Development of a Green Rainwater Infrastructure (GRI) Toolkit for Rainwater Management Near Underground Rapid Transit Stations in Vancouver

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DISCLAIMER

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organisations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability and climate action across the region.

This project was conducted under the mentorship of City of Vancouver staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of City of Vancouver or the University of British Columbia.

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EXECUTIVE SUMMARY

With the transition to becoming a water-sensitive city and addressing rainwater management issues, Vancouver is facing a need for changes in its approach to rainwater management strategies. Vancouver City Council has declared a climate emergency due to rising sea levels, and more extreme rain events are expected. Vancouver residents are experiencing the impacts of climate change, contributing to ecosystem vulnerability and increasing the risk of localized flooding and combined sewer overflow events resulting from excess rainfall. The City of Vancouver's *Rain City Strategy* requires the integration of Green Rainwater Infrastructure (GRI) into all projects built within the City, including capital projects, private developments and park projects. These projects serve purposes such as street sewer and drainage, water infrastructure renewal, or street modification for transportation purposes.

Meeting the city-wide long-term targets and recommendations requires a toolkit that facilitates communication among different stakeholders and translates the concept into a systematic rainwater management strategy. Therefore, to inspire placemaking near rapid transit stations in Vancouver and address localized flooding events, this report presents a comprehensive analysis of GRI as a sustainable solution for stormwater management in the vicinity of rapid transit station areas. The report also investigates the benefits, challenges, and current gaps associated with the application of GRI for transit plazas.

GRI contributes to numerous co-benefits, including improved urban aesthetics, heat island mitigation, enhanced biodiversity, and reduced strain on conventional stormwater infrastructure. Challenges associated with GRI implementation include technical and environmental stressors. Technical stressors encompass maintenance budget, utility protection and setbacks, limitations on soil volume, balancing landscape elements, risk of overflow, access to maintenance vehicles, and irrigation restrictions. Environmental stressors involve increasing population, competing interests, the urban heat island effect, and water pollution.

Through a review of the existing GRI within the City of Vancouver and an analysis of relevant worldwide GRI precedents potentially applicable to the vicinity of rapid transit nodes, ten GRI typologies were developed, with each encompassing a different function:

- Bioretention
- Bioswale
- Slope planting
- Tree trenches
- Bosque
- Pervious paving
- Water feature
- Ground planter
- Green furniture
- Green canopy

These elements manage rainwater through three strategies: 1) slowing down and redirecting,

2) storing and infiltrating, and 3) capturing and protecting. This helps reduce runoff near transit plaza areas, protecting station infrastructure and enhancing water quality.

A series of recommendations was developed to ensure the successful implementation of GRI programs for transit plazas and are as follows:

- municipalities should integrate GRI into urban planning and policies, incentivizing its adoption in new developments and retrofits;

- collaboration between local authorities, community groups, and experts can enhance GRI implementation, leading to more successful and sustainable outcomes;

- continued research and monitoring are essential to refine GRI practices, address challenges, and enhance its long-term performance.

In conclusion, GRI offers a holistic approach to urban stormwater management that aligns with the City of Vancouver's environmental, social, and city-building goals. While challenges exist in implementing GRI at rapid transit areas, strategic design, community engagement, and policy support can lead to the effective implementation of GRI, creating more resilient and livable cities.

Guiding policy & documents

There has never been a more pressing need for Vancouver to swiftly transition into a water-sensitive city in order to effectively tackle the water-related challenges it currently confronts. With rising sea levels and increasingly extreme rainfall events, Vancouver faces an elevated risk of flooding along its coastlines and overland areas. This, in turn, heightens the risk of combined sewer overflow events (City of Vancouver, 2019). Additionally, the increased occurrence of consecutive dry days during summer and the urban heat island effect have numerous negative impacts on human health, water usage, and the well-being of natural ecosystems (City of Vancouver, 2019). In response to Vancouver's *Climate Emergency Action Plan*, which highlights the urgent challenges posed by climate change, rainwater management has become extremely important for mitigating localized flooding, conserving water, reducing stormwater pollution, and enhancing the city's resilience to the impacts of climate change.

The *Rain City Strategy*, a green rainwater infrastructure (GRI) and rainwater management initiative adopted by the City of Vancouver in 2019, prompted a series of action plans that cover streets and public spaces, buildings and sites, parks, and beaches. The Strategy reiterates the existing goal of effectively managing 90% of Vancouver's yearly rainfall and raises the design standard for rainwater management to 48 mm per day for sites throughout the city by implementing GRI assets. Additionally, it sets an ambitious target to manage rainwater volume and water quality for 40% of the city's impermeable areas by 2050 through new developments, capital projects, and strategic retrofits. A total of 46 programs and initiatives were recommended and expected to be developed and implemented over the coming three decades. As the *Rain City Strategy* moves into implementation, more information is needed on the suitability of GRI typologies at transit station areas. A missing consideration, and a lesson learned from the *Broadway Subway Project* (BSP), is the implementation of GRI specific to rapid transit plazas and areas around transit stations.

Rapid transit plazas and concentrated development around transit stations have the potential to bring about substantial transformations in cities, providing a rare opportunity that emerges only once in a generation. The proposed *Broadway Plan* (2022) underscores the significant role played by the extension of the Millennium Line and how it can be strengthened through six guiding principles. As articulated in its vision, "Enhanced streets and connections, including Broadway as a Great Street, make it easy to get around by walking, rolling, or cycling in a lively and diverse public realm." And, "New and improved parks and public spaces support recreation and gathering, cultural expression, and access to nature." Without careful planning, rapid transit stations can contribute to urban heat and increase impervious surfaces. However, the incorporation of GRI can significantly contribute to reducing urban heat and improving access to nature within an urban context as part of the *Broadway plan*. As an integral aspect of City building, it is important to imagine how rapid transit station areas can incorporate GRI in terms of its potential to provide opportunities for supporting urban water management.

The *Transit Passenger Facility Design Guidelines*, developed by TransLink in 2018, underscore the significance of establishing a design framework for transit passenger facilities and their surrounding context. The document highlights the importance of community and stakeholder involvement, context and land-use integration, environmental impact, economic benefits, and the utilization of public funds. Among these factors, the urban heat island effect and water management are closely correlated with the GRI programs near transit plaza areas, making them an integral part of the transit passenger facility system. Shared interests include the protection of site water quality and the use of integrated building and landscape design strategies to manage stormwater on-site. In the context of landscape design, the document provides an overview of station landscaping, outlining design principles and standards with a focus on passenger safety, accessibility, and budget efficiency for both the hard and soft landscaping elements. However, it is important to note that there is a noticeable absence of references to considerations related to GRI or the potential impacts of climate change. A more substantive discussion of TransLink's requirements follows in the section "Project Context" of this report.

These overlapping targets suggest a common concern among various stakeholders, further emphasizing the significance of GRI implementation. This toolkit aims to explore the potential for bridging the gap among the current green rainwater infrastructure programs across the city of Vancouver in light of the guiding documents. Its goal is to inspire rainwater management for the BSP and future rapid transit stations in Vancouver.

Previous Sustainability Scholars (SS) Reports

The Sustainability Scholars Program is an innovative internship initiative that pairs UBC graduate students with both on-campus and off-campus sustainability partners. Through this program, students engage in applied research projects aimed at promoting sustainability throughout the region. Several previously conducted projects have informed this work, and they can collaborate to support the common vision.

Exploring Alternative Models for Green Infrastructure Maintenance (2019) developed a GRI operations and maintenance program while identifying potential delivery models for various GRI asset types in the public realm. These assets contribute to the City's economic, environmental, and social sustainability. The alternative maintenance framework serves as an inspiration for a fresh perspective on GRI maintenance, which could be valuable for envisioning new types of green infrastructure for transit station/ plaza areas.

Green Rainwater Infrastructure Assets Inventory for Private Sites (2021) provided an overview and analysis of GIS mapping overlay for GRI assets across twenty-two applications proposed for private developments at the building permit review stage on private sites, as of May 3, 2021. The results suggested a pattern of existing GRI programs and identified the Cambie Corridor as having the greatest number of GRI assets for private development when compared to other watersheds in southeast and northwest Vancouver. However, other parts of the city, particularly in the private realm, require more GRI programs.

Past Greenest City Scholar reports have laid the groundwork for this project. *Exploring Regenerative Planting Strategies for Green Rainwater Infrastructure* (2020) prompted a shift in GRI in Vancouver by introducing regenerative planting strategies and establishing connections between GRI and Blue-Green Systems. This report also supports the incorporation of GRI near transit stations/plaza areas as significant nodes.

Key terms & definitions

Green Rainwater Infrastructure (GRI)

Green Rainwater Infrastructure (GRI) functions as a sustainable and environmentally friendly system for managing rainwater runoff in urban and built environments. It combines engineered and nature-based techniques to protect, restore, and mimic the natural water cycle. GRI encompasses engineered systems such as blue-green roofs, swales, rainwater tree trenches and rain gardens, that utilized natural components such as plants and soil with engineered elements such as soil cells and pipes to effectively manage rainwater. This process enables the rainwater to be absorbed into the ground or reintroduced to water sources and the atmosphere. Moreover, GRI has the potential to encompass the collection and reuse of rainwater as well.

The implementation of GRI plays a role in helping Vancouver address the climate emergency and sequester carbon. It contributes to cooling the urban environment, mitigating flooding, reducing the use of drinking water, and creating new non-potable water supplies through distributed and resilient water management infrastructure, among other benefits. GRI is an essential measure to combat localized flooding, forming the foundation for the design of this toolkit.

GRI Typologies

Blue-green roof combines blue and green roof technologies.It is designed to increase the volume of water stored underneath the green roof and control the amount of water released (City of Vancouver, 2019).

Bioswale is a type of green rainwater infrastructure that takes the form of a linear bioretention practice.

Bio-retention is a form of green rainwater infrastructure that captures and purifies urban rainwater runoff. It usually consists of a shallow depression or basin featuring layers of rock, engineered soils, and resilient vegetation capable of withstanding periods of inundation and drought (City of Vancouver, 2019).

Rainwater tree trench directs water from adjacent impermeable surfaces into underground trenches to allow for infiltration and absorption by the street trees (City of Vancouver, 2019).

Permeable pavement comes in a variety of forms from permeable paving stones, asphalt and concrete. Thye allow for rainfall to soak into the ground where it infiltrates into the ground, through different aggregate layers, and ultimately into the underlying subsurface. It can also be diverted through a subsurface drain (City of Vancouver, 2019).

Nature-based Solution

An approach or strategy that harnesses nature and natural processes to tackle societal and environmental challenges. This approach involves the sustainable management, restoration, or creation of ecosystems and their services, aiming to deliver social, economic, and environmental benefits. It places a strong emphasis on integrating natural elements and processes into human-built systems to enhance their resilience and sustainability (IUCN, n.d.).

Receiving Water Bodies

Natural Water bodies that receive storm and combined sewer outflows. In the City of Vancouver, these bodies include the Fraser River, English Bay, False Creek, and the Burrard Inlet.

Rapid Transit

Rapid transit refers to a type of public transportation system designed to offer fast, efficient, and high-capacity service for transporting people within urban areas or between urban centers. It generally includes dedicated infrastructure, such as separate tracks or lanes, to ensure uninterrupted travel and higher speeds compared to standard public transportation. Rapid transit encompasses various transit modes, and for the purposes of this report, rapid transit specifically refers to the subway system (Phil. 2013).

Rapid Transit Station Areas

Area around the station that includes the plaza and adjacent streetscape (including sidewalk and boulevard) and may also include some considerations of integrated and /or adjacent development.

Subway System

A subway system is a kind of rapid transit system that mainly operates underground within tunnels, although it might also have sections above ground or elevated. It constitutes a form of public transportation that usually comprises a network of electrified railway lines connecting stations at key locations throughout the city.

Transit Plaza

A rapid transit plaza is a public space situated at or near a rapid transit station, intentionally designed to function primarily as a circulation space providing access to the station but can also function as a gathering area, aid in wayfinding for transit users, and a junction for various transportation modes. Usually, it incorporates pedestrian walkways, seating zones, waiting areas, and amenities such as information displays, ticketing kiosks, and facilities for bicycle parking.

Streetscape Adjacent to Station Plazas

The streetscape adjacent to station plazas pertains to the immediate surroundings and urban context that directly abut the plazas of rapid transit stations. This encompasses pedestrian-oriented spaces, streets, sidewalks, and public areas situated in close proximity to the station's entrance or plaza. Its design is fundamentally crucial for establishing a smooth transition between the transit station and the surrounding urban environment. The focus lies in enhancing the pedestrian experience, promoting walkability, and facilitating convenient access to and from the station. In this project, it was also recognized as a site for GRI and stormwater management.

Active Transportation

Active transportation refers to human-powered modes of transportation, such as walking, cycling, or using a wheelchair or other assistive devices. Active transportation infrastructure includes pedestrian walkways, cycling lanes, shared-use paths, and other facilities that support and encourage non-motorized travel (OpenAI, 2023).

Blue-green System

A blue-green system refers to an integrated approach that combines water management (blue) and nature-based solutions (green) to establish sustainable and resilient urban environments. Its goal is to replicate natural hydrological processes and improve the ecological and social aspects of urban spaces.

Onsite Stormwater Runoff

Onsite stormwater runoff for subway station areas refers to the water that flows over the surface of the station site during rain events or snowmelt. This runoff primarily originates from impervious surfaces like platforms, walkways, parking lots, and surrounding pavement. Considering the densely constructed environment, rainwater falling on the roof and facade of the building is collectively directed to the ground level. Subway station areas often generate a substantial amount of onsite stormwater runoff due to the prevalence of paved surfaces and limited green spaces in urban settings. In the absence of proper stormwater management measures, this runoff can accumulate pollutants such as debris, oil, grease, and chemicals as it traverses impervious surfaces.

Offsite Stormwater Runoff

Offsite stormwater runoff for subway station areas refers to the water that flows over the surface of the surrounding areas outside the station site during rain events or snowmelt. This runoff generally originates from adjacent streets, sidewalks, nearby buildings, and other impervious surfaces. Given that subway station areas are situated in densely constructed urban environments, the volume of offsite stormwater runoff can be substantial due to the prevalence of impervious surfaces in the neighboring areas.

PROJECT CONTEXT

Source: City of Vancouver

The anticipated development that will follow the construction of the BSP holds significant relevance for this project. It presents an opportunity to envision transit projects in a new light, along with other city-shaping components like open spaces and urban access to natural elements. The context for this toolkit is shaped by the forthcoming environment of the new BSP stations, including:

- Great Northern Way–Emily Carr: on the east side of Thornton Street, just north of Great Northern Way
- Mount Pleasant: at the southwest corner of Broadway and Main Street
- Broadway–City Hall: using the existing entrance to the Canada Line at the southeast corner of Broadway and Cambie Street
- Oak–VGH: on the southwest corner of Broadway and Laurel Street, near Oak Street
- South Granville: on the northeast corner of Broadway and Granville Street
- Arbutus: at the northeast corner of Broadway and Arbutus Street

The Broadway area, home to over 78,000 residents, witnesses 57% of its inhabitants opting for sustainable modes of transportation to commute to work – walking, rolling, cycling, or utilizing transit. Within the Broadway Plan area, 39% of residents choose to drive to work, a figure lower than the city's average of 45% (City of Vancouver, 2022). There is a growing demand for active transportation and the associated infrastructure. Future densification could lead to a notable increase in impervious areas, thereby exerting pressure on the urban rainwater management system and resulting in the loss of urban absorbent landscape areas with trees and natural systems that play a role in water management (City of Vancouver, 2019).

The Broadway area has a relatively low urban forestry cover ranging from 20% to less than 5%, which means less capacity to intercept, filter, and retain rainwater as a key actor in the natural water cycle. Impervious areas, including paved areas, roofs, and other hard surfaces, have a relatively high coverage ranging from 50% to 100% along Broadway. Although the Broadway Plan area has considered existing and future blue-green systems, currently there is little connection of existing systems to future BSP station areas.

Examining the characteristics of rapid transit station areas can help identify opportunities for rainwater management, flood mitigation, climate change adaptation and resilience, public health and well-being, urban growth, transportation connectivity, cultural and amenity services, as well as education and environmental literacy.

It is noteworthy that rapid transit-related infrastructure constitutes one of the most substantial urban infrastructure investments, serving a multitude of citizens and visitors. GRI, designed as a multifunctional and effective strategy to combat climate change, holds the potential to elevate transit plazas to places of significance, transforming them into amenity-rich civic assets. As articulated in TransLink's *Transit Passenger Facility Design Guidelines*, the well-being of regional watersheds, microclimates, and biodiversity is intrinsically tied to facility sites. Disruptions to air, water, soil, and ecosystem health within these sites can have far-reaching impacts on broader ecological networks. Well-designed transit facilities have the capacity to mitigate these on-site ecological challenges and contribute to the overall preservation and enhancement of local ecosystems. Nevertheless, it's important to acknowledge that the design guidelines recommend standardized landscape elements for the plaza area to prioritize customer safety and maintenance of the station and its surroundings. This approach has the potential to impede the effective realization of the climate adaptation goals set forth in the *Broadway Plan.* Some of the relevant design requirements include:

Plaza benches

The guidelines propose that benches located in transit plaza areas should prioritize accessibility for all customers. This includes specific features such as reserve backrests, armrests, kick space underneath the benches, and cane stops at the base of the benches. Additionally, the guidelines emphasize that benches must not be placed in areas where customers or the public could be approached from behind (TransLink, 2018, p. 179). These regulations might lead to a limitation in the flexibility of furniture design, making it challenging to integrate with GRI features like bioswales or other planting.

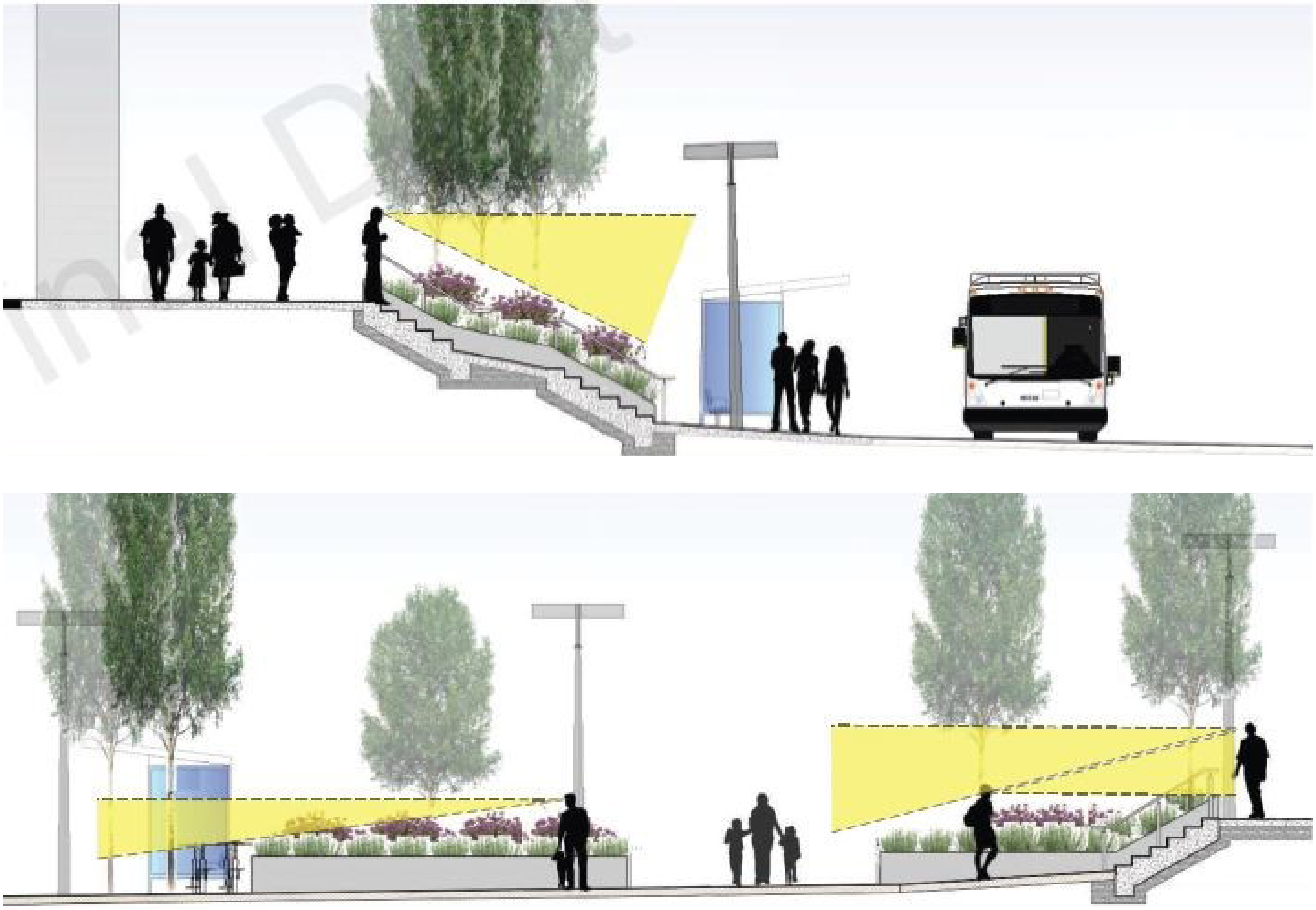
Paving

The manual emphasizes that selecting suitable paving materials can enhance the overall identity of the station while minimizing maintenance needs (TransLink, 2018, p. 185). However, the significance of permeable materials has not been adequately addressed. Careful consideration of balancing the maintenance budget with the provision of permeable paving utilization should be taken.

Shrub planting

According to the document, shrubs, as with all landscaping, shall adhere to an applied 3-7 Rule

TransLink's example of hard and soft landscape element placement



Source: TransLink

(foliage does not grow above 900mm (3.0') and/ or below 2100mm (7.0')), preserving sightlines through the plaza. Additionally, shrubs along walkways used by passengers using mobility devices shall not grow above 2' (600mm), to keep sightlines clear (TransLink, 2018, p. 191).

Trees

Trees, similar to all landscaping vegetation, must also adhere to the applied 3-7 Rule (where foliage does not grow above 900mm (3.0') and/or below 2100mm (7.0')), ensuring continuity throughout the plaza (TransLink, 2018, p. 188).

Although standardized plant size criteria contribute to ensuring customer safety, they can inadvertently restrict the range of GRI options available. Striking a balance between safety and GRI flexibility is crucial to harness the full potential of GRI typologies while creating a safe and inviting environment. This challenge underscores the need for careful design, innovative solutions, and collaboration among stakeholders to find ways to integrate GRI elements effectively without compromising safety.

PROJECT VISION & OBJECTIVES

Vancouver Burrard Station Entrance

Source: Darpan News Desk Translink

Vision

This project aims to conceptualize a toolkit of GRI typologies tailored for rapid transit station sites. This initiative seeks to establish a more robust transit infrastructure that advances climate change mitigation, addresses rainwater management and localized flooding, all while enhancing the overall public experience and well-being.

Objectives

- Identify potential challenges and opportunities of implementing GRI at transit sites, considering common environmental stressors.
- Provide an overview of existing green rainwater infrastructure programs, compiling precedent research suitable for rapid transit station areas.
- Develop an integrated urban design toolkit that effectively addresses stormwater volume reduction and mitigates water quality concerns, thereby promoting sustainable and resilient urban development in the region.
- Establish a framework of design decisions to facilitate the development of GRI at station sites, fostering their adaptability for potential retrofits of rapid transit nodes and future subway extensions in Vancouver.

CONTEXT ANALYSIS

Arbutus station area looking east

Source: City of Vancouver

Existing transit plaza inventory analysis

As part of the context analysis, the initial step involves examining the currently constructed station plazas in Vancouver. Five sites were chosen for detailed analysis, utilizing information sourced from the City of Vancouver.

This analysis yielded insights into diverse uses, required functionalities, and identified gaps demanding attention. By closely examining the present site infrastructure and elements, in addition to assessing the on-site rainwater management provisions, an evaluation was made on the expected extent of existing rainwater management.

The evaluation of anticipated water management levels is categorized as follows: good, fair, insufficient, and none – in descending order based on the availability of permeable ground level surfaces. This assessment is grounded in:

(1) Amount of polluted run-off intake

(2) The vertical and horizontal proximity to surface run-off

(3) The ability and efficiency to store and infiltrate water

King Edward

Partially Overbuilt

King Edward Station is a stop along the Canada Line, positioned at the juncture of Cambie Street and King Edward Avenue within the Cambie Village neighborhood. Serving as a pivotal transit station, King Edward Station provides links to an array of bus routes, simplifying the process for commuters to switch between various modes of public transportation.

King Edward station entrance

Source: City of Vancouver

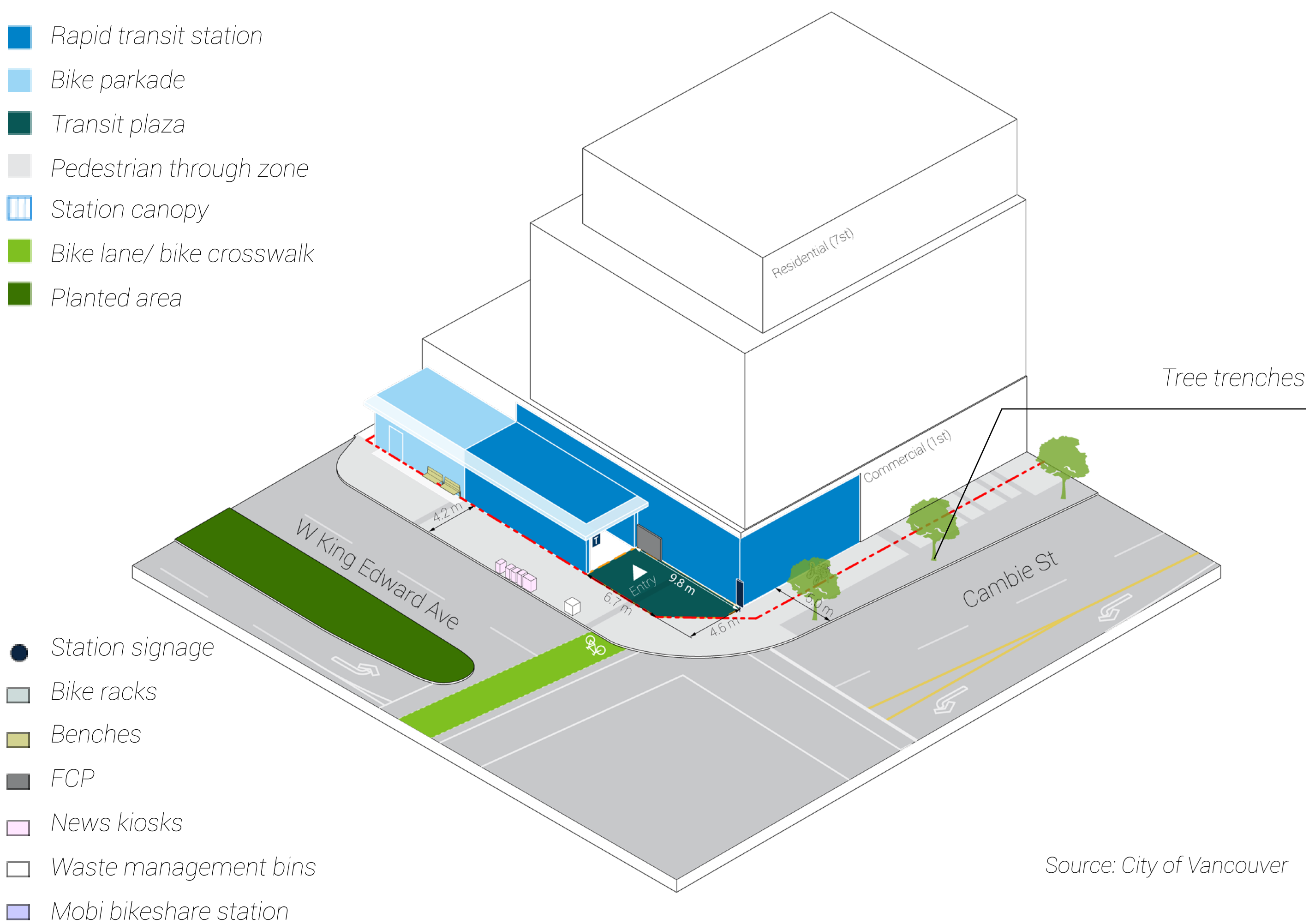
Rain water management:

GRI is currently absent from the area, leading to surface runoff flowing along the road and entering the surface drain located next to the curb. This runoff is then directed to the sewer system or directly enters receiving water bodies. The presence of small tree pits poses limitations in effectively managing rainwater. The soil within these trenches has limited capacity to temporarily store water, allowing tree roots to absorb it.

Existing site infrastructure:

Bike parkade, bike lane, bus stop, station signage, benches (2x), news kiosks.
Landscape elements include paving & street trees.

The anticipated level of water management is considered to be: **insufficient.**



Source: City of Vancouver

Vancouver City Centre

Connection underground to commercial context

Vancouver City Centre Station stands as a crucial transit hub nestled in the core of downtown Vancouver. It holds significant prominence as a key stop on the Canada Line of Metro Vancouver's SkyTrain rapid transit system. The station occupies a strategic position at the crossroads of West Georgia Street and Granville Street, rendering it conveniently reachable for commuters, tourists, and residents alike.

Vancouver City Centre station entrance

Source: City of Vancouver

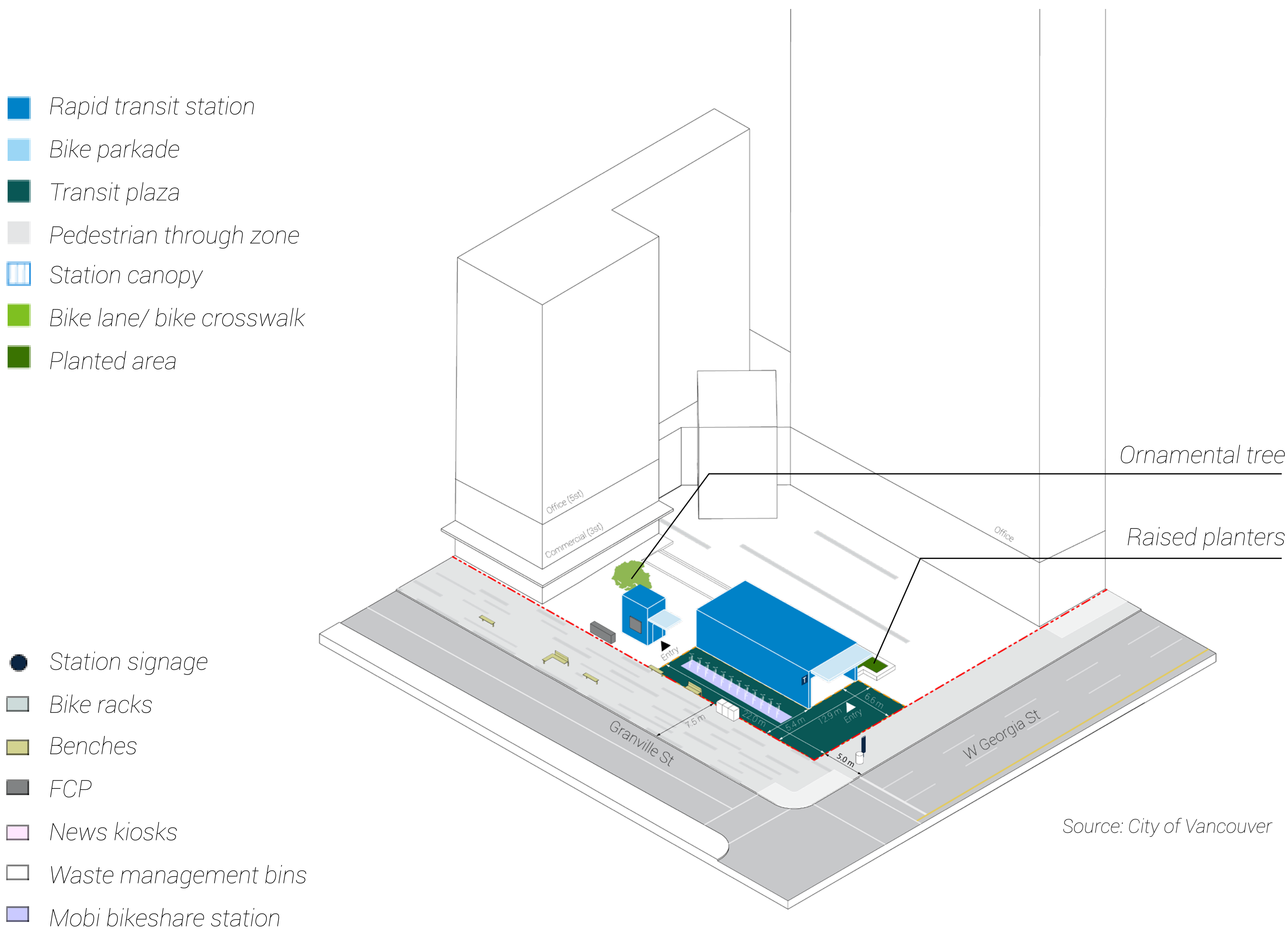
Rainwater management device:

GRI is currently not in place in this location. Surface runoff follows the path of entering the nearby surface drain adjacent to the curb, which can result in diversion to combine with sewage or direct entry into receiving water bodies. Although not entirely impervious, the raised planters in the area do not have the capability to effectively manage surface flow.

Existing site infrastructure:

Infrastructure include bus stop, benches (4x), waste management bins, Mobi bikeshare station. Landscape element is limited to raised planter, paving & ornamental tree.

The anticipated level of water management is considered to be: **insufficient**



Source: City of Vancouver

Langara- 49th

Stand-alone

Langar-49th station is a stop of the Canada Line, positioned at the junction of West 49th Avenue and Cambie Street. This station effectively caters to the Marpole and Oakridge neighborhoods within Vancouver. Its strategic proximity to Langara College, a significant post-secondary institution in the city, results in frequent utilization by students and faculty members for their commuting requirements to and from the college.

Langara - 49th station entrance

Source: City of Vancouver

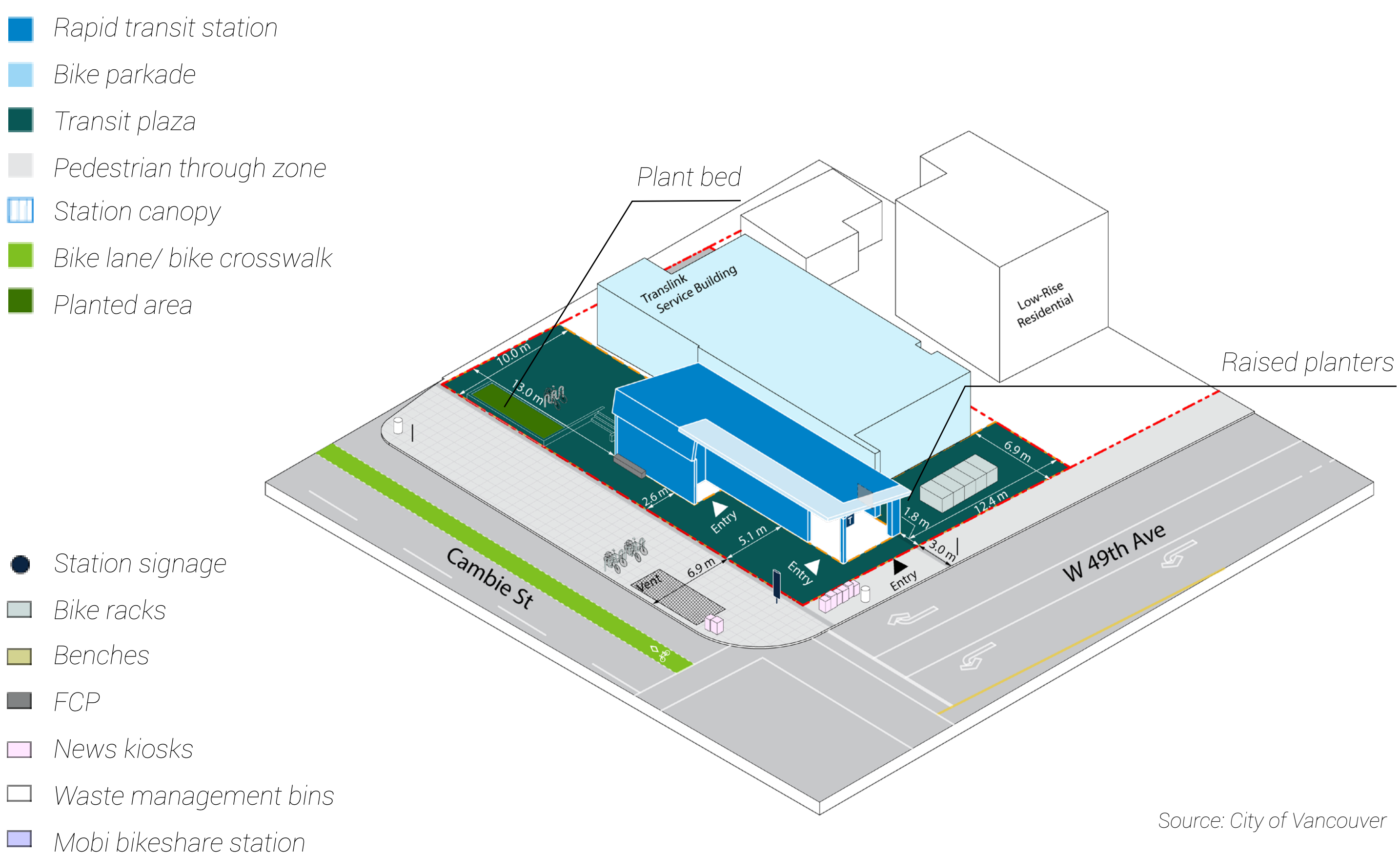
Rainwater management device:

GRI is absent. Plant beds located at the corner by the station entrance have an intermediate capacity to treat rainwater. Sidewalk is a naturally sloped surface, runoff flows along the curb and enters the stormwater catch basin to be diverted to combine with sewage, or directly to receiving water bodies.

Existing site infrastructure

Infrastructure include bike racks, bike lane, station signage, news kiosks.
Landscape elements include plant bed, raised planter, wall art, and pavement.

The anticipated level of water management is considered to be: **insufficient**



Source: City of Vancouver

Burrard

Stand-alone

Burrard Station holds significant importance within the downtown core. Positioned at the crossroads of Burrard Street and Dunsmuir Street, this station offers convenient accessibility to commuters, residents, and visitors traversing the downtown vicinity. The station's environs boast a myriad of commercial and cultural attractions, encompassing shopping centers, dining establishments, office edifices, theaters, art galleries, and its adjacency to Art Phillips Park.

Burrard station entrance

Source: City of Vancouver

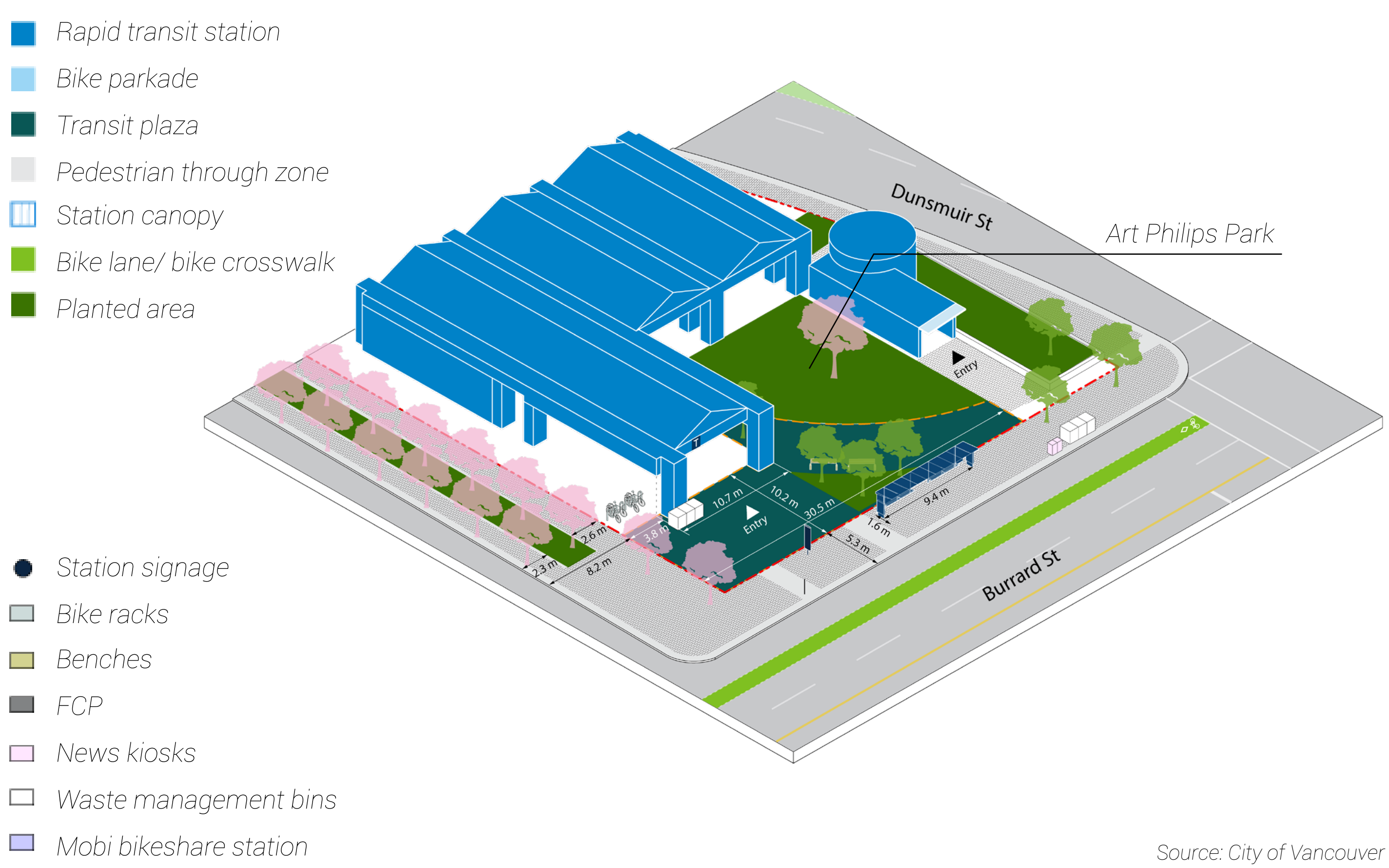
Rainwater management device:

The station's vicinity is enveloped by pervious surfaces, which possess the ability to absorb rainfall directly. However, these surfaces do not effectively manage surface water flow emanating from the neighboring impervious surfaces. Consequently, the surface runoff will enter stormwater catch basins, where it might be channeled to combine with sewage or directly enter receiving water bodies.

Existing site infrastructure

Infrastructure includes bike crosswalk, bike lane, bike racks, benches (2x), news kiosks, waste management bins.
Landscape elements include the park greenspace, planters, paving, statue, and street trees.

The anticipated level of water management is considered to be: **fair**



Source: City of Vancouver

Yaletown-Roundhouse

Stand-alone

Yaletown-Roundhouse Station is a stop along the Canada Line, positioned at the convergence of Davie Street and Mainland Street. It is in proximity to the Roundhouse Community Arts & Recreation Centre, a historically significant structure that previously functioned as a Canadian Pacific Railway (CPR) roundhouse. The station's nomenclature pays homage to this historical linkage. The station plaza and its adjacent areas thrive as vibrant public spaces frequently used for hosting community events and activities.

Yaletown-Roundhouse station entrance

Source: City of Vancouver

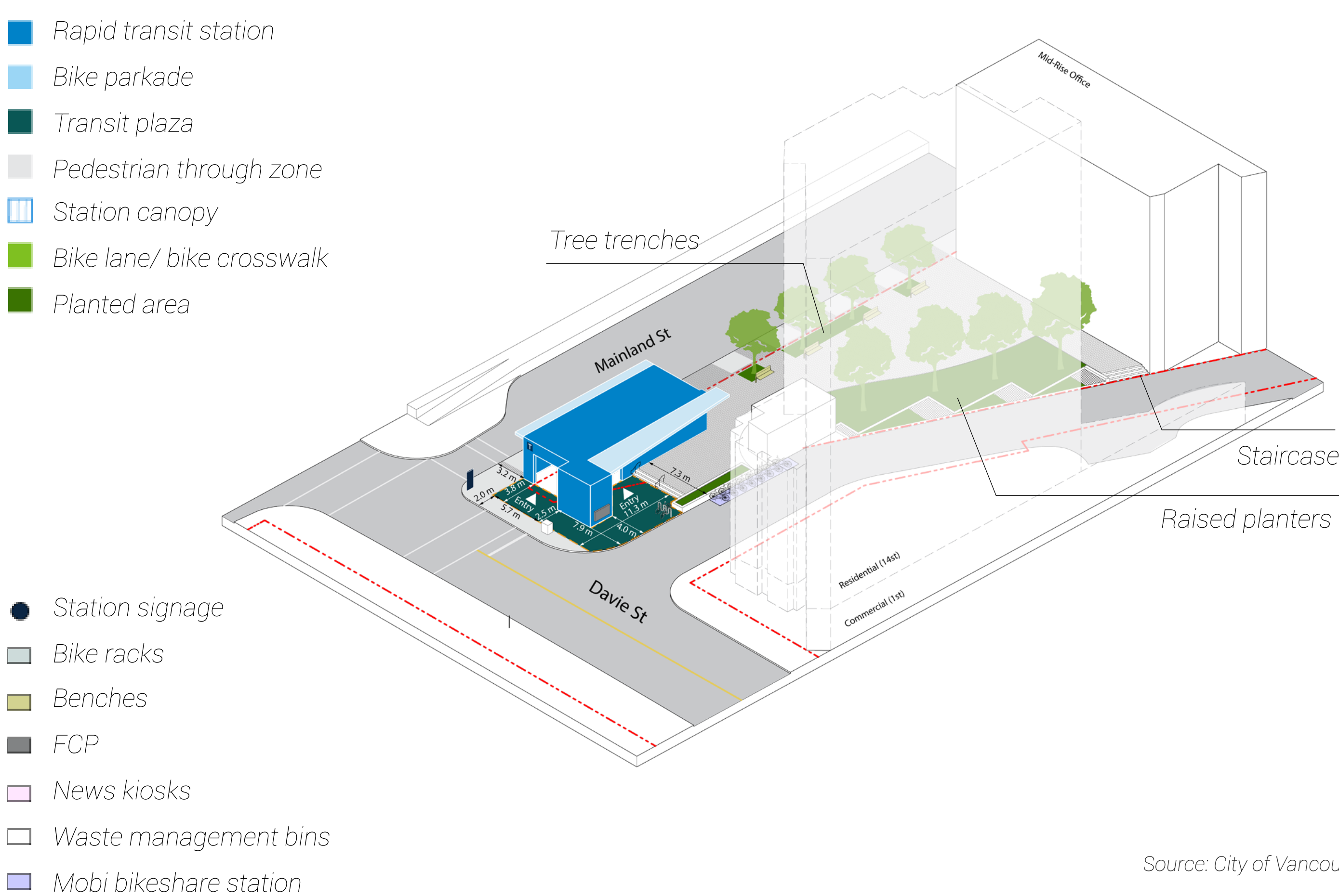
Rainwater management device:

The station vicinity is adorned with several ground planting beds and elevated planters, which exhibit rainwater absorption properties. In instances of surplus surface runoff, this excess water infiltrates the nearby stormwater catch basin. From there, it could be directed to combine with sewage or directly discharge into receiving water bodies.

Existing site infrastructure

Infrastructures include bike racks, bus stop, station signage, waste management bins, and Mobi bikeshare station.
Landscape elements include paving & street trees, public art installation, planting beds.

The anticipated level of water management is considered to be: **insufficient**



Source: City of Vancouver

Conclusion

Aberdeen Transit Plaza and No.3 Road Corridor Restoration by IBI Group

Source: IBI Group

- None of the identified station plazas are intentionally designed to employ GRI for water management. As a result, polluted rainwater runoff from the adjacent roadways directly enters the stormwater system, ultimately making its way untreated to receiving water bodies.
- Due to the availability of open pervious areas, station entrances that have been provided with generous setbacks and open space resulting in a larger plaza have a higher potential to absorb water. However, these existing pervious areas are not fulfilling the function of absorbing plaza runoff, as they are either raised planters or were not designed to receive runoff.
- It is anticipated that overbuild will occur at most BSP station sites. Given the land-use directions provided in the Broadway Plan, development at stations will result in a dense urban environment. While providing generous setbacks and open space can be a challenge due to the land economics of development in a highly urban context, they are of great importance in order to make increased density livable and provide room for GRI, especially at rapid transit areas. This circumstance brings about the potential risk of overlooking GRI integration, thereby necessitating a concerted effort to strike a balance between development intensification, civic amenities, and rainwater management infrastructure. Incorporating multi-use elements will be of great value, allowing for expanded open space within the context of dense urban conditions.

Existing GRI programs in Vancouver

Rainbow Park, Richards St

Source: City of Vancouver

Project type
City Park

GRI type
Water storage and reuse; bioswale.

Notes

- Rainwater, as well as the water from the spray park, is collected and stored in an underground cistern. This stored water is then reused for various purposes, particularly in the washrooms.
- Overflow from the cistern and all remaining rainwater eventually filters to the GRI feature in the alley. The strategic positioning of bioswales is of utmost importance; these bioswales are meticulously designed to be distanced from circulation and movement zones. Additionally, they are linked to the surface drain found in the laneway.
- Showcased how an underground cistern typology that reuses the runoff on-site can work with other GRI typologies such as bioswales on site.
- Water is managed from the park and the water feature.
- Variety of new trees, shrubs, perennials, and groundcover, providing habitat for insects and birds.

Richards Street

Source: City of Vancouver

Project type

Blue-Green System

GRI type

Rainwater tree trenches

Notes

- The trenches function as subterranean reservoirs, facilitating a gradual percolation of water into the soil. This gradual process serves to alleviate the pressure on stormwater systems and effectively diminishes the potential for flooding.
- The use of loose gravel in tree wells could pose challenges in a transit plaza, particularly due to the elevated pedestrian volumes present in such areas.
- This example illustrates the integration of paving patterns with GRI , concurrently raising public awareness about GRI and infusing character into the space. The manner in which sub-surface GRI harmonizes with the bike lane could be implemented in the right-of-way adjacent to transit plazas.
- Installation of over 100 trees over seven blocks, and hundreds of groundcover in phase two.
- Educational signages help to inform site users about GRI and its role in rainwater management.

Woodland Dr and 2nd Ave E

Source: City of Vancouver

Project type	**GRI type**
Blue-Green System	Bioswale

Notes

- Integration of recycled materials in GRI projects.
- Inlet stamps contribute to visual appeal and create a distinct sense of location.
- A critical procedure involves navigating around underground utilities.
- Matrix planting was employed as a regenerative planting strategy, facilitating the mixed planting of drought-tolerant plants.
- Inspired the design of bioswales, and the integration of public art and street painting into the landscape design was showcased.
- Water is redirected from adjacent roadways to channel into the bioswale.

Woodland Dr and E 14th Ave

Source: City of Vancouver

Project type
Corner Bulges

GRI type
Bioswales

Notes

- Employment of a sediment pad to reduce the accumulation of sediment within the bioswale.
- Integrate street painting to enhance the sense of place.
- The primary function of the inlet is not to retain water, but to decelerate its flow.
- Inspired the design of bioswales, as well as the integration of public art and street painting into the landscape design.
- Added landscape elements enhances the broader ecological connectivity and positively impacts the mental well-being of neighboring residents.
- Water directly flows off the roadway and enters the corner bulge bioswale.
- A combination of sedges, rushes, and perennials is planted to aid in water management and offer habitat.

Quebec and 1st Avenue

Source: City of Vancouver

Project type	**GRI type**
Bioswale	Bioretention planting, street trees, meadow.

Notes

- Microclimate and maintenance play a crucial role in plant establishment, and their significance is essential for the success of the project.
- Water directly flows off the roadway and into the bioswales.
- Roadside bioswales can provide ecological benefits to the area and contribute to urban cooling.
- Emphasized the importance of GRI maintenance and management. Ensuring the successful establishment of plantings and the proper functioning of features like pavers are crucial factors to consider for future monitoring and evaluation, aiming to ensure the effectiveness of GRI programs.

Olympic Village

Source: City of Vancouver

Project type

Permeable paved parking

GRI type

Permeable paving

Notes

- Permeable pavement requires consistent maintenance to prevent the accumulation of sediment and litter that can obstruct the gaps between the tiles, leading to the impaired functionality of the pavers.
- Emphasized the importance of GRI maintenance and management. Monitoring and evaluating the successful growth of vegetation and the functioning of infrastructure elements, such as pavers, are crucial components for future assessment. These efforts ensure the continued success of GRI projects and their ability to fulfill their intended goals.

Conclusion: existing GRI gaps

The range of GRI typologies encompasses the management of rainwater originating both directly on-site and from the surrounding roadways. The effectiveness of GRI increases as more water is redirected away from heavily trafficked roads. These projects have demonstrated numerous successes that can be transferred to the integration of GRI within transit plaza areas. Moreover, an assessment of disparities between existing and proposed GRI typologies at transit plazas has been conducted, highlighting areas for improvement and enhancement.

Appropriate sizing of GRI

Adapting GRI typologies to compacted settings with limited space is a critical consideration. This potential gap requires thorough evaluation and planning. It's essential to assess the expected rainwater volume and design the GRI infrastructure to have sufficient capacity to handle the anticipated flow, even within confined plaza areas. Proper sizing and design of features such as bioswales, rain gardens, or permeable pavements become paramount in ensuring their effectiveness.

In scenarios where the rainwater volume surpasses the treatment capacity of individual GRI elements, a hybrid approach can be adopted. Integrating GRI solutions of various scales and sizes can facilitate adaptation within limited spaces, ensuring effective rainwater management and contributing to the resilience of the urban environment.

Stakeholder preference

The operational and cost considerations of GRI may not always align with stakeholders' preferences. While GRI offers substantial long-term benefits, the initial investment required for design and installation can be higher compared to conventional stormwater management methods. Convincing stakeholders to allocate upfront funds for GRI projects can be a challenge, despite the potential for cost savings over time. Moreover, GRI installations can increase the complexity and cost of ongoing site operation and maintenance, which might pose challenges for entities like TransLink that provide services. Additionally, the visual aspect of public infrastructure may not always match the aesthetic preferences of the community. Different individuals or groups may have varying opinions about what constitutes an appealing design. In general, considering public perception is crucial, especially if the community values clear, well-maintained, and functional spaces near station entrances. Balancing the functional benefits of GRI with aesthetic preferences and cost considerations is a significant aspect in achieving successful implementation and public acceptance.

Hinge park in Olympic Village featuring the water recycle system

Source: Vancouver is Awsome

Equity and social justice

Public infrastructure projects that do not adequately address social or equity concerns can encounter resistance. For instance, certain design choices, such as using pervious pavers that create more joints between pavers, may not be suitable for wheelchair users, particularly those with spinal cord injuries, as it can be uncomfortable to navigate. In such cases, alternatives like pervious concrete or pervious asphalt should be considered to ensure accessibility for all.

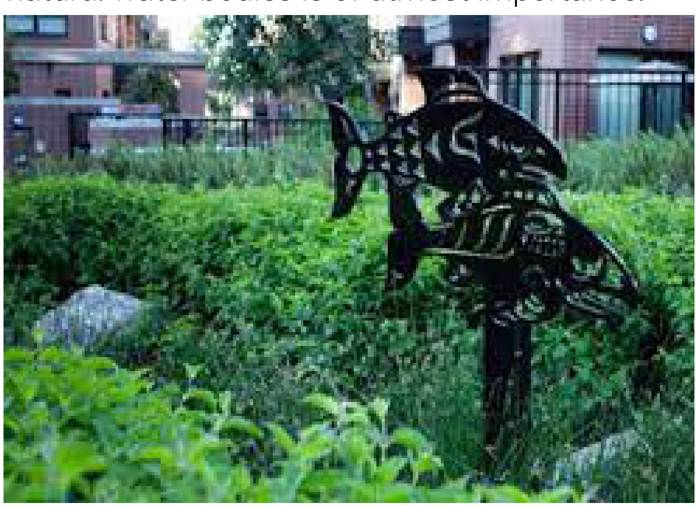
It's crucial to recognize that if a design fails to accommodate the diverse needs of various user groups or even worsens existing social disparities, it can lead to negative perceptions. This might result in the public perceiving the investment in GRI as less urgent than other pressing social needs, like affordable housing. Consequently, despite the value GRI brings, the lack of public acceptance can arise due to the perception that social priorities are not being adequately addressed. Achieving a balance between functional design, equity considerations, and social needs is pivotal for successful GRI implementation and public support.

Strengths and challenges of implementing GRI at transit sites

Strengths & opportunities

The implementation of GRI at transit areas offers significant advantages in mitigating the potential for severe localized flooding and the subsequent impacts on essential transit infrastructure. This not only safeguards critical infrastructure but also bolsters passenger safety while simultaneously fostering the development of sustainable and resilient urban environments. GRI plays a pivotal role in creating a more secure and adaptable transit system that can withstand the challenges posed by extreme weather events and contribute to the overall well-being of the community.

Transit stations are often strategically positioned near major roadways, which are prone to generating significant amounts of polluted rainwater. Implementing effective treatment measures for this polluted runoff before it reaches natural water bodies is of utmost importance.



63rd & Yukon Plaza , source: Vancouver is Awesome

Furthermore, there exists a significant social and psychological advantage in augmenting the presence of green and planted spaces within urban areas. By integrating GRI elements that manifest as visible green expressions, subway station plazas can offer a more appealing and inviting environment. This not only captures the attention of commuters and pedestrians but also serves to highlight the functional contributions of GRI programs. Such initiatives facilitate the creation of welcoming spaces and guide the design of transit corridors that prioritize landscaping and user-centric experiences.

These GRI practices serve as tangible illustrations of sustainable stormwater management strategies during rainy periods. Introducing educational signage or interpretive panels alongside these installations can offer insightful explanations regarding their functionality, environmental advantages, and role in ameliorating the effects of stormwater runoff. This approach triggers curiosity among the public, prompting inquiries about their purpose and design. Consequently, it opens avenues for educational engagement, allowing community members to gain insights into the significance of adopting sustainable stormwater management practices and ways in which they can actively participate in water conservation initiatives.

By incorporating green infrastructure in the transit plaza, it becomes an integral part of the larger blue-green system as well as the active transportation network. This integration creates a more resilient and interconnected urban environment, benefiting both the rapid transit plaza and the broader blue-green system as a whole. The typologies will be inclusive with consideration to accessibility for all, making the space more inviting, accessible, and environmentally friendly. This encourages active transportation and supports people with visual and physical impairments. Incorporating GRI strategies within transit plazas ties the space to the broader green-blue network, creating seamless and enjoyable experiences for pedestrians and cyclists, and contributing to the promotion of healthier and more sustainable modes of travel.

63rd & Yukon Plaza , source: Vancouver is Awsome

Viewed from an environmentally friendly perspective, the conversion of the plaza space for GRI programs enables the area to make an active contribution to ecological connectivity within the urban environment. This transformation not only establishes habitat and provides support for native species but also fosters pollinator populations, creating valuable opportunities to reinforce the connection between humans and nature. These combined efforts play a pivotal role in enhancing ecological networks and boosting urban biodiversity. Additionally, by addressing challenges such as the urban heat island effect and tree canopy deficiency through the establishment of more shaded areas, we can craft a more desirable environment that not only beckons but also actively promotes the use of rapid transit.

Challenges: technical stressors

Maintenance budget and Irrigation restrictions: plant choice is a primary consideration in designing for GRI. It's important to select a mix of drought-tolerant and moisture-tolerant plant species, and potentially group plants with similar water requirements together to optimize water usage. Amended soils with good organic content can retain moisture and reduce the need for frequent irrigation. Additionally, consider installing rainwater collection systems for irrigation during periods of drought. These low-maintenance regenerative planting methods collectively help reduce long-term maintenance costs.

Utility protection and setbacks: utility restrictions can pose challenges to the implementation and maintenance of green infrastructure. GRI installations, such as rain gardens or tree trenches, require meticulous consideration of underground utilities, including water pipes, gas lines, electrical cables, and communication networks. These considerations are necessary in addition to restrictions imposed by the underground station itself. For instance, the distance from the top of the station box to the street level is typically around 3 meters, although this measurement may vary based on the context and design of future BSP stations. TransLink mandates a 1-meter setback requirement for station maintenance. Ensuring proper airflow necessitates clearance for ventilation systems.

Soil volume limitation: rapid transit stations often contend with limited available space and may be situated atop underground structures and utilities. These conditions can restrict the depth and extent of soil available for planting and supporting vegetation. This limitation presents challenges to the establishment and long-term health of green infrastructure elements.

Balance of landscape elements: conventionally, the most important function of transit plazas has been to provide adequate and safe movement space for all passengers. In exploring how GRI strategies can be implemented within transit plazas, it's important to establish a balance between the hardscape elements that provide functionality, durability, and safety, with softscape elements that manage rainwater. Ideally, elements can serve dual purposes and/or work together with proper design.

Risk of overflow: designing green infrastructure for overflow situations requires careful consideration to effectively manage excessive stormwater runoff. Sometimes, rainwater capture exceeds the treatment capacity, which could lead to localized flooding. There is a need to explore additional ways to temporarily control overflow in such cases. Therefore, it is imperative to consider additional connections with nearby drainage devices.

Challenge of providing maintenance access: GRI programs require regular maintenance to ensure their ongoing effectiveness and longevity. This maintenance includes tasks such as vegetation care, sediment and debris removal, irrigation and water management, and structural inspections. While transit plaza areas are typically very accessible by vehicles, the maintenance process can create implications for traffic and pedestrian management.

Some additional challenges that require more in-depth investigation include: avoiding damage to existing street trees; managing private water in the public right of way; infiltrating near the building foundation; mechanically collecting and routing water to GRI from the roof; allowing all runoff to reach ground level without treating it where it falls, for example, on the roof or podium level; and addressing disturbances caused by the high volume of foot traffic and potential litter.

Challenges: environmental stressors

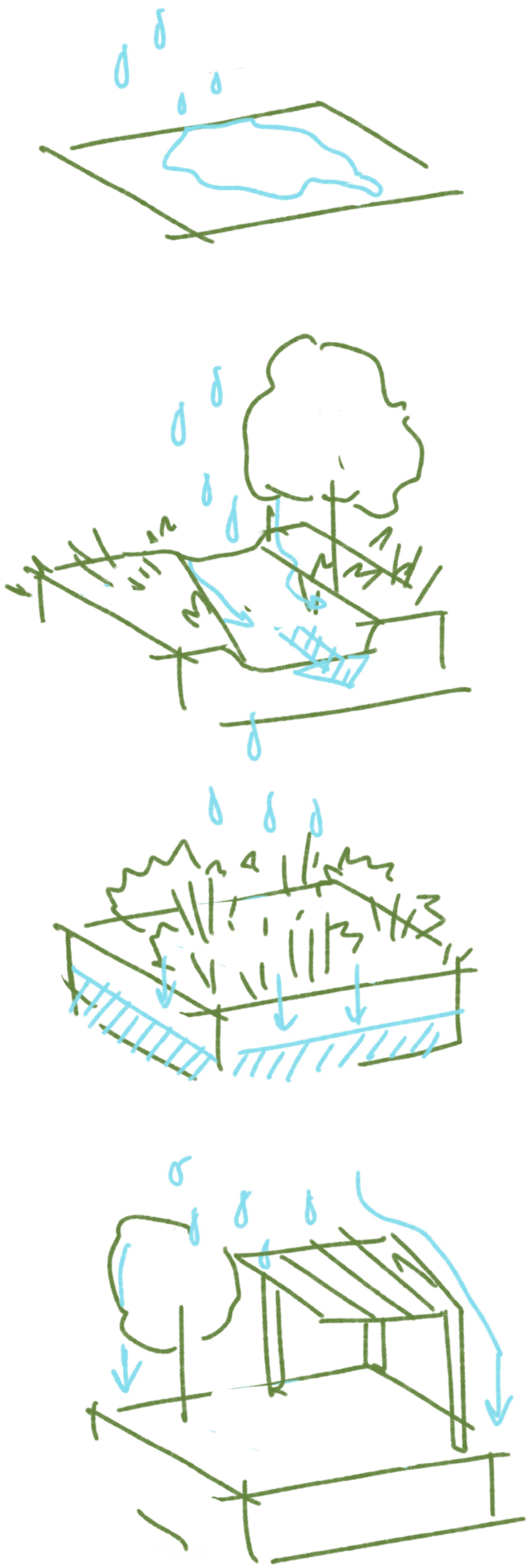
Rising population pressure: In station plazas, space constraints are particularly acute in densely populated urban areas. As passenger numbers swell, allocating ample room for pedestrian movement, waiting areas, entrances, exits, and other essential amenities becomes increasingly complex. Meeting the demands of a growing populace while ensuring safety and security demands design elements like clear sightlines, sufficient lighting, surveillance systems, and well-defined emergency routes.

Competing interests: Transit plazas are often prime locations for both formal and informal commerce, as well as entertainment activities such as musical performances by buskers. Conflicts can arise when attempting to strike a balance between the desire for commercial opportunities and the imperative to maintain open and accessible public spaces. Addressing these divergent interests calls for thoughtful deliberation, collaboration, and effective communication among multiple stakeholders, including transportation authorities, urban planners, architects, local communities, and commercial entities.

Urban heat island effect: Subway stations rely on ventilation systems to uphold air quality and expel exhaust emissions. The heat generated by these systems, coupled with the heat produced by trains and platform activities, can contribute to local temperature spikes. These factors collectively contribute to the regional urban heat island effect, which can poses health hazards to nearby residents and can undermine the success of GRI programs by causing vegetation mortality.

Water pollution: Conventional impermeable surfaces near station areas convey stormwater runoff, which can carry pollutants such as oil, grease, litter, and debris. This contaminated runoff ultimately flows into receiving water bodies, contributing to water pollution.

DESIGN STRATEGY



Conceptual drawing for design strategy

RELIEVE

GRI typologies mitigate concentrated flooding and alleviate the pressure of managing run-off in the transit plaza area.

SLOW DOWN & REDIRECT

GRI typologies facilitate the slowing down and redirection of water flow.

STORE & INFILTRATE

GRI typologies efficiently store and enable rainwater to permeate into the ground.

CAPTURE & PROTECTION

GRI typologies capture rainwater and provide a protective measure for both users and utilities.

Case Study: Plaza

FIRST AVENUE WATER PLAZA

NEW YORK, US | 2019

Setting: urban green roof plaza **Scale: 1,791 square metres** **Approach: store & infiltrate**

GI elements: rock-lined swales, scrim fountain, sloped planting

Program: recreation, education, storm water mitigation, water harvest

- Located atop an underground parking garage, it serves as a water-filtration system, a noise-pollution buffer, a de facto green roof, and a connection to the East 34th Street Ferry Landing (Azureeditorial, 2019).
- Features: A series of rock-lined swales around the perimeter collect stormwater runoff and create a sense of enclosure. A system of well-defined diagonal pathways guides commuters towards a conveniently located ferry stop along the East River. Additionally, a scrim fountain, particularly popular among children, is adorned with stepping stones and offers a refreshing and cooling ambiance.
- To enhance resilience against floods, the planting beds are designed with slopes and contain vegetation species capable of withstanding saltwater. For example, bald cypress trees are primarily located at the lowest levels.

Features applicable for transit plaza GRI design: the incorporation of geometrical green edges and boundaries; the alignment that maximizes accessible movement space; and the feasibility of implementing cistern typology in conjunction with an underground parking facility.

SourceL Azureeditorial

SourceL Azureeditorial

ZOLHALLEN PLAZA

FREIBURG, GERMANY | 2011

Setting: post industrial urban plaza

Scale: 5,600 square metres

Approach: slowdown & direct; store and infiltrate

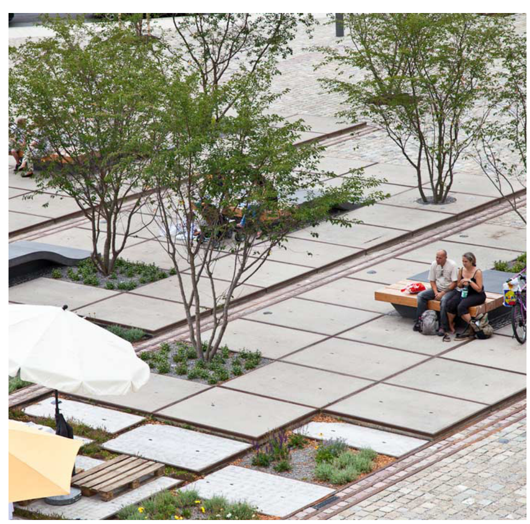
GI elements: planters beds, subsurface gravel trenches, in-built filter, urban forestry

Program: recreation, flood mitigation, storm water infiltration, mix use.

- The design emphasizes the creation of a dynamic and vibrant space that accommodates various needs and activities.
- The plaza showcases a spacious central courtyard encircled by a multi-level structure.
- The courtyard serves as a focal point and provides a welcoming gathering space for visitors. It is beautifully landscaped with lush greenery, trees, and water features.
- The architecture incorporates green building principles, including energy-efficient systems, water conservation measures, and the use of eco-friendly materials. The plaza also includes solar panels and green roofs to generate renewable energy and promote biodiversity (Landezine. (n.d.).

Features applicable for transit plaza GRI design: the use of recycled materials to reduce construction costs; the implementation of large-format paving to create accessible hardscape movement areas, with larger joints for permeability; rainwater channels directed towards planting areas; and subsurface gravel trenches to manage excess surface flow.

Source: Landezine



Source: Landezine

Case Study: Bioswale

ARIZONA STATE UNIVERSITY ORANGE MALL

TEMPE, US | 2018

Setting: school retrofit   Scale: 8,093 square metres   Approach: slowdown, store, capture

GI elements: bioswale, bio-retention area, underground pipe and drywell, silva cells.

Program: mobility, mix use, recreation, stormwater mitigation, precipitation event protection

- Creating a vibrant and inviting atmosphere for students, faculty, and visitors.
- The use of native desert plants and trees adds to the aesthetic appeal while also promoting sustainability and water conservation.
- Incorporates various gathering spaces and activity areas: open plazas, courtyards, and shaded seating areas with benches and tables, accommodating both small and large groups.
- The stormwater from the Student Pavilion's roof, as well as water from the surrounding roads and watershed, is directed through visible, oversized scuppers and surface runnels into a series of bio-swales.
- Bioswales lead to the bio-retention areas, which act as the largest basin and final destination for managing stormwater on-site.
- The rain garden is located next to a quiet seating area, separated from the busy pedestrian corridor. Excess water is drained through underground pipes to a large infiltration dry well beneath a nearby athletic field (ASLA Professional Awards, 2021).

Features applicable for transit plaza GRI design: the use of structural soil to accommodate underground utilities; a connected system involving roof runoff, bioswales, and bio-retention areas; and close proximity to the public gathering space.

Source: ASLA 2021

Source: ASLA 2021

GREY TO GREEN

SHEFFIELD, UK | 2016

Setting: urban green corridor **Scale: 1.3km/10,000 square metres**

Approach: slowdown & direct; store & infiltrate

GI elements: 25 swale cells in linear sequence

Program: transportation, mobility, stormwater mitigation, recreation

- The Grey to Green initiative in Sheffield is a design project aimed at transforming the city's urban spaces by converting gray, underutilized areas into vibrant green spaces.
- It emphasizes the introduction of green infrastructure, including the incorporation of trees, plants, and vegetation into the urban fabric, reimagines public spaces, such as roads, sidewalks, and plazas, by incorporating sustainable drainage systems.
- These systems help manage stormwater runoff by utilizing green infrastructure elements such as rain gardens, swales, and permeable pavements, which not only reduce flood risks but also enhance the visual appeal and functionality of public spaces.
- This project prioritizes pedestrian and cycling infrastructure, promoting active transportation and reducing reliance on cars, including the creation of green corridors and pedestrian-friendly pathways, encouraging healthier lifestyles and reducing carbon emissions (Grey to Green – Sheffield, n.d.).

Features applicable for transit plaza GRI design: considering pedestrian and cycling infrastructure; utilizing smaller-scaled sites like boulevards; and integrating seating within the GRI program.

Source: Grey to Green – Sheffield.

Source: Grey to Green – Sheffield.

Case Study: Soil Preparation

LINCOLN CENTER PLAZA

NEW YORK, US |2008

Setting: urban public plaza/ bosque renovation **Scale: 40,468 square metres**

Approach: store & infiltrate

GI elements: soil cells, urban forestry, permeable ground

Program: recreation, stormwater mitigation, flood mitigation, mix use

- The renovation of Lincoln Center's public spaces aimed to revitalize and enhance one of New York City's iconic cultural destinations.
- The redesign focused on improving accessibility, aesthetics, and functionality while preserving the center's architectural heritage.
- The outdoor public spaces were reimagined to provide more greenery, seating areas, and open spaces for relaxation and socializing.
- New landscaping elements, including trees, plantings, and pedestrian-friendly pathways, were introduced to soften the overall ambiance and create a more inviting atmosphere.
- The transformation of North Plaza offers a two-level restaurant with an undulating green roof above the underground parking garage.
- A bosque of trees offers a welcoming shaded grove for casual gatherings or performance viewing (MNLA, n.d.).

Features applicable for transit plaza GRI design: the potential for integrating soil cells into a large-scale site while accommodating an underground parking facility; the atmosphere created by an open canopy that minimizes safety concerns related to tree coverage; and the provision of shade to mitigate the urban heat island effect.

Source: MNLA.

Source: MNLA.

HUDSON SQUARE

NEW YORK, US | 2012

Setting: streetscape master plan/ GI system **Scale: 2,42,811 square metres**

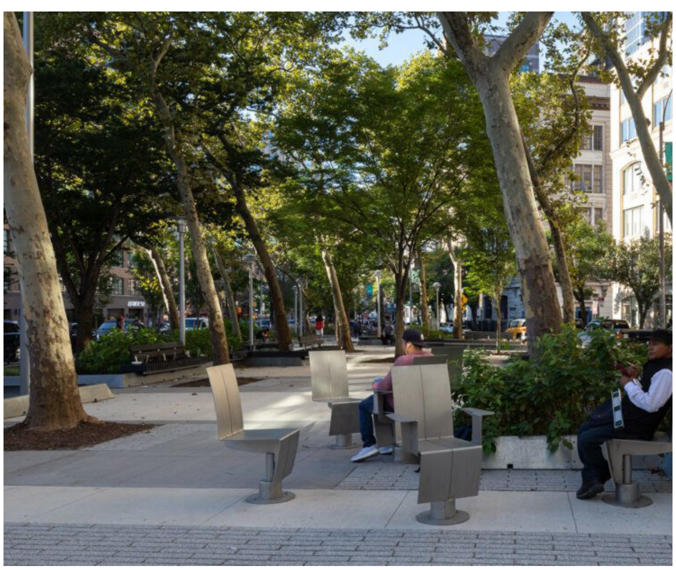
Approach: slowdown & direct, store & infiltrate, capture & protection

GI elements: continuous tree pits, bioswale, bioretention, structural soil, porous aggregate, permeable pavers, tree guards

Program: mix use, recreation, transportation, stormwater mitigation

- The Hudson Square Streetscape Master Plan is a comprehensive urban design strategy aimed at enhancing the streetscape and public realm in the Hudson Square neighbourhood of New York City.
- The plan focuses on improving the pedestrian experience, promoting sustainable transportation, and creating a more vibrant and accessible community.
- Key elements include: Pedestrian-friendly streets; Green spaces and public plazas; Cycling infrastructure; Streetscape enhancements; Wayfinding and signage; Stormwater management (Pintos, P., 2022).

Features applicable for transit plaza GRI design: the integration of interconnected urban greenspaces and GRI programs; the incorporation of tree pits and planting beds that synergize with GRI while also creating an inviting and secure public space.



Source: Pintos, P.

Source: Pintos, P.

Case Study: Infrastructure

JURONG SMART BUS STATION

JURONG, SINGAPORE |2016

Setting: project bus stop **Scale: 8 metres x 1 metre** **Approach: capture and protection**

GI elements: canopy, urban forestry

Program: transportation, mobility, stormwater protection

- The Jurong East Smart Bus Stop is an innovative transportation infrastructure located in Jurong East, a planning area in Singapore.
- One key element was the incorporation of a 3-metre mature Cratoxylon cochinchinensis tree within the bus stop as a greenery feature to express slices of distinctive environments, such as a garden.
- A system to support healthy tree growth and maximize soil volume in a removable precast planter box is required
- Stratavault was chosen as the ideal solution, fitting into the existing pit size, providing the soil volume, and featuring a rain funnel to irrigate the tree under the hardscaped surface (Ltd, N. P., 2023).

Features applicable for transit plaza GRI design: utilizing GRI in shelters with limited space.

Source: Ltd, N. P.

Source: Ltd, N. P.

BICYCLE SHELTER

OXFORD, UK

Setting: bicycle shelter **Scale: 7 square metres** **Approach: capture & protection**

GI elements: canopy with planting

Program: transportation, stormwater protection

- The bicycle shelter in Oxford, designed by James Wyman Architects, features a slender steel framework supporting a glass tile canopy designed to shelter bicycles situated within the front terrace of a city hotel.
- While the structural framework was designed to be as unobtrusive and slender as possible, the intention was also to provide a distinct architectural presence.
- The cantilevered structure, made of weathering steel and crafted by hand, supports a transparent glass tile canopy. The tiles are laid in a diamond pattern, echoing the design language of the nearby University Museum of Natural History's roof (AJ Buildings Library, n.d.).

Features applicable for transit plaza GRI design: utilizing the design language of surrounding buildings to establish a cohesive green canopy.

Source: AJ Buildings Library

Source: AJ Buildings Library

Case Study: Multi-use Elements

COPENHAGEN BUSINESS SCHOOL CAMPUS

FREDERIKSBERG, DENMARK | 2006

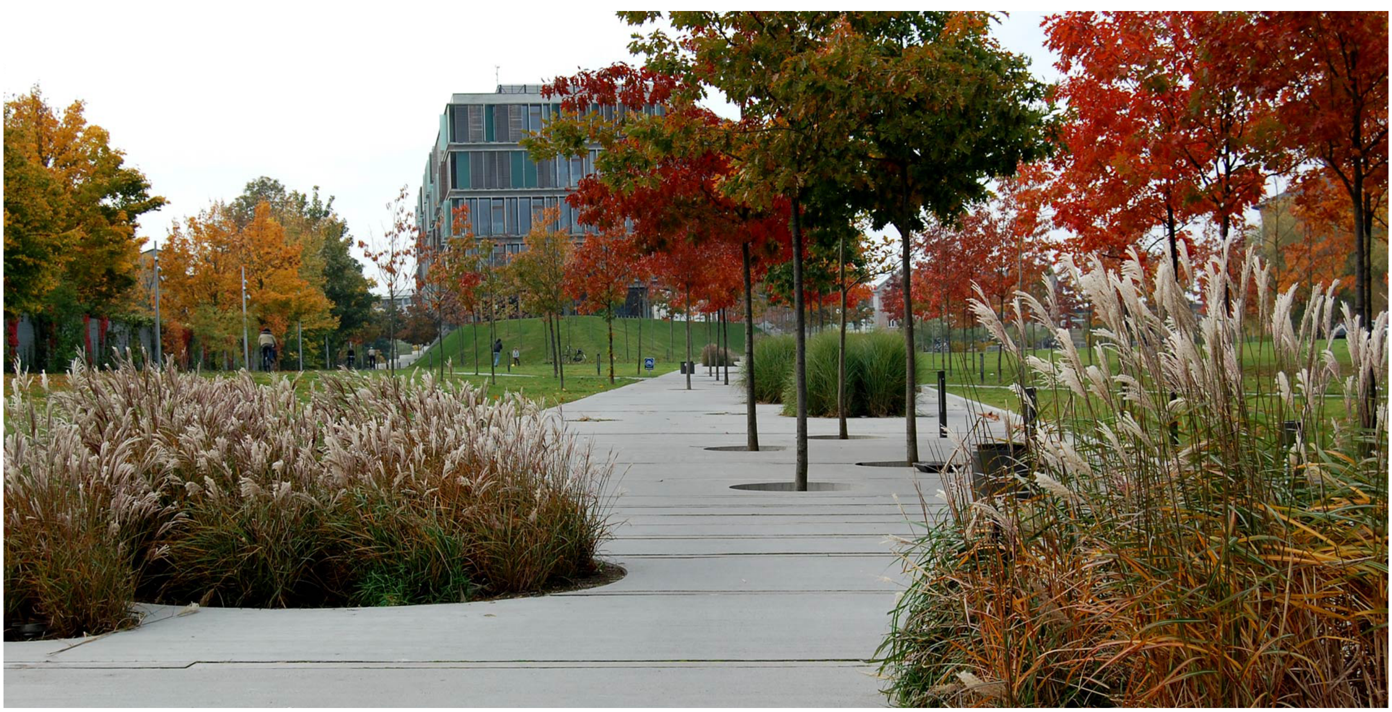
Setting: school **Scale: 34,020 square metres** **Approach: store & infiltrate**

GI elements: planted space, pervious surfaces, urban forestry

Program: mix use, mobility, recreation

- The campus is situated within the previously used railway line area known as the "Frederiksbergbane," which has undergone a conversion into a spacious urban environment.
- The promenade serves as an urban element that traverses the campus, facilitating movement within the vicinity by connecting important areas and sites.
- Walkways are thoughtfully incorporated, leading visitors through the landscape, while ensuring a seamless connection between indoor and outdoor spaces.
- The promenade surface is made of in-situ poured concrete with circular holes for trees and different ornamental grasses – a stylized picture of dilapidated or worn-out urban areas, where wild grasses and pioneer plants break through from below whenever there is a hole or crack in the pavement. (Landezine, n.d.).

Features applicable for transit plaza GRI design: Increasing permeable coverage for situations that require hard pavement.



Source: Landezine

WALLER PARK

SAN FRANCISCO, US | 2015

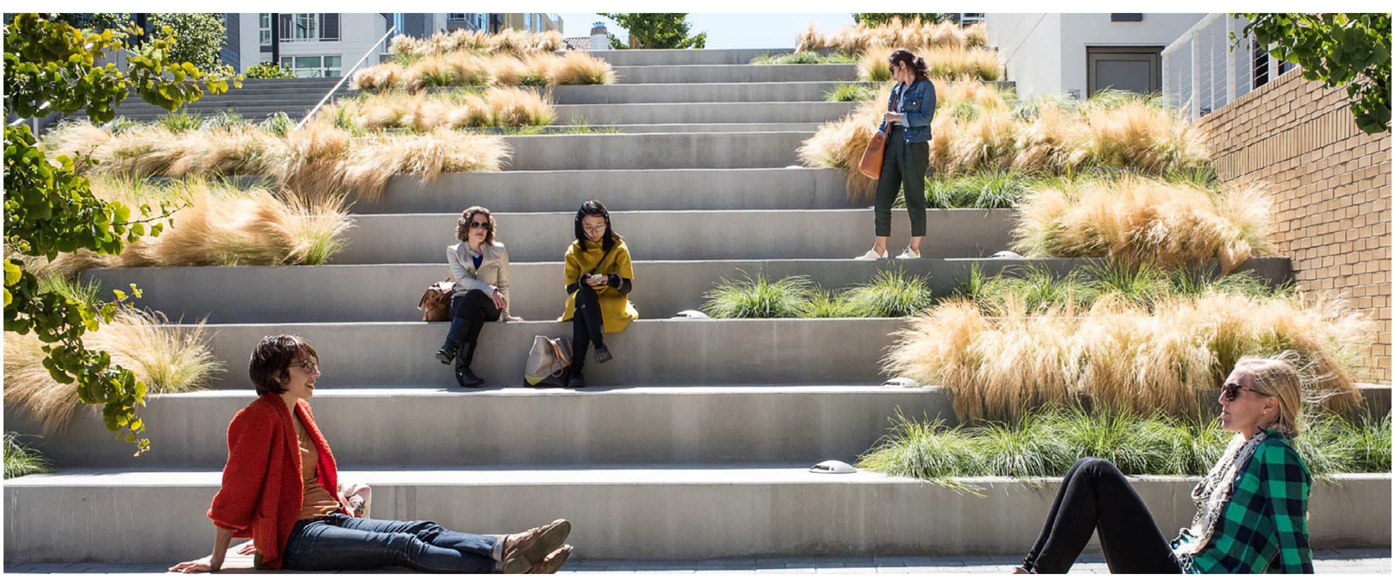
Setting: urban public plaza **Scale: 24,281 square metres** **Approach: store & infiltrate**

GI elements: vegetated staircases, pervious surfaces

Program: mobility, mix use

- Waller Park serves as the primary central pathway of the Development, running throughout the complex as a lively pedestrian promenade.
- It descends 50 feet with an impressive staircase, with a line of Ginkgo trees elegantly progressing.
- Various elements such as tree grates, trench drains, pavers, and furnishings are artistically combined to create a cohesive backbone for the park.
- Due to the presence of underground parking, a significant portion of the outdoor space is situated on a constructed platform.
- The underground parking facility was built six feet lower than the ground level to accommodate the projection of pavement and the creation of an extensive area filled with loose and porous soil, enabling the Gingko grove to flourish for many years to come.
- This design opposes the prevailing notion of a "disposable landscape" often seen in urban areas. Unlike many urban trees that struggle and need frequent replacement due to inadequate soil conditions for robust root development, Waller Park introduced a different mindset (Landezine, n.d.).

Features applicable for transit plaza GRI design: Accommodating an underground parking facility while providing additional impervious space for circulation between public and private sites; leveraging grade changes as an opportunity to incorporate GRI.



Source: Landezine

GRI TOOLKIT FOR TRANSIT PLAZAS

The sizing of GRI systems is a critical factor to consider. The City of Vancouver offers comprehensive guidance on sizing procedures for specific GRI typologies in the Green Infrastructure Standards. The recommended and minimum area for individual practices is determined using the Impervious-Pervious (IP) ratio (City of Vancouver, n.d.). This ratio serves as a valuable tool for preliminary GRI sizing, as it compares the contributing impervious catchment area to the pervious GRI system area.

Typology Parameters and Evaluation Criteria

400 sq m

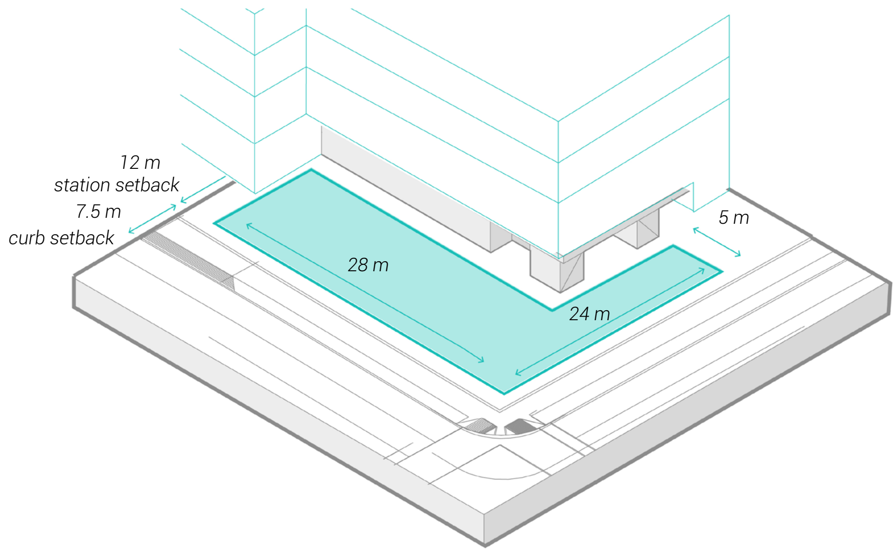
TOTAL AREA

MAXIMUM IP RATIO

MINIMUM GI AREA

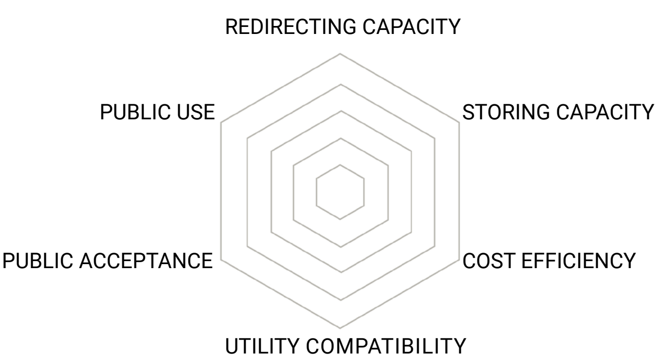
RECOMMENDED IP RATIO

RECOMMENDED GI AREA



Proposed plaza setting: The typologies are developed based on a hypothetical scenario

GRI TYPOLOGY

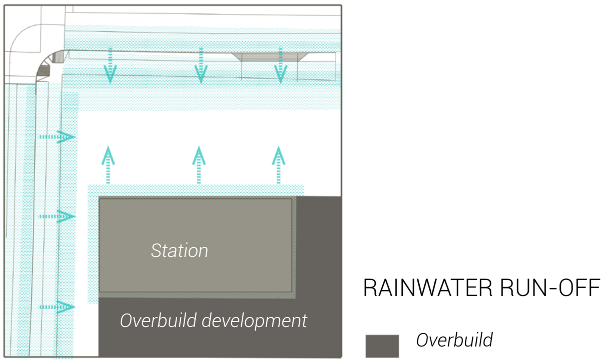


Different GRI exhibit variations in their design, function, and specific benefits. To establish a foundational comprehension of their diversity and aid in selecting the appropriate type for specific requirements, they are assessed across six criteria: stormwater redirection capacity, stormwater storage capacity, cost efficiency, utility compatibility, aesthetic acceptance by the public based on author's subjective inference, and public use. The outer ring represents the highest rating, while the inner ring represents the lowest rating. The solid polygon denotes the evaluation of each individual GRI typology.

Note that these evaluations are based on the author's current understanding of each practice, and further in-depth investigation is warranted.

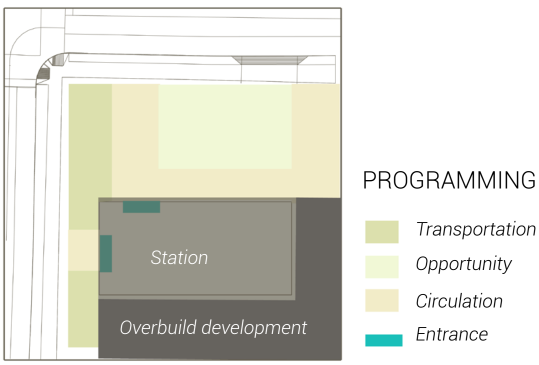
Typology Pre-Setting

There are several environmental prerequisites that play a crucial role in formulating rationales for the design of GRI typologies.



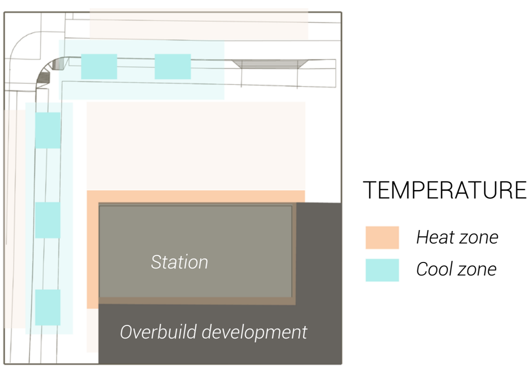
Rainwater surface flow:

The blue arrow indicates the path of major rainwater surface runoff. Considering that most future stations will feature overbuilt, roof capture directs flow along the façade, leading to accumulation at the base of the building.



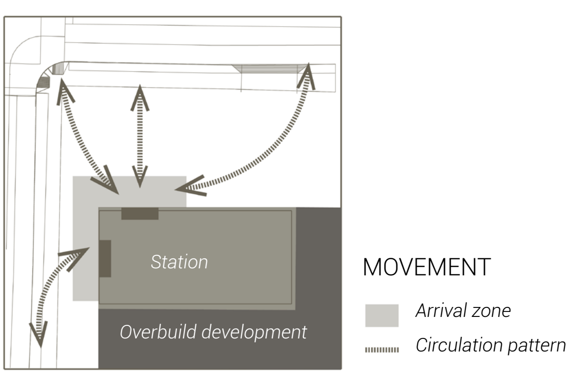
Programming:

This illustrates how the public utilizes the space. The entrances and preferred walking routes experience the highest circulation. Areas near the right-of-way, in proximity to bike lanes and bus stops, maintain a close connection with transportation. Additionally, allocating some space at the center of the plaza can accommodate other activities.



Temperature:

Major heat sources include the warmth generated by vehicular traffic and the heat released by station utilities. Street trees provide essential shade, regulating the micro-climate and reducing temperatures.



Circulation:

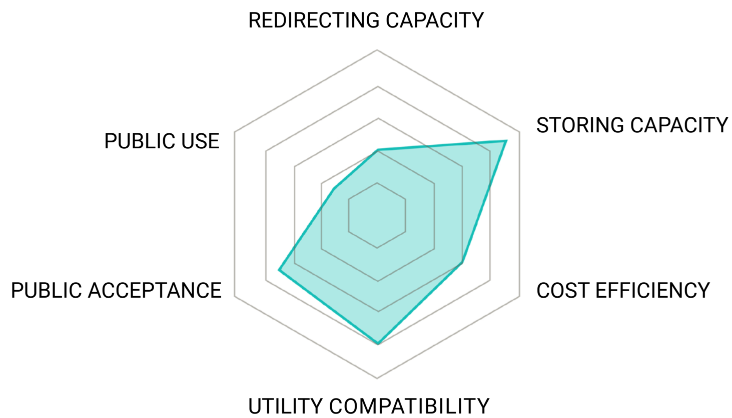
The arrows indicate the desired lines for people to access and exit the station area.

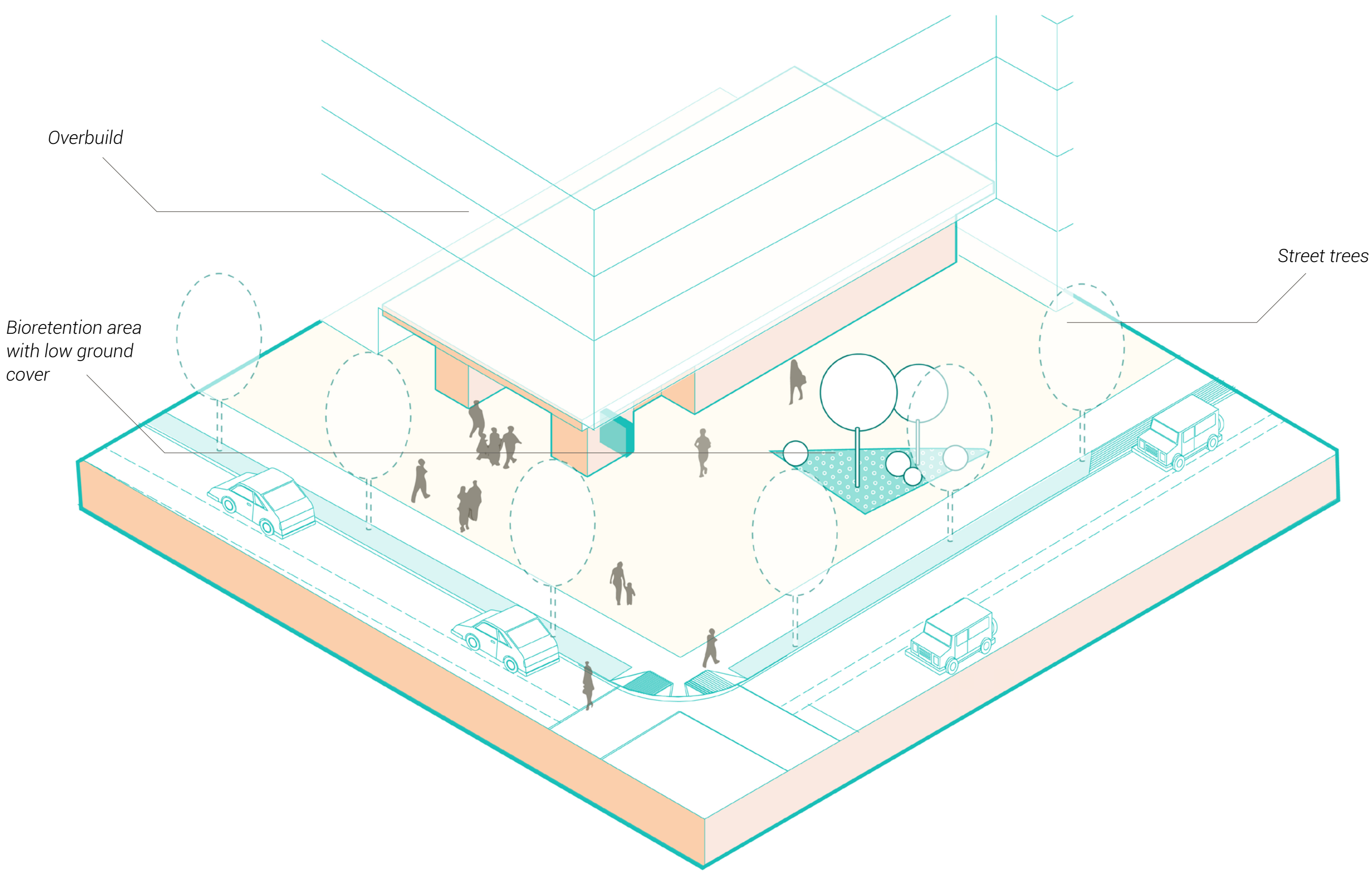
GRI Typology

01 BIO-RETENTION

Infiltrate & storage

35:1	MAXIMUM IP RATIO
11 SQM	MINIMUM GI AREA
20:1	RECOMMENDED IP RATIO
20 SQM	RECOMMENDED GI AREA

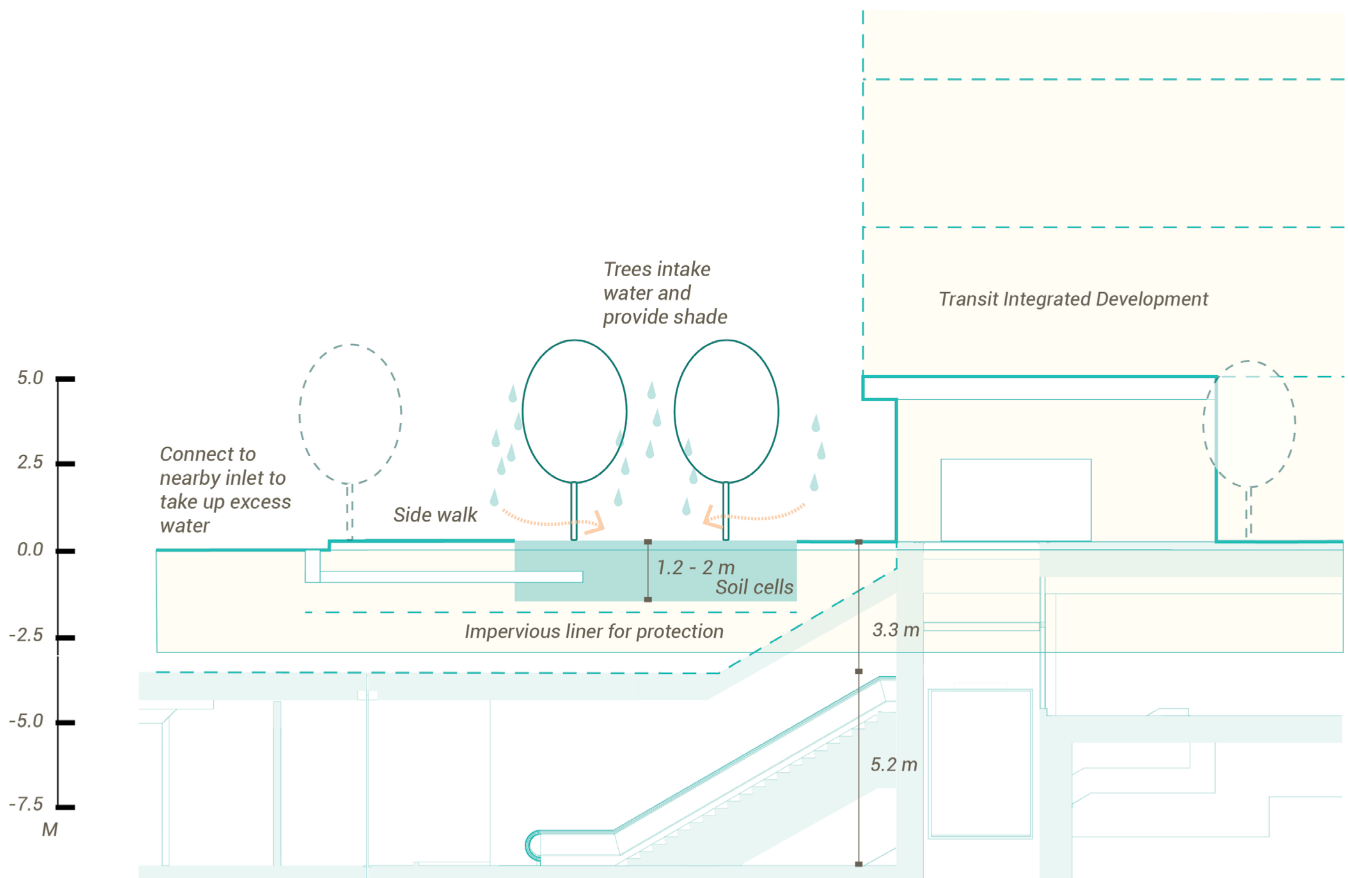




Bio-retention areas are shallow, landscaped depressions designed to capture and absorb rainwater runoff from rooftops, driveways, or other impervious surfaces. They are often planted with a variety of native or adapted vegetation that can thrive in both wet and dry conditions. Please refer to the Appendix to find a recommended plant list provided by the City of Vancouver.

Bio-retention areas receive directed water, filtering pollutants and recharging groundwater. Both bio-retention and bioswales typically have a similar depth requirement: 0.15m ponding depth and 0.45m growing medium. This ensures they are less likely to interfere with underground utilities. However, maintaining the plants in these areas can be challenging, necessitating a dedicated management strategy. While they are compatible with seating, they might be less suitable for street activities that require open space.

These areas are often designed as part of a comprehensive stormwater management system. Runoff inlets channel overflow to outlets located at a distance, maximizing residence time and treatment within the bio-retention area. Ideally, bio-retention areas should be designed to drain within 72 hours.



02 BIOSWALE

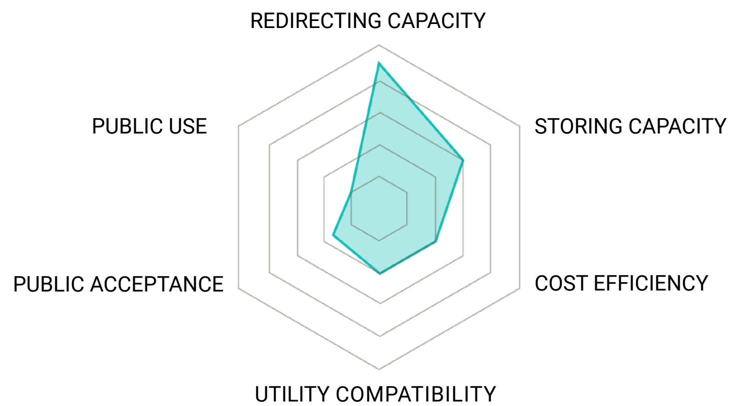
Slowdown & redirect

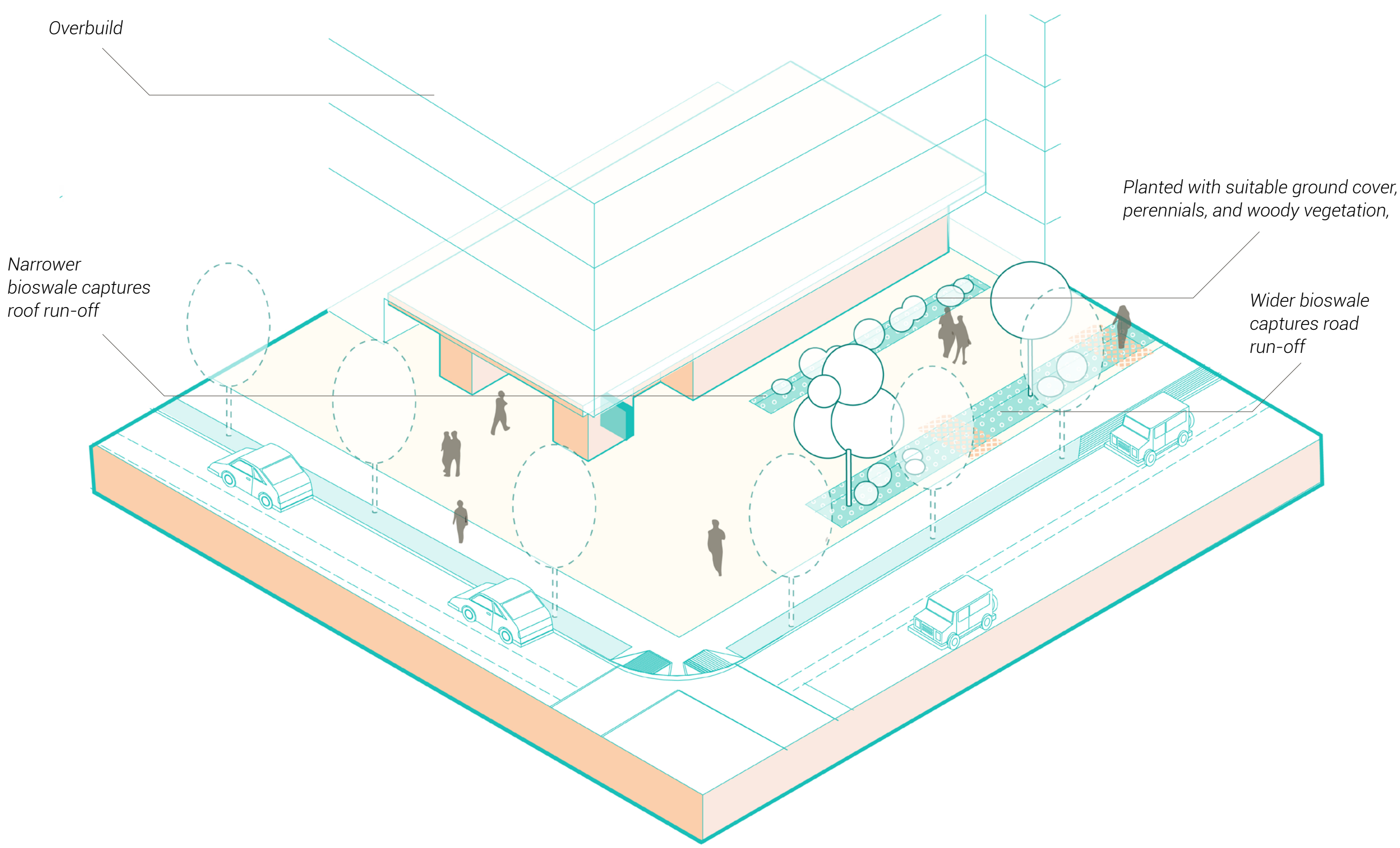
45:1 MAXIMUM IP RATIO

9 SQM MINIMUM GI AREA

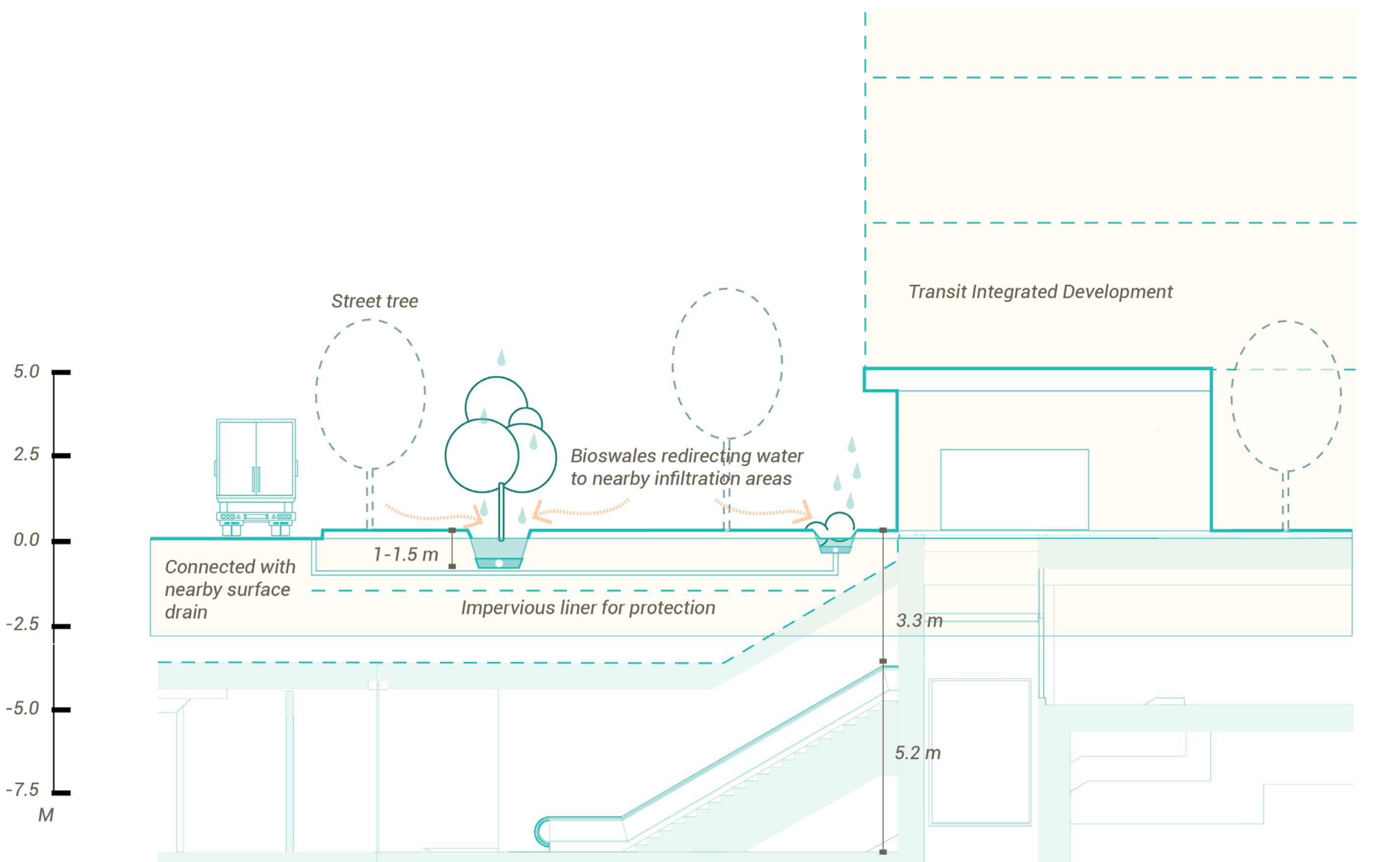
20:1 RECOMMENDED IP RATIO

20 SQM RECOMMENDED GI AREA





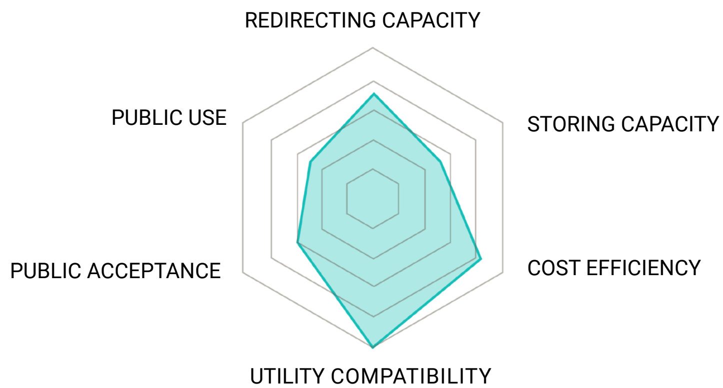
Bioswales are linear vegetated channels intentionally designed to convey and treat stormwater runoff. Their gently sloping and curving form aims to enhance water infiltration and pollutant removal. Bioswales typically share a depth requirement with bio-retention: 0.15m ponding depth and 0.45m growing medium. This design allows them to effectively accommodate underground utilities with careful planning. It's worth noting that the maintenance of the plants in bioswales can be challenging, necessitating an allocated management budget. Please refer to the Appendix for the recommended plant list provided by the City of Vancouver. Bioswales harmonize with seating arrangements, although they might be less suitable for street activities requiring open space.

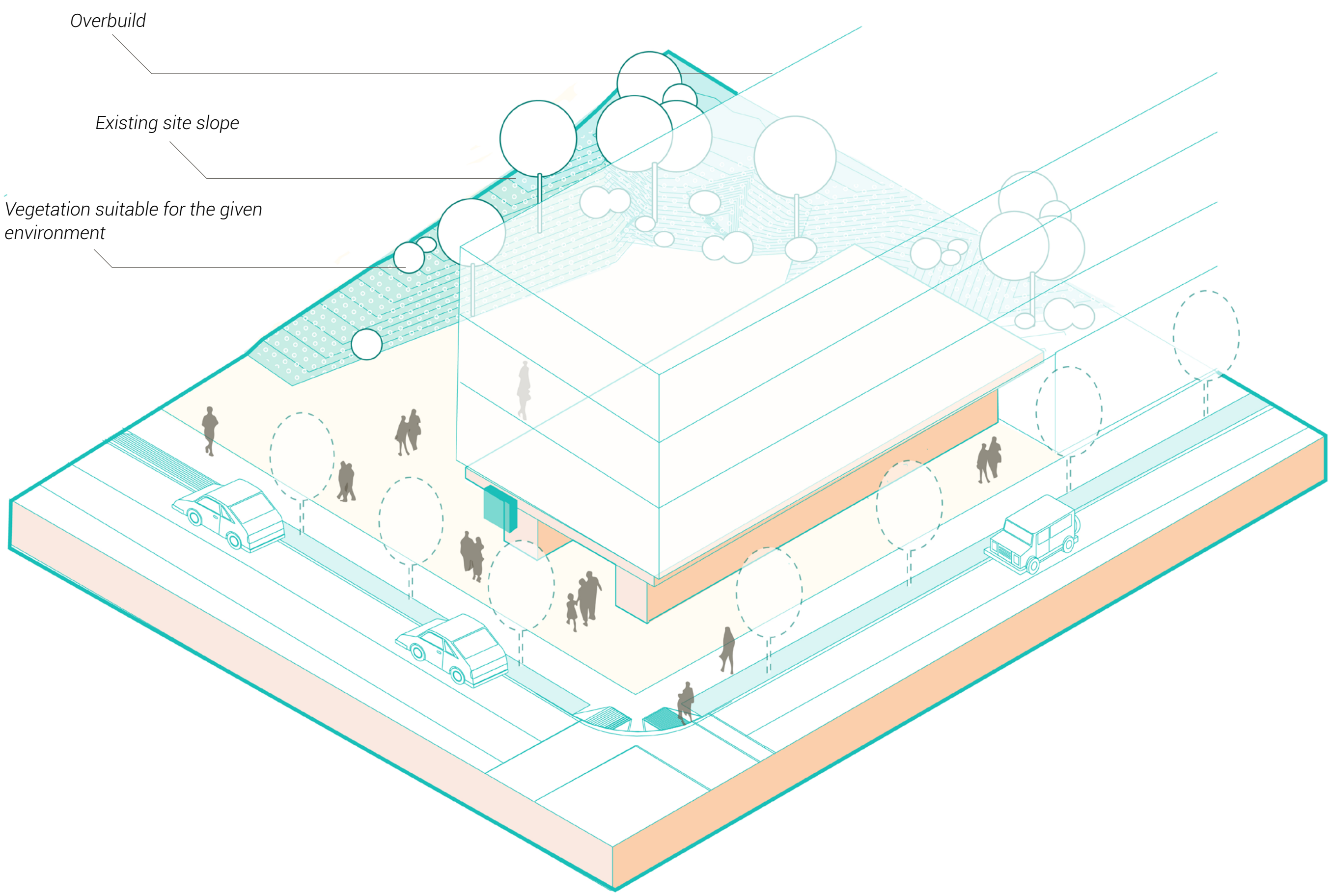


03 SLOPE PLANTING

Slowdown & redirect

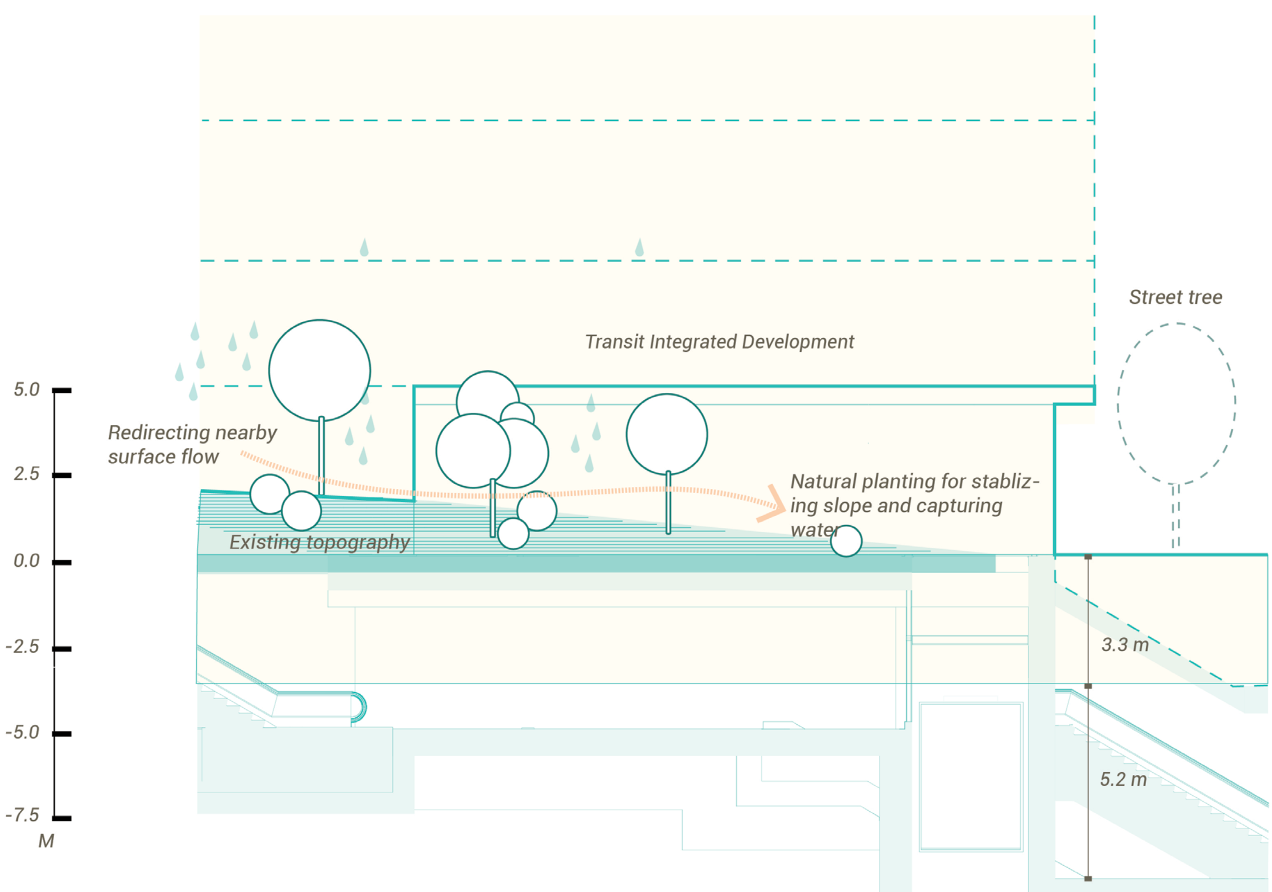
15:1	MAXIMUM IP RATIO
25 SQM	MINIMUM GI AREA
10:1	RECOMMENDED IP RATIO
37 SQM	RECOMMENDED GI AREA





Sloped plantings are designed with the dual purpose of transporting and absorbing water. They pose minimal interference with underground utilities due to their shallow depth requirements, setting them apart from underground typologies. The slope itself makes them less susceptible to waterlogging, rendering them suitable for a wide array of vegetation. The visual appeal they offer is contingent upon public perception. They coexist well with seating, though they might be less conducive to street activities requiring open space. However, they might prove less effective if direct circulation across the plaza is a necessity.

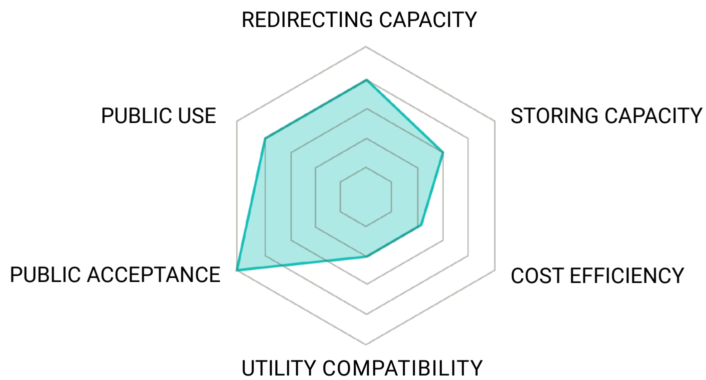
Sloped plantings capitalize on the existing site's incline, diminishing the need for constructing costly retaining walls. Vegetation planted along the slope guides surface runoff downward, draining water as it flows. This practice serves a dual role as a landscape feature and a GRI strategy, incorporating underground drainage systems at the slope's top and bottom. Sloped plantings are best suited to sloped sites and can be integrated with inlets at the slope's peak to channel runoff from adjacent locations, and drainage facilities at the slope's base to manage excess flow. It seamlessly aligns with a GRI system and complements other GRI practices.

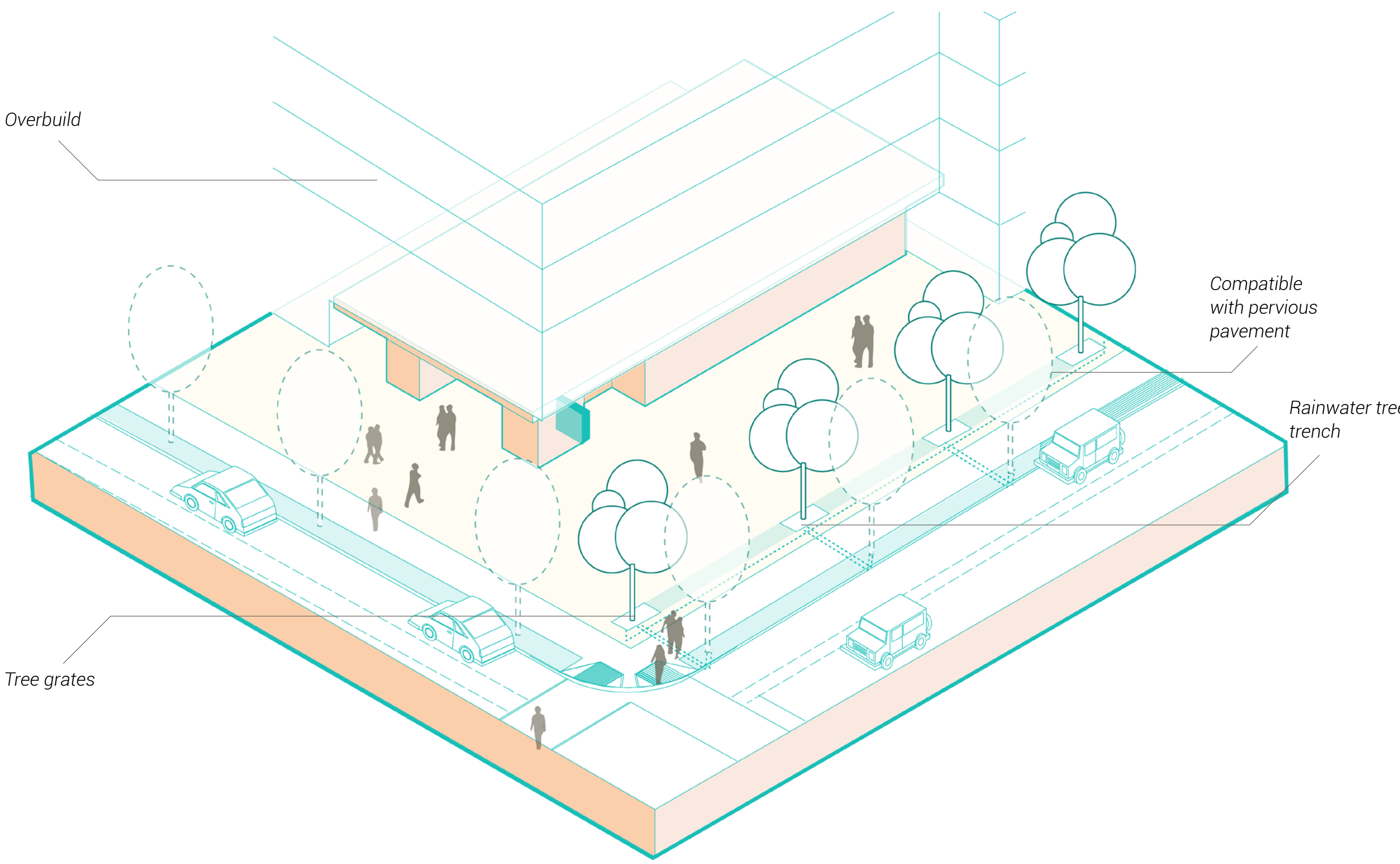


04 RAINWATER TREE TRENCHES

Slowdown & redirect

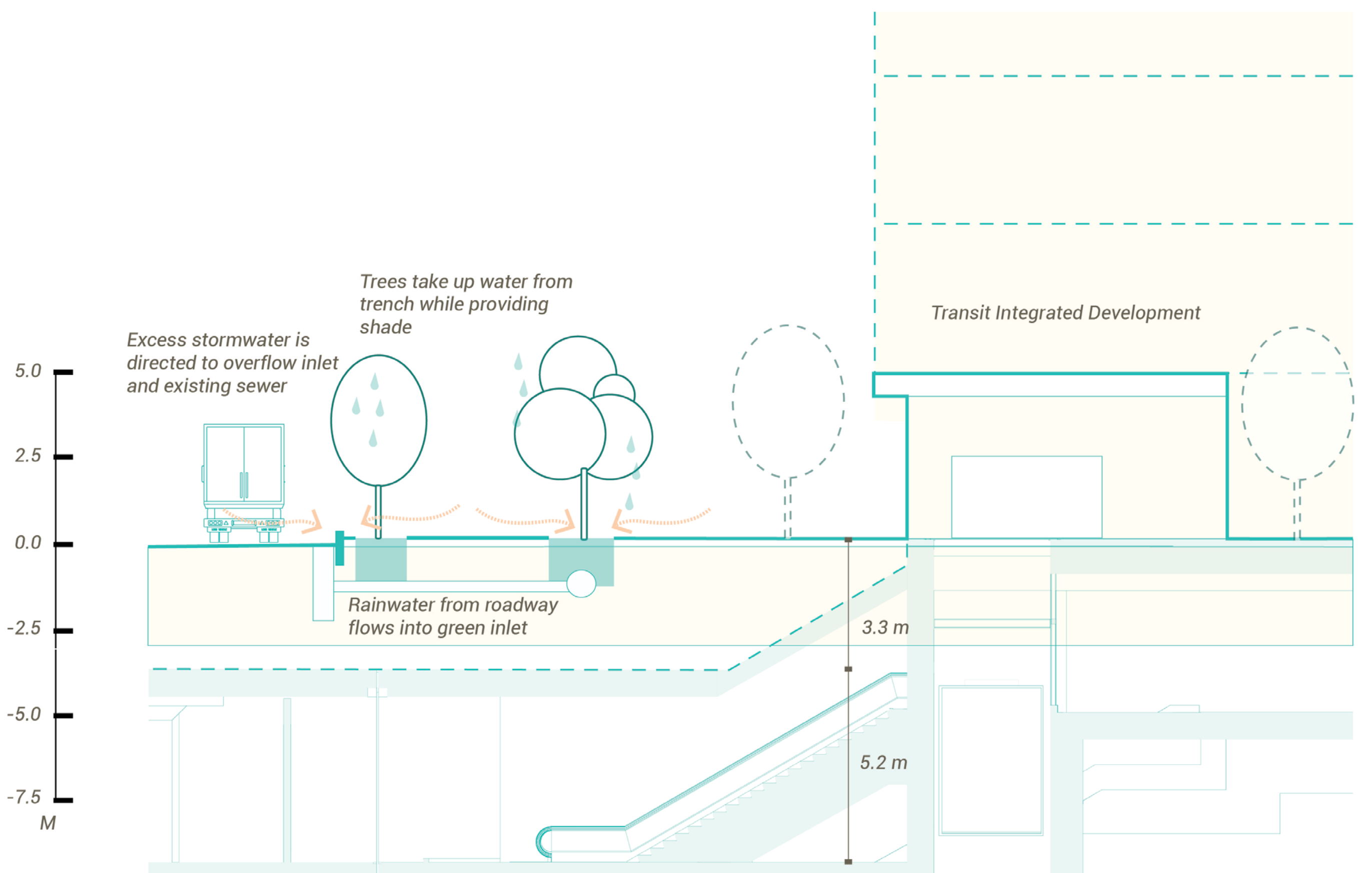
30:1	MAXIMUM IP RATIO
13 SQM	MINIMUM GI AREA
20:1	RECOMMENDED IP RATIO
20 SQM	RECOMMENDED GI AREA





Tree trenches are continuous and linear urban tree planting systems, typically situated within the road right-of-way behind the curb. These systems encompass sidewalk pavement with tree openings on top. Trench sections are interconnected hydrologically through sub-surface stormwater distribution and drainage pipes.

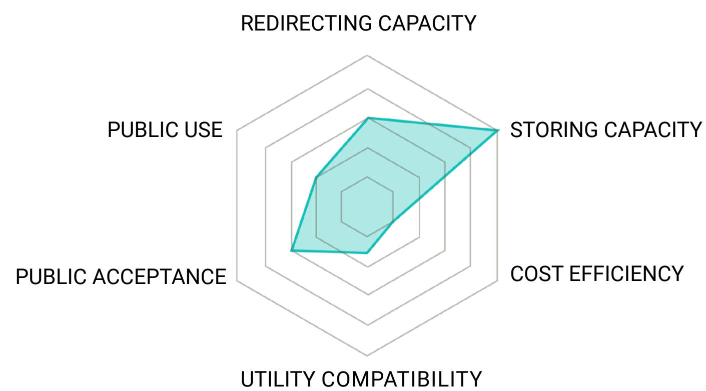
Designed to serve as both water transporters and absorbers, tree trenches tend to be more expensive in terms of installation and management. Their viability can also be influenced by potential conflicts with underground utilities, which is contingent upon treatment capacity requirements. Public perception may vary; however, the trees contribute to shading and cooling the environment. Their compatibility with other public activities is a notable advantage, as they can endure foot traffic. Being positioned by the right-of-way, they offer open space suitable for street activities.

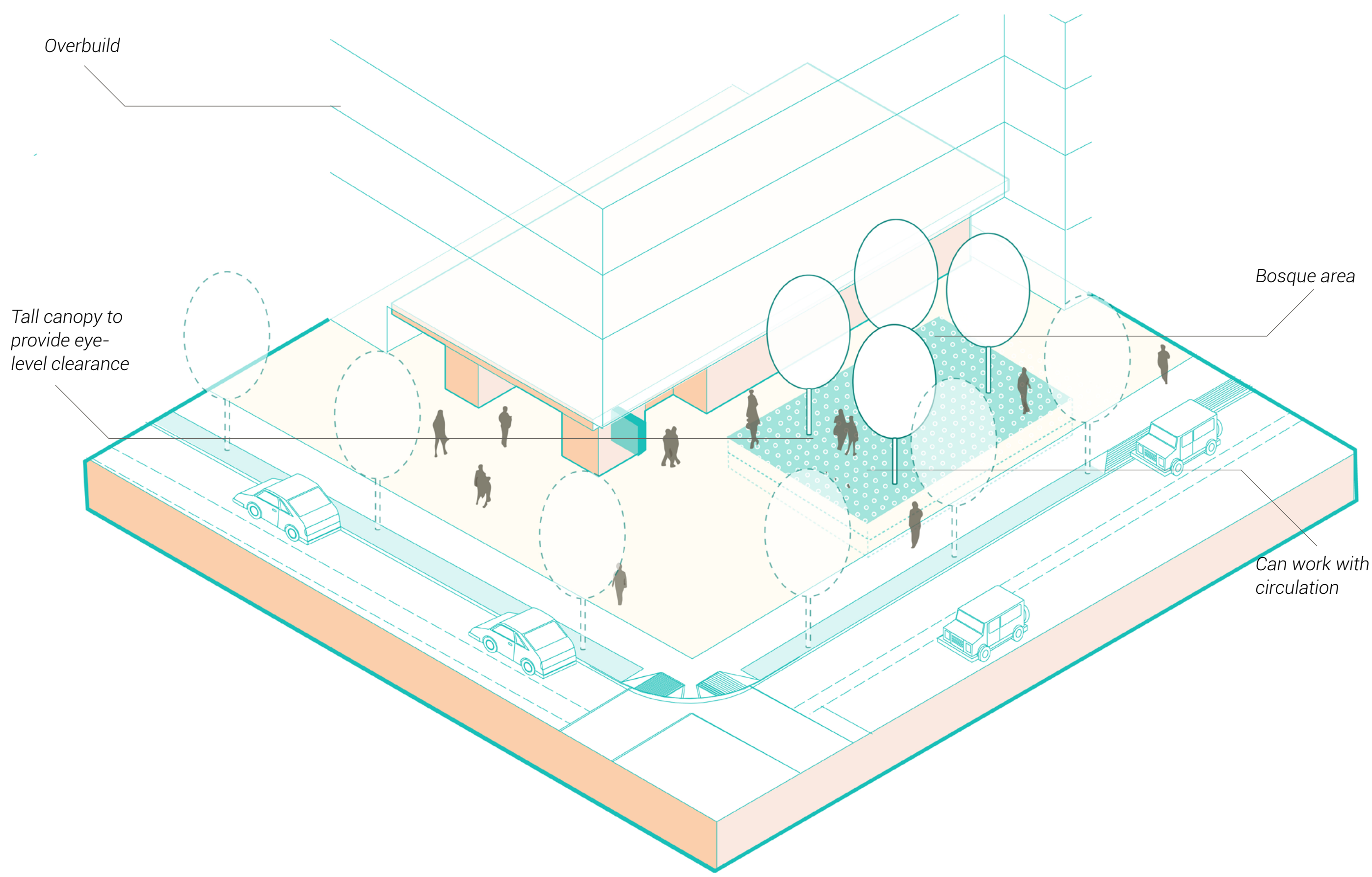


05 BOSQUE

Infiltrate & storage

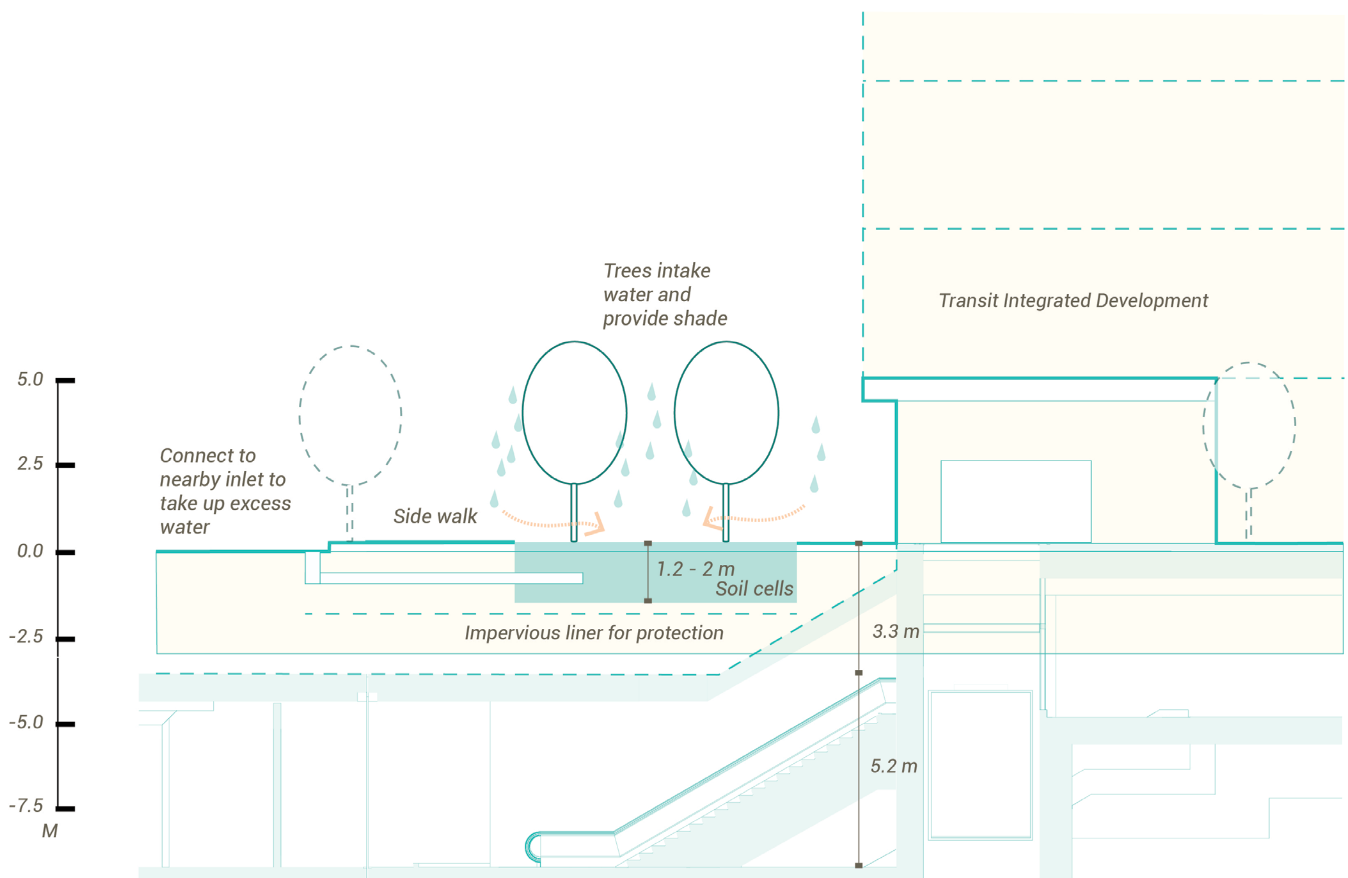
3:1	MAXIMUM IP RATIO
100 SQM	MINIMUM GI AREA
2:1	RECOMMENDED IP RATIO
133 SQM	RECOMMENDED GI AREA





A 'bosque' refers to a wooded area or a stand of trees, commonly incorporated as a landscape feature within urban plazas and parks. While bosques are not traditionally classified as conventional green rainwater infrastructure (GRI), they can be integrated with drainage systems and adapted into a GRI practice owing to their potential to enhance stormwater management and offer additional environmental advantages. Rainwater harvesting systems can be integrated. These systems collect rainwater from rooftops or other surfaces and reserve it for subsequent use in irrigating the trees and vegetation within the bosque.

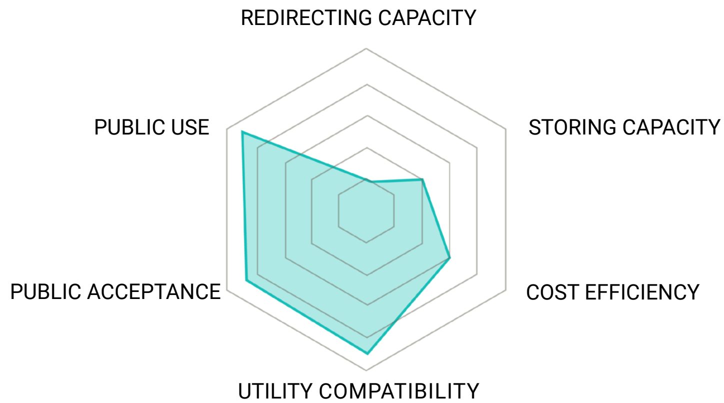
Bosques prove effective in water retention, owing to the benefits afforded by trees. However, they are more costly in terms of both installation and management, partly due to their scale. Moreover, they may potentially encounter conflicts with underground utilities, which depend on the treatment capacity requirements. The abundant shade and cooling effect they provide make them a preferred choice among pedestrians.

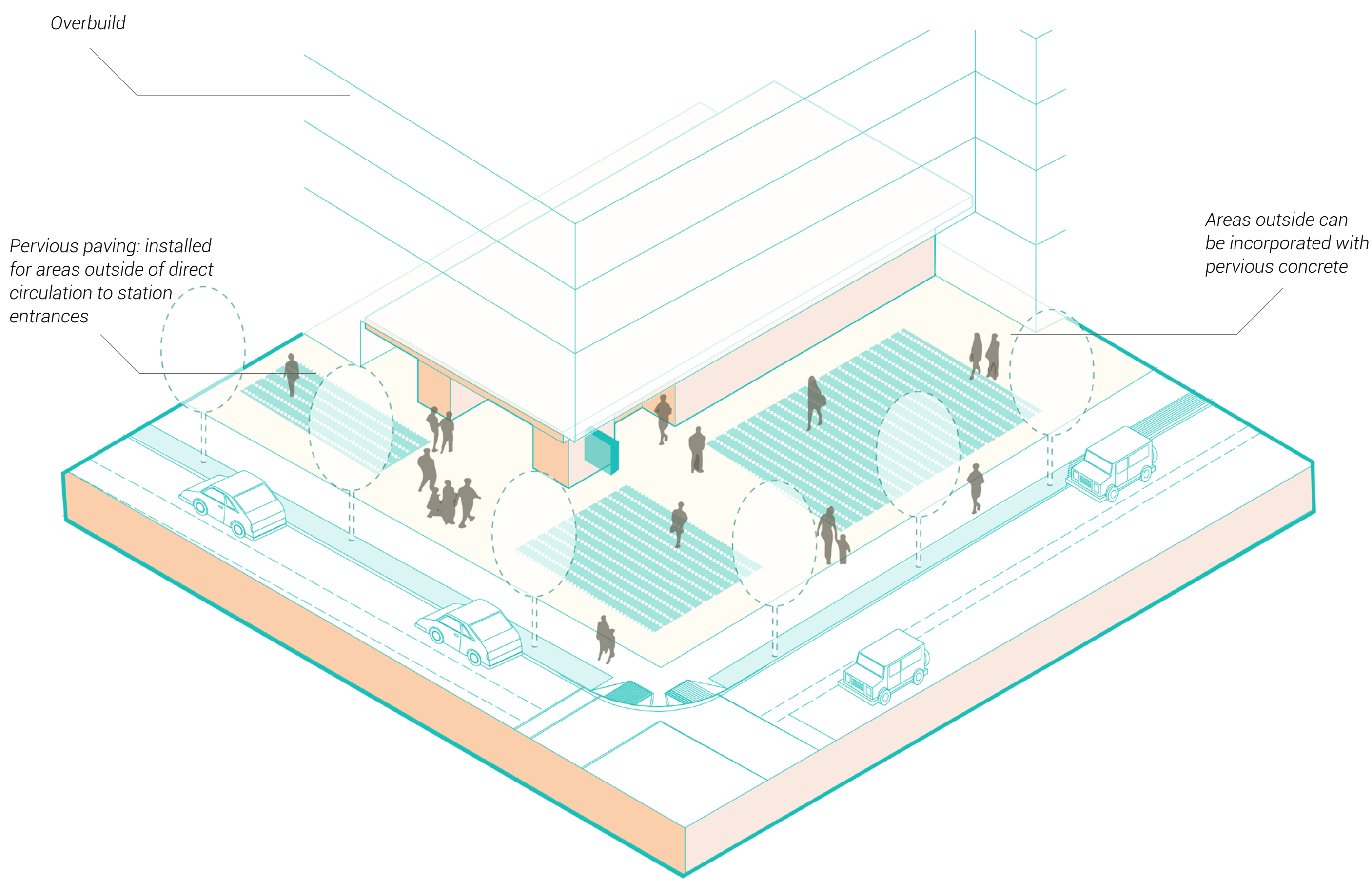


06 PERVIOUS PAVING

Infiltrate & storage

3:1	MAXIMUM IP RATIO
100 SQM	MINIMUM GI AREA
1:1	RECOMMENDED IP RATIO
200 SQM	RECOMMENDED GI AREA

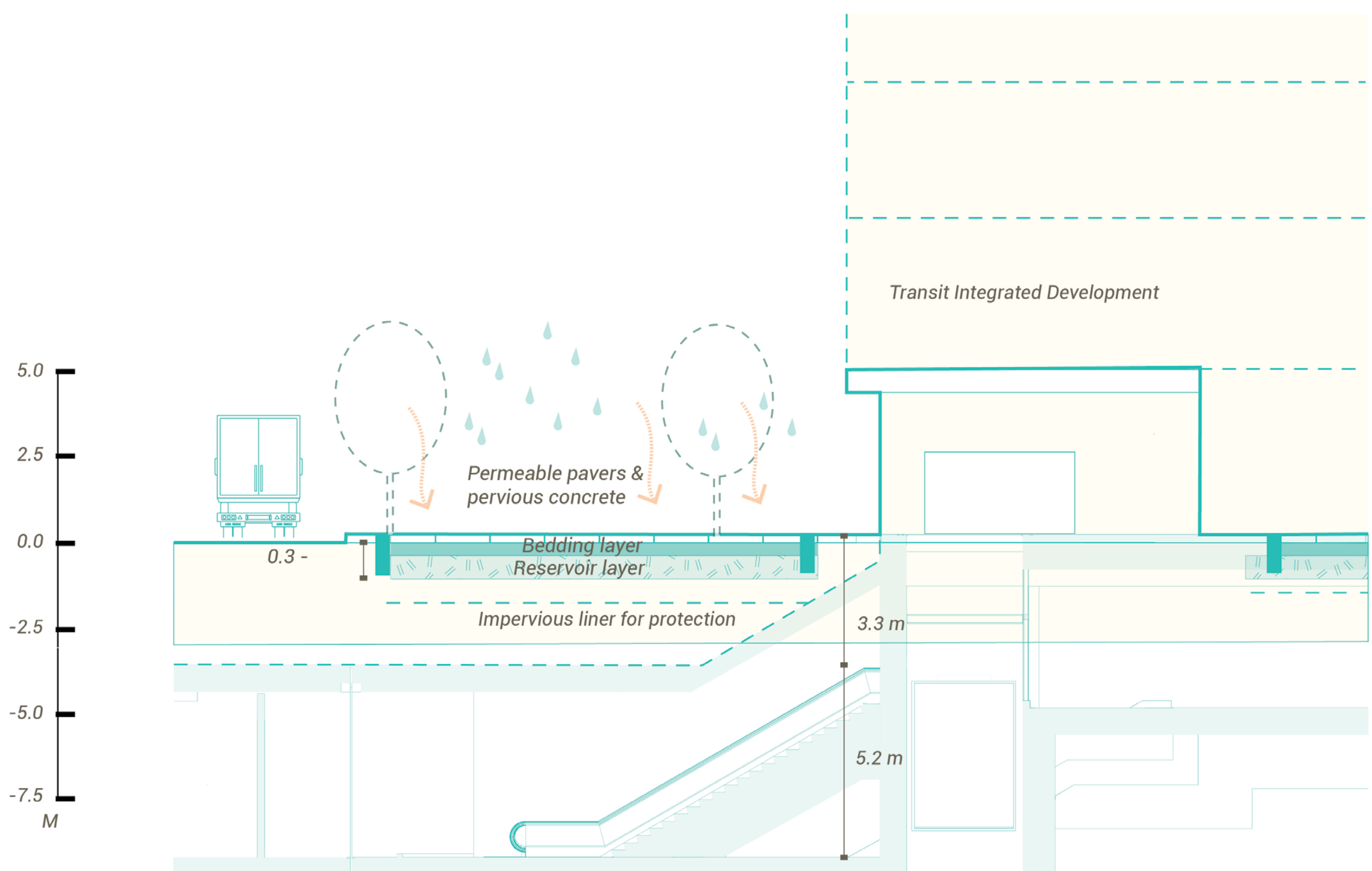




Permeable pavements are designed surfaces that possess the unique ability to allow rainwater to permeate through the pavement itself, mitigating runoff and facilitating the recharge of groundwater. Varieties of permeable pavements encompass permeable concrete, porous asphalt, and permeable interlocking pavers. These materials exhibit different levels of smoothness, thus delivering varied experiences for pedestrians and wheeled traffic.

While pervious paving offer advantages in water transport and storage, they are less efficient in these aspects when compared to other typologies. They entail higher costs related to both installation and management but demonstrate lower susceptibility to conflicts with underground utilities. Public perception may vary concerning aesthetic values. They harmonize well with street activities by providing ample open space.

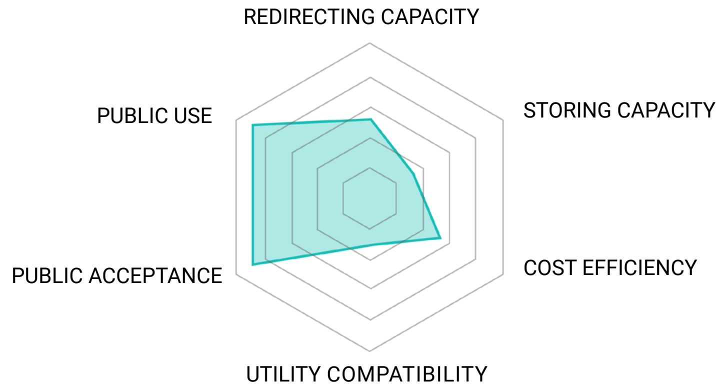
Components of pervious pavements encompass inlets that direct water to the device, the pavement surface itself, an overflow outlet, a sub-drain, and a control structure. The typical excavation depth is 0.4 meters (as outlined by the Sustainable Technologies Evaluation Program). Paving stones and the paver base necessitate a 0.3-depth, while the water-holding subgrade requires a minimum of 0.15, resulting in a combined minimum depth of 0.45m (City of Vancouver).

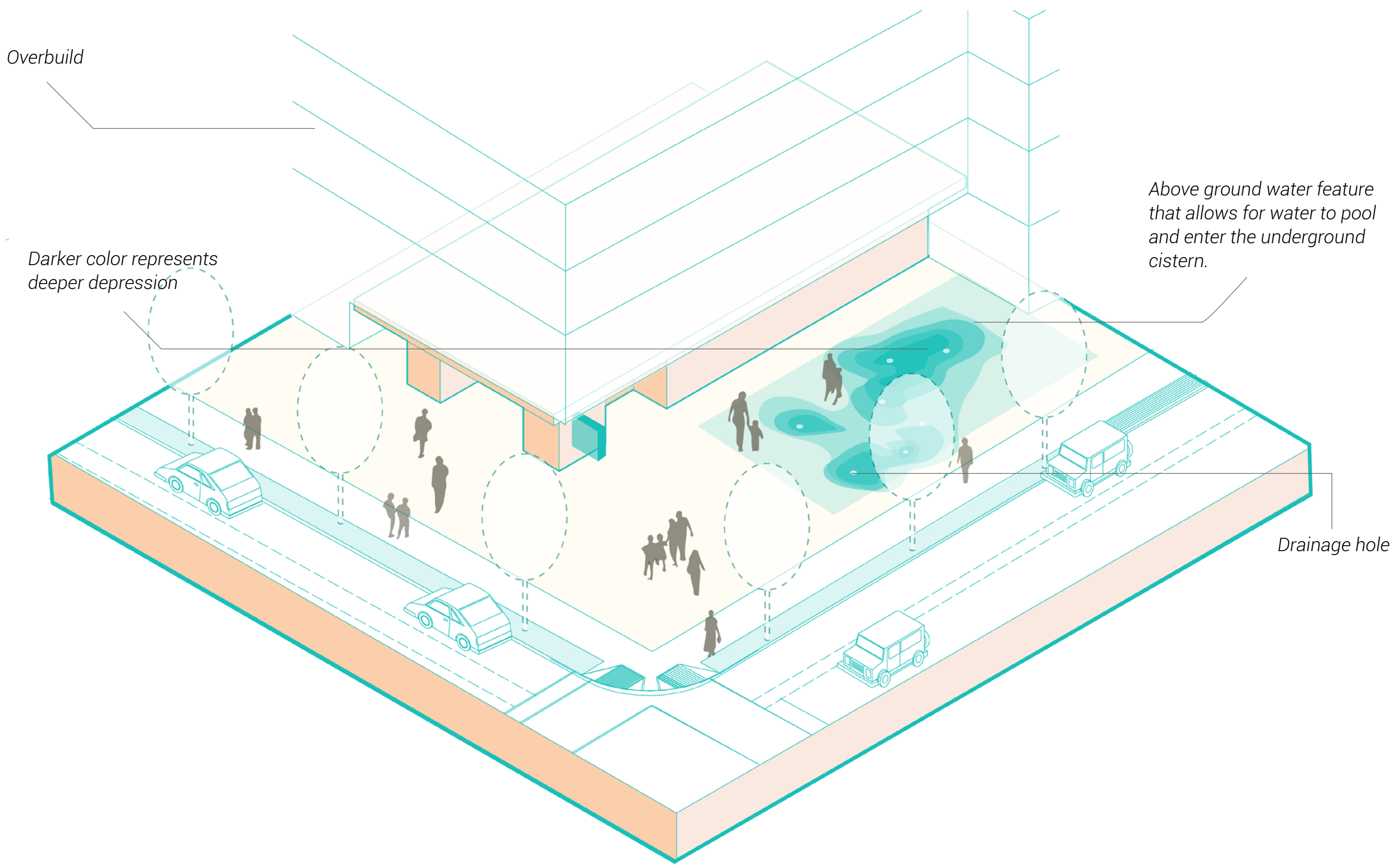


07 WATER FEATURE

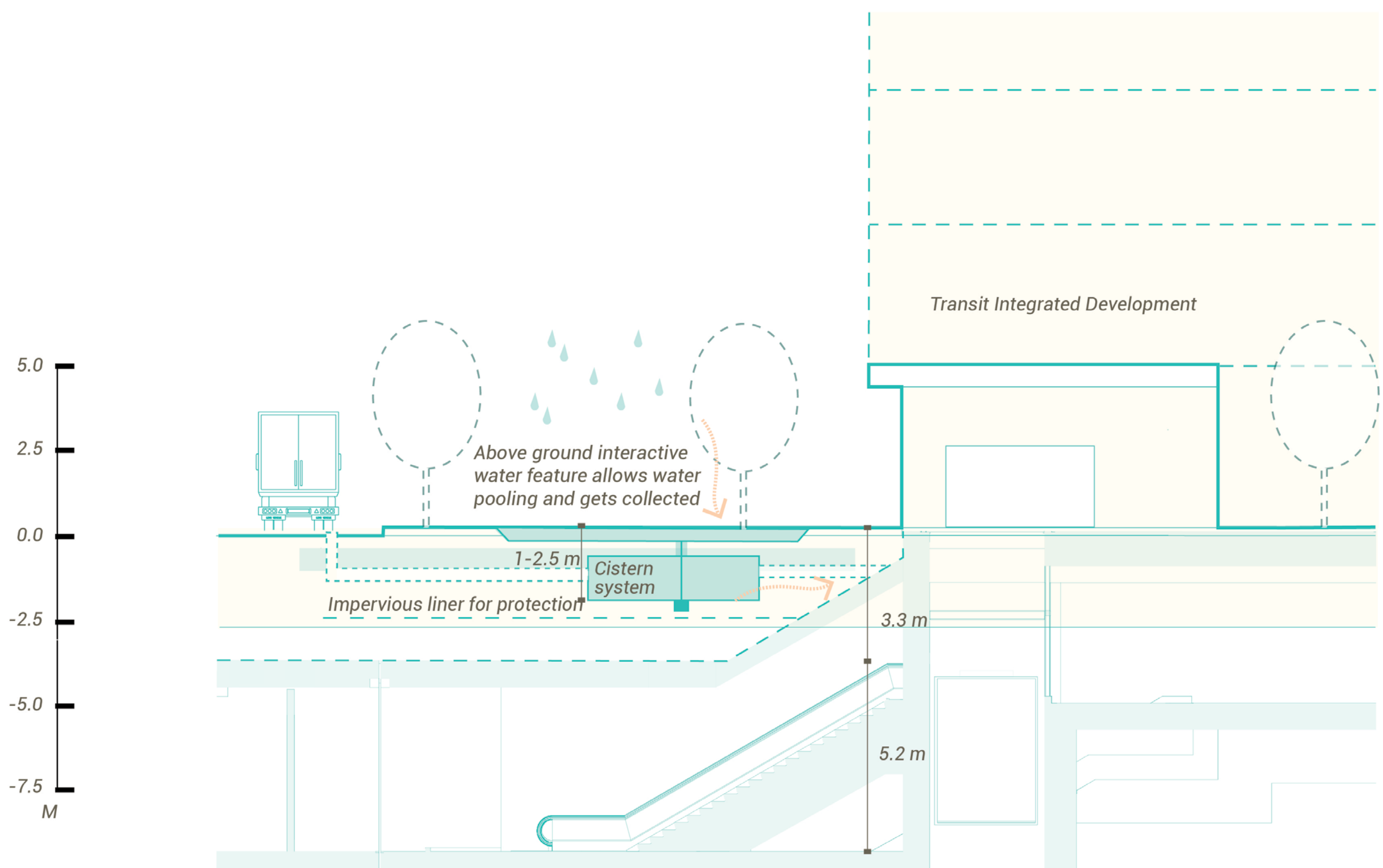
Infiltrate & storage

30:1	MAXIMUM IP RATIO
13 SQM	MINIMUM GI AREA
20:1	RECOMMENDED IP RATIO
20 SQM	RECOMMENDED GI AREA





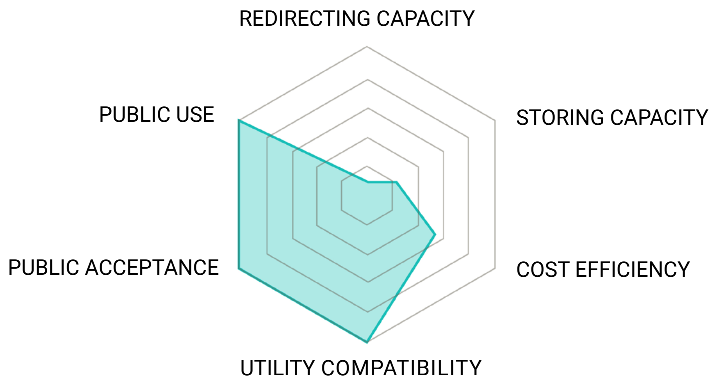
This water feature encompasses a blend of surface and underground typologies. It consists of depressions on the ground that mimic the pattern of puddles formed during rain events. These depressed areas feature drainage inlets, enabling the accumulated water to be conveyed into an underground drainage and recycling cistern system. This design isn't solely intended for redirecting or storing runoff, but rather serves as a mechanism to collect and recycle rainwater. The harvested water is intended for operational and maintenance purposes. However, this design demands higher installation and management costs, potentially posing conflicts with underground utilities, depending on the cistern's size. Beyond its functional aspects, this design also symbolizes the celebration of the water cycle, contributing a distinct character to the ambiance of the transit plaza area.

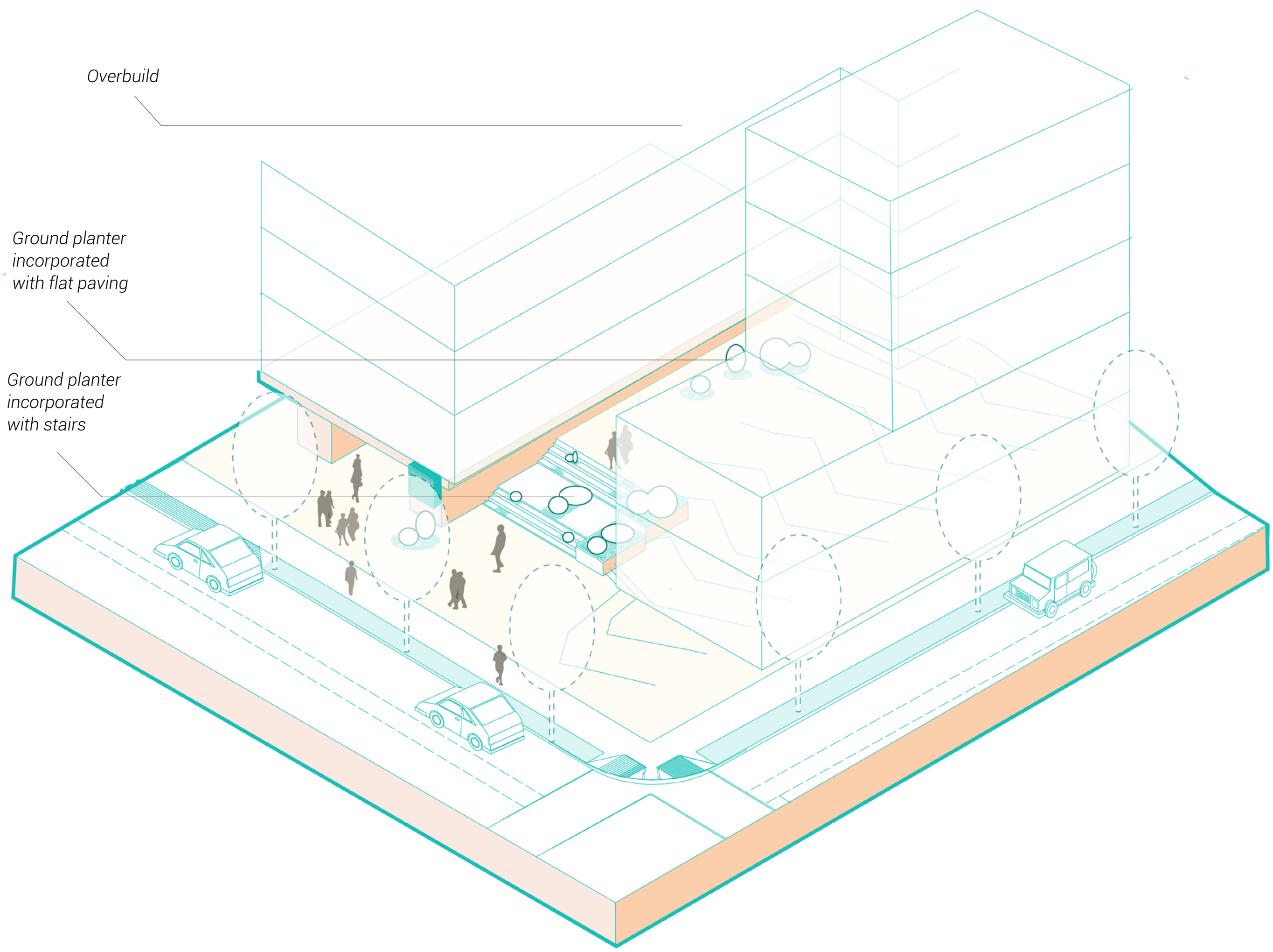


08 GROUND PLANTER

Infiltrate & storage

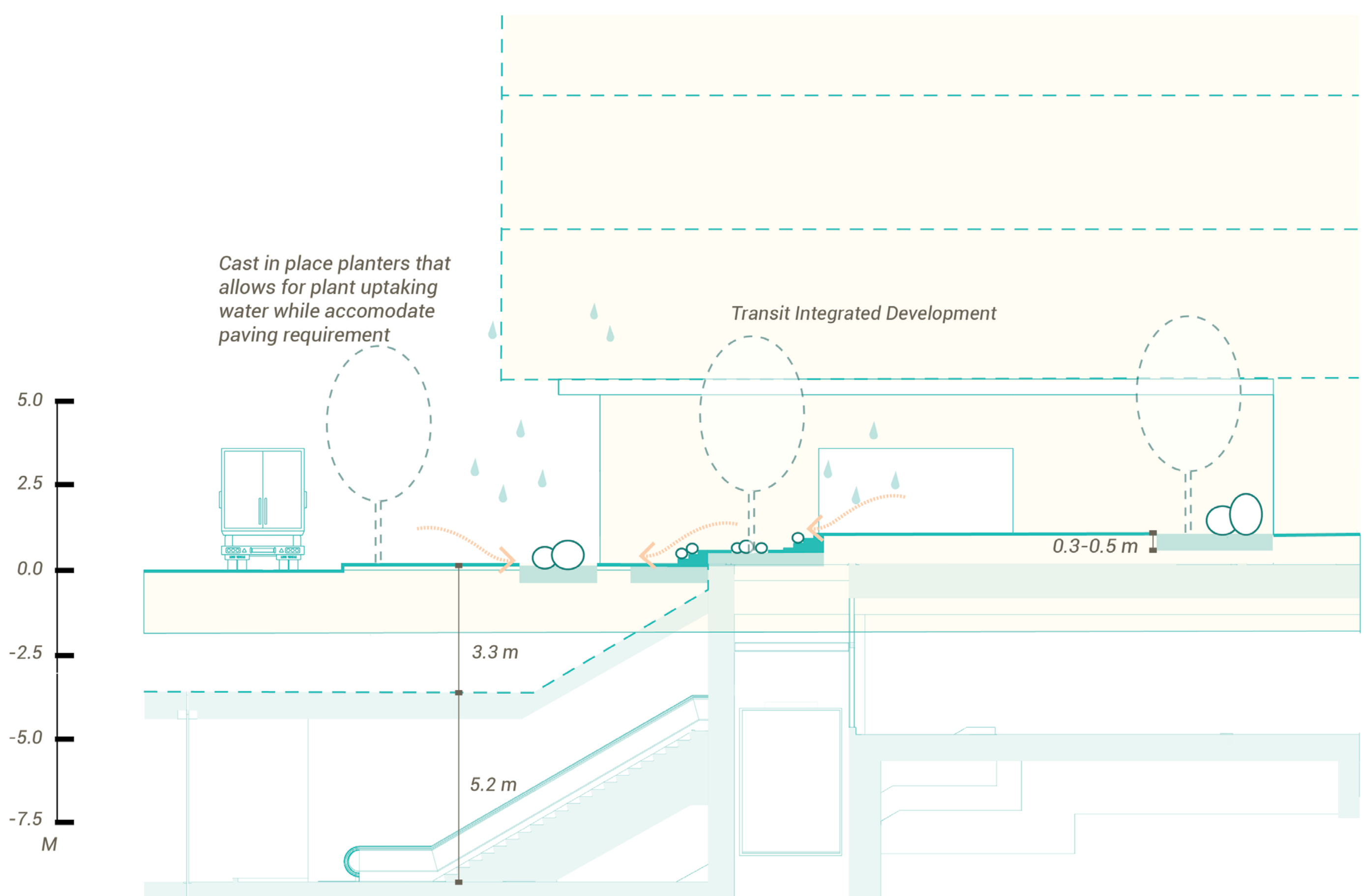
45:1	MAXIMUM IP RATIO
8.7 SQM	MINIMUM GI AREA
35:1	RECOMMENDED IP RATIO
11 SQM	RECOMMENDED GI AREA





Conventional ground planters possess the potential to undergo transformation into effective Green Rainwater Infrastructure (GRI) elements, serving dual purposes of stormwater management and environmental enhancement. Through incorporation of permeable materials, these planters permit rainwater infiltration into the soil, rather than allowing it to accumulate on the surface. Rainwater from rooftops or other surfaces can be channeled into the planters, where it's stored for irrigation during drier periods. Moreover, they can be interconnected with rainwater harvesting systems and pipes, linking to stormwater catch basins. This approach curtails the demand for potable water and encourages water conservation.

Ground planters can also function as filter strips, situated along paved surfaces or roadsides. Their spatial requirements underground are typically modest, ranging from 0.3 to 0.5 meters.



09 GREEN FURNITURE

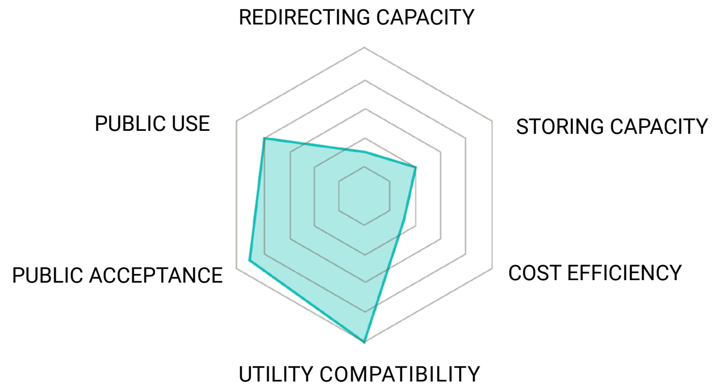
Capture & protection

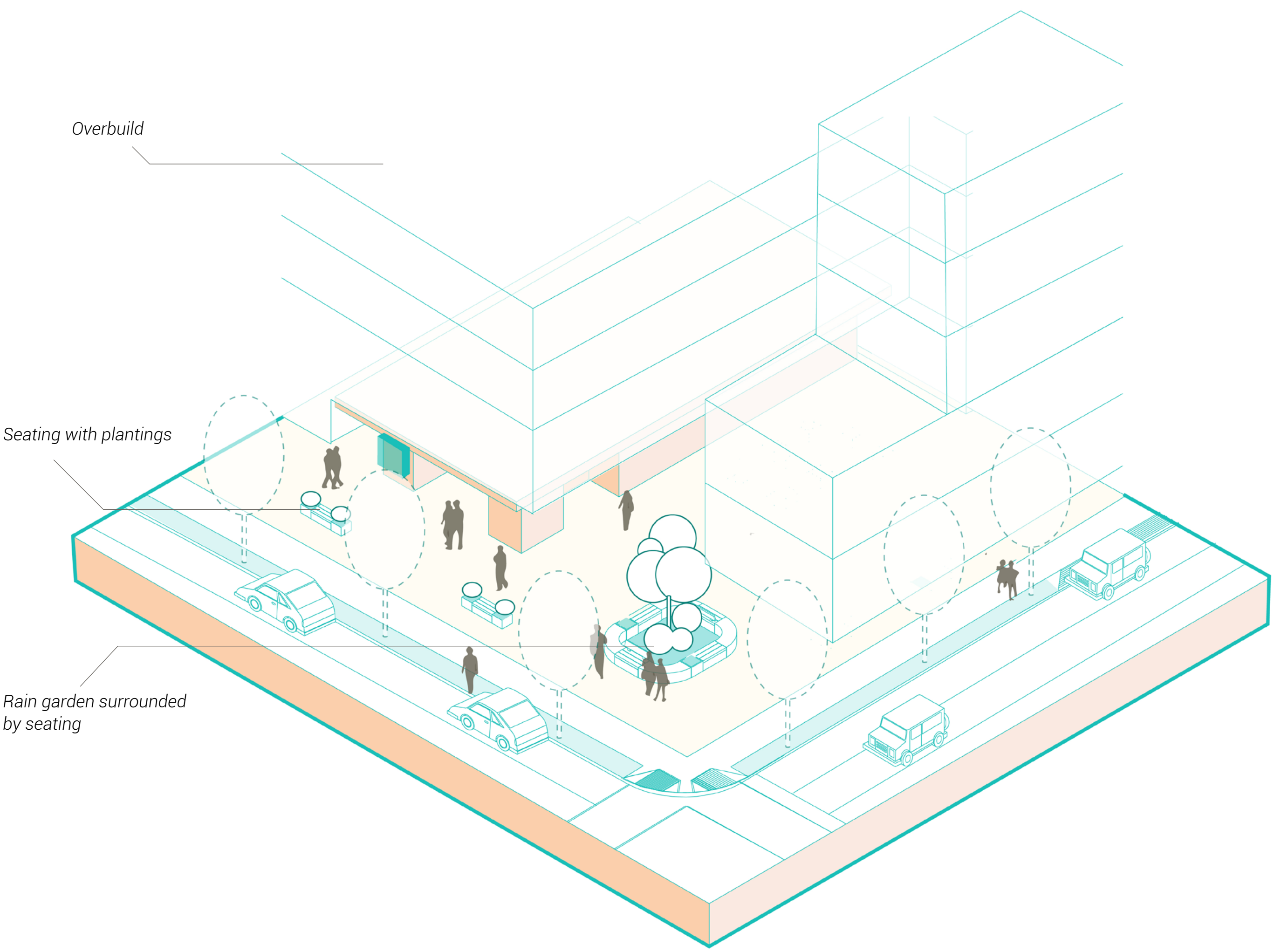
45:1 MAXIMUM IP RATIO

8.7 SQM MINIMUM GI AREA

35:1 RECOMMENDED IP RATIO

11 SQM RECOMMENDED GI AREA

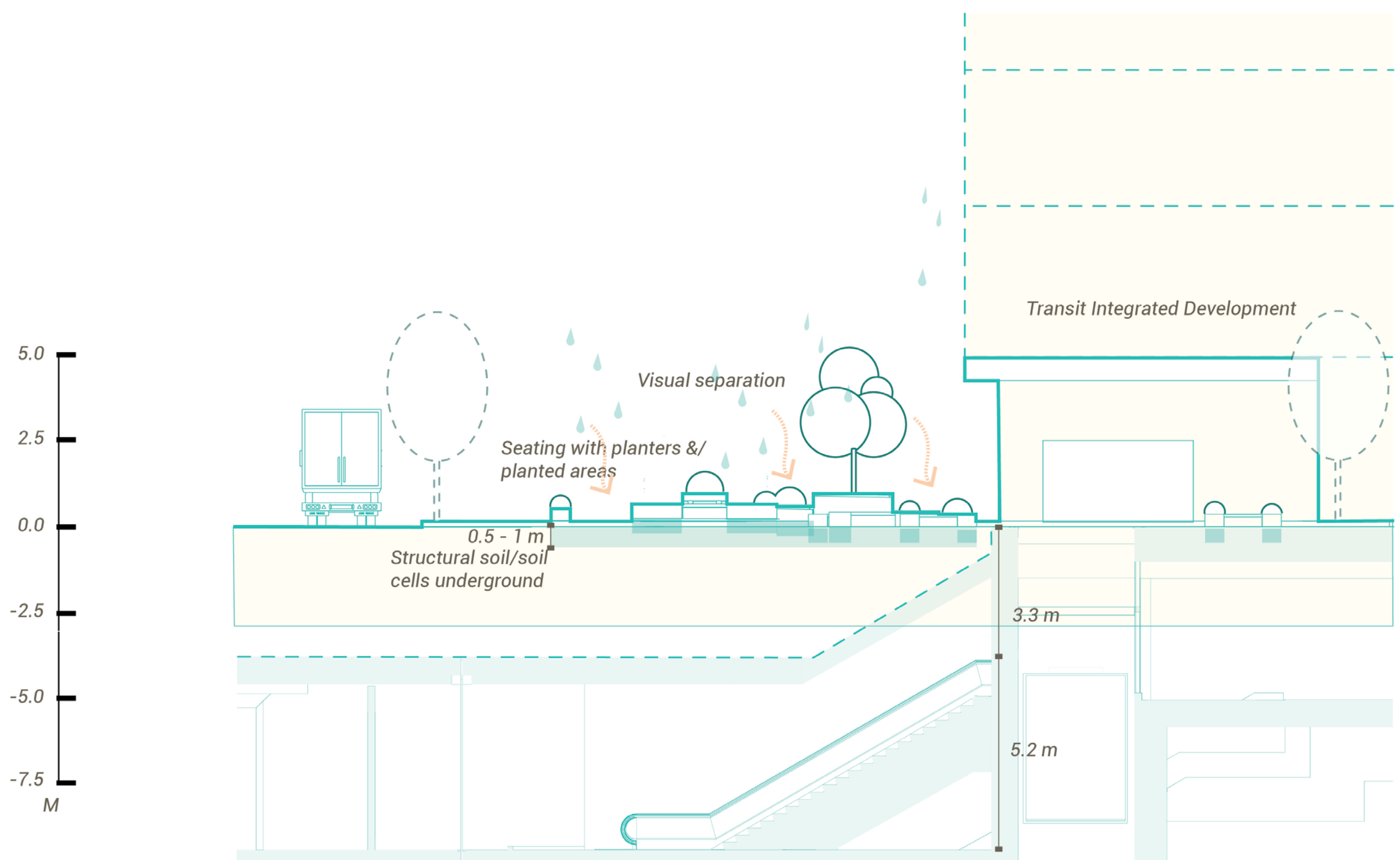




Green furniture, including benches, tables, and seating areas, can feature integrated rainwater collection systems. Rainwater from these surfaces or nearby areas can be directed towards storage containers or reservoirs within the furniture itself. This collected rainwater can subsequently be repurposed for irrigation or other non-potable water needs, effectively lowering the demand for municipal water supply.

Simultaneously, these green furniture installations can serve as demarcations between other GRI elements and public spaces. They offer practical resting spots for the public, enriching the overall functionality of the area. Diverse types of green furniture are designed for both individual and group use. Their design generally necessitates a depth of 0.5 to 1 meter underground to facilitate vegetation growth.

Green furniture serves as infrastructure that contributes not only to increased pervious and absorbent landscaping but also offers practical functions for site users. While their installation and management should be budgeted for, they typically do not conflict with underground utilities. Furthermore, they seamlessly accommodate other public activities like resting, waiting, and other interactions.



10 GREEN CANOPY

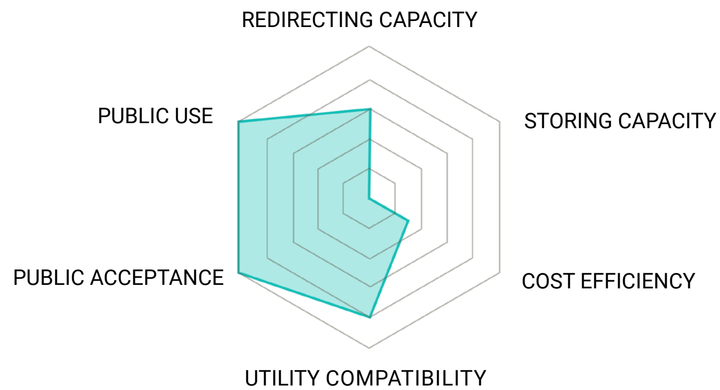
Capture & protection

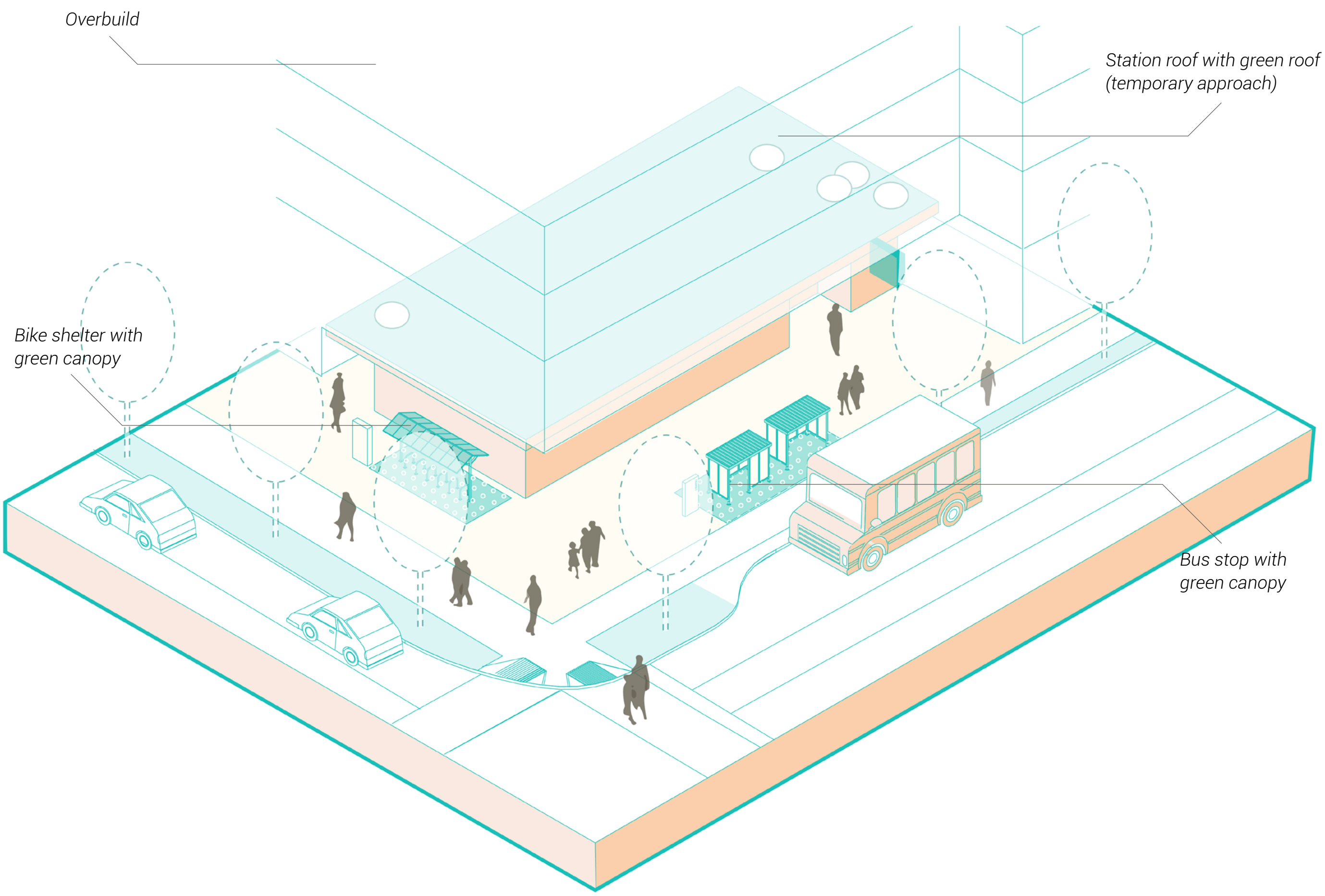
3:1 MAXIMUM IP RATIO

100 SQM MINIMUM GI AREA

2:1 RECOMMENDED IP RATIO

133 SQM RECOMMENDED GI AREA

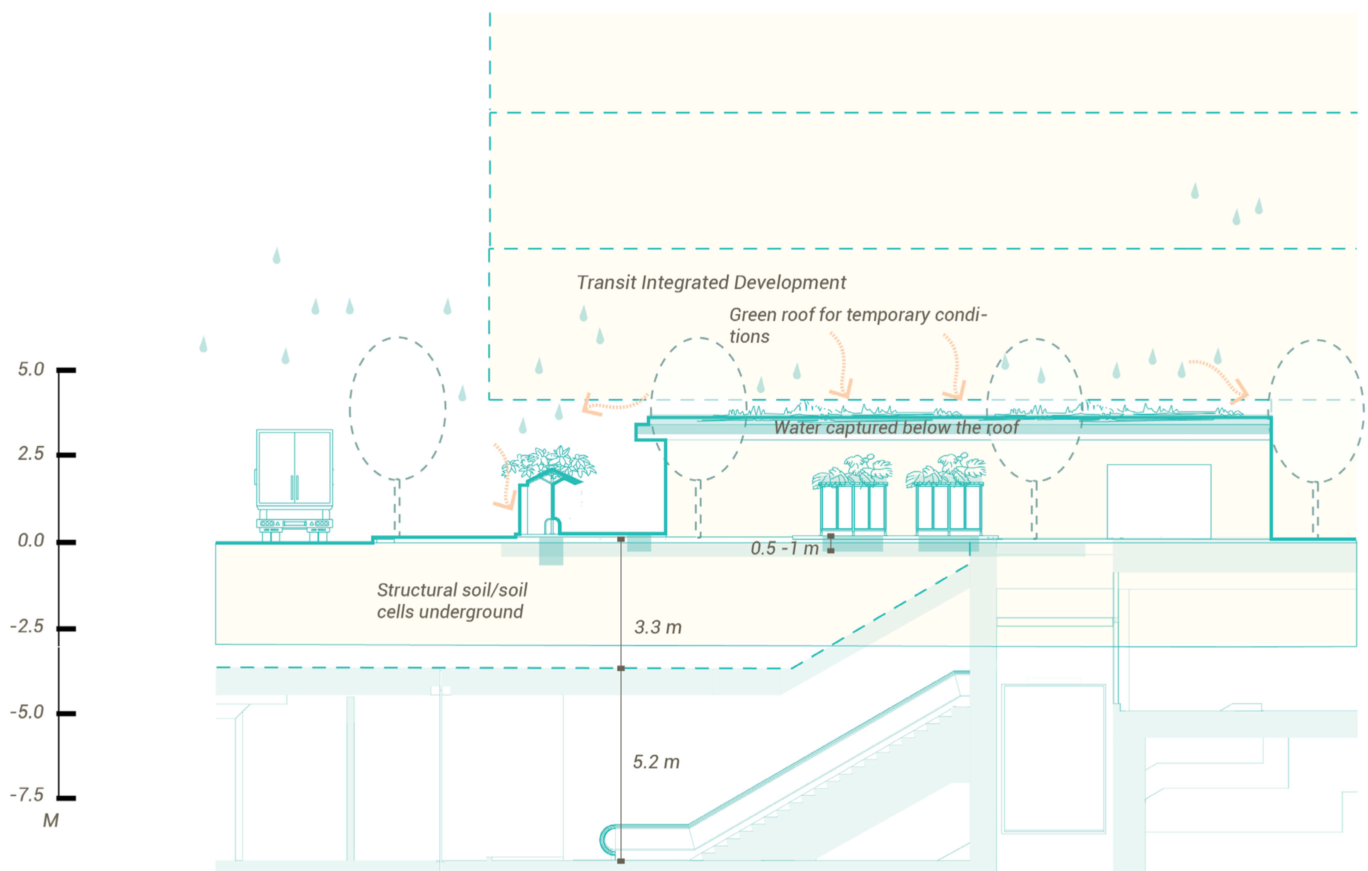




Green canopies, encompassing green roofs for bus and bike shelters, involve integrating vegetation into the roof surface, which thrives within specially prepared structural soil or soil cells. These canopies serve as infrastructure shielding site users and ground facilities from rainwater. Their installation typically doesn't clash with underground utilities, rendering them compatible with public activities as integral parts of elevated roof structures.

Green canopies function as absorbent surfaces, retaining rainwater and diminishing stormwater runoff. Additionally, they promote evapotranspiration, a process that cools the adjacent air and mitigates the urban heat island effect.

Innovative variations like vegetable awnings or vegetal canopies also fall within this typology. These versatile systems adapt to a myriad of tensioned sail shapes and sizes. Their lightweight nature and straightforward installation enable the infusion of shade and natural elements into commercial streets and public spaces, where space limitations might prohibit the placement of trees or other vegetation (Singular Green). The canopy can be inclined to allow drainage devices to capture excess water alongside the railing system.



GRI Toolkit Evaluation Table

Criteria / GRI Asset	Redirecting Capacity	Storing Capacity	Cost Efficiency	Utility Compatibility	Public Acceptance	Public Use
Bio Retention	●●	●●●●◖	●●●	●●●●	●●●◖	●◖
Bioswale	●●●●◖	●●●	●●	●●	●●	●
Slope Planting	●●●◖	●●◖	●●●●	●●●●●	●●●	●●◖
Tree Trenches	●●●●	●●●	●●	●●	●●●●●	●●●●
Bosque	●●●	●●●●●	●	●◖	●●●	●●
Pervious Paving	●	●●	●●●	●●●●◖	●●●●◖	●●●●◖
Water Feature	●●◖	●◖	●●◖	●◖	●●●●◖	●●●●◖
Ground Planter	◖	●	●●◖	●●●●●	●●●●●	●●●●●
Green Furniture	●◖	●●	●◖	●●●●●	●●●●◖	●●●●
Green Canopy	●●●		●◖	●●●●	●●●●●	●●●●●

● Poor
●● Fair
●●● Good
●●●● Very Good
●●●●● Excellent

The chart presented in this compilation outlines the evaluation outcomes for each GRI typology, providing a clear and concise basis for future reference. It is important to acknowledge that these evaluations have been derived from subjective knowledge and insights, and as such, they necessitate further investigation to substantiate their findings with supporting data. This chart serves as a preliminary tool to guide decision-making and planning, and it underscores the need for more comprehensive research and data analysis to validate the outcomes presented.

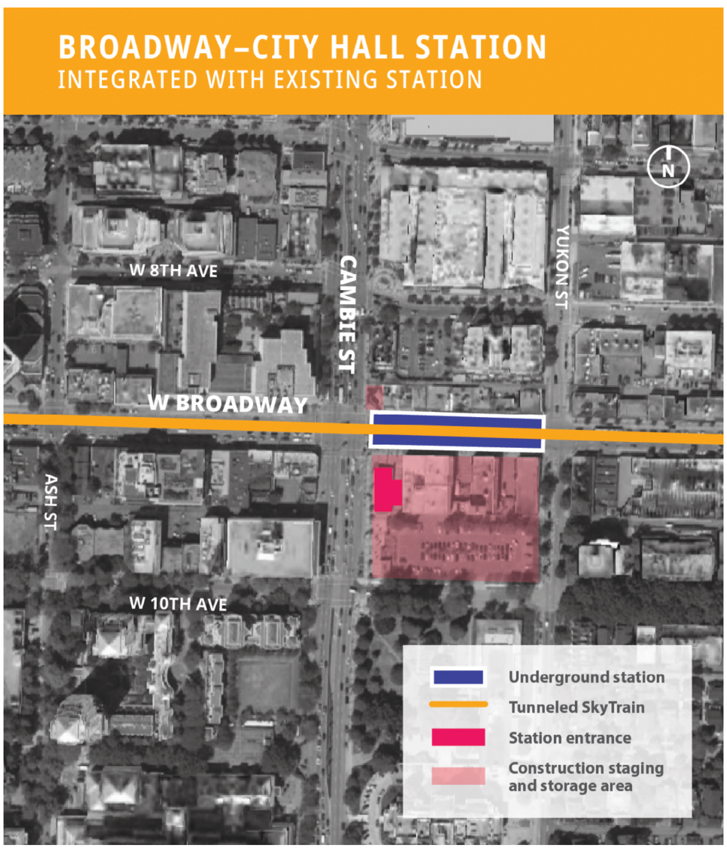
DESIGN PROPOSAL

BROADWAY-CITY HALL STATION

Among the six new underground stations proposed by the *Broadway Subway Project* (BSP), Broadway-City Hall Station was chosen due to its strategic location and context. As a future transfer station connecting the Canada Line and Millennium Line, it is poised to attract substantial foot traffic and its transit plaza offers the opportunity for incorporating GRI typologies within plaza placemaking and connecting to the future blue-green system. Situated in the vibrant Broadway Shoulder Area East, this location thrives as a hub for living, working, and recreational activities. The integration of GRI assumes a pivotal role in bolstering rainwater resilience and safeguarding neighboring infrastructures (City of Vancouver, 2022).

Key Station Context

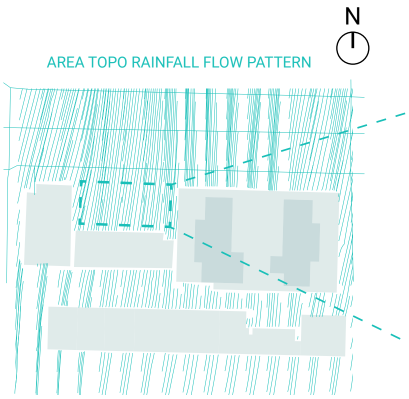
The context of the station plays a crucial role in shaping the design of the plaza and is pivotal in determining the most suitable GRI typologies.

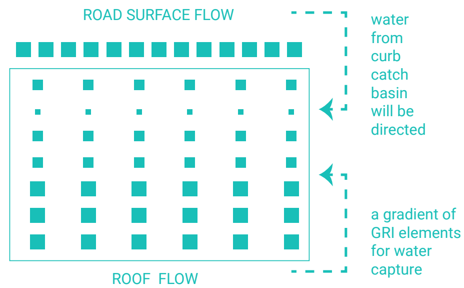


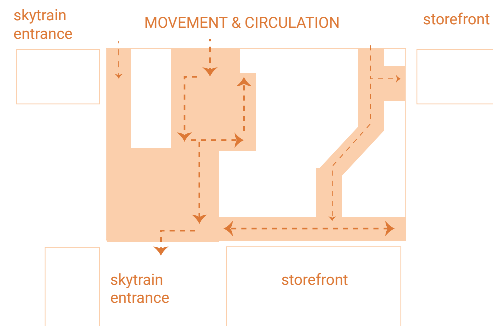
Source: City of Vancouver

- *All the new BSP stations, including Broadway-City Hall Station, will be located underground. This may encompass various station infrastructure such as platforms, vertical circulation elements, passenger information, and accessible surfaces, including tactile strips, as well as public art.*
- *Station design features good lighting and an open, transparent atmosphere that can also inform the plaza design.*
- *The stations will be integrated into the current streetscape along Broadway and will include street furniture and bike parking (City of Vancouver, 2022).*
- *Broadway-City Hall Station will be accessible by bus, walking, and cycling, providing a complete multi-modal experience.*

Site inventory & analysis







Area Topo Rainfall Simulation

The site's topography plays a significant role in determining surface runoff patterns. According to the simulations based on the digital 3D model, it is predictable that a majority of the runoff flows in the northward direction. As a result, the placement of the transit plaza is less likely to encounter localized flooding, and it will experience reduced pressure from surface runoff. However, this situation also presents opportunities for managing off-site runoff through collaboration with area drainage systems. The plaza will be equipped to handle rainwater treatment beyond the site boundaries, thereby enhancing rainwater resilience for the surrounding area.

Surface Flow Diagram

Larger blocks represent heavier surface flow, and the arrow indicates the general flow direction. The primary source of surface flow originates from the curb catch basin, given its connection to the plaza area. Simultaneously, rainwater from roof runoff will collect near the base of potential future overbuild and station entrance, creating a gradient that guides the water's gradual flow toward the road.

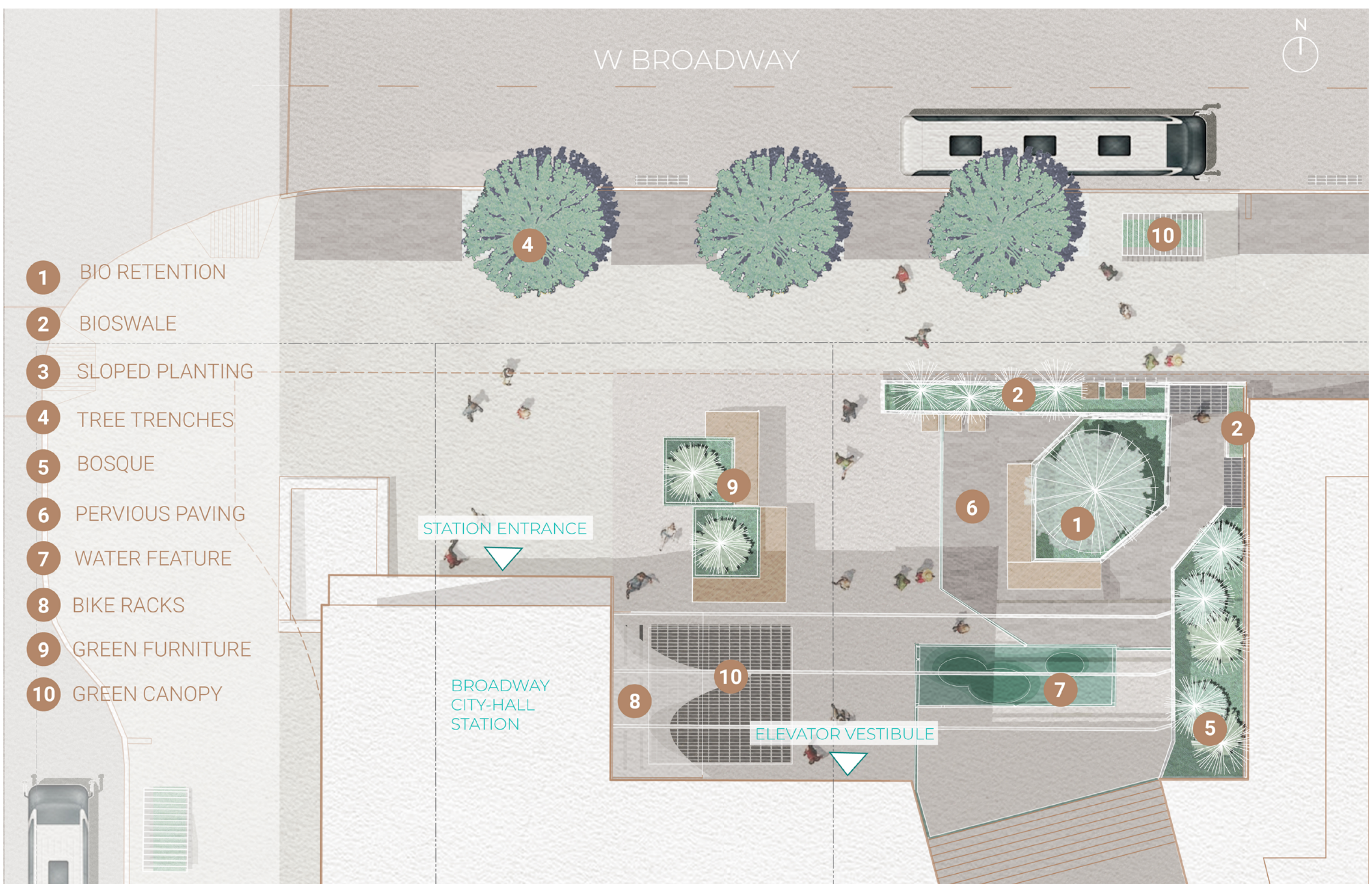
Movement and Circulation

The station entrances on both sides are significant elements to factor into the design. A considerable volume of foot traffic will be concentrated on the northern side of the plaza due to the primary entrance located near the road. Additionally, careful consideration should be given to creating a safe and well-defined access pathway for the new elevator lobby entrance situated on the right side of the station. Hence, it is imperative to devise a well-thought-out design strategy for the pathways within the transit plaza.

Proposed GRI system

This design proposal seeks to establish a comprehensive interconnected GRI system, including the following interventions:

- The tree trenches are seamlessly linked with the bioswale and bio-retention area typologies.
- Pervious concrete are employed for the pedestrian pathway to ensure accessibility for all to the entrances. The plaza area is surfaced with permeable paving materials that have expanded joint spacing, facilitating the natural infiltration of rainwater.
- Both the bus station and bike storage are integrated with a green canopy. The rainwater collected by the green canopy will gradually flow towards both the water feature and the bioswale area.



Site plan showing proposed design

Proposed Site programming

- Bio-retention areas and bioswales are positioned farther from the main circulation areas. Additionally, they serve to delineate and diversify the space, and they can also be integrated with seating arrangements.

- Tree trenches enable a more versatile utilization of curbside space. They establish a secure area for movement while also offering uncompacted soil for the trees.

- Lighter-coloured pavement stands for pervious concrete, characterized by fewer joints and greater suitability for all users. Darker coloured pavement represents permeable paving materials. This type of pavement not only adds visual intrigue but also aids in the differentiation of various areas.

- The seating area is strategically designed to create a versatile space in the center. This area serves not only as a pathway but also as a venue for various temporary street activities.

- The zone adjacent to the ventilation is allocated for bike storage, maximizing the utilization of the space alongside the station.

Axonometric diagram showing proposed design

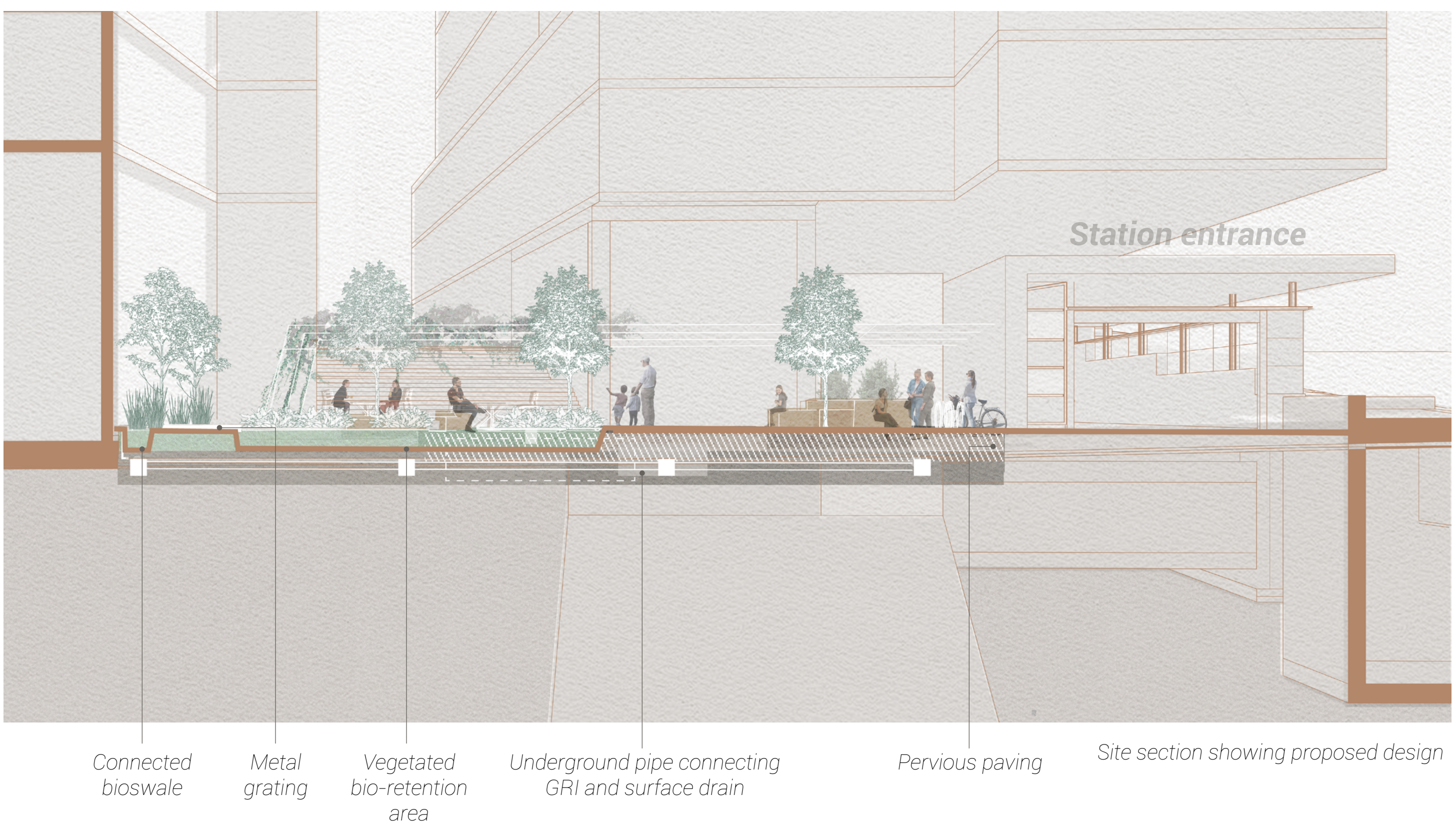
Proposed Underground composition

Referring to the typology description, the composition of various GRI elements underground may vary:

- High-depth requirements include a water feature with depths ranging from 1 to 2.5 meters, as well as rainwater tree trenches which feature a ponding depth of 0.15 meters and a growing medium depth of 0.9 meters.

- Intermediate-depth requirements involve bioswales and bio-retention areas, featuring a ponding depth of 0.15 meters and a growing medium depth of 0.45 meters.

- Low-depth requirements include permeable pavers with a depth of 0.45 meters, as well as green furniture and green canopies with depths ranging from 0.5 to 0.6 meters.



Site section showing proposed design

Conclusion

This proposal seeks to create a conceptual implementation of the GRI typology, offering a visual representation of how a transit plaza could transform upon integration of GRI elements. Broadway Subway Project presents a significant opportunity to rethink conventional transit plaza designs. In light of climate change, extending the application of GRI to public transit corridors has become a crucial consideration. This approach presents numerous advantages, including the mitigation of localized flooding, enhancement of social and psychological well-being, improved education about GRI, contribution to a broader blue-green system, and bolstered ecological connectivity.

Recommendation

The selection of GRI typologies is not governed by a single factor. Instead, it demands a methodical approach that encompasses factors such as the desired rainwater management capacity, desired functionalities, challenges related to underground utilities, and input from the community and stakeholders. The assessment of each typology, however, provides a point of reference and rationale, thus laying the groundwork for the forthcoming design of the transit plaza. This approach has the potential to be extrapolated and applied in a broader context to other station areas.

Eye-level perspective

How will the toolkit accommodate the identified gaps?

- The synergistic integration of various GRI elements holds the potential to substantially enhance the collective capacity for water management within a designated area. Through the collaboration of diverse GRI components, a more holistic and interlinked system for stormwater management is established. Consequently, the incorporation of multiple elements will help ensure a sufficient rainwater management capacity.

- The toolkit exhibits flexibility in its structure and variety, making it imperative to involve a wide array of stakeholders in the design process. This inclusive engagement should encompass residents, community organizations, businesses, and local authorities.

- Incorporate a range of scales: Advocate for the amalgamation of different GRI elements within a singular project. A blend of small, medium, and large-scale GRI components can yield a comprehensive and diverse system for managing stormwater. This toolkit strives to implement GRI in an unconventional way, aiming to seamlessly integrate GRI elements with pre-existing infrastructure and developments.

- Equity and social justice considerations: Ensure that GRI projects are crafted with cultural sensitivity, taking into account and honoring the values and preferences of the local community. Integrate features that mirror the community's identity and historical context. Simultaneously, it is essential to factor in various modes of movement and translate them into the site's design.

Budget and maintenance cost as a limitation

This is one of the most critical factors to contemplate for the sustained operation of GRI programs. Several suggested approaches to reduce maintenance costs encompass:

- Opt for low-maintenance vegetation: opt for indigenous and drought-resistant plants that necessitate minimal watering and trimming. Such flora is better acclimated to the local climate and can flourish with minimal upkeep.

- Employ recycled and sturdy materials: Utilizing recycled materials can help curb construction expenses, while the choice of durable, long-lasting materials for GRI elements can withstand wear and tear, consequently diminishing the necessity for frequent replacements.

Subway system construction *Source: City of Vancouver*

- Regularly conduct inspections: Carry out consistent inspections of GRI components to promptly detect any problems or maintenance requirements. Swiftly address any issues to prevent them from escalating into more substantial and costly concerns over time.

- Implement Smart Irrigation: Employ intelligent irrigation technologies, like drip irrigation or soil moisture sensors, to optimize water consumption and avert excessive watering. Smart irrigation methods can conserve water and curtail maintenance efforts.

- Prioritize Easy Access in Design: Design GRI elements with accessibility and maintenance in mind. Establish clear access points and pathways to facilitate routine inspections and upkeep tasks.

- Monitor Performance: Introduce monitoring systems to oversee the performance of GRI components. Monitoring data can pinpoint areas necessitating attention and optimize maintenance endeavors.

- Collaborate with Local Partners: Forge alliances with local organizations or businesses to distribute maintenance responsibilities and resources. Collaborative endeavors can result in cost-sharing and more effective maintenance strategies.

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Introduction

Green Rainwater Infrastructure (GRI) is a suite of rainwater management tools that use both engineered and nature based solutions to protect, restore and mimic the natural water cycle.

GRI is an important component of the City's sewer and drainage network and ensuring these systems are functioning is critical to the health, safety and well-being of the community. Proper grading and infiltration helps ensure these systems meet their infrastructure service objectives to:

- Improve water quality
- Increase flood resilience
- Reduce quantity of water entering the pipe system

Beyond rainwater management, GRI assets provide numerous co-benefits to the community such as urban cooling, increased tree canopy, and enhanced biodiversity, all of which contribute to a variety of city strategies, goals and targets.

Bioretention is one of the most common types of GRI in the City of Vancouver. Since 2007, more than 165 bioretention bulges, gardens and bioswales have been built across the city. In 2018, the City of Vancouver established a Green Infrastructure Implementation Branch, which has further increased the number of bioretention sites, and will continue to expand.

Plant selection, soil, grading, and design all play key roles in a successful bioretention facility. The following is a list of recommended plants based on sun exposure and location within the facility.

Plant selection should be mindful of height restriction within the right of way (maximum 0.6m near roadways), neighbourhood plans, biodiversity, pollination, sun exposure and location within the bioretention facility. Plants are also generally selected to require minimal maintenance of maximum annual shearing or cut back, preferably late winter/early spring. After establishment, the plants will receive no external watering and therefore must also tolerate summer droughts.

Zones within the bioretention facility are described as the following:

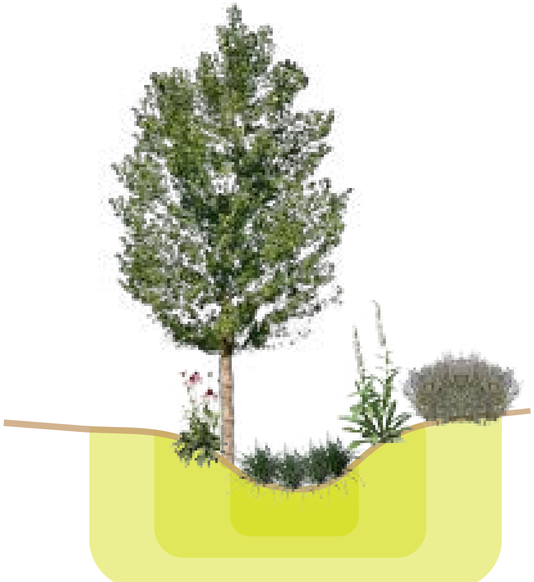
Zone 1 = Wet zone generally inundated throughout the winter. Wetland or estuary species can be considered, ensuring they are tolerant of drought.

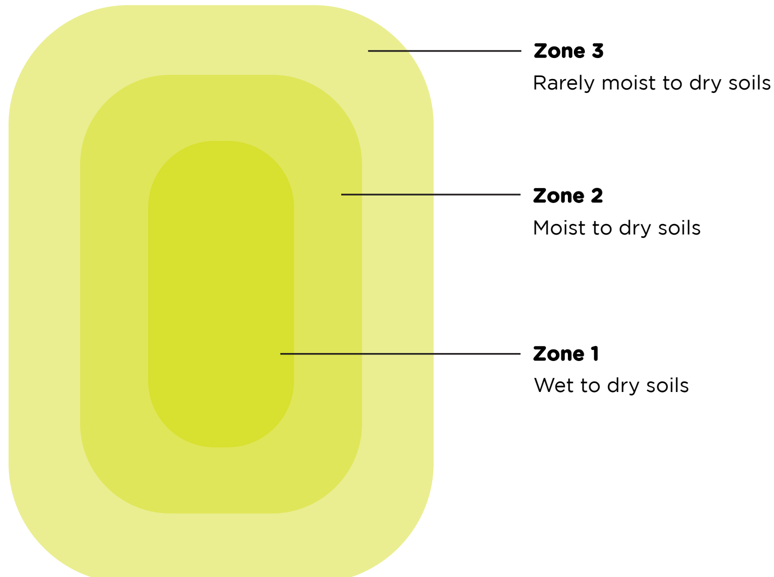
Zone 2 = Transition between Wet and dry; plants that tolerate moist conditions, and tolerant of drought.

Zone 3 = Dry Zone, along slopes that do not anticipate standing water, highly tolerant of drought, and urban pollution.

Bioretention Moisture Zones

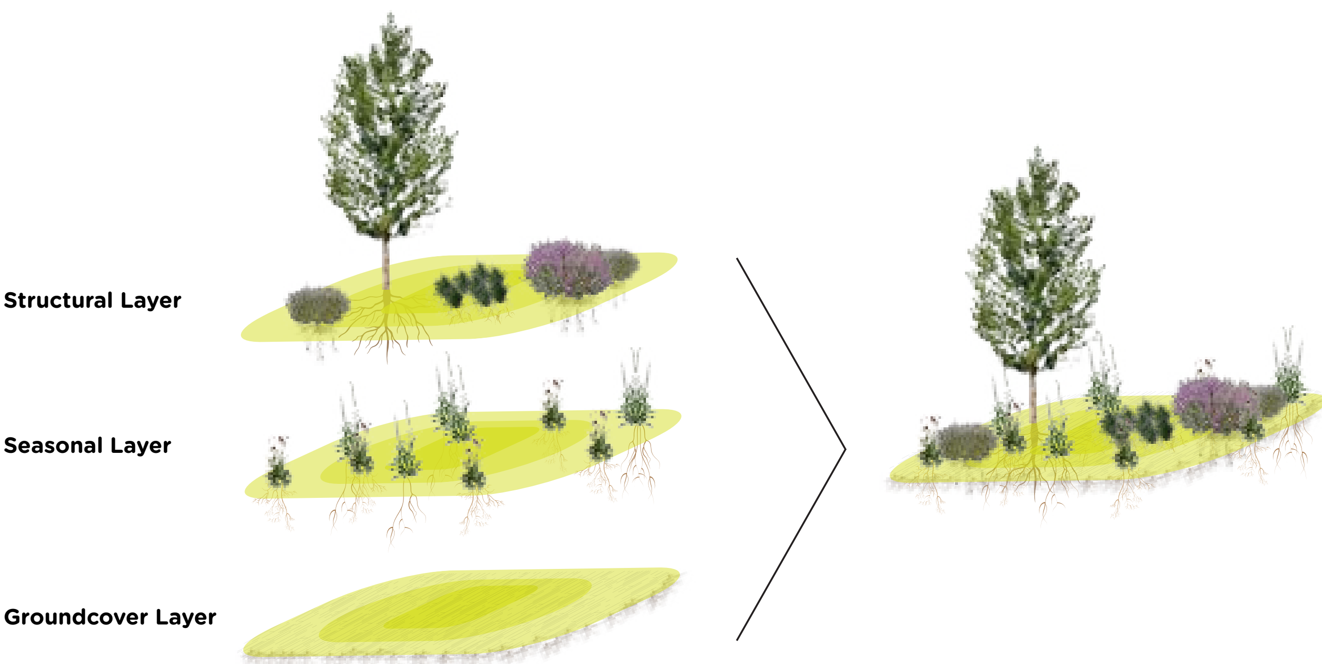
Plants in bioretention must be selected and arranged so that individual species are adapted to the distinct moisture conditions found in each zone.





Planting Layers

Bioretention planting palette should include a structural laytер for year-round interest, a seasonal layer for texture and colour, and a groundcover layer to prevent soil erosion and reduce weeds.



The following list of recommended species is not exhaustive, are recommended based on parameters laid out, and experience in the landscape:

SUN

Zone 1 (Wet Zone)
Carex flacca – .35m o.c.
Carex tumilicola .35m o.c.
Carex obnupta - .35m o.c.
Juncus effuses – .40m o.c.
Juncus inflexes - .40m o.c.
Juncas patens - .40m o.c.
Iris siberica – 0.3m o.c.

Zone 2 (Transition Zone – Wet to Dry)
Carex flacca – .35m o.c.
Carex tumilicola .35m o.c.
Carex obnupta - .35m o.c.
Iris douglasiana 0.4m o.c.
Sporabolus heterolepis -.40m o.c.
Carex testacea - .40m o.c.
Festuca 'Beyond Blue' .35 o.c.
Bouteloua gracilis ' blonde ambition '– 0.35m o.c.
Cornus sericea 'kelseyi' – 0.4m o.c.
Liriope muscari - 0.4 o.c
Cornus sericea 'kelseyi' – 0.4m o.c.

Zone 3 (Dry Zone Border Planting)
Sporabolus heterolepis -.50m o.c.
Carex testacea - .40m o.c.
Festuca 'Beyond Blue' –0.3m o.c.
Liriope muscari - 0.4 o.c
Sesleria autumnalis – 0.35m o.c
Salvia superba merleau blue 0.3m o.c

Feature Perennials
Sedum ' Autumn Joy' –.35m o.c.
Iris tenax – clumped/scattered
Echinacea purpurea – clumped/scattered
Achillea millefolium
Aquilegia Formosa – clumped/scattered
Aster oblongifolius 'Raydon's Favorite'- clumped/scattered
Phomis russeliana – clumped/scattered
Nepeta racemosa 'Walker's Low' - clumped/scattered
Rudbeckia goldstrum – clumped/scattered
Iberis semperverens – 30cm o.c

PART SHADE

Zone 1 (Wet Zone)
Carex flacca – .35m o.c.
Carex tumilicola .35m o.c.
Carex obnupta - .35m o.c.
Juncus inflexes - .40m o.c.
Juncus effuses -.40 o.c.

Iris siberica – 30cm o.c

Zone 2 (transition wet to dry)
Carex flacca – .35m o.c.
Carex tumilicola .35m o.c.
Carex obnupta - .35m o.c.
Iris douglasiana 0.4m o.c.
Deschampsia cespitosa 'Goldtau' -.40m o.c.
Carex testacea - .40m o.c.
Carex 'Ice Dance' - .35m o.c.
Bouteloua gracilis ' blonde ambition '– 0.35m o.c.
Cornus sericea 'kelseyi' – 0.4m o.c.
Liriope muscari - 0.4 o.c

Zone 3 (Dry Zone)
Lavandula angustifolia - .40 o.c.
Deschampsia cespitosa -.40m o.c.
Sporabolus heterolepis -.50m o.c.
Festuca 'Beyond Blue' –0.3m o.c.
Cornus sericea 'kelseyi' – 0.4m o.c.
Polystichum munitum - .40mo.c.
Juniperus conferta 'Blue Pacific' – .05m o.c.
Aster oblongifolius 'Raydon's Favorite' – scattered
Liriope muscari - 0.4 o.c

Feature Perennials
Iris tenax – scattered
Echinacea purpurea – scattered
Aquilegia Formosa – scattered
Aster subspicatus – scattered
Symphyotrichum subspicatum 'raydons favourite' – scattered
Phomis russeliana – scattered
Rudbeckia goldstrum – scattered

SHADE

Zone 1 (Wet Zone)
Carex obnupta - .35m o.c.
Acorus gramineus 'Ogon' - .35.o.c.
Carex tumulicola - .35m o.c.
Deschampsia cespitosa – 0.4m o.c.

Zone 2 (transition wet to dry)
Carex divulsa – .35m o.c.
Carex tumulicola - .35m o.c.
Polystichum munitum - .40mo.c.
Blechnum spicant - .40m o.c.
Mahonia nervosa - .40m o.c.
Deschampsia cespitosa – 0.4m o.c.

Zone 3 (Dry Zone)
Polystichum munitum - .40mo.c.
Blechnum spicant - .40m o.c.

Vaccinium ovatum 1.0m o.c.
Gaultheria shallon -.40m o.c.
Mahonia nervosa - .40m o.c.

Feature Perennials

Astilbe spp. – scattered