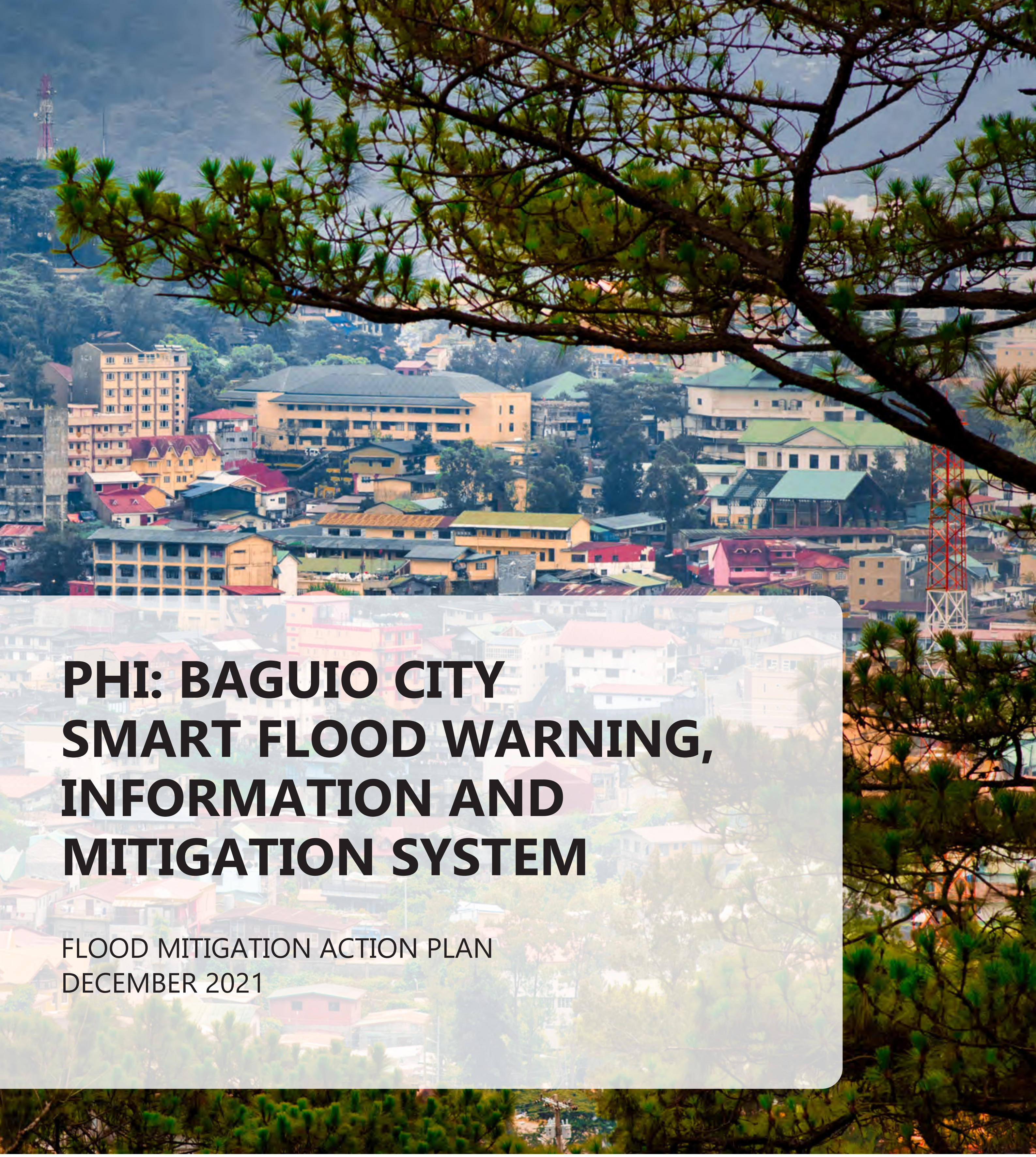

PHI: BAGUIO CITY SMART FLOOD WARNING, INFORMATION AND MITIGATION SYSTEM

FLOOD MITIGATION ACTION PLAN
DECEMBER 2021

ASEAN
AUSTRALIA
SMART CITIES
TRUST FUND
Asian Development Bank

ADB

Source: LGU

Project name	PHI: Baguio City Smart Flood Warning, Information and Mitigation System
Project no.	1100040737-002
Recipient	Asian Development Bank
Document type	Report - Final
Version	1
Date	22/12/2021
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Description	This Flood Mitigation Action Plan is the fourth deliverable in the project “PHI: Baguio City Smart Flood Warning, Information and Mitigation System”
Cover image	Adobe Stock

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ABBREVIATIONS

AASCTF	ASEAN Australia Smart Cities Trust Fund
ADB	Asian Development Bank
BGI	Blue Green Infrastructure
CAD	Computer Aided Design
CBA	Cost-Benefit Analysis
CDRRMO	City Disaster Risk Reduction and Management Office
CEO	City Engineer's Office
DFAT	Department of Foreign Affairs and Trade (Australia)
DPWH	Department of Public Works and Highways
ESIA	Environmental and Social Impact Assessment
EWS	Early Warning System
FEWS	Flood Early Warning System
GIS	Geographic Information System
GVA	Gross value added
HALY	Health Adjusted Life Years
LGU	Baguio City Local Government Unit
NbS	Nature-based Solutions
NPV	Net Present Value
O&M	Operations and Maintenance
OTJ	On-The-Job
QUALY	Quality Adjusted Life Years
SWOC	Strength, Weakness, Opportunity, Challenge analysis
TOC	Time of Concentration
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

In April 2019, the Asian Development Bank (ADB) approved the establishment of the ASEAN Australia Smart Cities Trust Fund (AASCTF or the Fund) under the Urban Financing Partnership Facility, with financing provided by the Government of Australia, through its Department of Foreign Affairs and Trade (DFAT). Through this mechanism, the ADB is supporting Baguio City in implementing the Smart Flood Early Warning, Information and Mitigation System project, which will include four outputs: (i) smart flood early warning information system (FEWS) established and operational; (ii) real-time data capture system established in four river basins in Baguio City; (iii) flood mitigation action plan prepared; and (iv) city twinning programme for smart flood warning and mitigation implemented.

By having a high vulnerability to climate hazards, combined with the expansion of impervious paved areas, Baguio is experiencing increasing runoff volumes and flood damages. Overcoming these challenges requires a holistic approach focused on integrated solutions. This report argues and demonstrates that NbS could be that cohesive element that binds everything together into a unified resiliency planning path, allowing for prioritization of multifunctional solutions that specifically address key urban challenges by including e.g., shifts in mobility patterns, connectivity, new suggested bike paths, and green and recreational areas, among other features.

To reduce the impacts of recurrent flooding, this Flood Mitigation and Action Plan report introduces a city-wide assessment for the conceptual design and implementation of nature-based solutions (NbS) as a new paradigm for climate adaptation, where both flood mitigation benefits, and other co-benefits are analyzed through a structured approach and in close consultation with the LGU and ADB. The report contributes to the knowledge base supporting the current paradigm shift in urban planning practices taking place in Baguio, guided by an overall vision to make the city more liveable, more resilient, and more sustainable.

The development of the action plan builds on the results from the previous hazard and risk mapping assessment from July 2021, by focusing on the Balili catchment as the most flood prone catchment in Baguio and targeting the conceptual design of NbS to a 3-year rainfall event (for future climate change conditions) as the service level. The definition of the service level was closely discussed with the LGU, including a participatory workshop on 11 November 2021, and is validated by the past ca. 20 years of historical flood damages in the city, as reported by the City Disaster Risk Reduction and Management Office (CDRRMO).

A set of high-level adaptation principles drives the vision for flood mitigation in Baguio: tangible benefits; feasible co-benefits; resilient infrastructure; sustainable land use management; multifunctionality; replicability; and scalability. These principles are in this study unfolded and practically implemented in an integrated approach comprising three steps: i) development of a NbS toolbox of typologies designed specifically to meet the challenges and utilize the opportunities identified in Baguio; ii) demonstration of the applicability of the NbS toolbox for three pilot sites; and iii) preparation of a roadmap for implementation of typologies. Moreover, this approach is carefully accounting for existing development plans in Baguio (e.g. the 'Green Walks' initiative or the 'Barangay Satellite Markets'), as well as including internationally recognized best practices within the field of NbS and Blue-green Infrastructure (BGI).

In the pathway towards becoming a more resilient city, Baguio is and will continue facing many challenges beyond flood risks, including accessibility, quality of public services and amenities, growing population, inclusiveness, and social justice. Specifically related to water, Baguio's challenges relate to both water quality and quantity, incl. lack of runoff management, accumulation of waste in rivers, and depleting water supplies.

To lay the ground of the action plan that aims at addressing these challenges, the study identifies geographic zones with similar characteristics where NbS can be applied in Baguio. The definition of zones supports the identification of specific areas that allow replicability of mitigation solutions in various locations city-wide. Three types of space were identified within each zone: open areas, roads/right-of-way, and canal/stream/river. Typologies are available for prioritized combinations of zones and space, on the basis of a prioritization exercise accounting for, among other parameters, cohesion with ongoing initiatives and plans, expert knowledge of NbS applicability and compliance with national guidelines stating that no land above 18 % of slope shall be developed.

The developed typologies included in the toolbox covering all of Baguio are: 1) stormwater park; 2) urban canal; 3) natural stream restoration; 4) green street; 5) stormwater boulevard; 6) liveable corridor; 7) terracing; and 8) non-urban fringe buffer zone. A replicability assessment shows how all these typologies can be applied city-wide at various scales to create a network of connected nature-based solutions. To demonstrate the applicability of the NbS toolbox, three pilot sites were selected and valeted by the LGU, following a multi-criteria assessment. All sites are also owned by the LGU. The sites and characteristics are:

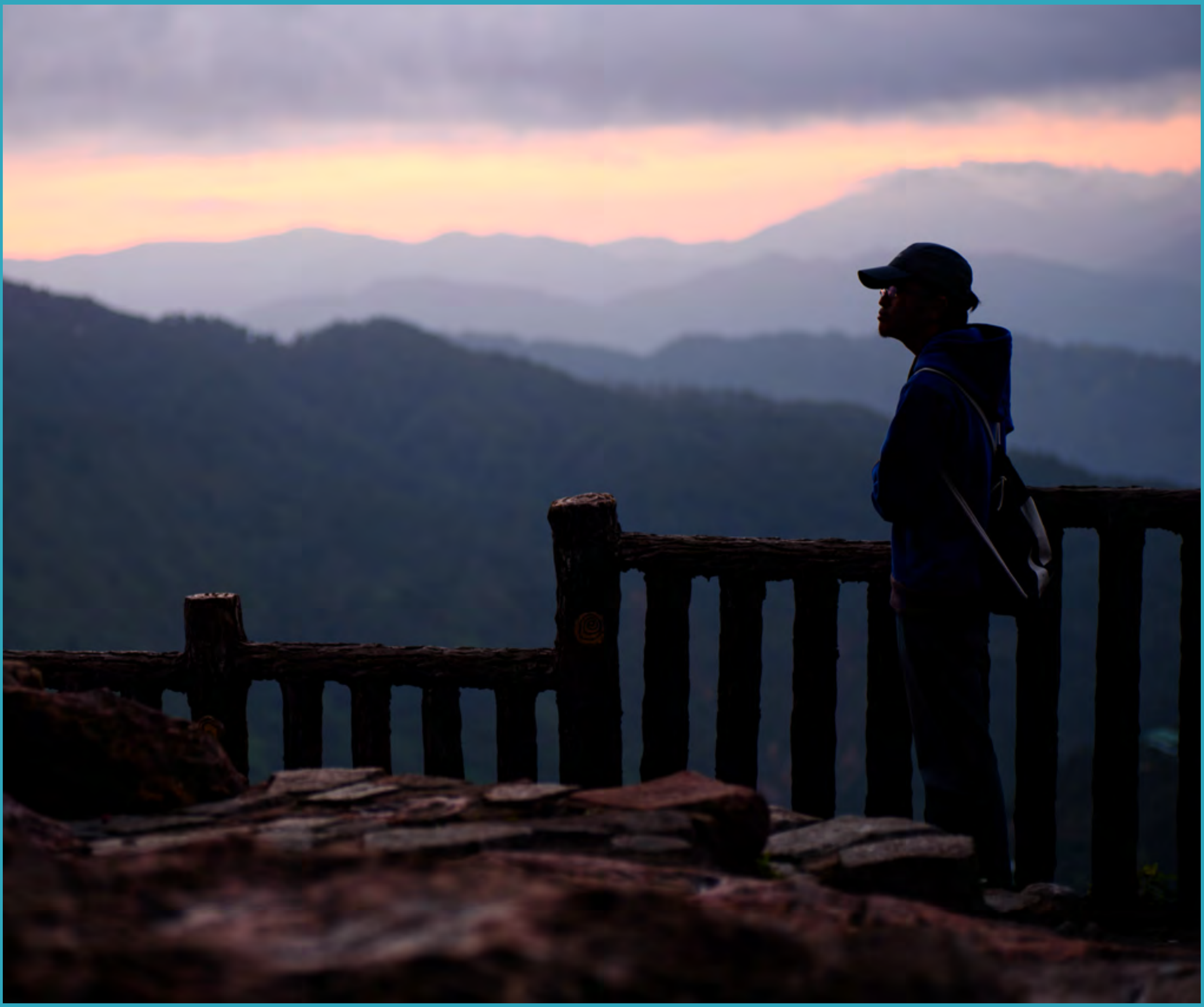
1. **Urban Canal near Manual Roxas (137-138)**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Canal
2. **Green Street at Carino Street**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Road
3. **Stormwater Park at Emilio Aguinaldo Park**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Open area

Each site undergoes a conceptual design approach, comprising a hydraulic assessment, an appraisal of the associated socio-economic benefits and an overall description of how the site should be designed, operated and upscaled. The functional requirements of all functions covered in these pilots are to capture, convey, and where possible store (retain or detain) stormwater. Natural water treatment functions are embedded in storage and conveyance systems to minimize needs for downstream treatment and improve local water quality. Three key co-benefits have been analyzed by outlining a valuation process integrating quantitative and monetary valuation methodologies, enabling a comparison of the trade-offs across locations and/or designs: i) increased demand for services (retail, hospitality); ii) increased amenity value; and iii) increased access to local, safe, and natural green/blue space and sports facilities.

Each pilot is analyzed in detail and fulfils the purpose of demonstrating the feasibility of NbS application in Baguio. In this regard, it's important to note that all designs presented in this report are at conceptual level. Therefore, the report offers a roadmap of implementation, which aims at presenting a step-by-step guide from project development to implementation of flood mitigation in Baguio, together with a set of recommendations pointing at how to go from conceptual design, to schematic and detail design, as well as implementation, monitoring, evaluation and learning.

This report highlights how a nature-based approach for stormwater management promotes resilience and sustainability through terrain-based solutions, offering a sustainable option for communities to cope with the challenges of climate change. A multifunctional, and highly adaptive network of terrain-based solutions in combination with traditional stormwater infrastructure can mitigate flooding, while improving overall liveability in Baguio.

1. INTRODUCTION



Source: Adobe Stock

1.1 PROGRAMME (AASCTF)

In April 2019, the Asian Development Bank (ADB) approved the establishment of the ASEAN Australia Smart Cities Trust Fund (AASCTF or the Fund) under the Urban Financing Partnership Facility, with financing provided by the Government of Australia, through its Department of Foreign Affairs and Trade (DFAT). The Fund's envisioned impact aligns with ADB's Strategy 2030, as well as ASEAN's Sustainable Urbanization Strategy which aims to promote high quality of life, competitive economies, and sustainable environments. The expected outcome of the Fund will be that through the adaptation and adoption of digital solutions, across three core functional areas (planning systems, service delivery and financial management), systems and governance in participating ASEAN cities are improved, in particular by way of:

- Strengthening city planning processes by enhancing the collection, storage, analysis, and utilization of data on geospatial platforms.
- Promoting the use of integrated and smart network management systems to strengthen operational systems and to improve quality and efficiency of service delivery.
- Introducing integrated financial management information systems to improve institutional credit worthiness and fiscal standing.

The Fund acts as a mechanism for facilitating and channeling resources and financing for eligible projects, as well as activities agreed between DFAT and ADB for project preparation, implementation, and capacity development.

1.2 BACKGROUND AND PROJECT RATIONALE

The occurrence of flooding and landslides, both regular phenomena in Baguio City, threaten Baguio's sustained and long-term economic development. Baguio City is considered the "summer capital of the Philippines", attracting 1.8 million tourists in 2018, with an annual growth rate of ca. 16%. In 2009, Baguio was significantly impacted by Typhoons Ondoy and Pepeng, resulting in more than 3,000 people being affected by flooding, and almost 2,500 people being affected by landslides. Japanese researchers from National Research Institute for Earth Science and Disaster Prevention have concluded that the underlying causes behind the 2009 flooding were related to a limited drainage capacity due to obstructions caused by the accumulation of waste, and also by the presence of built-up structures (urban sprawl)[1]. In addition, the presence of illegal settlers in flood prone areas worsens Baguio's exposure and vulnerability towards flood disasters. By being exposed and having a high vulnerability to climate hazards, combined with the expansion of impervious paved areas within the city and its surroundings, Baguio is experiencing increasing runoff volumes and flood damages. All these impacts are expected to be compounded by climate change, which will very likely cause an increase in the frequency and intensity of extreme rainfall events and further exacerbate flooding events and rain-induced landslides.

1 T. Inokuchi, T. Nakasu and T. Sato. 2011. Landslide Disaster around Baguio City caused by Typhoon Pepeng in 2009. National Research Institute for Earth Science and Disaster Prevention.

The ADB, through the AASCTF, is supporting Baguio City in implementing the Smart Flood Early Warning, Information and Mitigation System project. The project will assist the city with both the planning for flood mitigation and the delivery of the services of flood early warning and responses, using smart technologies. The project outcome is improved flood early warning system, responses, and mitigation measures of Baguio City. The project has also four outputs: (i) smart flood early warning information system (FEWS) established and operational; (ii) real-time data capture system established in four river basins in Baguio City; (iii) flood mitigation action plan prepared; and (iv) city twinning programme for smart flood warning and mitigation implemented.

The FEWS will be developed with Baguio Local Government Unit (LGU) and other key stakeholders to improve community disaster preparedness, raise awareness, and ensure ownership. The FEWS is also set to become an integral element within the overall vision of Baguio City to become a truly resilient, dynamic, and smart city.

1.3 PROJECT OVERALL APPROACH

The overall approach followed in producing this project's four outputs (outlined in section 1.2) is to breakdown the project into working tasks, with each task containing key activities, and where inter-dependencies between tasks/activities are accounted for by defining milestones while keeping close contact with the project's working group. The project tasks and associated key activities and deliverables are shown in Table 1-1.

In relation to Task 5, Flood Mitigation Action Plan, the following are important updates:

- In the Technical Memo 'Urban Drainage Modelling Assessment in Baguio', dated 10 September 2021 (see section 1.7), Ramboll presented options going forward in terms of addressing hydraulic assessments. These options were based on the findings of the drainage data gap analysis, described in the Technical Memo (Appendix A), which concluded that it is not feasible to set up a detailed urban drainage model for Baguio within the scope, timeline, and budget constraints of this project.
- The approach described above was agreed through consultations with LGU and ADB, and Ramboll's recommendation to move forward with a strategic hydraulic analysis through development of flood mitigation typologies for Baguio was accepted. This entails that the high-level flood mitigation action plan is based on the development of a toolbox of nature-based solutions tailored to the complex spatial and socio-economic context of Baguio, its application on 3 specific sites, and the inclusion of a mapping/identification assessment of other potential replicable sites in the city.

Table 1-1 Activities and deliverables for Baguio City Smart Flood Warning, Information and Mitigation System.

Task	KEY ACTIVITIES AND DELIVERABLES
Task 1 – Baseline Assessment	• Setup working group, conduct scope consultations, revise workplan • Data and Information Collection • Establish baseline on climate change data and information • Plan the on-the-job (OTJ) training component • **D1: Baseline Assessment Report** (delivered in January 2021)
Task 2 – Hydraulic model setup, including hazard and risk mapping	• Collect additional data, if needed, including river surveys • Confirm boundary conditions and target design levels for the hydraulic model and for inclusion of potential nature-based solutions (NbS) • Develop hydrologic model for all 4 rivers • Develop hydraulic model for the primary drainage system, incl. calibration • Hazard and Risk Assessment • On-the-job (OTJ) training • Twinning activities • **D2: Hydraulic Model and Hazard and Risk Mapping Assessment Report** (delivered in August 2021)
Task 3 – Design of a Flood Early Warning System (FEWS)	• Planning the framework of the FEWS • Procuring and installing measurement devices in selected locations for pilot river • Development of the pilot river real-time data acquisition system • Design the data storage and management system • Overall forecast system framework (database) • Setting up of FEWS at the LGU, and start of the real-time online simulations, before the monsoon • On-the-job (OTJ) training • Twinning activities • **D3: Flood Early Warning System Report** (delivered in September 2021)
Task 4 – Data dissemination and outreach plan	• Design dissemination and outreach activities, including: Website/Dashboard, web applications – SMS alerts, mobile apps, e-mail chimps, etc. • Define dissemination roles and responsibilities among key stakeholders • Development and dissemination of FEWS O&M plan. Maintenance will be undertaken during the monsoon period • On-the-job (OTJ) training • Twinning activities • **D4: Data Dissemination and Outreach Plan**
Task 5 – Flood Mitigation Action Plan (this report)	• Review and gap analysis of urban drainage data, including recommendations for actions. • Finalization of review of drainage data, documents, and guidelines for drainage infrastructure, initiated in task 2. • Development of multifunctional NbS typology toolbox, including key enabling criteria for implementation of typologies. • Demonstrate applicability and benefits of NbS typologies for 3 pilot-sites, including preliminary site-specific hydraulic calculations. • On-the-job (OTJ) training • Twinning activities • **D5: Flood Mitigation Action Plan** (this report)
Task 6 – Replication of real-time data capture, and Monitoring & Evaluation	• Procuring and installing measurement devices in the remaining three rivers • Evaluation of the FEWS (post-monsoon period) • Finalize data assimilation and forecast modelling • System Performance Assessment • On-the-job (OTJ) training • Twinning activities
Task 7 – Project completion	• Wrapping up everything • **D6: Final Report**

NbS - Nature-based Solutions, FEWS - Flood Early Warning System, LGU - Local Government Unit, O&M - Operations & Maintenance, OTJ - On-the-job
Source: Ramboll

1.4 TWINNING AND NETWORKING

The aim of the Networking and Twinning program is regional capacity building, knowledge sharing and strengthening the cooperation across ASEAN and Australian cities. After the launch in May 2021, the following themes and related challenges were selected by the city of Baguio to develop the city twinning cooperation in September:

- Smart traffic system integrated in the smart city command centre – Challenge: Air pollution
- Leak detection for fresh water / water harvesting / reuse of water – Challenge: Water scarcity
- Leak detection in sewage / sewer system management - Challenge: Water pollution

The AASCTF approached the city of Perth which has relevant experience in dealing with water scarcity (Waterwise project) and is currently awaiting the final approval of the Perth authorities to move on to the idea generation workshop that will result in the draft Twinning Plan. Implementation of the Twinning activities is planned in 2022.

1.5 ON-THE-JOB (OTJ) TRAINING AND CAPACITY BUILDING

The OTJ training plan has been already presented in previous deliverables, but due to a number of different reasons, implementation is still not up to speed. This is primarily due to two main reasons. To start with, after having identified the 4 people at the LGU who'd take part in the OTJ training, it became clear that there was a critical lack of essential capabilities which are a pre-requisite to have in order for the OTJ training to work as originally planned. Second, the OTJ training has from the offset been designed to primarily unfold through physical interactions where Ramboll experts would come to Baguio and hold hands-on sessions to train staff in the operation and maintenance of the FEWS. This has not been possible to do as the COVID-19 pandemic has not allowed Ramboll to travel and make the necessary field visits. This type of training is only possible through physical interactions, unless the knowledge and skill base of trainees is mature enough to adapt to a virtual setup. But, as explained above, this base is not at the level that allows for that approach.

For these reasons, Ramboll and ADB have agreed on implementing an extra capacity building component, with the following aims:

- Understanding of the different software tools used for the FEWS setup
- Understanding of the hydrological and hydraulic characteristics specific to Baguio
- Capability of managing annual post monsoon management and evaluations and applying changes to the system
- Capability of troubleshooting and operating the system in real-time during monsoon
- Capability to handle knowledge transfer to future trainees

This tailored capacity building program will kick-off in January 2022.

1.6 FLOOD RISK IN BAGUIO

Baguio City is drained by 4 major rivers, Balili flowing northwards, Bued flowing southwards, Galiano to the west and Ambalanga to the east. Out of the four rivers, Balili, Bued and Galiano drain most of the city, while Ambalanga drains very sparsely populated areas near the eastern boundary of the city. Local depressions in the terrain are likely to be flood prone due to limited drainage capacity. Flooding generally occurs as flash floods caused by intense rain events or by prolonged rain causing the rivers to overflow. Urban areas are particularly vulnerable to flash floods as built-up and paved areas provide limited infiltration, increasing runoff.

1.6.1 HISTORICAL FLOOD EVENTS IN BAGUIO

As part of the Baseline assessment, disaster data from CDRRMO[2] including flood events in Baguio City was assessed. The data covers the years from 2001 to 2018 (with some years missing data) and includes the number of people and number of houses affected due to flooding and landslides, as well as the number of flooding and landslide events recorded. This data has been normalized to facilitate understanding and to compare magnitudes of impact. Figure 1-1 is an example showing the number of people affected due to flood and landslide. It is evident that in 2009 the impact of flood was severe, which also led to massive landslide. It is seen that flooding and landslide events with significant impact have frequently occurred in the same years. The data shows that disaster events with large impact on people occur often, with a recurrence interval below 5 years. This indicates that mitigating events with frequent return periods could yield significant benefits in Baguio.

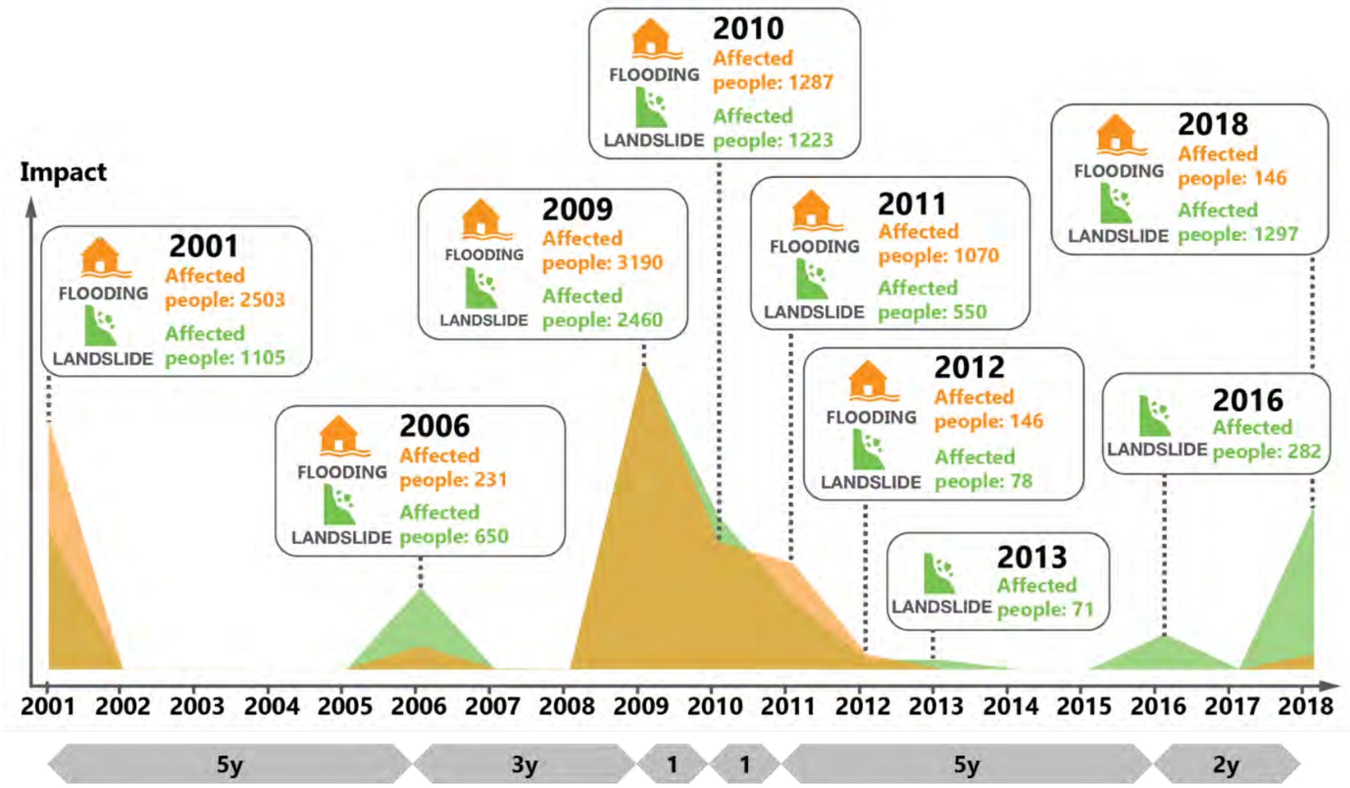


Figure 1-1 People affected due to flood and landslide from 2001 to 2018

Source: The figure is based on data from CDRRMO. 2020. Disaster Data Analysis. Baguio City[2])

2 Disaster Risk Reduction and Management Office (CDRRMO). 2020. *Disaster Data Analysis*. Baguio City.

1.6.2 SUMMARY OF TASK 2 – HAZARD AND RISK MAPPING

One of the primary outcomes of Task 2, 'Hydraulic Model and Hazard and Risk Mapping Assessment Report, July 2021'[3] is an evaluation of historical flooding and a flood risk assessment. As part of Task 2, comprehensive hydrodynamic flood modelling for Baguio was undertaken resulting in several flood hazard and risk maps for eight modelling scenarios including four different return periods (3, 10, 20 and 50 years). The results were validated by local
stakeholders and historical knowledge confirming that areas identified as particularly exposed to floods are indeed experiencing flooding on a regular basis. Key findings from this assessment are:

- Damaging floods occur regularly with significant impacts
- Over a longer period of time, frequent but less intense rain events will lead to more damage compared to rare and more intense rain events
- The flood risk is found to be highest in the Balili catchment, the main drainage catchment in Baguio, flowing north-west. Flood hazard maps show that many houses, alleys, and roads are exposed to flooding.
- At Barangay level, Barangays with high percentage of flooded area (above 10 cm flood depth) for a 3-year present rainfall event were identified.

The output of Task 2 is directly used in the development of the Flood Mitigation Action Plan. This will be documented in upcoming sections in this report.

1.7 URBAN DRAINAGE MODELLING ASSESSMENT

Through an assessment of the available data and information on drainage infrastructure in Baguio, documented in the technical note 'Urban Drainage Modelling Assessment in Baguio, dated 10 September 2021' (see Appendix A), significant gaps in available data were confirmed. These gaps include, among others, unknown dimensions and invert levels for drainage infrastructure, disconnected infrastructure detached from the main drainage network, unknown size and shapes of inlets, and unknown structural conditions of the drainage network.

To close the gaps, extensive field surveys will be required, which are currently hampered by the on-going Covid pandemic, and would also take much longer time than what is possible to accommodate in this project. Hence, in the absence of data, we have made assumptions for specific components of this report, explained in more detail in the following sections.

3 Ramboll. 2021. *Hydraulic Model and Hazard and Risk Assessment Report*. s.l.: Asian Development Bank.

1.8 REPORT OBJECTIVES AND STRUCTURE

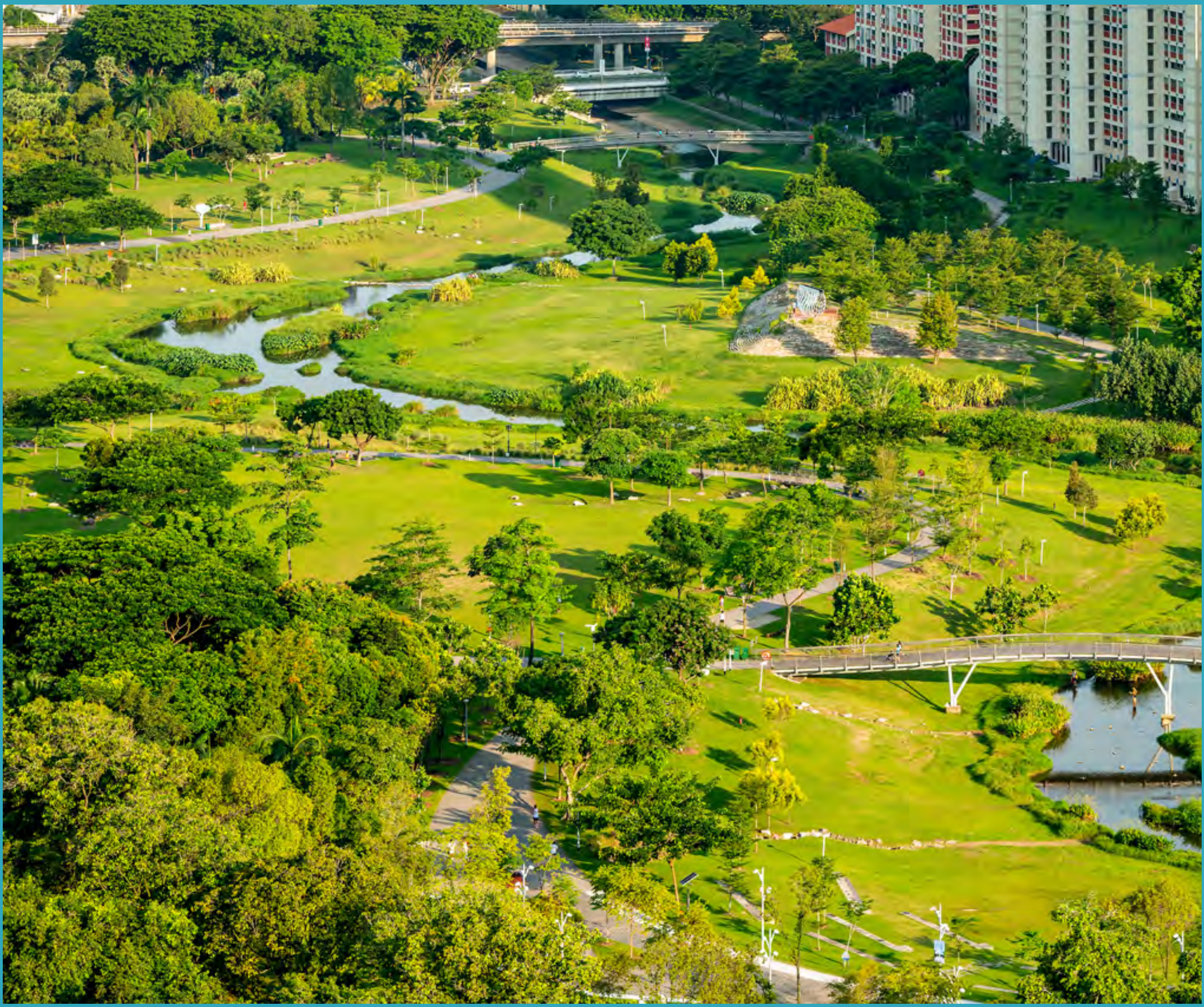
This Flood Mitigation Action Plan report is the fourth report out of seven reports to be produced in this project. The primary intended audience comprises technical personnel from the LGU and ADB. Other intended audiences comprise policymakers, city planning officials and the broad general audience with knowledge and/or interest in risk assessments, climate adaptation, NbS, and city resilience.

This report aims at answering the following questions:

- To which extent are NbS a feasible option for flood mitigation in Baguio, and which types of NbS are most feasible?
- What are the key design considerations for NbS in Baguio?
- What are the co-benefits of implementing NbS in Baguio?
- How may NbS be planned and implemented in Baguio?
- How may NbS be replicated and scaled city-wide?

Section 1 in this report introduces the AASCTF programme, describes this project’s rationale and overall approach as well as the main questions to be answered by this report. Section 2 briefly introduces the concept of nature-based flood mitigation and its socio-economic benefits. Section 3 presents the overall approach followed in the preparation of the action plan. Section 4 outlines the assessment of spatial and socio-economic benefits and also the development of a toolbox of nature-based solutions tailored to Baguio’s unique characteristics. In Section 5, the application of the NbS toolbox is demonstrated through three pilot sites. Section 6 outlines a roadmap for implementation of NbS, as well as further recommendations for flood mitigation actions. And finally, the main conclusions are summarized in Section 7.

2. NATURE-BASED SOLUTIONS - A NEW PARADIGM



Source: Ramboll

Although there is no unified definition of Nature-based Solutions, there is a shared understanding of the NbS concept to encompass the use of nature to target environmental, social, and economic challenges. The EU Research and Innovation policy agenda on Nature-based Solutions and Re-naturing Cities defines NbS to societal challenges as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions"[4].

2.1 NATURE-BASED FLOOD MITIGATION

In the context of flood resilience, we conceptualize NbS first and foremost as Infrastructure, just as any other type of urban/flood infrastructure in urban environments. NbS are therefore engineered solutions that mimic nature, connecting urban hydrological functions and permeable recreational spaces, with wider urban design and planning benefits. NbS can address typical drainage issues such as water quality and extreme flooding, while generating social and environmental value for local areas. A nature-based approach for stormwater management promotes resilience and sustainability through terrain-based solutions and offers an economical and sustainable option for communities to cope with the challenges of climate change. A multifunctional, and highly adaptive network of terrain-based solutions in combination with traditional stormwater infrastructure can mitigate flooding, while improving overall liveability in Baguio.

The functional requirements of these systems are to capture, convey, and where possible store (retain or detain) stormwater. Natural water treatment functions are embedded in storage and conveyance systems to minimize needs for downstream treatment and improve local water quality. A nature-based approach alters the local water cycle in a systemic way that benefits health and biodiversity for flora and fauna, while improving quality of life for all (Figure 2-1). When describing NbS, the term NbS typology is used to describe a combination of hydraulic elements (e.g., bioswale, permeable pavement, detention basin etc.) each comprising specific hydraulic functions (e.g., conveyance, cleansing, detention, retention etc.).

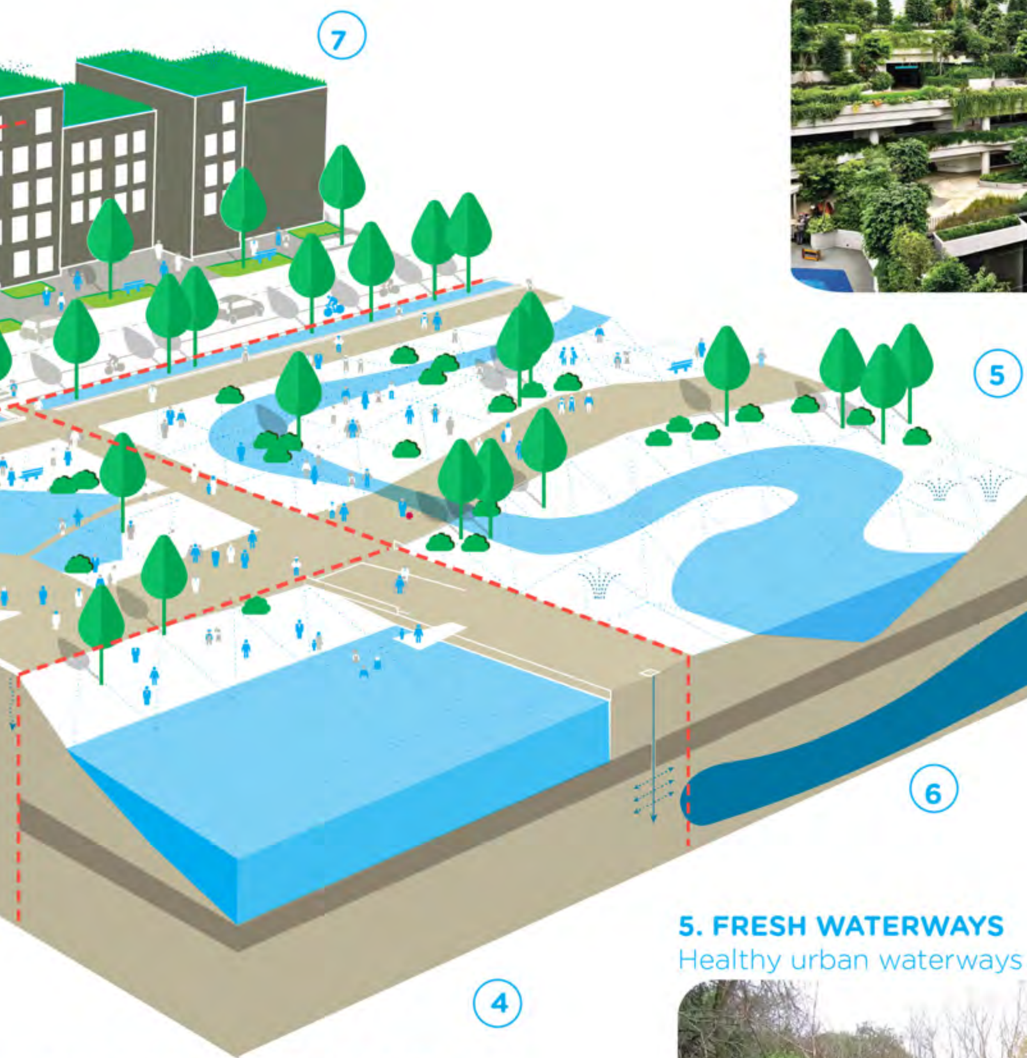
NbS can be applied at various scales and differ in size depending on the available space and location in the catchment. When NbS is considered as a common and accepted approach across the community and government agencies, the broad cumulative of NbS can be realized. In cities such as Copenhagen, New York, and Singapore, where water is now at the forefront of urban and infrastructure planning, NbS is driving an urban transformation and a positive societal change. Locally in Baguio, NbS can contribute to mitigating multiple urban challenges, bring about long-lasting socio-economic benefits and address climate justice.

In simple terms, flood mitigation based on NbS can be designed with **centralized** or decentralized components, each with their own specific benefits and limitations. A **centralized** system is centered around few major retention/detention areas, often characterized as partially permanent water bodies in the public realm. The focus of a centralized strategy is to convey water to these main storage areas for both water quantity and quality control. A **decentralized** system is characterized by many small, interconnected retention/detention areas distributed relatively even throughout a neighborhood. The system is characterized by few or no permanent water bodies as part of the stormwater system and typically rely heavily on multifunctional spaces to fulfil the role of stormwater detention and provide an extended treatment train for water quality control. It is recommended to prioritize NbS on government-owned sites to facilitate streamlined management and maintenance. A decentralized system of connected terrain based NbS combining multiple hydraulic functions is depicted in Figure 2 2.

4 European Commission. Nature-based solutions.

Figure 2-1 Typical concepts and benefits of implementing NbS throughout the urban landscape.

Source: Ramboll



7. GREEN ROOFS

6. RECHARGED AQUIFERS
Reliable drinking supply

5. FRESH WATERWAYS
Healthy urban waterways

4. HEALTHY WATERFRONTS
Active & clean urban canals

2.2 SOCIO-ECONOMIC BENEFITS AND CO-BENEFITS OF NBS

NbS can deliver flood risk management benefits comparable to those of a technical solution at typically lower costs. These include avoided damage to property (direct damage to buildings and household inventory and cleanup costs, indirect losses such as those associated to permanent evaluation or loss of income, and intangible losses such as mental health loss of community), as well as avoidance of road traffic disruption, flood recovery costs, damage to utilities, deaths, and injuries (See Figure 2-3).

Whilst their business case is largely dependent on the spatial scale and implementation context, examples of successful implementation are increasing in the literature.[5, 6]

In a flood mitigation context, the term NbS is generally used to describe how nature can be mobilized to render urban areas more resilient to the threat of climate change, while providing additional co-benefits in relation to climate resilience, water management, green space management, ecosystem restoration and biodiversity, air quality, place regeneration and liveability, knowledge and social capacity building, social justice and cohesion, participatory planning and governance, health and wellbeing and new economic opportunities and green jobs. However, the nature and magnitude of the co-benefits are context dependent and conditioned by the scale, design, and location of the NbS (see Figure 2-4).
By mapping and prioritizing the societal challenges and co-benefits against the potential solutions that NbS can bring and implementing a robust decision-making framework that incorporates those priorities along the process, co-benefits can be maximized through policy and planning. This process enables the selection of the most suitable locations and NbS typologies that deliver the greatest amount of the intended co-benefits, and the optimization of design and implementation. Outcomes can be strengthened through a participatory process that enhances support for the intervention and the social value it delivers, particularly when vulnerable and under-represented groups are involved, and contributes to improve design and implementation.

5 F. Turkelboom, R. Demeyer and L. Vranken. 2021. *How does a nature-based solution for flood control compare to a technical solution? Case study evidence from Belgium*. Ambio 50.

6 C. Spyrou et al. 2021. *Evaluating Nature-Based Solution for Flood Reduction in Spercheios River Basin under Current and Future Climate Conditions*. Sustainability, p. 3885.

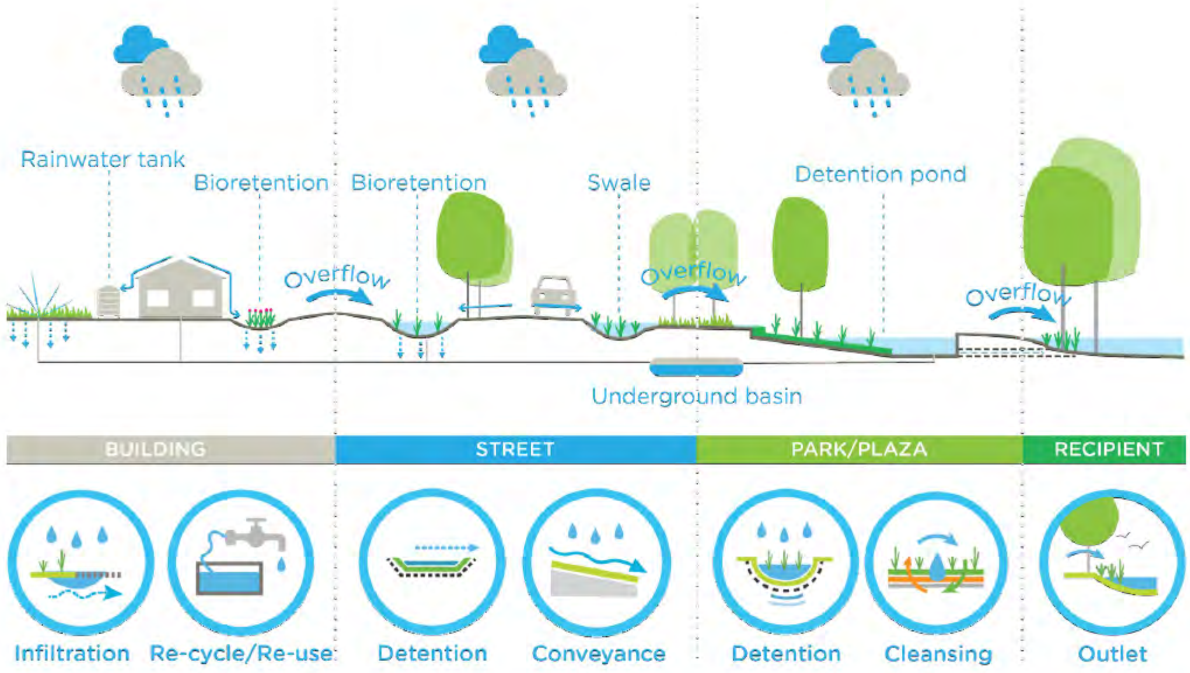


Figure 2-2 Decentralized conceptual system of connected NbS from building to recipient.
Source: Ramboll

Figure 2-3 Avoided damages from direct, indirect, and intangible flood mitigation benefits of NbS
Source: Ramboll

Rationalizing, measuring, and monetizing the benefits and wider co-benefits provided by NbS enables the assessment of the business case of each individual NbS in its own merit, as well as a comparison across alternative NbS alternatives. Lifecycle costs for the NbS (planning, implementation, operation, maintenance, and financing) expressed in net present value (NPV) terms can be directly compared with the NPV of the flow of benefits and co-benefits anticipated over the same time period.

Valuation of material co-benefits is important for a full understanding of the wider societal impacts (positive and negative) that NbS can bring, thus enabling a comparison of the trade-offs across alternative locations or designs, and the selection of the optimal alternative. Valuation can be conducted using a range of environmental economic and social valuation techniques, including amongst others market data, hedonic pricing, or benefit transfer approaches.

Typically, NbS have a different spatial effect on flood risk and operate at different time frames for delivering flood risk benefits relative to conventional infrastructure. In addition, NbS result in co-benefits, provide additional flexibility, are more robust in dealing with a changing environmental and climate, and have a different cost structure (i.e., lower investment costs but potentially higher operations and management costs). Therefore, temporal scope and the choice of discount rate are relevant considerations when scoping cost benefit analysis (CBA) for NbS.[7]

Figure 2-4. Potential co-benefits of NbS
Source: Ramboll

7 ADB. 2019. *Protecting and Investing in Natural Capital in Asia and the Pacific.* Consultant's report. (TA-9461)

Source: Adobe Stock

3. FLOOD MITIGATION APPROACH

Source: Adobe Stock

The approach followed in preparing this conceptual high-level flood mitigation action plan for the city of Baguio, is composed of three overarching elements: i) defining the vision for nature-based flood mitigation, driven by a set of climate adaptation principles and adaptation typologies; ii) aligning the action plan with both existing development plans in Baguio and international best practices; and iii) integrating technical and non-technical assessments through holistic development of typologies and conceptual demonstration at pilot-site level. This overall approach is based on a close communication with the LGU, to ensure local anchoring and validation of assumptions and outputs.

3.1 VISION FOR FLOOD MITIGATION IN BAGUIO

The vision for nature-based flood mitigation in Baguio is viewed through a lens of inherent sustainability, where terrain- and nature-based solutions are connected throughout the city to mimic a natural system. The key characteristics of the vision for flood mitigation are the reliance on natural solutions to manage stormwater flows and improve ecological conditions by incorporating technologies proven to yield direct risk-reducing benefits. The vision also intends to achieve a high level of water circularity, through rainwater harvesting and reuse, and to provide resilient planning and infrastructure that reduces the risk of flooding both in current and future climate conditions. Based on this vision, the Flood Mitigation Action Plan aims at presenting innovative solutions that are appropriate to the territorial and socio-economic complexity of Baguio City, to promote benefits beyond climate adaptation and resilience and to ensure inclusive and green urban spaces that promote health and quality of life for all citizens.

At the backbone of the Flood Mitigation Action Plan there is a set of high-level climate adaptation principles which guide the overall vision and objectives and steer the process (See Figure 3-1). These principles, follow good adaptation practices in both developed and developing cities and enable the development of typologies that show the benefits of adaptation solutions.

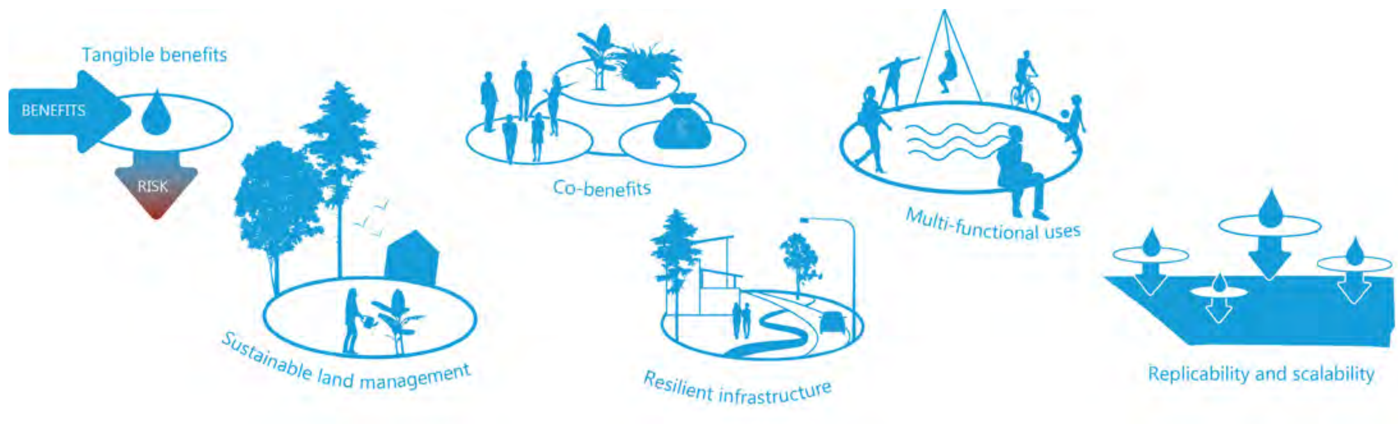


Figure 3-1 Vision for NbS as a tool for flood mitigation in Baguio
Source: Ramboll

- Tangible benefits: development of typologies incorporating best-practice technologies proven to yield direct risk-reducing benefits, for instance water-related benefits (improved quality through e.g. filtration; and improved quantity control through e.g. detention) or slope stabilization benefits (reduced erosion through e.g. vegetation management)
- Co-benefits: This principle embraces the environmental, social, and economic impact of climate adaptation solutions contained in the typologies, e.g. improved air quality, physical health, improved mobility, etc.
- Resilient infrastructure: flexibility and reliability across a range of environmental and future conditions, as well as continuous provision of co-benefits to enhance people's lives, secure development gains and drive positive change.
- Sustainable land management: Utilization of the existing topography and inclusion terrain-based principles, to the greatest extent possible, and a broad focus on green land management approaches, including land uses on slopes and rehabilitation considerations.
- Multifunctional uses: incorporating multiple purposes by diversifying urban components, connecting urban planning, landscape design, water management and urban ecology in typologies that help visualize a possible future and communicate the need to adopt a multidisciplinary approach to realize that future.
- Replicable and scalable: Ensuring replicability and scalability of solutions at various locations and scales across Baguio City.

3.2 COHESION WITH DEVELOPMENT PLANS FOR BAGUIO AND INTERNATIONAL BEST-PRACTICES

Baguio City is in continuous development. The city government is actively taking steps to improve mobility, urban cohesion, infrastructure and livability through plans, projects, and initiatives. The Flood Mitigation Action Plan is developed in alignment with and in support of ongoing development plans to foster sustainable and resilient growth.

The local government is currently working on the 'Green Walks' initiative. The Green Walks concept aims at creating green landscape connections throughout the public realm and features landscaping and streetscaping with sidewalk and road improvements.[8] Currently, plans are being prepared for a Green Walk to be implemented along the Central Business District, starting with one of Baguio's main streets, Session Road.

8 Correspondence with Arch. Donna G. Rillera-Tabangin, Enp, City Planning And Development Office. 9 November 2021.

Similarly, the ‘Blue Walks’ initiative, which was launched in November 2021, aims at creating a connective network of walks along rivers/canals with specific focus on restoration, conservation, education and co-existence initiatives with the citizens. The aim is to implement solutions that restore the rivers and organize clean up drives, discovery walks, water quality and quantity surveys, and waterway tours; all contributing to returning the biodiversity of the waterways.[9]

The ongoing Urban Mobility Plan 2021-2030[10] is geared towards micro-mobility together with improvement of public transportation. The mobility plan includes initiatives such as ‘car-calmed zones’, electrical vehicle charging and parking, pedestrian networks, alternative transport modes, and bike networks. This is closely linked with the Green Walks initiative and focuses especially on areas connecting major parks, tourism sites, and the City Business District. Furthermore, the City has implemented the Public Utility Jeepney (PUJ) Modernization program where old units will be replaced by no-emission Euro 4 vehicles. A Local Public Transportation Route Plan is also being developed as a way to decongest the Central Business District. Establishment of an integrated transport terminal has been initiated at the city outskirts for provincial buses, to limit buses entering the city.

The local government is working on a strategy for implementation of Food Coops (Barangay Satellite Markets) at Barangay scale across Baguio. The vision for a Satellite Market is described as ‘a community-owned food outlet that share decisions on how food is sourced, produced, bought, and disposed sustainably, making sure that food is local, fresh, and affordable, and where income and surplus stays within the community’.[11]

Several improvements to the area in and surrounding Burnham Park are proposed in the ‘Burnham Park Master Development Plan’ expected to be implemented by 2030. The proposed plan includes e.g. forest conservation areas, recreational facilities, food park, skating rink.[10]

The LGU is currently assessing reclamation of easements along river banks.[12] This would entail the potential clearing of up to 3m easement zones, as structures built in this area are typically the result of uncontrolled urban expansion and thus not legally approved. Implementation of easement zones along the major drainage canals would provide greater opportunities for transformation of the canal including implementation of ‘Blue Walks’.

9 City of Baguio - City Environment and Park Management Office. 2021. *Project Proposal: Baguio Blue Walk Project*. Baguio City.
10 City of Baguio. *The Burnham Park Master Development and Urban Mobility Plan 2021-2030*. Baguio City.
11 City of Baguio. n.d. *Food Coops - Barangay Satellite Markets*. Baguio City.
12 Correspondence with Arch. Donna G. Rillera-Tabangin, Enp, City Planning And Development Office. 25 November 2021.

Furthermore, plans for development, expansion, and maintenance of the drainage network of Baguio City are currently under development. According to the City Government of Baguio[13] preparation of a short-term development plan for the city's drainage system is underway and works are also underway for the preparation of a medium and long-term development plan.

As evident from the above, there is a strong drive towards integrating NbS in Baguio and improvement of infrastructure and thus, the vision of the Flood Mitigation Action Plan is aligned with the aims and expected outputs from ongoing initiatives and plans. The ambitions of the ongoing plans are aligned with co-benefits of the Flood Mitigation Action Plan, i.e., collect surface water, restore waterways, promote social cohesion, and engage the community.

Figure 3-2 The Green Walks initiative aims at creating green connections in the public realm utilizing streets as attractive spaces for active mobility.

Source: Conceptual graphic from 'The Burnham Park Master Development and Urban Mobility Plan 2021-2030' [10].

13 The City Government of Baguio. 2021. [5-year master plan for city's drainage system underway](#).

In addition to the above mentioned local urban plans and initiatives for Baguio, the following guidelines and scientific literature were reviewed to ensure alignment with international and national best-practices:

- ADB. 2016. *Nature-based solutions for building resilience in towns and cities*.
- Department of Public Works and Highways (DPWH). 2015. *Design guidelines, Criteria & Standards Volume 3, Water Engineering Guidelines*.
- Department of Public Works and Highways (DPWH), Japan International Coorporation Agency (JICA). 2003. *Manual on Flood Control Planning*.
- Department of Public Works and Highways (DPWH), Japan International Coorporation Agency (JICA). 2002. *Technical Standards and Guidelines for Planning and Design*.
- New York State. 2015. *New York State Stormwater Management Design Manual.*
- Office of the President of the Philippines. 1975. *Presidential Decree No. 705.* Manila.
- Office of the President of the Philippines. 1985. *Presidential Decree No. 1998* Manila.
- Public Utilities Board Singapore. 2018. *Active, Beautiful, Clean Waters, Design Guidelines*. Singapore.
- T.S. Bridges et al. 2021. *International Guidelines on Natural and Nature-Based features for Flood Risk Management.* U.S. Army Engineer research and Development Center.
- UNINA. 2019. *Comprehensive Framework for NBS Assessment*. Phusicos.
- Urban Nature Labs. 2019. *Nature Based Solutions – Technical Handbook Pat II.*
- U.S. Environmental Protection Agency. 2014. *Addressing Green Infrastructure Design Challenges in the Pittsburgh Region*.
- WHO. 1991. *Surface Water Drainage for Low-Income communities*.
- Ramboll and C40. 2021. *Climate Adaption Guide for Rio De Janeiro*.

3.3 INTEGRATED APPROACH: DEVELOPMENT, DEMONSTRATION, AND ROADMAP

Several conceptual flood mitigation strategies can be proposed for Baguio, both considering the complex spatial context and strategies for managing stormwater, and specific conditions for each sub-catchment within the city. As Baguio is characterized by high building densities and limited open spaces, a decentralized approach to flood mitigation (see Section 2.1) is recommended to match the characteristics of the Barangays and neighborhoods (e.g., topography, space limitations, massing). This will be expressed as a connected system of smaller interventions that utilizes the available spaces optimally and when combined creates a flood mitigation system that meets the demands of the city.

Our approach will rely mostly on NbS with hydraulic functions embedded for managing stormwater quantity and improving stormwater runoff quality reaching recipient water bodies. These solutions will be supported by traditional grey infrastructure where there are significant constraints on surface-based infrastructure, or where existing infrastructure is already in place and should be utilized so it does not become a redundant investment. The system of solutions should be developed as a strong green fabric or network which binds Baguio together. It should achieve connectivity between sites across the city. Connectivity may not always mean a direct physical connection between sites, although a physically connected network should be a priority and may be established over time.

The nature-based flood mitigation action plan in Baguio will be developed in three primary steps:

1. Development of a NbS toolbox of typologies designed specifically to meet the challenges and utilize the opportunities identified in Baguio (described in Section 4)
2. Demonstration of the applicability of the NbS toolbox for three pilot sites (described in Section 5)
3. Preparation of a roadmap for implementation of typologies (described in section 6)

Figure 3-3 details the approach applied in the primary steps. While the implementation of the mitigation measures recommended at the scale of individual pilot sites will have direct and immediate benefits when implemented, the toolbox typologies should be applied similarly across Baguio at city-wide scale to gain the full effect of the nature-based approach with interconnected systems that fulfil different hydrological and hydraulic purposes such as conveyance, treatment, storage, and infiltration.

The flood mitigation action plan is a high-level conceptual action plan. The conceptual design for pilot sites is presented and will need to be detailed further in upcoming phases. To guide the path from development to implementation, a road map for implementation is presented. As the designs in this report are conceptual, the hydraulic and socio-economic assessments are conceptual in their nature. As the technical and engineering components are refined in upcoming phases and survey results are collected, the methodology presented in this report will enable comparison of the socio-economic trade-offs across locations and/or designs. Extensive drainage and socio-economic field surveys will be required in upcoming phases, which are currently hampered by the on-going Covid pandemic, and expand beyond the scope of this deliverable.

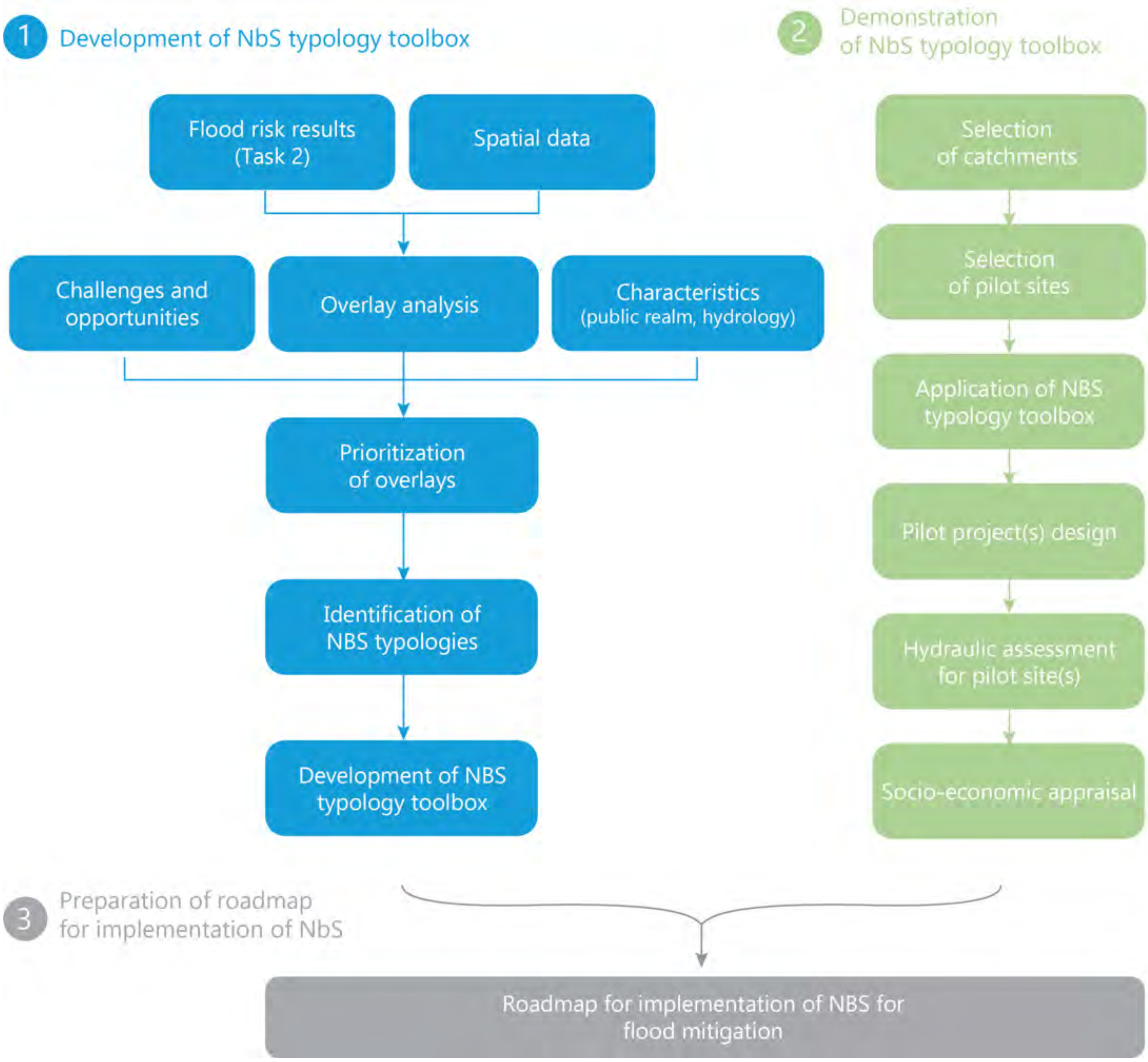


Figure 3-3 The primary steps in the approach for the development of the flood mitigation action plan for Baguio City.

Source: Ramboll

An overarching principle in the flood mitigation approach is inclusion of locally anchored knowledge and experience, which is realized through close collaboration with the LGU. Several meetings were held with LGU representatives to ensure alignment with current priorities and validation of proposed methods and designs. As part of the local engagement, a 'Development of NbS typologies for Baguio City' workshop was facilitated on November 11, 2021 with approximately 10 people from different organizations including several departments within the LGU. The findings and methodologies of this report were presented and discussed in an interactive and participative setup during the workshop, which also allowed participants to learn about NbS and their benefits.

4. SOLUTIONS FOR FLOOD MITIGATION IN BAGUIO

Source: Asian Development Bank

4.1 ASSESSMENT OF SPATIAL AND SOCIO-ECONOMIC CONTEXT

To develop holistic flood mitigation solutions tailored to the unique context of Baguio maximizing benefits beyond flood risk reduction, it is necessary to understand the spatial and socio-economic layers comprising Baguio City. Central to the NbS vision for Baguio is multifunctionality. The lens of multifunctionality can overcome multiple challenges in one integrated solution and transform these into opportunities for enhanced liveability. Solutions are designed to address numerous challenges and create added value. Hence, it is important to look beyond the hydrological and hydraulic characteristics of the catchment and assess potential synergies with other urban systems to allow for holistic and integrated flood mitigation planning that maximizes co-benefits for all.

4.1.1 CHALLENGES AND OPPORTUNITIES

Understanding the existing and future challenges and opportunities that may emerge in Baguio is key to ensuring robust design of mitigation measures. These should not be limited to flood risk related themes, but also assess social, economic, structural, or institutional themes. The LGU has undertaken a SWOC analysis[14] to identify Strengths, Weaknesses, Opportunities, and Challenges (SWOC) within urban planning in Baguio. Figure 4-1 shows weaknesses/challenges and opportunities of key importance for the Flood Mitigation Action Plan extracted from the SWOC analysis as well as additional themes identified by the project team.

Many of the challenges and opportunities identified by the LGU in the SWOC analysis speaks directly to the vision and aim of the Flood Mitigation Action Plan. The urban challenges identified include climate and natural hazard threats but also accessibility, quality of public services and amenities, growing population, inclusiveness, and social justice. Overcoming these challenges requires a holistic approach focused on integrated solutions. Assessment of the broad range of challenges allows for prioritization of multifunctional solutions that specifically address these by including e.g., shifts in mobility patterns, connectivity, new suggested bike paths, green and recreational areas, etc.

Specifically related to water, Baguio faces challenges related to both water quality and quantity, with water quality issues, lack of runoff management, accumulation of waste in rivers, and depleting water supplies. Poor water quality is a great challenge with the rivers currently being used for discharge of wastewater, although the magnitude of wastewater flows to the rivers is unknown. Waste in rivers further deteriorates water quality, while significantly decreasing river conveyance and increasing flood risk, when debris and waste is accumulating at bridges and weirs. Any waste that is not disposed properly in a catchment can eventually reach a river. In urban areas, trash and litter often are transported by stormwater runoff. Waste disposal accumulated on riverbanks is mobilized and flushed into the water system in case of heavy rainfall. Furthermore, waste is often illegally dumped directly in the rivers as means of quick disposal. Due to the significant impact on conveyance in rivers, this challenge is highly important to address to ensure the full potential of the flood mitigation action plan is achieved.

14 Baguio City Local Government Unit. 2021. *Situational Analysis (SWOC) draft.*

As evident from Figure 4-1, multiple additional opportunities for enhancement of values in the urban realm in Baguio have been identified. These opportunities are highly related to co-benefits of nature-based solutions, further described in section 4.1.4.

Figure 4-1 Urban challenges and opportunities in Baguio City

Source: Ramboll, based on LGU SWOC Analysis[14]

OPPORTUNITIES

IDENTIFIED BY THE CITY

- Rainwater may be stored or recycled for domestic/outdoor use
- Linkages with academic, research institute, business, professionalorg. (resources, assistance, studies)
- Resilient infrastructure
- Adoption of new/best practices and technologies from local and international places

ADDITIONAL OPPORTUNITIES

- Increase tourism
- Enhance local identity
- Create new destinations for residents and visitors
- Local food production
- Comfortable Micro-climate
- Social inclusion
- Improved air quality
- Noise reduction
- Recreational spaces
- Educational spaces
- Increased biodiversity
- Enhancement of feeling of safety
- Multifunctional public spaces
- Physical health improvement
- Improved water quality
- Sustainable soil management

4.1.2 CATCHMENT HYDROLOGY CHARACTERISTICS

Critical to the design of a connected system of NbS across the city and the calculations of storage requirements, is the delineation of sub-catchments. Sub-catchments can be delineated both in accordance with the existing underground stormwater infrastructure or based on the natural overland flows. Often a mix of the two will be relevant when designing the flood mitigation system, as it is connected to the existing (and future) underground drainage system and will need to respect existing catchments, flow directions and outlet capacities. When planning the connected system of solutions, division into sub-catchments assists in breaking the complex challenge of flood mitigation into smaller parts, making it easier to tackle. Thus, sub-catchments allow for localized assessments of hydrologic and hydraulic conditions and design of smaller scale connected flood mitigation networks that meet the required sub-catchment storage capacity.

As part of the flood mitigation action plan, the four major river basins in Baguio are divided into sub-catchments based on natural overland flows. The existing underground infrastructure is not considered for catchment delineation due to the steepness of the slopes and identified gaps in drainage data, as outlined in Section 1.7. The overland flow sub-catchments are delineated using a GIS-based approach by applying the hydrology toolset, defining outlets or ‘pour points’ at junctions of streamlines derived from flow accumulation. The streamlines are indications of the primary flow paths following the natural topography of the existing terrain. Figure 4-2 shows the overland streamlines and sub-catchments delineated.

When applying a holistic approach to flood mitigation planning, an assessment of the entire sub-catchment is recommended, and focus should not be limited to the most-at-risk areas within the sub-catchment. It may be feasible to implement flood mitigation measures to store and slow-down runoff in the upstream and less flood-prone areas of the sub-catchment, to reduce downstream flood risk. Utilizing the results from the flood risk assessment in Task 2[3], the sub-catchments with moderate to very high flood risk (bigger than 1 ha) are identified, see Figure 4-3.

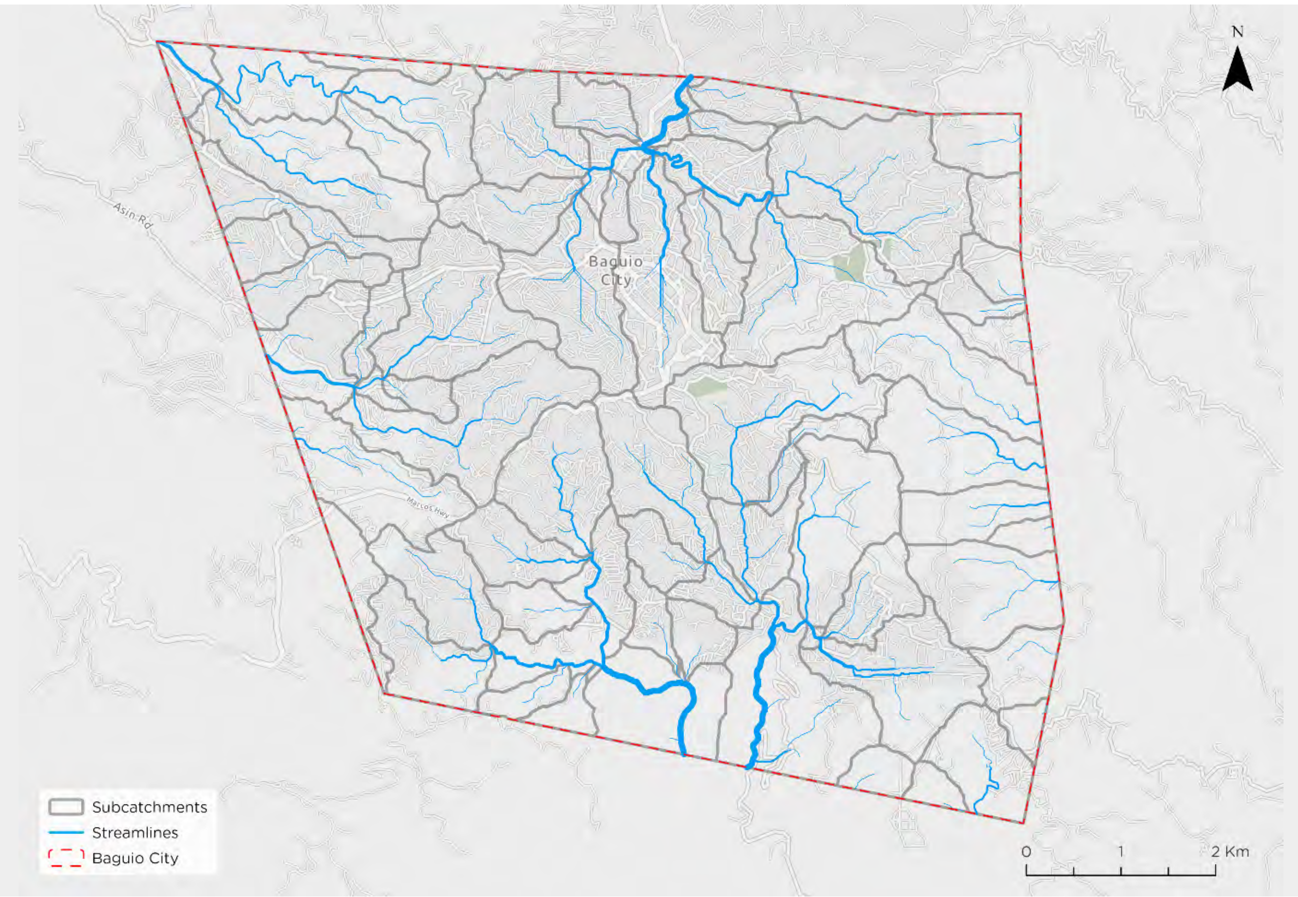


Figure 4-2 Overland streamlines and natural overland sub-catchments
Source: Ramboll

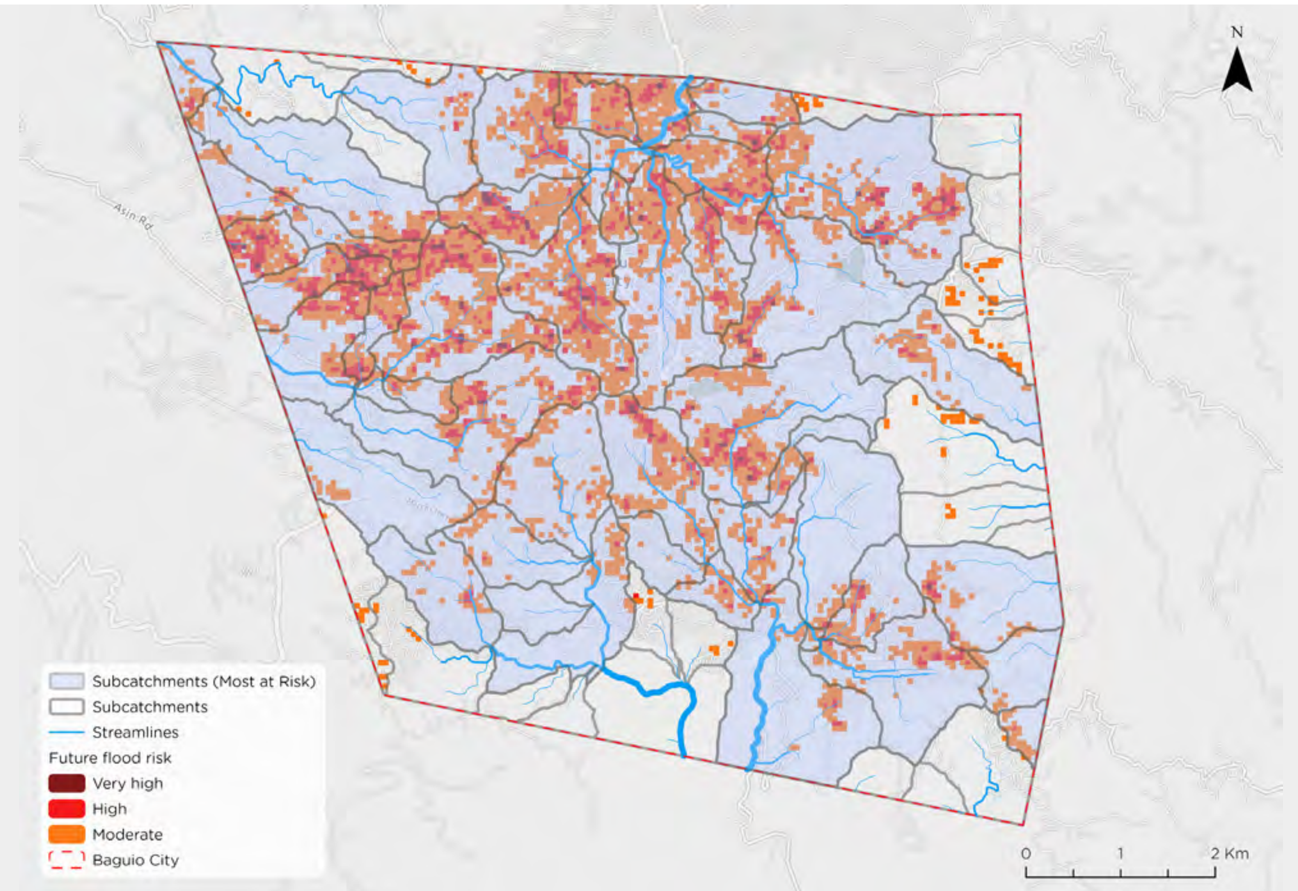


Figure 4-3 Sub-catchments with moderate to very high flood risk.
Source: Ramboll

4.1.3 PUBLIC REALM CHARACTERISTICS

Analyzing the public realm and assessing available space limits is crucial to understand the emerging special similarities in an urban landscape. Baguio City comprises a densely built-up urban realm that follows the mountainous topography and results in a predominantly irregular pattern of property lots and winding roads. Furthermore, this pattern is amplified by informal settlements expanding in the outskirts, hilltops, or river easements. There are a few areas, located mainly in valleys, that follow a clearly defined, rectangular plan.

The resulting available space for flood mitigation solutions is therefore defined by both natural and urban elements represented by rivers/streams, roads, and open spaces.

Baguio has a rich stream network that can be divided in two categories. The first category is represented by narrow, low flow streams located in the hill areas, in the outskirts of the city. These streams form narrow canals in between private lots or have informal settlements built on top of them. The second category is characterized by wide, deep canals crossing urban areas. In these areas, the easements are built up to the canal edge. The canals in Baguio have a purely functional character as drainage canals; they flow within built concrete infrastructure and have no public space amenities or ecological value.

The roads in Baguio are typically narrow, two-lane roads with undefined parking and sidewalks. At neighborhood level, small, one-lane access roads are common. The national roads in the city are generally larger, have four lanes and occasionally lane dividers when crossing large intersections or commercial areas.

Except for the national parks, the open space in Baguio is limited. At neighborhood level, there are basketball or football fields and very few small parks. Other types of open space found in Baguio are large sport facilities and agriculture lands.

An image-based analysis, showcasing examples of available public space, is undertaken to map the above-mentioned characteristics of the public realm in Baguio (Figure 4-4). The analysis represents a first step in understanding space functionality and emerging urban patterns within the public realm to identify areas with similar characteries where typologies may be applied and replicated across Baguio.

4.1.4 CO-BENEFITS OF NBS IN BAGUIO

Building on the results of the SWOC analysis undertaken by LGU (see section 4.1.1) and, in order to inform the design of the NbS typologies, a survey was conducted to identify the co-benefits more highly valued by the Baguio LGU. The survey took place in the context of the workshop on the Development of NbS typologies for Baguio City on November 11, 2021. The survey focused on overall opportunities offered by NbS and not around a particular NbS typology or location. The survey results are presented as Figure 4-6.

Overall, livability was the most highly valued co-benefit (5 votes), followed by habitat creation and ecological connectivity (4 votes each). Mobility and traffic, recreational green space and groundwater restoration were the third most valued categories (3 votes each), followed by tourism and reduced soil erosion (2 votes each).

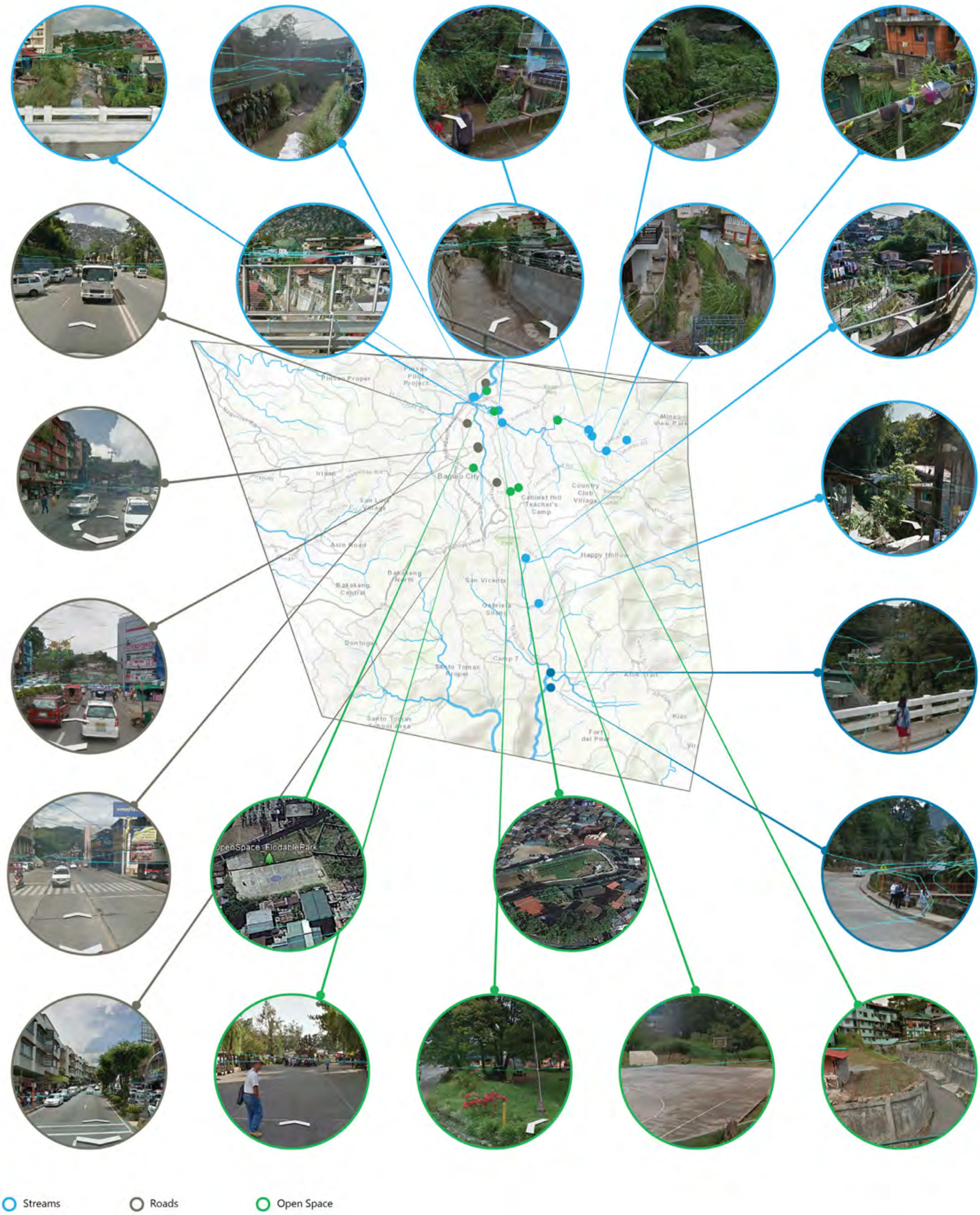


Figure 4-4 Examples of public space in Baguio
Source: Ramboll, images from Google Earth

On the other end of the spectrum, new businesses, property/land value, social interactions and community, visual amenity, participatory governance, health and wellbeing, air quality, carbon sequestration and rainwater harvesting (1 vote each) and water-based recreation, social justice and inclusion, educational value, community food gardens, microclimate regulation and reduced noise pollution (0 votes each) where the least valued co-benefits by the LGU.

4.1.5 SPATIAL OVERLAY ANALYSIS

A GIS-based overlay analysis utilizing the existing spatial data that is available for Baguio, as well as the results from the flood risk assessment in Task 2, is undertaken to identify 'zones' with similar characteristics where nature-based solutions can be applied. A 'zone' is defined as an area with a unique combination of spatial data. Inclusion of the risk results in the spatial overlay analysis allows for identification of areas where there is a need to mitigate, whereas inclusion of additional spatial data related to physical characteristics, allows for identification of areas where solutions can be implemented. Thus, the aim of the analysis is to identify areas that allow replicability of mitigation solutions in various locations city-wide.
In the overlay analysis for Baguio, four types of spatial data on hazard and risk, topography, land type, and infrastructure are included, as shown in Figure 4-5.

One of the challenges of urban development in Baguio is the steepness of the terrain. In large areas of Baguio, the slopes of the terrain are very steep which limits areas suitable for new developments and urban expansion. In the Philippines, the national guidelines state that "no land of the public domain eighteen per cent (18%) in slope or over shall be classified as alienable and disposable"[15] Baguio, and the entire province of Benguet, was exempted from this rule by the Minister of Natural Resources following the publication of Decree 1998,[16] for areas that are to be "developed for agricultural crops using effective erosion control practices or measures like terracing; and/or established and developed townsite within barangays or communities where basic structures, e.g., roads, schools, church are already existing". However, the LGU has expressed wishes to comply with the national guidelines[15] for all future development and planning. Furthermore, a review of international best-practices for NbS on steep slopes, identifies 25% as the maximum slope application of nature-based stormwater management. With these considerations in mind and to further promote sustainable land management practices, areas below 18% in slope will be higher prioritized for typology development.

Figure 4-5 Spatial data included in the GIS-based overlay analysis to identify areas for NbS typology application.
Source: Ramboll

15 Office of the President of the Philippines. 1975. Presidential Decree No. 705. Manila.
16 Office of the President of the Philippines. 1985. Presidential Decree No. 1998 Manila.

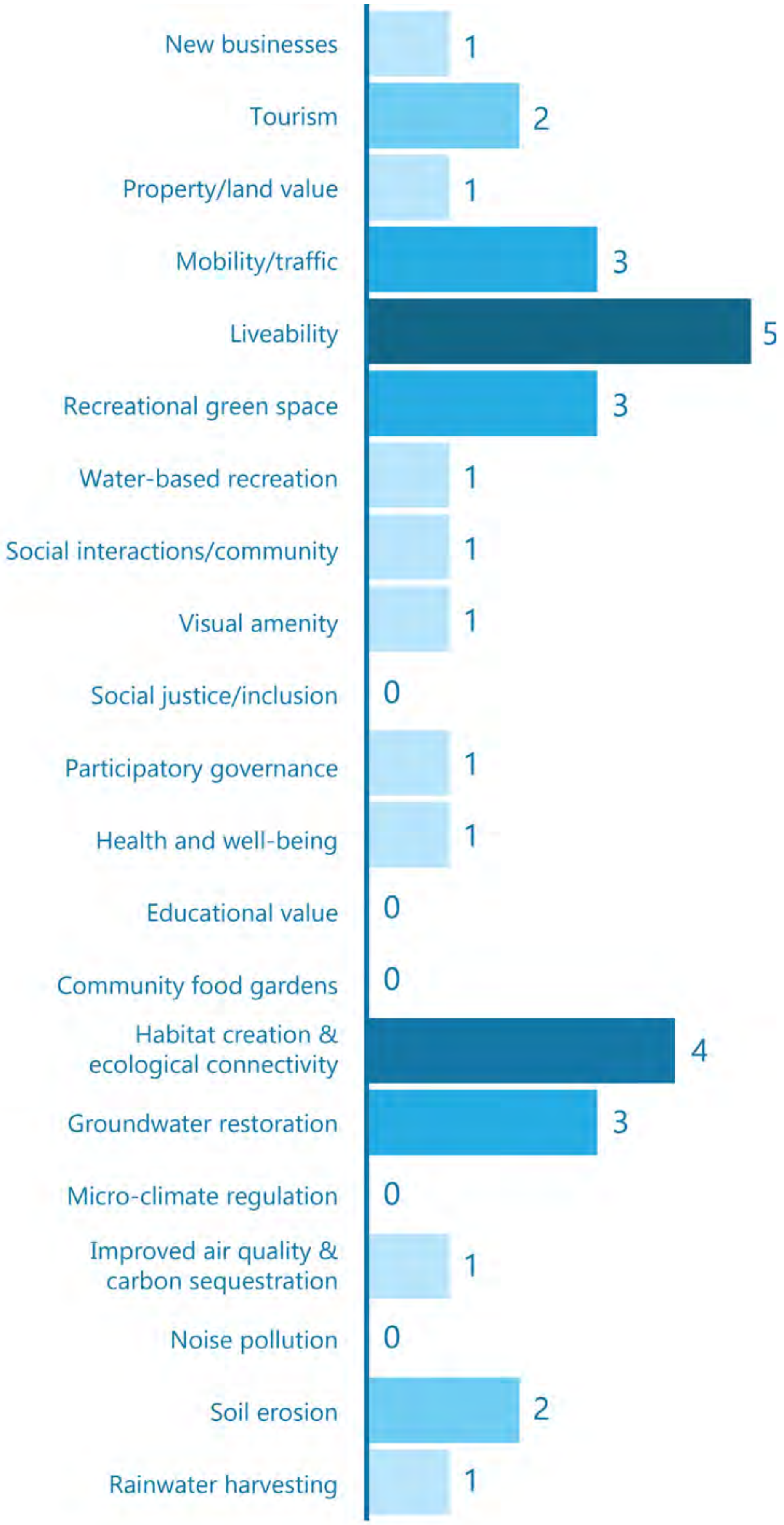


Figure 4-6 Survey results on the highest valued co-benefits in Baguio City.
Source: Ramboll

A prioritization exercise of 'zones' was undertaken to develop typologies based on the following:

- Cohesion with vision for the Flood Mitigation Action Plan as well as ongoing initiatives, guidelines and plans for Baguio
- Wish from LGU to comply with the national guidelines[15] stating that no land above 18% shall be developed.
- Determination of dominating overlays; Some overlays have much larger city coveragethan others and could deserve multiple typology development.
- Expert knowledge and international best-practice guidelines of NbS applicability.
- Identification of areas that allow replicability of the solutions in various locations in the city.

The structure of the overlay analysis as well as the prioritized zones are outlined in Figure 4-7. The prioritized zones consist of a combination of risk, topography, land type and infrastructure and have been validated by LGU to ensure integration of local knowledge and experience in the typology development.

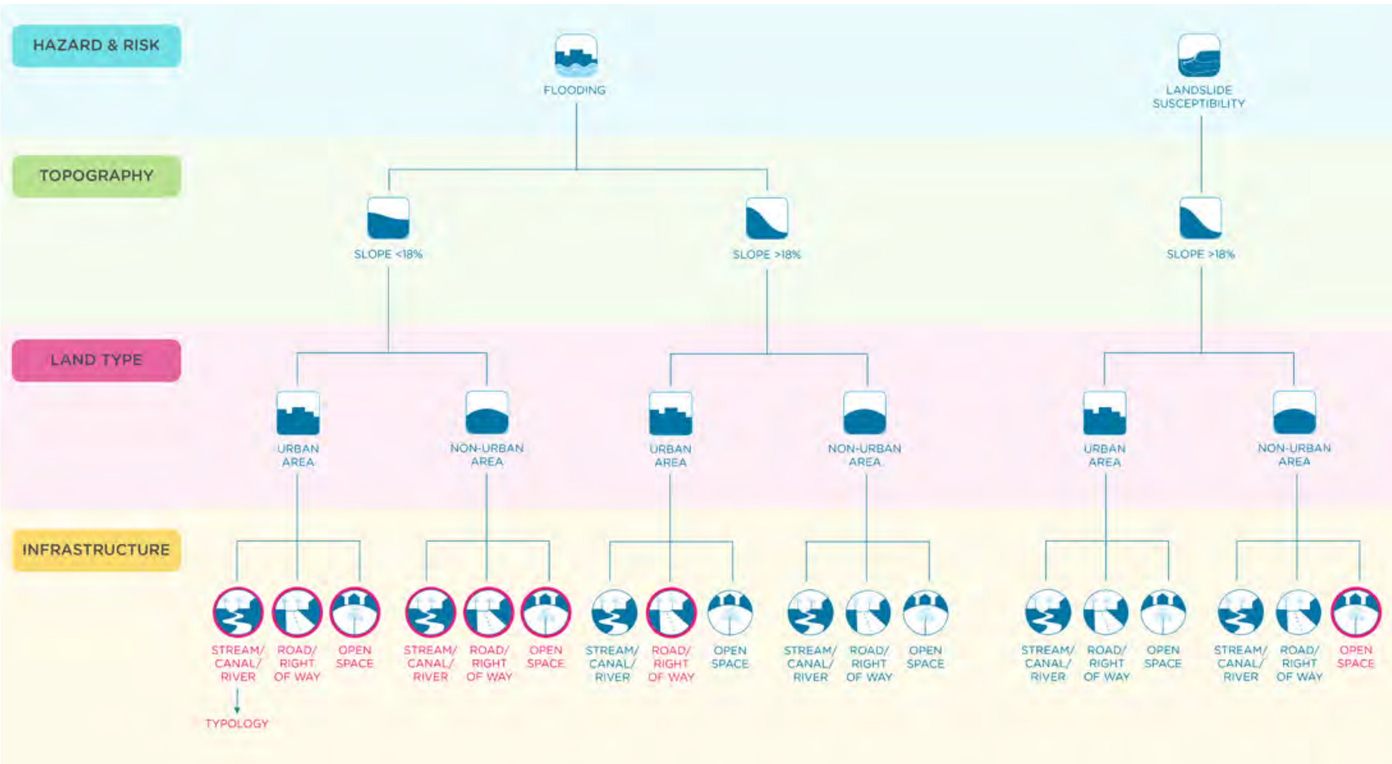


Figure 4-7 Overview of the structure of the GIS-based spatial overlay analysis. The zones prioritized for development of typologies are highlighted in pink, at the bottom of the figure.

Source: Ramboll

4.2 NBS TOOLBOX

As part of the Flood Mitigation Action Plan, a toolbox of nature-based typologies is developed and tailored to the unique public realm of Baguio. The toolbox can have many uses and provides a user-friendly and easy-to-understand narrative to communicate NbS to a broad audience, including experts and the general public.

A typology consists of a combination of hydraulic elements (e.g., bioswale, permeable pavement, detention basin etc.) each comprising specific hydraulic functions (e.g., conveyance, cleansing, detention, retention etc.). Each typology is developed with careful consideration of the complex spatial, social, environmental, and economic context of Baguio City. Typologies are conceptual in their nature. When applying a typology to a specific site, the typology will need to be adapted and the design further detailed to meet the site-specific requirements and context.

The toolbox of solutions consists of 8 typologies suitable for the prioritized spatial zones in the city, following a spatial overlay analysis to ensure city-wide replicability and scalability of flood mitigation measures. The prioritization of zones has been validated by the LGU.

Typologies are developed for the following zones:

1. FLOOD RISK / URBAN AREA / SLOPE < 18 % (Typologies for open space, road, river/canal)
2. FLOOD RISK / NON-URBAN AREA / SLOPE < 18% (Typologies for open space, road, river/canal)
3. FLOOD RISK / URBAN AREA / SLOPE > 18% (Typology for (narrow) road)
4. LAND-SLIDE SUSCEPTIBILITY / NON-URBAN AREA / SLOPE > 18 % (Typology for open area)

Some typologies are applicable in multiple zones. The common denominator in the typologies developed for Baguio is multifunctionality to optimize the use of land, generation of co-benefits, and opportunity for co-financing.

Ultimately, the co-benefits of NbS, along with their potential magnitude, are context dependent and conditioned by the scale, design, and location of the NbS. A full list of potential co-benefits for all typologies is presented in Appendix B. The table in Appendix B represents a long list of co-benefits and can be used to map and screen material co-benefits as part of the planning and design process.

4.2.1 STORMWATER PARK

Stormwater Parks present the greatest opportunity for large retention/detention spaces within urban areas. They can be located throughout the watershed and designed at various scales, from smaller detention areas in pocket parks to larger floodable areas where space is available. Ideally, they are located in natural depressions or low-lying areas and they can provide both temporary stormwater storage volume and include permanent water bodies for quality control. The design elements integrate a combination of various hydraulic functions including, filtration, retention, detention, harvesting and re-use.

The Stormwater Park is designed to manage everyday rain events while maintaining the recreational functions of a park as well as detain larger volumes of stormwater during extreme events through temporary inundation of the park area. Through a natural terrain-based drainage system that offloads the existing underground drainage system, the park handles everyday rainfall events from the immediate catchment area. NbS such as raingardens, bioswales and bioretention basins are integrated in the overall park design for stormwater quantity and quality control and will include local flora and attractive urban furniture that facilitates various leisure activities. Thus, the stormwater park will simultaneously function as recreational space allowing the nearby communities to enjoy the public realm, potential soccer fields, resting areas, etc. The park is designed to provide a comfortable public space for all seasons through a mix of shading elements and low and high vegetation. During extreme rainfall events the recreational areas will be temporarily used for stormwater detention. Rainwater harvesting techniques will be implemented to collect rainwater to be stored in a storage tank and used as non-potable water supply for irrigation. The stormwater park is designed to slowly empty into an existing drainage system after an extreme rainfall event within 24 hours to allow for the recreational activities to resume or to make room for the next rainfall event. The stormwater park might need cleaning after an extreme rainfall event, which can be organized as a collaboration between the local community and the owner of the park i.e. the LGU.

The potential co-benefits accompanying the proposed solution are mostly related to the multifunctionality of the park – recreational area for residents, with both formal and informal seating and games areas, sport facilities and shaded picnic areas. Separate one-way slow traffic lanes could be proposed to encourage a low noise, pedestrian friendly walking environment. Stormwater Parks have the potential to become new destinations for locals and visitors, contribute to tourist attraction, facilitate cohesion of local communities, and improve social life by offering an attractive space and opportunity to enjoy outdoor activities.

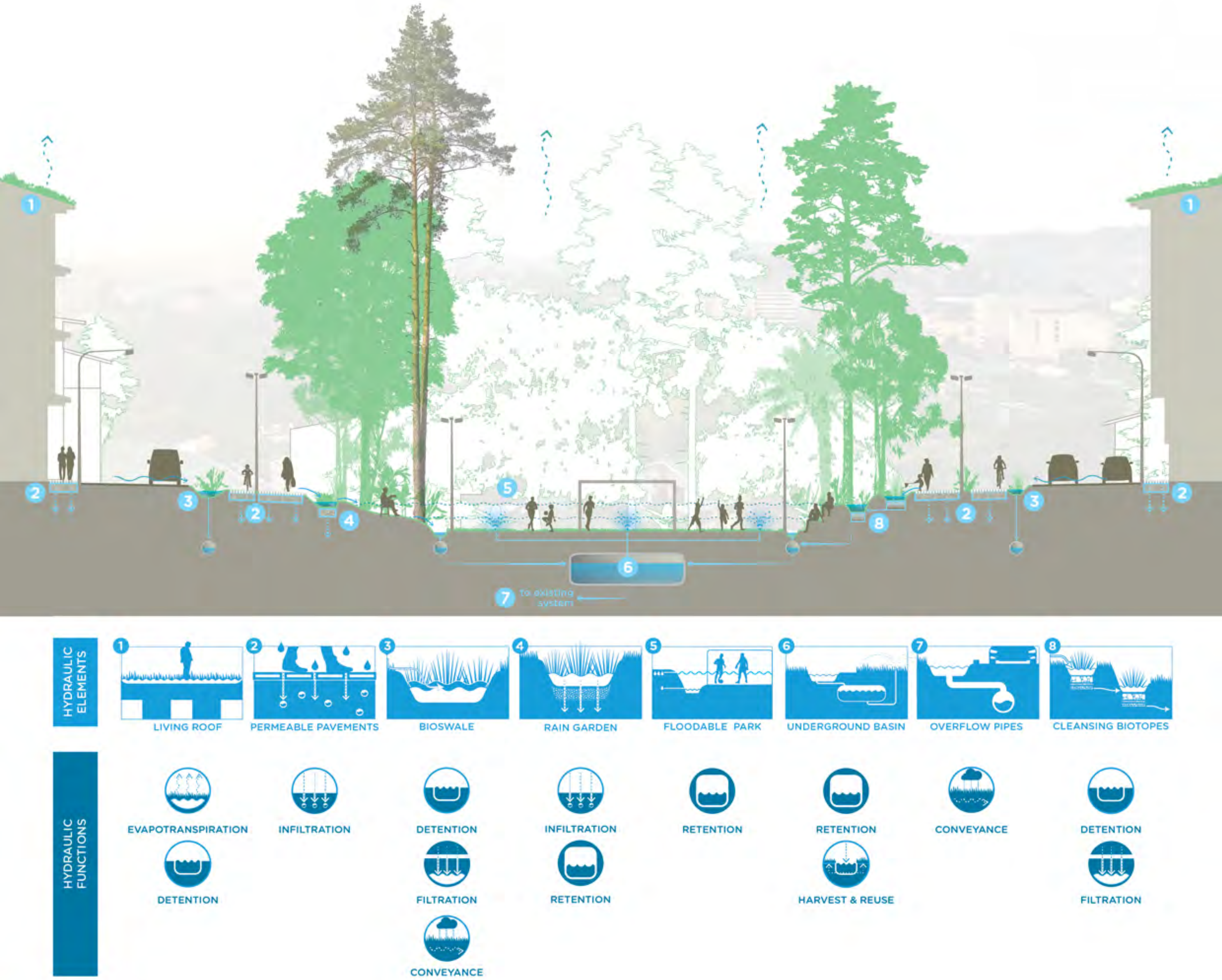


Figure 4-8 Conceptual cross-section of the 'Stormwater Park' typology

Source: Ramboll

4.2.2 URBAN CANAL

Urban Canals can be restored, strengthened, and widened to increase the conveyance capacity of the current canal system and mitigate flooding. Additionally, where adjacent space is available along the canal a redesign of stream or riverfront parks may allow for implementation of temporarily floodable areas to reduce downstream flooding in vulnerable areas. Such floodable areas can be designed to create new and healthy oases in the city while increasing biodiversity and stormwater volume capacity. Where feasible, natural water treatment systems should be implemented prior to discharge to the canal to facilitate an overall reduction of untreated overflows to the local waterbodies. The urban canal is envisioned as a concrete channel with natural elements embedded on the riverbanks.

Urban canals provide great opportunities for underutilized, strictly functional canals to be reshaped as valuable urban spaces. By reviving water bodies through both ecological interventions and water sensitive design, cities can gain green, vibrant social spaces that provide multiple opportunities for people to interact with water. Urban canals are highly adaptable typologies that can be applied on both narrow or wide streams, can be tailored for densely built areas or neighborhood social spaces and can be adapted to the local needs and leisure culture. The development of Urban Canals is directly linked to the Blue Walks initiative which aims at creating a connective network of walks along rivers/canals with specific focus on restoration, conservation, education, and co-existence initiatives with citizens. Using a mix of hard-scape and natural elements, urban canals can be shaped to host a large number of amenities, such as: benches, decks, lights, walkways, and other elements that enhance social cohesion and wellbeing. The water quality of the Rivers in Baguio is poor with the rivers being used as the main drainage system with little to no treatment of water before discharge. The water quality is being monitored today at monitoring stations along the rivers, and this will need to be continued be in order ensure safety for users of waterfront spaces. Temporarily floodable areas along the canals will need to be cleaned after an extreme event, before allowing use to be resumed.

The potential co-benefits are related to the urban upgrade of the area along the canal. In other words, the restoration of the canal will include an important focus of active use of the stream banks by implementing seating, recreational walking routes and steps. The design should focus on bringing people close to water, as it will be cleaned before entering the canal. The design of the banks and behind the banks will include a focus on comfortable micro-climate with increased vegetation and shading.

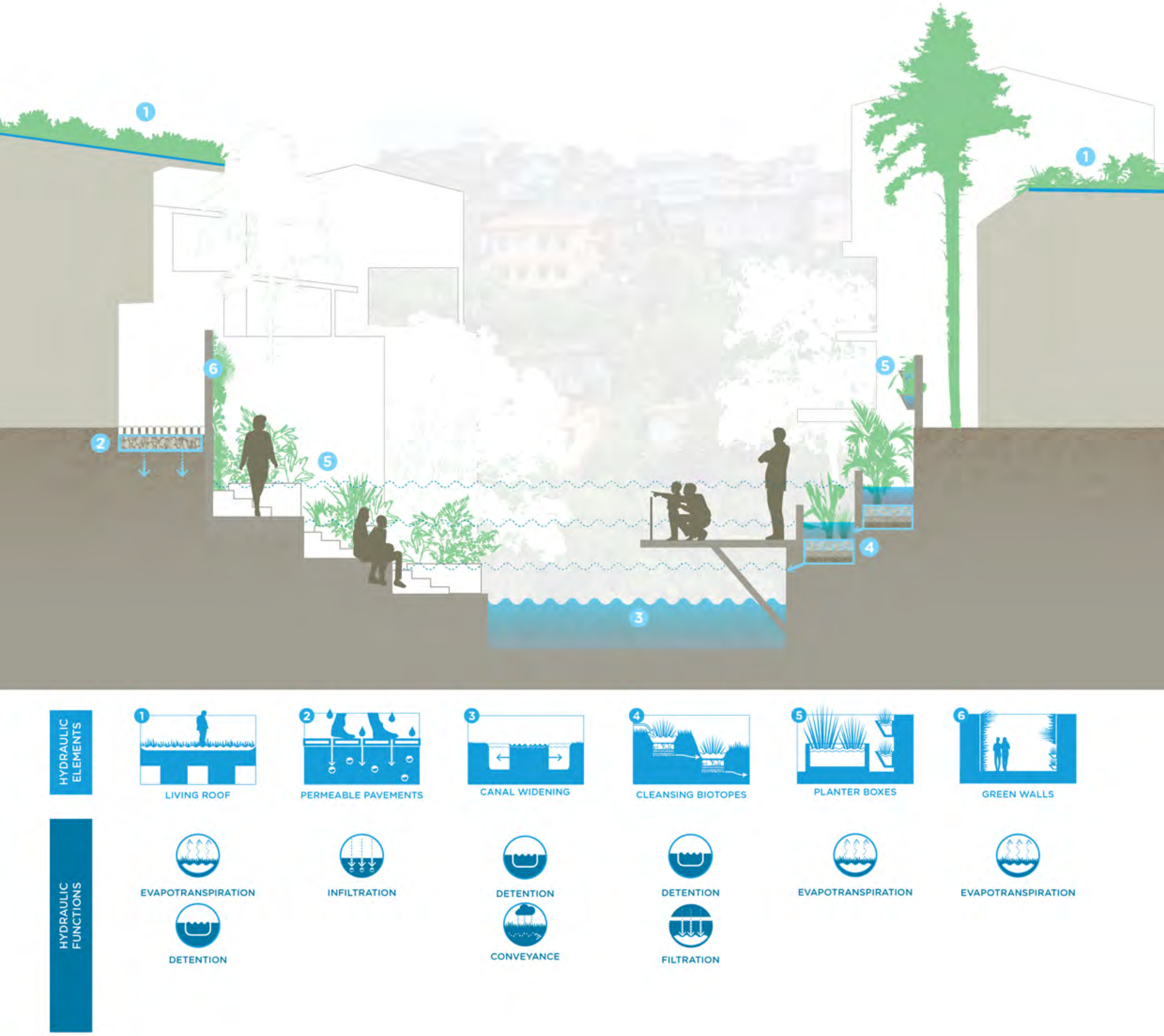


Figure 4-9 Conceptual cross-section of the 'Urban Canal' typology

Source: Ramboll

4.2.3 NATURAL STREAM RESTORATION

Natural Stream Restoration and re-profiling existing streams and rivers can help build capacity for stormwater through increased conveyance, as well as retention and detention. The rivers of Baguio have been physically modified through a variety of means for the purposes of urban development, drainage, irrigation, and industrial development. The stream restoration features attempt to restore natural physical processes and features to the channel and adjacent floodplain and allow capacity for seasonal changes in water levels. Stream restoration can be combined with floodplain and wetland enhancement features restore natural connections to floodplains, provide floodwater storage, and give aquatic species access to areas that were once naturally available.

The philosophy is to move from flood resistance to flood accommodation. The typology focuses primarily on restoration of the riparian zone—the river, its channel, and its banks. In a stream area, the riparian zone is widened and deepened, allowing it to fill during rain events and preventing stormwater from flooding urban areas. Vegetation on and along the riverbanks will provide a wide variety of habitats, and connections, supplying a broad range of fully integrated co-benefits. Natural Stream Restoration in Baguio is mainly feasible for non-urban areas where there is room for larger naturalized expansion of the channel, as the riverbanks in urban areas are densely built-up and have limited available space. The typology addresses a wide range of challenges including habitat loss, channel instability, water quality degradation and loss of floodplains and wetlands. Nature-based bioengineering techniques for erosion management will be applied to the river channel. Material eroded from the riverbanks or riverbed can deposit in the main channel, reducing its conveyance capacity and thus increasing flood risks. Thus, erosion management techniques contribute to reducing flood risks, although their main objective is to stabilize channel banks. Nature-based measures can replace hard engineering bank stabilization techniques with vegetated banks providing ecological benefits.

When applying this typology, it is important to recognize the location in the catchment. When applied in the upper part of a catchment, nature-based elements that intend to slow the flow should be prioritized including river bank vegetation, tree planting, or leaky barriers. Rainwater harvesting techniques should be implemented to collect rainwater from roofs to be stored in a storage tank and used as non-potable water supply for irrigation or other domestic purposes such as toilet flushing, reducing runoff to the river. In the middle reach and downstream, where the discharge is generally higher, the priority should be to restore the discharge capacity to reduce peak flood levels.

The areas along the stream can be transformed into attractive recreational pathways to encourage the community to enjoy the waterways of Baguio. Similar to the urban canal typology, natural stream restoration will be implemented hand-in-hand with the Blue Walks initiative. Recreational amenities such as walking trails, benches, look-out decks, and other outdoor facilities can be added to bring people closer to the water edge. Natural Stream Restoration can deliver a wide range of co-benefits mostly related to cultural, supporting and regulating services. The typology is particularly good at restoring habitat and providing aesthetic and cultural benefits.

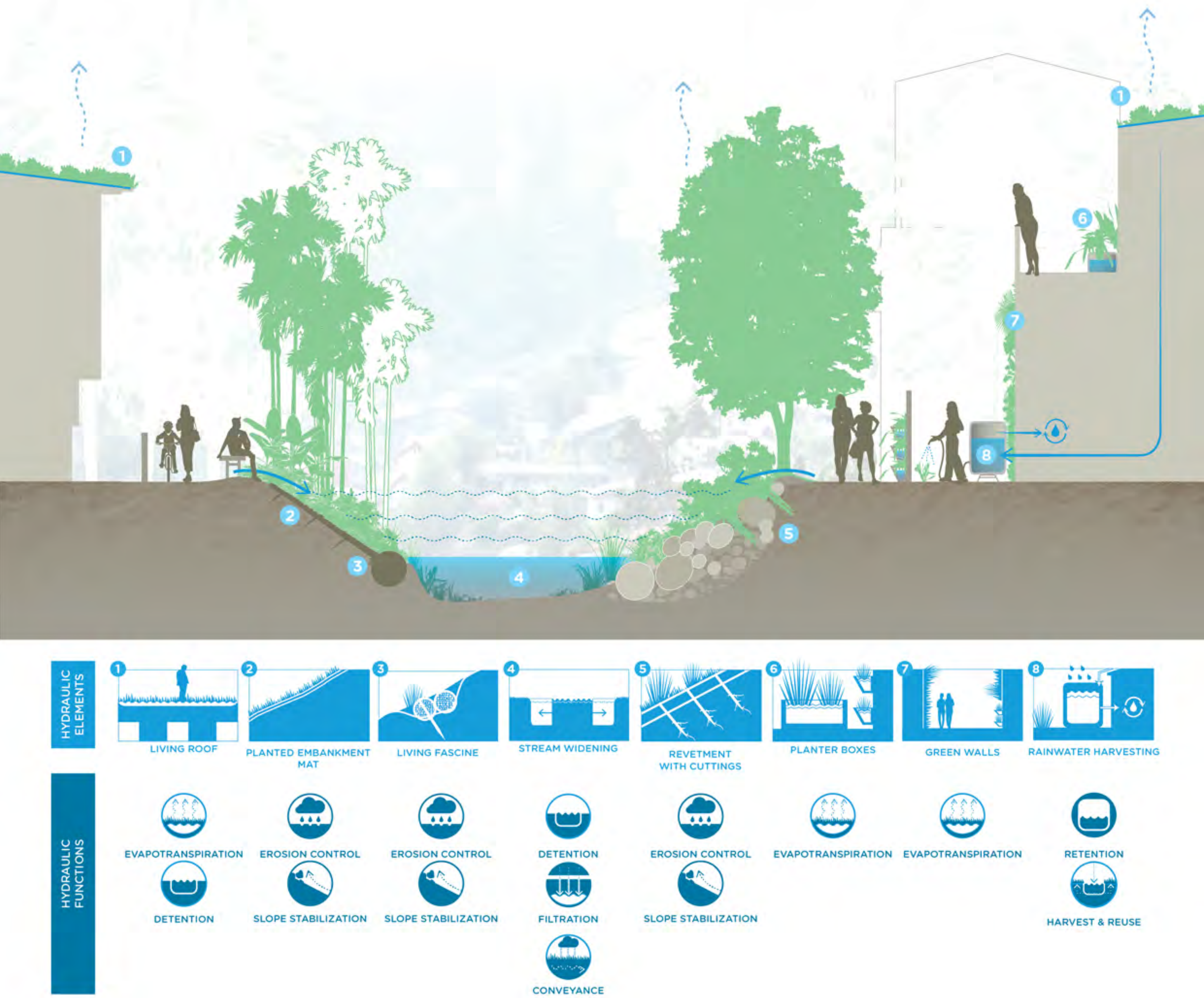


Figure 4-10 Conceptual cross-section of the 'Natural Stream Restoration' typology
Source: Ramboll

4.2.4 GREEN STREET

Green Streets incorporates vegetation (perennials, shrubs, trees) and small-scale engineered systems (e.g., bioswales, permeable pavements) to detain, slow, filter, and cleanse stormwater runoff from impervious surfaces (e.g., streets, sidewalks). Green Streets are proposed as upstream connections to all cloudburst roads or retention/detention areas. Stormwater from ‘everyday’ rain events should be collected and retention time optimized to ensure cleansing before discharge towards the downstream terrain-based solutions or the existing drainage system. If the typology is applied on streets with steeper slopes, cascading elements can be included in the bioswales to reduce flow velocity.

Green streets bring great regenerative value into traditional hard-scape cities and enable several opportunities for multifunctional use, especially with regards to mobility. Typically, by redesigning a traditional street, prospects of implementing wider sidewalks and bicycle lanes will emerge and shift priorities from a car centric design to a greener, human-centric approach. Depending on the available space, this typology can be adapted to include a multitude of natural elements and water sensitive designs. Tree planting is encouraged where space is available to enhance soil stabilization, intercept runoff through three canopies, increase air quality and contribute to a comfortable climate. The Green Street typology is directly linked to the Green Walks initiative in Baguio which aims at connecting the city with green corridors and streets, as well as providing more room for pedestrian space and bike lanes. This concept is incorporated in the Green Street typology and expanded to include stormwater management functions.

A holistic approach should be applied in the design of green streets and it is encouraged to consider green walls and roofs, dense vegetation and ideally linkages to other green areas. Rainwater harvesting techniques should be implemented to collect rainwater from roofs to be stored in a storage tank and used as non-potable water supply for irrigation or other domestic purposes such as toilet flushing. Green Streets are valuable socio-economic components of liveable cities. By connecting green areas or just compliementing low transit streets, they induce enjoyable, comfortable feelings among residents or visitors.

The potential co-benefits associated with a green street include traffic safety, air quality improvement, and noise reduction. By separating the car lanes and soft active mobility lanes with stretches of green, lowered velocities are encouraged and overall traffic safety improved, and citizens are encouraged to shift to active travel modes (with concomitant improvements in physical and mental health outcomes). By increasing green cover, the air quality in the immediate vicinity of the road is improved and noise levels potentially reduced. If there is space to include wider green strips with recreational amenities such as urban furniture and walking paths, the recreational value will be increased.

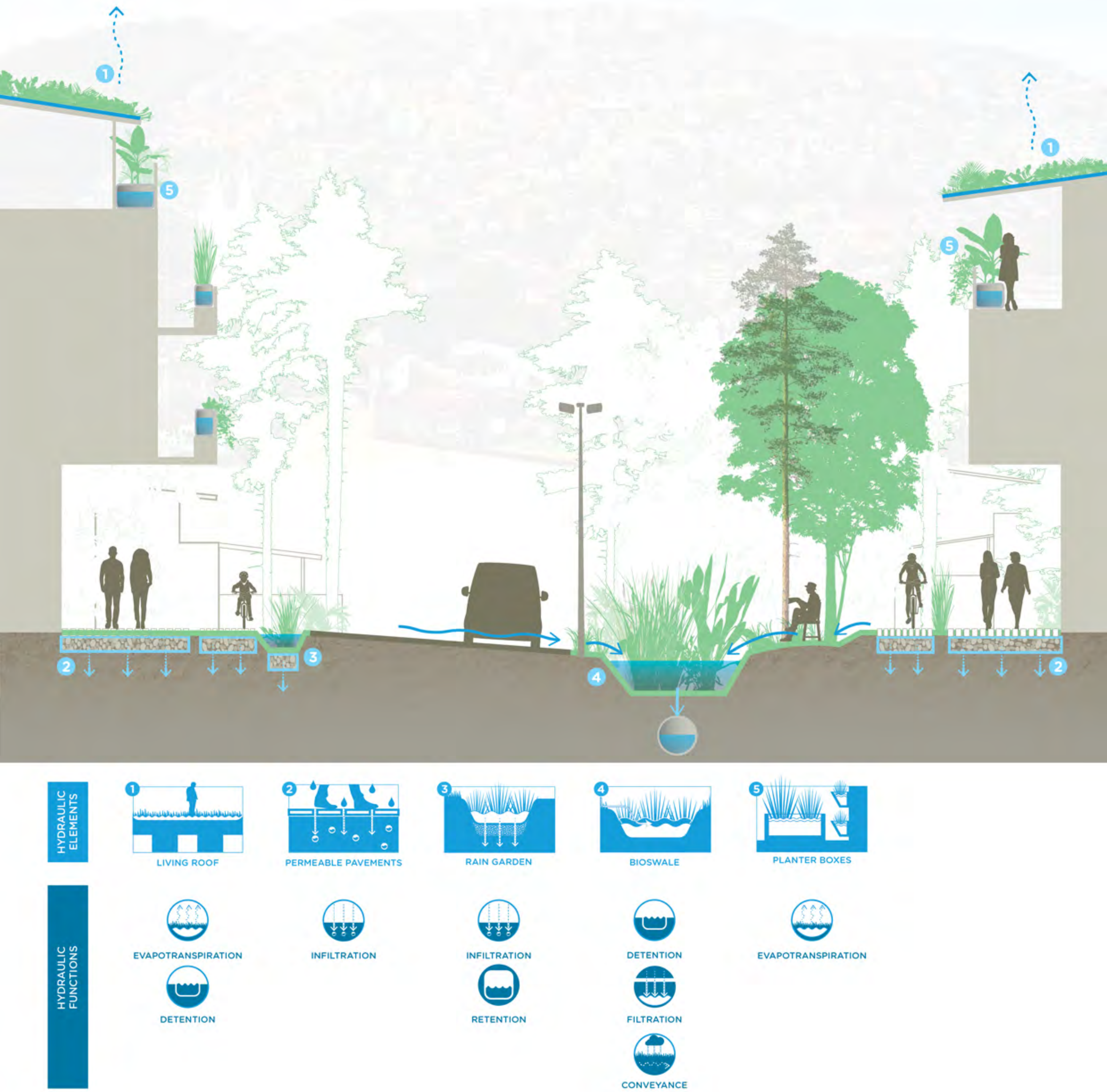


Figure 4-11 Conceptual cross-section of the 'Green Street' typology
Source: Ramboll

4.2.5 STORMWATER BOULEVARD

Stormwater Boulevards are used to channel and direct cloudburst runoff. These streets can be designed with a V-shaped profile and raised curbs to ensure water will flow in the middle of the road, away from the buildings. In addition, channels and swales can be established at the side of the road so that the water runs in urban rivers or green strips. Stormwater Boulevards are typically implemented on larger streets that can be utilized to channel large volumes of stormwater in case of extreme rainfall events.

A bioswale is proposed in the middle of the road, to capture and convey stormwater from every-day rainfall events. In case of extreme rainfall the entire V-shaped road profile can be utilized to effectively convey water to a stormwater park or a receiving water body. Additionally, it is encouraged to add further green elements and bioswales along parts of the road where space is available to collect and cleanse runoff from the immediate surrounding area. As the primary function of this typology is to convey large volumes of water in case of extreme rainfall, direction of water to the road profile from surrounding streets needs to be established.

A holistic approach should be applied in the design of Stormwater Boulevards and it is encouraged to consider green walls and roofs. Stormwater boulevards showcase opportunities to compliment busy, commercial streets with natural, water sensitive elements and thus promote a more comfortable, enjoyable ambiance along streets.

The potential co-benefits of the Stormwater Boulevard are highly dependent on the space available for green infrastructure. The co-benefits include traffic safety, air quality improvement, and noise reduction. By separating the car lanes and soft active mobility lanes with stretches of green, lowered velocities are encouraged and overall traffic safety improved. By increasing green cover, the air quality in the immediate vicinity of the road is improved and noise levels potentially reduced.

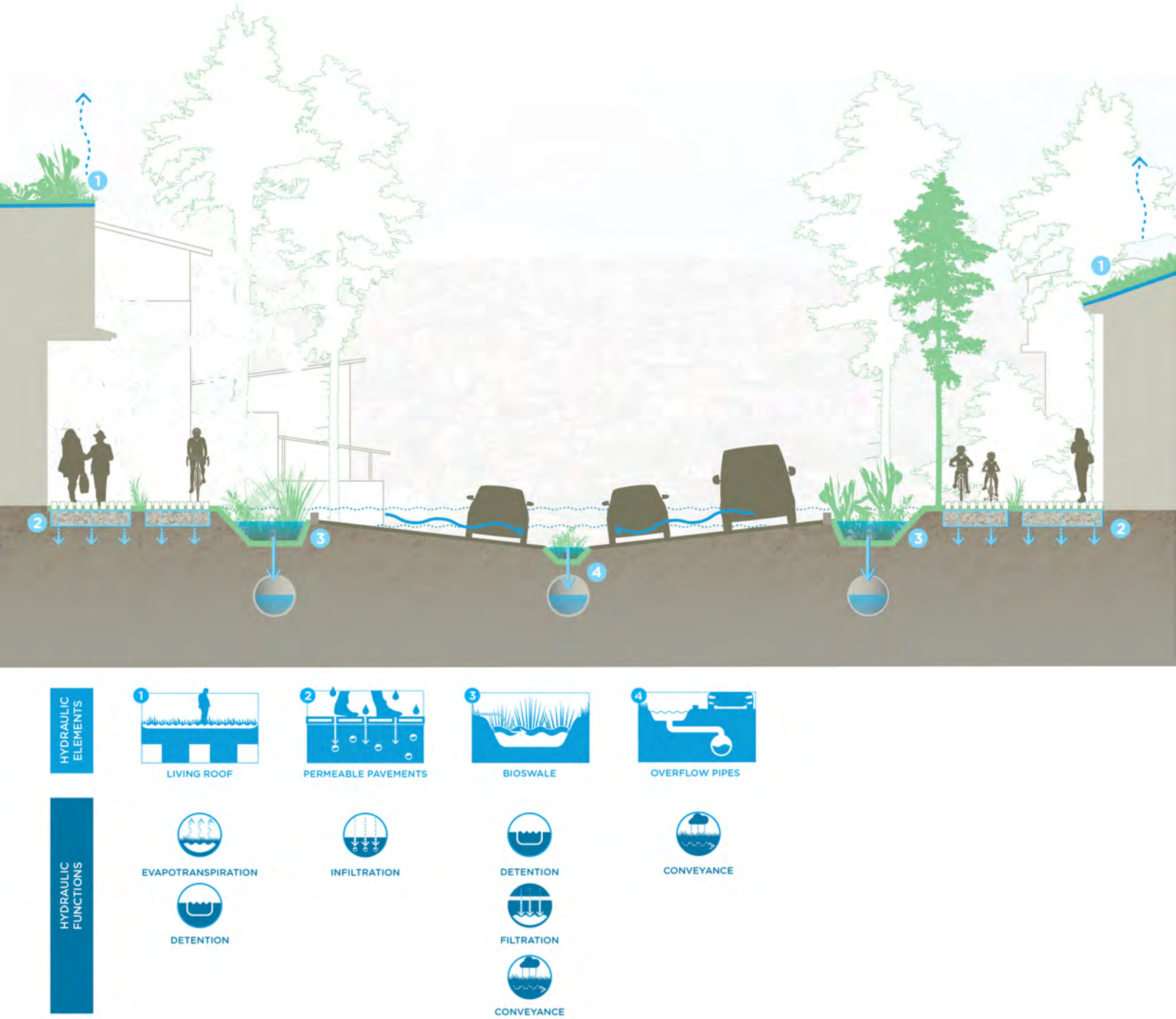


Figure 4-12 Conceptual cross-section of the 'Stormwater Boulevard' typology
Source: Ramboll

4.2.6 LIVEABLE CORRIDOR

Livable Corridors are designed to revitalize narrow streets and alleys that have limited space for terrain-based stormwater management. Green facades and extensive green roofs on buildings and smaller raingardens, provide a comfortable space for people. The vision for a Liveable Corridor is to bring nature into the heart of Barangays across Baguio to create green neighborhoods improving the public realm for residents and visitors, while reducing peak runoff from densely built-up areas. Liveable Corridors are suitable in large areas of Baguio, which are characterized by high population densities, closely located households, limited space, and high percentage of impermeable surfaces. The typology is directly linked to the Green Walks initiative in Baguio which aims at connecting the city with green corridors and streets.

The main hydraulic functions of Liveable Corridors are to intercept overland flow, slowing runoff and provide opportunities for evapotranspiration. Additionally, Liveable Corridors provide benefits related to enhanced biodiversity and public amenity. Livable Corridors create opportunities for community cohesion as most of the solutions implies working closely with owners of residential properties and neighbor collaboration. The effectiveness of the typology is increased if applied over larger areas with multiple alleys, corridors, streets, and households included. Wider application of this typology as a strategy has the potential bring a Barangay or smaller community together and strengthen the feeling of a common purpose striving towards being a green and more climate resilient neighborhood. Green roofs and walls should be encouraged on public and private buildings. These have the ability to absorb water, while improving micro-climate conditions, enhancing urban biodiversity, and improving the air quality. Rainwater harvesting techniques will be implemented to collect rainwater from roofs to be stored in a storage tank and used as non-potable water supply for irrigation or other domestic purposes such as toilet flushing. Where space is available smaller raingardens will be implemented to store and infiltrate rainwater. Pedestrian spaces will be permeable to intercept and infiltrate additional runoff.

Potential co-benefits relate to improved micro-climate, air quality benefits, enhanced biodiversity and decreased potable water consumption as rainwater is harvested and can be re-used for domestic purposes. If applied in larger areas, these areas have the potential to become new destinations for tourists demonstrating how nature can become an integral part of the city in low impact developments. Furthermore, the typology is providing social cohesion benefits by promoting a shared sense of neighborhood ownership as citizens are encouraged to come together and implement green solutions on private properties.

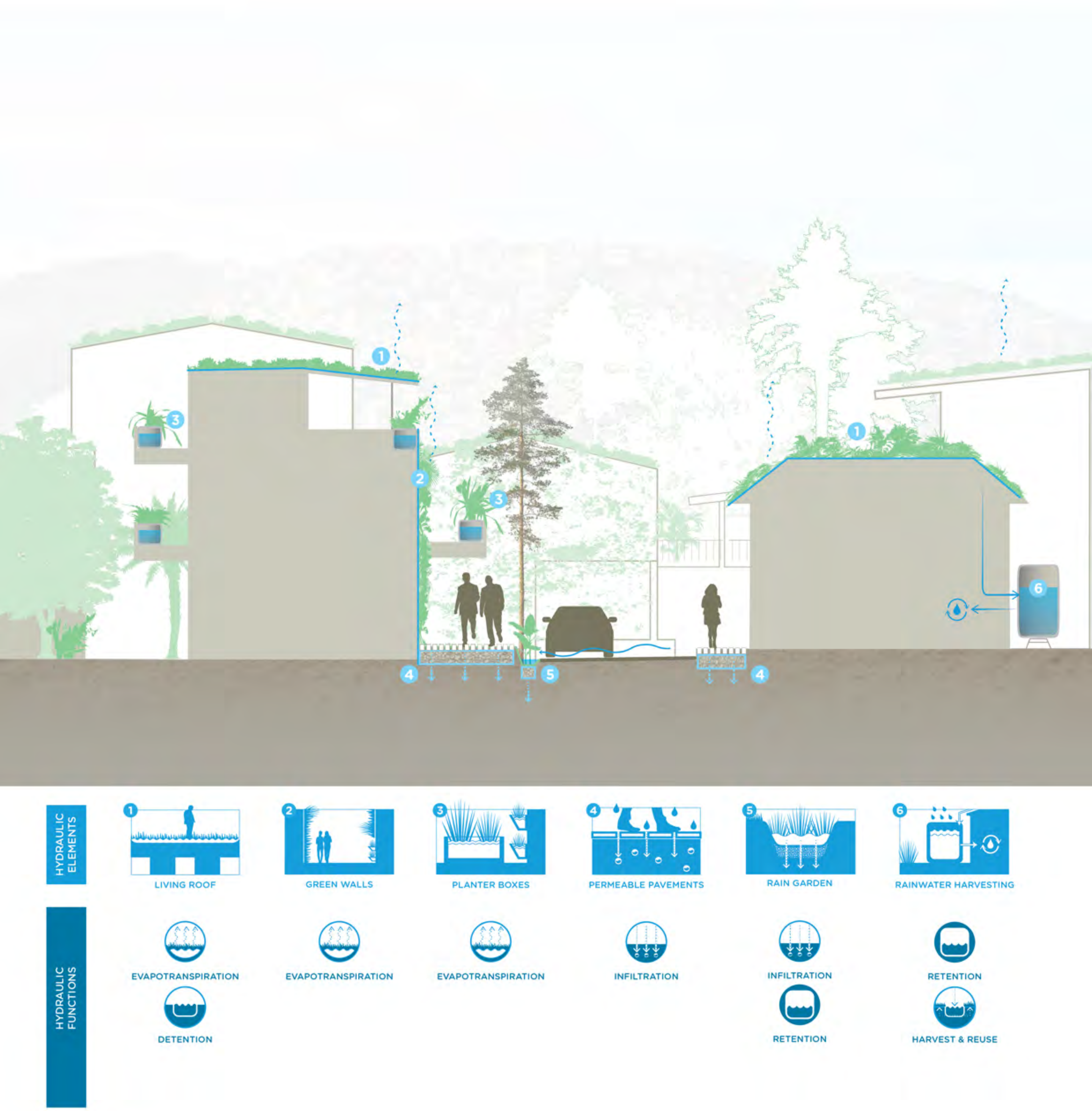


Figure 4-13 Conceptual cross-section of the 'Liveable Corridor' typology
Source: Ramboll

4.2.7 TERRACING

Terracing is applied for open spaces on steeper slopes as a method for slowing down surface runoff and reducing erosion risk by rebuilding the slope profile in steps rather than steep angles. Beside runoff velocity reduction, terracing allows the water to infiltrate, stabilize the land, and can host natural detention basins. Higher runoff flows can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure. By slowing down runoff, the peak flow to downstream areas is reduced, lowering the flood risk in low-lying downstream areas. Thus, this typology is especially suitable for upstream locations in the catchment where reduction of peak flows should be prioritized.

In this typology, revegetated diversion and infiltration berms are constructed along contours on the slope. A diversion berm is a mound of compacted earth with sloping sides to create a small trench for water collection and infiltration. Implementation of multiple berms on a slope as terraces has the potential to reduce runoff to downstream areas.

Terracing is recommended in open areas on steeper slopes where stormwater parks are less feasible due to high runoff velocities and the extensive earthworks it would require on such terrain. While it is important to consider site slopes in the design of any stormwater management system, it is particularly important in the design of green infrastructure systems for sites with steep slopes. Soil erosion and landslides are concerns whenever construction occurs on or near slopes but become even more of a concern when slopes are saturated with water. Thus, care must be taken when designing terrain-based green infrastructure for steeper slopes. For Baguio, it is recommended to comply with the national guidelines of the Philippines and development on slopes steeper than 18% is discouraged, and thus terracing for stormwater management should not be applied on slopes steeper than 18%.

Tree planting is applied as part of the terracing typology to ensure land stabilization. Leaf canopies intercept runoff and tree roots hold soil in place promoting infiltration and groundwater recharge. To further stabilize the slope, bioengineering and biotechnical stabilization techniques are applied. These techniques contribute to maintaining ecological balance and are cost-effective as well as environmentally friendly. Bioengineering techniques entails the use of plant material, living or dead, to stabilize slopes. The selected plants act as a structural component as well as an aesthetic addition and are usually chosen for their resistance to the stressors of the application such as erosion or landslides. Similar to bioengineering, biotechnical stabilization also use living plants, but in integration with inert structural components, such as geotextiles or geogrids. Maintenance of bioengineering and biotechnical stabilization includes conducting regular inspections to ensure the system is functioning correctly.

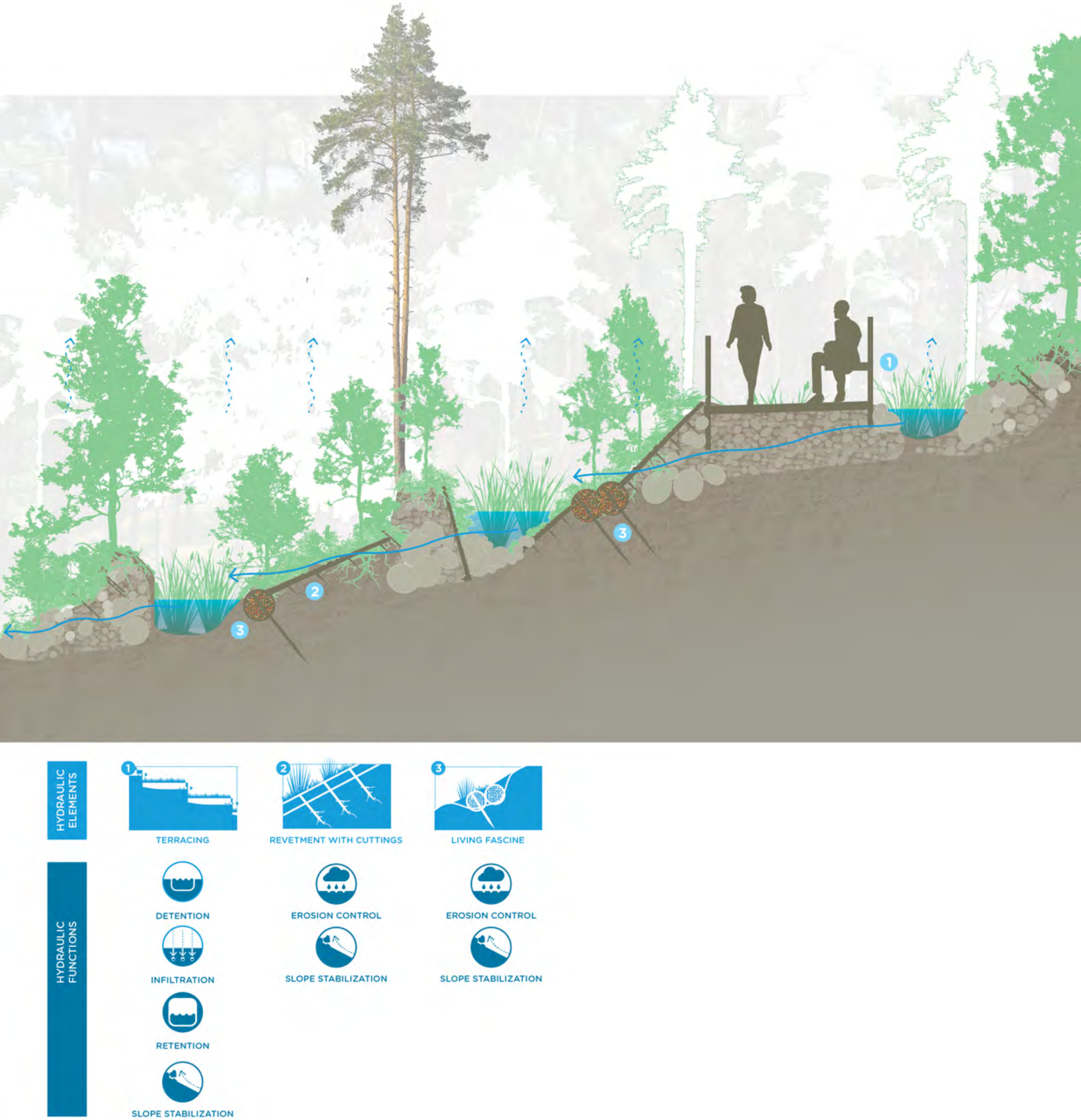


Figure 4-14 Conceptual cross-section of the 'Terracing' typology
Source: Ramboll

4.2.8 NON-URBAN FRINGE BUFFER ZONE

A fringe buffer zone is a protective boundary zone established between the existing urban tissue and protected natural areas. The main function of a buffer zone is landslide prevention by facilitating vegetation zones for erosion protection on steeper slopes to increase slope stability. Furthermore, these zones may host recreational spaces such as nature parks or educational amenities. Additionally, the fringe buffer zones aim at reducing the large number of informal settlements in areas of high environmental value.

For Baguio, urban fringe buffer zones are recommended in non-urban landslide susceptible areas with slopes steeper than 18 %. Steep slopes are considered an environmental resource because of their biodiversity, recreational potential, and viewsheds, and thus these areas should be protected and remain undeveloped.

To stabilize slopes in the fringe buffer zones, bioengineering and biotechnical stabilization techniques are applied for landslide prevention. Vegetation acts as structural components as well as an aesthetic addition, and is usually chosen for its resistance to the stressors of the application such as erosion or landslides. Shrub and tree planting reinforces and anchors the slope and ensures further stabilization as the vegetation grows. Thus, implementation of afforestation strategies in the non-urban fringe buffer zones ensures further land stabilization, while leaf canopies intercept runoff and tree roots hold soil in place promoting infiltration and groundwater recharge. Vegetation strategies are integrated with application of inert structural components, such as geotextiles or geogrids. Detailed site investigations and surveys of geological features should be carried out to determine the best techniques that match site conditions and perform their functions to stabilize the slopes. Maintenance of bioengineering and biotechnical stabilization includes conducting regular inspections to ensure the system is functioning correctly.

Areas in the fringe buffer zone can be transformed into attractive natural spaces for tourists and locals to utilize as recreational and educational spaces[17]. As the areas have steeper slopes, these can be utilized for mountainous hiking trails in nature that remains ‘untouched’ and where biodiversity can be conserved. These areas can serve to further promote Baguio as a city of nature with high regard of the environment, while at the same time also contributing to reducing landslide risk. The potential co-benefits relate mostly to improved biodiversity and habitat creation, as well as increased tourism, enhanced recreational value and aesthetic quality of the landscape.

17 Educational amenities in this context refers to the value provided by environmental settings of varying habitats. These settings inform and support educational activities and learning experiences through embodied ecological knowledge or increased productivity and ability to concentrate in the classroom through exposure to and engagement with nature.

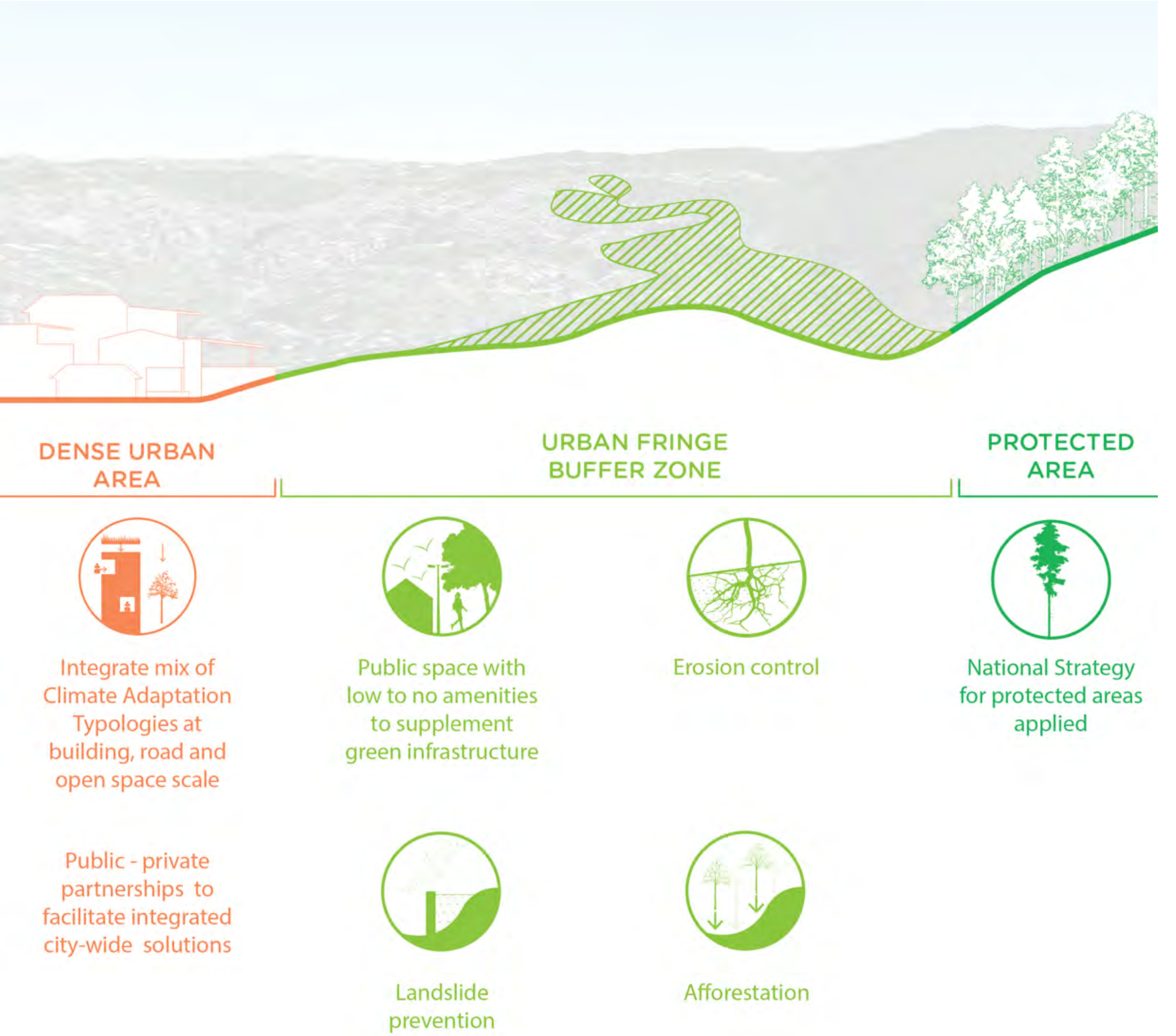


Figure 4-15 Conceptualization of the 'Non-Urban Fringe Buffer Zone' typology

Source: Ramboll

4.3 CITY-WIDE REPLICABILITY OF TYPOLOGIES

The typologies in the toolbox are designed to be applied city-wide at various scales to create a network of connected nature-based solutions.

The replicability map (see Figure 4-16) highlights the various zones identified across Baguio where the developed typologies are particularly suitable. As described in section 4.1.5, the zones have been identified based combinations of high risk to flooding or landslides, urban or non-urban context, and slope characteristics. Three types of space have been identified within each zone: open areas, roads/right-of-way, and canal/stream/river. Typologies are available for prioritized combinations of zones and space. The main

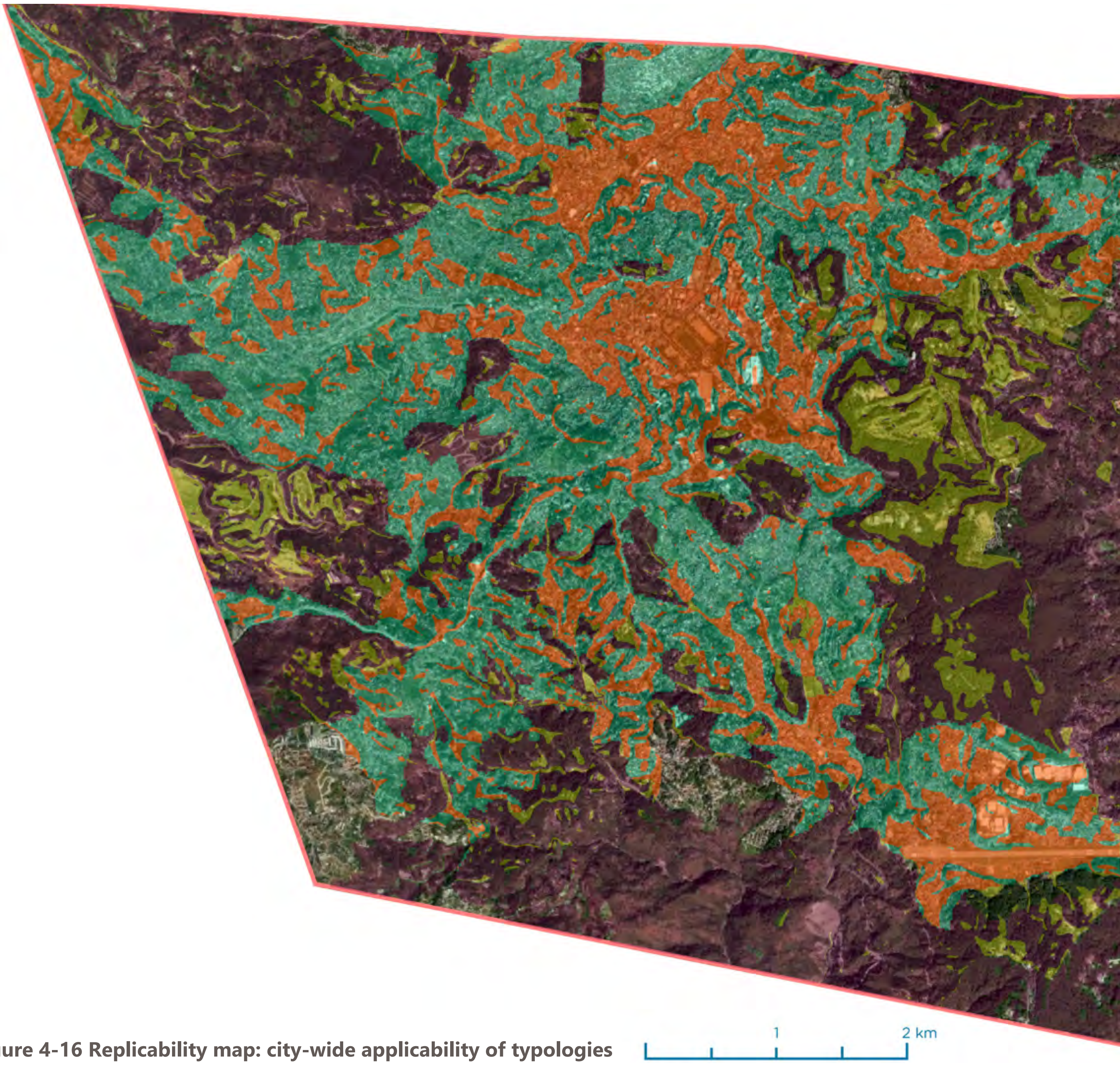


Figure 4-16 Replicability map: city-wide applicability of typologies

Source: Ramboll

considerations for prioritization were cohesion with vision for the Flood Mitigation Action Plan as well as ongoing initiatives and plans for Baguio, determination of dominating overlays, expert knowledge of NbS applicability, and a diverse representation of space.

The replicability map in Figure 4-16 can be used to identify a typology for specified site. The various zones (a combination of risk/hazard, spatial context, and slope characteristics) are represented by different colors on the map. Next to the map, colored circles correspond to each of the zones. Following the line from a colored circle, the spatial characteristics of the zone are visualized. To identify an applicable typology for a site, first identify a location on the map, then find the circle corresponding to the color of the zone and follow the line to the type of site (i.e. stream, road, open space).

5. CONCEPT DESIGN FOR PILOT SITES

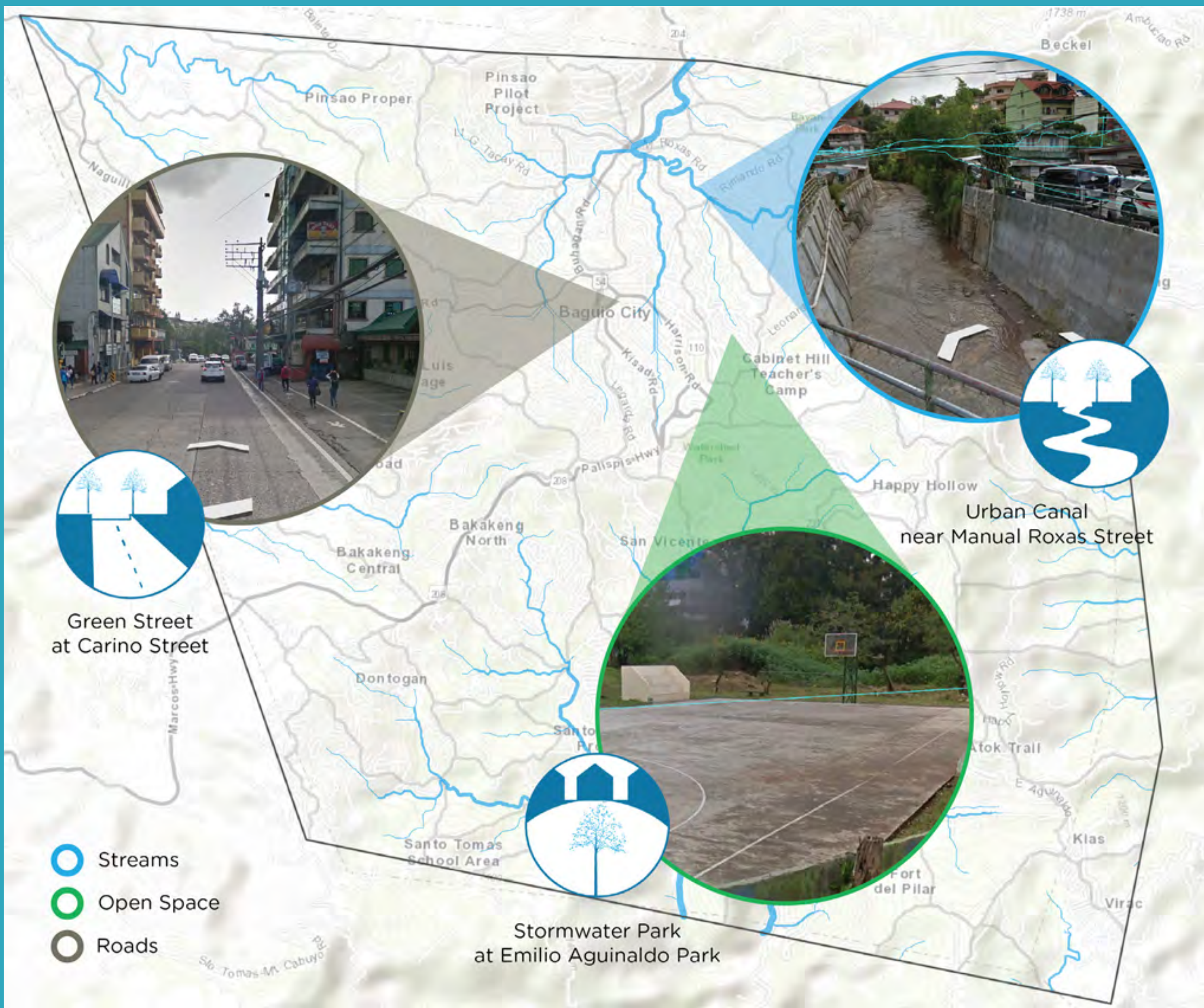


Figure 5-1 The three pilot sites selected in collaboration with the LGU.
Source: Ramboll

5.1 SELECTION OF PILOT SITES

To demonstrate the applicability of the NbS toolbox, the toolbox is applied at three pilot sites. The pilot sites were selected in close collaboration with the LGU to ensure the sites are aligned with city plans and initiatives. It is agreed with the LGU that the pilot sites should be located within the Balili catchment, following the common approach of prioritizing high-risk areas for improvements as the benefits are higher. As introduced in previous sections, it is recommended to apply a holistic approach to flood mitigation and design a connected network of mitigation measures for one sub-catchment at a time. However, this process was not possible to undertake within the timeframe of this project due to the complex nature of land ownerships in Baguio. Thus, as the primary purpose of the pilot sites is to demonstrate the application of the conceptual typologies to a specific spatial context in Baguio at sites where projects can be implemented, it was agreed with the LGU to select government-owned sites for three different typologies: a stormwater park, an urban canal, and a green street. Use of the replicability map (see section 4.3) allows for identification of areas where these typologies may be applied.

The following three pilot sites were selected in close collaboration with LGU:

1. **Urban Canal near Manual Roxas (137-138)**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Canal
2. **Green Street at Carino Street**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Road
3. **Stormwater Park at Emilio Aguinaldo Park**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Open area

The locations of the three pilot sites are seen in Figure 5-1. The selected pilot sites serve to demonstrate the wide range of concepts in the NbS toolbox and show how nature-based solutions are applicable for various types of spaces and infrastructure in the public realm in Baguio.

5.1.1 VALIDATION CRITERIA FOR PILOT SITE SELECTION

As part of the identification of the three pilot sites, a validation of the sites and their suitability for NbS implementation was undertaken in close collaboration with the LGU. A list of validation criteria is prepared and evaluated with respect to each of the pilot sites in collaboration with the LGU including representatives from the City Engineering Office and City Planning and Development Office. The results are presented in Table 5-1 below. As evident from the results, the pilot sites are deemed suitable as pilot sites for application of the NbS typology toolbox.

Table 5-1 Validation criteria matrix for the selected pilot sites.

Vaidation criteria	PILOT SITES		
	Stormwater Park	**Urban Canal**	**Green Street**
	Emilio Aguinaldo Park	**M. Roxas**	**Carino Street**
Is there a Risk to Mitigate?	Yes	Yes	Yes
Is the Site Located at NBS typology zone?	Yes	Yes	Yes
Is the Site Available for Development (Ownership)?	Yes	Yes	Yes
Is the Site Outside the Protected/ Heritage Area?	Yes	Yes	Yes
Are there Conflicting Development Plans?	No	No	No
Is Knowledge/Data on Drainage Infrastructure Available?	Limited data	No Available data	Size RCP = 18, L= 66m Connected to RCP = 24”, L = 33m, Invert Elev (top) = 2.3m (from 0 to 99)
Is there available Space for the applicable typology?	Yes, but, Relocation of the existing Recreational Facility is Required	Yes	Yes
Is there a Potential for Socio-Economic Benefits?	Yes	Yes	Yes
Does the Site Synergize with the existing/planned flood mitigation measures?	Yes	Yes	Yes
Conclusion	**All sites are suitable as pilot sites. Detailed site surveys to be undertak-en in upcoming project development phases, to take place outside of this project.**		

Source: Ramboll

5.2 HYDRAULIC ASSESSMENT FOR PILOT SITES

A preliminary assessment of the key hydraulic functions of the typologies at the three pilot sites allows for an analysis of the scale in terms of flood mitigation benefits and defines the pre-conditions that must be fulfilled for the typology to provide the full effect. One of the key outcomes of the hydraulic assessment is an evaluation of the impact the typologies have in the greater flood mitigation action plan. The calculations are based on parameters and assumptions described in D2: Hydraulic Model and Hazard and Risk Assessment[3]. The hydraulic calculations are further detailed in Appendix F.

The calculations outlined at this stage focus on providing bulk volumes and typical conveyance being achievable considering the constraints of the specific sites selected for the pilot project, while further detailing will be required following the roadmap presented in section 6, if the projects are selected for implementation. Furthermore, the calculations are based on the data currently available, which will have to be validated and supplemented through detailed surveys in the following phases of development.

The hydraulic calculations are built on the key findings from the dynamic 2-dimensional model developed for the purpose of risk mapping. The pilot sites are all placed in highly flood prone catchments and the calculated storage volumes required at the catchment level will include the constraining conveyance capacity that will have to be maintained in the recipient river to avoid overflow. The "hydraulic bottlenecks" are mapped to find the limiting flow capacity, as the cross-sections providing the lowest conveyance relative to the contributing catchment will be used as the downstream boundary conditions for discharge. Hence, it is assumed that the difference between the runoff and the constraining flow capacity will require temporary storage to avoid damages from flooding.

5.2.1 DESIGN CRITERIA

Any new infrastructure that is recommended to support the NbS, is dimensioned to manage the runoff from a 3-year event (in future climate conditions), and the physical constraint of the Balili river and tributary urban canals is considered in the design of storage volumes as the limiting discharge. The interconnectedness of runoff, discharge and storage volumes are presented in a simple visualization below (Figure 5-2), with the volume required to avoid uncontrolled flooding being a function of rainfall runoff and discharge.

As the pilot sites are designed to be part of an interconnected network (both nature-based and traditional gray infrastructure solutions), it is not expected that the single pilot projects can fully mitigate the flooding in the catchment. However, each pilot has direct benefits and enables the city of Baguio towards a more resilient future. The individual pilot projects contribute with conveyance, storage or a combination of both, and any pre-conditions or supporting infrastructure is described qualitatively with the resulting benefits being quantified relatively to the total requirements of the given catchment.

5.2.2 METHODOLOGY FOR HYDRAULIC CALCULATIONS

At the preliminary stage of calculating volumes and flows in a stormwater management system, basic equations may be applied which will then be validated in the following phases of development as the conceptual design is completed. The volumes and flows calculated as part of this assessment should be viewed as 'bulk' volumes and average flows, and dynamic model calculations will be applied in later stages when the levels and dimensions of the proposed infrastructure is defined as part of the schematic and detailed design phases.

The calculation applied in this phase can be viewed as a simple water balance approach containing three main parameters, that being rainfall runoff, conveyance, and volume.

Rainfall Runoff: Rainfall runoff is calculated using the standard rational method approach, which considers the area of the catchment, the average runoff coefficient, and the rainfall intensity. For conveyance purposes, this calculation is sufficient to estimate the required cross-sections and dimensions of conveyance infrastructure such as open channels or pipes, whereas simple runoff hydrograph is applied when calculating the required storage volume to capture the 'delay' in runoff caused by the size of the catchment (that being rainwater that falls at the point furthest from the site of storage will take longer to reach the site of storage). This delay is captured in the term 'Time of Concentration'.

Flow capacity: To calculate the flow capacity in channels, the standard Manning equation is applied. This considers the longitudinal slope of the drainage line and the 'roughness' of the surface, i.e., natural surfaces such as vegetation or stones resulting in more resistance compared to concrete or plastic pipes.

Volume: The primary function of storage volume in a drainage system is to reduce peak flows that would otherwise overwhelm the conveyance network, e.g. the canals and rivers, and lead to uncontrolled and damaging floods. The volume required in a system will be a function of the runoff generated by a rain event and discharge that can be maintained without flooding occurring. Adding volume in a drainage network will create a buffer that allows for temporary storage during peak rain intensities. The volume required can be visualized in a simplified format (Figure 5-3) as the difference between two curves symbolizing runoff (inflow) and discharge (outflow) as a function of flow and time.

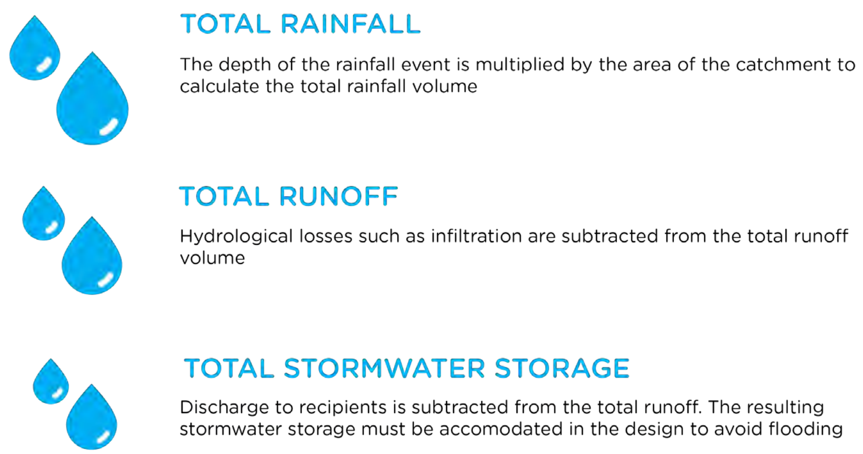


Figure 5-2 Concept of calculation method for total stormwater storage requirements.
Source: Ramboll

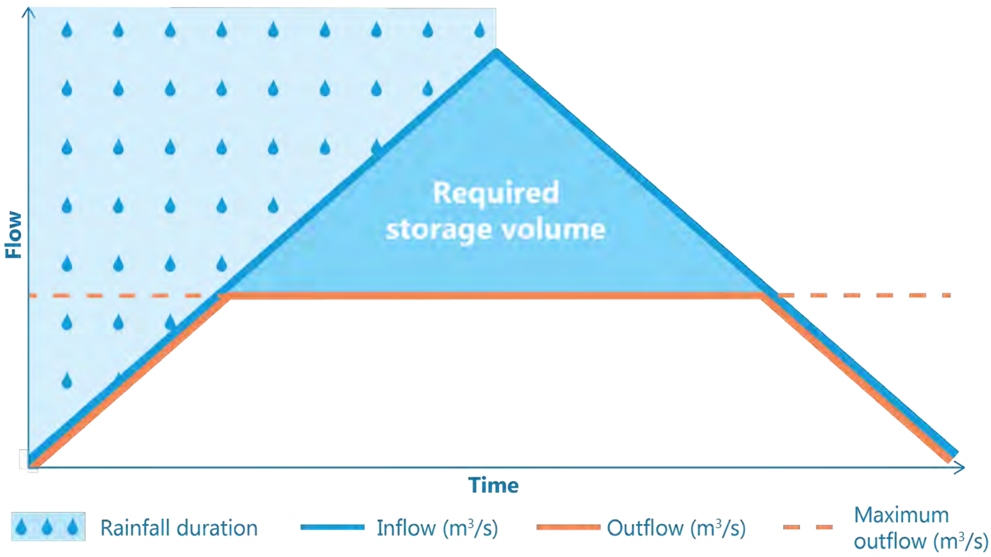


Figure 5-3 Simple visualization of the storage volume calculations
Source: Ramboll

5.2.3 EVALUATION OF HYDRAULIC FUNCTIONS

To evaluate the hydraulic functions of the proposed pilot projects, two key parameters are calculated. One parameter will be related to storage while the other evaluates conveyance capacity.

Evaluation of Storage Volume: The effect of the storage volume provided by the typologies proposed for the pilot sites will be evaluated based on the area the mitigation measure can 'support' in the sub-catchment. This will be a function of the required storage volume in the catchment, the total area of the catchment and the available storage at the pilot site. As such, the effect of the pilot sites is normalized to make the values comparable. On this basis, catchment with higher runoff coefficients i.e., catchments with a high percentage of impermeable surfaces will require more volume to support the same area as catchment with lower average runoff coefficients. Normalized parameters will provide a sense of scale for the impact of the typologies at the pilot sites and be a point of comparison between the typologies.

Evaluation of Conveyance Capacity: The conveyance capacity of the typology will be calculated using the standard manning equation as described in section 5.2.2. Conveyance infrastructure will be dimensioned to convey a flow equivalent to the peak runoff from a 3-year rainfall event (in future climate conditions). Where the recommended NbS does not have sufficient capacity to achieve this, supporting gray infrastructure is recommended.

5.3 SOCIO-ECONOMIC APPRAISAL FOR PILOT SITES

As noted in Section 2.2, NbS have the potential to provide a wide range of socio-economic co-benefits for Baguio City (both the LGU and its citizens) in addition to flood mitigation. By taking a multi-purpose approach, NbS can help revitalize urban areas and improve liveability by leveraging space, infrastructure, and the environment, bringing amenity and recreational values to serve a community's interest, drive change, growth and transformation and improve the well-being of its inhabitants.

Yet co-benefits are often ignored or only partially captured when formulating any given project's economic analysis since their associated values are often considered immaterial, or are viewed as intangible, indirect or hard to ascribe and therefore, are not valued in quantitative or monetary terms. This can lead to co-benefits not being optimized and skewed analysis toward a more positive outcome for conventional grey infrastructure and the selection of sub-optimal alternatives. Therefore, a prerequisite for qualified decisions on NbS initiatives is to quantify and monetize the material co-benefits anticipated to be delivered, hence, assisting decision-makers facilitate a more efficient allocation of society's resources.

A critical conceptual aspect of this approach is that valued benefits are measured relative to the status quo or baseline ("do-nothing" scenario). In this way, the co-benefits assessment is an ex-ante analysis conducted both from a with- and without-project basis, and hence includes only incremental values for the benefit criteria (net change).

Application of the above-mentioned process would fall under a more schematic design approach, where several details necessary for co-benefits to be properly quantified, would have to be addressed. These details can range from a better technical dataset on urban drainage infrastructure, which would allow including urban drainage modelling to have a better and more local flood mapping, to tailored socioeconomic surveys that would give a more representative sample and reality check. As this is a conceptual high-level flood mitigation action plan, the focus is on conceptual designs, for which a number of assumptions are made, and where we have outlined the methodology to follow in upcoming phases once better data is obtained and a more accurate valuation of co-benefits can occur. See also the roadmap presented in Section 6.1.

5.3.1 SELECTION OF THE SHORT-LIST OF MATERIAL CO-BENEFITS

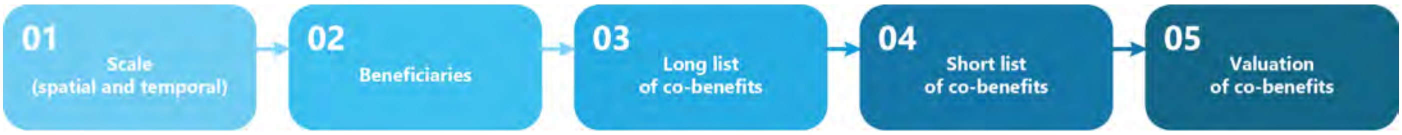


Figure 5-4 Methodological process for estimating co-benefits

Source: Ramboll

The estimation of co-benefits follows a five-step iterative process, illustrated in Figure 5-4 below.
Based on the conceptual models for each NbS, as initial actions, steps 1 and 2 require an appraisal of the scale over which each co-benefit accrues (both spatial and temporal) and their respective beneficiaries (i.e., what benefits are delivered, over which area, and over what timeframe do each of the co-benefits accrue). This will enable the prioritization of co-benefits materialize for each particular NbS, based on the long list of potential co-benefits presented in Appendix B, to obtain a short list of material benefits for the intervention.

Prioritization of co-benefits is conducted though a screening process using professional judgment and a series of selected and agreed materiality criteria, such as:

1. Anticipated presence or absence of co-benefit
2. Relevance to beneficiaries that may be affected
3. Anticipated changes in co-benefits across scenarios (i.e. extent and magnitude of the change)
4. Other aspects such as e.g. recovery time, based on the level and nature of disturbance of existing habitats

Data availability and regulatory requirements should be considered as part of the process, as mentioned before. However, data availability in itself should not be used as a criterion for prioritization, as a lack of data should not be equated to a lack of impact. In the event of data gaps that prevent a full quantitative or monetary valuation impacts, a qualitative assessment should be conducted, and uncertainties and data gaps identified. Once co-benefits have been prioritized, they are taken forward for economic valuation in Step 5. This valuation process is described in detail in the following section.

A list of anticipated changes that could be delivered by each co-benefit, indicators of value (i.e., valuation proxies) and baseline data needs is presented in Appendix C.

5.3.2 OVERVIEW OF THE ECONOMIC VALUATION PROCESS FOR NBS CO-BENEFITS

The economic valuation of co-benefits is two-fold:

- Quantitative valuation of co-benefits. For all the material impacts included within the scope of the assessment, anticipated changes in the level of co-benefit provision with the NbS scenario relative to the without NbS scenario are quantified in biophysical units (e.g. hectares for each type of habitat created, number of trees). Impact factor multipliers are subsequently identified for each co-benefit (e.g. pollutant deposition capacity (ton/ha) per habitat type). The quantitative valuation of co-benefits should be net of any disbenefit (temporal or permanent) resulting from the NbS.

- Monetary valuation of co-benefits. Using either market prices or a value transfer approach, a literature/database search is conducted to identify relevant monetary values for each co-benefit (e.g. avoided health costs per ton of pollutant deposited in vegetation). When market prices are not available, the monetary values obtained through the value transfer approach are based on 'willingness to pay' (or willingness to accept compensation) values obtained from environmental valuation techniques (i.e., revealed or stated preferences methods). . The monetary value is adjusted (e.g. inflated to real prices, adjusted to the Philippines based on purchasing power parity) and applied to the quantitative units (e.g. total pollutant deposition by the NbS x avoided damage cost per ton of pollutant per year). The flow of benefits anticipated over the lifetime of the project[18] is then discounted to express each co-benefit in present value terms.

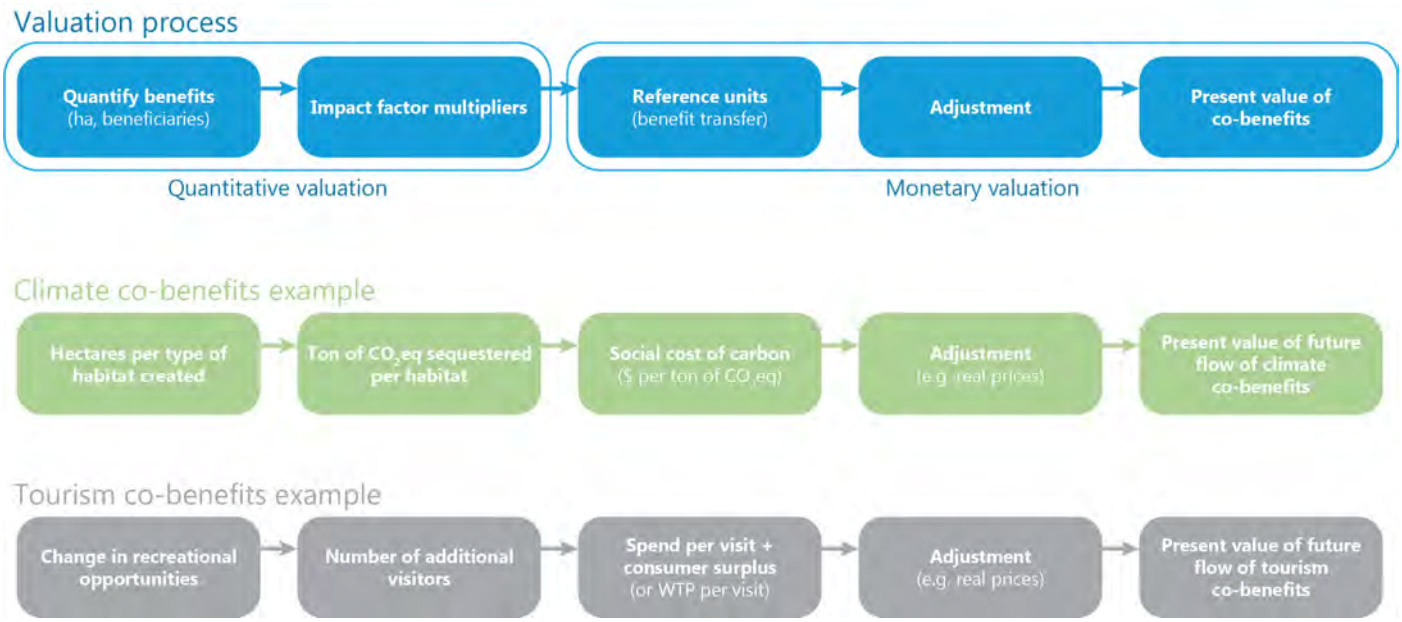


Figure 5-5 Economic valuation process of co-benefits
Source: Ramboll

18 The temporal scope of the assessment is consistent across all co-benefits and, in a CBA context, project costs.

Figure 5-5 below presents an overview of the key steps involved in valuing co-benefits. A sensitivity analysis can also be conducted to assess the influence of various indicators and to test assumptions. Net Present Value (NPV) of the co-benefits for each option enable comparison across, for example, design alternatives for each NbS or across potential NbS locations, and the identification of trade-offs.

In addition, non-monetizable benefits, risks, constraints, dependencies, and uncertainties can be identified and documented as part of the assessment to support the interpretation of the co-benefit valuation results and inform the selection of the preferred option. The results of the appraisal are used in subsequent phases to inform the design of the preferred option so as to maximize the benefits and minimize disbenefits.

5.3.3 ECONOMIC VALUATION METHODOLOGY

Further to the shortlisting process described above, three of the co-benefits anticipated to present higher materiality[19] for the three pilot NbS interventions are presented in Table 5-2 below.

The reader must be advised that in the absence of local and technical design data, all presented data points are indicative and rely on assumptions. They are intended to demonstrate co-benefit valuation for NbS options in the Baguio context could be executed. In practice such an economic assessment would include gathering additional local data. This is also outlined in the roadmap in Section 6.1.

Table 5-2 Economic valuation approach for the three most material co-benefits

	NbS Driven Changes	Co-benefit	Indicator of change	Value	Baseline Data Needs
1	Attracting more visitors and users	Increased demand for services (retail, hospitality)	Business growth (increased business turnover, increased number of businesses)	Employment, taxes	Customer numbers Average spend Number of businesses Number of jobs GVA in vicinity
2	Aesthetic setting, attractiveness to residents and businesses	Increased amenity value	Increased demand for property in close proximity to the NbS	Property value premiums	Number of households or properties within 50m Property values
3	Recreational green/blue space, sports, and leisure facilities	Increased access to local, safe, and natural green/blue space and sports facilities	Increase in physically active visitors	Avoided health costs; reduced morbidity	Number of physically active visitors; Quality Adjusted Life Years (QALY) attributable to physical activity

Source: Ramboll

19 Preliminarily determined based on the information available at this stage.

The following sections provide an overview of the general economic approaches used for their respective monetary valuation. Methodological considerations specific to each site are presented in section 5.4.4, section 5.5.4, and section 5.6.4, respectively.

Co-benefit 1: Increased demand for services
To value the anticipated increase in demand for services resulting from the NbS, the economic value associated to the additional taxes and employment driven by the increase in the number of visitors and users attributable to the intervention is assessed.

The potential trickle-down effects of increased employment and taxes may be substantial, but certainly complex. For this reason, the scope of economic impact is limited to the gross value add (in monetary terms) from increased disposable income associated with higher employment, and increased tax revenue associated with growing business turnover.

To calculate this co-benefit, the following calculations are suggested to be conducted in the with and the without NbS scenarios (to be confirmed during schematic design and also dependent on data availability) (Figure 5-6).

Co-benefit 2: Amenity value
To value the co-benefit of increased amenity value, the impact of the NbS on property value premiums is assessed. This is typically measured using hedonic regression or hedonic demand theory[20]. In the absence of localized revealed preference proxy values, and following a benefit transfer approach, data from primary studies conducted at other locations from international best-practice are proposed to be utilized.

Many studies around the world find a positive impact of the view on, and proximity to, green space and water bodies to urban property values. For those NbS solutions that don't necessarily create new green space (such as the stormwater park), the improved value is linked to the increase in quality and accessibility of the nearby green space. Generally, the impact of green space on property values decreases with distance: directly adjacent properties with a view on the green space have the highest added value, and a smaller effect is generally measured within a larger radius.

To calculate this co-benefit, the following calculation is suggested in the with and without NbS scenarios (to be confirmed during schematic design and also dependent on data availability) (Figure 5-7).

Co-benefit 3: Access to local, safe green/blue space and sports facilities
The co-benefit of increased access to local, safe, and natural green/blue space and sports facilities in stormwater parks, regenerated green streets and urban canals is anticipated to have a positive impact on engagement with these assets and therefore increased recreational use and physical activity. This improves both physical and mental health of residents, which, in turn, reduces health costs and produces a higher quality of life.

To calculate this co-benefit, the following calculation is suggested in the with and without NbS scenarios (to be confirmed during schematic design and also dependent on data availability) (Figure 5-8).

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20 A revealed preference method of estimating the demand for a property, with its value being broken down into its constituent characteristics, obtaining estimates of the contributory value of each characteristic.

The health benefit proxy defines the monetary value of improved health outcomes from increased physical activity. The impacts of increased physical activity such as walking, and cycling, are usually measured through Health-Adjusted Life Years (HALYs) – life years adjusted with disability weightings related to loss of health-related quality of life. Ideally, local studies exist with HALY baseline data with which to use. In the absence of travel time or entry fees for recreational uses, relevant welfare values can be identified.

As in previous co-benefits, benefit transfer methods will be applied based on previous studies from the Philippines in the first instance when available, or else, international studies. For instance, appraisal guidance from Sydney Australia suggests using a health value proxy of AUS$1.83 per km walked.

Figure 5-6 Proposed methodology for calculation of increased demand for services.
Source: Ramboll

Figure 5-7 Proposed methodology and for calculation of amenity value.
Source: Ramboll

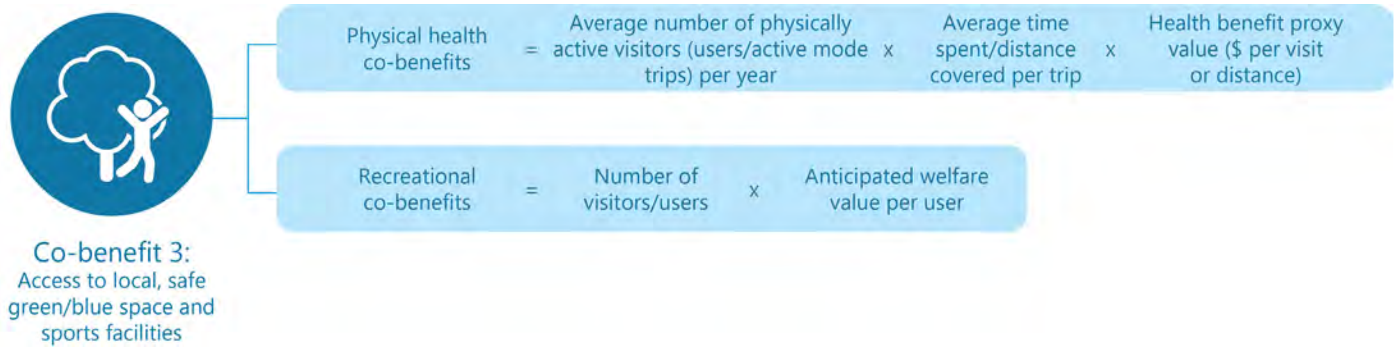
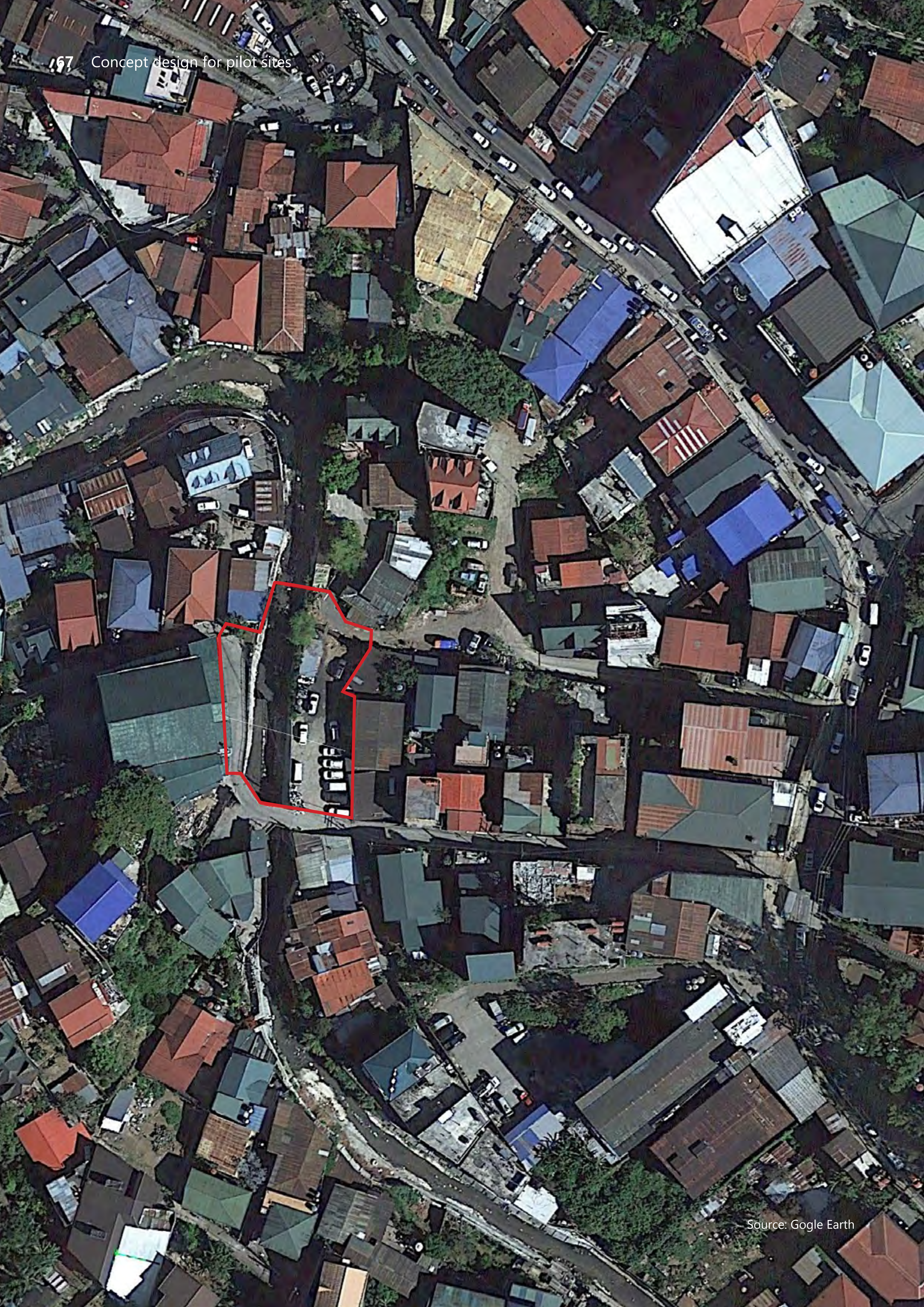


Figure 5-8 Proposed methodology for calculation of access to local, safe green/blue space and sports facilities.
Source: Ramboll



Source: Gogle Earth

5.4 CONCEPTUAL DESIGN: URBAN CANAL, NEAR MANUAL ROXAS

5.4.1 DESCRIPTION OF SITE

The urban canal site is located on the Bailli River close to Manuel Roxas street. The northern and southern limits of the chosen site are two (unnamed) access streets emerging west of Manuel Roxas Street, located between lots numbers 137 (north) and 138 (south). The site is owned and managed by the LGU, through the CEO. Development will either be coordinated by the DPWH or the LGU will prepare a project proposal to be implemented by the DPWH.

The site is located within a densely built urban area hosting primarily residential properties, but also a mix of other functions such as hotels, restaurants, stores, gyms, auto shops, churches, and schools. The space consists of roadways, canal margined by a safety rail and the parking lot. There are no public space amenities or green spaces within the site.

The northern access street ends approximately 65 meters west of Manuel Roxas street and opens into an undefined open space and access roads. The southern access street, extending in the same direction, continues with a small bridge over the canal (southern limit of site), and turns 90 degrees north for approximately 30 meters (western limit of site) then turns another 90 degrees west. This part of the site is margined by two 4 level buildings, an apartment rental house, and a church. The eastern side of the site is an open space, currently used as a parking lot (for an auto shop). This side of the site is bordered by private lots characterized by 2 to 4 level houses with adjacent yards. The northern limit of the site is considered to edge the buildings north of the parking lot.

Within a 200m radius, the canal presents a few connection elements such as car and pedestrian bridges and access roads. The waterway easements are currently built close to the canal margin and there is little to no green space.

Figure 5-9 Pilot site at Balili River near Manual Roxas

Source: LGU

5.4.2 PROPOSED CONCEPTUAL DESIGN FOR SITE

The urban canal conceptual design proposes reshaping the canal, which currently only serves as drainage infrastructure, to a vibrant recreational public space by rethinking the waterway easement to include spaces for people and nature. The future canal is to be a place for people to informally meet and gather and is to serve as a new community destination. The vision is to create a green, comfortable space that brings people closer to water and enriches nature within the urban realm. By allowing people to access the waterfront, the incentive in the local community to protect the water quality is increased by creating a shared sense of community ownership. The conceptual design for the urban canal is presented in Figure 5-10. The design proposes an expansion of the eastern side of the canal to create a recreational area that provides detention volume in extreme rain events while providing a comfortable recreational space in normal weather conditions.
In the western side of the canal, at ground level, a balcony structure serves as a viewpoint and features elevated planter boxes for taller vegetation. In connection to this structure, the canal wall is proposed to have built-in planter boxes forming a green wall facing the sitting area. At the eastern part of the site the existing parking lot will be replaced by a five-level amphitheater structure with an organic shape, accommodating sitting areas, walkways, cleansing biotopes, and vegetation.

The five levels (level 1-5, starting from street level) of the amphitheater include:

- Level 1 is at street level has a transit functionality and links the two access streets defining the site edges.
- Level 2 consists the largest sitting area as it's margined by a continuous wooden bench that follows the organic shape of the steps.
- Levels 3 and 4 are narrow and have limited sitting areas but create space for high vegetation.
- Level 5 is the widest strip of the structure, brings people close to the canal and is proposed to continue downstream the canal until it reaches access roads or other bridges and thus, enabling a walking path long the canal that will serve as part of the 'Blue Walks' initiative.

The levels are linked by arched stairs with a small green area planted with trees. Safety railing is proposed between levels 1,2 and 3.

The distribution of space on the north-south axis is asymmetrical, giving more space for vegetation in the north and accommodating sitting and transit in the south. Taller vegetation will provide shading and contribute to a comfortable microclimate. Biotopes will be implemented in the northern and southern part of the site.

Even though this project can stand on its own, it should be considered as part of the ongoing efforts of easement reclamation along the canals and rivers[9] as it will provide benefits to both the hydraulic capacity of the drainage network as well as recreational benefits for the population. The project also provides a strong link to the "Blue Walks" initiative that aims at bringing the population closer to the water and restore more natural conditions.

Figure 5-10 Plan view of Urban Canal conceptual design
Source: Ramboll

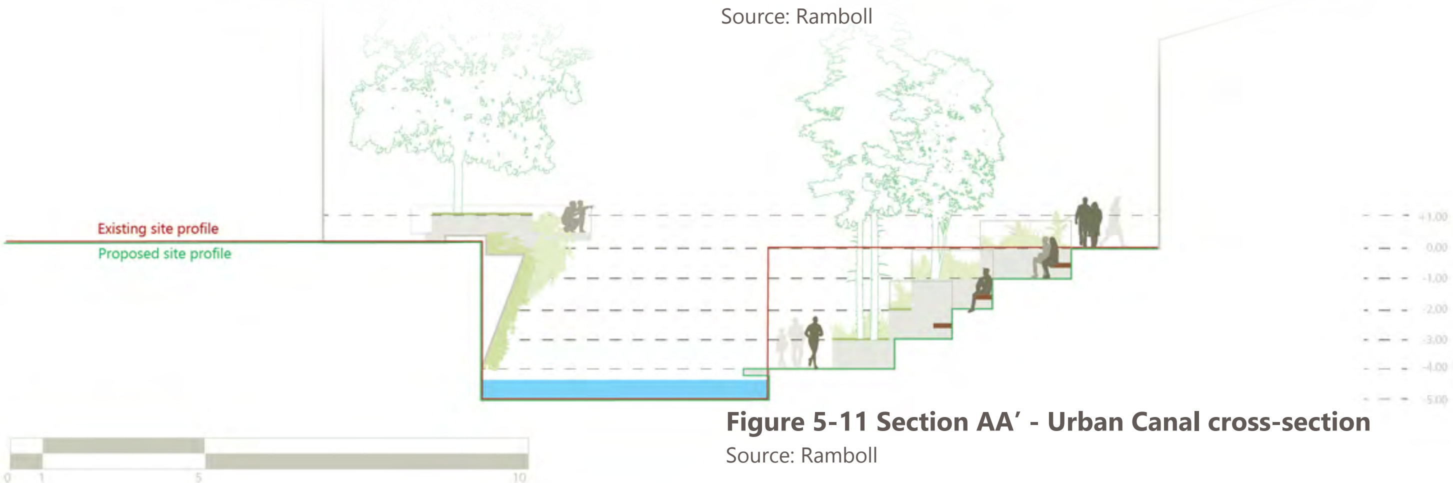


Figure 5-11 Section AA′ - Urban Canal cross-section
Source: Ramboll

5.4.3 HYDRAULIC ASSESSMENT

The primary purpose of the application of the typology at the selected pilot site is to demonstrate how the confined river may be transformed into a vibrant active space for people. The proposed expansion of the canal at the pilot site location near M. Roxas will provide a storage buffer to be used up on the rising limb during extreme rain events to reduce overflow from the river network. Runoff from the immediate surrounding area will be filtered through cleansing biotopes before discharge to the canal. The implementation of cleansing functions along the canal is a priority due to the poor water quality of the rivers in Baguio. The hydraulic assessment is briefly described below and further detailed in Appendix F.

Figure 5-12 shows the pilot site with its respective catchment area.

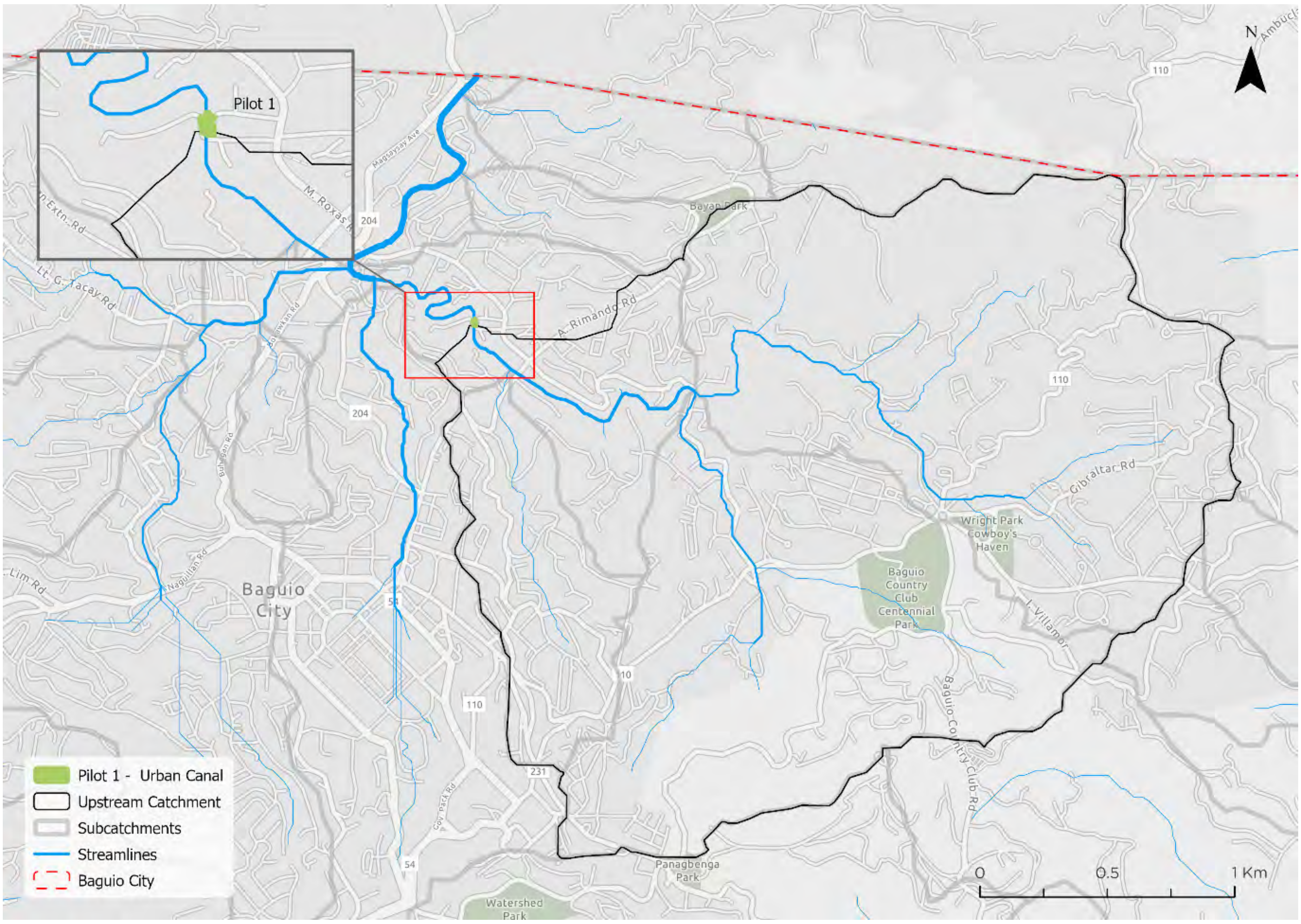


Figure 5-12 Pilot 1 - Urban Canal and Catchment Area

Table 5-3 outlines the key hydraulic functions, design parameters and flood mitigation benefits of this NbS.

Source: Ramboll

Table 5-3 Hydraulic Assessment - Pilot 1 Urban Canal

Site conditions	
Location	Balili River near Manual Roxas (137-138)
Catchment Area	586 ha
Average runoff coefficient	0.57
Length of canal section	45 m
Area of the canal expansion	1250 m^2
Hydraulic design parameters	
Hydraulic pre-conditions	• The canal is well maintained and free of solid waste • The canal is free from encroachment, including infrastructure such as utilities that obstructs the flow • Rainfall runoff reaches the canal unobstructed, through supporting NBS and traditional gray infrastructure such as pipes and drains
Time of concentration	60 min
Design Rainfall intensity (3-year event)	97.89 mm/hr
Peak runoff (3-year event)	90.59 m^3/s
Limiting discharge	77.23 m^3/s
Total volume required in catchment	7,098 m^3
Volume required per hectare	12 m^3/ha
Hydraulic Functions	
Primary hydraulic functions	Filtration, Conveyance
Hydraulic elements	Biotopes, terracing
Full flow capacity	• Existing Section: 168m^3/s (~10-year event) • Proposed section: 286 m^3/s (~20-year event)
Proposed design storage volume at site	452 m^3

Source: Ramboll

Based on the proposed design, the flow capacity is increased from an existing full flow capacity of 168 m3/s to 286 m3/s along the section of the river that is expanded. It should be noted that this increase in flow capacity is localized, and the allowable discharge from areas in Baguio will still be limited by the identified hydraulic bottleneck i.e., the specific discharge calculated as the lowest discharge capacity in the Balili river relative to the catchment area. As the full flow capacity at this specific section of the canal is significantly higher than the limiting capacity elsewhere in the canal, overflows may occur elsewhere in the catchment before the proposed cross-section of the canal can be fully utilized. The full flow capacity may be improved along the entire length of the canal in future development programs, to reach a similar flow capacity.

The Urban Canal typology primarily serves to increase full flow capacity of the river in a way that adds benefits beyond flood mitigation. The hydraulic benefits at this particular location are limited as the increase in flow capacity is localized, and the implementation is primarily driven by co-benefits. When easement clearing plans are finalized, it is recommended that the urban canal typology is applied at hydraulic bottlenecks to increase flow capacity of the river.

The catchments contributing to the primary drainage network of canals and rivers in Baguio are by definition relatively large, hence it is critical that any interventions implemented along the canal and rivers are supported by decentralized flood mitigation measures throughout the catchment contributing to the canal. This typology should be viewed as a layer in a multilayered system of mitigation measures, and measures to convey water to the canal and decentralized volumes through the catchment will be required to successfully provide flood protection.

5.4.4 APPRAISAL OF SOCIO-ECONOMIC BENEFITS

The co-benefits anticipated to present higher materiality for the Urban Canal are presented below, alongside the general economic formulas used to value them (for a more detailed understanding of the proposed economic approach to valuation, please see Section 5.3). It should also be noted that this is a conceptual high-level action plan, and actual valuation of the co-benefits is not taking place. We have proposed a detailed methodology, and a roadmap where we describe the process to follow in the upcoming phases.

Where available, existing baseline information used to inform the calculations are included. Data gaps in relation to baseline socio-economic conditions and technical design considerations are illustrated by red cells in the formulas below. There are different actions that can be taken to address these gaps, i.e. analysis of primary data from Baguio City or based on relevant studies or methodological guidance. These actions would be needed to undertake in the schematic design proposed in the roadmap (Section 6.1) in order to undertake a monetary valuation. In this regard, the formulas are merely indicative at present.

Co-benefit 1: Increased demand for services
To value the co-benefit of increased demand for services, the economic value of increased taxes and employment associated with business growth around the NbS intervention is assessed. To calculate this co-benefit, the following calculations are suggested (to be confirmed during schematic design) (figure 5-13).

Co-benefit 2: Amenity value
To value the co-benefit of increased amenity value, the impact of the NbS on property value premiums is assessed. The following calculation is suggested (to be confirmed during schematic design) (figure 5-14).

Co-benefit 3: Access to local, safe green/blue space and sports facilities
The co-benefit of increased access to local, safe, and natural green space and sports facilities in stormwater parks, regenerated green streets and urban canals is assumed anticipated to have a positive impact on engagement with these assets and therefore increased recreational use and physical activity.
To value this co-benefit, the following calculation is suggested (to be confirmed during schematic design) (figure 5-15).

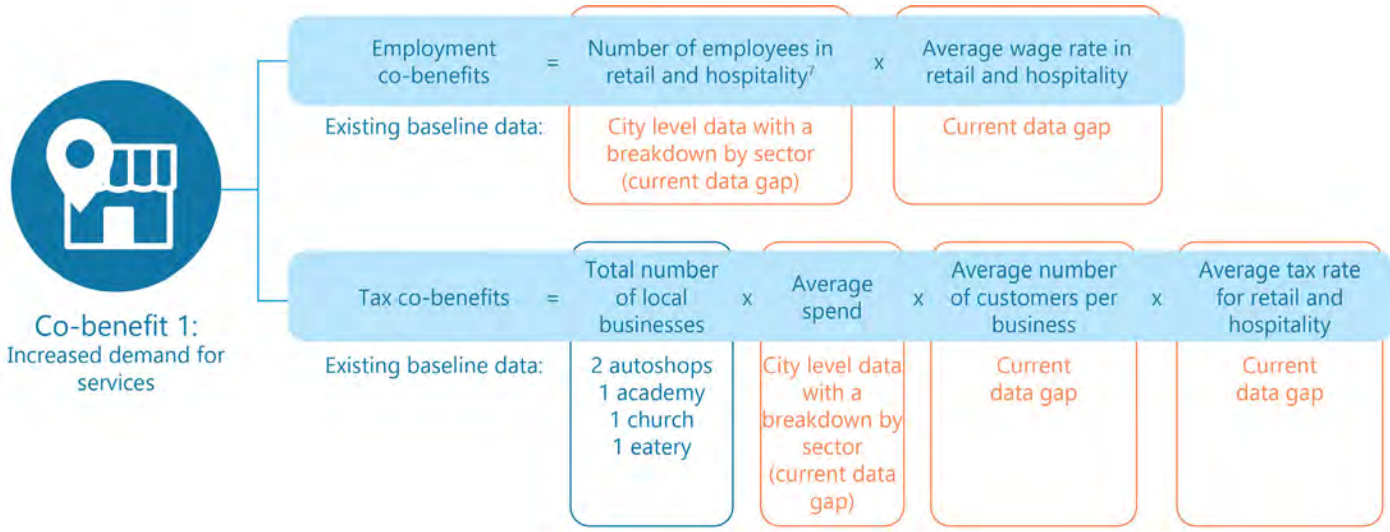


Figure 5-13 Proposed methodology for calculation of increased demand for services for the urban canal.

[7] This number can be directly or indirectly estimated (i.e. calculated from number of new businesses multiplied by average number of employees)

Source: Ramboll

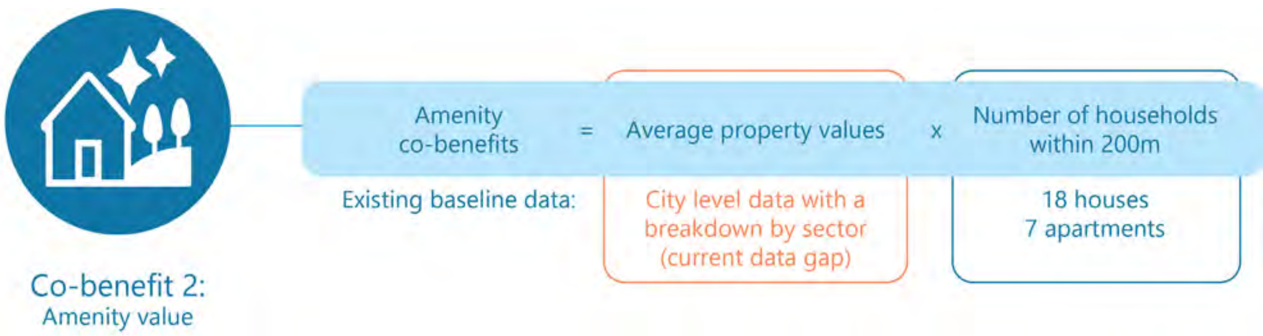


Figure 5-14 Proposed methodology and existing baseline data for calculation of amenity value for the urban canal.

Source: Ramboll

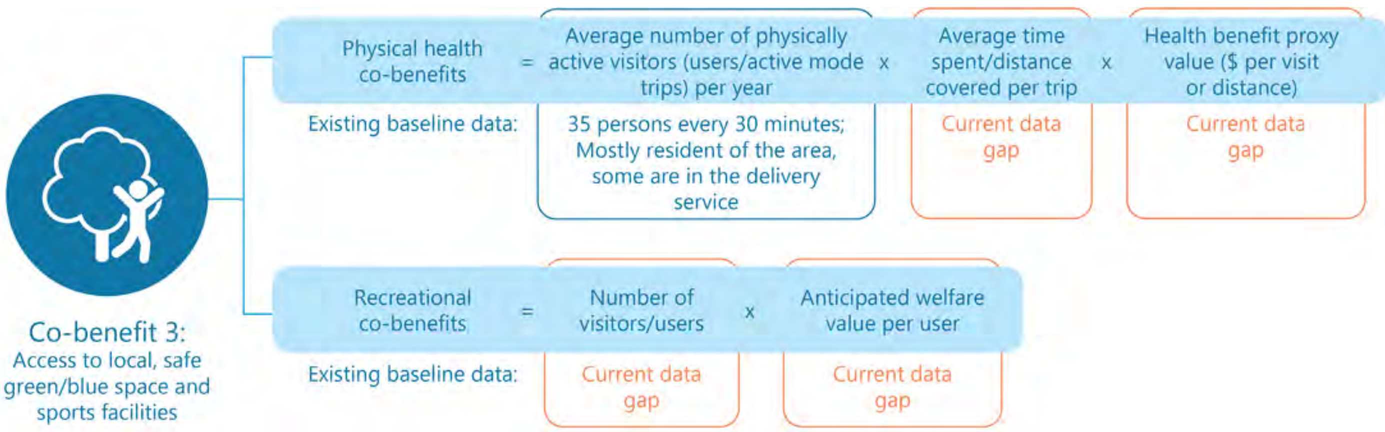
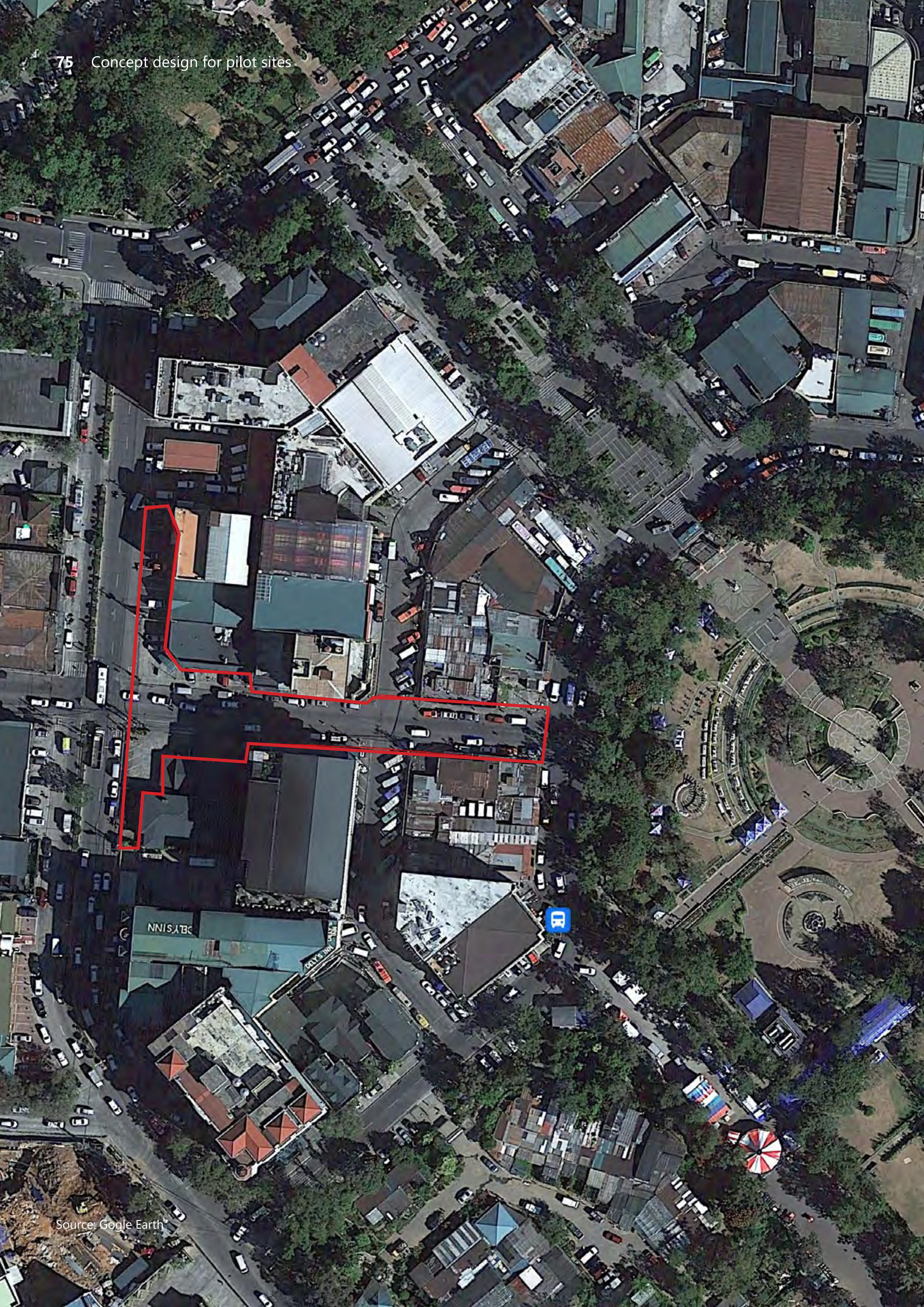


Figure 5-15 Proposed methodology and existing baseline data for calculation of access to local, safe green/ blue space and sports facilities for the urban canal.

Source: Ramboll



Source: Gogle Earth

5.5 CONCEPTUAL DESIGN: GREEN STREET AT CARINO STREET

5.5.1 DESCRIPTION OF SITE

Carino Street is located in the Rizal Monument Area west of Burnham Park and is part of a well-defined half-octagonal street structure in the close to Baguio City Hall. It is situated on a WE direction and is divided in three segments intersected by Legarda Road and Kisad Road on the western part and Otek Street and Shanum Street on the eastern part. The closeness to Burnham Park makes it an ideal location for a green street, as there is an opportunity of extending the green space of the park wider into the public realm. Cariono Street located close to the Central Business District and it's a highly transited area connecting institutions and main touristic attractions. The site is owned and managed by the LGU through the CEO.

The considered site extends from Kisad road in the west to Shanum Street in the east. The site for the green street extends from Kisad Road in the west to Shanum Street in the east. The buildings on Between Otek and Shanum Street, Carino Street houses smaller stores, businesses, and offices. Towards Burnham Park, Carino Street is margined by low height, private-owned, market-like low buildings and structures. The Department of Tourism is located on the street.

Carino street's profile is made up of approximately 1 m sidewalks on both sides, multiple traffic lanes, and right-of-way parking. At the corner buildings of the street, additional parking lots are available.

Figure 5-16 Pilot site at Carino Street

Source: LGU

5.5.2 PROPOSED CONCEPTUAL DESIGN FOR SITE

The Green Street concept design proposes reprofiling the traditional streetscape into a green, comfortable, and enjoyable space. The future Carino Street is shaped for people with the vision of improving conditions for active mobility. People are prioritized by including space for bikers and pedestrians and space for motorized vehicles is limited.

The design tailored to Carino Street showcases green space connectivity and promotes room for nature and water in streetscapes. The street profile will be redesigned as a one-way-street which allows room for vegetated bioswales along the sidewalks. Nature is brought into the streetscape by replacing impermeable surfaces with lush vegetation. The street will serve as a green extension of Burnham Park, as demonstrate integration of the natural and built environment. Recreational areas for people to rest and enjoy nature with be included in the design of the streetscape.

The new street profile for Carino Street consists of an enlarged sidewalk, a 3-meter-wide green strip with a bioswale, a one-way car lane margined by bicycle lanes and a sidewalk at the southern site of the site. On the south part of the road, the car and bicycle lane are separated by a small bioswale. A shared space approach is proposed for the areas overlapping with parking access and the intersection with Otek street. This approach entails priority-based use of common space, by vehicles and people, and should be tailored to local legislation.

The 3-meter-wide green strip enacts as a road-side park. The road-side park includes a bioswale for conveyance, detention and treatment of stormwater, low, medium and high vegetation as well as smaller 'pockets' with urban furniture for resting placed on permeable pavements. Towards the eastern side of the street, space for bicycle parking is envisioned, connected to the sidewalk by small wooden bridges.

The western end of the site includes the adjacent parking lots in the design of green spaces serving as smaller 'pocket parks' in the urban realm. These are proposed to host multiple plant species of varying heights and include seating areas. The entrances to the two restaurants in the corner buildings are marked by arched wooden pathways.

Medium to tall vegetation is proposed along all the newly introduced green areas and it is envisioned to link with the vegetation canopy of Burnham Park to allow microclimate formation, natural habitat expansion, and shading. To achieve a complete transformation to a green street it is encouraged that the neighboring buildings adopt green elements, such as living roofs or green walls.

The Green Street at Carino Street is directly linked to the 'Green Walks' initiative. It creates a green urban corridor and encourages people to walk, bike and actively move in the urban realm. Furthermore, the conceptual design is aligned with plans for active mobility in the Masterplan for Burnham Park[10].

Figure 5-17 Plan View of Green Street Conceptual Design at Carino St.

Source: Ramboll

Figure 5-18 Section AA′ - Green Street Conceptual Design at Carino St.

Source: Ramboll

5.5.3 HYDRAULIC ASSESSMENT

The hydraulic assessment for the green street is described below and further detailed in Appendix F. The hydraulic functions of a green street may vary depending on the physical constraints of the site. Where the available space is limited, traditional gray infrastructure will be required to support the conveyance function of the terrain-based vegetated swales with the functions of the swales being primarily limited to detention and improving water quality of the recipient. Water quality benefits are obtained as the runoff from daily rain events will be filtered through the vegetated layers of the swale. To accommodate runoff from more intense rain events, the swales proposed at Carino Street will be connected to an underground pipe through a number of pits, with the aim of quickly conveying water away from the surface and protect the surrounding areas from damaging floods. At sites with more space availability, the swales may be wide enough to contribute significantly to the conveyance of rainwater and may in some cases function without the support of gray infrastructure.

As the volume in the swales is limited by the available space on the street, additional measures such as raingardens and stormwater basins are required in the catchment to ensure that peak flows do not exceed the limiting flow capacity of the recipient canal. However, as the street is upstream from Burnham Park, which may function as one of the primary detention basins in the city, the primary function of the green street in this setup will be to convey and treat rainwater runoff from daily events.

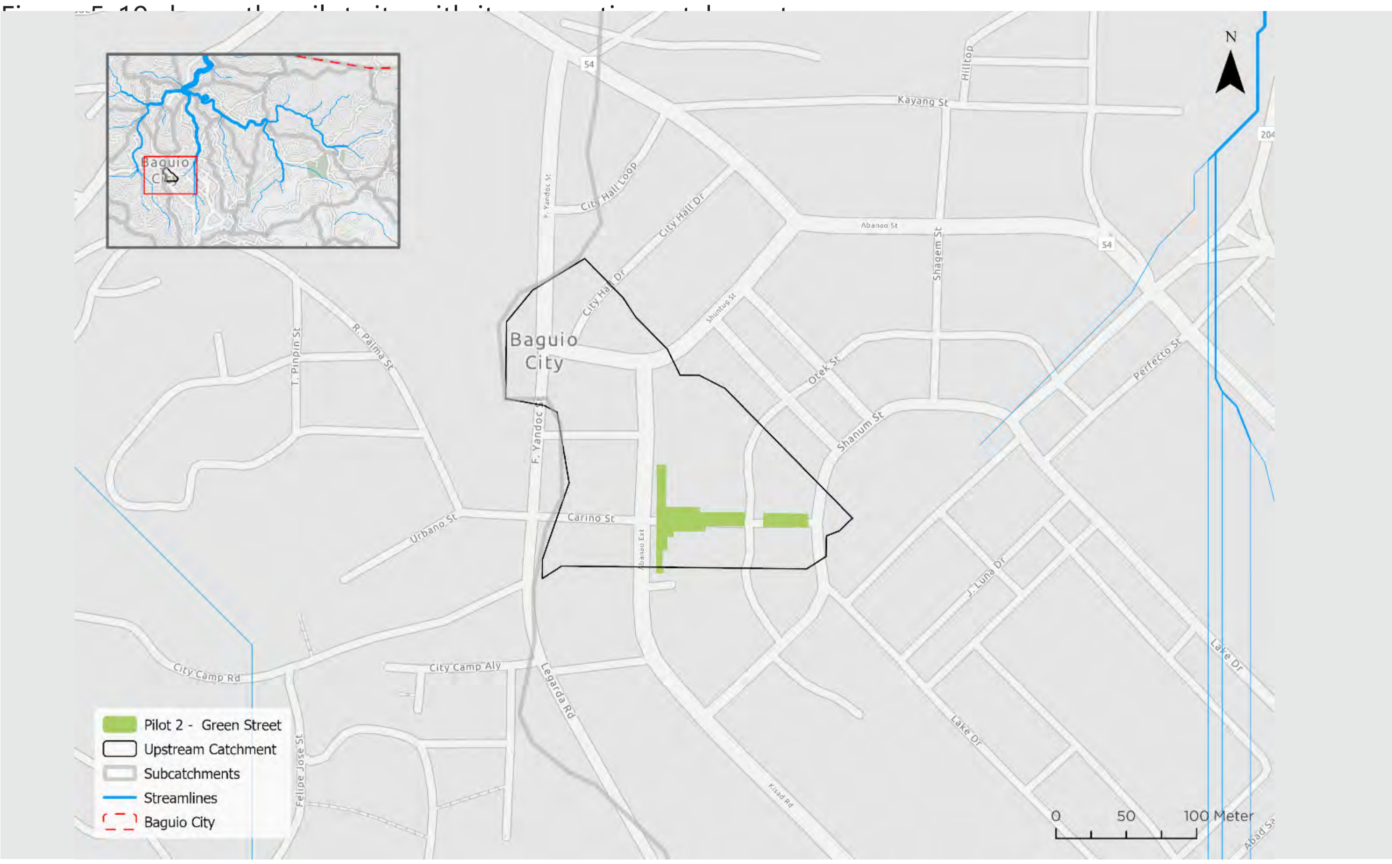


Figure 5-19 Pilot 2 - Green Street and Catchment Area

Source: Ramboll

Moreover,Table 5-4 outlines the key hydraulic functions, design parameters and flood mitigation benefits of this NbS.

Table 5-4 Hydraulic Assessment - Pilot 2 Green Street

Site conditions	
Location	Carino Street
Catchment Area	3.03 ha
Average runoff coefficient	0.8
Area of the site[a]	855 m^2
Hydraulic design parameters	
Hydraulic pre-conditions	• The swales are well maintained and without excessive vegetation • The swales are free from blockages, such as solid waste • There are pits connecting the swales with pipes with sufficient capacity to convey the runoff of a 3-year rain event • Runoff is carried on the surface from the catchment to the swales • Culverts does not restrict the flow
Time of concentration	10 min
Rainfall intensity (3-year event)	218.21 mm/hr
Peak runoff (3-year event)	1.473 m^3/s
Limiting discharge	0.400 m^3/s
Maximum Flow Velocity in Swales	1.2 m/s
Total volume required	470 m^3
Volume required per hectare	155 m^3/ha
Volume required per hectare	
Primary hydraulic functions	Filtration, Detention, Conveyance
Hydraulic elements:	Vegetated swales, permeable pavements, pipes
Full flow capacity	• 0.238 m^3/s in swales • 1.24 m^3/s in 2*450 mm pipes[b]
Total detention volume at site:	19 m^3
Area supported by storage volume	0.20 ha

[a] Surface area of the road
[b] Minimum diameter required, next available diameter on the market should be used
Source: Ramboll

The primary function of the green street at Carino Street will be to convey and treat runoff from daily rainfall events. Based on preliminary calculations, the swales will be able to convey (and treat) runoff for rainfall intensities up to 35 mm/hr. This will contribute to improving the water quality in the receiving water bodies such as in Burnham Park and improve the experience of visitors to the park.

5.5.4 APPRAISAL OF SOCIO-ECONOMIC BENEFITS

The co-benefits anticipated to present higher materiality for the Green Street are presented below, alongside the general economic formulas used for valuation (for a more detailed understanding of the proposed economic approach to valuation, please see Section 5.3). It should also be noted that this is a conceptual high-level action plan, and actual valuation of the co-benefits is not taking place. We have proposed a detailed methodology, and a roadmap where we describe the process to follow in the upcoming phases.

Where available, existing baseline information used to inform the calculations is included. Data gaps in relation to baseline socio-economic conditions and technical design considerations are illustrated by red cells in the formulas below. There are different actions that can be taken to address these gaps, i.e., analysis of primary data from Baguio City or based on relevant studies or methodological guidance. These actions would be needed to undertake in the schematic design proposed in the roadmap (Section 6.1) in order to undertake a monetary valuation. In this regard, the formulas are merely indicative at present.

Co-benefit 1: Increased demand for services

To value the co-benefit of increased demand for services, the economic value of increased taxes and employment associated with business growth around the NbS intervention is assessed. To calculate this co-benefit, the following calculations are suggested (to be confirmed during schematic design) (figure 5-20).

Co-benefit 2: Amenity value

To value the co-benefit of increased amenity value, the impact of the NbS on property value premiums is assessed. To calculate this co-benefit, the following calculation is suggested (to be confirmed during schematic design) (figure 5-21).

Co-benefit 3: Access to local, safe green/blue space and sports facilities

The co-benefit of increased access to local, safe, and natural green space and sports facilities is assumed to have a positive impact on engagement with these assets and therefore increased physical activity. This improves both physical and mental health of residents, which, in turn, reduces health costs and produces a higher quality of life. To calculate this co-benefit, the following calculation is suggested (to be confirmed during schematic design) (figure 5-22).

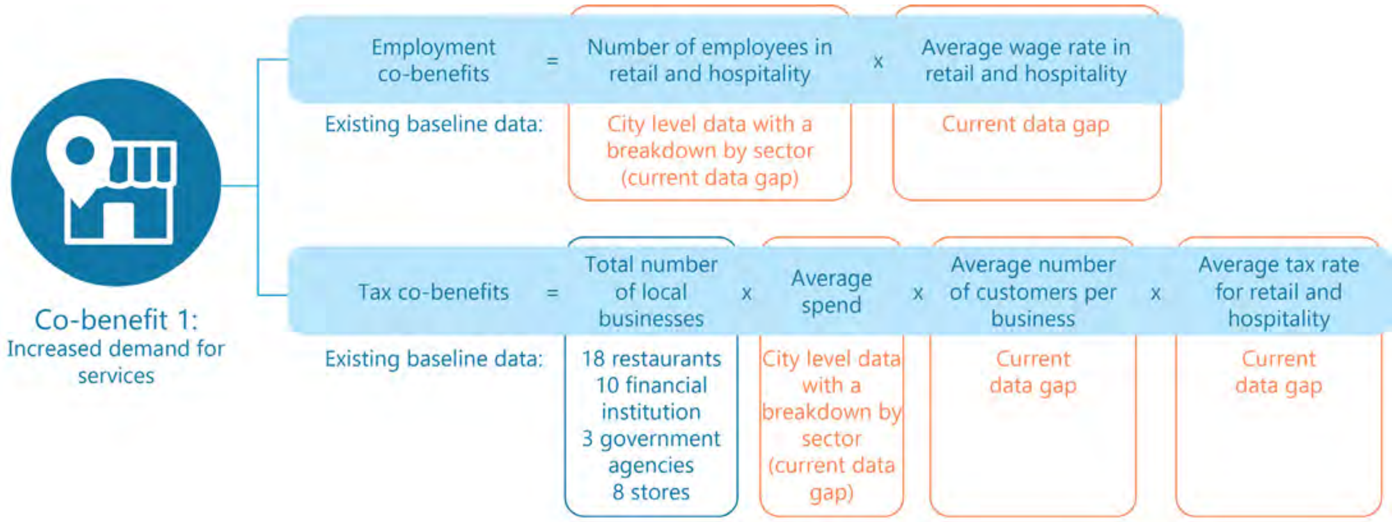


Figure 5-20 Proposed methodology for calculation of increased demand for services for the green street.

Source: Ramboll

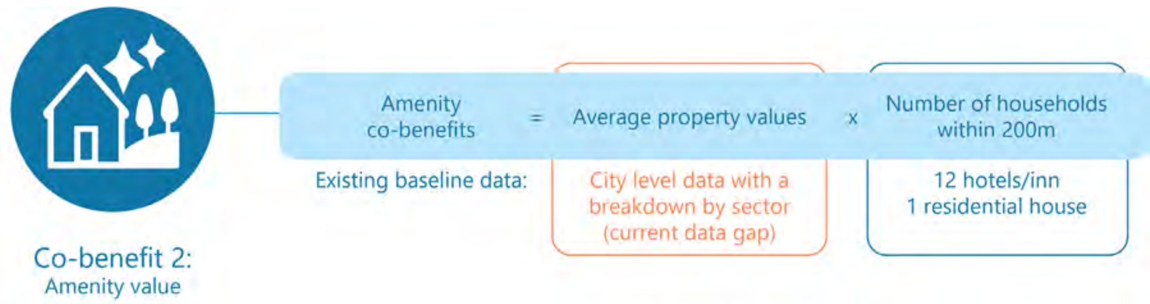


Figure 5-21 Proposed methodology and existing baseline data for calculation of amenity value for the green street.

Source: Ramboll

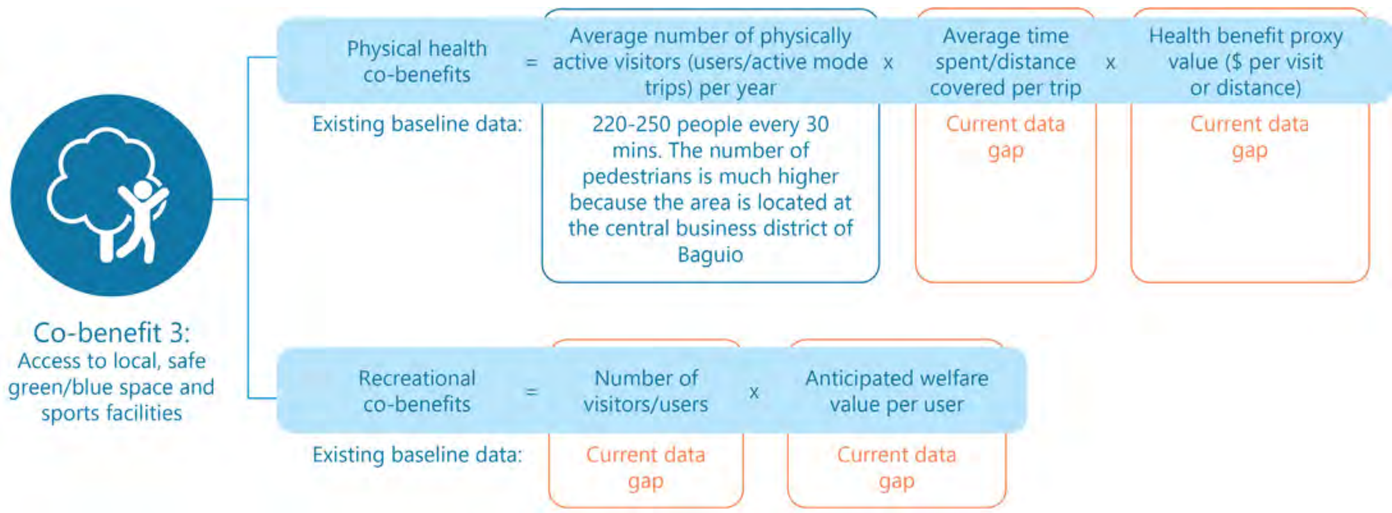
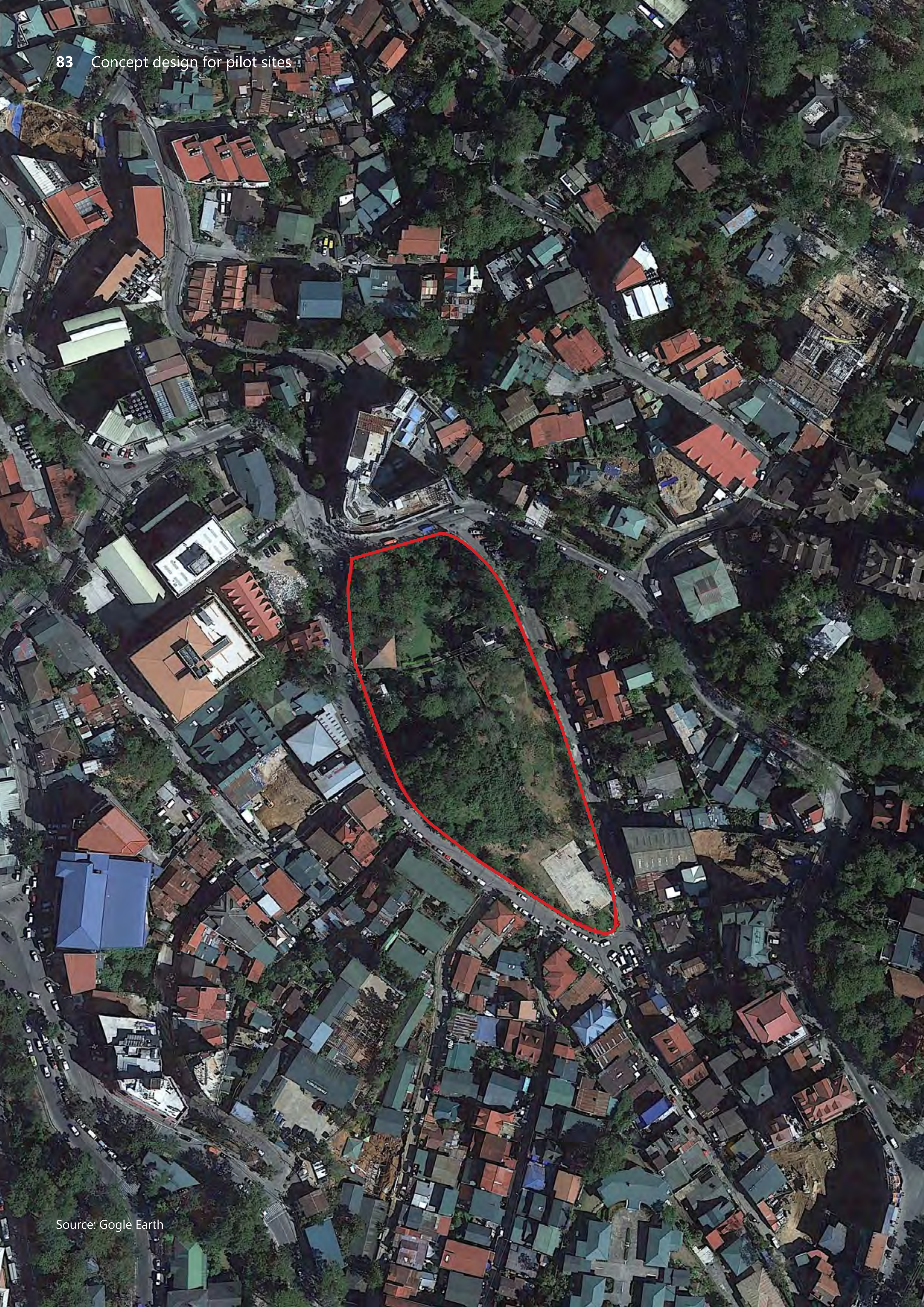


Figure 5-22 Proposed methodology and existing baseline data for calculation of access to local, safe green/ blue space and sports facilities for the green street.

Source: Ramboll



Source: Gogle Earth

5.6 CONCEPTUAL DESIGN: STORMWATER PARK AT EMILIO AGUINALDO PARK

5.6.1 DESCRIPTION OF SITE

Emilio Aguinaldo Park and the adjacent basketball court are located approximately 500m SE from Burnham Park, a 20-minute walking distance. The park is located within a residential area; however, the nearby area hosts educational institutions including the University of Baguio, smaller businesses, offices, and shops. The park is owned and managed by the LGU through CEPMO. Development in the park shall be consulted with CEPMO and CPDO, while the CEO will carry out monitoring of the project.

The park is located in a natural depression making it an ideal location for the implementation of a stormwater park. The depth varies between 1 m (SE) to 2.5 m (center) compared to street level with a natural centered depression towards the eastern side of the park, a steeper slope in the north-wester side that extends across the north margins (currently defended by a tall fence), a larger green area with a mild slope, and a plane area in the southern end of the park on which the basketball court is located. Besides the basketball court, the park hosts a few amenities such as a small museum (home of the first Philippine flag) and a statue of the national hero, Emilio Aguinaldo.

The outer edge of the park and the center-western area are covered with high sporadic vegetation consisting of trees and bushes. The eastern part is covered in high grasses and small plants and presents dirt paths. Most of the park edge is marked by a tree alignment. There is a small drainage canal through the park at the lowest point of the depression (north side).

Figure 5-23 Pilot Site at Emilio Aguinaldo Park

Source: LGU

5.6.2 PROPOSED CONCEPTUAL DESIGN FOR SITE

At Emilio Aguinaldo Park, the stormwater park concept design utilizes the potential of the park to serve as a detention basin for stormwater and proposes reshaping the park, using mainly natural elements and vegetation to facilitate recreational activities.

The main considerations for the conceptual design are utilizing the natural terrain depression, improving site ecology, historical value, educational potential and linking the existing assets.
Extending from the northern part of the park to central and then western side, the design proposes a large floodable area. The northern and southern margins are proposed to be surrounded by green structures that protect the park areas from the street. The west and east margins are proposed to be opened and facilitate free movement around the park. However, the proposed pathways across the park considers the anticipated transit patterns that are expected through the park.

As the northern part of the park is presenting steep slopes, three design features are introduced with the aim of maximizing space utility. First, the slopes will be adapted to host cleansing biotopes that take over and filter street runoff. Second, and also in connection with the slopes, the design proposes a rounded 2.5 meter wide, circular bridge connecting the museum entrance with the statue area. A second bridge is proposed to connect the newly introduced north entrance with the circular bridge and a path leading to the existing western entrance. The third feature, proposed in the northern part of the park, is the use of vegetation to create a plant labyrinth that functions as a playground and includes other natural elements such as rocks and tree trucks.

Together, the three features form a playful, vegetated area, margined by areas for water that can be overseen from the rounded bridge. In connection with the statue and the museum, the space is thought of as having great potential for educational activities.

The southern part of the park is proposed to maintain the basketball court and add adjacent 'amphitheater-like' structures will green elements, built from excavated soil to promote a sustainable soil balance and balance cut/fill volumes on site. The amphitheater seating area is designed to be a small hill with a proposed vegetated back area that has the function of providing shade.
The central area is proposed to be an open area crossed by paths and hosting urban furniture such as benches and tables. The proposed design suggests covering the western side with high vegetation that provides a large, shaded area, while the ester side is left open.

Figure 5-24 Plan view of Stormwater Park conceptual Design at Emilio Aguinaldo Park

Source: Ramboll

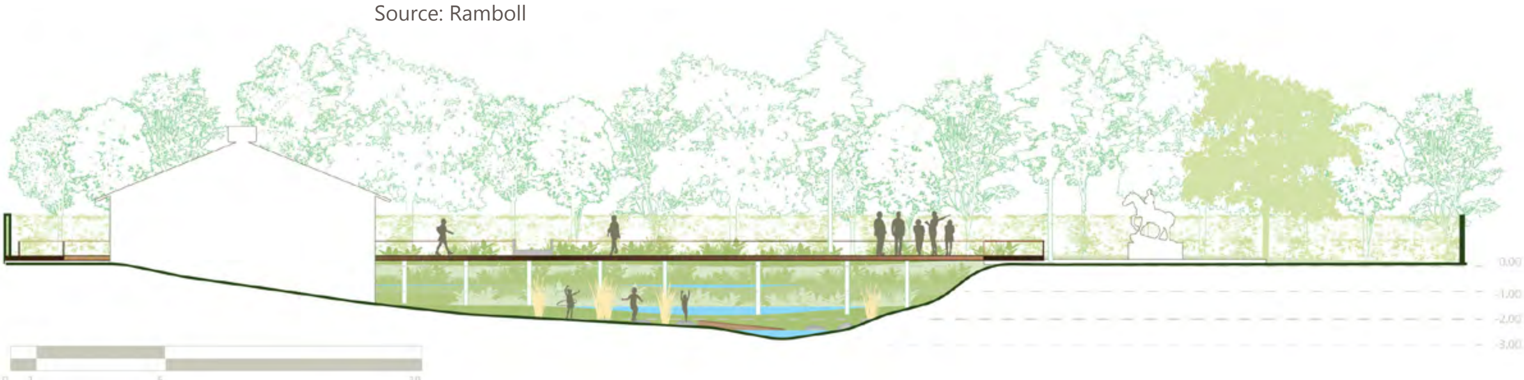


Figure 5-25 Section AA' - Stormwater Park conceptual Design at Emilio Aguinaldo Park

Source: Ramboll

5.6.3 HYDRAULIC ASSESSMENT

The primary hydraulic function of a stormwater park is to allow for significant volumes of controlled flooding within the confinement of the park. The functions and typology of the park will allow for temporary inundation without the park requiring reconstruction after the flood event has occurred. By designing the park to have more than one function, i.e., having the traditional recreational function outside of periods with extreme rainfall depths, it is possible to limit the space allocated solely for drainage infrastructure, which is particularly valuable in densely populated cities such as Baguio. The park will be designed to accommodate a runoff volume that will allow for limiting the outflow from the catchment to match the constraint of the recipient river. This will effectively limit the peak discharge from the catchment and reduce flooding and overflow volume downstream from the pilot site.

The park will require supporting infrastructure to collect and discharge rainwater, which may consist of surface conveyance utilizing NBS or more traditional gray infrastructure such as pipes and drains.

Figure 5-26 shows the pilot site with its respective catchment area.

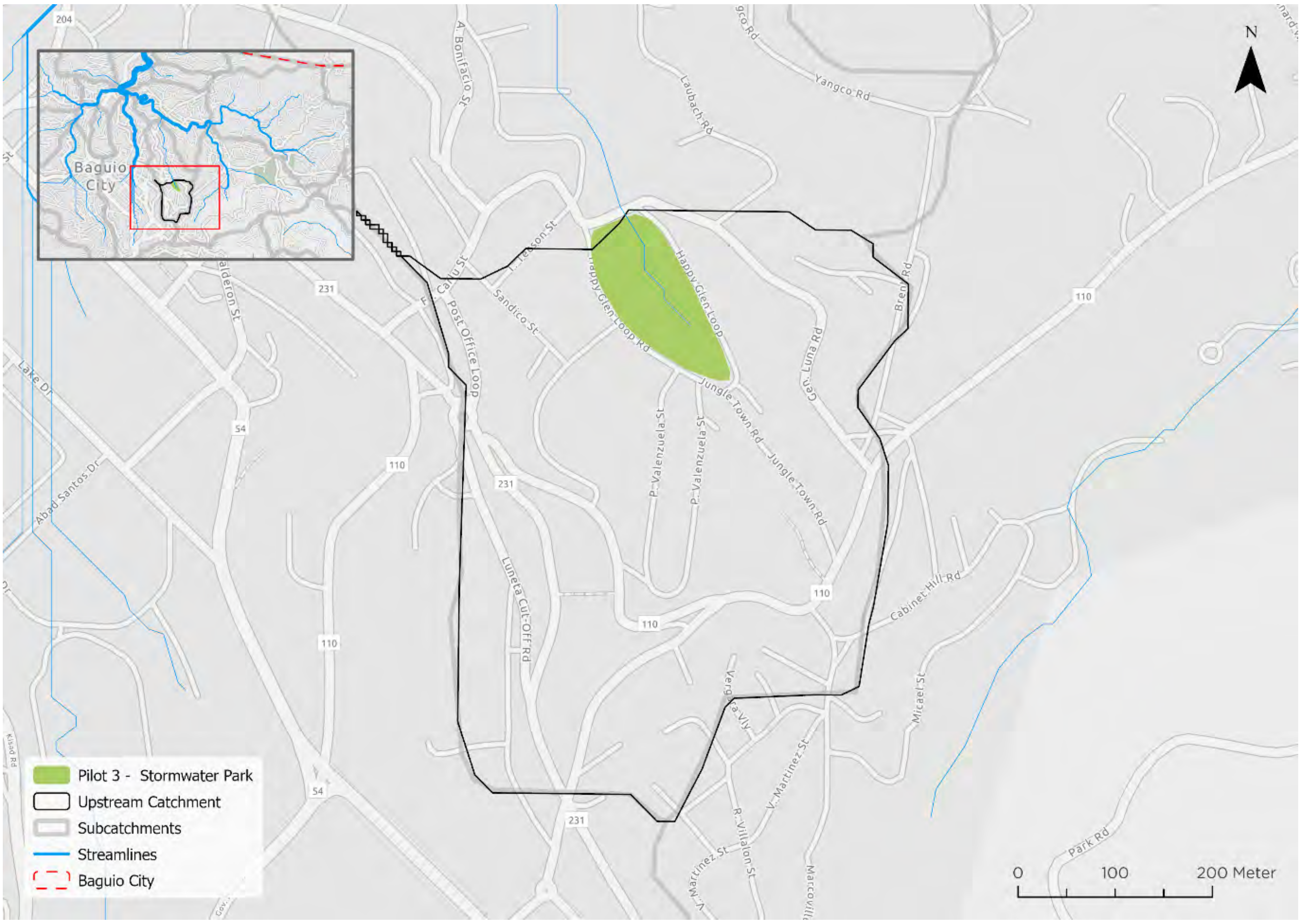


Figure 5-26 Pilot 3 - Stormwater Park and Catchment Area

Source: Ramboll

Table 5-5 ooutlines the key hydraulic functions, design parameters and flood mitigation benefits of the stormwater park. The hydraulic assessment is further detailed in Appendix F.

Table 5-5 Hydraulic Assessment - Pilot 3 Stormwater Park

Site conditions	
Location	Emilio Aguinaldo Park
Catchment Area	24 ha
Average Runoff Coefficient	0.77
Area of park	Approx. 1.28 ha
Hydraulic design parameters	
Hydraulic pre-conditions	• Connections are made to the existing drainage network to ensure that stormwater is collected in the park • Infrastructure to empty the park, utilizing existing or new infrastructure, must be in place for the park to function according to the proposed conceptual design
Time of concentration	20 min
Rainfall Intensity (3-year event)	168.9 mm/hr
Peak runoff (3-year event)	8.64 m3/s
Limiting discharge	3.16 m3/s / 2.51 m3/s [a]
Total Volume Required	4,121 m3
Volume Required per Hectare	171 m3/ha
Volume required per hectare	
Primary hydraulic functions	Detention, Filtration
Hydraulic elements	Swales, raingardens, biotopes, stormwater detention basin
Detention volume at site	5,153 m3
Area supported by the storage volume	30 ha
Additional storage volume needed in catchment	-1,032 m3 / 0 m3

[a] The discharge can be lowered to the benefit of other sub-catchments contributing to the same recipient canal while maintaining a service level of 3-year rain event.
Source: Ramboll

It should be noted that the required volume is calculated based on the assumption that the limiting discharge, i.e., the discharge that can be maintained in the recipient canal without overflows, is distributed evenly throughout the catchment. This will require the implementation of flood mitigation measures throughout the catchment that aims at reducing peak runoff, which will take time to implement. As such, while the hydraulic assessment indicates that the stormwater park may hold more than the required volume, this will simply contribute to the flood mitigation effort in the other sub-catchments contributing to the same recipient canal. The discharge may be limited to 2.58 m3/s to the benefit of sub-catchments contributing to the same recipient canal, or the service level can be considered to be higher than the 3-year event. Following the proposed strategy of improving the service level throughout the city to a 3-year event in the short term, it is recommended to limit the discharge from the park to 2.58 m3/s while the remaining sub-catchments are being developed.

5.6.4 APPRAISAL OF SOCIO-ECONOMIC BENEFITS

The co-benefits anticipated to present higher materiality for the Stormwater park at Emilio Aguinaldo Park are presented below alongside the general economic formulas used to value them (for a more detailed understanding of the proposed economic approach to valuation, please see Section 5.3). It should also be noted that this is a conceptual high-level action plan, and actual valuation of the co-benefits is not taking place. We have proposed a detailed methodology, and a roadmap where we describe the process to follow in the upcoming phases.

Where available, existing baseline information used to inform the calculations are included. Data gaps in relation to baseline socio-economic conditions and technical design considerations are illustrated by red cells in the formulas below. There are different actions that can be taken to address these gaps, i.e., analysis of primary data from Baguio City or based on relevant studies or methodological guidance. These actions would be needed to undertake in the schematic design proposed in the roadmap (Section 6.1) in order to undertake a monetary valuation. In this regard, the formulas are merely indicative at present.

Co-benefit 1: Increased demand for services
To value the co-benefit of increased demand for services, the economic value of increased taxes and employment associated with business growth around the NbS intervention is assessed.

To calculate this co-benefit, the following calculations are suggested (to be confirmed during schematic design) (figure 5-27).

Co-benefit 2: Amenity value
To value the co-benefit of increased amenity value, the impact of the NbS on property value premiums is assessed. To calculate this co-benefit, the following calculation is suggested (to be confirmed during schematic design) (figure 5-28).

Co-benefit 3: Access to local, safe green/blue space and sports facilities
The co-benefit of increased access to local, safe, and natural green space and sports facilities is assumed to have a positive impact on engagement with these assets and therefore increased physical activity. This improves both physical and mental health of residents, which, in turn, reduces health costs and produces a higher quality of life. To calculate this co-benefit, the following calculation is suggested (to be confirmed during schematic design) (figure 5-29).

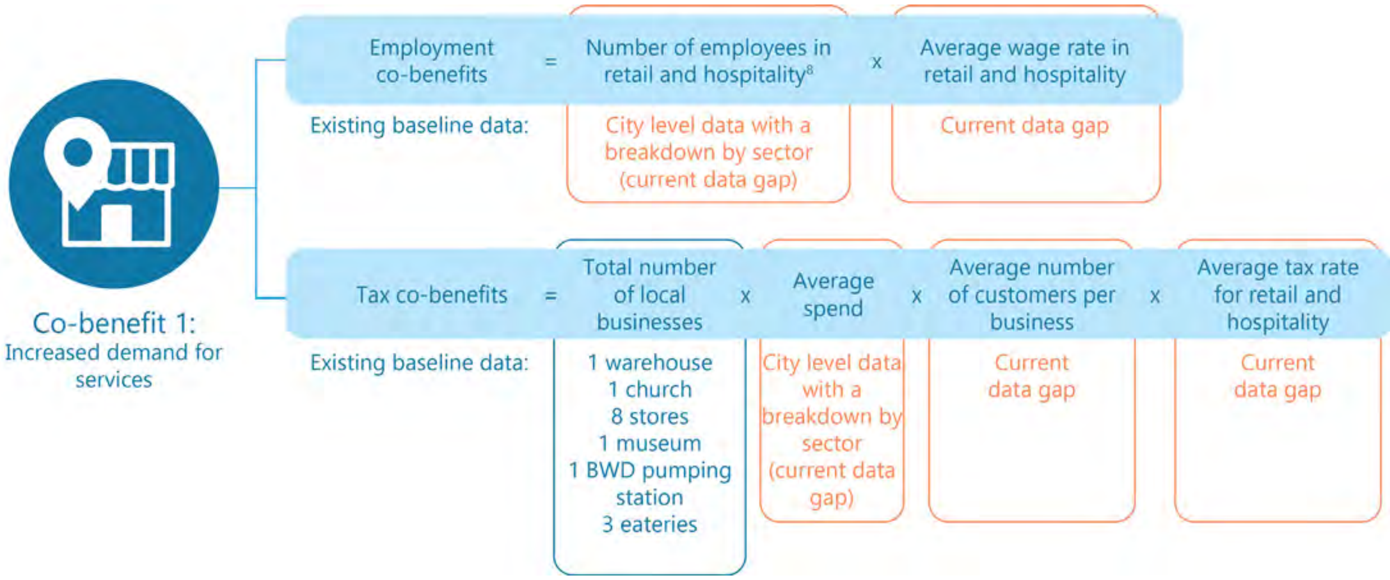


Figure 5-27 Proposed methodology for calculation of increased demand for services for the stormwater park. (8) This number can be directly or indirectly estimated (i.e. calculated from number of new businesses multi-plied by average number of employees)

Source: Ramboll

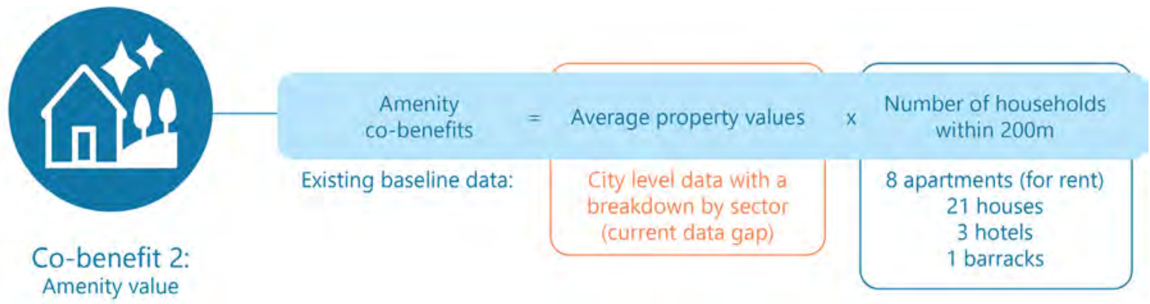


Figure 5-28 Proposed methodology and existing baseline data for calculation of amenity value for the storm-water park.

Source: Ramboll

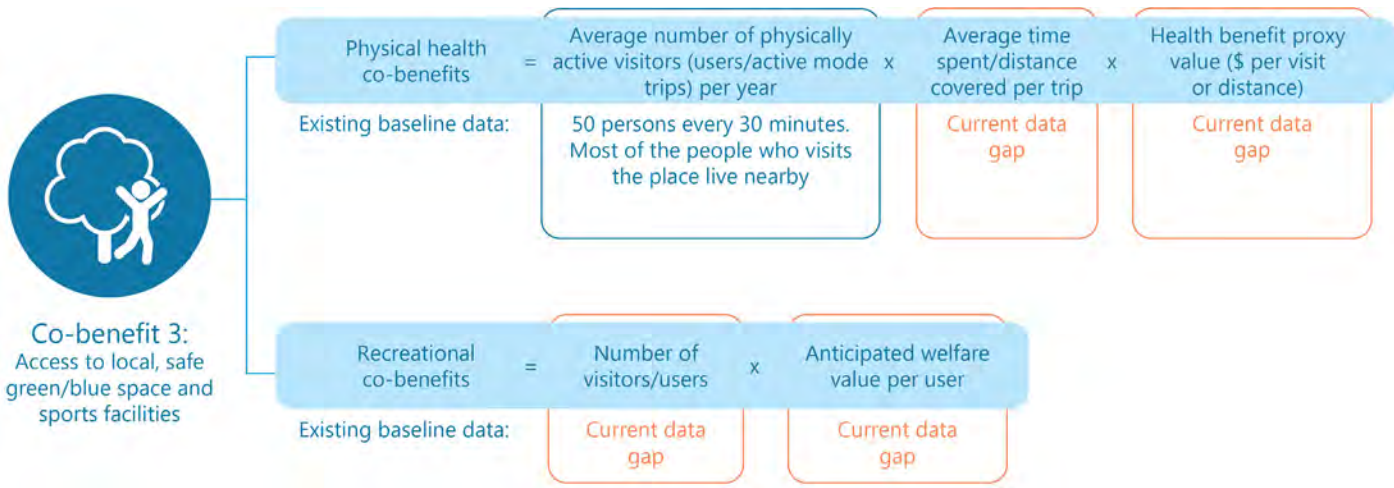


Figure 5-29 Proposed methodology and existing baseline data for calculation of access to local, safe green/ blue space and sports facilities for the stormwater park.

Source: Ramboll

6. RECOMMENDATIONS AND NEXT STEPS

Source: Adobe Stock

6.1 ROADMAP FOR IMPLEMENTATION OF FLOOD MITIGATION MEASURES

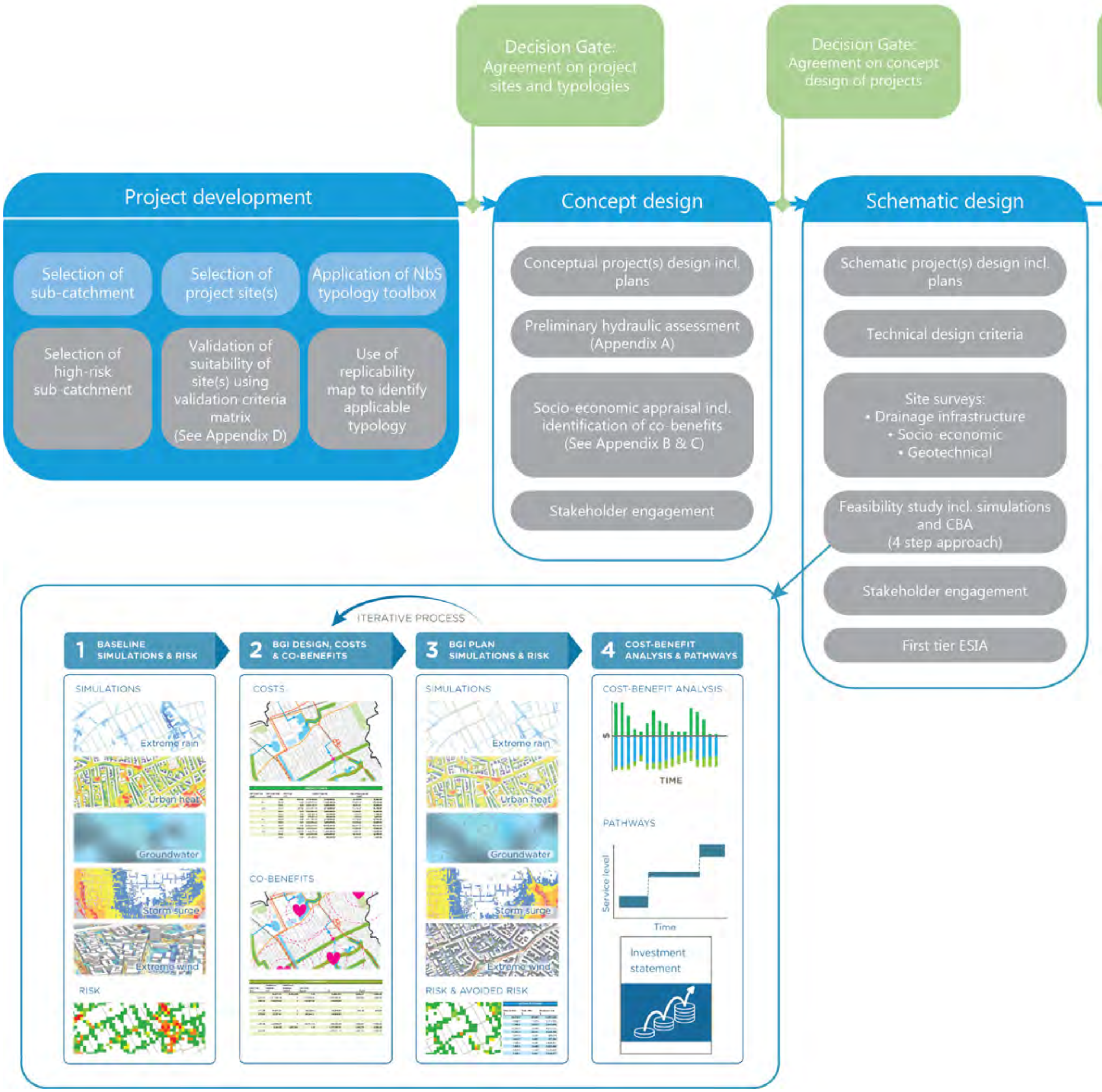
The NbS typology toolbox serves as a tool in the planning of resilient flood mitigation measures for Baguio City. It uses a user-friendly and easy-to-understand narrative to communicate NbS to a broad audience, including experts and the general public. The toolbox is to be applied in the development of projects in the flood mitigation action plan.

Figure 6-1 presents a road map for implementation of flood mitigation measures in Baguio. The road map is to be used as a simple step-by-step guide from project development to implementation of flood mitigation in Baguio. The road map is prepared with the intention of visualizing the processes for implementation of the NbS typology toolbox and is to be used by a multi-disciplinary project team comprising professionals from various offices at the LGU. The road map aims at presenting a standardized approach for NbS projects, albeit well knowing that a standardized approach may not suit all projects. The end of a project phase is marked by a decision gate, where the project team comes to agreement and decides on the continuation of the project. The steps comprising the road map are described below.

The designs presented in report are at the level of conceptual design, much in line with the overall scope of making a high-level conceptual action plan for Baguio. In this context, the level of detail is not enough to start assessing an 'optimal design'. To do this, the next step would be bringing these designs into a schematic design phase, where simulation and evaluation of alternatives for designs would be undertaken to establish the design or location which generates the most benefits. The proposed methodology for valuation of co-benefits included in this report enables a comparison of the trade-offs across locations and/or designs. This methodology can then be refined during upcoming phases (Schematic Design) while also refining the technical and engineering components of the designs presented in this report.

Project development

a. Selection of sub-catchment: A sub-catchment with high flood risk is selected for implementation of NbS. A prioritization exercise between sub-catchments can be undertaken considering e.g. the area at risk within a sub-catchment. The prioritization of sub-catchments can be linked to ongoing initiatives and plans to ensure alignment with urban development plans.
b. Selection of project site(s): Potential project site(s) are identified within the sub-catchment. It is recommended to assess the sub-catchment holistically. The project sites should be connected in a network of solutions that utilizes the available spaces optimally and when combined creates a flood mitigation system that meets the demands of the sub-catchment. Validation of suitability of the site(s) for implementation of NbS is undertaken using the Validation Criteria Matrix (see Appendix D).
c. Application of NbS typology toolbox: Using the replicability map, an applicable typology suitable for the spatial context is identified and selected for each of the project sites.


Decision Gate:
Agreement on project sites and typologies
Decision Gate:
Agreement on concept design of projects
Project development
Selection of sub-catchment
Selection of project site(s)
Application of NbS typology toolbox
Selection of high-risk sub-catchment
Validation of suitability of site(s) using validation criteria matrix (See Appendix D)
Use of replicability map to identify applicable typology
Concept design
Conceptual project(s) design incl. plans
Preliminary hydraulic assessment (Appendix A)
Socio-economic appraisal incl. identification of co-benefits (See Appendix B & C)
Stakeholder engagement
Schematic design
Schematic project(s) design incl. plans
Technical design criteria
Site surveys:
• Drainage infrastructure
• Socio-economic
• Geotechnical
Feasibility study incl. simulations and CBA (4 step approach)
Stakeholder engagement
First tier ESIA
ITERATIVE PROCESS
1 BASELINE SIMULATIONS & RISK
2 BGI DESIGN, COSTS & CO-BENEFITS
3 BGI PLAN SIMULATIONS & RISK
4 COST-BENEFIT ANALYSIS & PATHWAYS
SIMULATIONS
Extreme rain
Urban heat
Groundwater
Storm surge
Extreme wind
RISK
COSTS
CO-BENEFITS
SIMULATIONS
Extreme rain
Urban heat
Groundwater
Storm surge
Extreme wind
RISK & AVOIDED RISK
COST-BENEFIT ANALYSIS
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TIME
PATHWAYS
Service level
Time
Investment statement

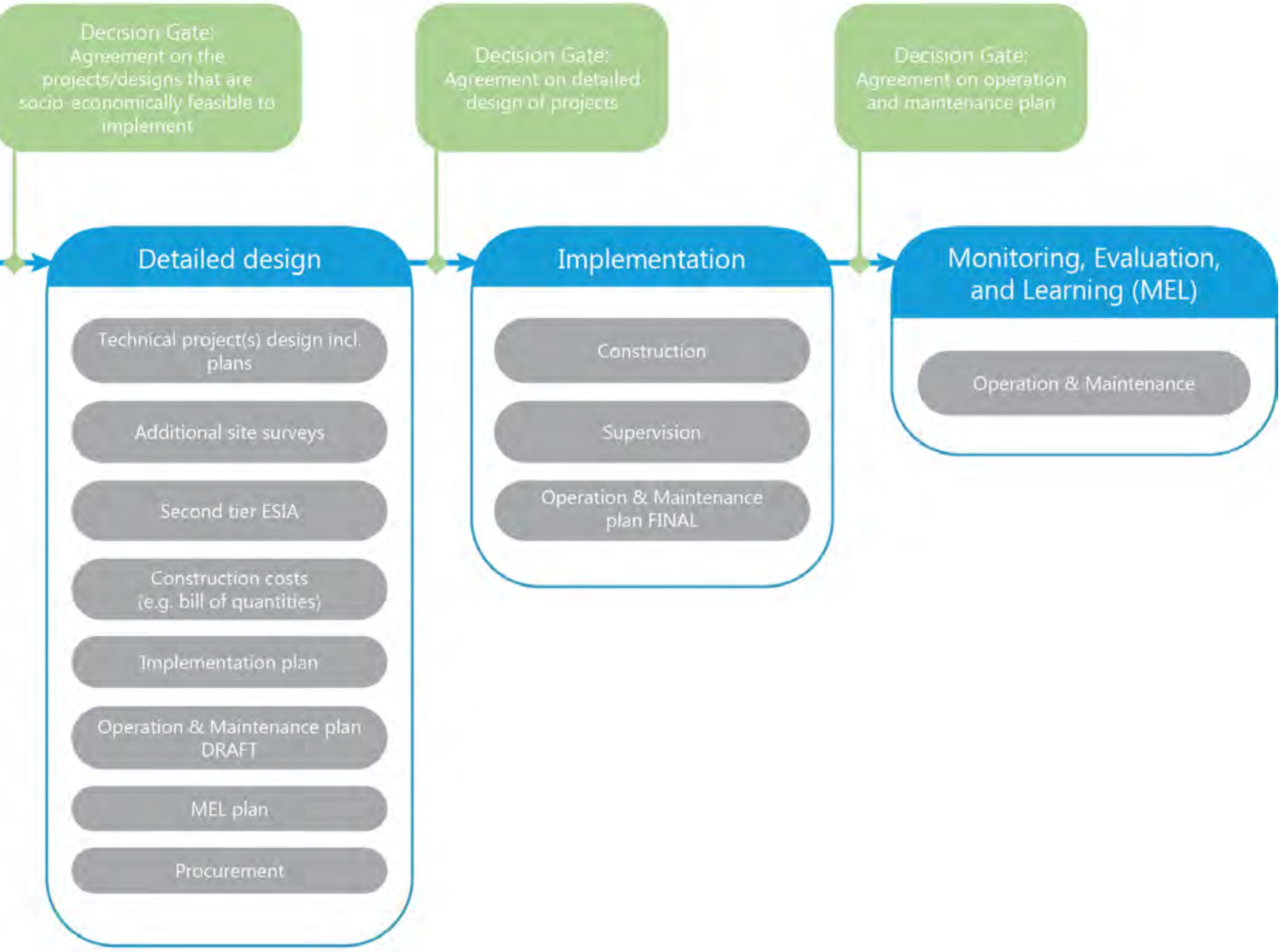

Figure 6-1 Road map for implementation of NbS in Baguio City.

Source: Ramboll

Concept design

In the concept design phase, the identified typologies are developed into site-specific concepts. The vision for the site is developed and the hydraulic elements, additional amenities and landscape features are conceptualized. A preliminary hydraulic assessment (a template is provided in Appendix E) is undertaken including assessment of sub-catchment requirements, site-specific storage volume, limiting discharge etc. Site-specific co-benefits are mapped and methodologies for valuation of benefits are identified e.g. by using the tables provided in Appendix C. A preliminary valuation of benefits should be undertaken in a socio-economic appraisal depending on data availability. Stakeholder engagement and community outreach should be prioritized in this project phase to ensure solutions are tailored to the specific needs and wishes of the local community. At the end of this stage, the concept design for the project site(s) is agreed upon within the project team.

Schematic design

The design for the project site(s) is developed further in the schematic design phase. Technical design criteria for the hydraulic elements are specified e.g. geometry and dimensions (weirs, pipes, basins, inlets etc.), materials, etc. Site surveys should be undertaken (e.g. drainage network surveys, socio-economic surveys, geotechnical surveys) to be used in scenario modelling. Feasibility of the projects should be evaluated i.e. by applying a four-step approach that includes (1) baseline risk simulations, (2) design, costs, and co-benefit assessment, (3) documenting the effects of the design (avoided risk) through simulations, and (4) incorporate the outcomes into a Cost-Benefit Analysis (CBA). As part of the schematic design, an Environmental and Social Impact Assessment (ESIA) should be initiated as part of the feasibility evaluation. Stakeholder engagement efforts should also be continued, seeking to obtain buy-in from the community. At the end of this stage, agreement on the projects/designs that are socio-economically feasible to implement should be established.

Detailed design

In the detailed design (DD) phase, the technical project design is finalized, and technical drawings of design elements prepared, e.g. CAD plans and sections. Additional site surveys should be undertaken if necessary, to ensure no gaps are found in the design. The ESIA is completed fully, and a bill of quantities is prepared to establish the costs of the design. It is also likely that the CBA will have to be refined as more information regarding costs and a more concrete approach to quantification of benefits and co-benefits has now been established. Plans for implementation, monitoring, evaluation, and learning, as well as operation and maintenance should be prepared, together with cost estimations. Likewise, procurement should be initiated as part of this project phase.

Implementation
Following the agreement on detailed design and finalization of procurement, implementation of projects is commenced. It is important that for the implementation of NbS projects, the firms in charge of building the infrastructure show experience in working with NbS components, especially expertise with landscape solutions and green vegetation is important. Supervision of the project site(s) should be carried out through the entire phase. Plans for operation and maintenance should be finalized.

Monitoring, Evaluation and Learning
After project implementation, operation and maintenance of the site should be commenced in accordance with the operation and maintenance plan. Continuous monitoring should be established and learnings from all project phases should be compiled and included in future planning of projects.

6.2 ADDITIONAL FLOOD RISK MITIGATION STRATEGIES AND RECOMMENDATIONS

In addition to physical flood mitigation measures, the adaptive capacity of the population, institutions and governmental bodies will play a key role in the continuous shift towards a resilient city in future climate conditions. The ability to prepare for, and recover from, flooding will be critical when adapting to the impacts of climate change. Awareness of flood risk in Barangays and encouragement to take mitigating actions is a key priority. In many Barangays where floods frequently occur, awareness will likely be high and needs only to be reinforced. The Flood Early Warning System being developed for Baguio is one of the tools to achieve this objective, but efforts to prepare individual households and build technical and institutional capacities across stakeholders in Baguio will add to the adaptive capacity of the city and thereby improve resilience.

To ensure the functionality of the proposed flood mitigation measures, efforts to limit blockages in the conveyance network and basins should be emphasized. Dumping of solid waste in drainage channels and excessive sedimentation caused by unregulated construction must be minimized through a combination of policies, awareness strategies and education. Measures that emphasize local ownership and bring the population closer to water with direct recreational benefit will work towards achieving this goal, however, this must be actively prioritized at city level to ensure the successful implementation and operation of the recommended flood mitigation measures.

In November 2021, the LGU initiated the Blue Walks project in the Busol watershed[9]. The project recognizes that all stakeholders play an important role in the rehabilitation and protection of the water resources in Baguio. A clean-up drive of waterways within the forest reserve is proposed to be conducted to heighten the level of awareness, particularly in the barangay level, on the importance of clean and solid-waste free waterways. Similar education and community awareness projects should be replicated in Barangays city-wide to ensure that residents do not treat the streams as waste disposal areas.

It is recommended as a short-term goal to prioritize sub-catchments that have been identified as having a high flood risk for flood mitigation measures and, as a minimum, ensure that the statistical 3-year event (in future climate conditions) can be managed without any significant flood damages occurring. While this is an ambitious goal considering the historical flood damages that have occurred in Baguio, it is believed to be within reach with the correct investments and following the principles outlined in this report. It should be noted that critical infrastructure and institutions (health centers and schools) should be protected against rain events that occur more rarely as the consequences of even limited flooding may be unacceptable at 3-year intervals. Once the service level of the city has been brought up to an acceptable level and as the city continues to develop and grow, the long-term goal may be to further improve the service level, targeting return periods of e.g. 5-10 years.

While implementation of flood mitigation measures reduces flooding, flooding is expected to occur at rain events that exceed the service level. Planning for flood emergencies is necessary to minimize the impact of floods, reduce loss of life and damage on critical infrastructure. A crucial component in this planning is ensuring that operational and management plans for evacuation and shelters are thoroughly established and continuously reviewed each year before the flood season. Planning also means deciding what needs to be done during the flood and deciding who will do those tasks. The details of government evacuation plans must be transparent and communicated clearly to the public including vulnerable population groups. Similarly, at community level, Barangays should plan how best to respond to flood emergencies in advance. This means that they need to think in advance about what effects a flood might cause, what problems they might encounter, and develop corresponding response plans. The community level plan must be carefully matched to the city level plans.

7. CONCLUSION

Source: Adobe Stock

This report has aimed at answering five key questions:

- To which extent are NbS a feasible option for flood mitigation in Baguio, and which types of NbS are most feasible?
- What are the key design considerations for NBS in Baguio?
- What are the co-benefits of implementing NbS in Baguio?
- How may NbS be planned and implemented in Baguio?
- How may NbS be replicated and scaled city-wide?

Through the outputs produced in this report, the interactions with the LGU, the review of existing plans and strategies in Baguio and the technical and non-technical assessments undertaken when developing the typologies and the pilot sites, the overall conclusion is that NbS are indeed a feasible option for flood mitigation in Baguio. In this regard, NbS can be juxtaposed to any other kind of urban infrastructure for flood mitigation or flood control in Baguio, but attention must be put into the targeted service level when planning and designing NbS. For the work done in this report, the service level was chosen, in coordination with the LGU, as rainfall events with a return period of 3 years, based on the historical data reported by the LGU in terms of the frequency and magnitude of flood impacts in the city.

The NbS typology toolbox developed presents conceptual NbS deemed feasible for the socio-economic and spatial context of Baguio. The typologies comprise a wide range of nature-based hydraulic functions including conveyance, retention, detention, and treatment. For the design of NbS, and following our typology-driven approach for conceptual designs, the key considerations are:

Overall, toolbox typologies should be applied similarly across Baguio at city-wide scale to gain the full effect of the nature-based approach with interconnected systems that fulfil different hydrological and hydraulic purposes such as conveyance, treatment, storage, and infiltration.

Regarding the co-benefits, the report presents an economic valuation methodology comprising two main components: i) quantitative valuation of co-benefits, and ii) monetary valuation of co-benefits. The first component relates to quantification in biophysical units (e.g. hectares for each type of habitat created, number of trees) and impact factor multipliers for each co-benefit. The second component (monetary valuation) uses a value transfer approach and literature/database monetary values for each co-benefit, as well as adjustments to the Philippines based on purchasing power parity and applied to the quantitative units (e.g. total pollutant deposition by the NbS x avoided damage cost per ton of pollutant per year). The main co-benefits identified and dealt with in this report are: Increased demand for services, Amenity value, and Access to local, safe green/blue space and sports facilities

Regarding the replicability of NbS at city-scale, we developed a replicability map highlighting the various zones identified across Baguio where the developed typologies are particularly suitable. Three types of space have been identified within each zone: open areas, roads/right-of-way, and canal/stream/river.

Typologies in this report cover prioritized combinations of zones and space, considering cohesion with vision for the Flood Mitigation Action Plan as well as ongoing initiatives and plans for Baguio, determination of dominating overlays, expert knowledge of NbS applicability, and a diverse representation of space.
The following three pilot sites were selected in close collaboration with LGU:

1. **Urban Canal near Manual Roxas (137-138)**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Canal
2. **Green Street at Carino Street**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Road
3. **Stormwater Park at Emilio Aguinaldo Park**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Open area

The selected pilot sites served to demonstrate the wide range of concepts in the NbS toolbox and showed how nature-based solutions are applicable for various types of spaces and infrastructure in the public realm in Baguio.

The toolbox of solutions consists of 8 typologies suitable for the prioritized spatial zones in the city, following a spatial overlay analysis to ensure city-wide replicability and scalability of flood mitigation measures. The prioritization of zones has been validated by the LGU.

While NbS is considered a strong tool to mitigate flooding, while also providing significant co-benefits that are aligned with other development strategies in Baguio, some typologies may have primary functions other than flood mitigation, including microclimate improvements, natural water treatment or recreational value. This should be considered when selecting the typologies most relevant in a specific sub-catchment.
A combination of larger scale interventions, such as stormwater parks and stormwater boulevards to provide the bulk conveyance and volume capacities in combination with catchment wide interventions like living corridors and green streets will likely provide the best overall results.

Source: Adobe Stock

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