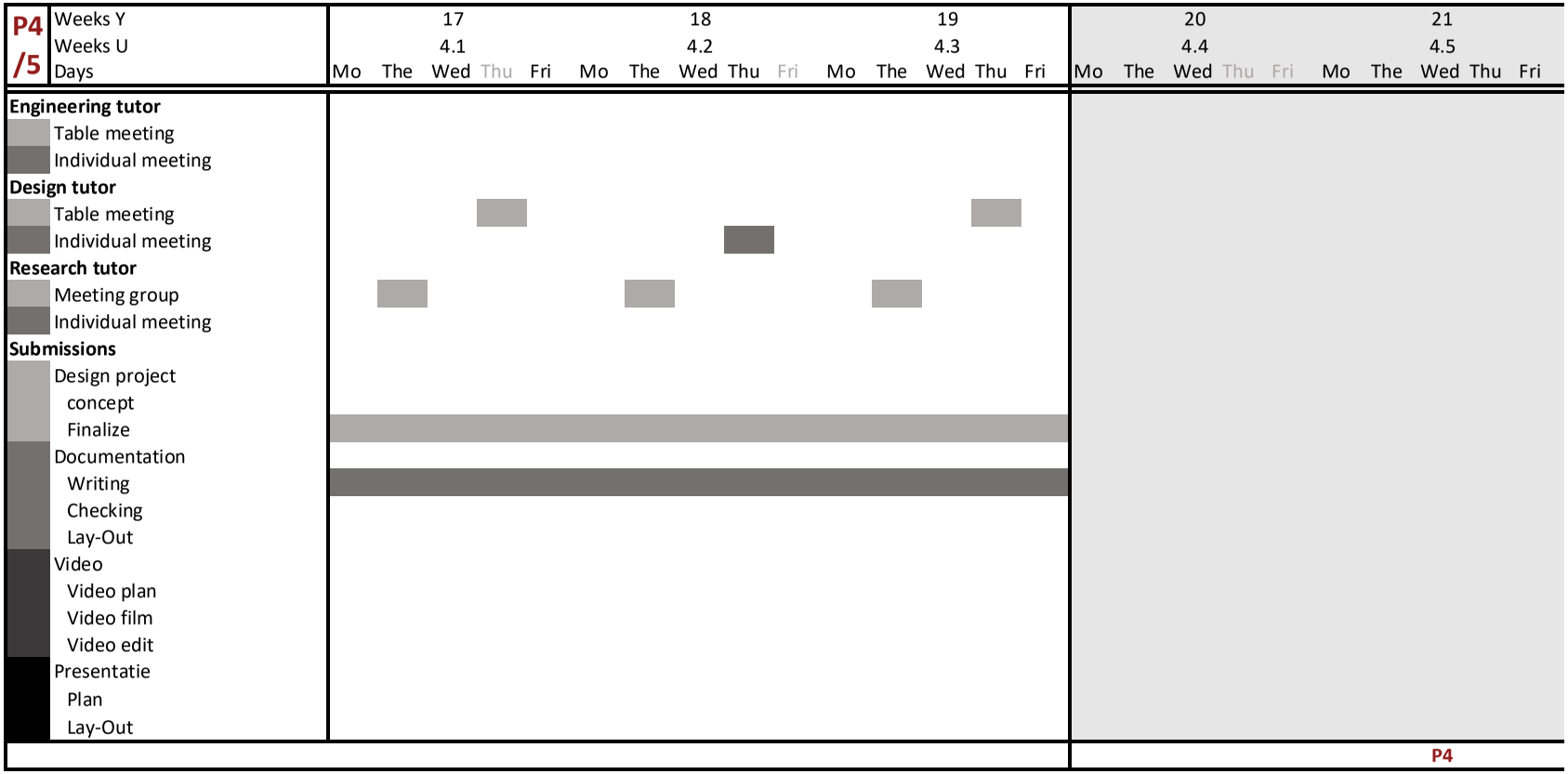
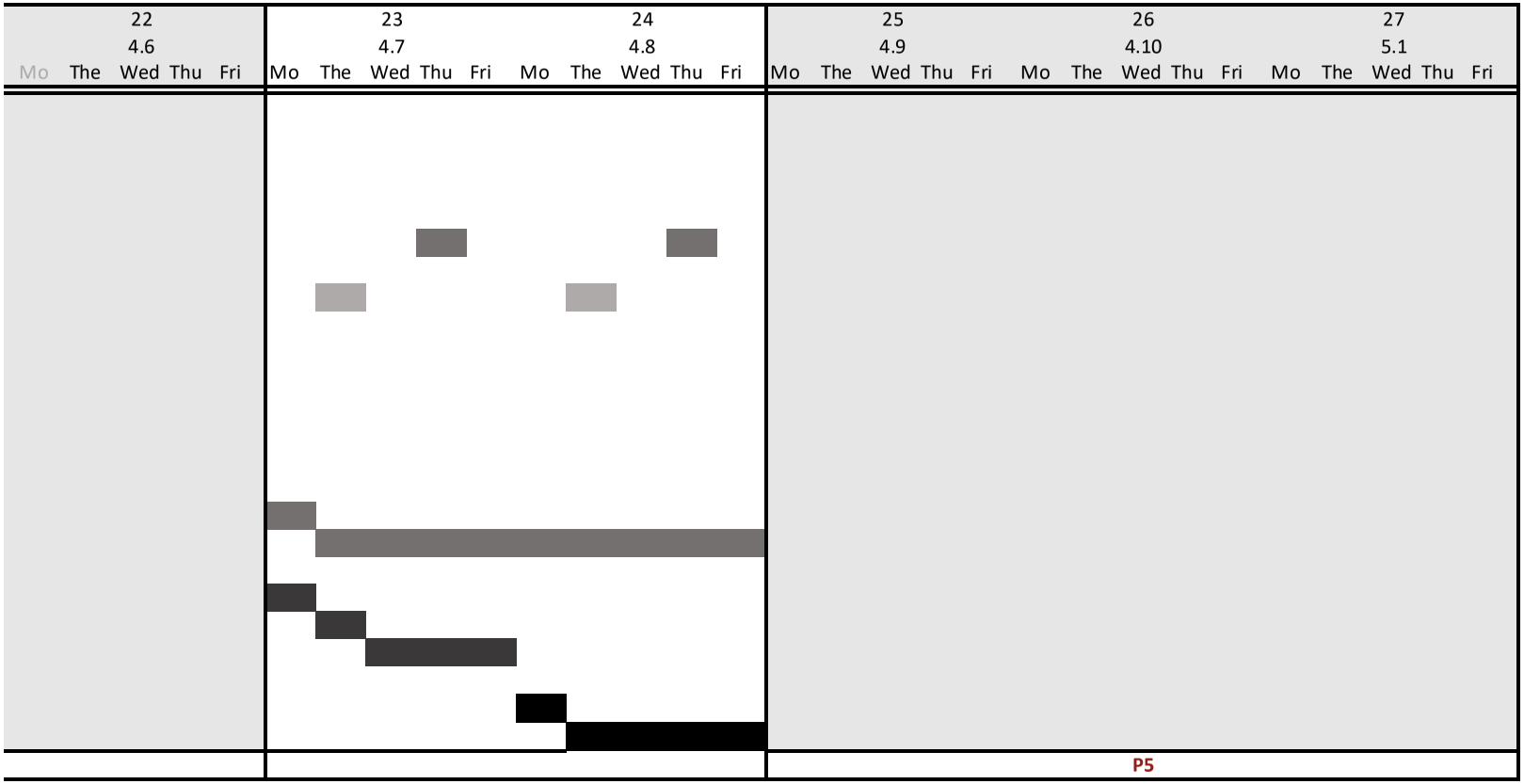


Figure 6d
Planning graduation P4/5
Own image.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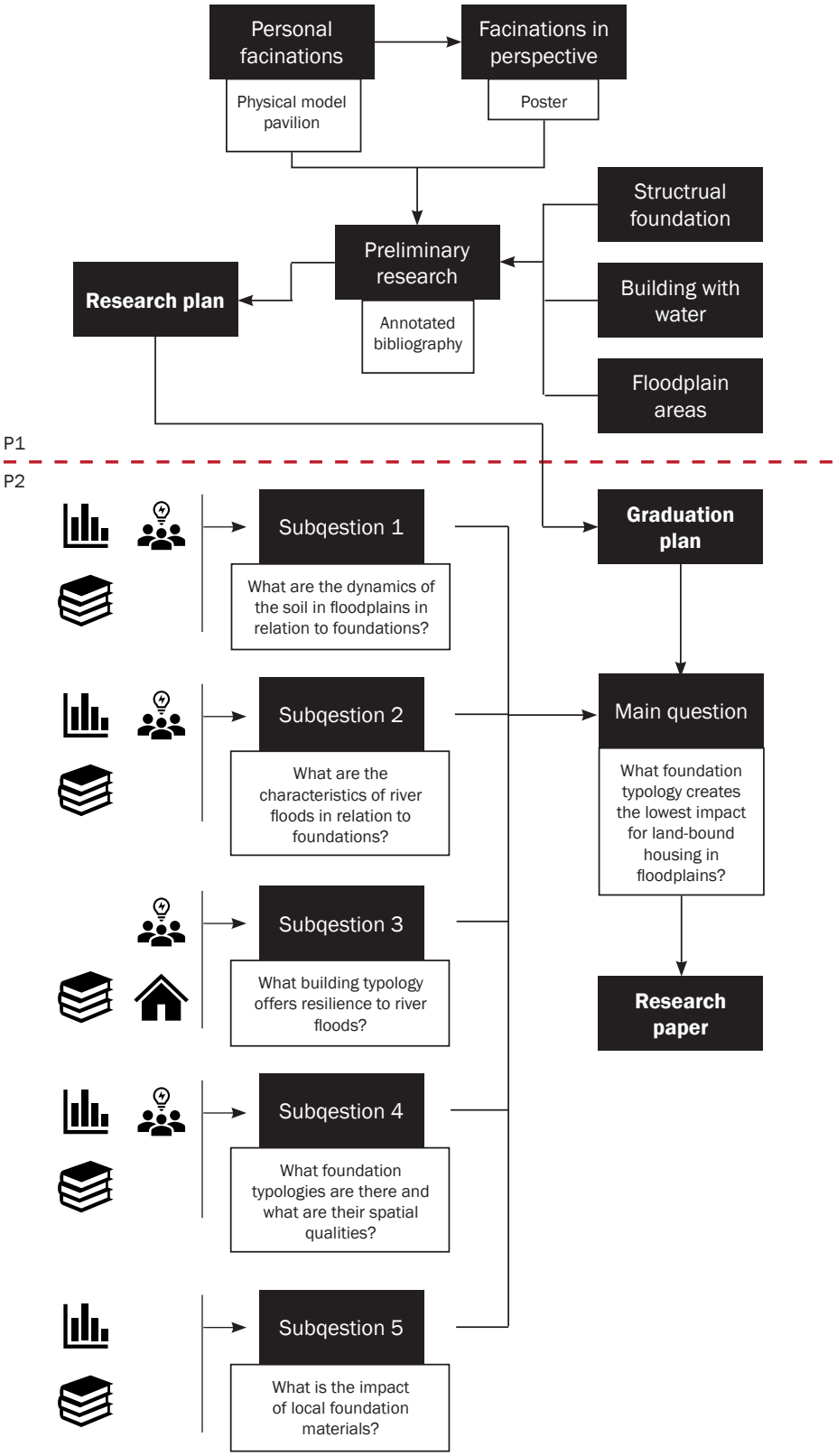
P5

Conclusion

Visualisation research plan

◄ **Picture page 20**
Floodplains of the Waal river near Druten the Netherlands.
Own image

Figure 7 ►
Visualisation research plan
Own image.



Risks

The risks this project has are timewise and the knowledge that I don't have. Timewise can be solved with strict planning and preserving myself on not researching the subject in a very broad manner but framing it to a very specific question. In my opinion, I was able to do this. The one thing I will not be able to control which poses a big risk, is that I need to involve experts in my thematic research because my knowledge alone would not result in a validated and academic research. I can not control the number of experts that will respond to my brainstorming sessions. This can result in a less credible thematic research.

Percieved outcome

The result at the end of the graduation project is a low-impact, land-bound family home located in a floodplain. It can offer resilience to the dynamics of this location. This will be based on the outcomes of the thematic research that offers literally and figuratively the foundation for this to-be-designed family home.

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Picture back page
Floodplains of the Waal near Deest, the Netherlands
Own image. ►

Colophon

Graphic design: Renée de Vries
Photos: Renée de Vries
Illustrations: Renée de Vries
Text: Renée de Vries

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Low-impact home in floodplains

Designing a land-bound, low-impact family home that is located in floodplains offering resilience against flooding.

Research plan - Appendix

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Low-impact home in floodplains

Designing a land-bound, low-impact family home that is located in floodplains offering resilience against flooding.

Research plan - Appendix

Student
Renée de Vries
5429978

Studio
Architectural engineering
Design tutor: Anne Snijders
Research tutor: Luca Iourio

Date
07-11-2022

Stage
Final

Appendix 1

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Appendix 2

List of websites to use for desk research and data analysis

Sub question 1, What are the dynamics of the soil in floodplains in relation to foundations?

- For soil composition and load bearing capacity of floodplains at multiple locations along the rivers: www.dinoloket.nl
- For soil types based on interactive maps along the rivers: www.pdok.nl

Sub question 2, What are the characteristics of river floods in relation to foundations?

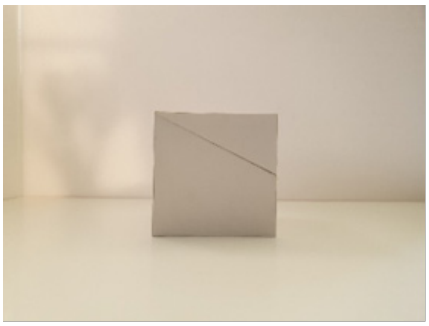
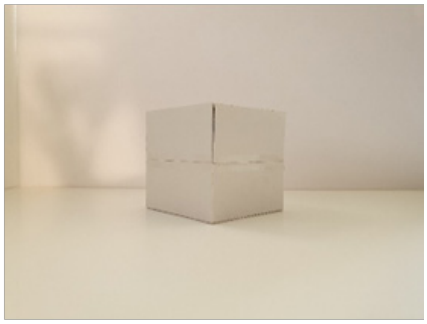
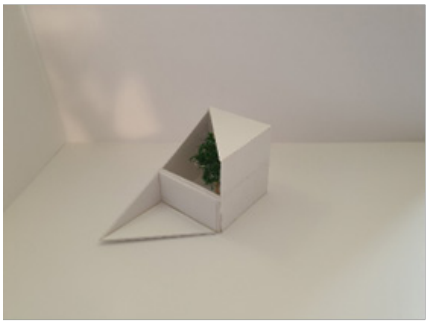
- For dat about the reocurrence of flooding, the water level relative to the floodplain and the speed of the stream: https://waterinfo.rws.nl/#!/nav/index/

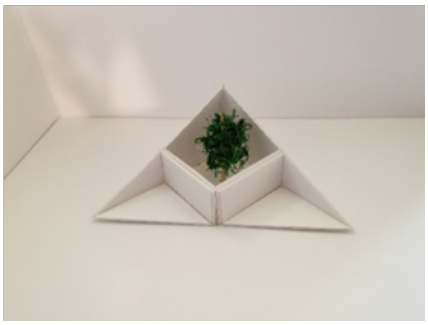
Sub question 5, What is the impact of local foundation materials?

- For the milieu classifications: https://www.nibe.info/nl

Appendix 4

Pavilion week 1

Appendix 5

Collage week 3

Colophon

Graphic design: Renée de Vries
Photos: Renée de Vries
Illustrations: Renée de Vries
Text: Renée de Vries

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