A NATURE IN THE SPACE DESIGN GUIDE FOR STRESS RELIEF THROUGH BIOPHILIC DESIGN

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ABSTRACT

People are becoming disconnected from nature, mainly due to the urban environment, resulting in high stress levels in modern society. Biophilia, our innate attraction to the patterns and processes of nature, is used by biophilic designs to reduce stress. This research focuses on translating biophilic theories into stress-reducing design parameters through the biophilic category 'nature in the space'. Nature in the space involves the direct presence of nature in a space, including plant life, water, and animals, as well as natural elements like breezes, sounds, and scents. The goal is to develop a practical design guide that architects can use to integrate appropriate design patterns and parameters on a project-by-project basis. The six biophilic stress-relieving design patterns are visual and non-visual connection with nature, non-rhythmic sensory stimuli, thermal and airflow variability, presence of water, and dynamic and diffuse light. Designing for multiple sensory experiences through natural and living processes is crucial. This can be achieved by using the following design parameters: high-quality view of natural elements, biodiversity, clean flowing water, exposure variations, and day and seasonal shifts.

KEYWORDS

Stress Relief, Design Guide, Biophilic Design, Nature in the Space, Natural In-Between Place, Biophilia, Nature

I. INTRODUCTION

''We humans are programmed as we experienced the world years ago in nature, but over the years, we lost our balance. We moved from being a part of nature to being apart from nature'' (Attenborough & Hughes, 2020, p. 125).

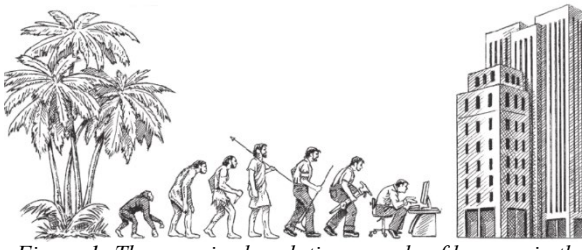


Figure 1: The perceived evolutionary role of humans in the modern world and their movement to the city (Kellert, 2018)

Modern society increasingly sees nature as a relic of the past, a recreational and aesthetic amenity rather than an essential part of life. People are becoming more disconnected from nature due to various factors, mainly because they spend most of their time in urban environments. This disconnection between humans and nature results from a society prioritising technology and indoor activities while neglecting the importance of the natural world. Figure 1 humorously illustrates the perceived evolutionary role of humans in the modern world and their movement to the city (Kellert, 2018). Urban dwellers' relationship with nature is complex. Raised in urban environments, they are susceptible to environmental stimuli and stress but less inclined to seek out nature. This leads to a stimulus-seeking strategy that compromises attention and self-control, resulting in a stressful and busy life (Joye et al., 2013). According to de Graaf et al. (2010), approximately one in five people in the Netherlands experience either a depressive or anxiety

disorder at least once throughout their lifetime. So, despite the temptation to ignore nature's importance, growing evidence shows that our innate connection to the natural world is crucial for human stress levels. Neglecting this need will harm our body, mind, and spirit. Therefore, a significant challenge we face is finding ways to integrate the beneficial experience of nature into our built environment (Kellert, 2018).

This challenge can be addressed through biophilia, our innate attraction to the patterns and processes of nature (Kellert, 2018). In the past decade, there has been a growing intersection between neuroscience and architecture, with biophilic design incorporated into sustainable building standards for its positive impact on indoor environmental quality and sense of place (Kellert, 2018; Terrapin Bright Green, 2014). Recently, biophilic design has gained recognition as a strategy to address workplace stress, student performance, patient recovery, community cohesion, and other health and well-being challenges (Terrapin Bright Green, 2014). Roger Ulrich's research on evidence-based healthcare design played a significant role in establishing the connection between biophilic design and stress relief. In his study, View Through a Window May Influence Recovery from Surgery (1984), the healing power of a connection with nature was established, comparing recovery rates of patients with and without a window (Kellert et al., 2011). More recently, the connection between biophilic design and stress relief has been shown in ‘’14 Patterns of Biophilic Design’’ by Terrapin Bright Green. In addition, the Living Building Challenge has further provided essential understandings, insights, and methodologies.

In summary, research confirms that stress is exacerbated by the disconnection from nature in the modern world. Biophilic design offers a suitable solution because many biophilic theories explain how nature can relieve stress. However, the research gap is the need to translate theories into practical design opportunities for architects. This study aims to translate existing biophilic theories into stress-relieving design parameters through the biophilic category ‘nature in the space’ by analysing theories on biophilic design patterns derived from Terrapin Bright Green's 14 Patterns of Biophilic Design (2014). Nature in the space involves the direct presence of nature in a space, including plant life, water, and animals, as well as natural elements like breezes, sounds, and scents. Ultimately, a practical design guide will emerge that will allow the architect to investigate which design patterns and associated design parameters can best be integrated on a project-by-project basis. The next chapters will further explain biophilic design, stress relief, and nature in the space.

1.1 Objective

The design guide will consist of the following ingredients:

- Six design patterns: visual connection with nature, non-visual connection with nature, non-rhythmic sensory stimuli, thermal and airflow variability, presence of water, and dynamic and diffuse light

  Each pattern consists of the following information:

  - Influence related to stress relief
    - People’s general experience of the pattern
    - The stress relief symptoms induced by the pattern as described in theories
  - Design goal to reach stress relief
  - A design diagram
  - A design example
- Toolbox

The research gap described above leads to the following thematic research question:

How to use the biophilic design category nature in the space to increase stress relief as an architect?

Sub-thematic research questions:

1. *Biophilic design has been shown to reduce stress; how is the relationship between biophilic design and stress relief characterised?*

2. *How to make a spatial impact using the biophilic category nature in the space that relieves stress?*

3. *How to translate existing biophilic theories about stress relief into a nature in the space design guide for architects?*

4. *How to use the nature in the space design guide as an architect to provide stress relief?*

1.2 Paper outline

The research methods will include literature research and a prototype. The entire research is divided into five parts. Each part is related to a research sub-question.

II. Biophilic design for stress relief

There will be a deeper discussion of the terms biophilia and biophilic design. Also, the relationship between biophilic design and stress relief will be discussed.

III. The nature in the space

This chapter aims to clarify the meaning and spatial use of the biophilic category nature in the space.

IV. Design Guide

Within the explained field, this section will translate existing theories into stress-relieving design parameters through design patterns that can be applied in the natural in-between place. Together, this will result in a toolbox for architects, as explained in the objective.

V. Application

The architect needs information on how to use the design guide to provide biophilic natural in-between places. This chapter will explain how to use the design guide as an architect. Also, a case study will be utilised as an example design project.

VI. Conclusion & discussion

The thematic research question will be answered by addressing the various sub-research questions. Furthermore, generalizability, limits of the method and suggestions for further research will be discussed.

1.3 Prototype

The TNW building situated on the Delft University of Technology campus, as shown in Figure 2, has been chosen as a prototype. This building needs to be renovated and is looking for a new function. The various arguments for this choice will be discussed. The main arguments are the high stress levels of students at TU Delft, the suitability of the TNW building for integrating nature in the place and TU Delft's aspiration for a natural, biodiverse campus where people and nature co-exist (TU Delft, 2023). These arguments show that nature in the place for stress relief could significantly impact this building.

Figure 2: TNW building in context (TU Delft, 2022)

Students at TU Delft use the TNW building, and this target group, in particular, experiences much stress. A study by GGD & RIVM in 2022 called "Health Monitor Young Adults 2022" shows that young adults, especially those aged 16-25, experience stress most often. This study revealed that 82.3% of young adults experience stress occasionally or frequently, with 48.3% experiencing it very often. This study also found that studying is the main reason for stress, accounting for 62.1% of cases. At TU Delft, the stress level appears to be even higher than the national average. Another study conducted by RIVM, GGD GHOR, and the Trimbos Institute showed that 97% of TU Delft students experience stress, with 70% experiencing excessive performance pressure and 51% reporting psychological complaints such as anxiety and gloom (Rooijakkers & TU Delta, 2021).

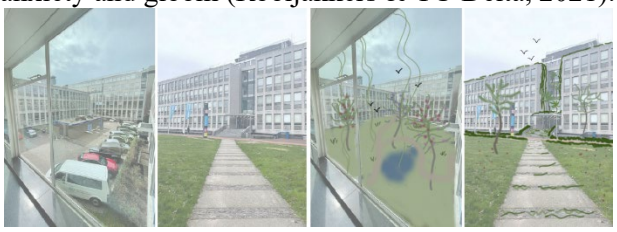


Figure 3: Opportunities for integrating biophilic stress relieving nature in the space (by author)

The design of the TNW building is very suitable as a prototype, as this is of a common typology as a building. Namely, the building comes from 1963 and at that time, buildings were designed very closed to their surroundings. In addition, the impact of nature in the space can be significant in this building because of its very closed character. However, the form is in relation to the outside, which creates opportunities, as illustrated in Figure 3. A building that has to be renovated has been selected as a prototype because, due to sustainability requirements and changing demand for functions, many buildings in the Netherlands will have to be renovated in the coming years.

Also, the vision of TU Delft regarding the incorporation of nature into the built environment aligns perfectly with the vision of this study, as evident from the following quote: ‘’We strive for a natural, biodiverse campus where people and nature co-exist’’ (TU Delft, 2023). This building is centrally located on campus, allowing the building and its surroundings to make a significant impact on the biodiversity of the campus

II. BIOPHILIC DESIGN FOR STRESS RELIEF

This chapter provides the groundwork for the upcoming chapters by exploring biophilia, biophilic design, stress relief, and their connections.

2.1 Biophilia

Humans have been intimately connected to nature for 99% of our species' history. Our ability to adapt to nature has been biologically ingrained, resulting in a natural tendency to align with its patterns and processes. This tendency to interact with and experience nature is called biophilia (Kellert, 2018). For instance, we are particularly drawn to other forms of life that have played a crucial role in our survival. Biophilia explains why the sound of crackling fires and crashing waves captivate us, how a garden view enhances our creativity, why shadows and heights evoke fascination and fear, and why interactions with animals and walks in parks have restorative effects. Biophilia may also account for preferences for certain urban parks and buildings over others (Terrapin Bright Green, 2014).

2.2 Biophilic design

Biophilic design draws on our biologically ingrained tendency to interact with and experience nature. Biophilic design has been shown to reduce stress, enhance cognitive functions, promote creativity, improve well-being, and aid healing. Above all, biophilic design fosters a love for the environment (Terrapin Bright Green, 2014).

Biophilic design encompasses three categories: nature in the space, natural analogues, and nature of the space, which serve as a framework for integrating diverse strategies into the built environment. The framework consists of 14 patterns, an overview of which can be seen in Appendix 1.
Nature in the space involves the direct presence of nature in a space, including plant life, water, and animals, as well as natural elements like breezes, sounds, and scents.
Natural analogues encompass indirect evocations of nature through organic, non-living elements such as objects, materials, colours, shapes, sequences, and patterns found in nature.
Nature of the space pertains to spatial configurations inspired by nature, including our inherent desire to have a broader view of our surroundings, our fascination with the slightly unknown or dangerous, obscured views, revealing moments, and even properties that induce phobias when they incorporate a sense of safety (Terrapin Bright Green, 2014).

2.3 Stress relief

The main goal of biophilic design for this research is to create stress-relieving environments. After conducting numerous studies, the American Institute of Stress has linked most health issues to stress (Boyd, 2022). In this research, they found that the primary detrimental effect of stress is its inhibition of crucial hormones that combat heart diseases, depression, and anxiety.

In relation to the nature in the space design guide, stress relief is defined as direct relief of physical and psychological stress and indirect relief of physical and psychological stress symptoms (Kellert et al., 2011). Biophilic design has a lot of stress-reducing effects, leading to positive changes in reduced levels of negatively toned emotions (fear, anger), elevated positive emotions (pleasantness), and changes in physiological systems. For example, studies in natural environments and laboratories demonstrate that viewing nature can quickly restore physiological indicators like blood pressure, heart activity, and muscle tension within three to five minutes (Kellert et al., 2011). Notably, initially stressed individuals experience the most significant therapeutic effects regarding positive physiological and emotional changes (Ulrich, 1999).

The overview of the 14 design patterns consists of eight patterns that have a stress relief effect, as shown in Appendix 1. These are the following patterns: visual connection with nature, non-visual connection with nature, non-rhythmic sensory stimuli, thermal and airflow variability, presence

of water, dynamic and diffuse light, complexity and order, and prospect. The first six patterns belong to the biophilic category nature in the space. The complexity and order pattern belongs to the category natural analogues and the prospect pattern belongs to the category nature of the space.

To answer the sub-thematic research question, *Biophilic design has been shown to reduce stress; how is the relationship between biophilic design and stress relief characterised?* it can be concluded that biophilic design uses our innate attraction to nature to reduce stress. Stress relief involves both direct and indirect alleviation of physical and psychological stress symptoms. Integrating nature into the built environment through biophilic design has numerous stress-reducing effects, resulting in positive changes such as reduced negative emotions, increased positive emotions, and modifications in physiological systems. Integrating biophilic design can provide stress relief by using the following biophilic design patterns: visual connection with nature, non-visual connection with nature, non-rhythmic sensory stimuli, thermal and airflow variability, presence of water, dynamic and diffuse light, complexity and order, and prospect.

III. NATURE IN THE SPACE

This chapter will discuss the spatial use of nature in the space. The spatial use provides interesting information on making an impact through the nature in the space design guide.

As emerged in the previous chapter, nature in the space is one of the three biophilic design categories that serve as a framework for integrating various strategies in the built environment. Nature in the space refers to the direct presence of nature in a space, including plants, water and animals, as well as natural elements such as breezes, sounds and smells. (Terrapin Bright Green, 2014).
This research will focus on nature in space because of its significant impact on stress reduction (Kellert et al., 2011). Moreover, this category offers numerous opportunities for ecology, passive climate and sustainability. In this way, architects can integrate stress relief through nature in space into their overall design vision. The framework for this consists of the following six patterns, as shown in Appendix 1: visual connection to nature, non-visual connection to nature, non-rhythmic sensory stimuli, thermal and airflow variability, presence of water, and dynamic and diffuse light.

In recent times, the meaning and experiential aspects of specific places have been emphasised in psychological and architectural research. This includes awareness of the transition to places (Vakoch & Castrillón, 2014). Applying biophilic design for stress relief will majorly impact the concept of the natural in-between place. This awareness of the transition to places and the use of nature in its purest form are part of the natural in-between place concept. The natural in-between place comprises nature in the space and the in-between place. The term in-between space will be explained, after which the definition of the natural in-between place will become clear.

The in-between place is an abstract space in architecture with an intermediate relationship between solid. These solids consist of the primary functions of a building. Thus, the in-between place contains the transition of functions. This makes it a perfect place to distract the mind by integrating nature into the space, thus providing stress relief. For the architect, the connection of functions is essential here. When functions outside the boundary framework of the design have a great connection with functions within the boundary framework, it is essential as an architect when designing the in-between places to establish a connection with the intervening nature, which is part of nature in the space. Furthermore, there is a difference between new construction and renovation; in new construction, the integration of in-between places and, thereby, connections can be included in the construction of the building as a volume, while in renovation, the building form will remain largely the same. In renovation, cores of buildings will often be appropriate, as they often have a connection with both the primary functions of a building and the nature in the space of its surroundings. In addition, despite being an intriguing and opportune location, limited

research has been conducted on the in-between place.

The natural in-between place consists of three components, as shown in Figure 4: character of the location, sense of place, and form, collectively defining a place (de Wit & Piccinini, s.d.). The character of the location of the natural in-between place establishes a connection between primary functions visited one after the other and nature of the space surroundings. The sense of place of the natural in-between place focuses on stress relief by incorporating the nature in the place category of biophilic design. Lastly, the form of the natural in-between space relates to the cores within the building, aligning with both the contextual nature and the functional aspects.

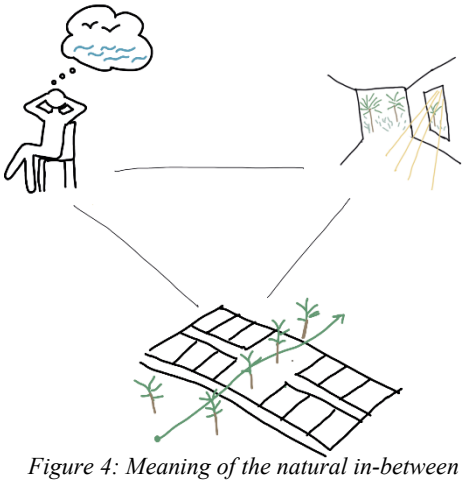


Figure 4: Meaning of the natural in-between space (by author)

When designing with nature in the place, it is essential to consider the placement of natural elements within a space. The natural analogues and nature of the space biophilic categories incorporate stress-reducing patterns through thoughtful composition.

The natural analogues category's complexity and order pattern positively impacts perceptual and physiological stress responses, as shown in Appendix 1. It aims to create a visually healthy environment with symmetries, fractal geometries, and a coherent spatial hierarchy similar to those observed in nature. To incorporate this pattern into the design of the natural in-between place, it is essential to consider compositions that reveal fractal geometries and hierarchies. Examples include the selection and placement of plants, complex plant oil fragrances, and auditory stimuli. Striking a balance is crucial, as excessive or prolonged exposure to high-fractal dimensions can cause discomfort or fear, while avoiding or underutilising fractals may result in predictability and disinterest (Terrapin Bright Green, 2014).

The prospect pattern of the nature of the space category can relieve stress, as shown in Appendix 1. Prospect refers to an unobstructed view over a distance, enabling surveillance and planning. The objective of the prospect pattern is to offer users a condition that allows them to visually survey and contemplate the surrounding environment for opportunities and potential hazards. In landscapes, the prospect is characterised by elevated positions or expansive views.
In the composition of the in-between space, the prospect pattern can be incorporated by designing with focal lengths of at least 6 meters, elevated planes, and open floor plans. Additionally, incorporating existing or planned savanna-like ecosystems, bodies of water, and evidence of human activity or habitation will enrich the information the prospect view provides. This approach helps create views that align with the visual connection with nature pattern. (Terrapin Bright Green, 2014)

To answer the sub-thematic research question, *How to make a spatial impact using the biophilic category nature in the space that relieves stress?* It can be concluded that nature in the space involves the direct presence of nature in a space, including plant life, water, and animals, as well as natural elements like breezes, sounds, and scents (Terrapin Bright Green, 2014).
This research will focus on nature in the space due to its significant impact on stress relief and the opportunities related to passive design, ecology and sustainability. To make a spatial impact in terms of stress relief with the nature in the space category, the nature in-between place can be an interesting space due to its essential connection between various primary functions and nature. For the classification of nature in the space elements, inspiration can be taken from the complexity and order pattern of the natural analogues category and the prospect pattern of the nature of the space category.

IV. Design Guide

The design guide offers a menu of options for designers, which can be adapted to project-specific circumstances and conditions (Kellert, 2018). The menu includes six overlapping and interacting design patterns derived from the 14 Patterns of Biophilic Design and the Economics of Biophilia by Terrapin Bright Green, as shown in Appendix 1. The six identified patterns:

1. Visual connection with nature: View of natural elements, living systems, and natural processes.
2. Non-visual connection with nature: Engaging auditory, haptic, olfactory, or gustatory stimuli related to natural and living processes.
3. Non-rhythmic sensory stimuli: Unpredictable and ephemeral connections with nature.
4. Thermal and airflow variability: Mimicking natural environments with subtle changes in temperature, humidity, airflow, and surface temperatures.
5. Presence of water: Enhancing the experience through sight, sound, or touch of water.
6. Dynamic and diffuse light: Utilizing changing intensities of light and shadow to replicate natural lighting conditions.

The design guide will consist of the following ingredients:

- Six design patterns: visual connection with nature, non-visual connection with nature, non-rhythmic sensory stimuli, thermal & airflow variability, presence of water, and dynamic & diffuse light

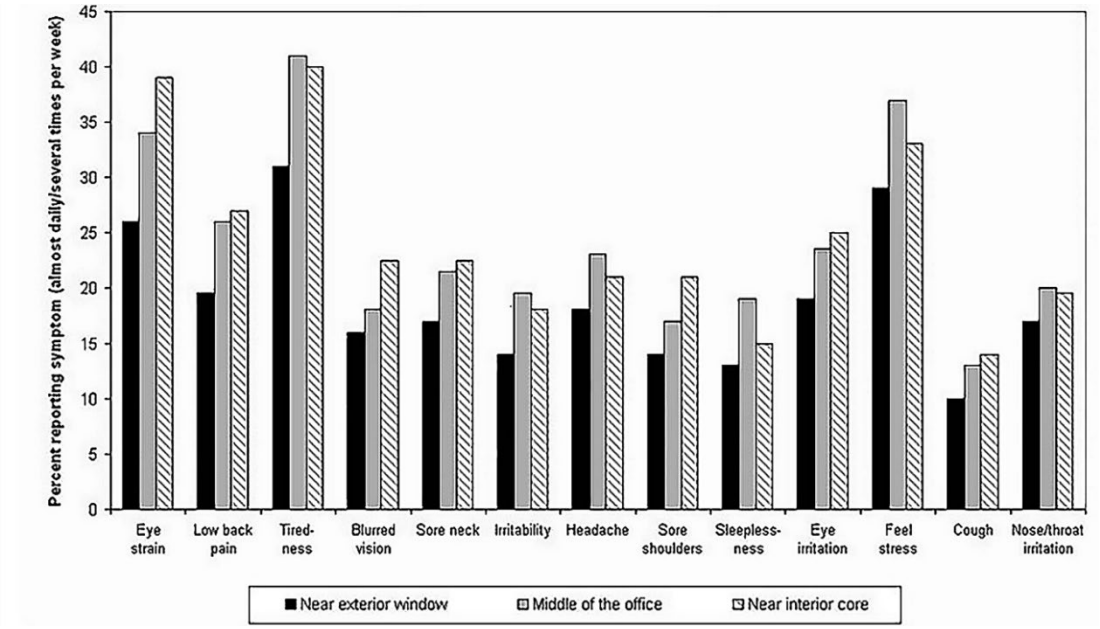
  Each pattern consists of the following information:

  - Influence related to stress relief
    - People's general experience of the pattern
    - The stress relief symptoms induced by the pattern as described in theories
  - Design goal to reach stress relief
  - A design diagram
  - Design example
- Toolbox

4.1 Design pattern: Visual connection with nature

A visual connection with nature involves views of natural elements, living systems, and natural processes. A space with a strong visual connection with nature captures attention, evokes stimulation or calmness, and conveys a sense of time, weather, and other living entities (Terrapin Bright Green, 2014). In humans, the visual sense overwhelmingly dominates and serves as the primary means through which people perceive and react to plants, animals, water, landscapes, and other elements of the natural environment. This visual dominance can be attributed to humans evolving as diurnal creatures heavily dependent on sight to identify opportunities and threats (Kellert et al., 2018).

The visual connection with nature pattern is based on research showing reduced stress, improved emotional functioning, and enhanced concentration and recovery rates when exposed to nature views (Kellert et al., 2011; Terrapin Bright Green, 2014). Office workers with a window view of nature reported significantly fewer physical complaints, as shown in Figure 5, and lower frustration, higher life satisfaction, and better overall health (Kellert et al., 2011). Lack of access to nature can lead to confusion and anxiety (Kellert, 2018). Visual connections with nature positively affect mood, self-esteem, blood pressure, heart rate, attention, and happiness. Experiencing nature, such as through exercise in a green space, positively impacts mood and self-esteem within the first five minutes (Ulrich, 1999; Barton & Pretty, 2010). Viewing nature for ten minutes before a mental stressor stimulates heart rate variability and parasympathetic activity. High heart rate variability enables the body to function optimally, while the parasympathetic nervous system facilitates relaxation and recuperation after physical activity (Brown et al., 2013).



Additionally, viewing a forest scene for 20 minutes after a mental stressor relaxes blood flow and brain activity. Nature scenes stimulate more pleasure receptors in the brain, leading to prolonged interest and faster stress recovery (Tsunetsugu & Miyazaki, 2005).

Figure 5: Comparison between window proximity and health complaints (Kellert et al., 2011)

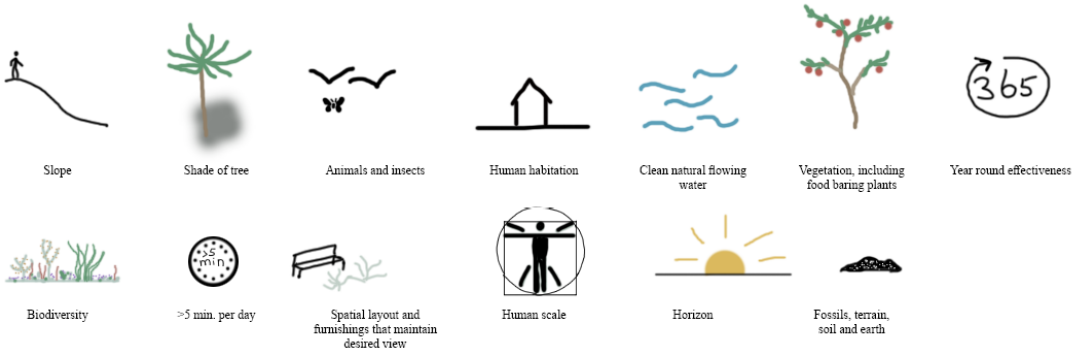


Figure 6: Design diagram visual connection with nature pattern (by author)

The design goal for stress relief experience in the natural in-between space is to create an environment that promotes relaxation and reduces cognitive fatigue by allowing individuals to shift their focus and relax their eye muscles (Terrapin Bright Green, 2014). The design guidelines

for this pattern can be found in Appendix 2 and are brought together in the design diagram depicted in Figure 6. Generally, a high-quality view of natural elements, living systems and natural processes can achieve the design goal. In addition, increased visibility of biodiversity is essential.

The birch tree and moss garden in the New York Times Building is an excellent example of a designed environment with a strong visual connection with nature, as shown in Figure 7. It is located in the middle of the building and serves as a peaceful oasis amidst the busy Times Square, accessible to everyone entering or leaving the building (Terrapin Bright Green, 2014).

Figure 7: The birch tree and moss garden as example of visual connection with nature pattern (Terrapin Bright Green,

4.2 Design pattern: Non-visual connection with nature

A space with a strong non-visual Connection with nature feels refreshing and harmonious. The ambient conditions are perceived as both complex and variable yet familiar and comfortable. The sounds, aromas, and textures resemble the experience of being outdoors in nature (Terrapin Bright Green, 2014).

Studies have indicated that experiencing nature through a non-visual connection with nature can positively affect blood pressure, stress hormones, cognitive performance, and mental health (Terrapin Bright Green, 2014). Here is a short overview of the research findings for each sensory system:

Auditory: Exposure to nature sounds accelerates restoration after a psychological stressor (Alvarsson et al., 2011) and reduces cognitive fatigue (Jahncke et al., 2011). Participants listening to river sounds or watching a nature movie with river sounds reported increased energy and motivation compared to those exposed to office noise or silence (Jahncke et al.,2011). Also, when integrating nature views, there is a strong connection between our visual and auditory sensory systems and psychological well-being (Hunter et al., 2010).

Olfactory: The sense of smell directly affects the brain and can trigger powerful memories. Olfactory exposure to herbs and essential oils from trees positively affects healing and immune function (Kim et al., 2007; Li et al., 2012).

Haptic: Interactions like pet therapy, gardening, and touching real plant life have calming effects, reduce fatigue, and promote environmental stewardship (Yamane et al., 2004). Likewise, touching natural elements like water or raw materials may have similar health benefits (Koga & Iwasaki, 2013).

Gustatory: Tasting is another way to experience and learn about nature, as seen in infants and toddlers exploring their environment through their mouths (Terrapin Bright Green, 2014).

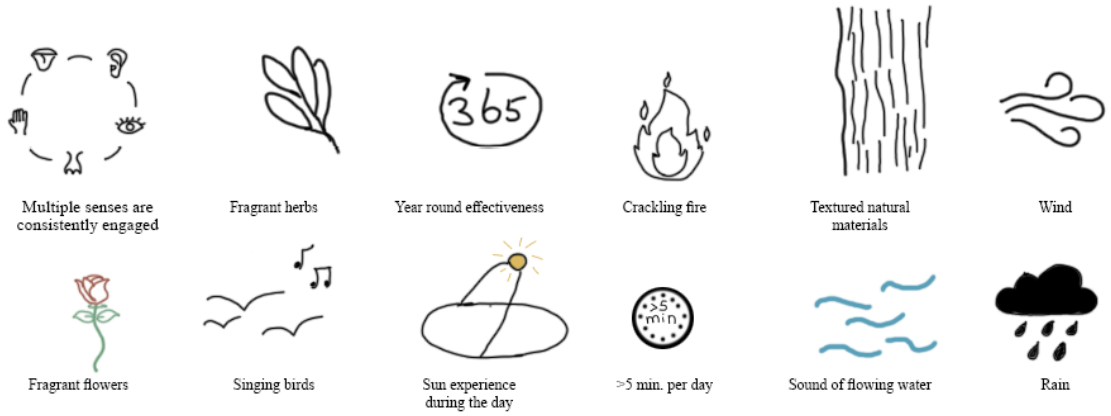


Figure 8: Design diagram non-visual connection with nature pattern (by author)

The design goal for this pattern, preferably in the natural in-between space, is to provide an environment that uses sound, scent, touch and possibly even taste to engage the individual in a manner that helps reduce stress and improve perceived physical and mental health (Terrapin Bright Green, 2014). The design guidelines for this pattern can be found in Appendix 2 and are brought together in Figure 8. To meet the design objective, it is crucial to incorporate elements that cohesively engage multiple senses.

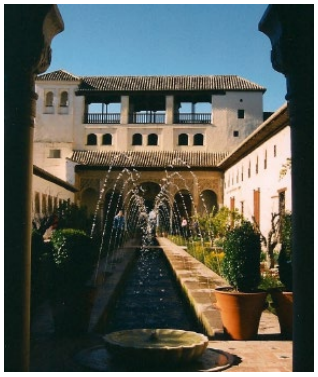


Figure 9: The Alhambra as example of non-visual connection with nature pattern (Terrapin Bright Green, 2014)

The Alhambra in Granada, Spain, exemplifies non-visual connections with nature, as shown in Figure 9. Integrated water features and natural ventilation connect indoor and outdoor spaces seamlessly. In addition, using gardens, water fountains, and fragrant plants enhances the sensory experience, while stone floors and handrails provide cooling effects (Terrapin Bright Green, 2014).

4.3 Design pattern: Non-rhythmic sensory stimuli

Non-rhythmic sensory stimuli are unpredictable and fleeting connections with nature that cannot be precisely predicted but can be analysed statistically. A space with a strong presence of non-rhythmic sensory stimuli provides a sense of experiencing something unique, fresh, engaging, stimulating, and invigorating. It offers a brief yet welcomed distraction (Terrapin Bright Green, 2014).

The non-rhythmic sensory stimuli pattern has evolved from research on looking behaviour, eye lens focal relaxation patterns, and physiological measures like heart rate and blood pressure (Terrapin Bright Green, 2014). Studies have shown that exposure to the stochastic movement of objects in nature and natural sounds and scents supports physiological restoration. For example, prolonged visual focus on a computer screen or a task can cause eye strain and fatigue. However, taking periodic breaks with brief visual or auditory distractions, where one looks up (for > 20 seconds) and focuses on a distant point (of > 20 feet), allows the muscles to relax and the lenses to flatten (Terrapin Bright Green, 2014).

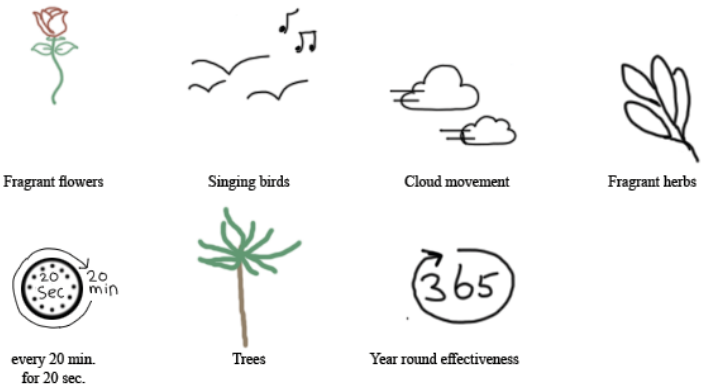
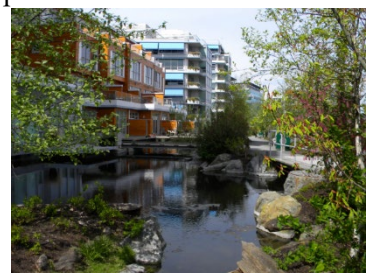


Figure 10: Design diagram non-rhythmic sensory stimuli pattern (by author)

The goal for the natural in-between place related to this pattern is to use natural sensory stimuli that unobtrusively attract attention to replenish focus and reduce mental fatigue and physiological stress (Terrapin Bright Green, 2014). The design guidelines for this pattern can be found in Appendix 2 and are brought together in Figure 10. To achieve the design goal, it is essential to focus on elements that provide brief exposure to unpredictable movement, peripheral vision, and periodic scents or sounds.



Dockside Green in Victoria, BC, Canada, is an excellent example of non-rhythmic stimuli, as shown in Figure 11. Habitat restoration and rainwater management create fleeting encounters with swaying grasses, falling water, and the sounds of insects and animals. These experiences are visible from various locations within the community (Terrapin Bright Green, 2014).

Figure 11: Dockside Green as example of non-rhythmic sensory stimuli pattern (Terrapin Bright Green, 2014)

4.4 Design pattern: Thermal and airflow variability

Thermal and airflow variability refers to subtle changes in temperature, humidity, airflow, and surface temperatures that mimic natural environments. A good thermal and airflow variability creates a refreshing, active, and comfortable space that invigorates. In addition, it provides a sense of flexibility and control because the user can adjust the climate of a particular place. (Terraping Green Bright, 2014).

The thermal and airflow variability pattern has evolved from research on natural ventilation, worker comfort and productivity, sensory variability, and the impact of nature in motion on concentration (Terrapin Bright Green, 2014). People prefer moderate sensory variability in the environment, including light, sound and temperature variations. When there is a lack of sensory stimulation and variety in the environment, it can result in feelings of boredom and passivity. (Heerwagen, 2006). According to Kaplan's Attention Restoration Theory, soft fascination elements like light breezes improve concentration, and various thermal conditions can enhance concentration and performance (Heerwagen & Gregory, 2008; Kaplan, 1995; Elzeyadi, 2012). Changes in ventilation velocity positively impact comfort and may improve access to short-term memory (Wigö, 2005).

The objective of the natural in-between place related to this pattern is to provide users with the sensory experience of airflow and thermal variability along with control over thermal conditions (Terrapin Bright Green, 2014). The design guidelines for this pattern are in Appendix 2 and are brought together in Figure 12. To achieve the goals of this pattern, it is essential to focus on natural systems and flexibility.

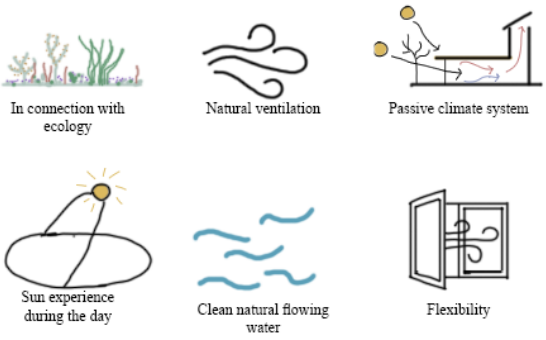


Figure 12: Design diagram thermal and airflow variability pattern (by author)

Figure 13: Singapore's Khoo Teck Puat Hospital as example of thermal and airflow variability pattern (Terrapin Bright Green, 2014)

Singapore's Khoo Teck Puat Hospital by RMJM Architects exemplifies thermal and airflow variability, as shown in Figure 13. The hospital's passive design utilises exterior courtyards to bring in fresh air, ensuring thermal comfort. Patients also have operable windows in their rooms for personal control. In addition, the design incorporates façade and internal layouts that optimise daylight and light/shade variability, minimising glare. Elevated exterior walkways connect the spaces, offering access to breezes, shade, and solar heat (Terrapin Bright Green, 2014).

4.5 Design pattern: Presence of water

Water enhances the place experience through sight, sound, and touch (Ulrich, 1993). It is visually appealing and engages various senses. Water can transform a dull environment into something extraordinary (Kellert, 2018). A space with a good water presence feels compelling and stimulating. Fluidity, sound, lighting, proximity, and accessibility contribute to the atmosphere. (Terrapin Bright Green, 2014)

The presence of water pattern is based on research showing positive emotional responses and reduced stress in environments with water elements. Water features can lower heart rate and blood pressure and improve concentration and memory. Multiple senses stimulated by water enhance perception and responsiveness. Nature images with water elements reduce blood pressure and heart rate (Terrapin Bright Green, 2014). Water presence in green spaces improves self-esteem and mood compared to green environments without water. To a certain extent, humans still possess the innate and pressing sense that compelled our ancient ancestors towards the water's edge. (Kellert et al., 2011).

Water is essential for life and has made Earth habitable. It unifies nature and connects all aspects of the landscape. However, water has become hidden and managed in the modern built environment, separating it from the natural world. This is unfortunate, as integrating natural water flows can have a significant impact when considering the meaning of water to us. Water provides numerous services and enhances our recreational life. It is shapeless, yielding, and reflects its surroundings. Water's restorative powers have long been recognised in hydrotherapy (Kellert, 2011).

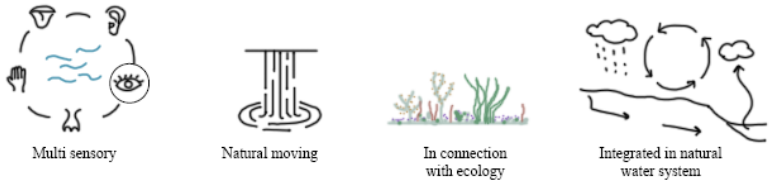


Figure 14: Design diagram presence of water pattern (by author)

The goal of this pattern related to the natural in-between place is to enhance the place experience by utilising water's multisensory attributes (Terrapin Bright Green, 2014). The design guidelines for this pattern are outlined in Appendix 2 and are visualised in Figure 14. To achieve the goal of this pattern, it is essential to focus on natural systems and water features, which focus on multiple senses.

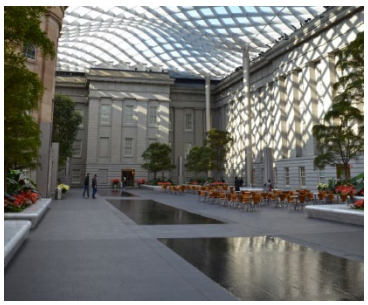


Figure 15: The Robert and Arlene Kogod Courtyard as example of presence of water pattern (Terrapin Bright Green, 2014)

The Robert and Arlene Kogod Courtyard at the Smithsonian American Art Museum in Washington, DC, exemplifies the presence of water, as shown in Figure 15. It features an expansive water feature that doubles as an event space. The enclosed outdoor space has an undulating canopy design resembling water or clouds by Norman Foster Architects. Water flows from slits on the sloping floors, reflecting light and inviting touch. The water is drained during events, seamlessly integrating with the floor (Terrapin Bright Green, 2014).

4.6 Design pattern: Dynamic and diffuse light

Dynamic and diffuse light creates changing intensities of light and shadow over time, evoking drama, intrigue, and a sense of calm in a space (Terrapin Bright Green, 2014).

Lighting design impacts mood, productivity, and well-being. Quality daylighting has been linked to positive moods. Research focuses on illuminance fluctuation, human perception, and lighting's effects on the circadian system (Terrapin Bright Green, 2014). Natural light affects spatial and temporal responses, orient itself to its surroundings, and relates to daylight patterns and seasonal shifts. (Kellert, 2018) The body responds to the colour transition of daylight. The response is apparent in body temperature, heart rate, and circadian functioning. Sunlight changes colour from yellow in the morning to blue at midday and red in the afternoon/evening. Serotonin and melatonin levels influenced by light impact sleep, mood, and health conditions(Kandel et al., 2013). Natural daylight variability benefits patients in recovery and mental health treatment. Bright visible light during the day and darkness at night is essential for health. Lack of natural light can lead to health, performance, and well-being issues (Kellert, 2018).

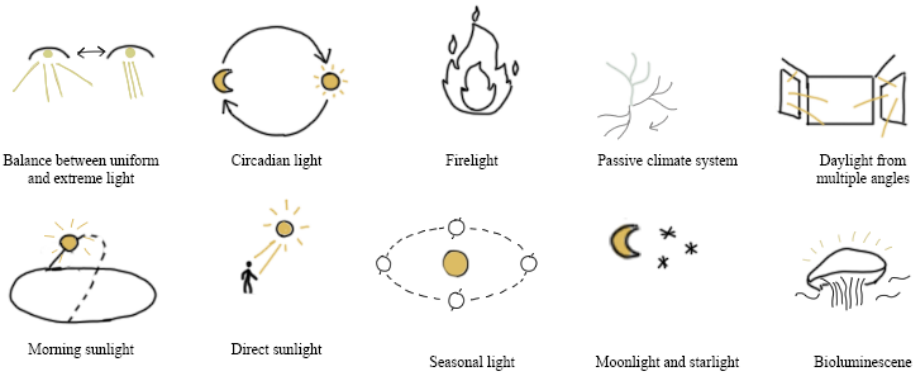


Figure 16: Design diagram dynamic and diffuse light pattern (by author)

The goal for the natural in-between place related to this pattern is to provide stimulating lighting options that promote positive psychological and physiological responses and support circadian system functioning (Terrapin Bright Green, 2014). The design guidelines for this pattern are outlined in Appendix 2 and are summarised in Figure 16. To achieve the design goal of this pattern, it is essential to focus on natural light systems and changing intensities of light and shadow over time.

Figure 17: Paimio Sanatorium terrace as example of dynamic & diffuse light pattern (Heikinheimo, 2014)

Alvar Aalto's Paimio Sanatorium is an example of the dynamic and diffuse light pattern, as shown in Figure 17. He gained international acclaim for its design allowing tuberculosis patients' beds to be wheeled onto adjacent terraces for outdoor sunshine therapy, even in harsh Scandinavian climates (Kellert et al., 2011).

4.8 Toolbox

This design guide aims to provide architects with guidance on creating stress-relieving environments through natural in the space. After providing information on the six biophilic stress-relieving patterns for nature in the space, it is essential to translate these theories into a design toolbox. This is done by analysing the design diagrams of the different patterns. This analysis, shown in Appendix 3, translates the design diagrams into a summary design diagram. The summary design diagram, as shown in Figure 18, consists of the main design criterion, design parameters and design patterns. First, we will discuss the summary design diagram's structure, followed by a manual. Together, they form the toolbox.

The two design criteria are as follows:

- Design for multiple senses

  Incorporating biophilic design elements that stimulate multiple senses increases the likelihood of effectively integrating nature into the built environment (Kellert, 2018). Experiencing nature through the senses plays a significant role in all patterns. In both the patterns non-visual connection with nature and presence of water, it is part of the main purpose of the pattern. Furthermore, seeing plays the leading role in the experience, followed by smelling and hearing.

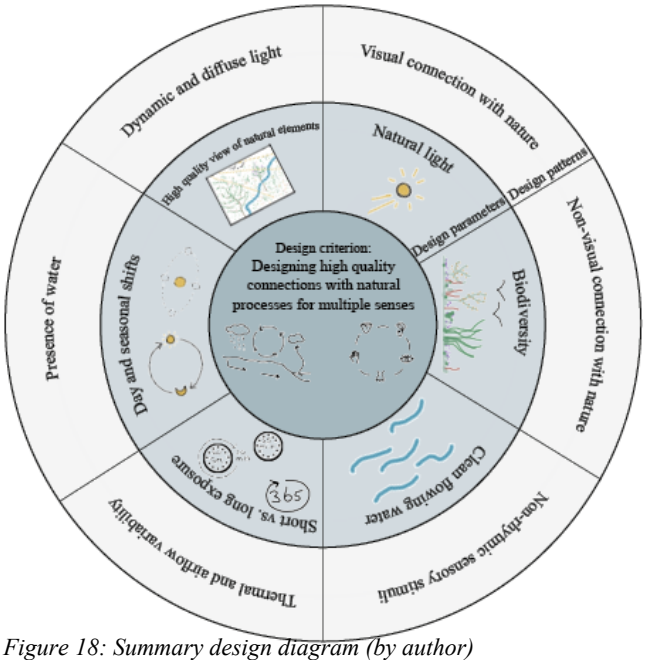


Figure 18: Summary design diagram (by author)

- High-quality connection with natural and living systems or processes for orienting users to their surroundings

  These natural connections are the primary goal of the pattern presence of water and the pattern thermal and airflow variability. In addition, all other patterns are also linked to natural processes, the most important being water flow, sunlight and biodiversity.

These two design criteria lead to the following main design criterion: Designing high-quality connections with natural processes for multiple senses. This design criterion is represented in the core of the design diagram, shown in Figure 18. The following design parameters, shown in the middle layer of Figure 18, are the most important and can be a translation between the design criterium and the design:

- High-quality view of natural elements

  Besides the non-visual connection with nature pattern, seeing natural processes within all patterns plays a significant role. Examples include seeing moving water, moving natural light, moving clouds, flowers and biodiversity.

- Biodiversity

  In all patterns, biodiversity plays an important role. Biodiversity is part of the main goal of the visual connection with nature pattern. For instance, the non-visual connection with nature pattern stimulates the senses in different ways through biodiversity. In the presence of water pattern, biodiversity in connection with ecology has a reinforcing effect. In the dynamic and diffuse light pattern, biodiversity ensures that natural light is received in different layers of light.

- Flowing clean water

  The design parameter flowing clean water is part of the primary purpose of the presence of water pattern. Furthermore, it also plays an essential role in both the design patterns non-visual connection with nature and the design pattern dynamic and diffuse light. In the other two design patterns, flowing clean water does not emerge from the analysis. However, a connection can be made, for instance, by focusing on life in the water in the

non-rhythmic sensory stimuli pattern. Also, the dynamic and diffuse light pattern can use water as a reflection of light and the composition of water and the sun.

- Short (ephemeral and stochastic) exposure versus long exposure (up to 20 minutes)

  A short exposure belongs to the main goal of the non-rhythmic sensory stimuli pattern, while the design patterns visual connection with nature and non-visual connection with nature aim for an exposure of at least five minutes. The other patterns show a combination of short and long exposure. For instance, in the presence of water pattern, a waterfall will have a short exposure, while a view of water will have a long exposure. In the dynamic and diffuse light pattern, sun exposure will provide stress relief for a longer time, while many dynamic lights will require a short exposure in terms of stress relief. For the thermal and airflow variability pattern, a small variability over a long period is desirable, while a high variability will only provide stress relief when the exposure is short. It can therefore be concluded that layering the different patterns and possibilities of patterns works very well to arrive at these design parameters.

- Natural light

  The pattern dynamic and diffuse light primarily focuses on natural light. This provides variety and shows a natural system positively influencing our hormones and rhythm. Sun exposure during the day also plays a role in the non-visual connection with nature and the thermal and airflow variability patterns. The thermal and airflow pattern also includes a passive climate system in which natural light from the sun plays a role.

- Day and seasonal shifts

  The shifts between days and seasons show natural processes and occur with sunlight, for example. When designing, it is essential to be aware of this so that a design exists that has quality 365 days a year. According to the analysis, this consistently 'on' of patterns is especially important with non-rhythmic sensory stimuli, visual connections with nature and non-visual connections with nature.

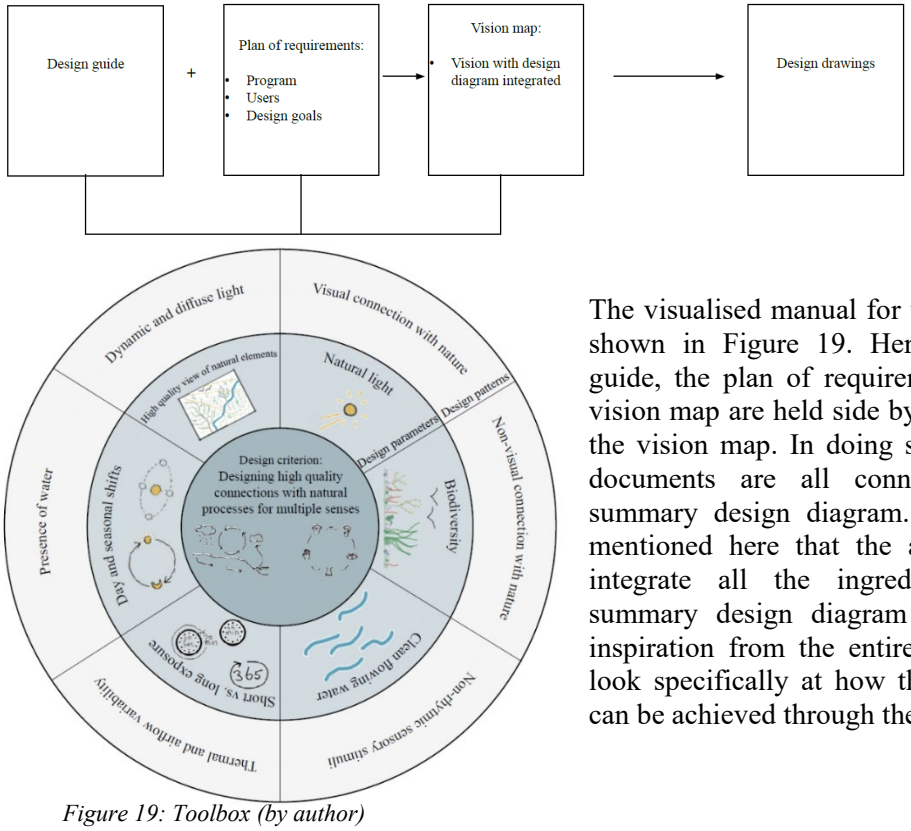


Figure 19: Toolbox (by author)

The visualised manual for this toolbox is shown in Figure 19. Here, the design guide, the plan of requirements and the vision map are held side by side to shape the vision map. In doing so, these three documents are all connected to the summary design diagram. It should be mentioned here that the aim is not to integrate all the ingredients of the summary design diagram but to draw inspiration from the entire diagram and look specifically at how the most profit can be achieved through the diagram.

In conclusion, to answer the sub-thematic research question *How to translate existing biophilic theories about stress relief into a nature in the space design guide for architects?* there are six design patterns which are analysed to create design parameters. The six design patterns are visual connection with nature, non-visual connection with nature, non-rhythmic sensory stimuli, thermal & airflow variability, presence of water, and dynamic & diffuse light. Focusing on multiple sensory experiences through natural and living processes is crucial when designing. This can be achieved by considering the following design parameters: quality view, diversity of nature, flowing clean water, short versus long exposure, and shifts over day and season. These elements comprise the architect's toolbox for developing a project-specific vision centred around stress relief through natural in-between places, guided by biophilic design principles. This toolbox can be combined with the design guide and the plan of requirements by an architect to make a vision map for a project.

V. APPLICATION OF DESIGN GUIDE

This chapter will be an example for architects to use the design guide within a design project. For this purpose, the steps from the manual, as discussed in the previous chapter, will be addressed individually, resulting in a stress-relief vision through natural in-between places for the renovation design of the TNW building. To get a better idea of this building and understand the ideas of the vision map for this building, Appendix 6 shows a drawing set of the TNW building to be renovated.

5.1 Natural in-between place

The TNW building will integrate the natural in-between places. Figure 20 shows the natural in-between places, the connections made with surrounding nature, and the primary functions of the building. Each natural in-between place to be integrated consists of a core of the building. In these cores, the different zones of the building come together, and this is also where the stairs are found. So this is a place where many movements from one function to another take place. This makes it a very suitable place to incorporate nature in the space and thus stress relief, as users have mentally had a break when they start the next activity.

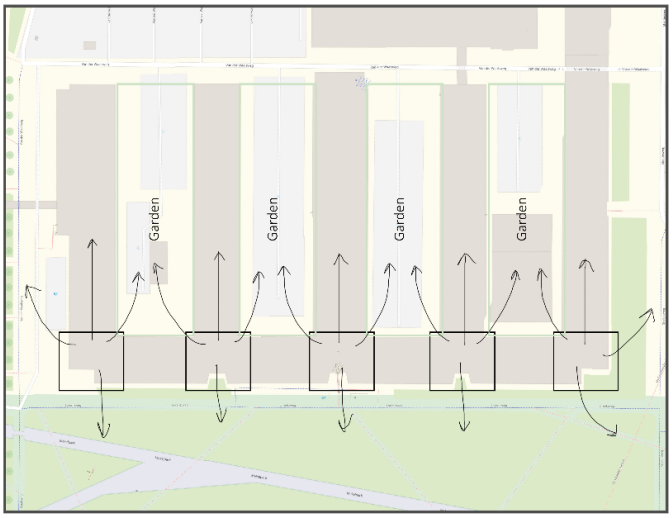


Figure 20: Natural in-between places integrated in the TNW building (by author)

5.2 Design Guide

After reading through the design guide, it is possible to focus on creating stress relief through natural in-between places from the beginning of the project. While reading, attention can also be paid to opportunities in and around the TNW building. For instance, at the TNW building, it is essential to retain water. Also, many paved car parks are behind the building, and little nature exists. Furthermore, the building is centrally located on campus, making connecting with surrounding nature and functions easy.

5.3 Plan of Requirements

When the client sets the program of requirements, the architect needs to be involved in this and talk about the opportunities. The new users of the TNW building will primarily be students. Since stress reduction is very important for students, as the introduction shows, integrating natural in-between places can have a significant impact. As a program, the TNW building will consist of study areas, student housing and wellness/biophilic activities. Moreover, the area of natural in-between places is included in the new program of the TNW building. Also, the building is now very closed, and a more open building with more daylighting has been included in the program, for example, through open study areas. Finally, a new program with a biodiverse landscape has been developed for the area around the building, which now mainly consists of parking spaces. In addition to the program, a goal has been drawn up: campus as landscape, building as a natural system, and water as connecting element. The entire program of requirements can be seen in Appendix 4.

5.4 Vision map

The vision map is created by placing the design guide, design diagram, and plan of requirements side by side. By thinking creatively about opportunities now, ideas emerge. Appendix 5 shows the vision map for the TNW building with the design diagram in the middle. By thinking creatively about the opportunities mentioned in 5.1 Natural in-between place, 5.2 Design Guide and 5.3 Plan of Requirements, ideas emerge, such as a natural water process that collects rainwater and uses it for the toilets in the TNW building and then filters this water so that the clean water can be retained in the biodiverse landscape around the building. At the same time, the residue from the filtration is used as food for the biodiverse landscape, creating, among other things, a high-quality view of natural elements. The design parameters to which this idea relates are also shown for each idea.

In conclusion, to answer the sub-research question, *How to use the nature in the space design guide as an architect to provide stress relief?* in the example of the TNW building, the plan of requirements, the design guide and the design diagram are integrated. This creates an entire vision for stress relief through nature in the space in the natural in-between places. This is done by using the theory of the design guide right from the start of the design process and linking it to the situation of the TNW building. As a result, opportunities are analysed from the start. In addition, it also creates a clear argumentation of how the vision relates to nature in the space.

VI. CONCLUSION AND DISCUSSION

This thesis investigates biophilic stress relief theories to achieve the nature in the space design guide for architects for stress relief through biophilic design. Each chapter is linked to a sub-thematic research question. The thematic research question: *How to use the biophilic design category nature in the space to increase stress relief as an architect?* will be answered by discussing the conclusions for each sub-thematic research question.

Chapter 2. Biophilic design has been shown to reduce stress; how is the relationship between biophilic design and stress relief characterised?

Our natural adaptation to align with nature's patterns and processes, called biophilia, can reduce stress. Biophilic design integrates nature into the built environment and has various stress-relieving effects, including reduced negative emotions, increased positive emotions, and physiological changes. Integrating biophilic design can provide stress relief by using the following biophilic design patterns: visual connection with nature, non-visual connection with nature, non-rhythmic sensory stimuli, thermal and airflow variability, presence of water, dynamic and diffuse light, complexity and order, and prospect.

Chapter 3. How to make a spatial impact using the biophilic category nature in the space that relieves stress?

Nature in the space involves the direct presence of nature in a space, including plant life, water, and animals, as well as natural elements like breezes, sounds, and scents.
This research will focus on nature in the space due to its significant impact on stress relief and the opportunities related to passive design, ecology and sustainability. To make a spatial impact qua stress relief with the nature in the space category, the nature in-between place can be an interesting space due to its essential connection between various primary functions and nature. For the classification of nature in the space elements, inspiration can be taken from the complexity and order pattern of the natural analogues category and the prospect pattern of the nature of the space category.

Chapter 4. How to translate existing biophilic theories about stress relief into a nature in the space design guide for architects?

There are six design patterns: visual connection to nature, non-visual connection to nature, non-rhythmic sensory stimuli, thermal & airflow variability, presence of water and dynamic & diffuse light. In conclusion of the six patterns, focusing on multiple sensory experiences through natural and living processes is crucial in design. This can be achieved by considering the following design parameters: high-quality views of natural elements, diversity of nature, flowing clean water, short versus long exposure, natural light and shifts throughout the day and season. Together, these elements form the architect's design diagram. This design diagram can be used to develop, through the design guide and plan of requirements, a project-specific vision aimed at stress reduction through natural in-between places, guided by biophilic design principles.

Chapter 5. How to use the nature in the space design guide as an architect to provide stress relief?
In the example of the TNW building, the design guide, plan of requirements and design diagram are integrated, so an entire vision stands for stress relief through natural in-between places. This is done by using the theory of the design guide right from the start of the design process and linking it to the situation of the TNW building. As a result, opportunities are analysed from the start. It also clearly argues how the vision relates to nature in the space.

Thematic research question: How to use the biophilic design category nature in the space to increase stress relief as an architect?

Biophilic design can increase stress relief through the nature in the space category by translating existing biophilic stress-relieving theories into a practical design guide for the architect. The meaning of nature in the place is as follows: nature in the space involves the direct presence of nature in a space, including plant life, water, and animals, as well as natural elements like breezes, sounds, and scents. The design guide consists of six patterns: visual connection to nature, non-visual connection to nature, non-rhythmic sensory stimuli, thermal & airflow variability, presence of water and dynamic & diffuse light. After analysing these six patterns, the main criteria appear to be: designing high-quality connections with natural processes for multiple senses. These criteria are translated into the following six design parameters: high-quality views of natural elements, diversity of nature, flowing clean water, short versus long exposure, natural light and shifts throughout the day and season. Finally, when applying the design guide, it is essential to put it alongside the plan of requirements and then create a vision map that increases stress relief through biophilic design in the natural in-between place.

The generalisability of this research is very high, as stress is present in many places in modern society. At the same time, both nature-in-the-space and nature-in-between places can be integrated into many places

The limit of the methods used is that architects have not sufficiently tested the use of this design guide to prove that this guide gives promising results in the design process. Therefore, a suggestion for further research is to investigate how architects experience the design guide within the design process.

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Figures

Appendix 1

TABLE 1. BIOPHILIC DESIGN PATTERNS & BIOLOGICAL RESPONSES

Table 1 illustrates the functions of each of the 14 Patterns in supporting stress reduction, cognitive performance, emotion and mood enhancement and the human body. Patterns that are supported by more rigourous emphirical data are marked with up to three asterisks (***), indicating that the quantity and quality of available peer-reviewed evidence is robust and the potential for impact is great, and no asterisk indicates that there is minimal research to support the biological relationship between health and design, but the anecdotal information is compelling and adequate for hypothesizing its potential impact and importance as a unique pattern.

	14 PATTERNS	*	STRESS REDUCTION	COGNITIVE PERFORMANCE	EMOTION, MOOD & PREFERENCE
NATURE IN THE SPACE	Visual Connection with Nature	***	**Lowered blood pressure and heart rate** (Brown, Barton & Gladwell, 2013; van den Berg, Hartig, & Staats, 2007; Tsunetsugu & Miyazaki, 2005)	**Improved mental engagement/ attentiveness** (Biederman & Vessel, 2006)	**Positively impacted attitude and overall happiness** (Barton & Pretty, 2010)
	Non-Visual Connection with Nature	**	**Reduced systolic blood pressure and stress hormones** (Park, Tsunetsugu, Kasetani et al., 2009; Hartig, Evans, Jamner et al., 2003; Orsega-Smith, Mowen, Payne et al., 2004; Ulrich, Simons, Losito et al., 1991)	**Positively impacted on cognitive performance** (Mehta, Zhu & Cheema, 2012; Ljungberg, Neely, & Lundström, 2004)	**Perceived improvements in mental health and tranquility** (Li, Kobayashi, Inagaki et al., 2012; Jahncke, et al., 2011; Tsunetsugu, Park, & Miyazaki, 2010; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003)
	Non-Rhythmic Sensory Stimuli	**	**Positively impacted on heart rate, systolic blood pressure and sympathetic nervous system activity** (Li, 2009; Park et al, 2008; Kahn et al., 2008; Beauchamp, et al., 2003; Ulrich et al., 1991)	**Observed and quantified behavioral measures of attention and exploration** (Windhager et al., 2011)	
	Thermal & Airflow Variability	**	**Positively impacted comfort, well-being and productivity** (Heerwagen, 2006; Tham & Willem, 2005; Wigö, 2005)	**Positively impacted concentration** (Hartig et al., 2003; Hartig et al., 1991; R. Kaplan & Kaplan, 1989)	**Improved perception of temporal and spatial pleasure (alliesthesia)** (Parkinson, de Dear & Candido, 2012; Zhang, Arens, Huizenga & Han, 2010; Arens, Zhang & Huizenga, 2006; Zhang, 2003; de Dear & Brager, 2002; Heschong, 1979)
	Presence of Water	**	**Reduced stress, increased feelings of tranquility, lower heart rate and blood pressure** (Alvarsson, Wiens, & Nilsson, 2010; Pheasant, Fisher, Watts et al., 2010; Biederman & Vessel, 2006)	**Improved concentration and memory restoration** (Alvarsson et al., 2010; Biederman & Vessel, 2006) **Enhanced perception and psychological responsiveness** (Alvarsson et al., 2010; Hunter et al., 2010)	**Observed preferences and positive emotional responses** (Windhager, 2011; Barton & Pretty, 2010; White, Smith, Humphryes et al., 2010; Karmanov & Hamel, 2008; Biederman & Vessel, 2006; Heerwagen & Orians, 1993; Ruso & Atzwanger, 2003; Ulrich, 1983)
	Dynamic & Diffuse Light	**	**Positively impacted circadian system functioning** (Figueiro, Brons, Plitnick et al., 2011; Beckett & Roden, 2009) **Increased visual comfort** (Elyezadi, 2012; Kim & Kim, 2007)		
	Connection with Natural Systems				**Enhanced positive health responses; Shifted perception of environment** (Kellert et al., 2008)
NATURAL ANALOGUES	Biomorphic Forms & Patterns	*			**Observed view preference** (Vessel, 2012; Joye, 2007)
	Material Connection with Nature			**Decreased diastolic blood pressure** (Tsunetsugu, Miyazaki & Sato, 2007) **Improved creative performance** (Lichtenfeld et al., 2012)	**Improved comfort** (Tsunetsugu, Miyazaki & Sato 2007)
	Complexity & Order	**	**Positively impacted perceptual and physiological stress responses** (Salingaros, 2012; Joye, 2007; Taylor, 2006; S. Kaplan, 1988)		**Observed view preference** (Salingaros, 2012; Hägerhäll, Laike, Taylor et al., 2008; Hägerhäll, Purcell, & Taylor, 2004; Taylor, 2006)
NATURE OF THE SPACE	Prospect	***	**Reduced stress** (Grahn & Stigsdotter, 2010)	**Reduced boredom, irritation, fatigue** (Clearwater & Coss, 1991)	**Improved comfort and perceived safety** (Herzog & Bryce, 2007; Wang & Taylor, 2006; Petherick, 2000)
	Refuge	***		**Improved concentration, attention and perception of safety** (Grahn & Stigsdotter, 2010; Wang & Taylor, 2006; Wang & Taylor, 2006; Petherick, 2000; Ulrich et al., 1993)	
	Mystery	**			**Induced strong pleasure response** (Biederman, 2011; Salimpoor, Benovoy, Larcher et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001)
	Risk/Peril	*			**Resulted in strong dopamine or pleasure responses** (Kohno et al., 2013; Wang & Tsien, 2011; Zald et al., 2008)

Appendix 2

Pattern 1: Visual Connection with Nature

The Visual Connection with Nature pattern aims to create an environment that promotes relaxation and reduces cognitive fatigue by allowing individuals to shift their focus and relax their eye muscles. The effectiveness of this approach improves with a higher quality view and increased visibility of biodiversity (Terrapin Bright Green, 2014).

Design considerations for establishing a strong visual connection with nature:

• Prioritize biodiversity over size or quantity. Increased quality and visible biodiversity enhance intervention effectiveness (Fuller et al., 2007).

• Promote exercise opportunities near green spaces. Activities in nature have been proven effective for stress relief. However, as a connector of context and functions, the nature in between space may also involve routing. Therefore, it is essential to place activities in a quiet environment of the nature in-between place to ensure their effectiveness. Both the movement and the time spent in the nature in-between places contribute positively to stress relief (Barton & Pretty, 2010).

• Consider spatial layouts and furnishings that maintain desired views (Terrapin Bright Green, 2014).

• Even small instances of nature can be restorative, especially in limited spaces (Terrapin Bright Green, 2014).

• Preferred views include slopes with shade trees, flowering plants, calm, non-threatening animals, human habitation, and clean water (Orians & Heerwagen, 1992).

• Natural views should be compatible with the human scale and not overly restricted or unfamiliar. (Kellert et al., 2011)

• Views to the horizon are appealing and stimulate imagination and response to important information. (Kellert et al., 2011)

• Repeated viewing of real nature maintains interest over time, unlike non-nature views (Biederman & Vessel, 2006).

• Naturally occurring examples are the natural flow of a body of water, vegetation, food baring plants, animals and insects, fossils, terrain, soil and earth (Terrapin Bright Green, 2014).

• The spacing of elements is crucial in creating the natural in-between place. Konijnendijk (2022) researched nature's health benefits, including stress relief, which resulted in the development of the 3-30-300 guideline. This guideline advocates for equal access to trees and greenery, ensuring that every home, school, and workplace has a minimum of 3 visible trees, every neighbourhood has at least 30% tree coverage, and every home is within 300 meters of the nearest public green space.

Pattern 2: Non-Visual Connection with Nature

The objective of the Non-Visual Connection with Nature pattern is to provide an environment that uses sound, scent, touch and possibly even taste to engage the individual in a manner that helps reduce stress and improve perceived physical and mental health. These senses can be experienced separately, although the experience is intensified, and the health effect is compounded if multiple senses are consistently engaged together (Terrapin Bright Green, 2014).

Design considerations for establishing a strong non-visual connection with nature:

• Prioritize congruent nature sounds, like birds, breezes and water.
(Ulrich, 1999)

• Design non-visual connections for easy access from multiple locations, enabling daily engagement of 5 to 20 minutes at a time.

• Integrate non-visual connections into the overall design program.

• A versatile intervention enhances its impacts through multiple experiences.

• Design for simultaneous visual and non-visual connections to maximise health benefits.

• Naturally occurring examples are fragrant herbs and flowers, songbirds, flowing water, weather (rain, wind, hail), natural ventilation (operable windows, breezeways), textured materials (stone, wood, fur), crackling fire/fireplace, sun patches, warm/cool surfaces (Terrapin Bright Green, 2014).

Pattern 3: Non-Rhythmic Sensory Stimuli

The Non-Rhythmic Sensory Stimuli pattern uses natural sensory stimuli that unobtrusively attract attention to replenish focus and reduce mental fatigue and physiological stress. Nature provides various non-rhythmic stimuli like birds chirping, rustling leaves, and subtle scents. However, the built environment is often predictable and lacks these qualities, even in manicured gardens and indoor spaces (Terrapin Bright Green, 2014).

Design considerations for establishing accessible and effective non-rhythmic stimuli by Terrapin Bright Green (2014):
• Design for brief exposure to unpredictable movement, peripheral vision, and periodic scents or sounds.
• As a guideline, non-rhythmic sensory experiences should occur approximately every 20 minutes for about 20 seconds and, preferably, from a distance of over 20 feet for visual stimuli.
• Ensure year-round effectiveness by overlapping interventions that align with different seasons.
• Focus on ephemeral and stochastic qualities rather than specific interventions.
• Naturally occurring examples are cloud movement, breezes, plant life rustling, water babbling, insect and animal movement, birds chirping and fragrant flowers, trees and herbs.

Pattern 4: Thermal & Airflow Variability

The Thermal & Airflow Variability pattern aims to provide users with the sensory experience of airflow and thermal variability, along with control over thermal conditions. The conventional thermal design aims for a narrow comfort range, while this pattern promotes variations similar to outdoor conditions and personal control (Terrapin Bright Green, 2014).

Design Considerations for thermal and airflow variability by Terrapin Bright Green (2014):
• Incorporate airflow and thermal conditions into materials, daylighting, ventilation, and fenestration for distributed variability over space and time.
• Thermal comfort is crucial for bridging biophilic and sustainable design, especially in the face of climate change. Implementing thermal and airflow variability can broaden the perception of comfort and reduce energy consumption.
• Design features that allow users to modify their thermal conditions to increase the acceptable temperature range by two degrees Celsius.
• Early coordination among the project team is vital for achieving design intent, involving architects, lighting designers, and engineers.
• Offering options like variable materials, seating, and access to operable windows can enhance satisfaction.
• Individual architectural or mechanical control is crucial due to subjective and varied thermal comfort preferences. Creating a positive thermal experience does not require discomfort, as users can adapt to their preferences.

Pattern 5: Presence of Water

The Presence of Water pattern aims to enhance the place experience by utilising water's multisensory attributes. It aims to soothe, encourage contemplation, improve mood, and provide restoration from cognitive fatigue (Terrapin Bright Green, 2014).

Design considerations for optimising the impacts of the presence of water:
• Prioritize multi-sensory water experience for maximum benefits

• A generally preferred view of people's contains bodies of clean water. Vistas or access to clean water bodies have positive health responses (Heerwagen & Orians, 1993; Jahncke et al., 2011; Karmanov & Hemel, 2008; White et al., 2010).
• Emphasize natural fluctuation in water movement for stronger biophilic attraction.
(Kellert, 2018)
• Consider proximity to maintain comfort, humidity, and acoustic quality (Terrapin Bright Green, 2014).
• Use water features sparingly, especially in water-scarce climates. Minimise water loss through shading, high albedo surfaces, and reducing exposed water surface area (Terrapin Bright Green, 2014).
• Focus on freshwater, the less-than-1-per cent of the earth's water, which is the visible and essential component of the earth's water cycle. (Kellert, 2018)
• One small water feature may be sufficient as repeated water experiences maintain interest (Biederman & Vessel, 2006).
• Studies have revealed that engaging in activities within green spaces with water present has a more positive impact on self-esteem and mood compared to activities in green environments without water. (Barton & Pretty, 2010).
• Auditory and tactile access to water also reduces stress (Alvarsson et al., 2010; Pheasant et al., 2010).
14 patterns, p. 34-35
• Water's appearance and mood change based on sunlight, with varying hues and reflections. In bright sunlight, water becomes animated, reflecting the surrounding environment with sparkling movements. (Kellert et al., 2011)
• Strategies for enhancing water visibility include fountains, wetlands, ponds, waterfalls, and more. (Kellert, 2018)
• Water can be integrated into a building in different ways: as an interior element that can be easily removed, as a structural component requiring significant effort if absent, as a connector to the immediate surroundings, as an element of the exterior environment, or as a means to integrate the building with the larger landscape. (Kellert, 2018)
• The presence of flora and fauna enhances water's significance. Wetland vegetation, riparian plantings, and water-based plants like water lilies contribute to the biophilic elements of life. In the built environment, adding fish mainly enhances water's biophilic attraction.(Kellert et al., 2011)
• Challenges in implementing water in the built environment include unwanted growth, increased humidity, moisture damage, filtration needs, ice formation, energy requirements, mineral deposits, insect-related issues, maintenance needs, and legal liability. (Kellert et al., 2011)
• Naturally occurring examples are a river, stream, ocean, pond, wetland, visual access to rainfall and flows, and seasonal arroyos (Terrapin Bright Green, 2014).
• A concise list of strategies to incorporate water into the built environment, enhancing our biophilic experience: roof gardens and green roofs, indoor plumbing, water as interior pools or basins, water as recreation, providing natural function in concert with aesthetics, interior ecosystems, exterior water gardens, aquarium, waterfall, cascade, blurring the distinction between inside and outside, using water to produce sounds, fountains, accessible fountains, an element of a work of art and sculpture, expended waterscapes, integration with the earth, a connection with adjacent existing natural features, engineered emulations of natural settings, hydromimicry, interior water handling, water handling on urban neighbourhood scale, stormwater handling on a small neighbourhood scale, stormwater handling on a site scale, biological wastewater treatment and traversing a watercourse (Kellert et al., 2011).

Pattern 6: Dynamic & Diffuse Light

The Dynamic and Diffuse Light pattern aims to provide stimulating lighting options that promote positive psychological and physiological responses and support circadian system functioning (Terrapin Bright Green, 2014).

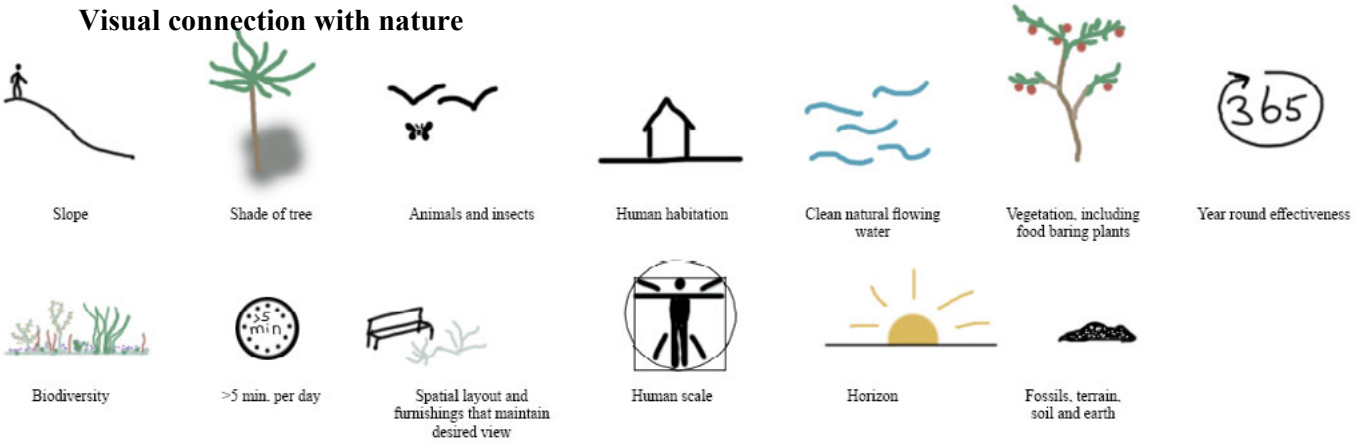
Design considerations for establishing a balance between dynamic and diffused lighting conditions:

• Biophilic design strategies can manipulate qualities of light and darkness to enhance the experience and stimulate interest and awareness of space. (Kellert, 2018)
• Dynamic lighting transitions aid in moving between indoor and outdoor spaces
• Extreme lighting conditions may not be suitable for tasks requiring focused attention.
• Circadian lighting is crucial for spaces where occupants spend extended periods.
• Balance between uniform and extreme lighting distribution is essential to avoid discomfort.
• Diffuse and accent lighting creates a visually pleasing environment, while personalised lighting adds flexibility. These layers help create a pleasing visual environment.
• Movement of light and shadows attracts attention and can be achieved through fractal patterns.
• Naturally occurring examples are daylight from multiple angles, direct sunlight, diurnal and seasonal light, firelight, moonlight and starlight, and bioluminescence (Terrapin Bright Green, 2014)

• Circadian lighting supports physical health and should incorporate illuminance fluctuation, light distribution, and colour variability without causing discomfort, enhancing the user experience (Kandel et al., 2013).
• Design strategies for natural lighting in interior spaces include glass walls, clerestories, skylights, atria, reflective materials, and artificial lighting that mimics natural light. (Kellert, 2018)
• For our mental health, the balance of prospect places and refuge places is essential. Regarding natural light, it is crucial to create a balance through contrast. Here, natural light stands about varying ceiling heights, opaque boundaries for refuge, and open views for prospects. (Kellert et al., 2011)

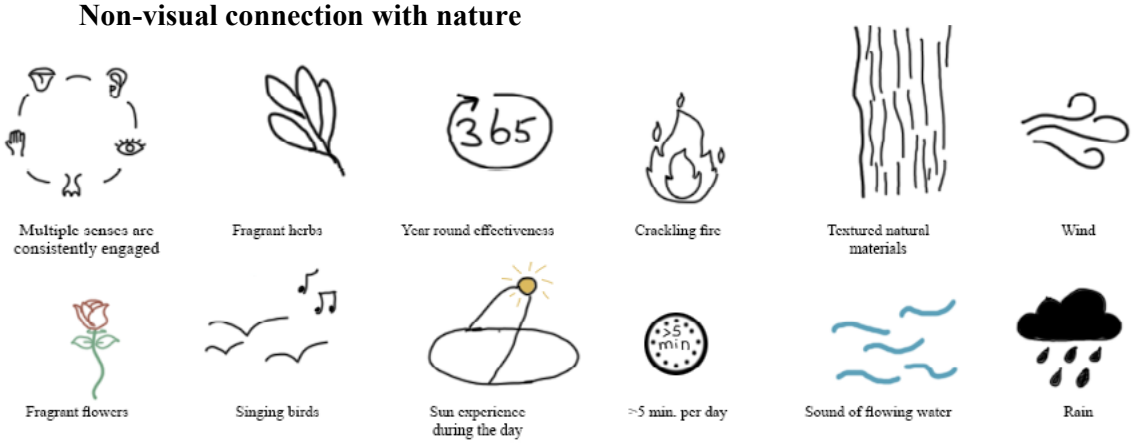
Appendix 3

Visual connection with nature



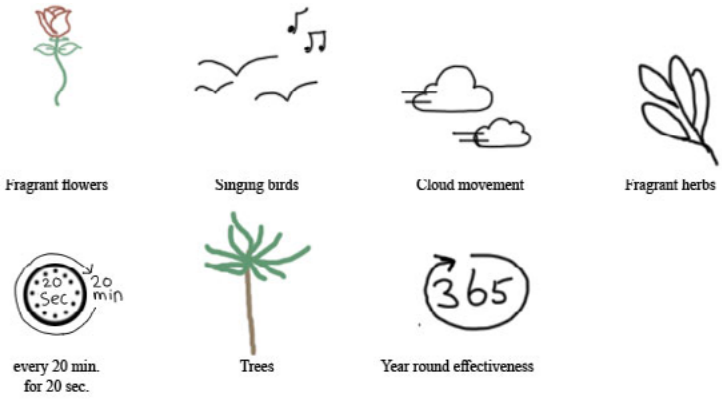
The design goal can be achieved by **high quality view of natural elements**, living systems and natural processes. In addition, increased visibility of **biodiversity** is very important.

Non-visual connection with nature



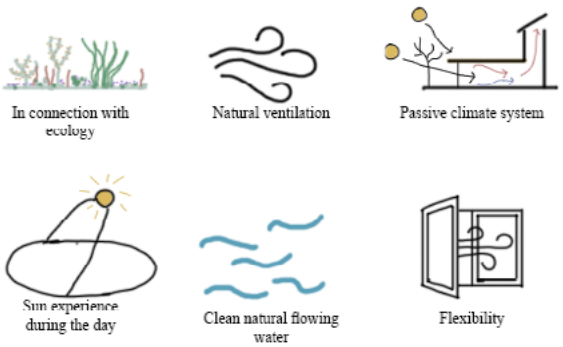
It's important to focus on elements which provide that **multiple senses** are consistently engaged together.

Non-rhytmic sensori stimuli



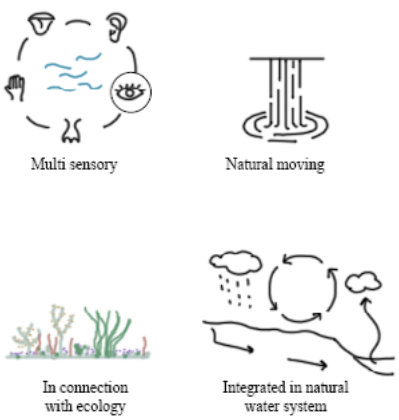
It's important to focus on elements which provide **momentary exposure** to unpredictable movement, peripheral vision, and periodic scents or sounds.

Thermal and airflow variability



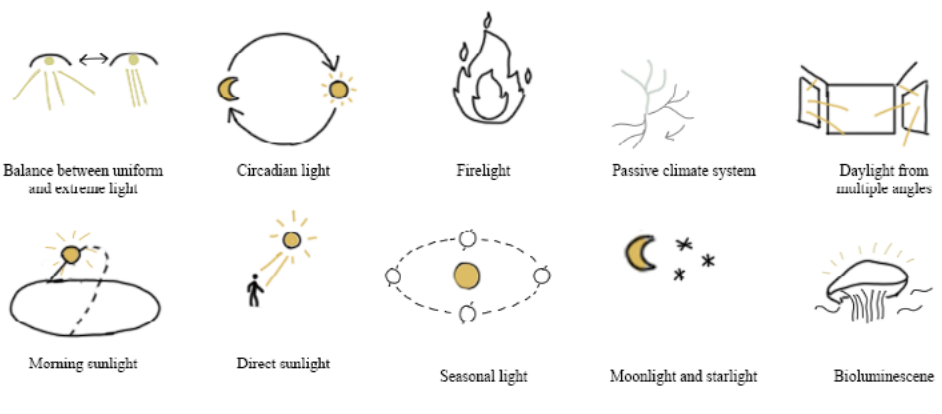
It is essential to focus on **natural systems** and **flexibility**.

Presence of water



It's essential to focus on **natural systems** and **flowing clean water** which focus on **multiple senses.**

Dynamic and diffuse light



It's essential to focus on **natural light systems** and changing intensities of light and shadow over time.

PLAN OF REQUIREMENTS

TNW BUILDING

CURRENT PROGRAM
Area: 33370 m2

Ground floor, 1st and 2nd floor: 9350m2 x 3
3rd floor: 3620m2
4th floor: 1560m2
5th floor: 140m2

Area between building parts:

Parking: 8000 m2

NEW PROGRAM
Area indoors: 33370 m2

Meeting place and entrance = biophilic core and galleries
Biophilic cores (short exposure): 5000m2
Circulation (galleries): 4000m2
Study places: (Ground floor + 1s floor) 14300m2
- Open plan
- Closed spaces
- Canteen
- Sanitary
- Auditorium

Student housing (2nd +3rd floor) 10370 m2
- Houses

Welness / biophilic activities
Technical room
Bike places (basement)

Area between building parts:

Biodiverse landscape (long exposure) 8000 m2
- Water area (clean flowing water) 2000 m2 (calculation required)
- Land 6000 m2
  - Circulation
  - Welness / biophilic activities
  - Space for plants and trees

CAMPUS

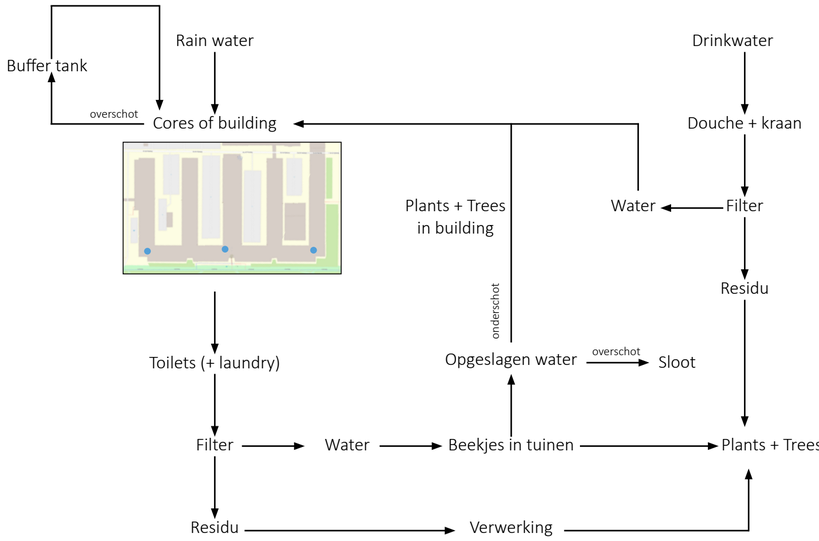
CURRENT LANDSCAPE
Landscape
Routing
Meeting places
Bike places

NEW PROGRAM
Landscape
Routing
Meeting places
- Welness / biophilic activities

Bike places

USERS:
Students
Staff
Researchers

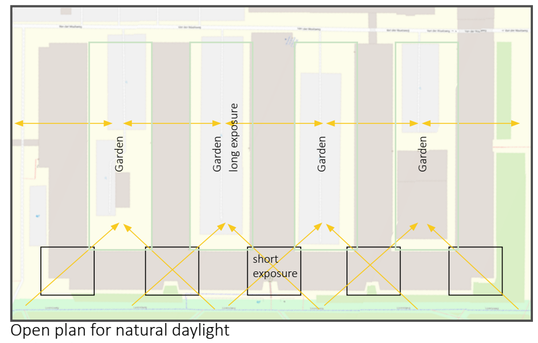
Goal:
Campus as a landscape,
Building as a natural system,
Water as connecting element



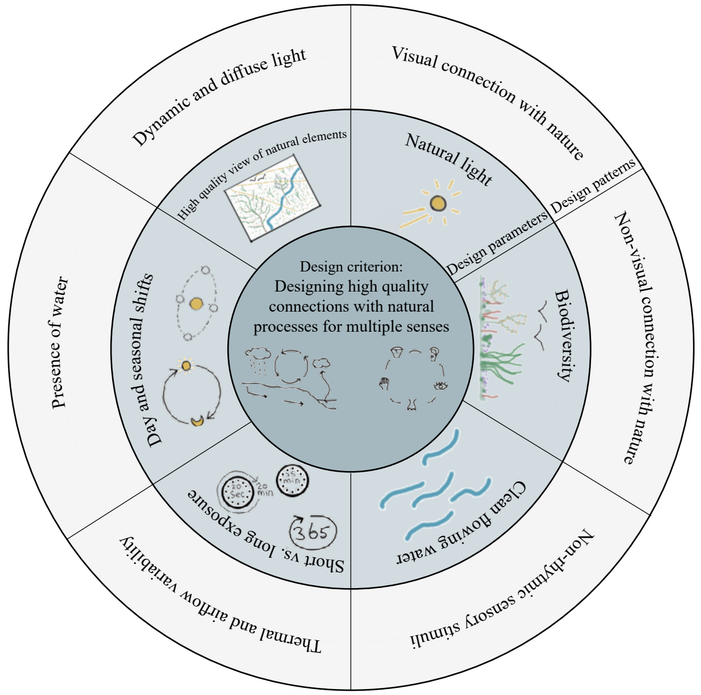
Water cycle

Goal:

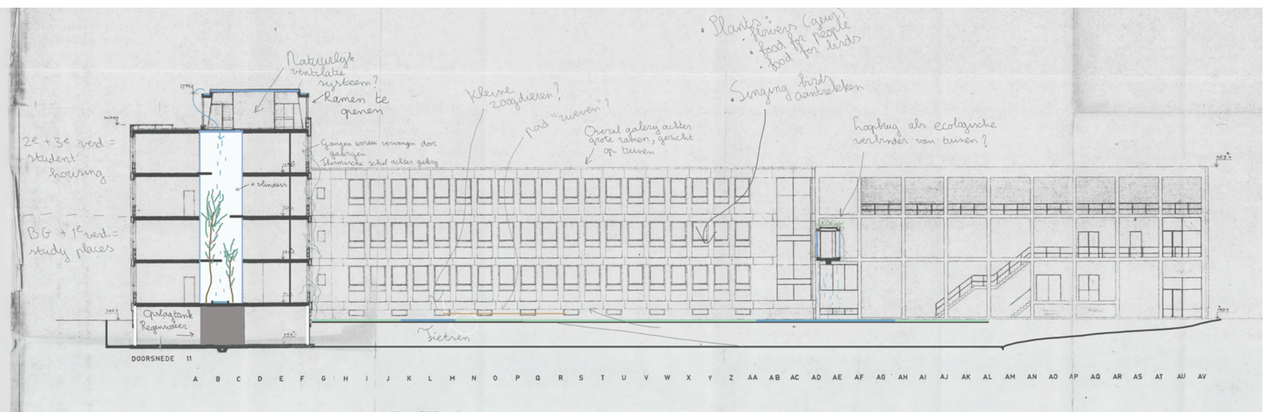
Campus as a landscape,
Building as a natural system,
Water as connecting element



Open plan for natural daylight
and quality views

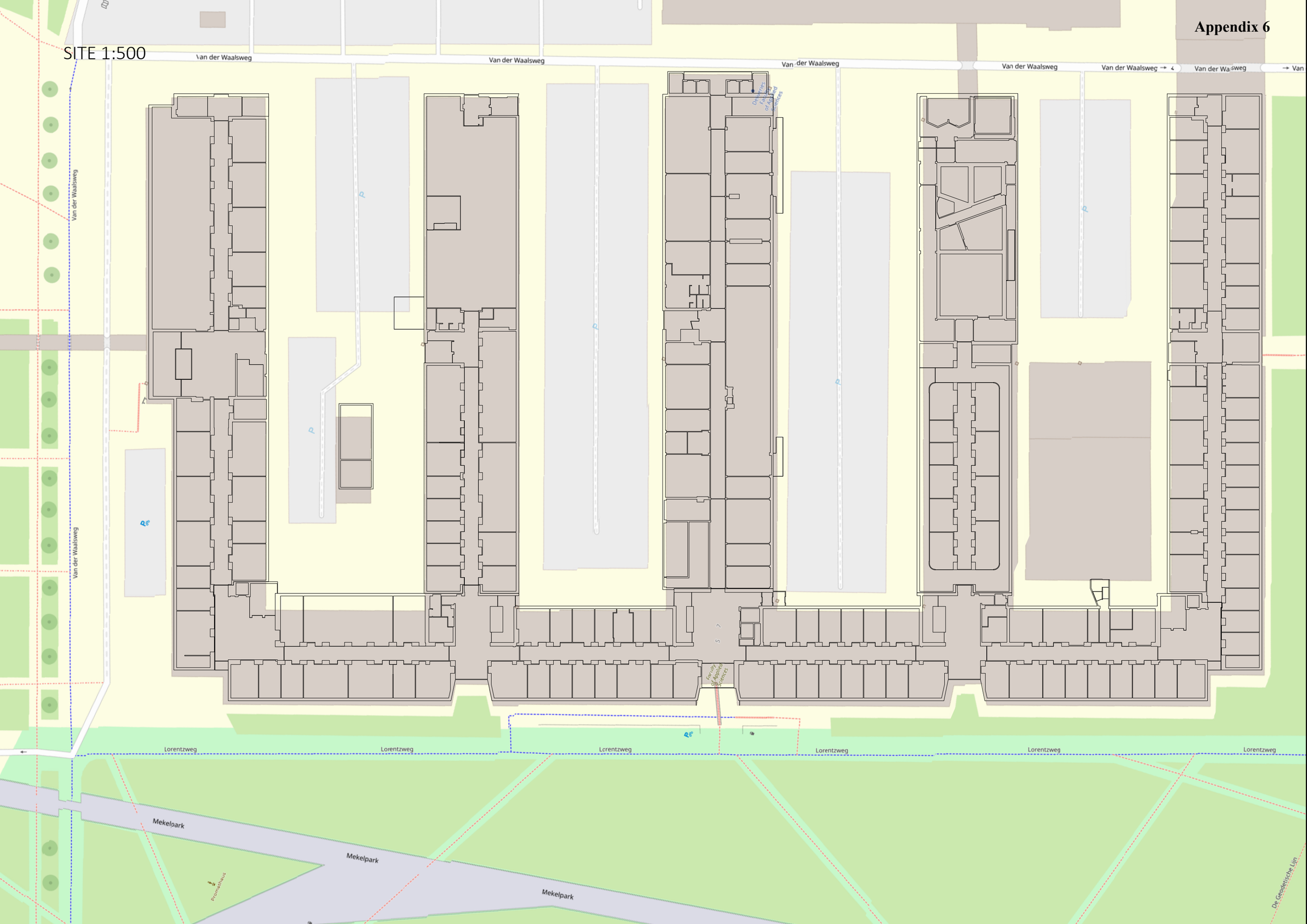


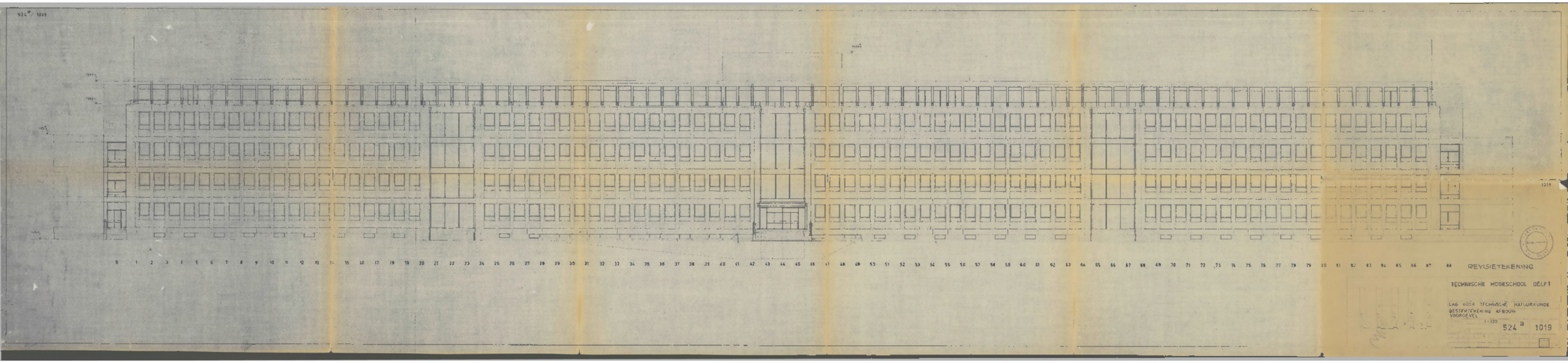
Prospect pattern



Appendix 6

SITE 1:500





WEST FACADE - ENTRANCE

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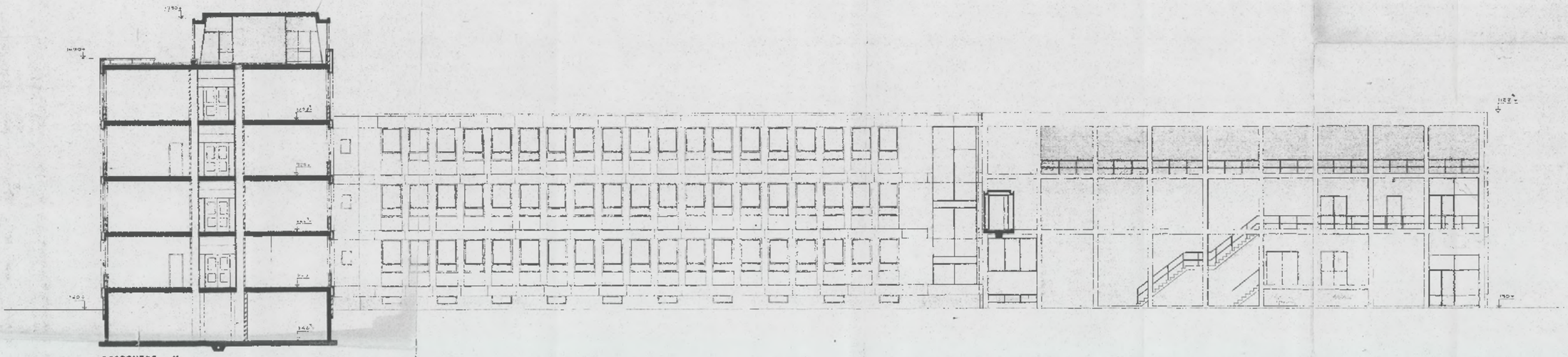

DOORSNEDE 11

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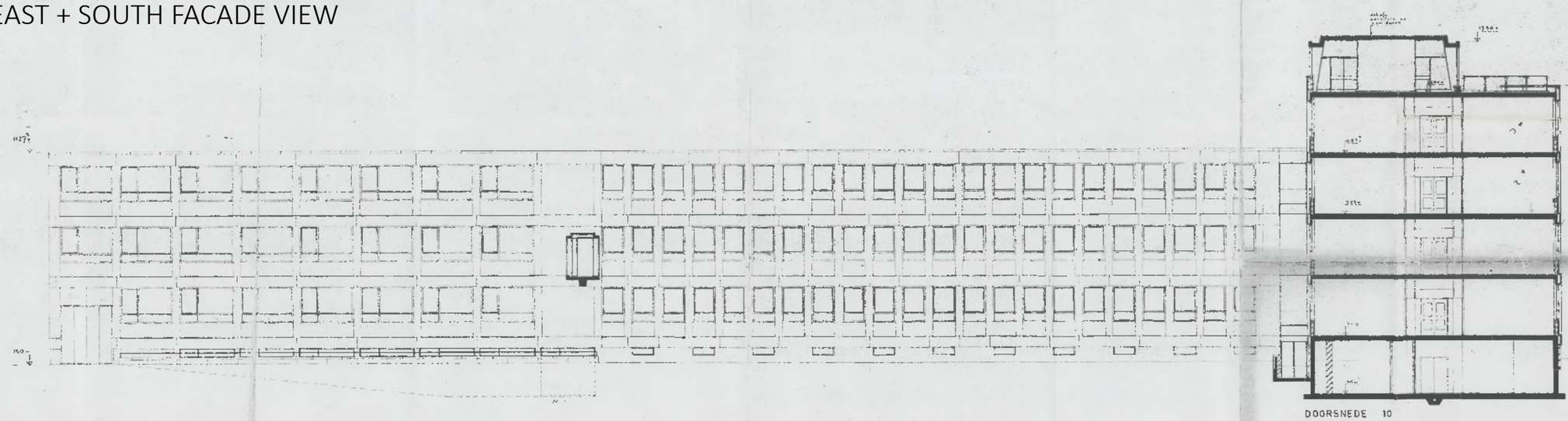
ZUIDGEVEL VLEUGEL D

SECTION WEST-EAST + SOUTH FACADE VIEW



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SECTION EAST WEST + NORTH FACADE VIEW

DOORSNEDE 10

1024

REVISIETEKENING

TECHNISCHE HOGESCHOOL DELFT

LAB. VOOR TECHNISCHE NATUURKUNDE

BESTEKTEKENING AFBOUW
GEVELS VLEUGEL D DOORSN 10 EN 11

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