Resiliente Stadtplanung.

Resiliente Stadtplanung bedeutet, dass Städte angepasst werden müssen im Hinblick auf die Herausforderungen des Klimawandels und der Reduzierung des Katastrophenrisikos.

Krisenfestigkeit und belastbare Raumstrukturen werden für Städte und Regionen von immer grösserer Bedeutung. Lebensräume gelten dann als «resilient», wenn sie Krisen vorausschauend oder auch reaktiv durch strategische sozio-technologische Infrastrukturinvestitionen begegnen können. Vor dem Hintergrund akuter und künftiger Hausforderungen in Bezug auf Klimakrise, Ressourceneffizienz, Bodennutzung oder sozialer Teilhabe stellt sich die Frage: Welche Voraussetzungen sind notwendig, damit Städte, Gemeinde und Regionen gut und belastbar in die Zukunft blicken können?

In dieser Studie im Rahmen eines Semesterprojektes an der ETH Zürich im Fach «nature-based solutions and blue-green infrastructure» geht es um bauliche Verdichtung aufgrund des Bevölkerungswachstums, Hitzewellen, Starkregen und der Verlust der Biodiversität.

In dieser Studie – Mitautor Georg Odermatt – wird ein Konzept für eine naturbasierte Lösung (Nature-based Solution, NbS) für die Stadt Biel entwickelt, um die Stadt widerstandsfähiger gegenüber zukünftigen Herausforderungen durch Bevölkerungswachstum und Klimawandel zu machen. Die Standortanalyse von Biel zeigt, dass die wichtigsten umweltbezogenen Herausforderungen, denen Biel in Zukunft gegenübersteht, Hitzewellen, Starkregen und der Verlust der Biodiversität sind. Diese bereits auftretenden Herausforderungen werden durch die Haupttreiber der globalen Erwärmung und die Verdichtung aufgrund des Bevölkerungswachstums in Zukunft noch verstärkt. Naturbasierte Lösungen bieten multifunktionale Vorteile zur Bewältigung dieser Herausforderungen. Daher spielen NbS in den Zielen für die zukünftige Entwicklung von Biel eine zentrale Rolle.

In vorliegender Studie werden Zukunftsvisionen für Biel als eine biodiverse, widerstandsfähige und attraktive Stadt vorgestellt. Basierend auf diesen Visionen wurde ein Konzept für ein Netzwerk aus Grünflächen und miteinander verbundenen grünen Korridoren entwickelt. Der Bau eines solchen Netzwerks wird der Stadt vielfältige Vorteile bringen und dazu beitragen, dass Biel auch in Zukunft ein attraktiver Wohnort bleibt.

Als zweiter Teil wird eine Entwurfsstrategie für das Sägefeld-Viertel entwickelt – ein Gebiet, das als Vorbild für dichte, multifunktionale und risikoresiliente Nachbarschaften dienen könnte. Durch den Einsatz unterschiedlicher Bauformen, wie U- und L-förmige Gebäude, entstehen sowohl private als auch öffentlichere Freiräume, die dennoch eine hohe Bevölkerungsdichte ermöglichen. Drei Plätze und mehrere Korridore sorgen für Vernetzung, sowohl für Menschen als auch für Insekten und Pflanzen. Unterschiedliche blau-grüne Infrastrukturen, wie etwa Muldenrigolen, Baumkronendächer und ein Regenrückhaltebecken, werden vorgeschlagen, um maximale multifunktionale Vorteile zu schaffen. Mit dem vorgeschlagenen Entwurf entsteht ein dicht bebautes Viertel, das eine hohe Lebensqualität bietet, die Biodiversität fördert und den Wasserkreislauf weitgehend schliesst, indem über 90 % des jährlichen Regenwassers vor Ort versickert werden.

paesaggio
diverso

Resiliente Stadtplanung.

Resiliente Stadtplanung bedeutet, dass Städte angepasst werden müssen im Hinblick auf die Herausforderungen des Klimawandels und der Reduzierung des Katastrophenrisikos.

Creating a Nature-Based and Blue-Green

Future for Biel

A Concept for Incorporating Green Corridors applied to Sägefeld district

by BiodiverCity

Lina Hassoun

Georg Odermatt

Marvin Trottmann

22.12.2022

118-0114-00L Course Design Project

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1. Introduction

The scope of this report is to develop a nature-based solution for urban water management in the city of Biel to make the city become resilient to the impending threats of climate change, ever-increasing challenges of extreme events and water supply security. To establish a specific solution, there will be first conducted background research on the site, including a brief history of Biel, understanding the current situation by local context such as climate and hydrology but also population and housing. The key challenges of today and tomorrow are identified, with a focus on future hazards like dry periods, floods, and biodiversity loss. Out of this analysis, three future vision statements are derived that indicate the path the city of Biel should follow in the next 30-50 years. According to these statements, a proposal of a nature-based solution that accounts for the challenges of the future will be proposed and outlined. The concept as well as the implementation and the maintenance of that NbS will be further discussed.

In a second step, the developed concept will be applied for the Sägefeld district. There will be a suggestion for implementing high density housing in this site while implementing different blue green infrastructure accounting for the potential and constraints of that specific site, having in mind the general concept for Biel.

2. Context

2.1 History and demography

Biel is a city in the canton of Bern that was founded between 1220 and 1230. With around 55'000 inhabitants today, Biel is the the biggest bilingual and overall, the tenth biggest city of Switzerland. The city is located in the north-west of Switzerland, at the upper point of lake Biel. The city of Biel has a total area of 21.21 km^2 in an elongated form, starting from the lake and lying between two chains of hills (Figure 1). To transit between the most distant points in the city it takes around 20 minutes by bicycle and 30 minutes by public transport.

Until the 1850s, Biel was a small town. Then it experienced a rapid boom thanks to the watch industry. Today, Biel is a flourishing city and regional and economic center with a steady population growth over the last 10 years, resulting from a positive net migration pattern. Biel harnessed the boost it received as the host of the 2002 Swiss National Exhibition (Expo.02) to continue expanding its economic fabric over the past two decade. 75 % of households are one or the person households, which is slightly above the Swiss average [1]. The city is expected to continue growing in the future, especially in places like the Sägefeld district with big potential due to a lot of unused building ground.

2.2 General Landscape, Topography, Environment

Recently areas in the city limits that used to be used as farmland have been developed to large storage or office-related facilities resulting in a densification of the city and floor sealing [2]. The city center has a high economic activity with more than 20 enterprises per ha. According to the urban development plan published in 2021, the city of Biel has four areas of major importance for its revitalization and enhancement of the cityscape as displayed in

Figure 1. The Sägefeld district is located just at the outside the left border of the "Bäzingenfeld"

1. «Train station/Lake»
2. «Esplanade»
3. «Gurzelen»
4. «Bözingenfeld»

Figure 1: The city of Biel has 4 different focus areas for urban development [3].

In 2010, Biel had 1.16 kha of tree cover, extending over 46% of its land area. The overall land cover is dominated by forest and settlements and some smaller patches with agriculture and grassland. Aside from two areas belonging to the Federal Inventory of Floodplain Areas of National Importance, there are no areas under protection except for a wildlife corridor of cross-regional importance in the north-east of the city. The mean elevation of the city is at 657 m.a.s.l. It is interesting to note that the Sägefeld currently has a higher proportion of green surfaces than other locations in the city center, albeit of low green cover quality (see details in Section 5).

2.3 Hydrology and Groundwater

The most important waterways are the Schüss river, discharging into lake Biel with a mean annual flow of 6,15 m^3/s and the Nidau-Büren Kanal, originating from the lake in direction of Aare River and was built as a part of the "Jura Stream-Correction", using lake Biel as a water retention reservoir. The outflow of the lake to Nidau-Büren canal can be regulated by a weir. While water quality in these water bodies is at a good level, the river morphology is mostly heavily impacted, and the water courses are channelized within the city. The groundwater thickness in loose rock is around 2-3 meters. The precipitation on the Sägefeld is, when not evapotranspiring or seeping into the groundwater, flowing towards the Schüss river.

2.4 Climate

The climate in Biel is characterized by temperatures between -2 C° and 26 C° with highest temperatures in July and lowest in January. Till now, the most precipitation is falling in the summer, but according to the climate scenarios Switzerland "CH18", summers will get drier and temperatures will rise over the whole year [3]. The wind is dominated by the south-east "Joran" thermal downdraft coming from the highlands of the Jura.

2.5 Hazards

Whereas earthquakes and landslides are not a major danger in the urban area, there is the risk of droughts, heat periods, wildfires, storms, and floods in the summer. Since the city has access to the water of the lake, during heat periods or droughts the water availability and accessibility should not be a big concern. The flood risk is overall small with just some punctual high-risk locations. Infrastructure near the lake is under the risk of flooding from the lake since the lake acts as a buffer for water coming from the two other jurassian lakes and was for example one meter over normal sea level in 2021 after a heavy rain period [4]. According to the "CH18" the number of heat days will increase significantly in cities in the future as well as the maximum temperature and maximum time of heat periods. There will be a regime shift to lower precipitation in summer but higher frequency and intensity of rainfall events [3].

2.6 Existing planning policies

Biel calls itself a "Divers-City", socially and economically diverse, bilingual, urban and influential, with attractively designed meeting places next to lively industries. They want to protect the climate in an exemplary manner and use the participation of the population and private initiatives in the further development of their city [5].
To achieve this, they use different policy instruments such as the 2021 published agglomeration program "Biel/Lyss" where they want to diversify usable open and green spaces, strengthen and protect the networking of biodiversity and upgrade the water shores of rivers & lakes [6]. Another instrument is the "action plan biodiversity" with which the municipal council wants to assume its responsibility and preserve and promote in urban spaces [7]. Last but not least there is the plan "Vision Biel 2030" where the main topics are are diversity, bilingualism, city-growth, open spaces as well as climate adaption and mitigation [8]. All this planning policies play a major role for the development of the Sägefeld district and were accounted for in our strategy.

2.7 Challenges

Out of the background analysis, four major challenges were identified that Biel needs to tackle to make the city more resilient to future hazards.

- Heat waves
- Intense rainfall
- Biodiversity & habitat loss
- Population growth and traffic increase

All of these challenges are also important when applying high density housing in the Sägefeld.

3. Future Vision and Nature-based solutions

3.1 Opportunities and constraints in Biel and Sägefeld

The interdisciplinary site analysis shows that the most crucial future challenges for Biel will be heat waves, biodiversity loss, intense rainfall, and population growth. The first three are natural hazards, enhanced by global warming and require climate mitigation as well as climate adaptation in the city design. Population growth instead is independent from climate change. It brings additional need for living and working space and causes increased traffic.

Biel is however in a comfortable situation and has a good existing infrastructure to address these future challenges. The city has different types of open spaces and parks spread over the whole city area. As well, it is surrounded by large natural habitats such as the lake and two forests. This fact gives a great opportunity to create an interconnected network of attractive and biodiverse green spaces by the construction of blue or green infrastructure. This would support heat mitigation and flood prevention and enhance biodiversity. In addition, the existing development strategies such as the *Vision Biel 2030* [5] bring a good framework to embed further processes.

The main constraints to perform any changes on existing infrastructure are space constraints and the different interests of multiple stakeholders involved. Space is always a limited resource in urban areas. This is especially a challenge in streets, where the same space is used for different purposes such as car, bike and pedestrian lanes, parking lots and vegetation measures. Therefore, conflicts between different interests such as biodiversity connections and car traffic routes have to be identified and trade-offs must be set.

Another difficulty for urban planning is the Swiss ownership structure. While streets and open spaces often belong to the public, this is not the case with buildings. Therefore, the implementation of any measures on buildings, such as refurbishment or the construction of green roofs needs the engagement of private building owners, which complicate city wide strategies and a fast establishment of city development strategies.

The opportunities and constraints that have been identified for the city of Biel apply on the district scale to Sägefeld. A closer look at the district is nevertheless still needed to uncover the intricacies of its current situation.

The Sägefeld district is home to multiple protected, heritage buildings, out of which the Shedhalle stands out as the most iconic. This heritage factor is a major constraint in developing a strategy for the district, as planning must be done around these buildings and must ensure their incorporation in the new concept. However, it also presents an opportunity to highlight the cultural history of the district, enhance the structures' integration within the surroundings, and invigorate the area via capitalizing on its unique quality of connecting industrial, commercial, residential, and cultural assets.

Key road corridors, namely Jakobstrasse, Längfeldweg, Länggasse, and Sägefeldweg, bound the district. Two additional key roads cross the district, yet they are not currently used by vehicular traffic. This poses a challenge for function and building distribution on the district plots and complicates achieving connectedness between the northern and southern sections of the district. Despite the added complexity due to the road corridor situation, these roads provide an opportunity to implement the city-wide green corridor strategy (defined in section 4) and have them serve as a lighthouse project that sets an example for the city.

Further, Sägefeld has been identified as one of the priority development areas ("Prioritäres Entwicklungsgebiet") and specifically one of the regional residential focal points ("Regionale Wohnschwerpunkte") as per the 4th Generation of the Biel/Lyss Agglomeration Program. This sets the constraint to focus primarily on residential development in the district. It is worth mentioning that this program includes Sägefeld as one of the districts in which development must prioritize each of consistent and high-quality inward settlement development, creation of diverse open and green spaces for leisure and recreation, ecological strengthening and networking of animal and plant habitats, and orientation towards mobility that is compatible with settlement, space-saving, and low-emissions. This declaration provides the confidence that the local authorities are on board with the mission inherent to our study and confirms that the in-place policies provide the necessary ground for environmentally conscious planning interventions.

Sägefeld as it is now has been assessed by the program. It was concluded that the district's current traffic capacities are sufficient for its needs and projected development in the 2024-2027 horizon. This draws attention to the point that that generated traffic within the district and its periphery due to the proposed development does not exceed the current capacities before 2027.

3.2 Instrument of nature-based solutions

Nature based solutions (NbS) and Blue-green infrastructure (BGI) can bring various benefits and address multiple of the identified challenges. Figure 2 gives an overview of possible benefits of BGI. However, there are many BGI measures and none of them brings all the possible benefits. Therefore, the right measures should be identified for each place, and it should always be aimed for a combination of several measures.

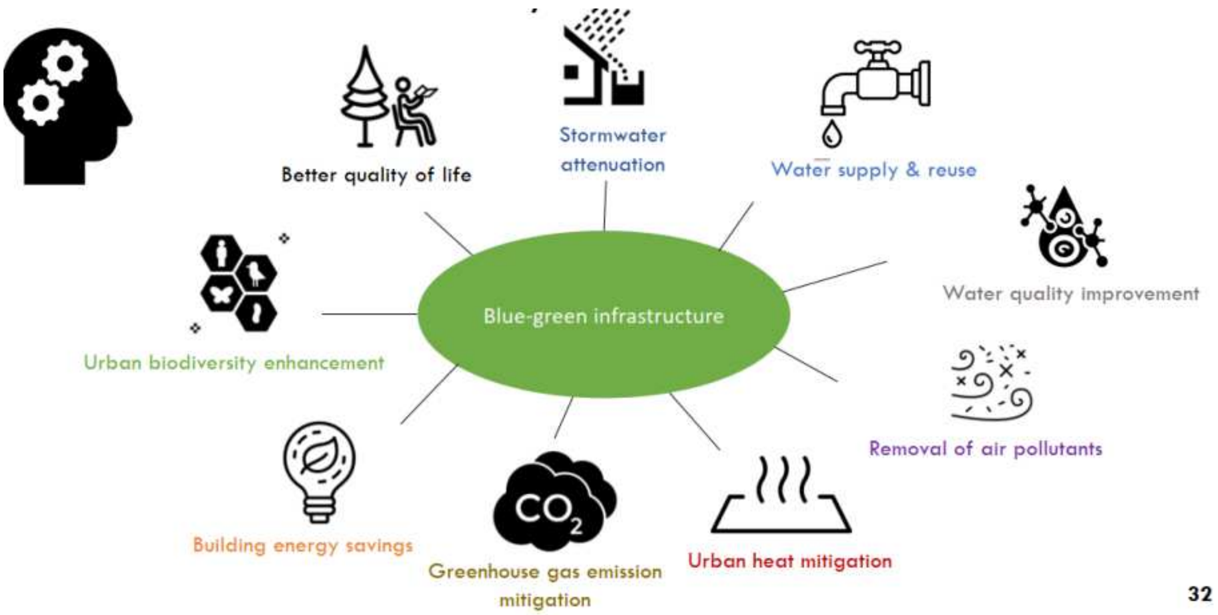

Figure 2: Benefits overview of blue-green infrastructure [9].

Considering the identified main environmental challenges of intense rainfall, biodiversity loss and heat waves, the most effective BGI measures can be identified. According to Table 1 in the appendix the BGI measures addressing all the named challenges are green roofs/façades, bioretention basins, bioswales and urban tree canopy. These BGI measures were applied when developing the strategy for high density housing in the Sägefeld district.

3.3 Vision

3.3.1 City Level: Vision Statements

Building on the basis of the site analysis, the existing strategies and the investigation of blue green infrastructure, along with their opportunities and constraints, the following vision statements for Biel are formulated:

> Vision statement 1: **Biodiversity**
> Biel creates a biodiverse city environment by creating interconnected green spaces that can serve as habitats and migration corridors.
>
> Vision statement 2: **Disaster risk reduction**
> Biel strives for a nature-based decentralized infrastructure to increase the resilience to future challenges and to reduce the risk of disasters such as heat waves and floodings.
>
> Vision statement 3: **Mobility**
> Biel increases the livability and attractiveness of its neighborhoods by enhancement of public transport services and by creating an area-wide network of attractive and secure routes for pedestrians and cyclists.

These vision statements were also the basis when identifying the opportunities and constraints for the project in Sägefeld.

3.3.2 District Level: Vision Statements, Objectives, and Measuring Methods

Vision Statement 1: **Biodiversity**
Sägefeld sets an example for the symbiotic existence of flora and fauna in the urban context, bridging key green areas and thus facilitating species' migration between them.

Vision Statement 2: **Disaster Risk Reduction**
Sägefeld uses decentralized blue-green infrastructure to increase its resilience to future local, regional, and global challenges and reduce the risk of disasters such as heat waves and floods.

Vision Statement 3: **Socio-economic Prosperity**
Sägefeld is a "Complete Community" (in the words of the "Visualizing Density" pilot project in Vancouver). It is socially, culturally, and economically rich district, where residents feel rooted in and connected to their surroundings, have access to a variety of leisurely activities that are reachable by foot or bike, and are provided with

To this end, we set the following objectives for Sägefeld.

Table 1: Objectives for the district of Sägefeld.

#	Objective	Type	Indicator	Measuring Method
1	Increasing the district's connected green cover	Biodiversity; Heat Mitigation; Leisure	30% Canopy Cover	Hemispherical Photography (HP) and Digital Analysis
2	Limiting urban runoff in the district	Flood Resilience	Below 30% Runoff	Water Balance Analysis
3	Creating a "Complete Community"	Connectivity; Socio-economic prosperity; Mobility	Amenities available in a 400-meter radius	GIS Analysis, Google Maps Analysis
4	Ensuring residents' wellbeing	Socio-economic prosperity	Green areas at a maximum distance of 300 m	GIS Analysis, Google Maps Analysis
5	Monitoring the effects on species	Biodiversity	Population distribution and composition	Gene Flow Analysis

Indicator 3 is based on the “Complete Community” framework indicators developed as part of the “Visualizing Density” pilot project in the city of Vancouver. Indicators 1 and 4 borrow from the 3-30-300 rule by the Nature-Bases Solutions Institute (NBSI), whereby: 3 refers to the minimum number of trees that should be visible from a person's home [10]. This is based on the idea that having trees in view can have a positive impact on mental health and wellbeing. The 30 component of the rule refers to the percentage of tree canopy cover that every neighborhood should have. Tree canopy cover provides a range of benefits, including cooler temperatures, improved air quality, and noise reduction. A minimum threshold of 30% canopy cover is recommended to ensure that these benefits are realized. The 300 component of the rule refers to the maximum distance that a person should be from the nearest park or green space. Proximity to green spaces is important for encouraging the recreational use of these spaces and can have a positive impact on physical and mental health. A maximum distance of 300 meters from the nearest green space is recommended by the European Regional Office of the World Health Organization.

4. Concrete nature-based solution project

4.1 Potentials, Measures, and Effects

Drawing from the conducted context analysis and defined future vision, we propose that the city of Biel incorporate green corridors, which act as ecological corridors that facilitate migration, within its strategy. Green corridors constitute a nature-based solution whereby linear natural infrastructure in cities connect open green spaces (such as parks, fields, etc.), creating a green urban network [11].

The potential benefits of green corridors are multi-functional. The resulting network from this strategy provides a solution for the increasingly fragmented habitats of the local flora and fauna. Well-planned green corridors ensure connectivity on the structural and functional levels, allowing species to flourish and safely migrate from a micro-region to another. Further, the added vegetated stretches along the urban network yield a more effective stormwater management mechanism due to resultant system’s water retention capacity, thereby reducing peak discharges and acting as a flood prevention tool. Notably, the corridors provide an opportunity to introduce sources of cooling, via evapotranspiration and shading, to otherwise densely built overheating areas, effectively addressing the issue of Urban Heat Island (UHI) and offering citizens a more comfortable micro-climate [12].

When it comes to transportation, green corridors support walking and sustainable mobility, as they provide connections between spaces that foster social interaction and fluidity as well as physical activity. The shading that green corridors offer renders conditions more favorable for both outdoor leisure activities and commuting by foot, bike, or public transportation [11].

Beyond these aspects, green corridors improve air quality, dampen noise pollution, enhance urban aesthetics, and reduce energy consumption. However, in line with our defined future vision, we will focus on the influence of green corridors in the context of biodiversity, disaster risk reduction, and mobility.

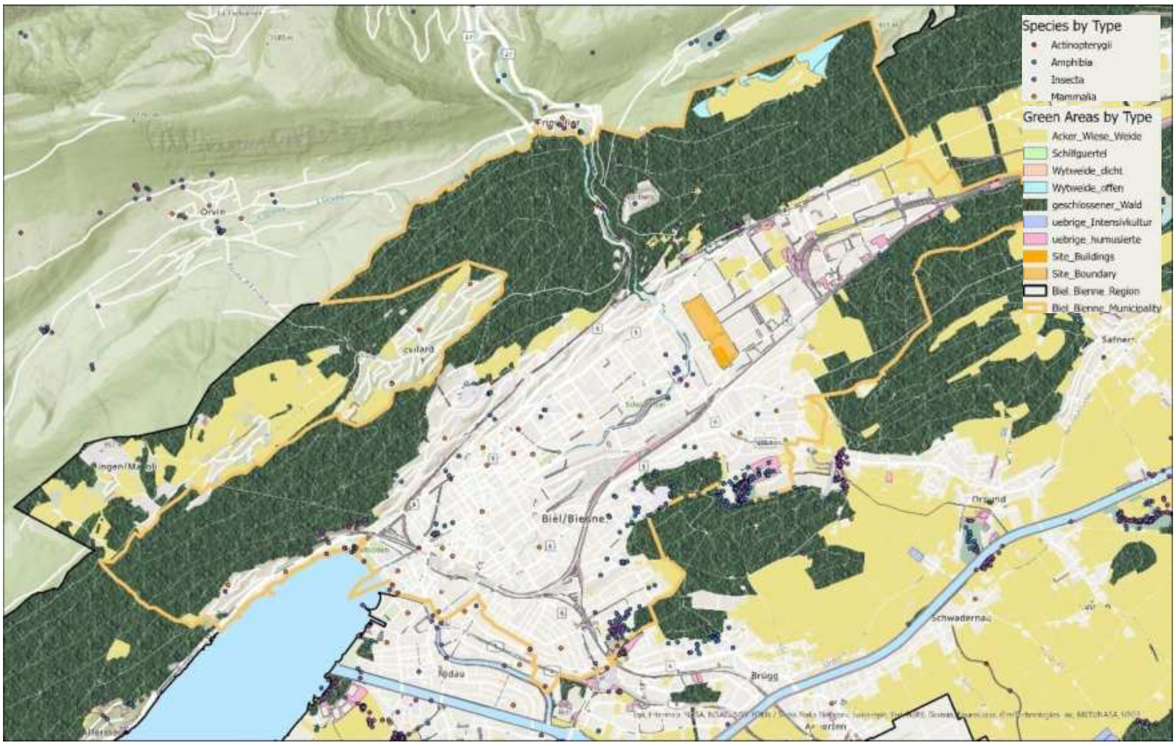

Figure 3: Analysis of Green Areas and Species in the Biel Municipality by Type

4.2 Considered Factors

Upon devising a green corridor strategy, a considerable number of factors must be considered. In the forefront of those are identifying key green spaces, detecting existing green networks, and locating gaps and opportunities. The existing flora and fauna must be audited and studied in terms of ecological needs, spatial distribution, and movement patterns. This would inform the planning process and ensure the strategy specifically caters for the local ecological scene.

Further, current walkability and existing public transport offerings must be assessed and integrated into the strategy. Critical locations, where anthropogenic structures such as major roads or train tracks must be crossed, for instance, should be identified. The feasibility of overpasses or underpasses as a solution to these flow disruptions, as well as aids for different species to cross otherwise dangerous locations, must be investigated at every unique location.

Community approval and the policy scene must be studied. In the case of Biel, both show promise. The community is remarkably active on the communal event scene, evidenced by the city's self-identification as a "city of events". On the environmental and biodiversity policy scene, the municipal council has formulated an action plan to protect its biodiversity and applied for a commitment credit of CHF 600,000.00 for relevant measures. This existing culture and governmental approach further motivate our suggestion [5].

Lastly, targets and metrics must be established to track the performance of the obtained system.

4.3 Challenges and Concerns

Despite the great promise that green corridors hold, it is important to be aware that anthropogenically established links or relinks can cause disruptions. Unintended consequences might include accidental proliferation of invasive species, facilitated spread of parasites, or increased predation due to streamlined movement patterns in narrow areas [13]. Further, edge effects must be accounted for upon the design of green corridors. Edge effects are brought upon due the long, narrow shape that are inherent to corridors. These narrow stretches create a larger perimeter of critical boundaries between habitat and non-habitat areas. As a result, species behavior at the edges might be erratic, causing instability within those connective patches of habitat [14].

There is no evidence of large-scale negative effects of green corridors in literature nor in practical studies, yet even though the pros outnumber the cons, a good design of a green corridor strategy is contingent on the attentiveness to potential detriments, knowledge of site intricacies, and careful mapping of species and needed ecosystems. It is worth mentioning that maintenance is key for a well-functioning green corridor strategy. The functionality of the installations along the corridors must be kept in check to reap the designed-for benefits. Regular reassessment is also required to check the effectiveness of human-induced measures and avoid long-term side-effects on biodiversity.

4.4 Analysis

With these considerations and concerns in mind, a GIS analysis was conducted to explore the available typological and spatial variation of green spaces as well as wildlife. The results of this analysis are displayed in Figure 3. Key findings include the evident gaps in species dispersal in the city center which coincide with the highest population concentrations, which confirmed our expectations based on initial observations. The city is shown to be predominantly bordered by forests. The distribution of wildlife hubs outside the city borders appears to be much denser, corroborating the detrimental effect of urban development on biodiversity. Further, an investigation was conducted to pinpoint the major urban parks and green areas within the city of Biel. Seven key locations were identified and visualized in Figure 4. An existing green corridor connecting Tierpark to Schüssinsel was detected and visualized in green Figure 4. Looking more closely at the location, Schüssinsel has an extensive existing network of paths for cyclists and pedestrians [15]. This in-place infrastructure offers an attractive starting point. The corridor and this network, however, are discontinued beyond Schüssinsel. Zooming in on this city region to illustrate the possibilities, this corridor can be built upon and expanded towards Stadtpark, for example. This proposed connection is visualized in green in Figure 4.

Figure 4: Key Urban Parks and Green Areas (1: Strandboden, 2: Elfenau Park, 3: Laure-Wyss Esplanade, 4: Stadtpark, 5: Friedhof Biel Madretsch, 6: Schüssinsel, 7: Tierpark) showing existing green corridor (green) and planned corridor example (red) and Sägefeld (orange).

This exercise is to be replicated based on the subjective conditions of each location. The key urban areas are to be connected to each other and eventually utilized to connect the larger forest areas across the city. The envisioned subsequent connections in the structural and functional sense are demonstrated in Figure 5. From this same Figure, we make two additional observations. First, the project site situated in the Sägefeld district lies at a significant bed of interactions, offering an opportunity for serving as a key node due to its intermediate location between forests and its proximity to the existing corridor. Second, we note that the planned connections will entail crossing rail tracks and major roads, namely Mettstrasse, Reuchenettstrasse, Längfeldweg, and Bözingenstrasse. This heightens the level of intricacy and associated cost of building the green corridors around these locations.

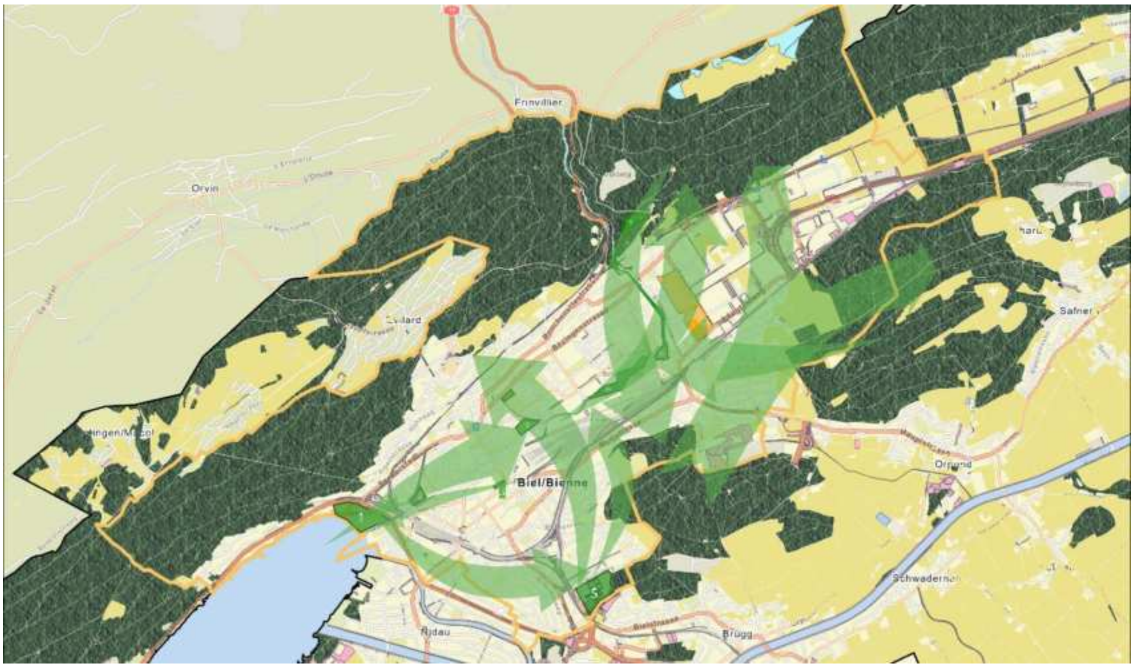

Figure 5: Envisioned ecological interactions via implementing the green corridors strategy in Biel.

4.5 Metrics

The following metrics can be used to quantify the performance of the resultant system:

1. Comparison against a canopy cover target
2. An established benchmark for cumulative corridor length
3. Monitoring the changes in species composition and distribution. Gene flow, defined as the transfer of genetic material through a population, can be used as a measure of how connected populations are [11].
4. Tracking urban trends pertaining to temperature, runoff, sustainable mobility usage etc.
5. Gauging acceptance and utilization by means of regular surveys to cater to the community's specific needs. Green spaces have been found more likely to be used if they are located within 800 m from residences [11]. However, the daily needs of Biel residents might differ.

4.6 Network of Cities

By adopting the green corridor network strategy, Biel itself would be joining an existing network of cities, spread across the globe, that are working together to learn from each other's experiences in planning, building, and managing green corridors. Examples include Montreal's "Green Alleyways" initiative, Medellín's "Corredores Verdes" initiative (Figure 6), and Singapore's "Park Connector Network" program (Figure 7). This international network enriches the context analysis and widens the supportive knowledge infrastructure to carry Biel's future vision forward. The project in Sägefeld could serve as a pilot project but optimally also as a reference and lighthouse project in Biel for increasing the resilience of the city to the identified challenges and implementing the developed strategy of incorporating green corridors.

Figure 6: An example of a green corridor in Medellín, Colombia [16].

Figure 7: An example of a green corridor in Singapore [11].

5. Analysis of Sägefeld

The Sägefeld district is located in the northeast of the city, between the Schüss river and industrial areas (Fig. 4). It has a total area of around 0.12 km^2 and an elongated rectangular form from north to south with a length of around 600 meters and a width of around 200 meters. The area can be divided into three four main zones: On the top the living zone with small housing and an agriculture field. On the bottom the industrial zone with an agriculture field and in between soccer fields.

5.1 Topography

When roughly analyzing the surface cover by drawing individual areal polygons in the webGIS of Biel it can be seen that around 2/3 of the area consists of green surfaces (trees, grass and agriculture) and 1/3 of impermeable surface and roofs (Figure 8). It can be concluded that there is a lot of green space, but with a low quality (not many different type of plants).

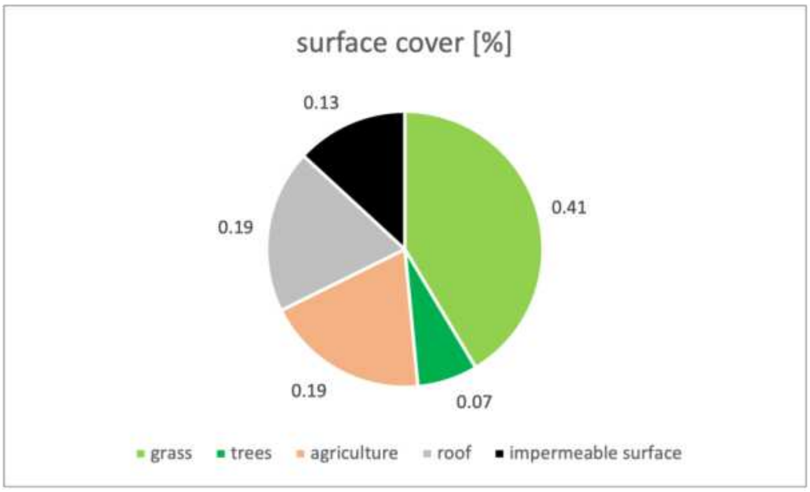

Figure 8: Analysis of surface cover for the Sägefeld district.

5.2 Building Zones

The webGIS of Biel contains information about the building zones of the Sägefeld district. The different shares of building zones can be seen in Figure 9. When compared to the actual situation it can be concluded that there is a lot of potential for high density housing.

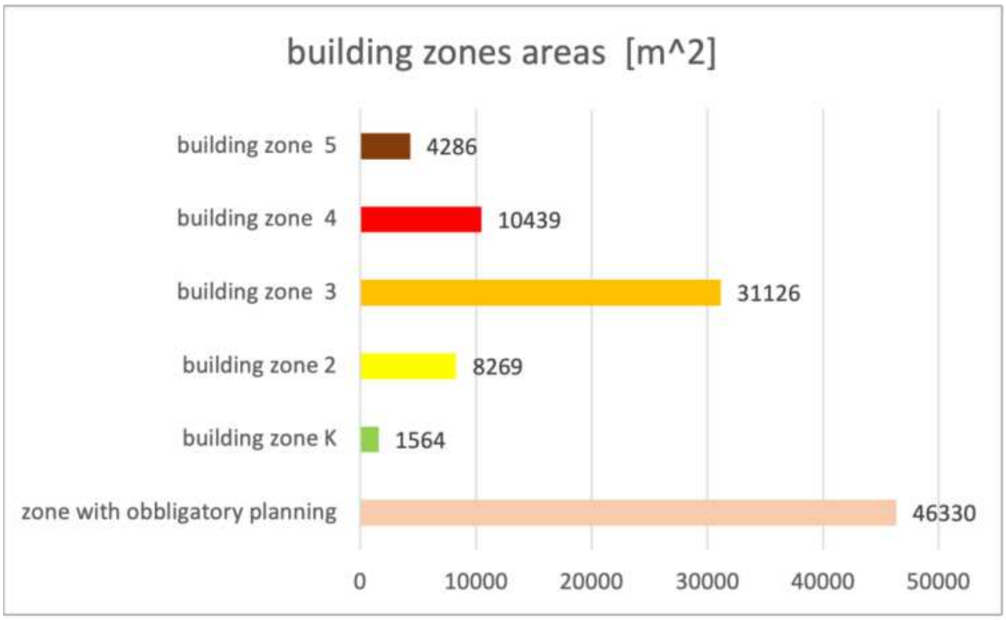

Figure 9: Analysis of building zones in the Sägefeld district.

5.3 Water Balance before Development

A water balance was conducted for the current site with the existing infrastructure and different surface areas. The borders of the Sägefeld equal the border of the catchment the water balance was applied to. An existing pre-coded Excel-Spread was used for the analysis, which can be found in appendix Y. The estimated input values were the occupancy of 250 people for the whole area, the total annual rainfall of 1470 mm [17]and the surface areas of chapter 6.1. The runoff coefficients were chosen to 90% for the paved area, 10% for the green space runoff and other pervious areas. Out of this, the water balance in Figure 10 resulted.

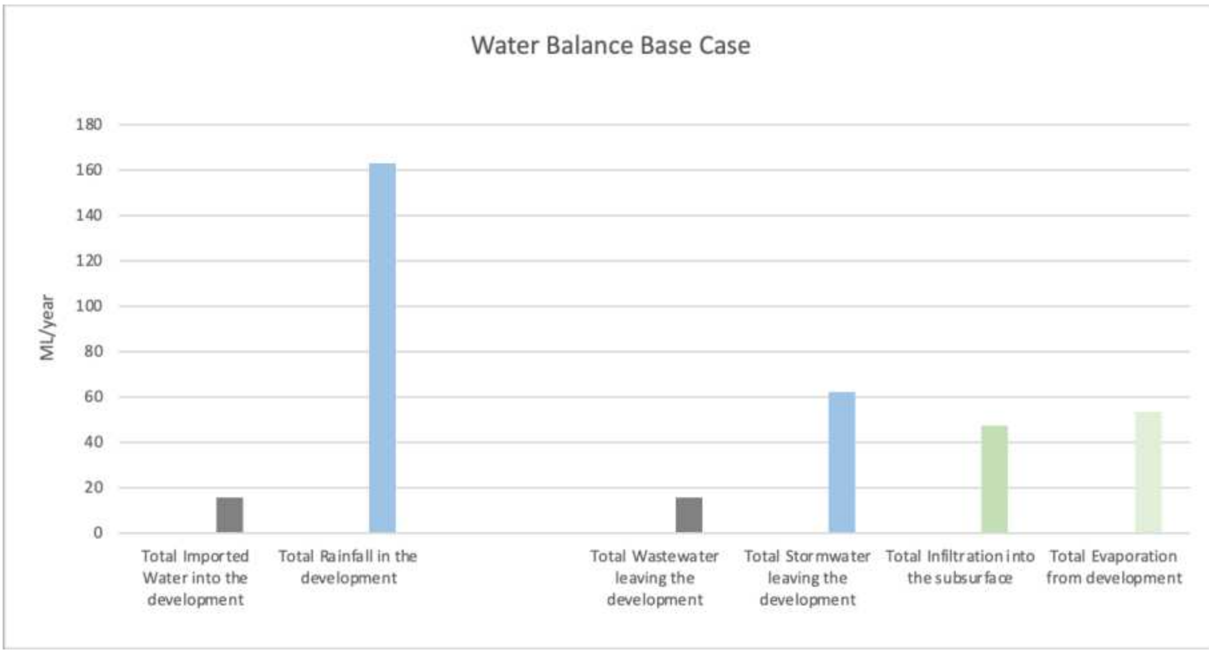

Figure 10: water balance in [ML/year] for Sägefeld. On the left side there is the water coming to the catchment and on the right side the water that's leaving it. The assumption was made that there is no difference in storage, so the two incoming fluxes on the left side equal the total of the four outflows on the right side.

The total rainfall leaves the site through rainwater surface runoff, infiltration to the groundwater and evaporation according to the values in Figure 11. The value of 33% of the precipitation evaporating agrees with the mean percentage of Switzerland of around ⅓ ([1]). The value of interest is the rainwater runoff of 38%, which determines the resilience of a site to cope with events with a high amount of rainwater in a short time, which will increase in future due to climate change. A good value would be around 30% (Peter Bach, 2022). If the Sägefeld should experience traditional high-density housing, this value would even increase due to more paved and roof area, but with the implementation of BGI's it is tried to lower the value.

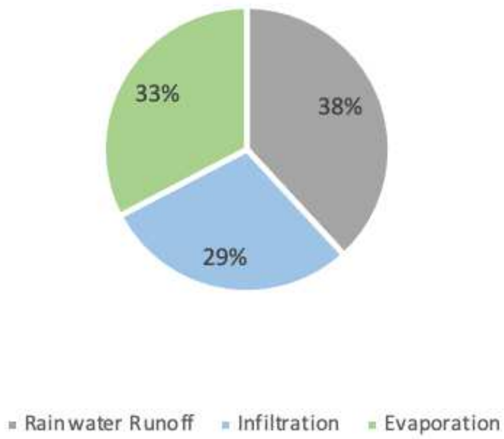

Figure 11: proportions of outflows of the incoming stormwater to the site in [%].

6. Presentation of the Blue Green Solution for Sägefeld

6.1 Building Development Strategy

In response to the client's wish to use the Sägefeld district to push the densification strategy of Switzerland and Biel forward, emphasis was laid on new, dense construction. The primary guiding principle for the buildings' configuration was ensuring connectivity on multiple levels:

(1) Connecting building courtyards to walkways, key roads, and green corridors via using U-shaped, T-shaped, and H-shaped buildings wherever possible.

(2) Connecting the district to the rest of the city by directing courtyards to the outside, thereby inviting visitors and potential customers to the green spaces and commercial services in Sägefeld

(3) Connecting the passageways and open spaces within the district by avoiding large blocks of construction and ensuring the traversability of buildings, which not only serves the residents and visitors and enhances the connection of the district to

[1] (https://portal-cdn.scnat.ch/asset/03214974-bdcb-57ce-a775-6ee3b2a8dd33/Nr.25_Verdunstung_Schweiz?b=4cb6e762-86c6-502d-999d-11df5b5d3a9a&v=e9a30c9c-1948-5de4-ad28-d3622431e881_0&s=WQYBtCi4I7UeXVKiocGg7N8lFsx2ak2QWL5Uu4oIpYKLr8pfms93t3jqgfLPYNMfJ6AX3wucmr8GpsTSJu2MfAzu5c8X8EtHpMumTP8bkzSv08RM1izV-F-IM21_0LQbDfVe5-TfUxr-XwAI-PsSQ1lUI2zjgs1Th3TpSKOHziQ)

the city and of the two district functions (residential and commercial), but also facilitates the migration of species in multiple directions

Permeable pavements are chosen as the primary surface cover for the corridors to ensure comfortable mobility while allowing for infiltration and contributing to limiting the percentage of rainwater runoff. Wherever possible, paths are left unpaved to maximize rainwater infiltration.

Further, an effort was made so as not to completely block the access of existing single-family houses to views and open spaces by providing squares where possible and longer newly built courtyards to maintain some of the qualities of the available sightlines from these homes to the green spaces.

Figure 12: proposed design of the Sägefeld district

6.2 Green Corridors: Urban Canopy and Bioswales

In line with the suggested city-wide solution of establishing a green corridor network, the Sägefeld district would host the first such implementation in Biel. The two horizontal key roads are transformed into green corridors with exclusive access for pedestrians and cyclists. A vertical green corridor runs across the district, connecting the commercial end in the Southern part to the residential part in the North and accommodating pedestrians and cyclists as well. The corridors between the buildings are designed as wide spaces that lead into squares and courtyards as they traverse the district. The corridors are lined with trees, boosting the urban canopy cover and thus providing shade, contributing to cooling, increasing the system's water retention potential, improving the air quality, and adding to the leisurely experience of visiting or living in Sägefeld. The width of the corridors also allows for their potential use for seasonal markets (e.g. Christmas Markets) or festival kiosks.

Three different squares provide versatile open space for the site: square A is located directly at the Shedhalle and provides space for a café and commercial activities, such as a flea market, craft workshops, art studios, and event venues. Square B marks the entrance to the Northern part of the site and connects the site with the existing neighborhood in the West. Square C acts as a playground/park for children and as a communal meeting point, connecting the new multi-family buildings to the existing single-family houses. At the same time, the playground serves as a floodable stormwater bio-infiltration basin. The corridors are to be lined with bioswales that redirect stormwater either to the irrigation system or to the basin in square C.

The courtyards that are open to the outside of the district and to the rest of the city provide prime attraction points for visitors and thus the ground floors of these buildings are suitable for restaurants and cafes with outdoor seating or shops with aesthetic views and attractive centerpieces (such as fountains or rain gardens).

6.3 Green Roofs

It is planned to include a green roof construction on the newly developed buildings in Sägefeld and, wherever structurally applicable, on the existing buildings in the district. A priority is given to the installation of intensive green roofs over extensive ones.

This design decision stems from the following rationale. Owing to the deeper substrate layer on intensive green roofs, such constructions are able to support a wider range of plant species, including shrubs and small trees. As a result, intensive green roofs offer a higher degree of design flexibility and can serve as higher-quality recreational, communal, and even commercial spaces than their extensive counterparts, which satisfies the objective of supporting the socio-economic prosperity of the region. What's more, the thicker soil layer offers a greater potential for water retention, which alleviates part of the increased runoff load due to the new constructions. Further, from an economic and environmental point of view, intensive green roofs are also more attractive due to their energy-saving potential. The deeper soil and vegetative layers in an intensive green roof increase the thermal mass of the roof construction, thereby regulating a building's temperature and reducing the demand for active cooling. Aside from the subsequent energy savings and reduced carbon emissions, this strategy contributes to the objective of disaster risk reduction when it comes to the risk of heat waves and to the urban heat island effect.

6.4 Bioretention Basin

In the northern, residential part of the district, a bioretention basin is installed as part of a floodable park that serves both the Sägefeld residents and Biel citizens. Bioretention basins are shallow depressions that are designed to capture and filter stormwater runoff, mimicking the natural water cycle. Stormwater collected from the roofs of pre-existing and newly constructed buildings is to be redirected into this basin to address the otherwise increased magnitude of rainwater runoff due to the dense development. Details on the water balance that was the basis of this decision and on the sizing of the basin are included in section 7.

The envisioned design of the floodable park aims to control stormwater flow rates into the drainage system, thereby shaving the peaks and reducing the risk of floods. The effects of this installation go beyond risk reduction, however. The floodable park contributes to the overall goals of biodiversity preservation, community building, and enhancing residents' wellbeing.

7. Quantitative Evaluation of the Proposed Blue Green Solution

7.1 Area utilization factor

The proposed building constructions and squares decrease the share of green spaces (grass,trees, agriculture) from a total of 67% to a drastically lower number. However, if all the new gardens and the spaces between the buildings are designed in compliance with green principles, a share of 36% of green spaces will remain. Additionally, the roofs of the new constructed buildings should be implemented as intensive green roofs, which makes up another 23% of the total site area. So, with our proposed design, still only 16% of the soil must be paved. The squares, which should be designed in a mixed way (paved and unpaved areas), make up 9% of the total area.

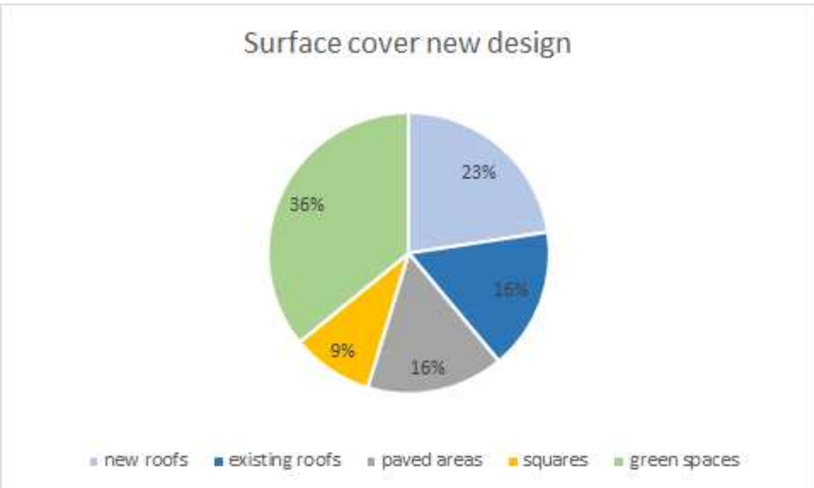

Figure 13: Share of surface cover in the Sägefeld district with the proposed design.

7.2 Water Balance after Development

To estimate the water quantities for infiltration, retention and drainage in the district with the proposed design, another water balance was conducted. The same methodology and same Excel tool was used. While the annual rainfall was assumed to remain constant at 1470mm per year, the occupancy was now assumed to be 1'700 people. It was assumed that the mix of newly constructed green roofs and existing tile roofs leads to an overall roof runoff factor of 60%. Same as in the base case water balance, surface runoff of green areas and paved areas were assumed to be 10% and 90%, respectively. The runoff of the squares was assumed to be 40%. The results of the new water balance can be seen in Figure 14.

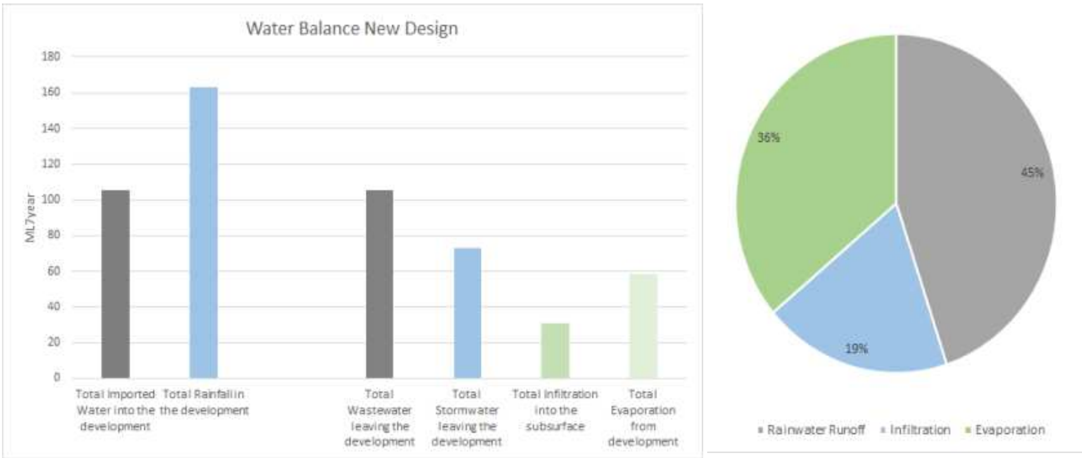

Figure 14: Water balance in the Sägefeld district with the proposed building layout (without infiltration basin).

Due to the high amount of additional households, the total imported freshwater and exported wastewater increased a lot compared to the base case. The rainwater runoff increased from 36% (base case) to 45% if no additional BGI measures would be implemented. However, the infiltration and retention basin is there to decrease this share by as much as possible.

7.3 Dimensioning of the Bioretention Basin

To estimate the required size of the retention basin, the *Regenwasserrechner* of the *Office for Waste, Water, Energy and Air (AWEL)* from the canton of Zurich was used. An infiltration basin that is designed for a one year storm event and takes up and infiltrates the runoff from all paved areas and roofs, an area of about 900 m2 is required, if the basin can be flooded by 1m. This area is about 40% of the square C (see Figure 12 in chapter 6). The infiltration area could be reduced to 650 m2 if an overflow is accepted twice a year, or if in addition to the infiltration basin a deeper retention pond is implemented that can store the water in storm events for later re-use or infiltration.

Table 2: Required infiltration area and retention volume for infiltration basins depending on the annularity.

Annuality	Rainfall	Infiltration area	Flood height	Retention volume
1	20mm/80min	900 m2	1.03 m	930 m3
1/2	15mm/80min	650 m2	1.03m	670m3

With a combination of a retention pond (that may be always filled with some water) and an infiltration basin, the rainwater cycles on the site can be almost completely closed and the drainage runoff is almost zero in an average year. Only during high intensity stormwater events rainwater must be drained through an overflow.

8. Conclusion & Recommendations

This report aims firstly to develop a nature-based solutions concept for the city of Biel and secondly to design the neighborhood of Sägefeld as a role-model example. Like every other city in Switzerland, Biel will have to deal with enhanced climate change driven challenges such as heat waves, floods and enhanced biodiversity loss in the future. At the same time, the city is still expected to grow, which requires strong inner densification. There are several blue-green infrastructure measures that can serve as nature-based solutions to address these challenges.

The authors propose three vision statements that Biel should anchor as future development guidelines, addressing the following three topics: biodiversity, disaster risk reduction, and mobility.
To achieve these visions, a city-wide network of green-corridors that connects the surrounding forests, parks, the rivers and the lake should be implemented. These green spaces do not only serve as habitats for multiple species, but also act as important open spaces for people for relaxing and social life. The green network would create multifunctional benefits for biodiversity, health, resilience to disasters, and mental health. Especially the last two aspects should not be underestimated from an economic perspective, as mental illnesses and disasters can cause immense societal costs.

Biel is a rather small town surrounded by a lake and forests, which makes the implementation of an interconnected habitat network rather easy compared to other cities. However, there will be challenges and trade-offs for the implementation of every green corridor. Especially in the city center, the space is very limited and used by multiple stakeholders. At the same time, the inner city is also the part that is most affected by heat waves and flooding. Therefore, solutions must be found to also implement blue-green infrastructure in the city center.

To achieve this goal, the authors recommend the city to develop a thorough strategy for a green-corridor network in more detail and to start soon with the implementation of first projects. To enhance the social understanding for the development, it is recommended to not start projects only at not much discussed spots according to the principle of “weakest resistance”, but also implement blue-green infrastructure at key spots that can serve as role models for a greener and more nature-based city.

The Sägefeld district is a large, low density area that is located at a strategically important spot connecting more residential to industrial areas and has large land reserves. Due to these facts, it has the potential to act as a role model and represent a modern, dense, biodiverse and risk resilient neighborhood that at the same time provides functions to satisfy the every-day needs for the tenants as well as opportunities for social activities and space to relax. The proposed layout of U-shaped, H-shaped and L-shaped buildings provides the neighborhood with a lot of public space, large corridors and squares assure connection within the neighborhood as well as to surrounding neighbors. However, only slow traffic mobility is possible within the neighborhood, as it is car free. To support the city-wide green corridor concept, the horizontal as well as one vertical green-corridor are proposed. In addition, the buildings should be designed consisting of green roofs and façades. A floodable playground that acts as a social space and at the same time as a bio-infiltration and retention basin is proposed to close the water cycle within the neighborhood. The water balance conducted shows that with such a multifunctional basin, the rainwater runoff can be reduced from currently almost 40% to less than 10% in an even denser neighborhood.

The proposed design gives an example of a high convenient neighborhood that can fulfill multifunctional goals. To achieve a satisfying result, it is key that the blue-green infrastructure is planned thoroughly and the state of biodiversity etc. is also monitored afterwards. As the Sägefeld has a complicated ownership structure in the Sägefeld is rather complicated, it is suggested to bring the stakeholders together and make the motivation for an integrated design concept clear.

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Appendix

Table 3: Overview of which benefits can be achieved by which blue-green infrastructure [9].

Benefit	**Mechanism**	**Blue-green-Infrastructure**
Runoff retention	Interception Infiltration Detention Ponding Evapotranspiration	Green roofs/walls Bioretention basins Bioswales Permeable pavement Urban tree canopy Downspout disconnection Rainwater harvesting
Water supply & reuse	Direct water capture Groundwater recharge	Bioretention basins Bioswales Permeable pavement Rainwater harvesting
Water quality improvement	Pollutant take-up by plants & by substrate	Green roofs & façades Bioretention basins Bioswales Downspout disconnection Rainwater harvesting
Removal of air pollutants	Uptake by stomata Interception of particles (leaves) Breakdown of certain organic pollutants	Green roofs & facades Bioswales Tree canopy
Biodiversity enhancement	Creation of habitats Connection of habitats	Green roofs & facades Bioretention basins Bioswales Urban tree canopy
Heat mitigation	Evaporative cooling Reflection	Green roofs/walls Bioretention basins Bioswales Urban tree canopy
Energy savings Greenhouse gas mitigation	Reduction of heat flux (insulation) Shading of roof/wall/windows CO_2 uptake	Green roof & façade Trees Urban tree canopy Bioswales Bioretention basins