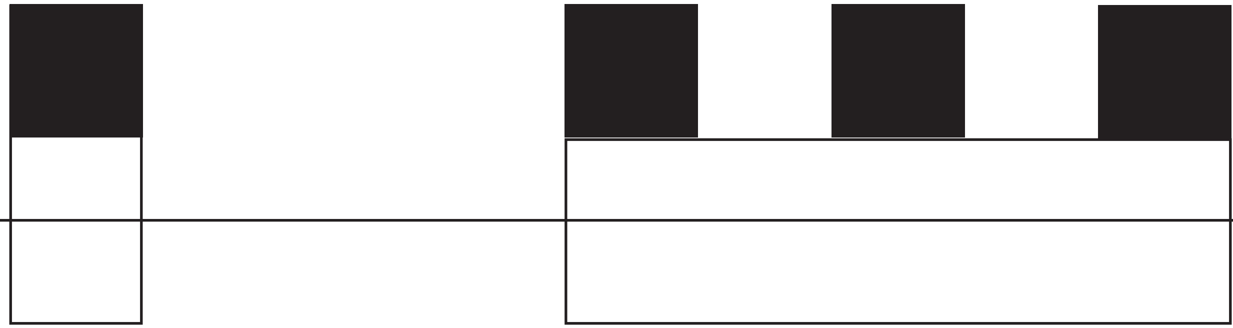
June
2024



FROM DIKE HOUSE
TO DIKE ARCHITECTURE

ANN A. A. AYAD

Research Report
Ann Ayad
19 | 06 | 2024

Preface

This research introduces the main topic of my graduation project and represents my personal interest in the theme of "water & edges." Originally from Egypt and now residing in the Netherlands, a country situated below sea level, has been a source of fascination and concern for me. I have sensed that not everyone in the Netherlands fully comprehends how climate change and rising sea levels may impact our future. The research investigates how we can heighten awareness of water-related issues and develop strategies for coexisting with and adapting to it.

The Netherlands is renowned for its extensive knowledge of land reclamation and protection strategies, particularly in civil engineering. However, the escalating threat of sea level rise due to climate change presents a significant challenge for architects, engineers, and policymakers. The key dilemma revolves around whether we should accept the flooding of specific areas or construct higher and larger dikes and dams. Additionally, addressing the housing shortage in the Netherlands becomes a complex problem if available land becomes restricted. The unpredictability of these scenarios suggests that finding a 100 percent waterproof solution is nearly impossible. Nevertheless, as a future architect, it is my role to raise awareness, take a stance, and proactively prepare the built environment for potential challenges.

In this graduation studio, I explore and investigate perspectives and solutions for the built environment. I focus on the edges where water and land converge, aiming to contribute insights to address these challenges.

It is crucial to note that my graduation project requires interdisciplinary research, encompassing civil engineering, architectural engineering, architecture, and biological engineering. While the primary focus is on architectural research, minimal exploration of other subjects is necessary for informed decision-making in the project. Subjective assumptions are integral to this research. As architects, we endeavor to create innovative solutions that may not always align with fully scientific research. Therefore, assumptions and discussions with professors serve as crucial elements to support the feasibility of proposed solutions.

The research commences with an exploration of potential future scenarios for the Netherlands. From there, a scenario is selected where reinforcing and elevating dikes is the conventional solution. I take this conventional solution a step further by investigating how dikes could serve not only as protectors but also as infrastructure for future towns. The research delves into Architecture on the dike, requiring civil engineering research. However, the focus remains on possibilities and justifications for the design of a multifunctional dike, potentially on a larger, more urban scale. Architectural research explores foundation possibilities in relation to Groningen's soil types. Additionally, structure and building research is conducted to design a building that can withstand flooding on the ground floor while still functioning structurally and programmatically.
Assuring the possibilities for buildings on the dike, the research continued in exploring the differet architectural principles that suit this new type of architectural language. This has been conducted through research by design.

Throughout my research and the subsequent stages of my graduation, I am supported by my research tutor Peter Koorstra, architecture tutor Veerle de Vries, and building engineering tutor Koen Mulder.

This research lays the foundation for my design graduation project at Delft University.

A.A.A. Ayad
June 2024

| Research Question |

In the context of elevated sea dike, what foundation types and structural systems demonstrate the highest suitability for buildings on the dike?

| Sub-question |

How can these elements be optimized to accommodate potential future reinforcements of the dike?

| Sub-question |

Which architectural language and principles suits buildings on the dike?

TABLE OF CONTENT

1 | Introduction

Climate change and sea level rise play a pivotal role in shaping the future of the Netherlands. According to Van Den Dobbelsteen et al. (2009) it is recommended to raise the sea dikes in the northern regions of the Netherlands by at least 2 meters to mitigate the anticipated sea level rise. This imperative becomes more pronounced if we do not curtail the use of fossil fuels. (Van Den Dobbelsteen et al., 2009)
However, the extent to which global efforts will be dedicated to reducing CO2 emissions remains uncertain. Consequently, it raises the possibility that, within a decade, there may be a need to elevate the dikes by 4 or even 10 meters.

A parallel concern arises when contemplating the potential heightening of the dike. A 2-meter increase would result in a threefold elongation of the slope on each side. Consequently, the dike would transcend its conventional role as a mere protector, evolving into a substantial massif element within our landscape. As Van de Wal's mentioned in one of his interviews, an alternative scenario is contemplating migration to other countries and allowing parts of the Netherlands to succumb to flooding (Van de Wal's, 2021). However, such a course of action would precipitate an economic catastrophe.

The uncertainty surrounding our future prompts questions without an answer:
What will our future look like?
Unfortunately, this question cannot be answered because the future is unpredictable and we are facing a problem that is not on a regional scale but on a global one, Climate Change.
As a future architect, I am trying to understand the situation, take a position, and act from there.
My perspective is to protect and continue with what the ancestors of the Dutch folk did but in an innovative way. The Dutch folk have been for centuries living behind the dikes, this graduation project is introducing living on the dike. Dikes are massive elements in our landscape and have an important function.
However, predicting the dikes in the future will be bigger and higher. Their high position is interesting, it may give a feeling of safety.
The idea of a dike as land to live on is the base for this graduation research.

Therefore, the research question is:
"In the context of an elevated sea dike, what foundation types and structural systems demonstrate the highest suitability for buildings on the dike?"
Furthermore, 2 sub-questions are also answered through this research. 1-"How can these elements be optimized to accommodate potential future reinforcements of the dike?"
2- Which architectural language suits buildings on the dike?
The research methodology employed for this project involved a literature review across various study fields, with a particular focus on Architecture. In addition to the literature review, case studies were analysed to extract details regarding

structural requirements and potential obstacles.

The research process also incorporated design research, wherein the literature review served as the foundational knowledge base for generating innovative design ideas. This approach facilitated the exploration and analysis of possibilities, allowing for an informed design process.

Later during the design phase, research has been conducted through design, to explore which architectural language suits the dike.

This booklet starts with the introduction that explains the interest which was the reason to start this graduation project. The second section analyses the dikes of the Netherlands and the one of Groningen. It further explores the possible scenario and what is the chosen strategy. In the third section, the concept of multifunctional dike is introduced and justifications through literature have been accentuated. In the fourth section, the main research question and the first sub-question are answered through analysis, design, and literature. In the fifth section, 5 principles has been drawn which will lead the deisgn phase. In section six , the design brief is defined and how the research complimented the design. The second sub-question is answered through research by design, which will be shown in the section after. The research report ends with the conclusion and the bibliography.

2 | Dikes of the Netherlands

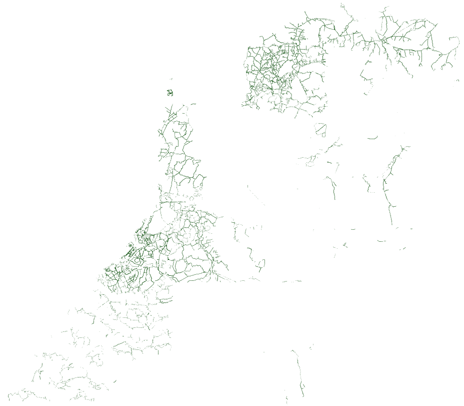
The Netherlands wouldn't be the same without dikes. Dikes make it possible to live in cities like Den Haag, Rotterdam, or Amsterdam. Our ancestors chose to settle below sea level, reclaiming land by building dikes. Since then, it has been a continuous effort to construct higher and stronger dikes. Essentially, our protectors, the dikes, have shaped the identity of the Netherlands. (Pleijster et al., 2014)

The country boasts 880 km of coastlines and an extensive 22,000 km of dikes. These waterfronts are categorized into Primary dams and storm surge barriers, Primary dikes, Secondary dikes, and "line" dikes, as seen in Image 1. (Pleijster et al., 2014)

In this booklet, our focus is on the dikes situated in the Groningen area in the north of the Netherlands. Image 2 displays a map of the dikes in this region, with particular emphasis on the sea dike that safeguards Groningen from Lauwersoog. (Pleijster et al., 2014)

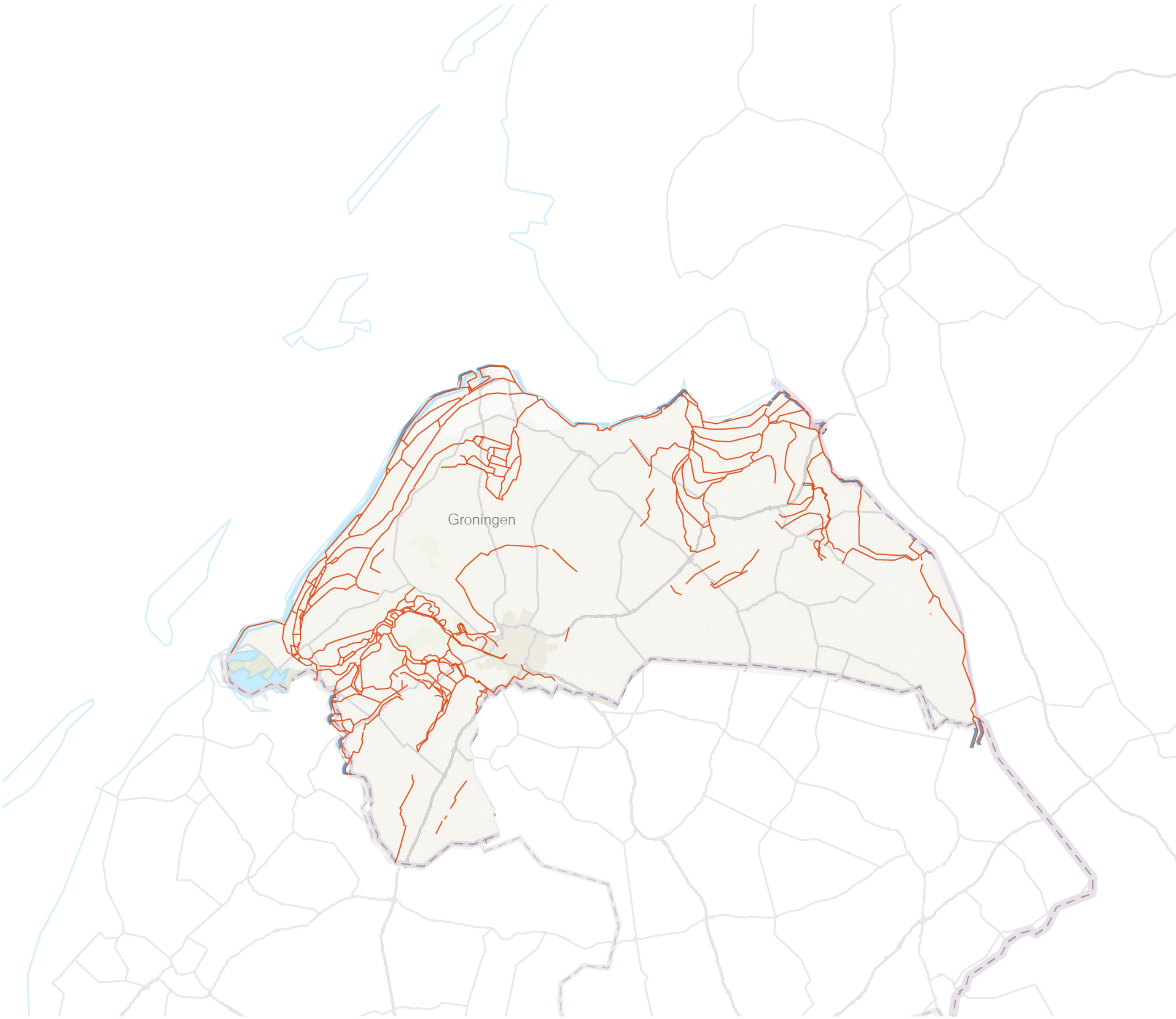
Primary Dikes & Dams

Secondary Dikes



Linie Dikes

1. Dutch Dikes, own illustration based on Book "Dutch Dikes" by Lola Architects.



2. Dikes of Groningen, own illustration based on Book "Dutch Dikes" by Lola Architects.

DIKES OF GRONINGEN

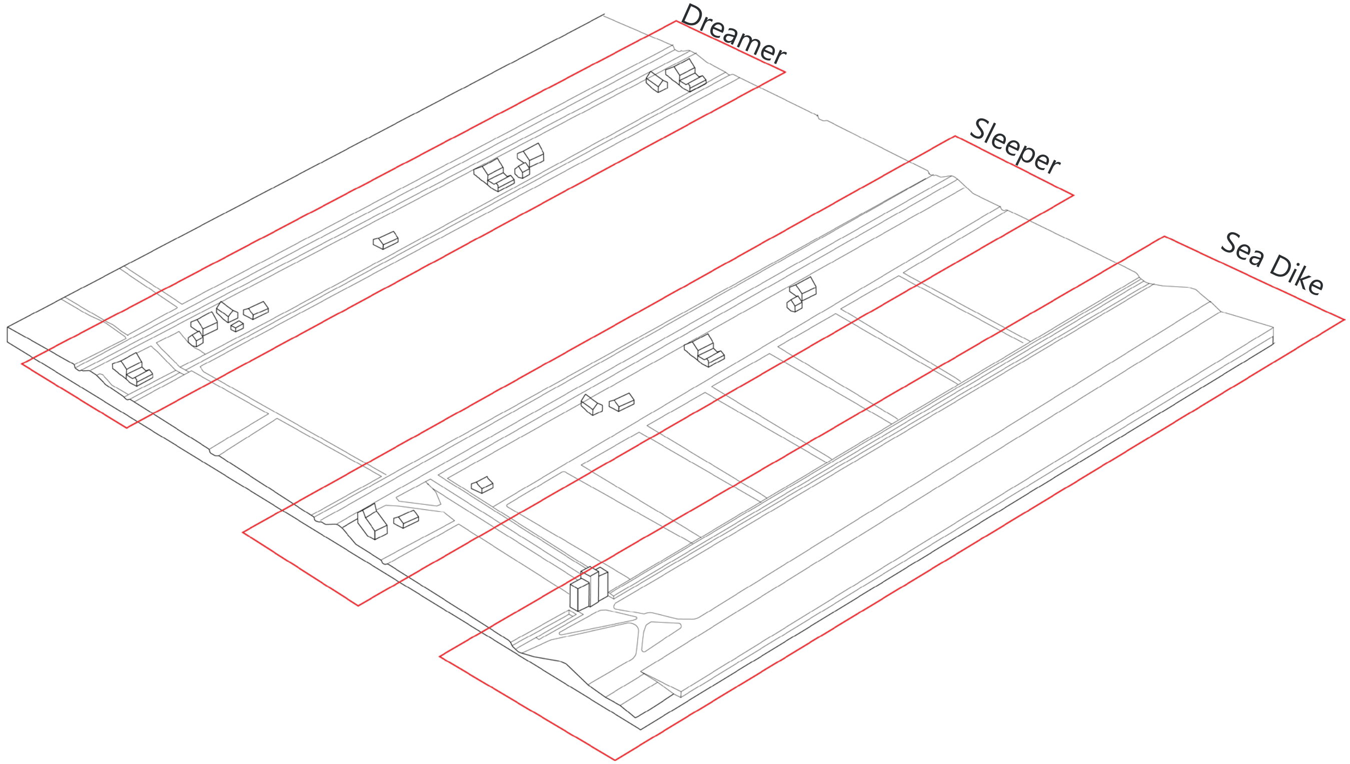
The Netherlands distinguishes different dike typologies, each of which categorizes various dike systems, and each system further specifies dike types. (Pleijster et al., 2014)

The book "Dutch Dikes" by Lola Landscape Architects comprehensively explains all dike typologies, systems, and types. The primary typologies include Sea Dike, River Dike, Polder Dikes, Canal Dikes, and Dams & Stormvloedkeringen.

In this section, our focus is solely on the sea dike typology because we are concentrating on the sea dike of Groningen. The sea dike typology comprises three sea dike systems: (Pleijster et al., 2014)

Dike System - Watcher Sleeper Dreamer
Dike System - Watcher "Inlaagdijk"
Dike System - Harbour Canal - Spuikomdijken
The sea dike of Groningen is one of the examples of the system Watcher, Sleeper and Dreamer (see image 3) .
(Pleijster et al., 2014)

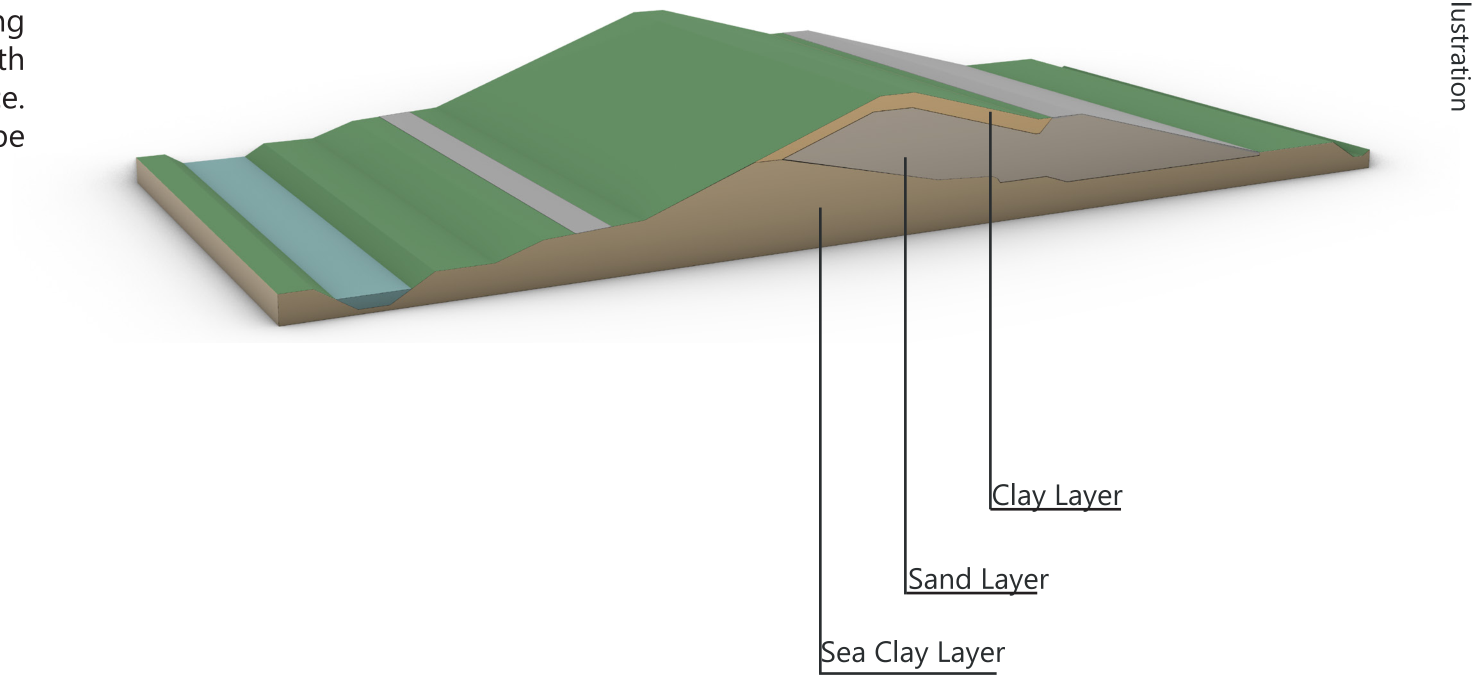
TYPOLOGY OF THE SEA DIKE



3. Groningen Sea dike typology, own illustration based on Book "Dutch Dikes" by Lola Architects

SOILS OF THE SEA DIKE

Zooming in on the underground soil types of the Sea dike of Groningen (Image 4). Three layers are distinguished. The upper layer is a clay layer. Under it a sand layer is set and at the bottom of the area a sea clay layer (Bos, 2011). This information is important for the foundation analysis for building on the dike. More information on the depth of these layers is also of great importance. However, no source or literature could be found on that matter.



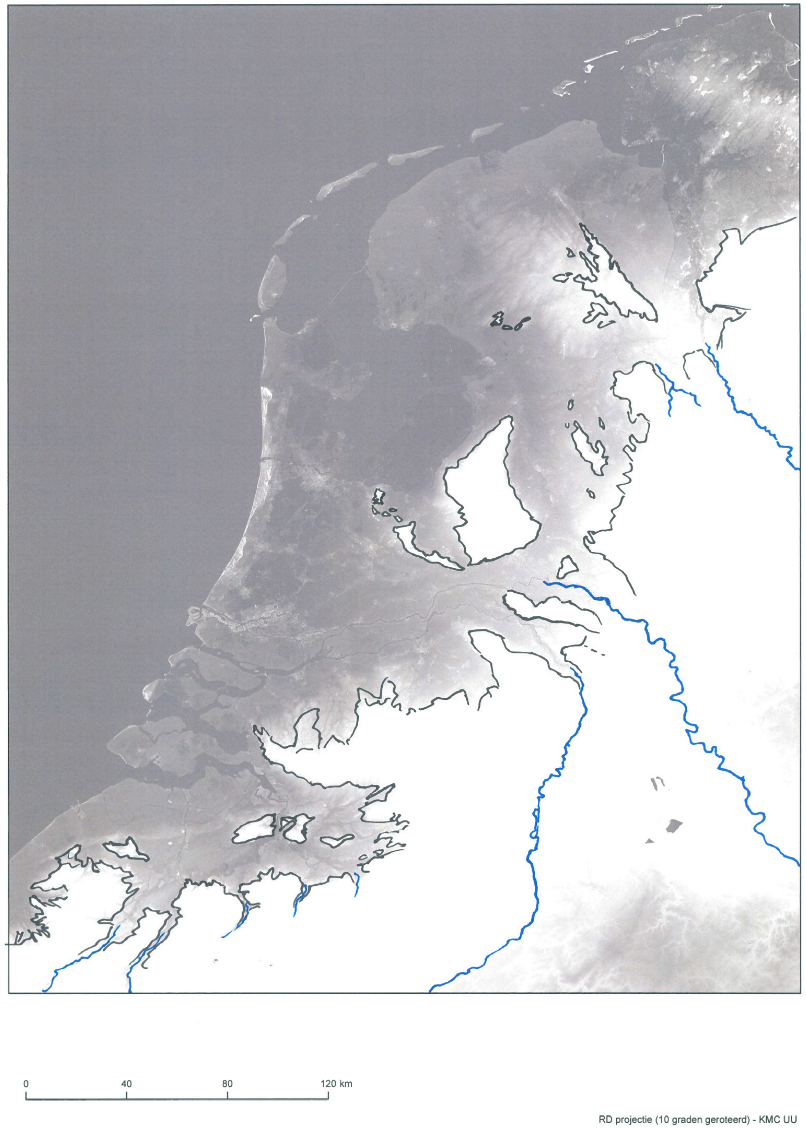
4. Technical section Sea dike of Groningen, own illustration

EXTREME FUTURE SCENARIO

This graduation research started by investigating the worst-case scenarios available and acting from there. Many scenarios have been found. However, this one captured the attention. It is a scenario where the world can end up with a sea level rise of almost 3 m in 2100 and 2 centuries later 5 to 8 meters high.
To draw a picture that illustrates what this means and how this would look like. Kim Cohen, a geographer at the University of Utrecht drew a map of the Netherlands in the year 2300 with an extreme climate change and high sea level rise and this would be the result (Image 5). The Netherlands would be unrecognizable. A lot of regions would disappear. (Grevink, 2021)

This scenario is very extreme and pessimistic and may cause panic. However, this graduation research aims to try to prevent this by building high sea dikes that can protect the Netherlands from this extreme scenario and explore new scenarios.

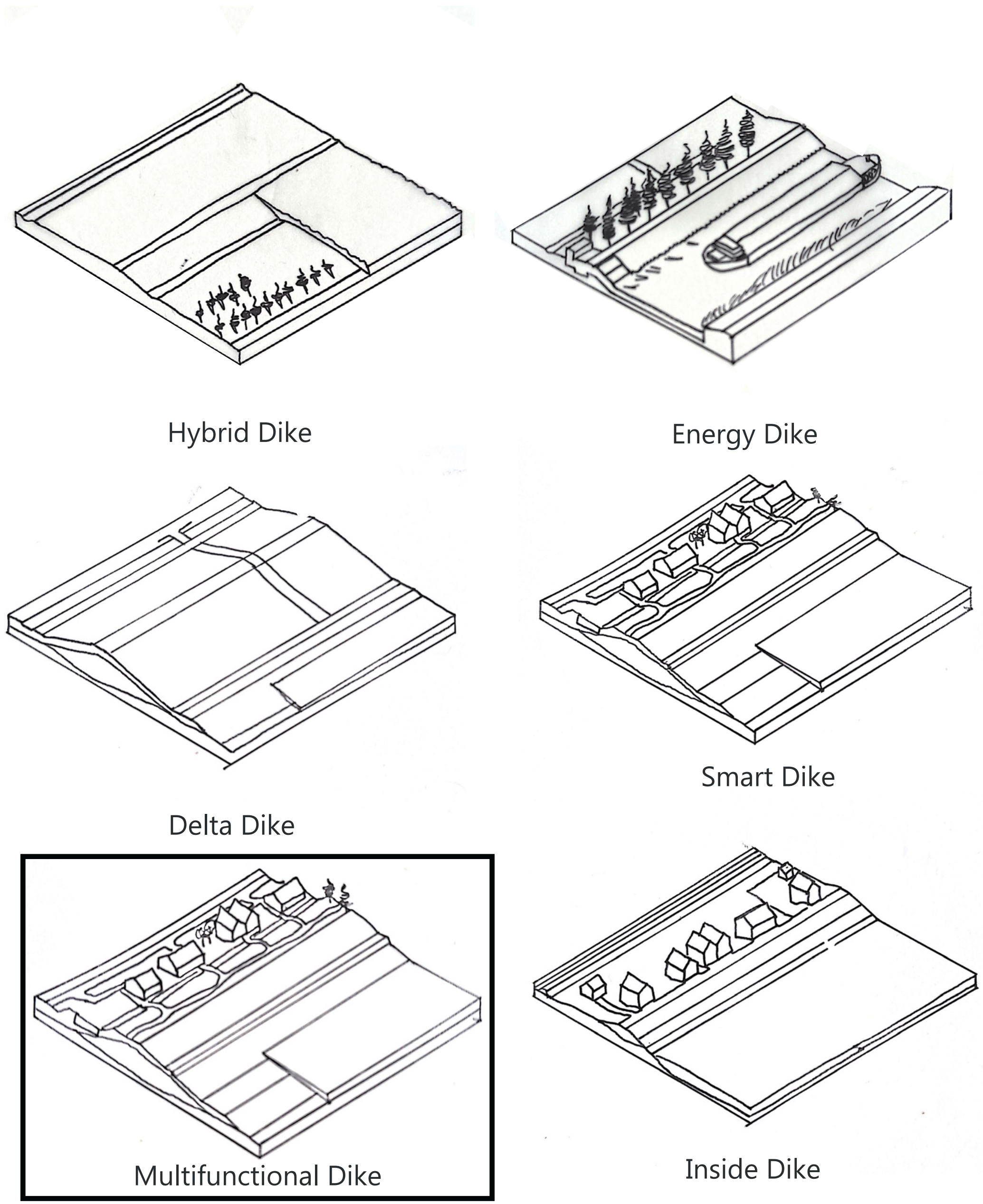
In the next section the ideas of living on the dike are being more visual through literature and the concept of multifunctional dike. Furthermore, the next section introduces the chosen scenario which forms the foundations of the graduation research and future scenario.



5. Map of The Netherlands in the year 2300 in an extreme scenario, Kim Cohen (Cohen, 2019)

3 | Concept of Multifunctional Dike

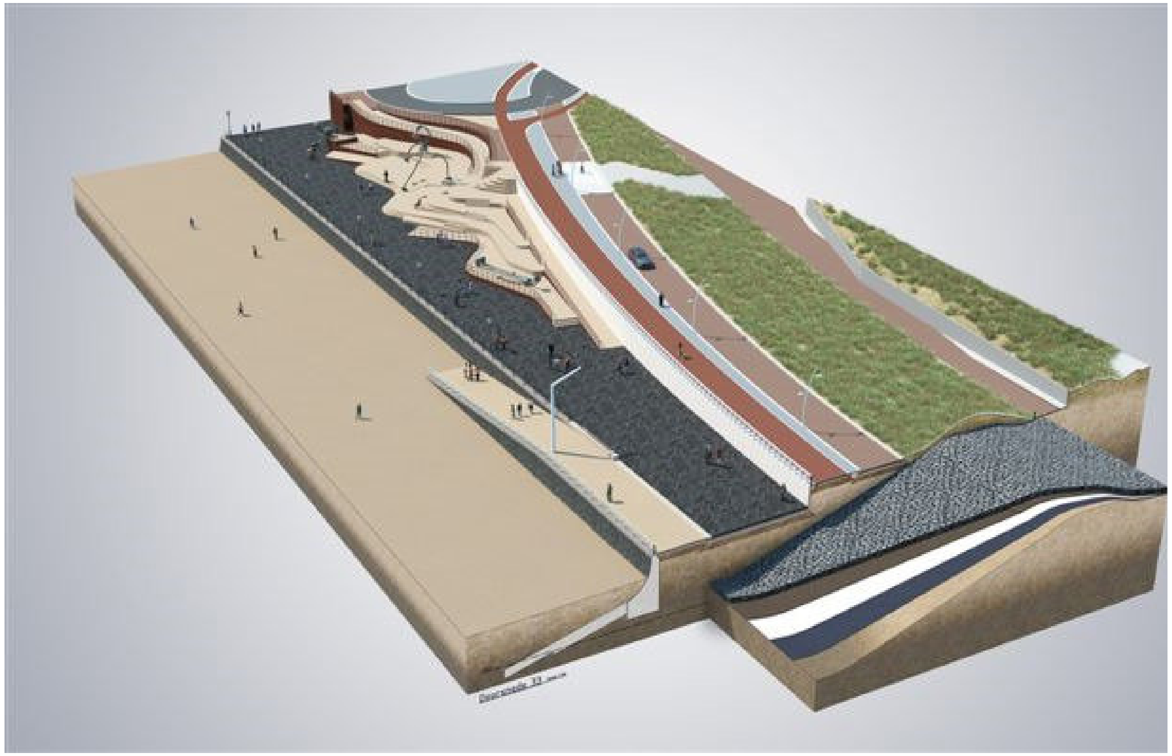
Dikes need to be reinforced every approximately 10 years to satisfy the new sea level rises. This dike upgrade is one of the many that can be analyzed for the future of dikes. 6 dike upgrades have been found in the literature (Image 6). One of these is the multifunctional dike which is also called Super-dike or Climate-dike. These dikes are delta dikes with more functions than just protection. Because of their extra horizontal width possibilities to build on the dike or have infrastructures are possible. These dikes have a section of 1:3 which means each meter wider means 3 meters longer slope on both sides. (Pleijster et al., 2014)



6. Dike Upgrades, own illustration based on Book "Dutch Dikes" by Lola Architects

DIKES UPGRADES
LOLA ARCHITECTS | DUTCH DIKES

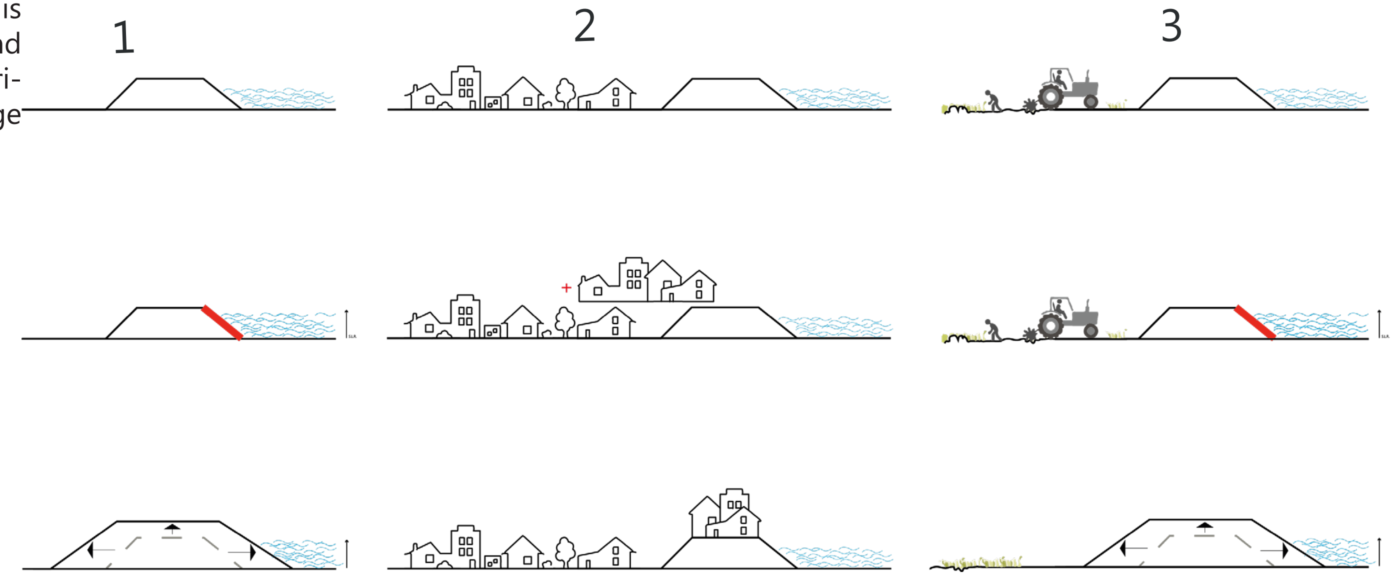
What makes these dikes interesting is their resistance to flooding or tsunamis. Japan is one of the few countries that have these types of dikes. In the Netherlands, we also recognize a multifunctional dike, which is the Scheveningen in Den Haag (Image 7). It is a dike with more functions such as a boulevard, restaurants, a driveway, and a beach. (Saathoff et al., 2016)
However, why would we build multifunctional dikes?



7 . Hidden dike of Scheveningen , (M. Tettero, 2013)

MULTIFUNCTIONAL DIKE EXAMPLE
SCHEVENING | DEN HAAG

Four justifications have been found in the literature. The first one is that because of the climate change adaptations new dike technologies are needed. The second justification is that dikes rival urban areas with housing and infrastructure. The third reason is that dikes rival in rural areas with agricultural uses (Image 8). (Saathoff et al., 2016)



8 . Justifications for Multifunctional dikes, own illustration (Saathoff et al., 2016)

THE NEED FOR A MULTIFUNCTIONAL DIKE

Moreover, the most important reason is that According to multiple sources in the literature, multifunctional dikes are estimated to be 100 times safer than traditional mono-functional dikes. This enhanced safety is attributed to their increased width, structural mass, and the additional support from integrated functions, which collectively enhance their resilience (Image 9).

However, there is a significant gap in the legal and regulatory frameworks governing multifunctional dikes; such regulations are either minimal or nearly non-existent. Moreover, there is a notable deficiency in technical research and literature concerning the foundations of structures built on dikes, a gap which this graduation research aims to address (Van Loon-Steensma & Vellinga, 2014).

Additionally, the diagram highlights that conventional dikes lose their functionality after experiencing excessive loads, a limitation not observed in unbreachable (multifunctional) dikes.

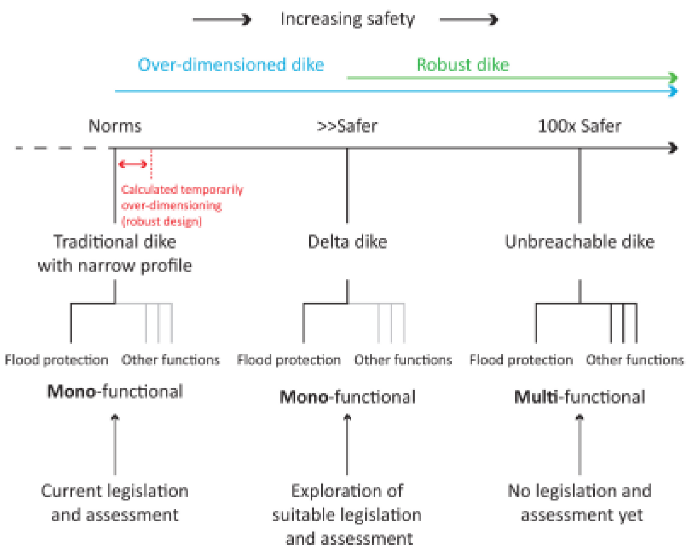


Fig. 1. Visualization of the relation between the various dike concepts in the Netherlands; these concepts are described in Table 1.

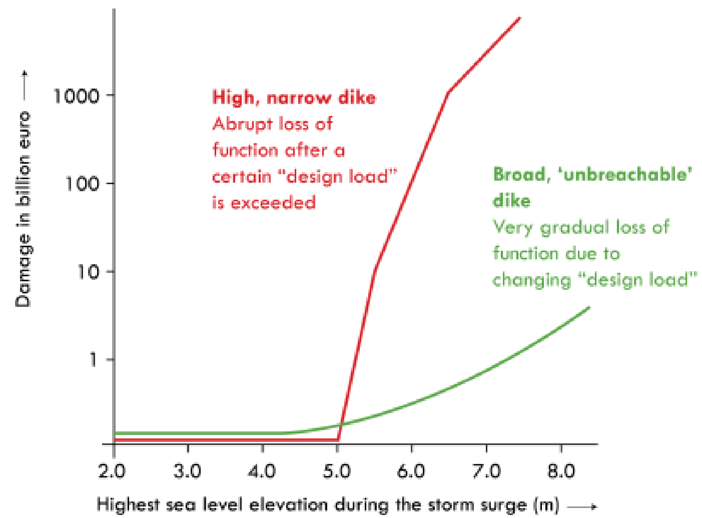
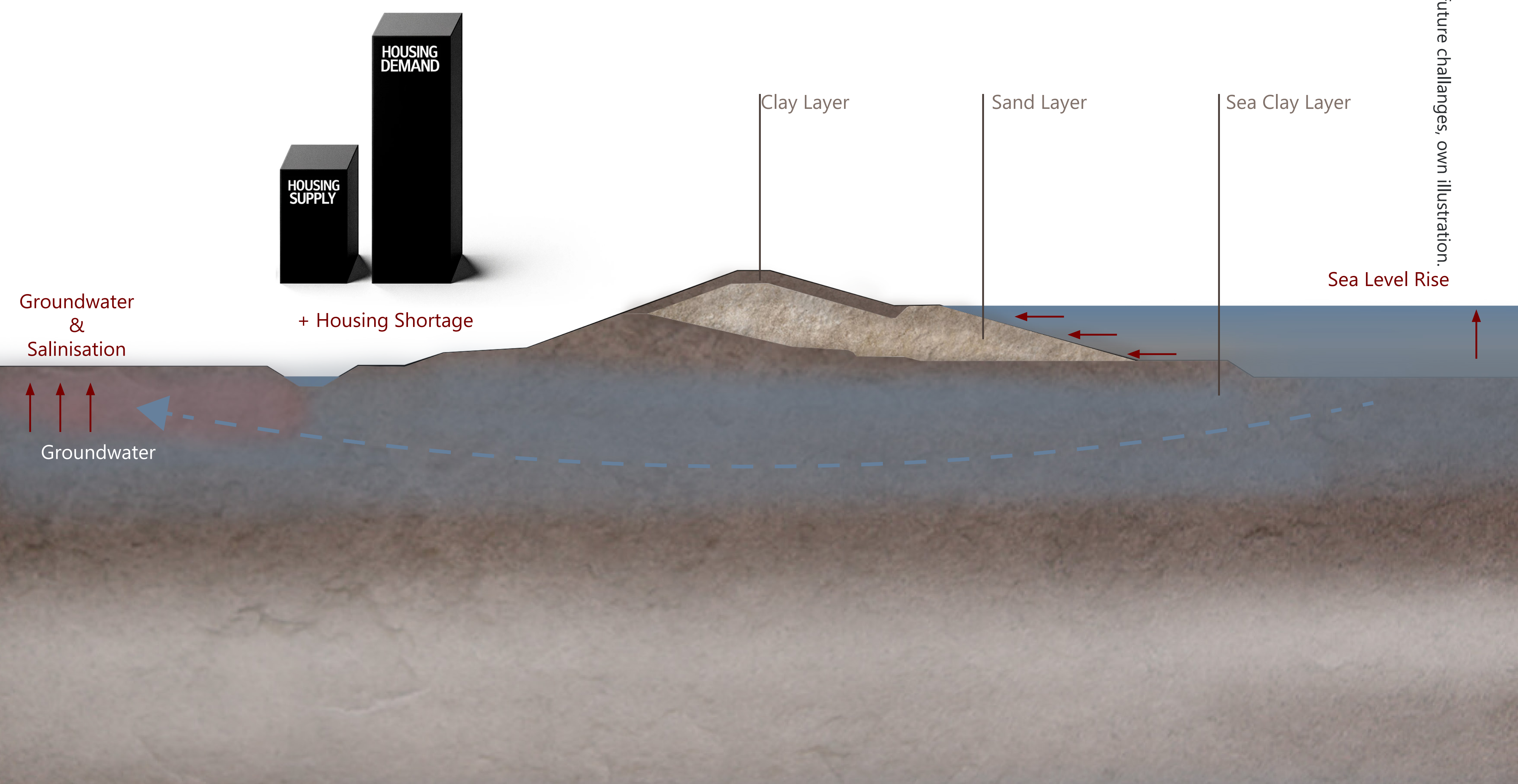


Fig. 2. Damage functions of narrow and broad dikes (Vellinga, 2008).

9 - . Multifunctional dike, (M. Tettero, 2013)

Image 10 depicts the traditional sea dike as of 2024, which currently stands at a height of 10 meters and has a horizontal span of 73 meters. The image also illustrates potential future challenges that could impact the landscape, including groundwater and salinization issues, sea level rise, and globally recognized challenges such as housing shortages.

FUTURE CHALLANGES

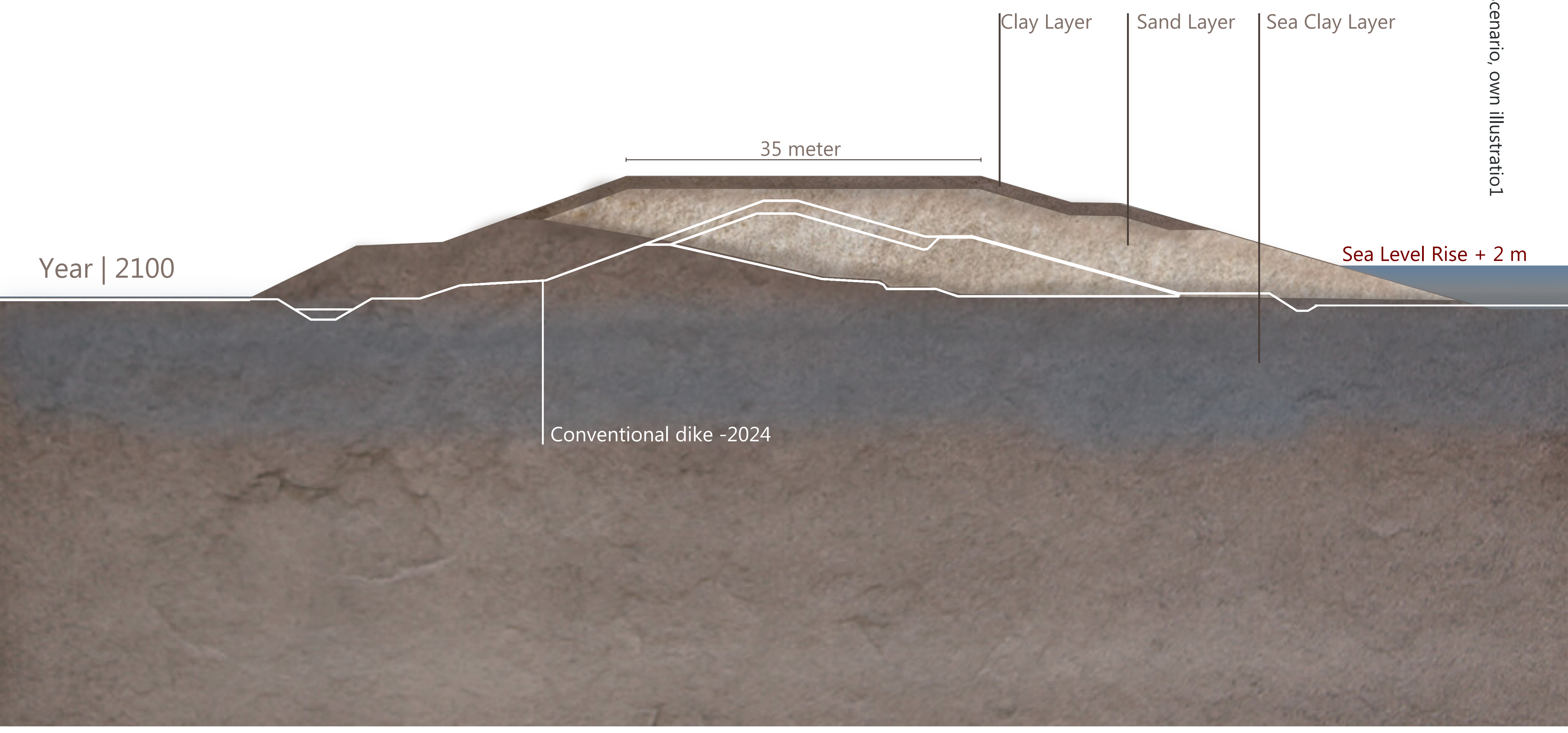


10 - Conventional dike and future challanges, own illustration.

In summary, the chosen scenario envisions a multifunctional dike that can withstand a sea level rise of 8 meters and remain intact during flooding (Image 11). The next section will analyze the foundations and structures of buildings in relation to the unique conditions of being situated on a dike, focusing on how these structures respond under the selected scenario where potential reinforcement may be required after the year 2300.

Conventionally, to prevent the scenario depicted by Kim Cohen, the dike would need to be heightened by approximately 8 meters.

CHOSEN SCENARIO



11. Multifunctional Sea dike Chosen Scenario, own illustratio1

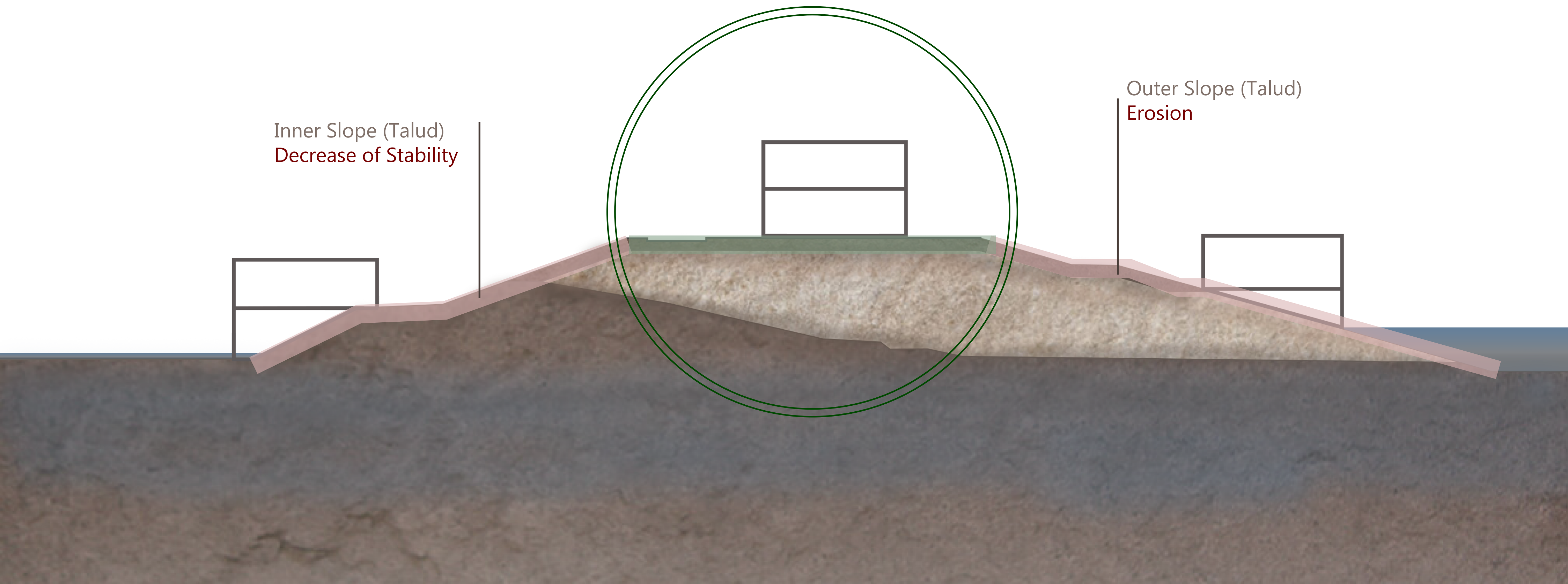
The positioning of buildings on a dike is crucial not only for urban planning but also due to the significant impact these buildings have on the dike's stability.

This research investigates which positions on the dike are most suitable for maintaining stability. As shown in Image 12, buildings can be positioned on the inner slope, the outer slope, or the horizontal platform of the dike.

However, according to Pilarczyk et al. (n.d.), positioning any element or building on the inner slope may decrease the dike's stability. Additionally, placing any element on the outer slope can lead to erosion of the dike body.

The only feasible option remaining is the horizontal platform of the dike. In the analysis of multifunctional dikes, buildings and other functions are typically situated on the horizontal platforms. Therefore, this research concludes that, in line with other studies on multifunctional dikes and slope stability, buildings should be placed exclusively on the horizontal platform of the dike (see Image 12).

POSITION OF THE BUILDING



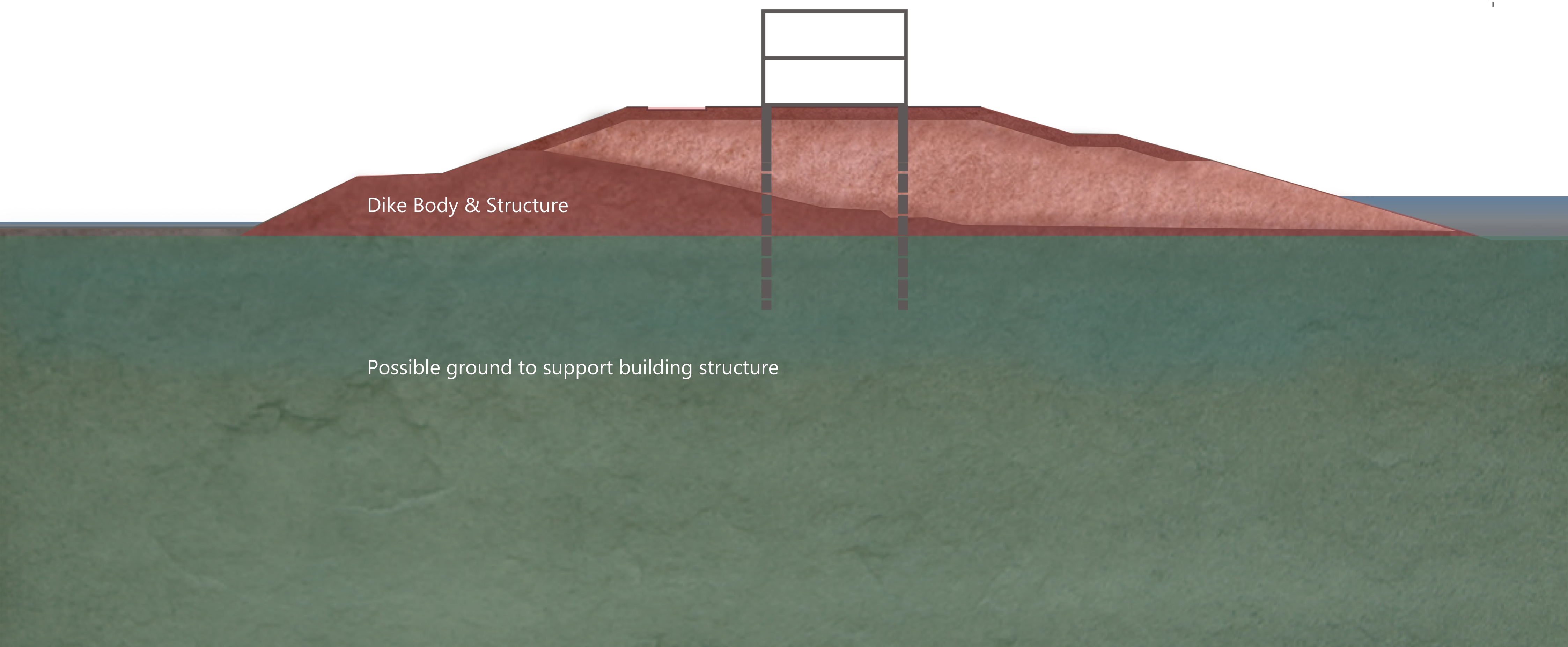
12. Chosen position on the dike, own illustarion.

After determining the optimal position for buildings on the dike, the next step in the research was to investigate which foundation types are suitable for constructing on this multifunctional defense (Image 13).

To minimize the risk of dike failure, buildings on the dike should be separately structured and not integrated with the dike's structure. This ensures that both structures function independently rather than as a single entity (Van Veelen et al., 2015).

Consequently, the foundation of the building should not be embedded within the dike body but should be positioned below it (see Image 13).

FOUNDATION POSITION

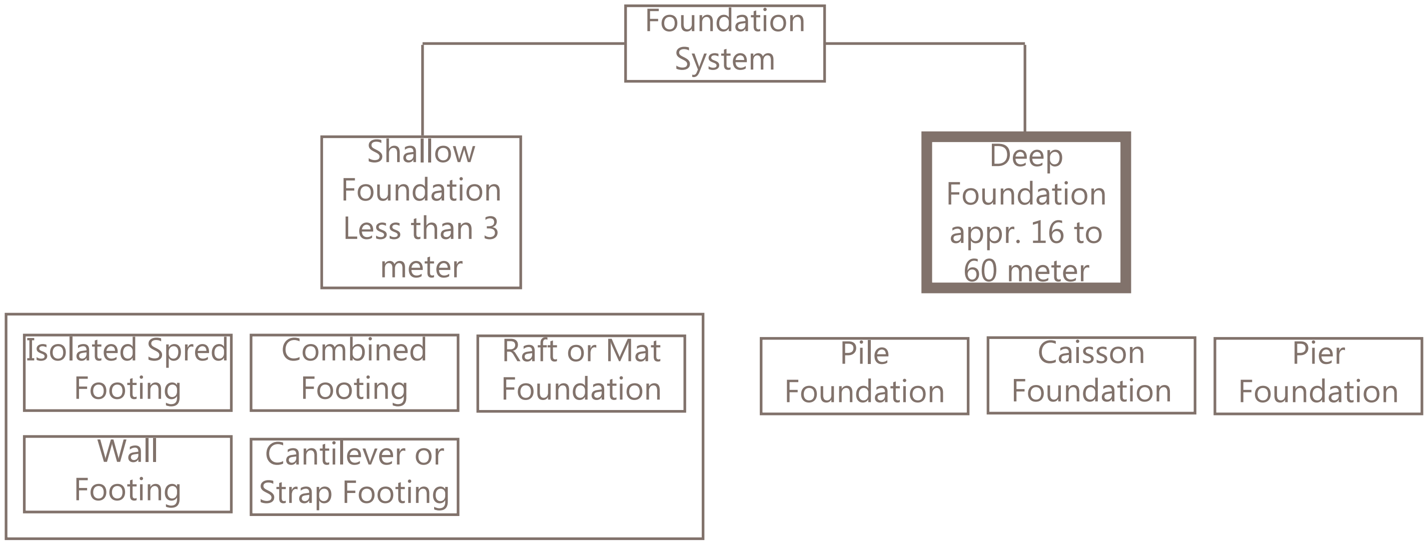


13. Foundation position below dike body, own illustra-ton

This means that the foundation should be placed at a depth of at least 20-25 meters. According to Das (1984), foundation systems are divided into two categories: shallow foundations (less than 3 meters) and deep foundations (16 to 60 meters). In this scenario, deep foundations are the most suitable for buildings on the dike.

Deep foundations include three different types: pile foundations, caisson foundations, and pier foundations (see Image 14).

In the subsequent pages, a table outlines the properties of these three types. After analyzing these properties, it became clear that caisson foundations are not suitable for buildings, and pier foundations may not reach the same depths as pile foundations. Pile foundations emerged as the most suitable option. Their properties align with the scenario's requirements, as they can reach greater depths and are typically used when the upper soil layers cannot support the structural load (Das, 1984).



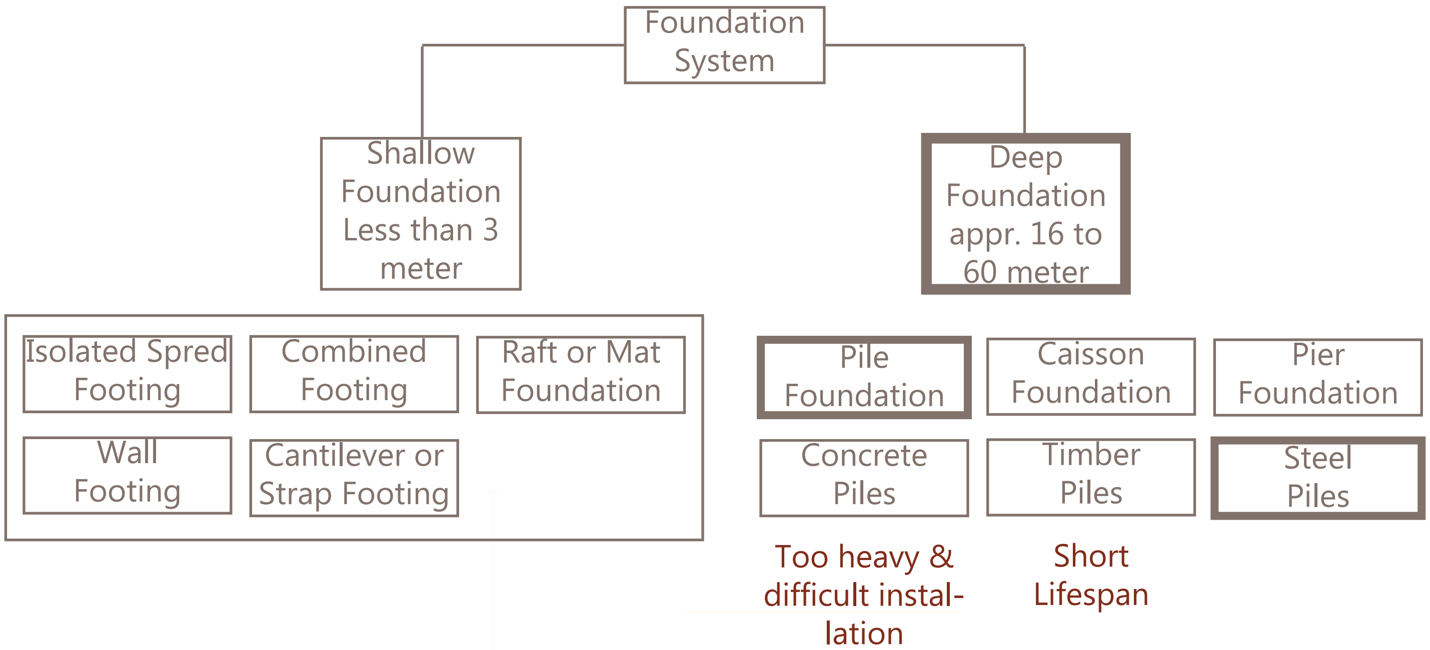
14. Principles of Foundation Engineering. http://ndl.ethernet.edu.et/bitstream/123456789/39193/1/51.pdf

	Pile Foundation	Pier Foundation	Caisson Foundation
Construction Method	Long, slender columns driven into the ground using a pile driver. Made of wood, steel, concrete, or composite materials.	Drilling or digging a large hole and **filling it with concrete to create a solid foundation. Wider than piles.**	Watertight retaining structure **used, especially in underwater construction**. Can be open, box, pneumatic, or floating types.
Applications	**Used when soil at shallow depth can't support the structure's load.** Suitable for high-rise buildings, bridges, and piers in areas with poor soil.	Transfers loads through an unstable soil layer to a stable layer closer to the surface.	Ideal for structures requiring support from bedrock or deep soil layers, such as **bridges and piers.** Used extensively in underwater constructions.
Load Bearing	Works through friction (friction piles) or end-bearing (end-bearing piles).	Transfers load through both end-bearing and skin friction, with emphasis on end-bearing stratum capacity.	Primarily utilizes end-bearing strength, but also can benefit from skin friction depending on the type.
Diameter & Depth	Smaller diameter, can be driven to **greater depths.**	**Larger in diameter, may not reach as deep as piles.**	Varies in size; designed to reach stable ground below water or unstable soil and distribute loads evenly.
Installation	Can cause vibration and noise due to the driving process.	Involves excavation and drilling, potentially less disruptive in terms of vibration and noise.	Construction involves excavation or air pressure to keep water and mud out.

FOUNDATION TYPOLOGY

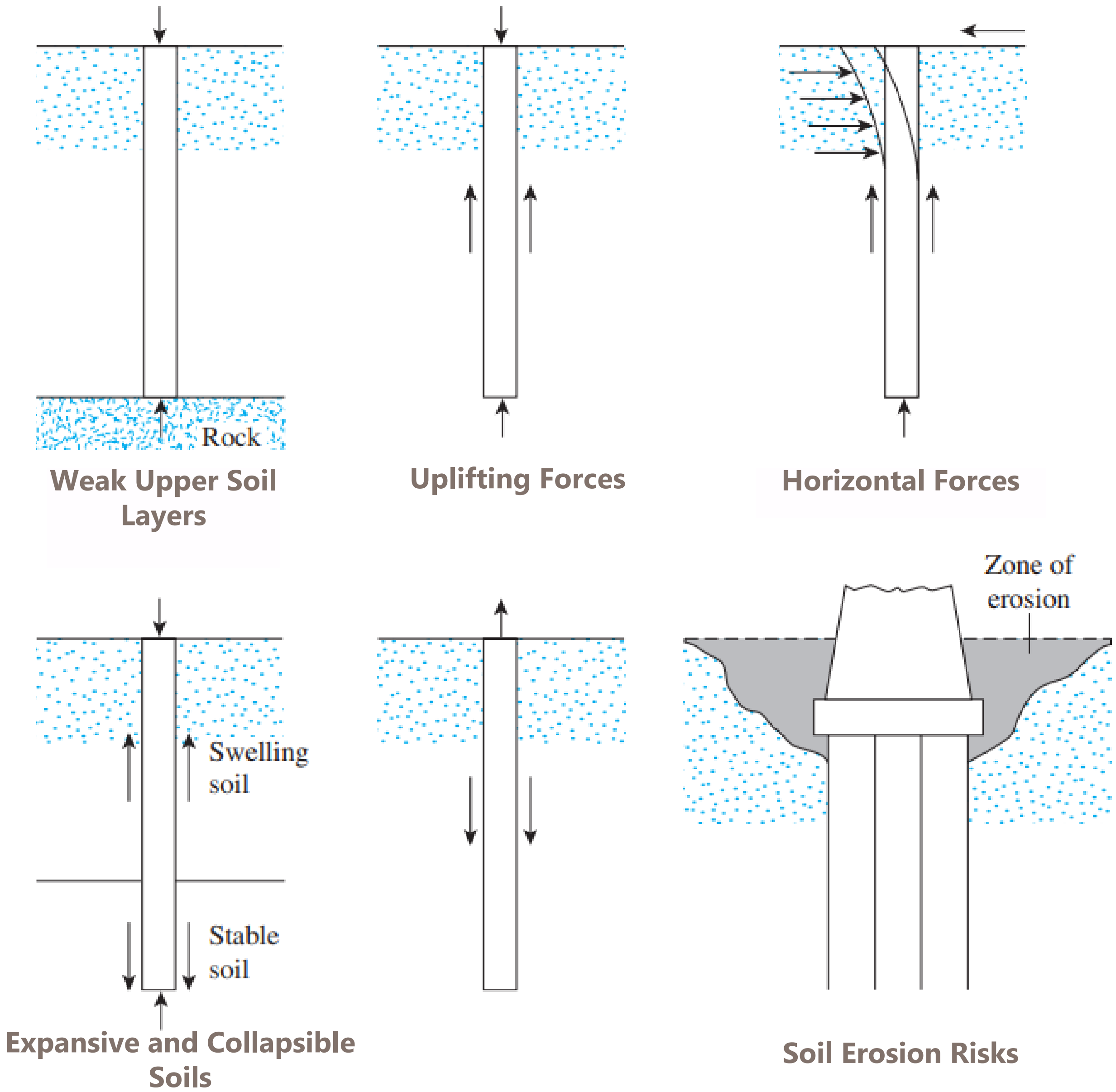
Reese, L. C., Isenhower, W. M., & Wang, S. (2005). Analysis and Design of Shallow and Deep Foundations. https://doi.org/10.1002/9780470172773

Pile foundations can be made from three different materials: concrete, timber, and steel. Concrete piles are too heavy and difficult to install. Furthermore, timber piles have a short lifespan, and since we are building for the future, it is essential that the foundation lasts for many years. Steel piles, however, are durable and much easier to install. Therefore, this research will proceed with steel piles as the primary foundation material (see Image 15).



15. Principles of Foundation Engineering. http://ndl.ethernet.edu.et/bitstream/123456789/39193/1/51.pdf

Das (1984) also explains which forces, (steel) pile foundation, may be absorbed. This is very interesting to analyse for the case of buildings on the dikes.
Image 16 shows these forces and challanges. The fact that pile foundation can abdorb horizontal forces such as wind load or floading pressure, is very handy for buildings on the dike. Furthermore, we see that it also can absorb uplifting forces whihc is also very intesing im case of groundawter rise. And as ealrlier mentioned it is used in case of weak upper soil layers whihc is the case for buildings on the dike. Furthermore, They are not affceted by erosion which in the furture can as well be challange.

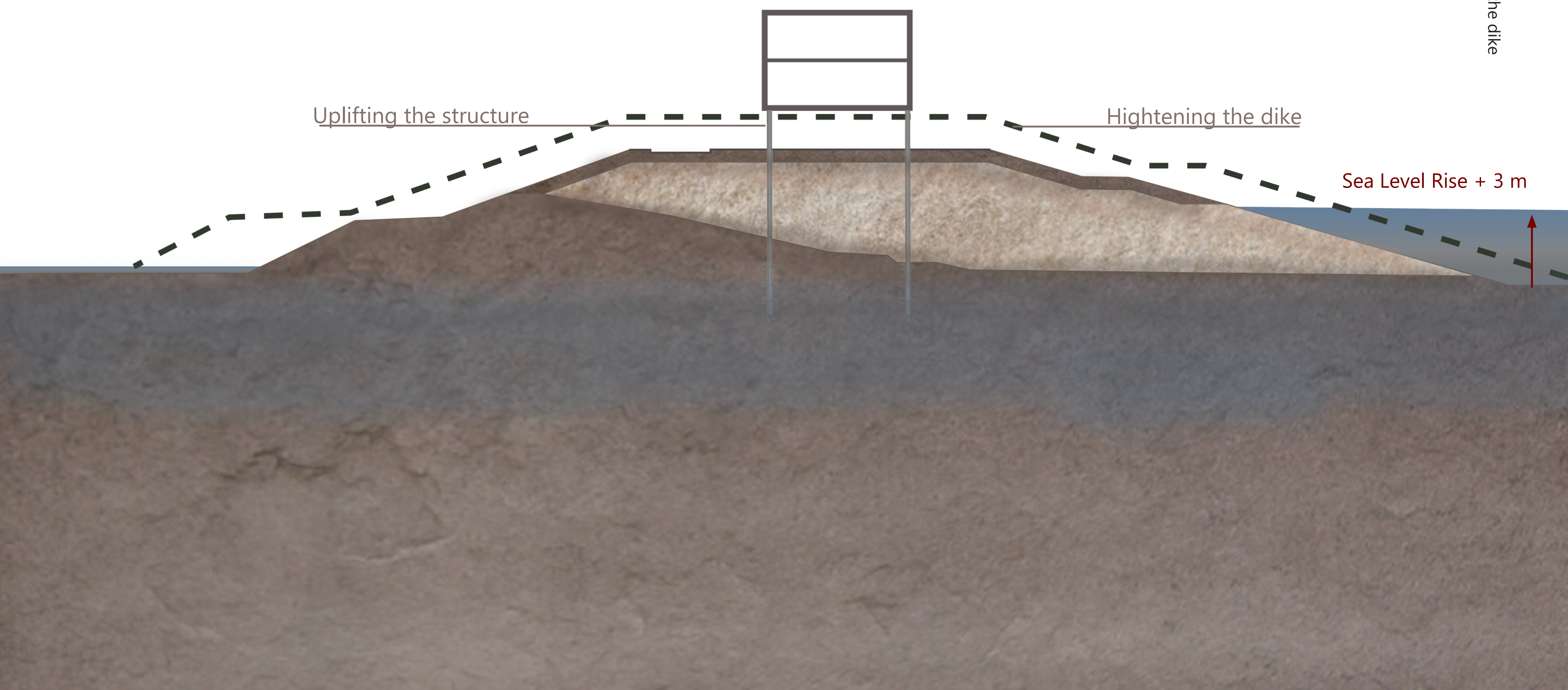


16. Das, B. M. (1984). Principles of Foundation Engineering. http://ndl.ethernet.edu.et/bitstream/123456789/39193/1/51.pdf

This research also explores the possibilieties in how the building may be uplifted in case the diek needs to be reinforced or heightened again. On image 17, is explained through drawings how this process may with the years may find place.

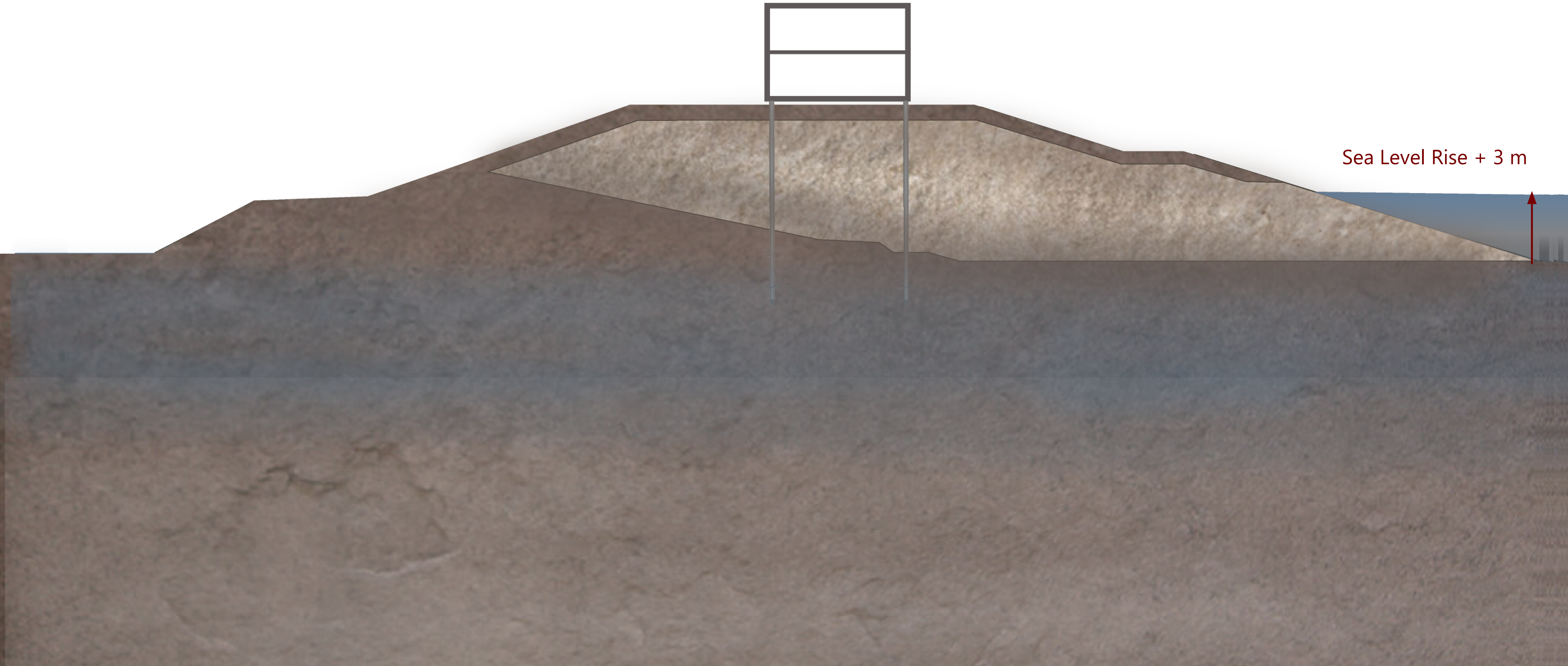
Das (1984) explains the types of forces that steel pile foundations can absorb, which is highly relevant for buildings on dikes. Image 18 illustrates these forces and challenges. The ability of pile foundations to absorb horizontal forces such as wind loads and flooding pressure is particularly advantageous for buildings on dikes. Additionally, they can absorb uplifting forces, which is crucial in scenarios of rising groundwater. As previously mentioned, pile foundations are also suitable for weak upper soil layers, a common condition for dike construction. Moreover, they are not affected by erosion, which could pose a significant challenge in the future.

FOUNDATION IN RELATION TO FUTURE DIKE REINFORCEMENTS

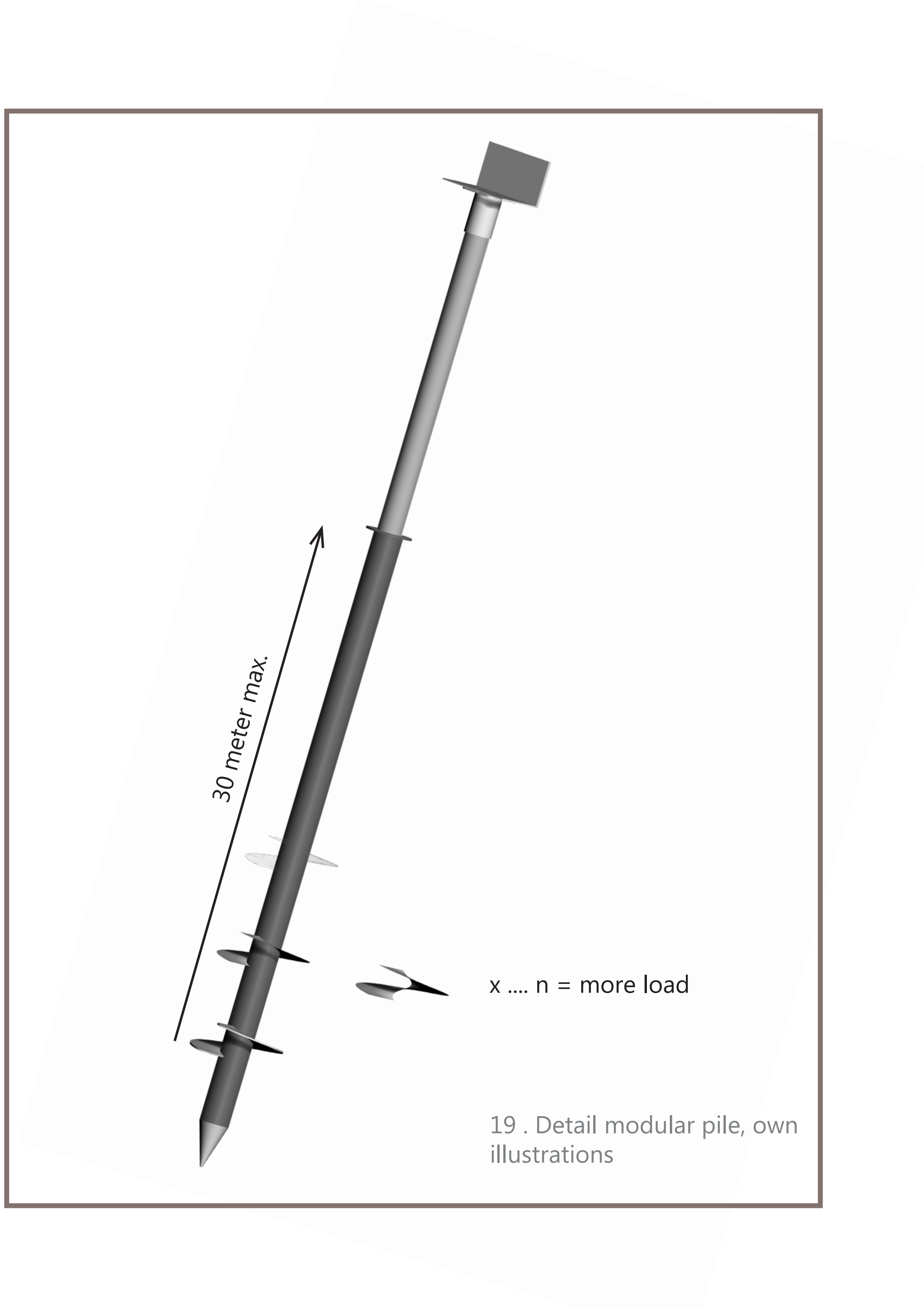


17. Liftingthe buiding up to adjust th height of the dike
, own illustaration

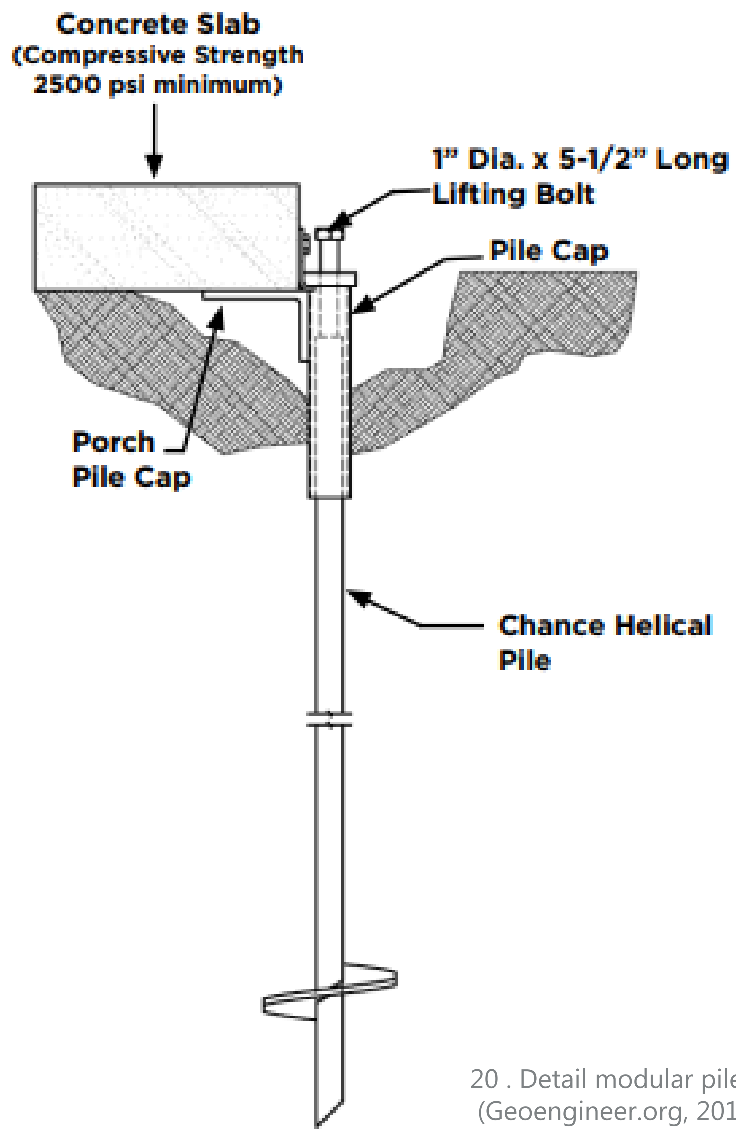
Further research has explored the potential for steel piles to be uplifted or elongated to facilitate future reinforcement. Various literature and suppliers of steel piles indicate that steel screw piles can incorporate an additional modular pile that can be added later (Mohajerani et al., 2016).
Image 19 provides an illustration of what this modular pile could look like, while Image 20 details how screw steel piles are attached to the upper structure, as shown by one of the suppliers.



18. Height of the dike adjusted, own illustaration



19 . Detail modular pile, own illustrations

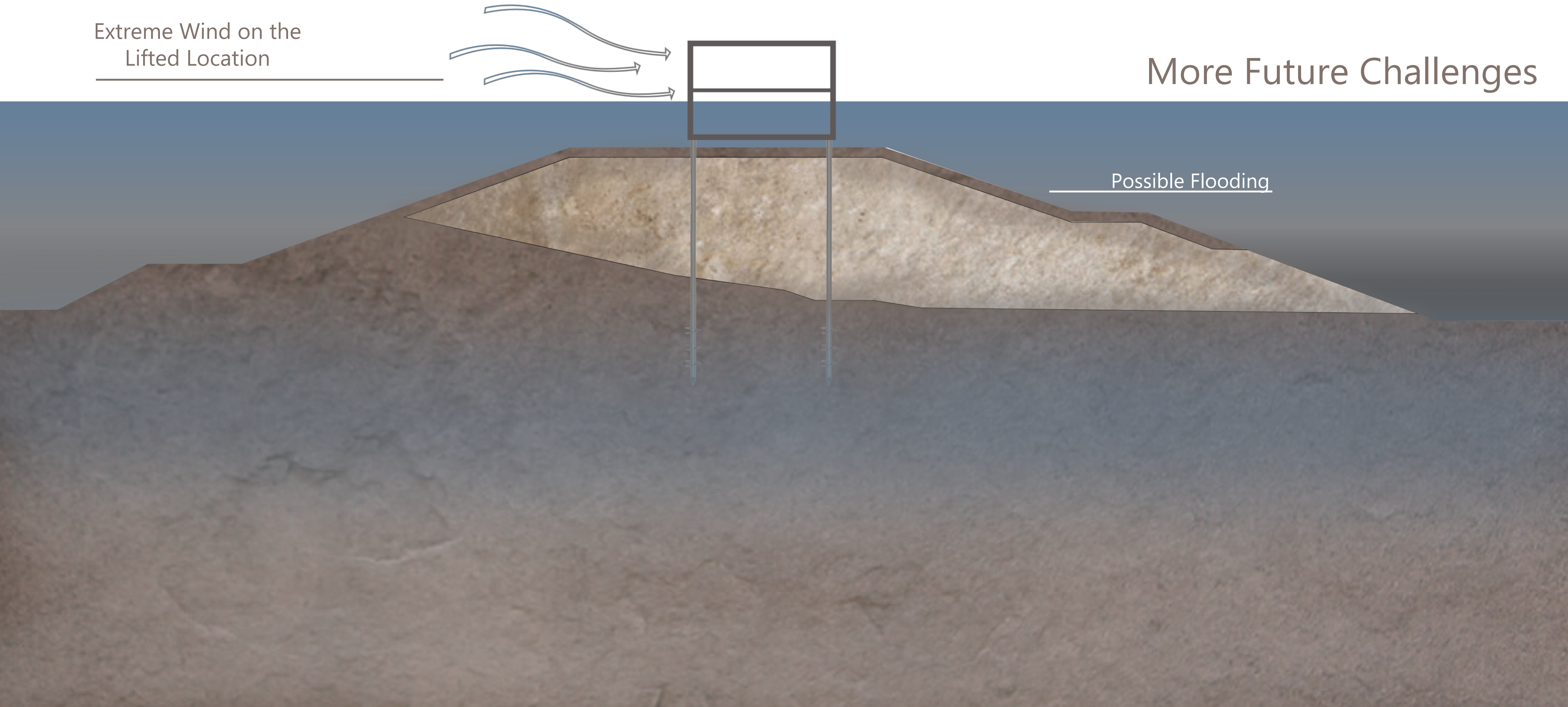


20 . Detail modular pile cap (Geoengineer.org, 2019)

Considering potential future challenges such as flooding and extreme winds at elevated locations (see Image 21), further research has delved into methods for making buildings flood-proof on the ground floor while employing lightweight structures for upper floors. This approach aims to avoid excessive heightening of buildings at the site (see Image 27).

MORE FUTURE CHALLANGES

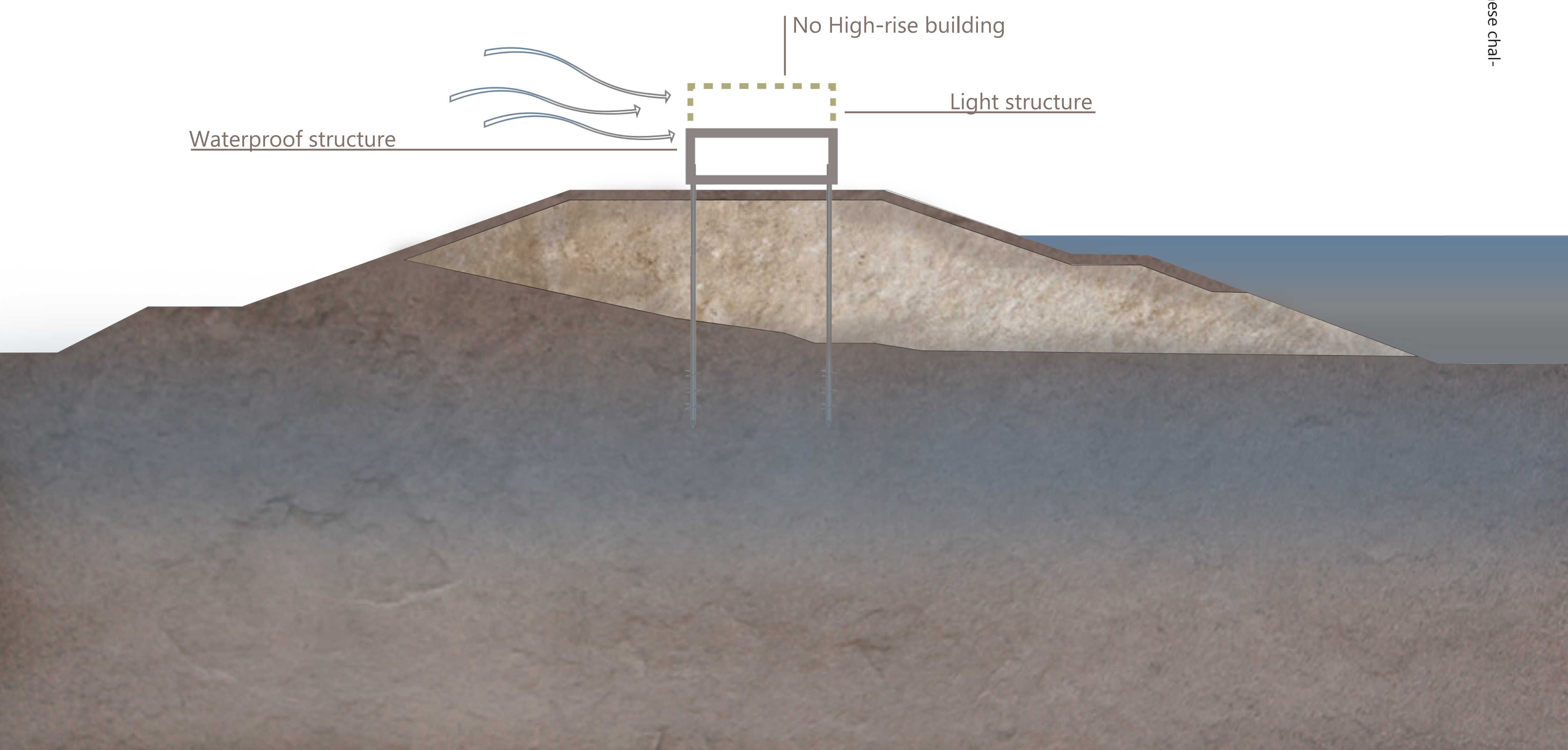
More Future Challenges



21. Future challanges, own illustaration

The proposed structure adopts a hybrid design approach. The ground floor is constructed using concrete, harnessing its inherent properties for flood resistance, while the core of the building also features concrete for structural integrity. Conversely, the upper floors and ceilings are crafted from CLT (cross-laminated timber) or glulam (glue-laminated timber). This hybrid construction combines flood resilience at the ground level with the use of timber materials for the upper sections, presenting a flexible and sustainable solution to architectural design.

PROPOSED STRUCTURE - HYBRID STRUCTURE

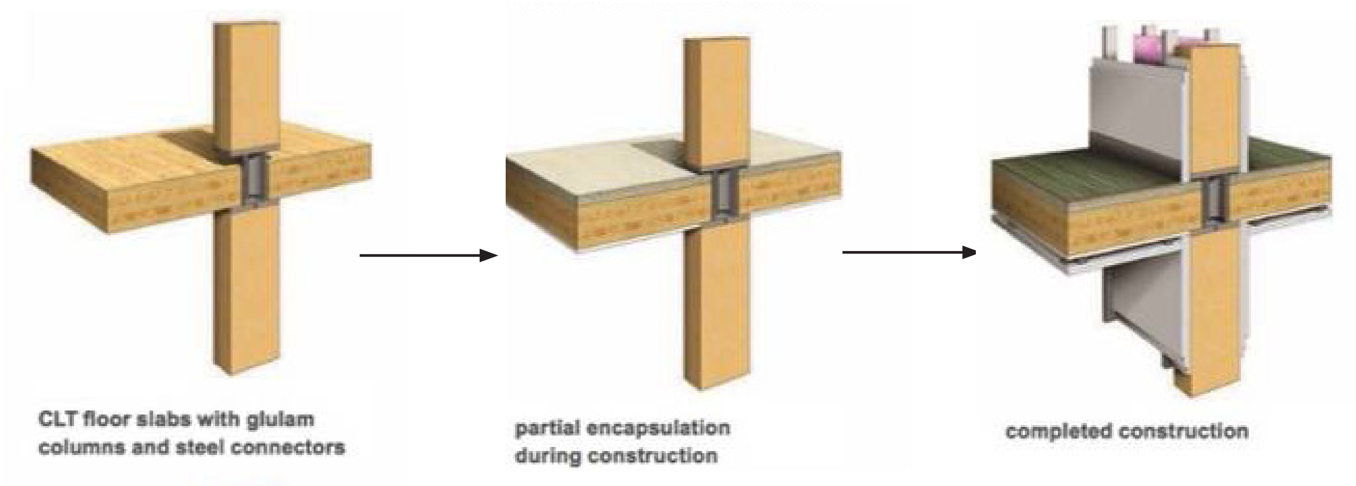


22.Possible structure concept against these chal-
langes, own illustaration

Hybrid buildings manifest in diverse forms, exemplified by the Brock Commons Residential Building designed by Hk Architekten in Vancouver (Image 23). This structure incorporates two concrete cores linked to the concrete entrance floor, while the upper floors feature CLT (cross-laminated timber) floors and glulam (glue-laminated timber) columns supported by interconnected steel connectors. To ensure fire protection, a layer of concrete is applied atop the CLT floors (Image 24).

Similarly, Haut by Vteam adopts a similar typology, underscoring the adaptability of this approach. Notably, these architectural typologies demonstrate the potential to achieve remarkable heights, with the Brock Commons Residential Building soaring to 18 stories.

23. Buiding under construction (Schmidinger, 2023)

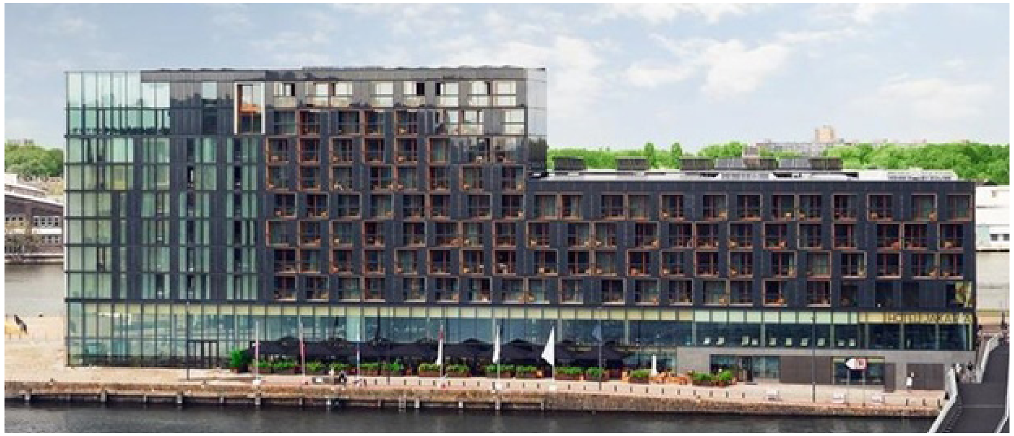


23. Details CLT floors and gluelam columns (Schmidinger, 2023)

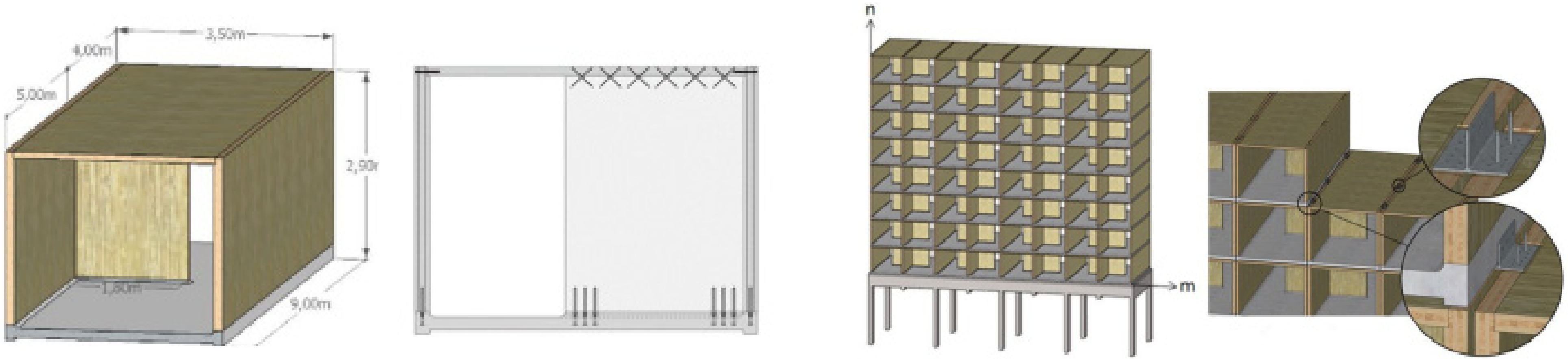
The Jakarta Hotel in Amsterdam, designed by SeArch, represents another example of a hybrid building, albeit with distinct characteristics from the previous example (Image 25). The hotel rooms in this establishment are modular, measuring 9 by 3.5 by 2.9 meters in height. These modular rooms are interconnected atop a "concrete table" structure. Each modular room features gluelam walls and ceilings, with a concrete floor, and they are linked together using steel joints (Image 26).

This typology allows for the construction of up to 13 stories, with various configurations possible (Hotel Jakarta | References | DERIX, 2022).

Two hybrid systems are discernible (Image 27), one with a concrete core and the other with a concrete table on the ground floor. During the design phase, both possibilities will be examined, and further integration of one of these options may be incorporated into the final design through detailed analysis.

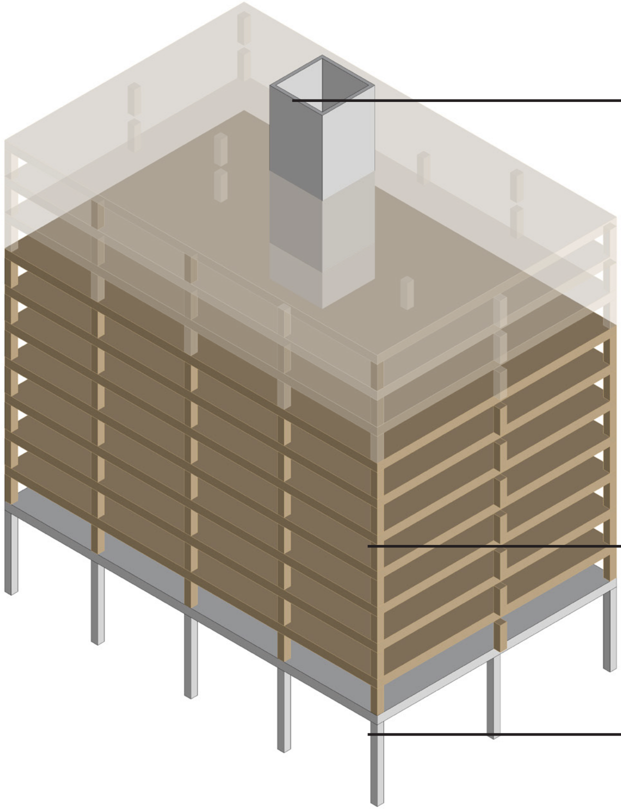


25 . Hotel Jakarta (Blanc, 2022)

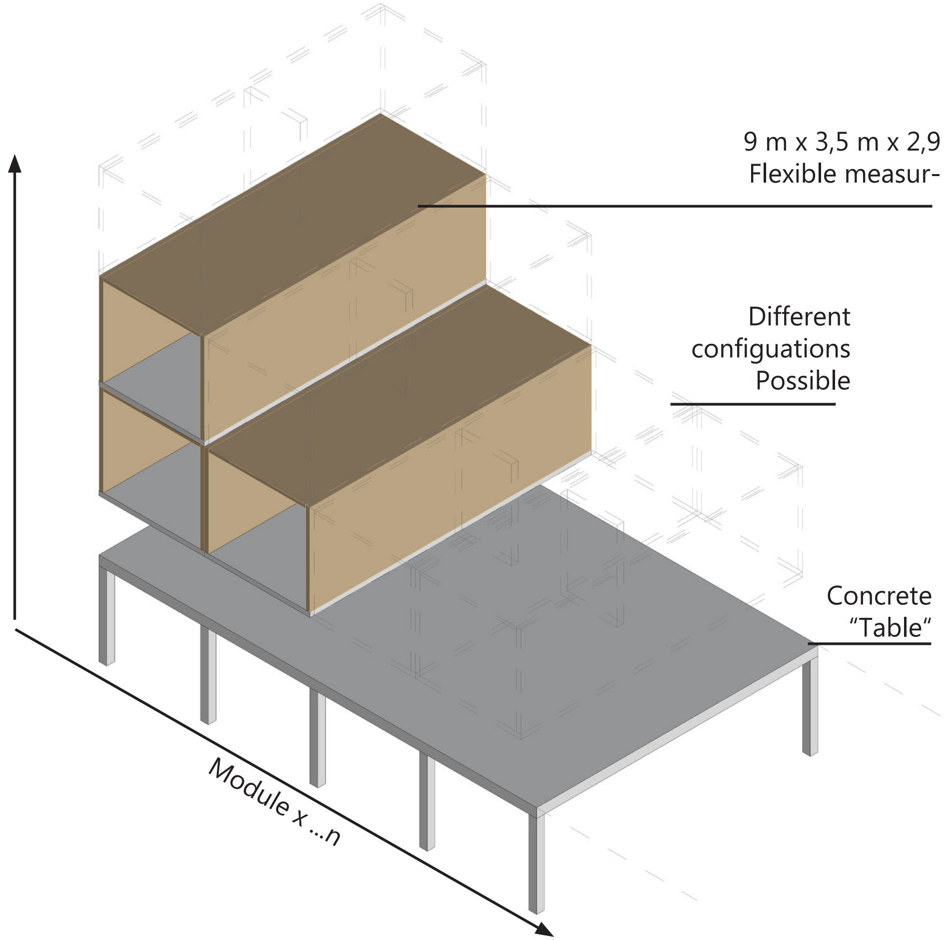


26 . Modular system, (Hotel Jakarta | References | DERIX, 2022)

Concept Structure 1
High-rise system (Concrete core)



Concept Structure 2
Modular System



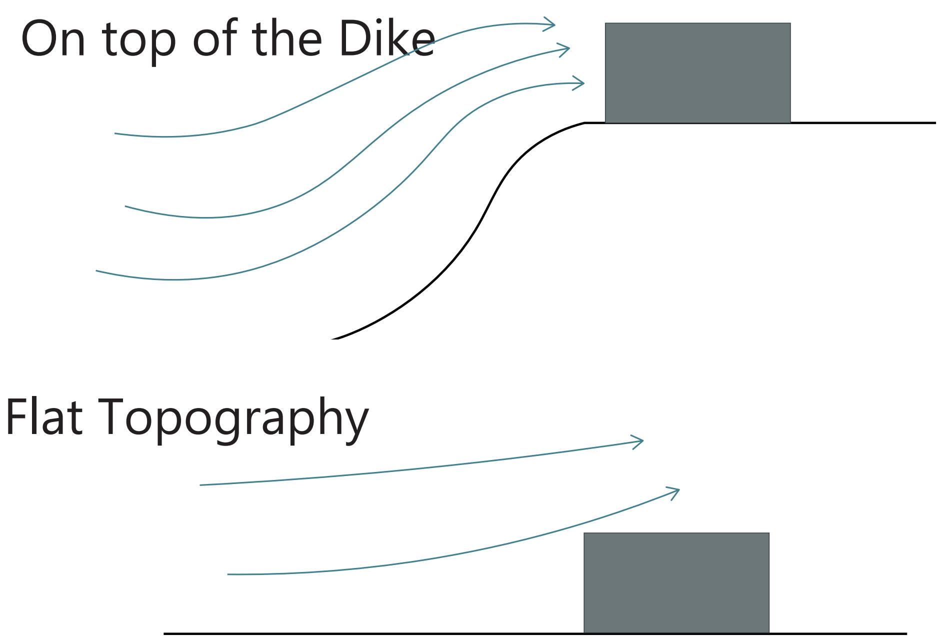
27. Concept structures, own illustrations

COMPARISON BETWEEN BOTH CASE STUDIES

During this phase of the research, after analyzing the feasibility of building on the dike and considering how the architecture can integrate with the surrounding landscape, attention is now turning towards developing an architectural language that harmonizes with the unique rural environment

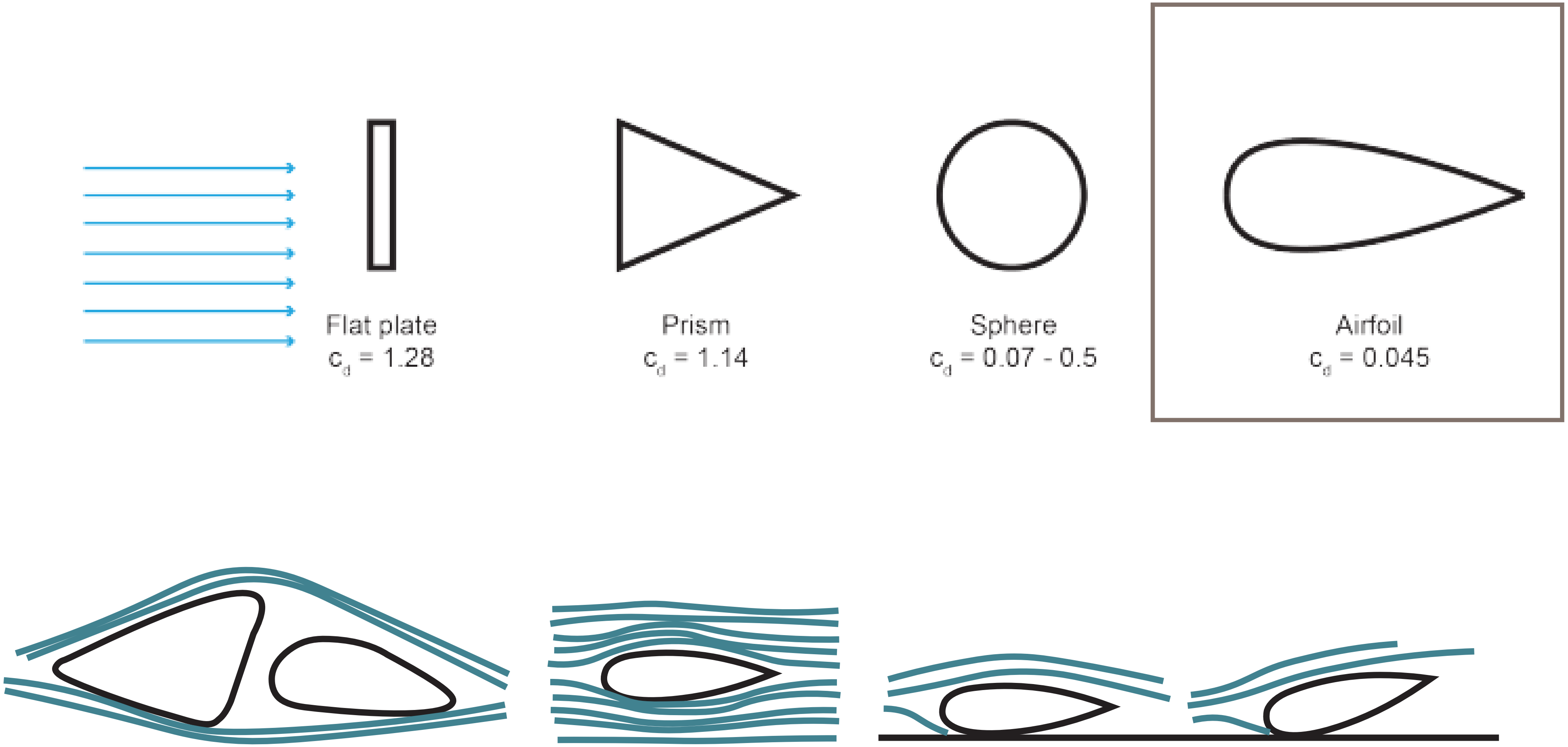
As previously noted, an anticipated future challenge involves extreme windy climates. In the selected location, wind predominantly originates from the southwest direction (see Image 28). Moreover, according to literature, areas with flat, elevated topography experience more severe wind conditions compared to those at lower elevations (see Image 29) (Ruel et al., 1998).

Building upon this information, further research has been undertaken to identify forms that minimize wind forces (see Image 35). According to Kabošová et al. (2023), structures with an airfoil shape, also known as an aerodynamic shape, are most effective in mitigating extreme wind forces against buildings.

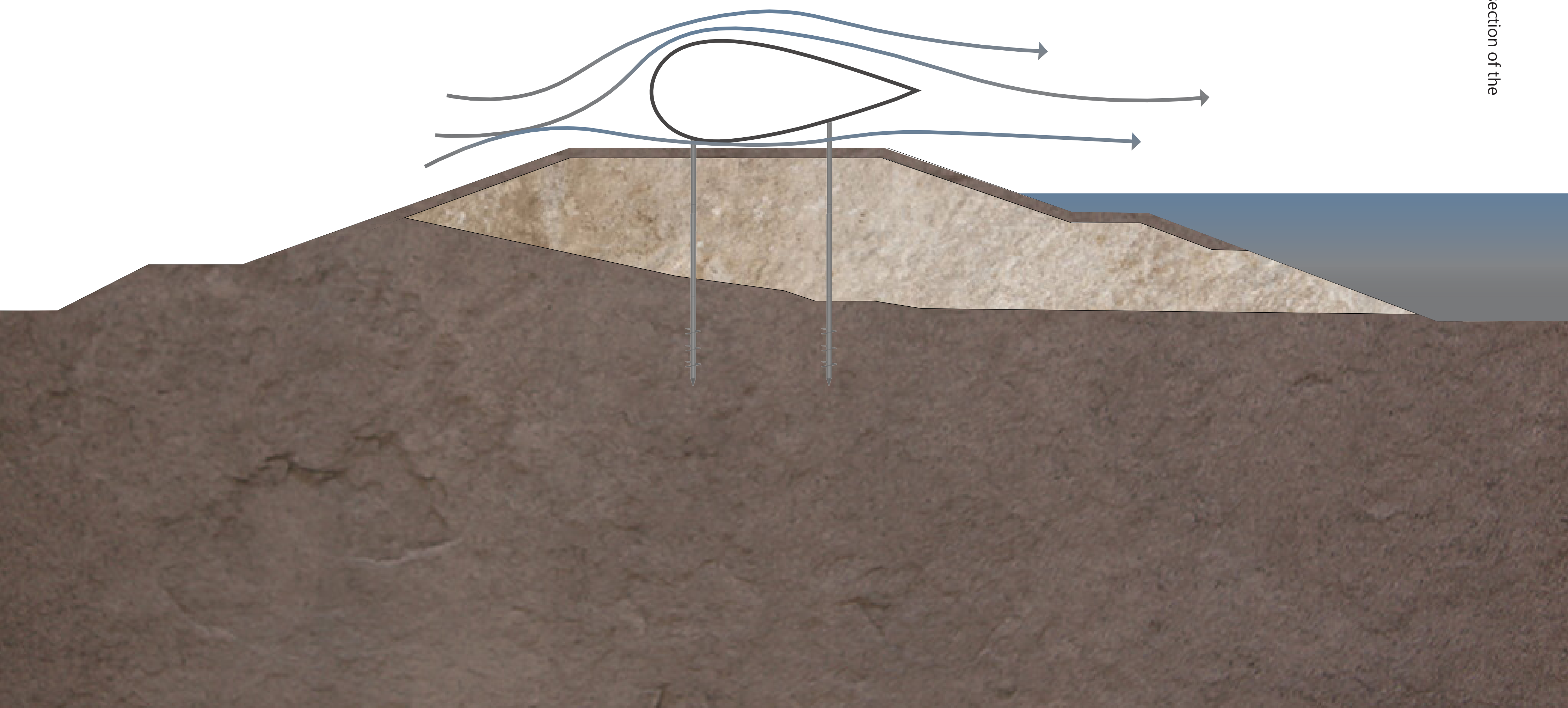


29 . The difference in wind between a flat topographt and on top of the dike, own illustration.

28. Location drwaing with wind direction, own illustration.



30. Shape in relation to wind. (Kabošová et al., 2023)

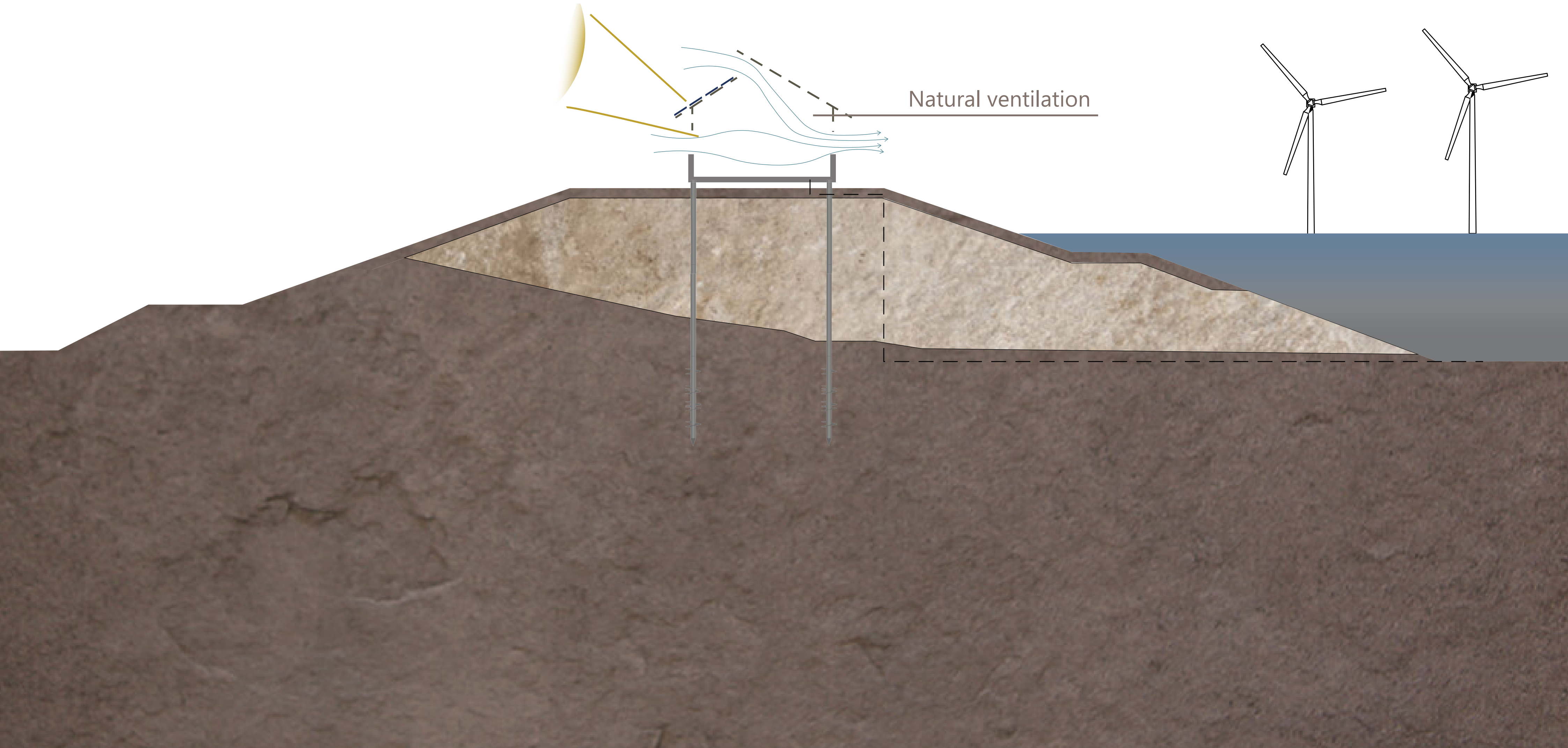


31. The aerdynamic shape projected on the section of the dike, own illustration

Another important aspect that has already been analyzed for P1 is passive climate. The group's research conducted during P1 provides the input for Image 38, which illustrates the various climate aspects that can inform the design phase.

Summarizing the research into five principles that can be applied during the design phase, these are illustrated on pages 51-52. Additionally, on pages 53 and 54, the five principles are depicted in integrated drawings.

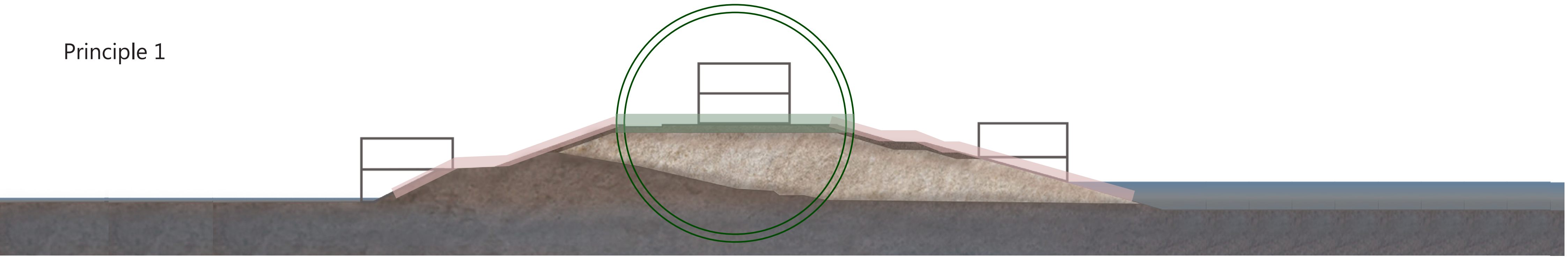
These principles can serve as the starting point for the design but can also provide input for later stages in the design phase.



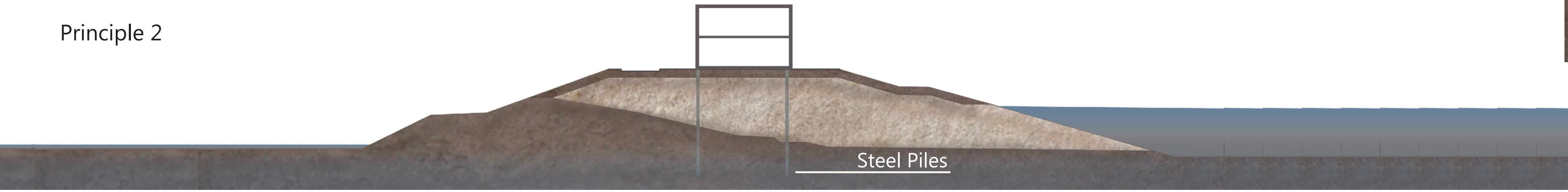
32. Climate concept, own illustration.

5 | 5 Principles to continue with

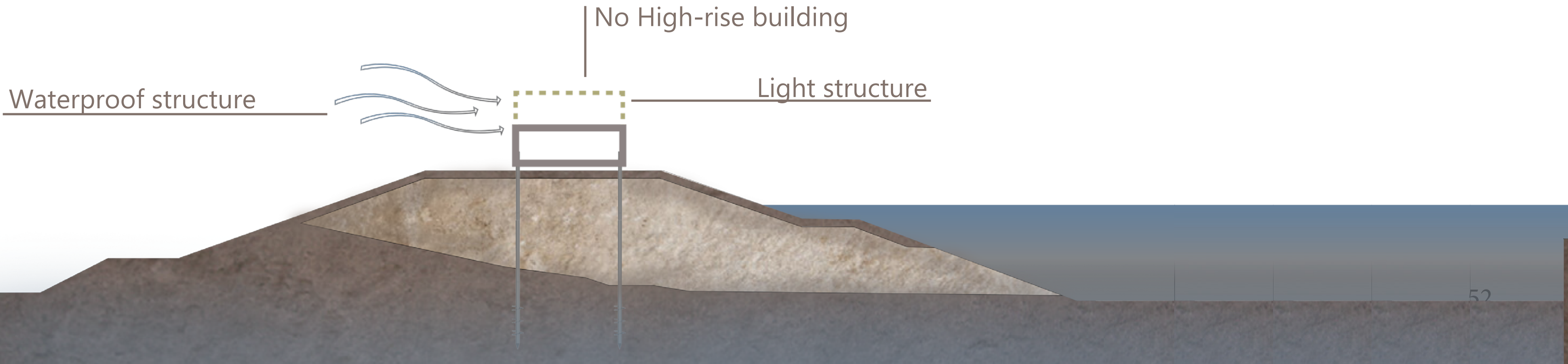
Principle 1



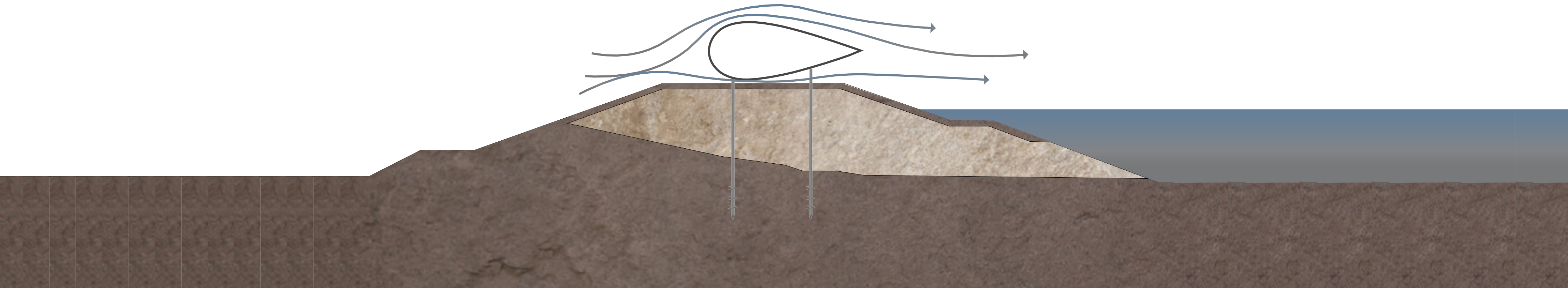
Principle 2



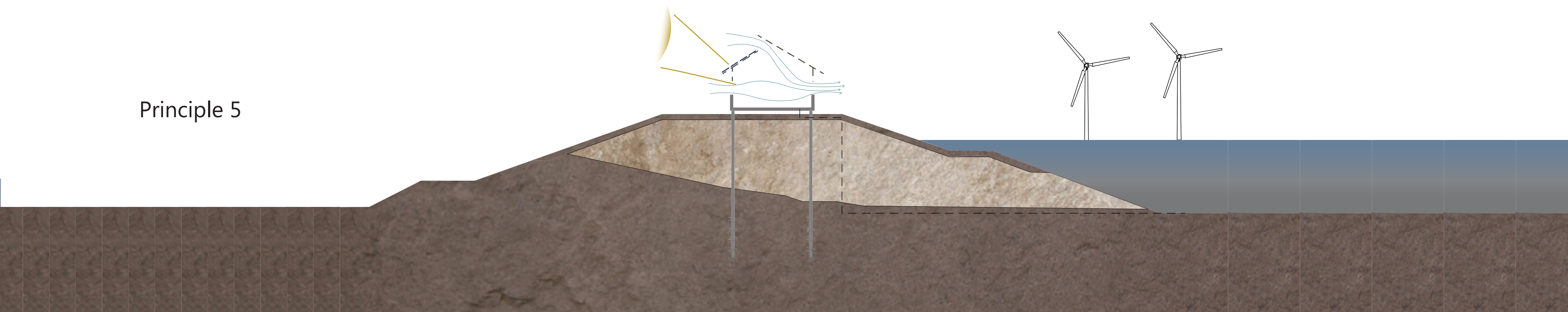
Principle 3



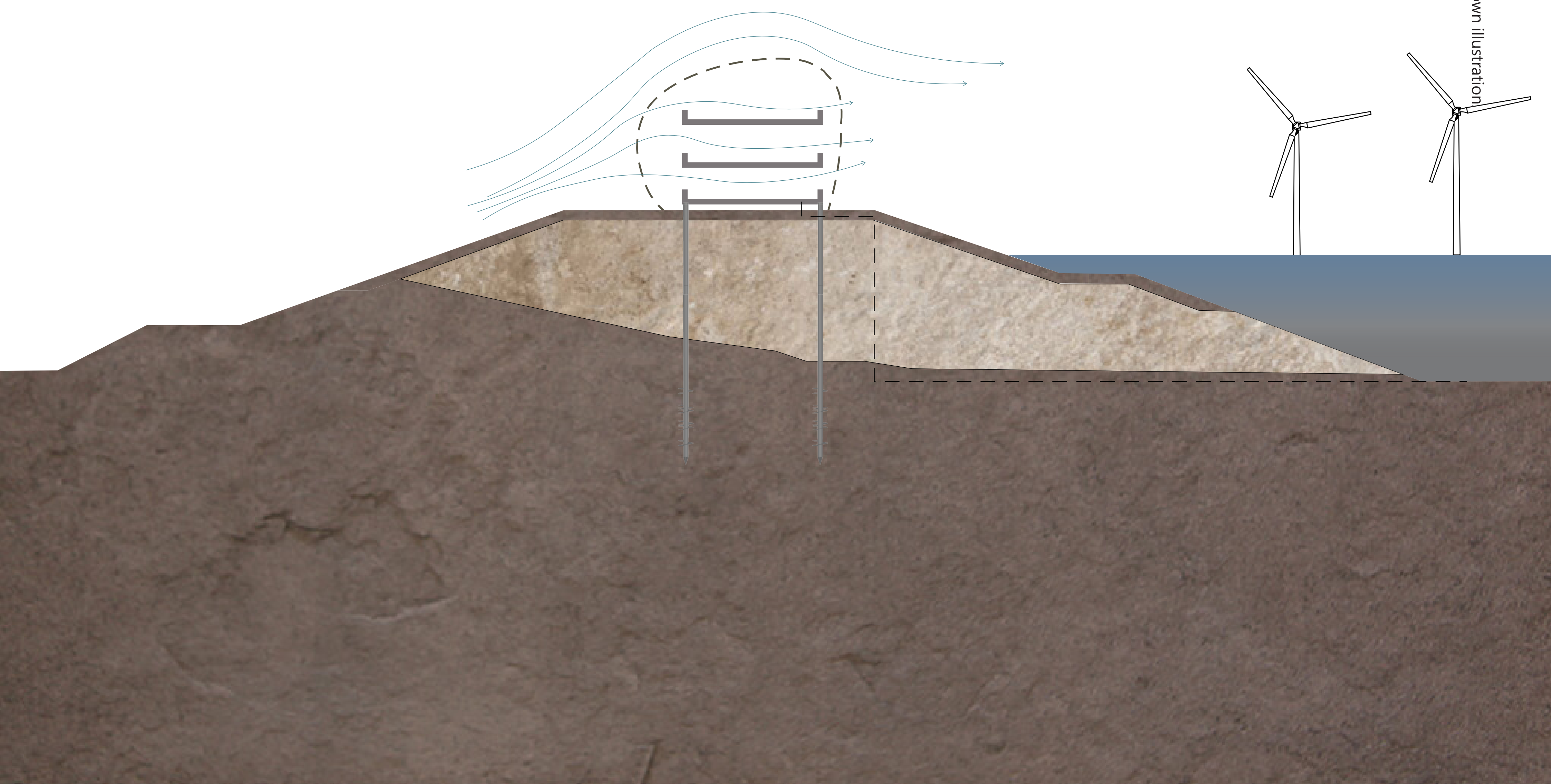
Principle 4



Principle 5

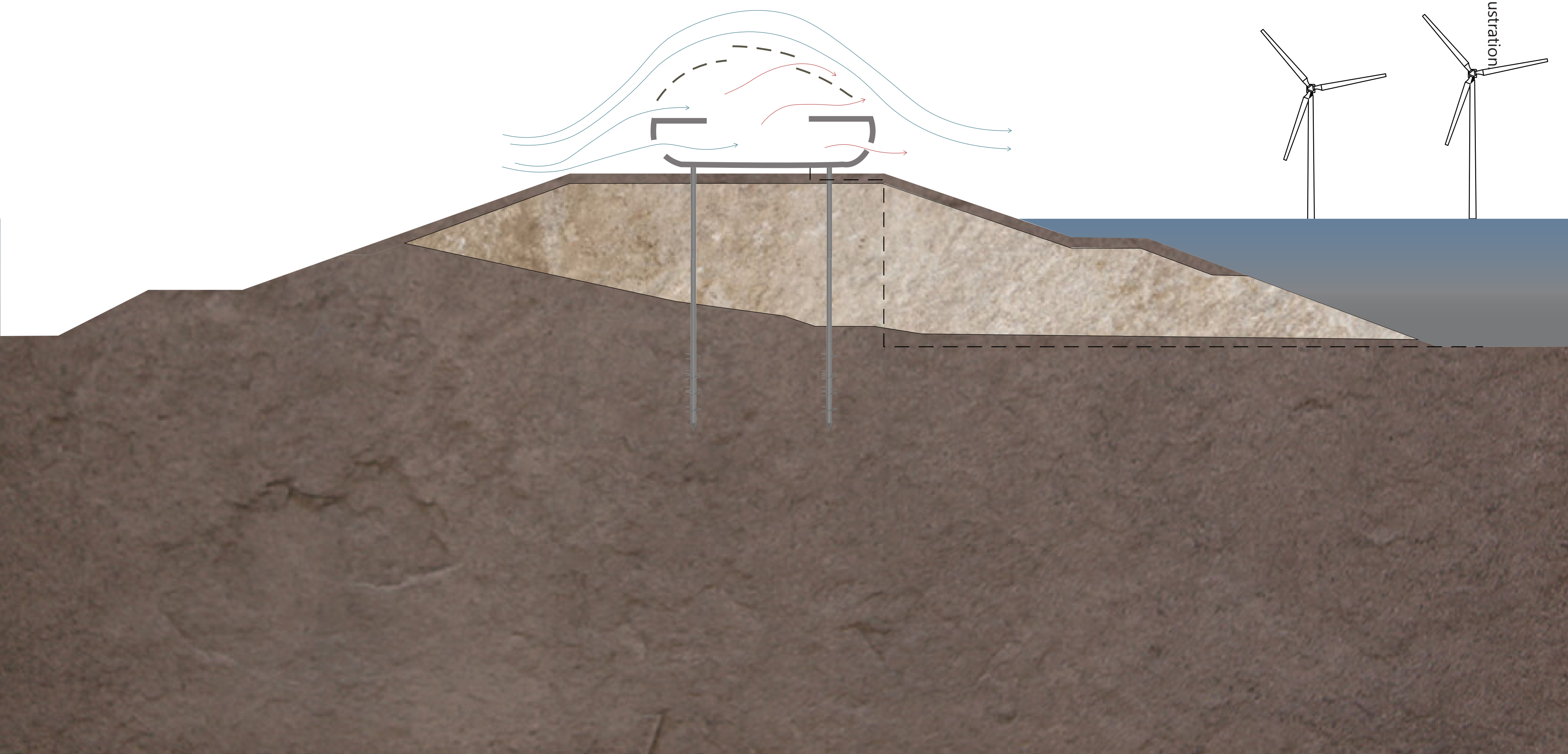


5 Principles Integrated



39. Integration of the principles, own illustration

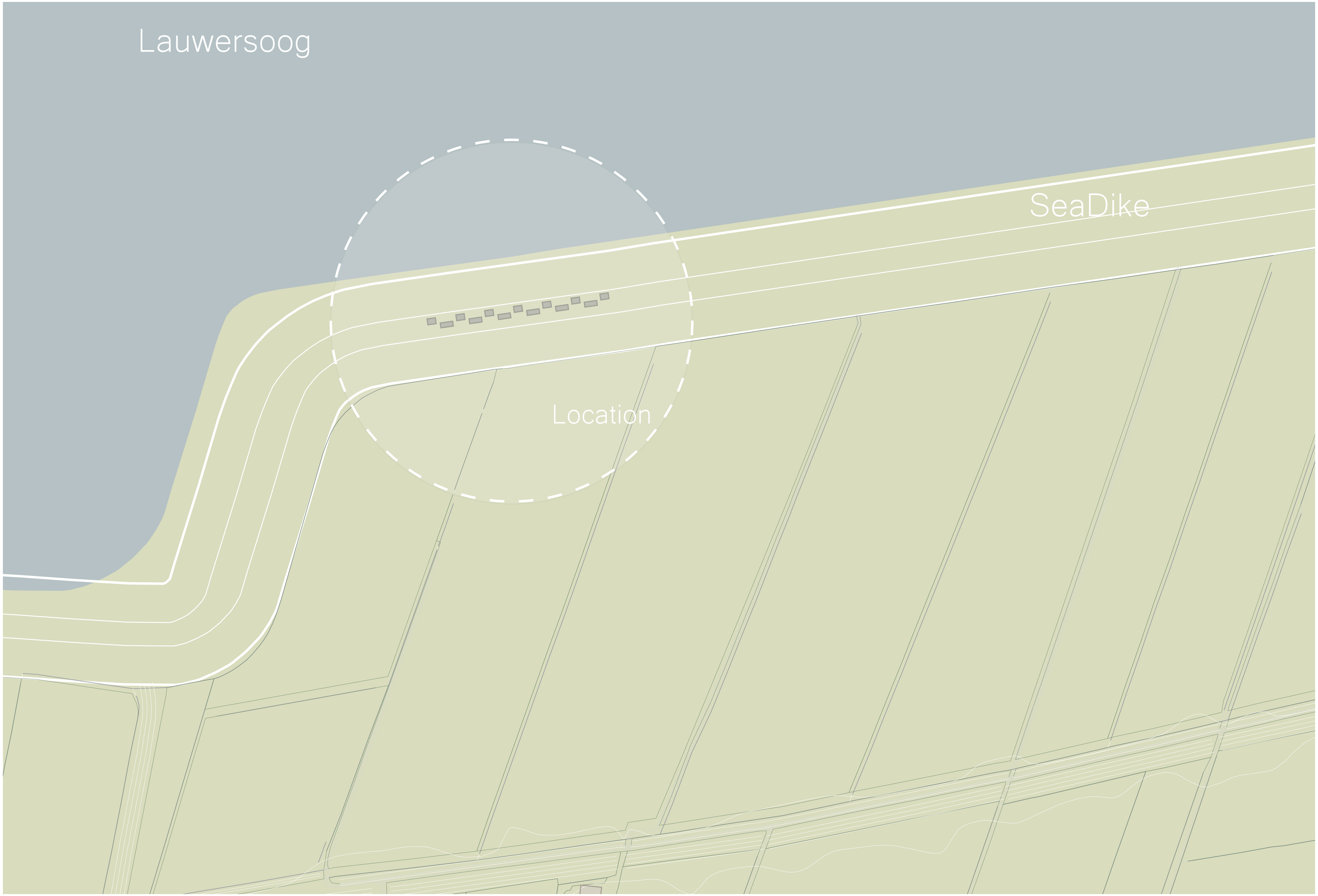
5 Principles Integrated



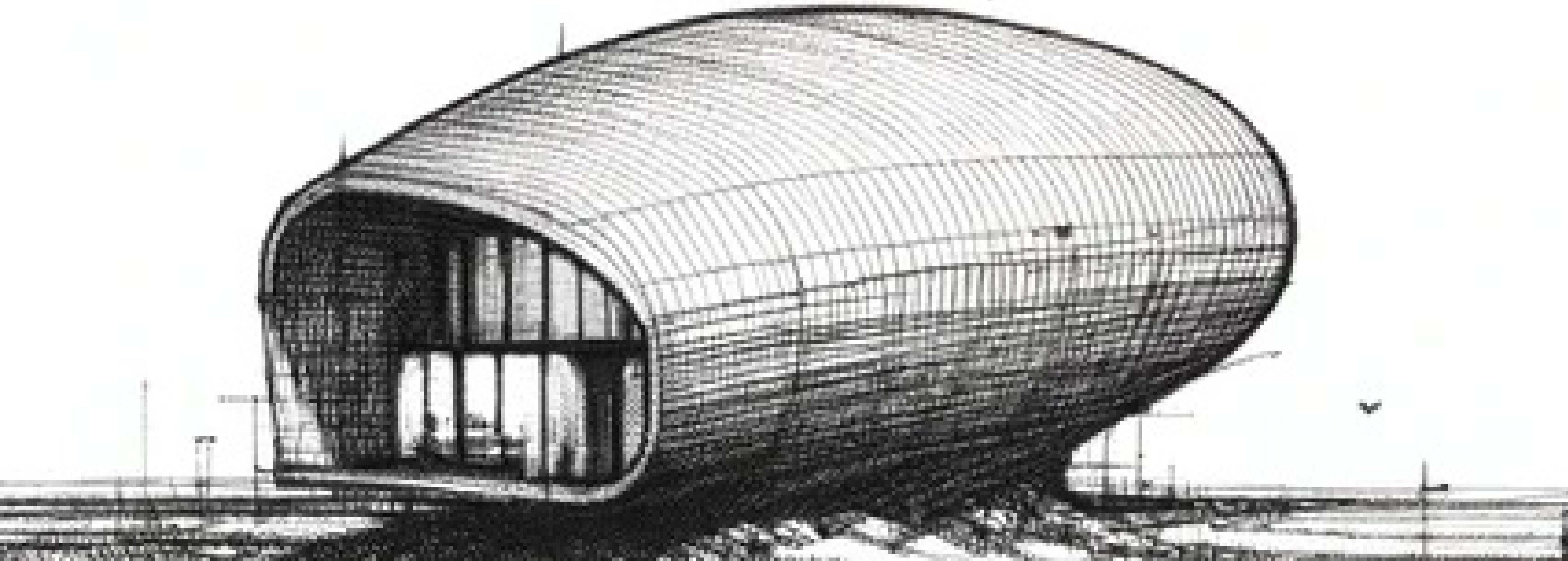
40. Integration of the principles, own illustration

The primary concept of this graduation project involves developing architecture on the sea dike that protects Groningen from Lauwersoog. The project's main focus is on housing, with a design concept for observation towers that facilitate social interaction and integrate parts of the energy and sewage systems. These towers are envisioned to accommodate additional energy features in the future as this type of architecture expands along the dike.
This project anticipates a potential sea level rise of 8 meters by the year 2300. In response, the design includes raising the dike and creating architecture capable of being elevated and withstanding overtopping program.
This innovative approach not only addresses the challenges posed by future sea level rise but also enhances the interaction between the built environment and the natural landscape, offering sustainable and resilient living solutions for the future.
Design Features
- Housing is situated 4.2 meters above ground level, ensuring habitable conditions even during flooding.
- The elevated structures preserve the visual integrity of the dike's infrastructure.

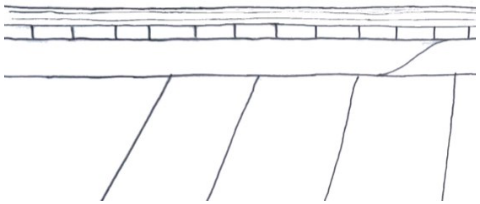
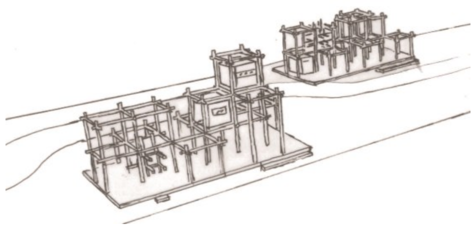
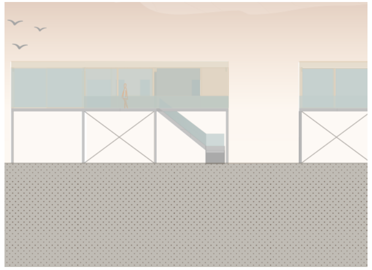
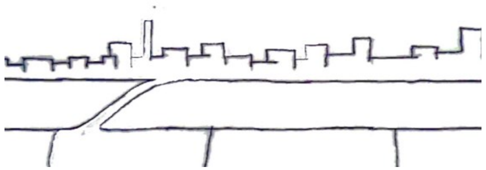
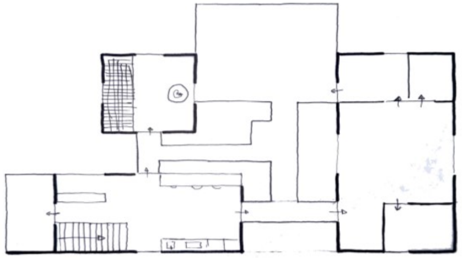
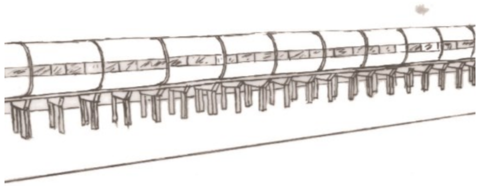
- The design fosters a seamless connection between the landscape and Lauwersoog.

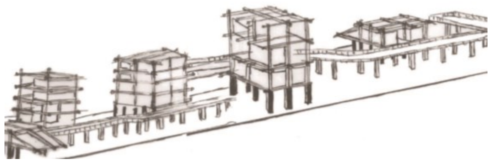
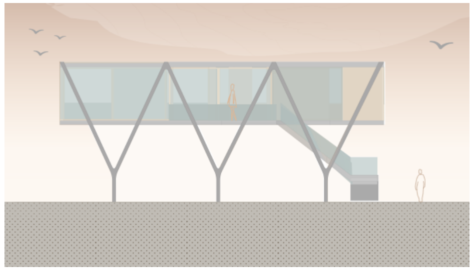
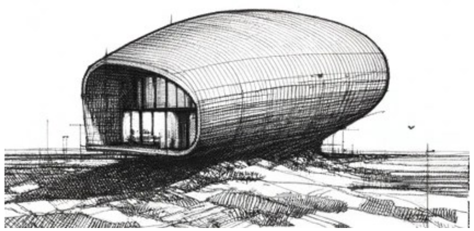
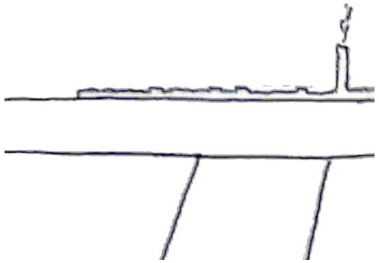

Lauwersoog
SeaDike
Location

FIRST TRANSLATION TO FORM



The second sub-question, “Which architectural language suits buildings on the dike?”, has been answered in the third phase of the graduation studio through research by design. On page 60, various sketches from the design phase are presented. These sketches have led to the identification of four architectural principles that are crucial to implement in the design. The following page explains these principles in detail.

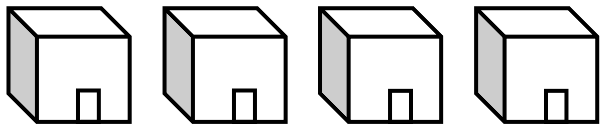
The first principle is unity. Visiting the location, it was clear that the landscape felt cohesive, encompassing Lauwersoog, the dike, and the agricultural surroundings. Because of this quality, I believe the architecture should also embody unity, accentuating the landscape. Unity can be achieved through the consistency of different volumes using texture and materiality.

The second principle is scale. This elongated horizontal landscape was tranquil and free of buildings. Ideally, a building integrated into the landscape itself would be best. However, due to structural constraints, creating such a building within the landscape is not possible. Therefore, the building on top of the dike should be low to accentuate the horizontality of the dike.

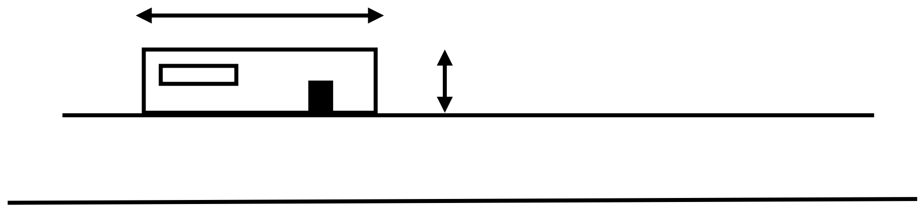
The third principle is context. The dike functions as a connecting element between Lauwersoog and the agricultural landscape. Therefore, maintaining the visual connection on the dike is crucial, which allows for the possibility of elevating the building.

The fourth principle is resilience, which relates to future climate challenges. The structure of this architecture should be resilient to these challenges, incorporating this resilience not only in building technology but also in the architectural design.

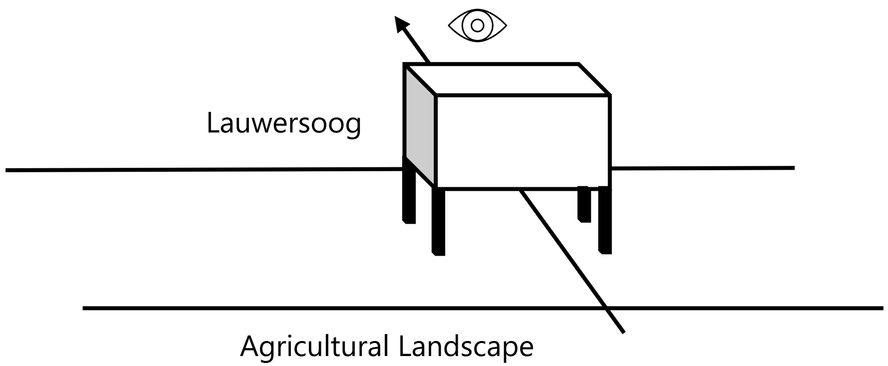
UNITY



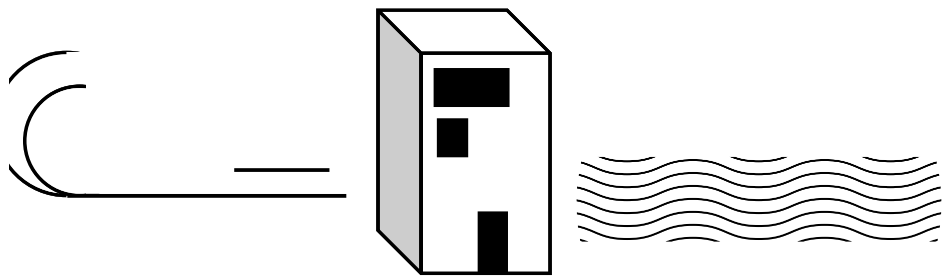
SCALE



CONTEXT



RESILIENCE



8 | CONCLUSION

Concluding the research phase of this graduation project, the findings are divided into two sections. The first section is summarized into five principles that address the research question and sub-question:

Research Question: "In the context of an elevated sea dike, what foundation types and structural systems demonstrate the highest suitability for buildings on the dike?"
Sub-Question 1: "How can these elements be optimized to accommodate potential future reinforcements of the dike?"

This section will serve as a guideline during the design phase to ensure the structural feasibility of the design.

The second section is summarized into four principles: unity, scale, context, and resilience. These principles guide the architectural design to suit buildings on the dike. Through this, the second sub-question is addressed:

Sub-Question 2: "Which architectural language suits buildings on the dike?"

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THANK YOU