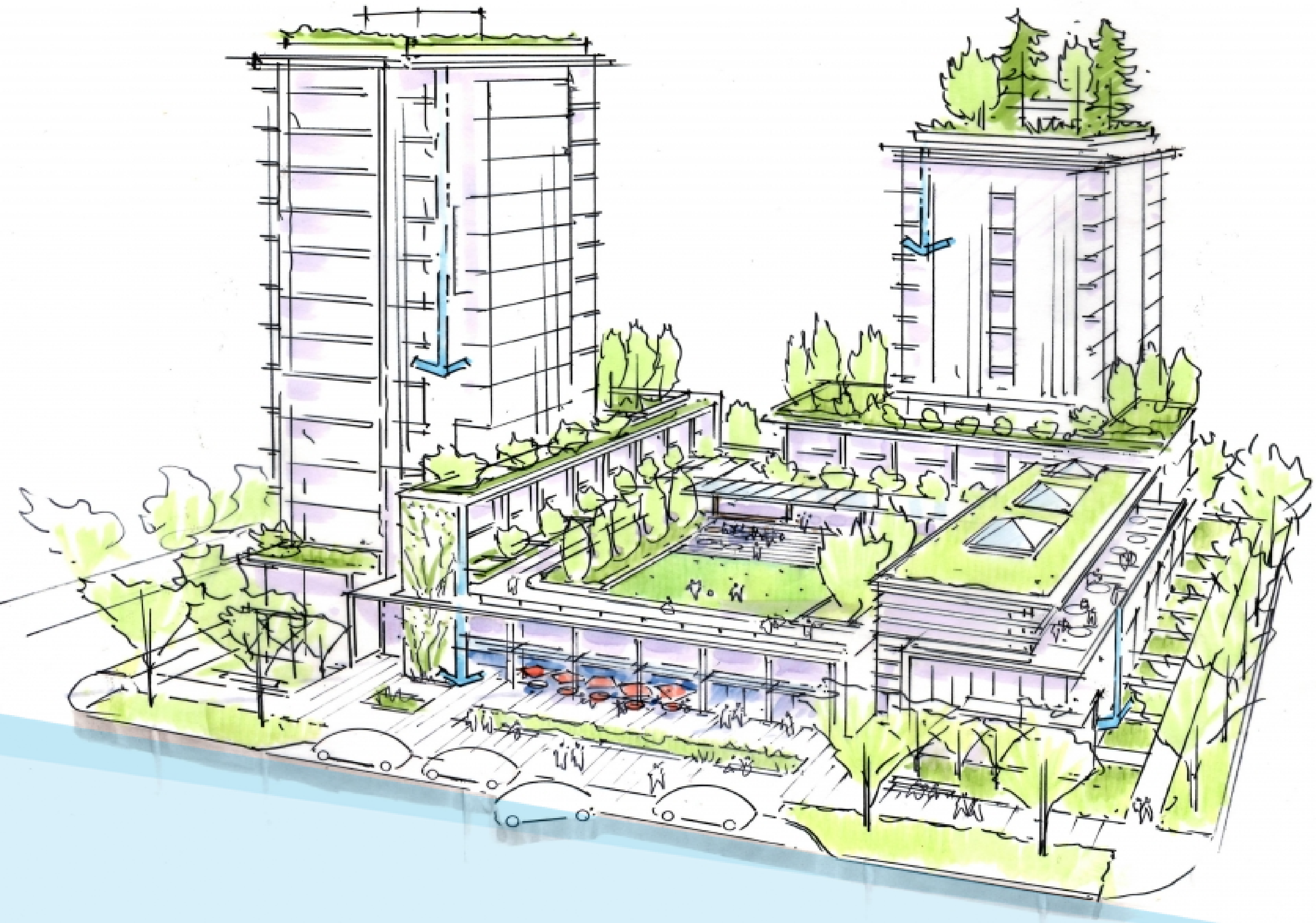

Green Rainwater Infrastructure Assets Inventory for Private Sites

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

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This paper and the research behind it would not have been possible without the exceptional support of my mentors, Craig Busch and Jenikka Javison. Their sincerity, enthusiasm, immense knowledge and exacting attention to detail have inspired and kept my work on track.

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1.0 Executive Summary

This report includes an overview and analysis of GIS mapping overlay for green rainwater infrastructure (GRI) assets at twenty-two applications proposed for site developments at the building permit review stage on private sites as of May 3, 2021. As the project is in support of the *Rain City Strategy* and *Rainwater Management Bulletin*, the analysis focuses on how GRI could impact the volume of rainwater capture, the total area of green space, and peak flow rate. The analysis also considers on-site conditions, such as the lot area, land uses, building typologies and comparing the pre-development to post-development site conditions. The findings of this report show GRI plays an important role in rainwater management, which could help to reduce the amount of rainwater flow into sewer systems and treatment facilities, increase the pervious area for rainwater infiltration, and control the rainwater flow rate. It is important to note that the results presented in this report are based upon a small selection of sites (twenty-two site developments undertaking building permit application review); the data trends will become more accurate as more permits are added into the mapping overlay in time. Therefore, further updates to the ArcGIS tracking list will be necessary to help the City analyze and report on their rainwater management targets.

2.0 Introduction

This project aims to create a GIS mapping overlay to catalogue and visualize green rainwater infrastructure (GRI) assets on private sites in the City of Vancouver and to be used as an engagement piece for communicating the benefits of GRI to both internal and external stakeholders. The GIS overlay will capture information including, but not limited to: the location of GRI assets, the various land uses and building typologies where GRI assets are located, the total volume of rainwater captured, and the different types of treatments using these GRI assets. This information will help City staff to analyze how effective GRIs have been in mitigating climate change, improving hydrologic cycles for aquatic ecosystems, enhancing neighborhoods in terms of livability, and the cost effectiveness of GRI in terms of capturing rainwater, cleaning pollutants and slowing the discharge from private developments. This in turn helps to divert rainwater discharge that would otherwise flow into combined sewers and onto larger treatment facilities. This analysis also speaks to the influence of GRI assets at different scales, including in specific watershed catchments and across the City of Vancouver as a whole. This project focuses on twenty-two building permits that have been reviewed by the Development Water Resources Management Branch as of May 3, 2021.

GRI is an emerging tool to rainwater management that uses nature-based solutions that aims to mimic, protect, and retain the natural water cycle at its source through engineered and ecological practices that provide environmental, social, and economic benefits (City of Vancouver, 2019). GRI are systems composed of native plants, soils, and bioengineered structures that collectively capture and filter rainwater before sending them back to nearby waterways (City of Vancouver, 2019). They also provide various ecosystem services to enhance the ecosystems they reside within and help to mitigate the effects of climate change (City of Vancouver, 2019).

The main forms of GRI include: bioretention practices, including bioswales and rain gardens; rainwater tree trenches (RTTs); resilient roofs, including green, blue, and blue-green; permeable pavement; large scale practices, such as parks, greenways, and plazas; non-potable water systems; subsurface infiltration practices; and absorbent landscapes (City of Vancouver, n.d.).

3.0 Background

This project is in support of the *Rain City Strategy*, a document that reimagines and transforms how Vancouver manages rainwater with the goals of improving water quality, resilience, and livability through creating healthy urban ecosystems (City of Vancouver, 2019). Specific to this project is the Buildings and Sites Action Plan, one of three implementation action plans that aims to advance the implementation of GRI on private sites and civic facilities.

Table 1. The *Rain City Strategy* 's goals, objectives and targets (City of Vancouver, 2019).

Rain City Strategy	
Goals	Improve and protect Vancouver's water quality.
	Increase Vancouver's resilience through sustainable water management.
	Enhance Vancouver's livability by improving natural and urban ecosystems.
Objectives	Remove pollutants from water and air.
	Increase managed impermeable area.
	Reduce volume of rainwater entering the pipe system.
	Harvest and reuse water.
	Mitigate urban heat island effect.
	Increase total green area.
Targets	Capture (infiltrate, evapotranspiration, and/or reuse) and clean (treat) a minimum of 90% of Vancouver's average annual rainfall volume (long term).
	Manage urban rainwater runoff from 40% of impervious areas in the city by 2050.

The *Rainwater Management Bulletin* provides further direction for this project in that it establishes the site-specific requirements developers must meet in submitting rainwater management plans, including guidelines for volume reduction, release rate and water quality.

Table 2. The requirements of the *Rainwater Management Bulletin* (City of Vancouver, 2018).

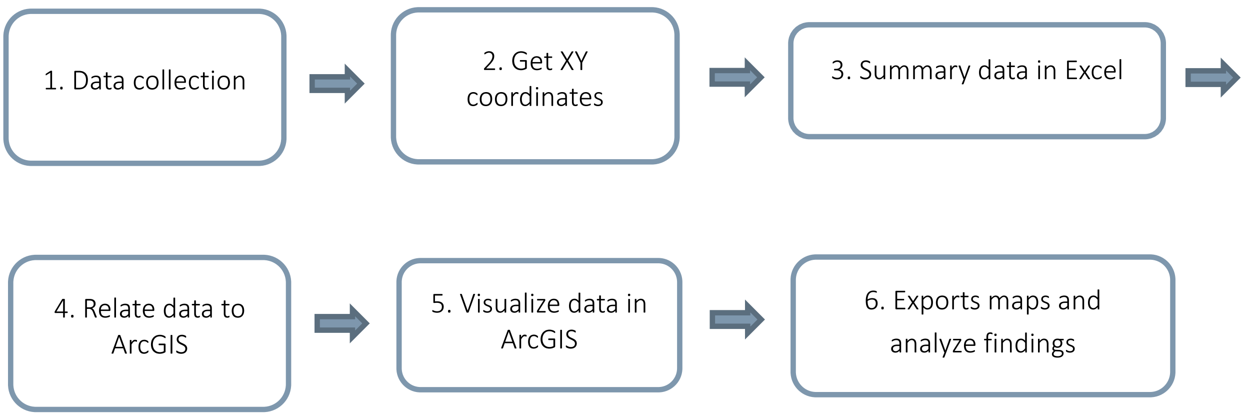
Category	Requirements
Volume Reduction	Capture 24 mm of rainfall in 24-hours (or 70% of the average annual rainfall volume) from all areas, including rooftops, paved areas, and landscape and infiltrate, evaporate or reuse it.
Release Rate	The rainwater management system for the building(s) and site shall be designed such that the peak flow rate discharged to the sewer under post-development conditions is not greater than the peak pre-development flow rate for the return period specified in the City of Vancouver's Intensity-Duration-Frequency curve (IDF curve) (see attached IDF curves). The City of Vancouver's 2014 IDF curve shall be utilized for pre-development design flow

	calculations, and the City's 2100 IDF curve, which takes into account the effects of climate change, shall be utilized for post-development design flow calculations. Pre-development, in this context, means the site's immediate use preceding development.
Water Quality	The first 24 mm of rainfall from all pervious and impervious surfaces shall be treated to remove 80% Total Suspended Solids (TSS) by mass prior to discharge from the site. For impervious surfaces with high pollutant loads, including roads, driveways, and parking lots, the rainfall to be treated increases to the first 48 mm of rainfall. Treatment can be provided by either one green infrastructure practice or structural Best Management Practice (BMP) or by means of a treatment train comprised of multiple green infrastructure practices or structural BMPs that can be demonstrated to meet the 80% TSS reduction target.

4.0 Methodology

All of the data for this project was provided by the City and the visualizations were created using ArcGIS Pro. To accomplish this, data was first collected by reviewing the City's summary reports and the final Rainwater Management Plan (RWMP) from developers. The BC Address Geocoder was used to get XY coordinates for each BP location. All of the data was then summarized in an Excel spreadsheet that could then be imported into ArcGIS Pro as an attribute table. The XY coordinates were connected to points in GIS by projecting the projection system and coordinate systems. Different symbology was used to illustrate different features according to what each overlay represents for. From this, the final layout maps and charts were created and exported.

Below is a flow diagram that illustrates the high-level illustration of the process.



5.0 Visualizations and Findings

The following section includes visualizations of GRI assets on private sites in the City of Vancouver. Listed below are the ten major layers of visualizations included in this project with the findings and highlights. These ten different layers and the specific technical considerations and analysis will be explored further in the following report.

For each visualization, there are several subsections listed below. The Display Method and Rationale section represent the methods that are used to display the information in mapping overlays, and explain the reasons why the chosen method is best to visualize certain information. The Findings and Highlights section represents the major take away from the visualizations and will highlight the reason why this information is important to the City of Vancouver staff.

For reference, a polygon base layer of the different watershed catchment areas has been overlain onto each map.

5.1 Rezoning and Development Permit Locations

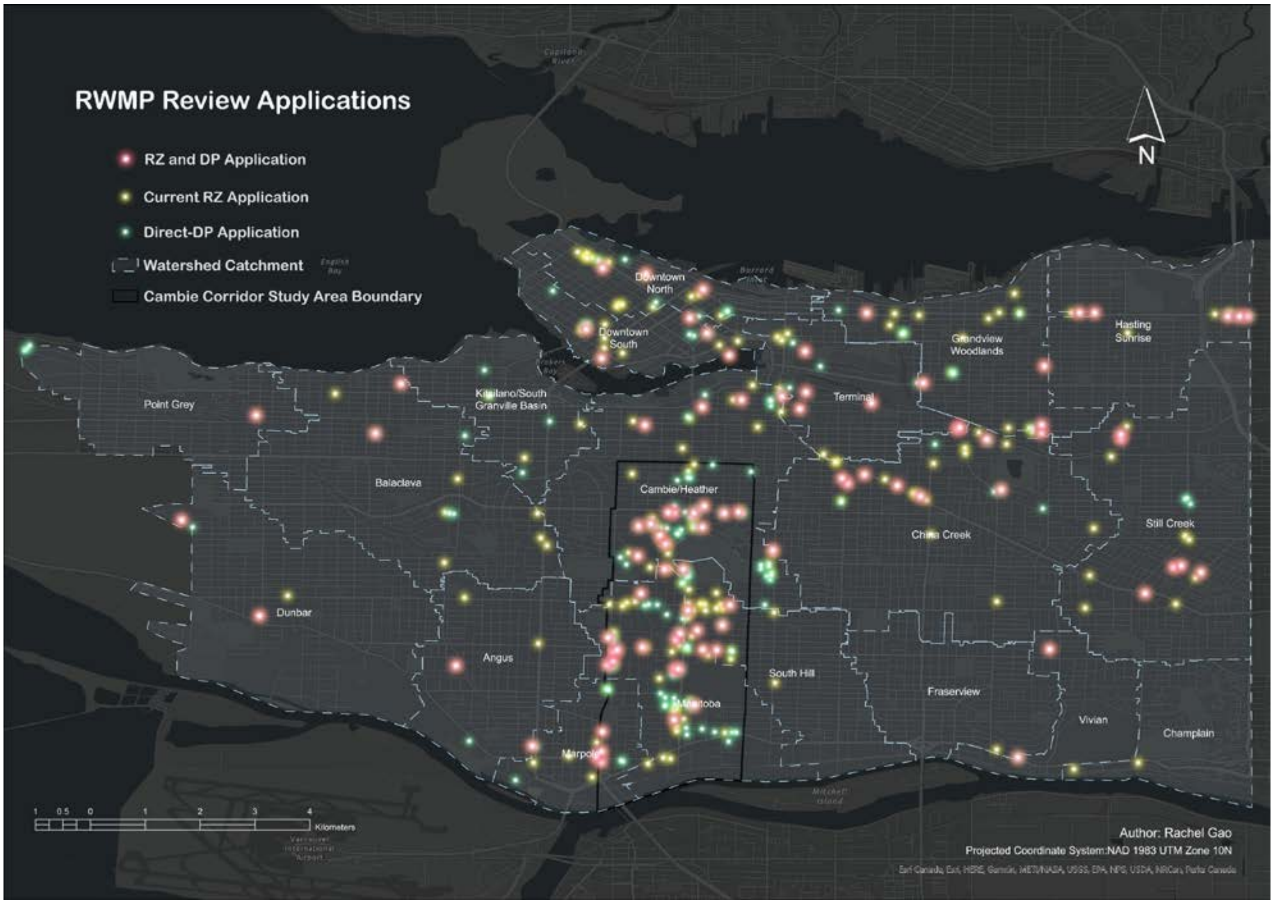


Figure 1. A point overlay that illustrates the locations of rainwater management reviews for rezoning (RZ) and development permit (DP) sites in the City of Vancouver.

Display Method and Rationale

This layer was displayed as a point layer to show the location of each application. Different colours were used to represent different application stages. By clicking on each of the individual points, a pop-up will show additional contextual information relative to each address, such as the application stages, City of Vancouver reference number, project status, and geographic coordinates.

Findings and Highlights

From this visualization, it is apparent that the majority of reviews are located within the Cambie Corridor, which is denoted by the black boundary. It is likely because there are specific requirements established for the Cambie Corridor that exist in addition to the *Rainwater Management Bulletin*.

5.2 Building Permit Locations

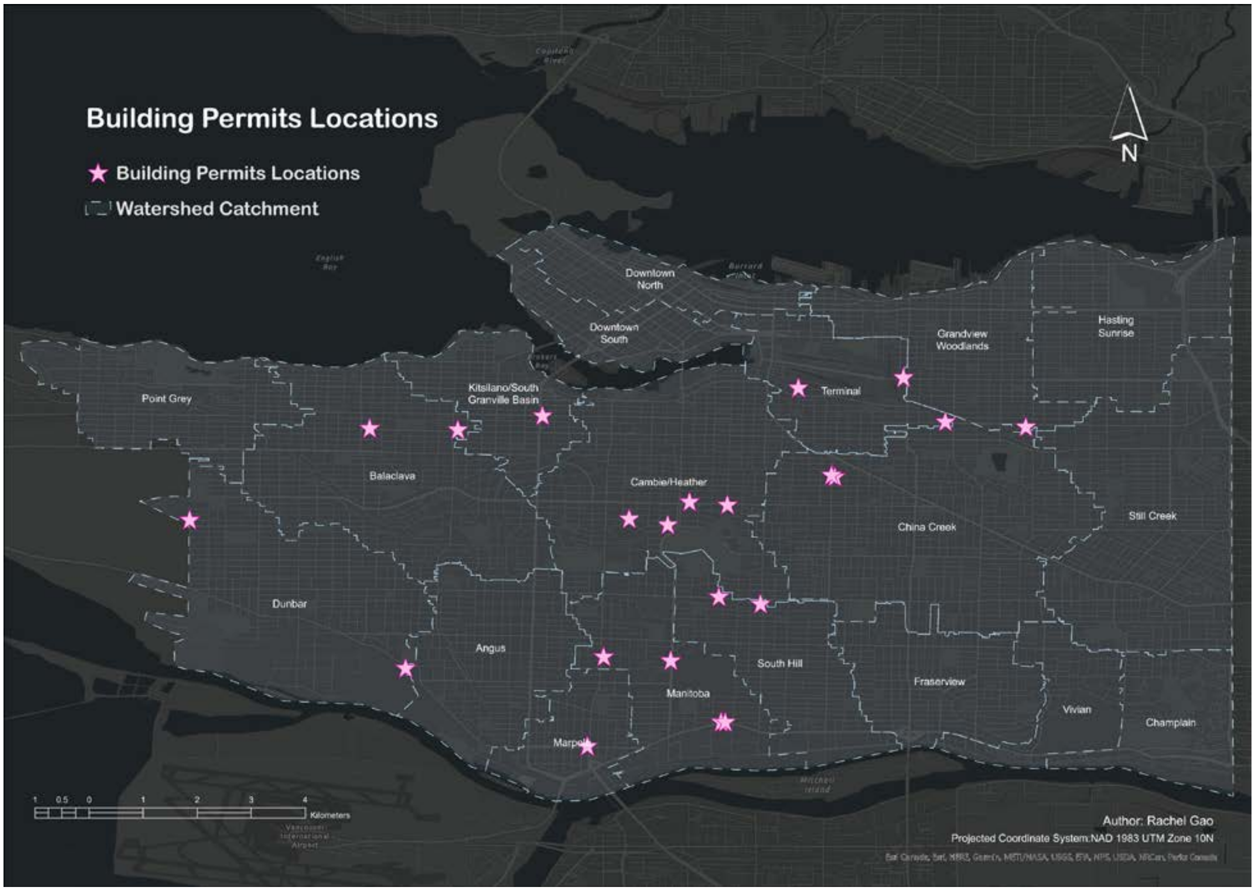


Figure 2. A point overlay illustrating the locations of rainwater management reviews for twenty-two building permits (BP) sites in the City of Vancouver.

Display Method and Rationale

This layer was displayed as a point layer to show the location of each application. A point layer was chosen instead of a polygon layer for display as the sites were considered to be too small for visualization purposes when viewed at a citywide scale.

Findings and Highlights

These twenty-two BPs were used to input data values for the subsequent eight layers. A comparison of the number of BPs in each watershed is shown in Figure 3. Based upon the provided information of twenty-two sites, the Manitoba and Cambie Watersheds have the highest number of BPs located within them.

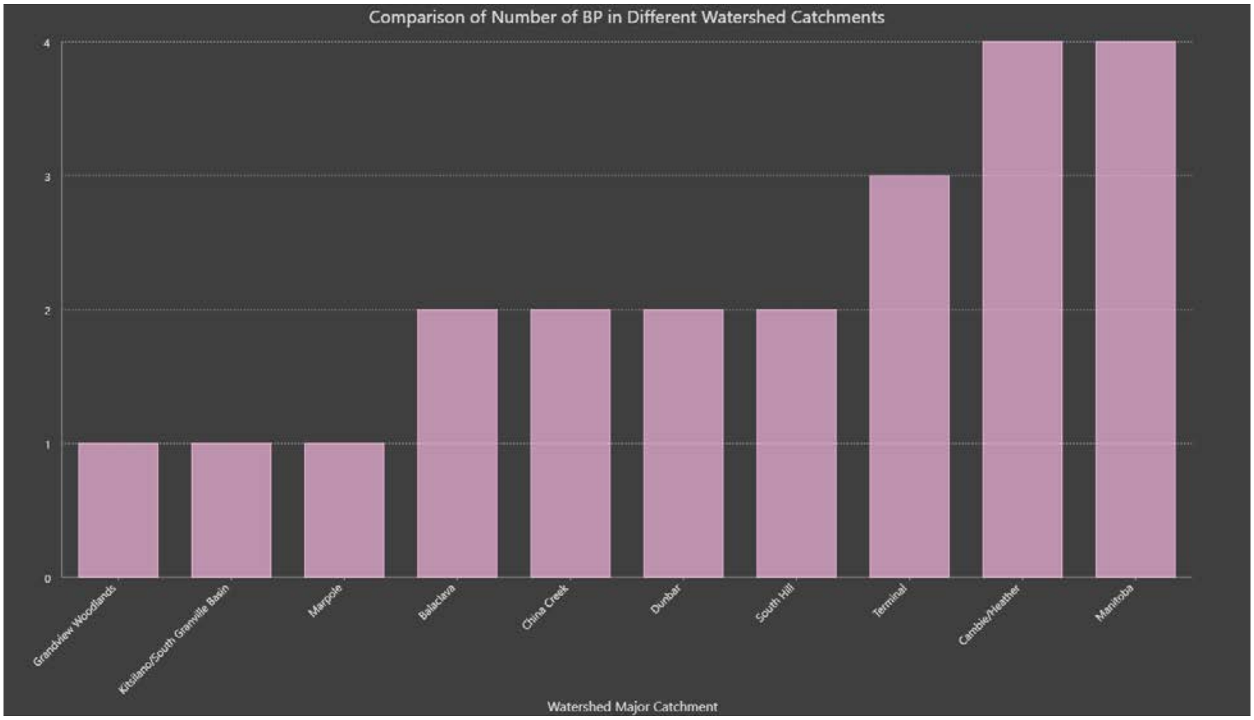


Figure 3. The total number of BPs in each watershed catchment based on twenty-two BP site locations.

5.3 Total Lot Area

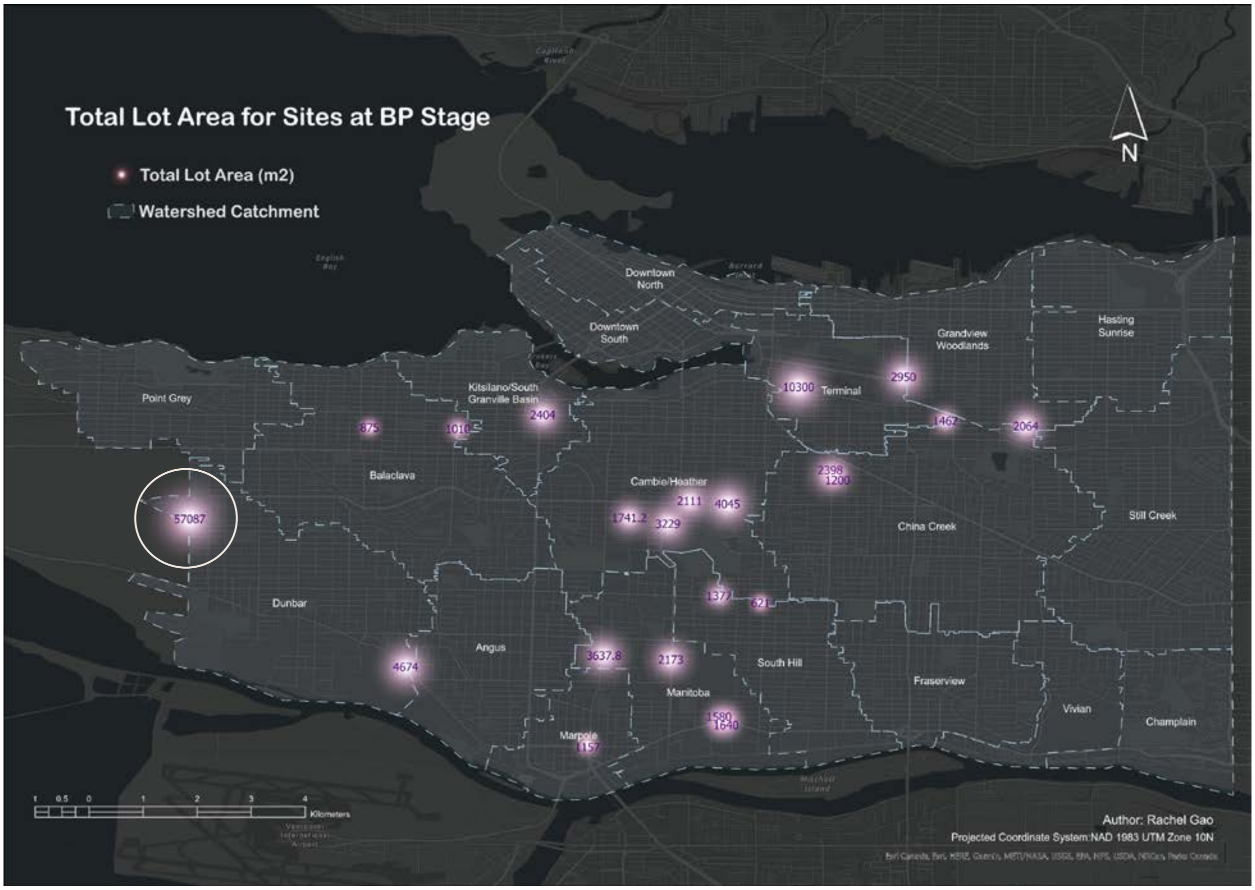


Figure 4. A point layer that represents the lot area of each site at the BP stage.

Display Method and Rationale

This layer was displayed as graduated size points that represent the different areas of each site. The number on each point is the actual total lot area of each site. The graduated sizing display method was used as it can better visualize the differences in lot areas.

Findings and Highlights

St. George's Senior School represents the largest BP area in the above visualization, which is 57,087 square metres in size. Comparing to other sites reviewed as part of this project, St. George's Senior School is about ten times bigger . This site includes many school buildings, field houses, parking areas and ample greenspaces to support and implement onsite GRIs.

5.4 Land Uses

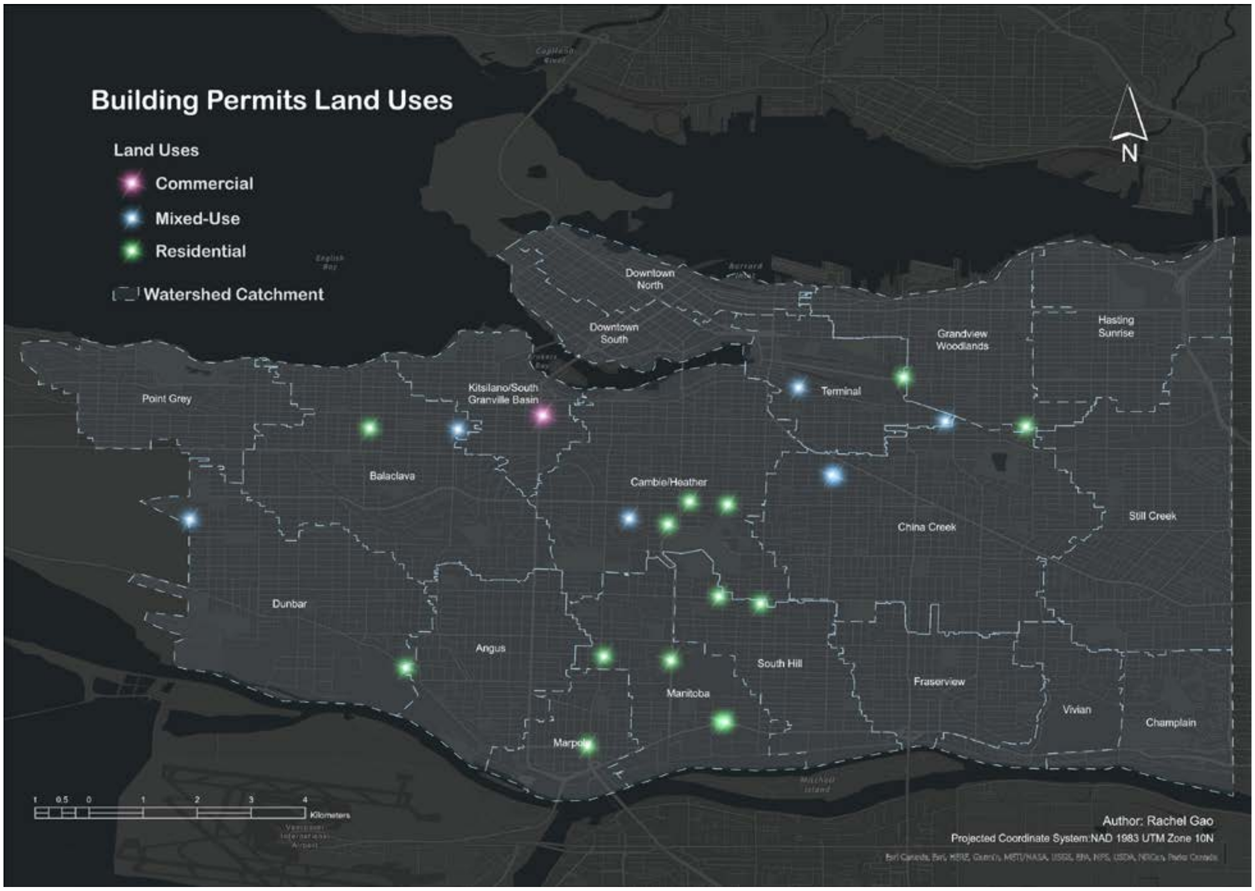


Figure 5. A point overlay illustrating the different land uses for BP sites.

Display Method and Rationale

This layer was displayed as a point layer to show the different land uses of each application. Different colours were used to represent different land uses. This display method allows people to see different types of land uses clearly with different site locations.

Findings and Highlights

Figure 6 shows the comparison of the number of BPs in different land uses. Among the twenty-two sites, the most common land use is residential (14), followed by mixed-use (7) and commercial (1). One preliminary assumption as to why there are more residential sites then mixed-use and commercial sites is that there are more residential properties being developed within private sites. One of the reasons why this is happening may because of the increase in housing demands due to the dramatic increase in urbanization and densification (Walks, 2014). Meanwhile, the general trend of commercial construction is more expensive and holding to stricter building codes than residentials (CDMG Team, 2019). Therefore, based on the highly demands and less specialized and complicated requirements, residential developments are far more lucrative to developers in terms of making a quick buck.

The one commercial development is located at 1477 West Broadway Street. The proposed site consists of six-stories of commercial use and five-levels of underground parking.

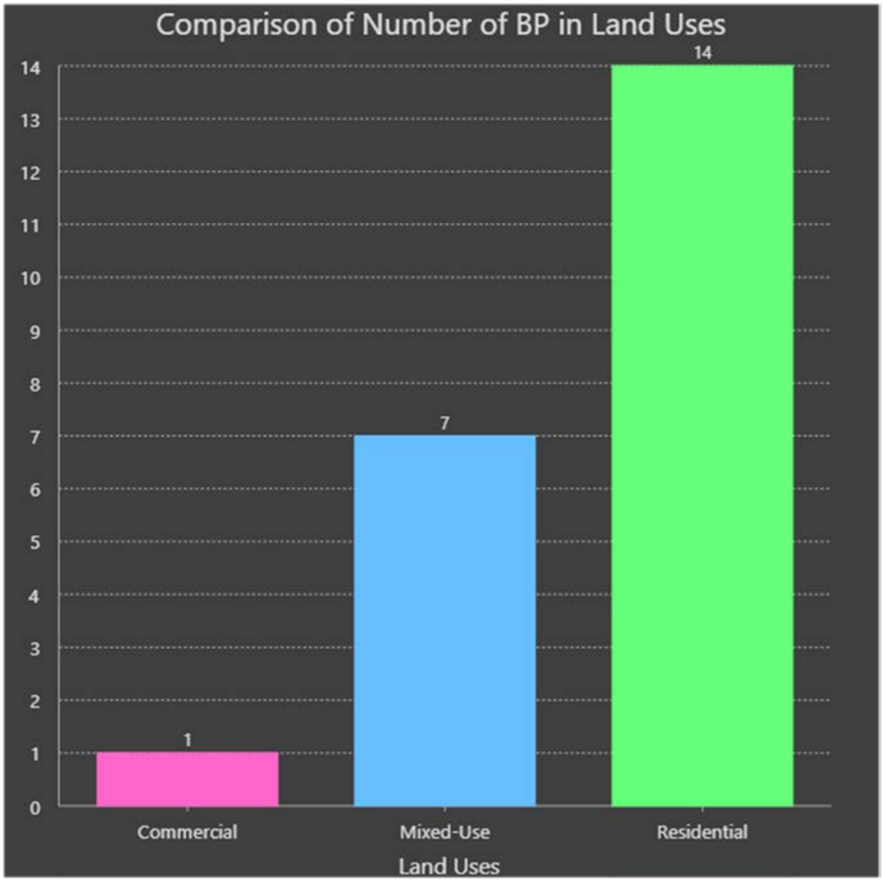


Figure 6. The total number of BPs for each land use.

5.5 Building Typologies

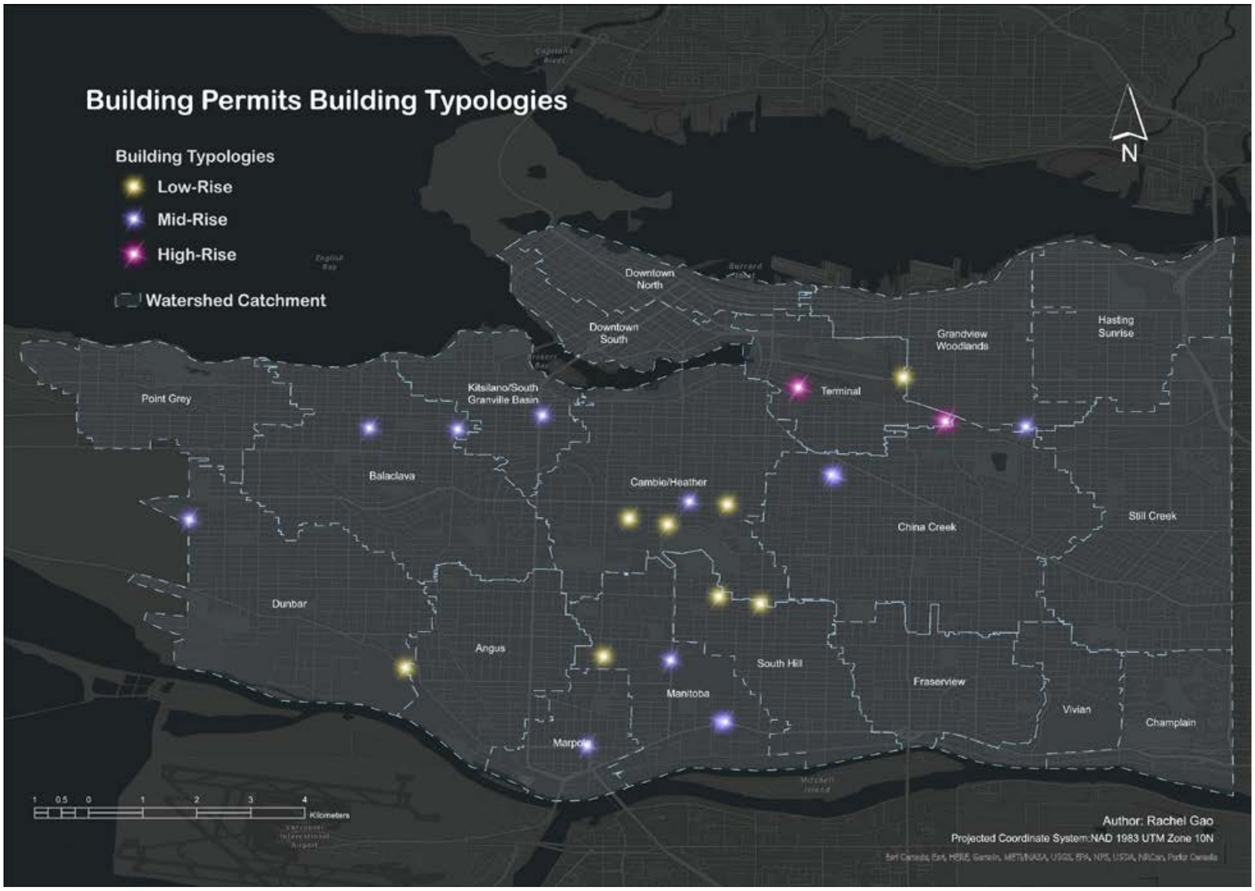


Figure 7. A point overlay that illustrates the building typologies for BP sites.

Display Method and Rationale

This layer was displayed as a point layer to show the different building typologies of each application. Different colours were used to represent different typologies. This display method allows people to see different building typologies clearly with different site locations and find the highlights or what they are concerned.

Findings and Highlights

Figure 8 shows a comparison of the total number of BPs for each building typology. Among the twenty-two sites, the most common building typology is mid-rise buildings (12), followed by low-rise (8) and high-rise (2). The preliminary assumption as to why there are more mid-rise buildings might be that mid-rise buildings are cost-effective due to the affordable building material, have a faster construction time and may lend themselves better to achieving requirements of sustainable building programs, such as LEED (RMG Engineers, 2017).

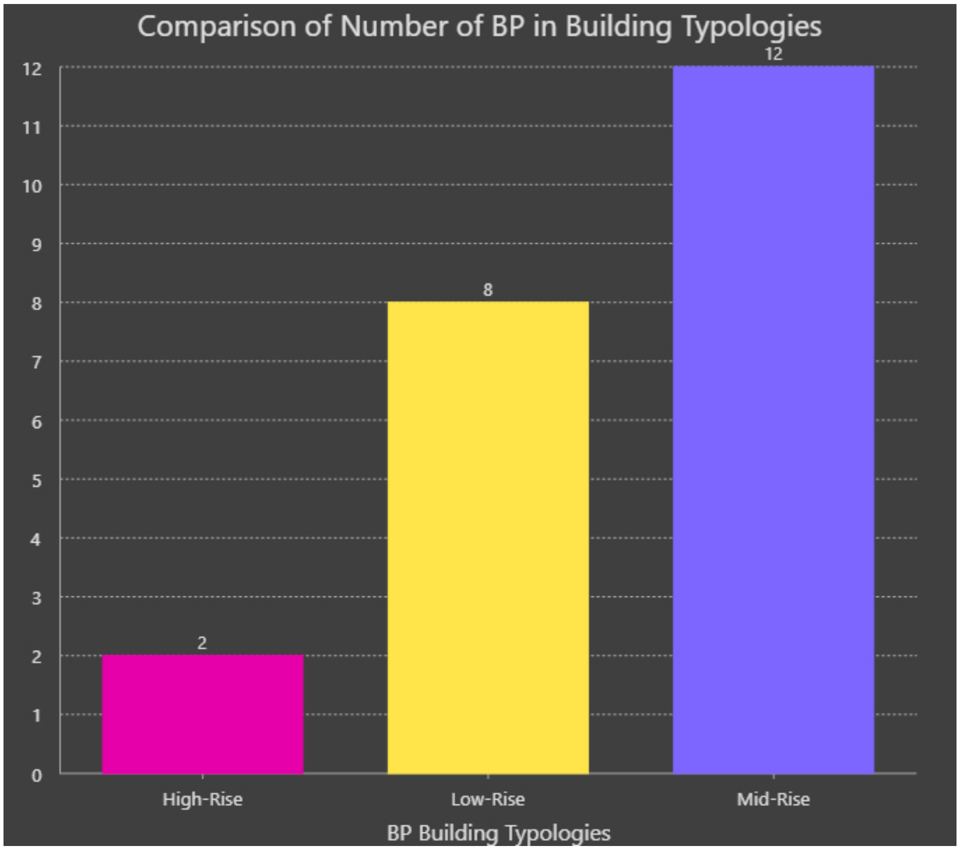


Figure 8. The total number of BPs for each building typology.

The highlight here is the two high-rise buildings, one of which is proposed for hotel, retail, office and light industrial use, with five levels of underground parking. The other site is proposed as a 10-storey mixed-use development.

5.6 Water Quality Treatment

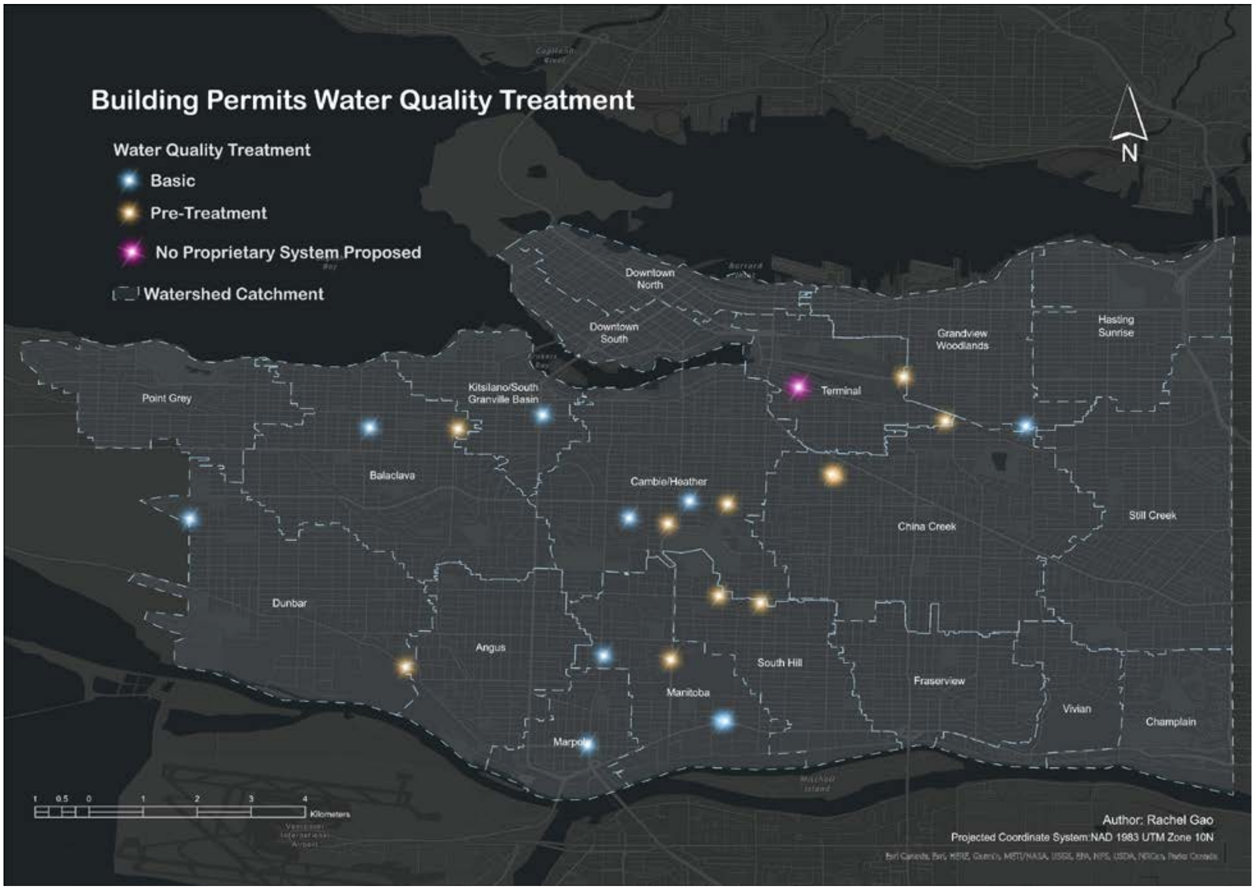


Figure 9. A point overlay that illustrates the water quality treatment for BP sites.

Display Method and Rationale

There are two main types of water proprietary systems observed: basic and pre-treatment. As per the Washington TAPE program, a basic treatment system is evaluated to remove 80% of total suspended solids (TSS), while pre-treatment system can remove 50% of TSS (Washington State Department of Ecology, n.d.).

This layer was displayed as a point layer to show the different proprietary systems for each application. Different colour represents different treatment systems. This display method allows people to see different types of water treatments clearly that have been used in different site locations and find the highlights or what they are concerned.

Findings and Highlights

Figure 10 is the comparison of the total number of BPs for different water quality treatments. To date, eleven pre-treatment systems and ten basic systems have been proposed.

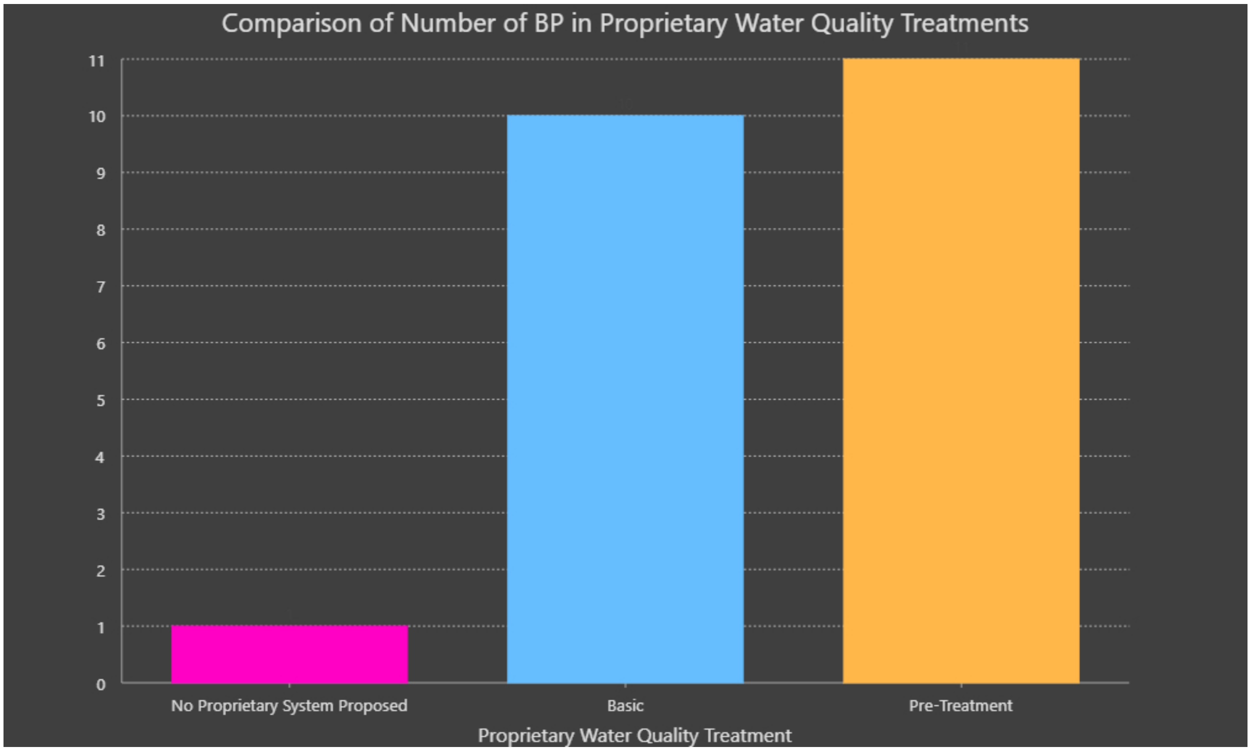


Figure 10. Total number of BPs for each water quality treatment.

The highlight is the site that has no proprietary system proposed, being 375 East 1st Avenue. The site is a relatively large one with a lot area of 10,300 square meters. The proposed GRIs include bioswales, roof-top planters, absorbent landscaping on slab, closed bottom planters and lined bioretention systems. The runoff will be directed to the GRI, such as bioswales, where it will be treated before it is discharged into the City's infrastructure. As a result of this, the developer has indicated that no additional water quality treatment will be required.

5.7 Total Number of GRI

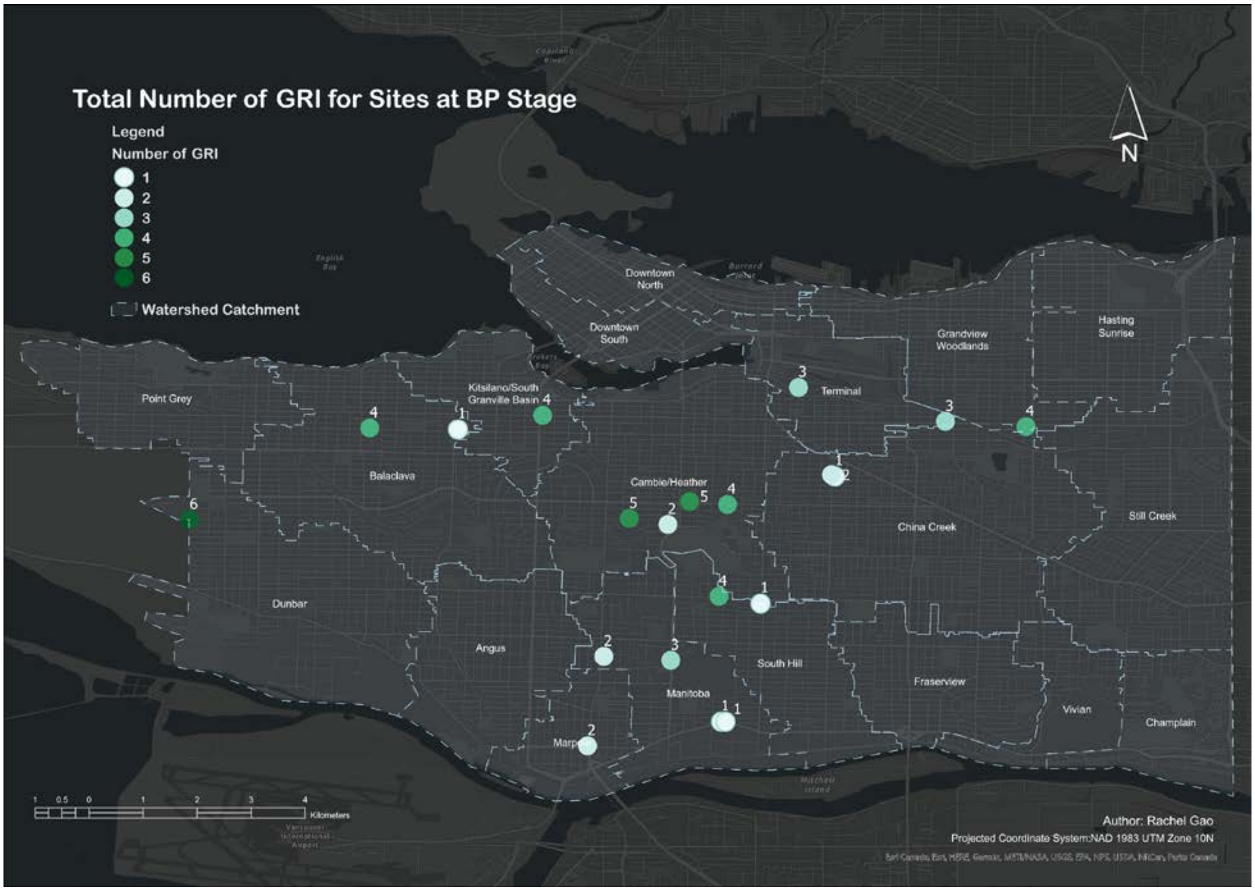


Figure 11. A point overlay that illustrates the total number of GRI for BP sites.

Display Method and Rationale

This layer was displayed as graduated colour points using the number of different types of GRI in each site. The main types of GRI identified are bioretention practices, resilient roofs, permeable pavement, surface infiltration and absorbent landscapes. Total number of GRI was shown from high to low using a dark to light green colour scheme. This display method allows users to visualize the general comparison of the number of GRI for each site at BP stage.

Findings and Highlights

Figure 12 shows the average number of GRI per site in different watershed catchments. Dunbar has the highest average number of GRI per site because of St. George's Senior School which has the largest number of GRI proposed for any site. The analyzed result may be biased due to the limited number of reviews that are currently tracking in GIS, but this analysis will increase in accuracy as more reviews are added into the database over time.

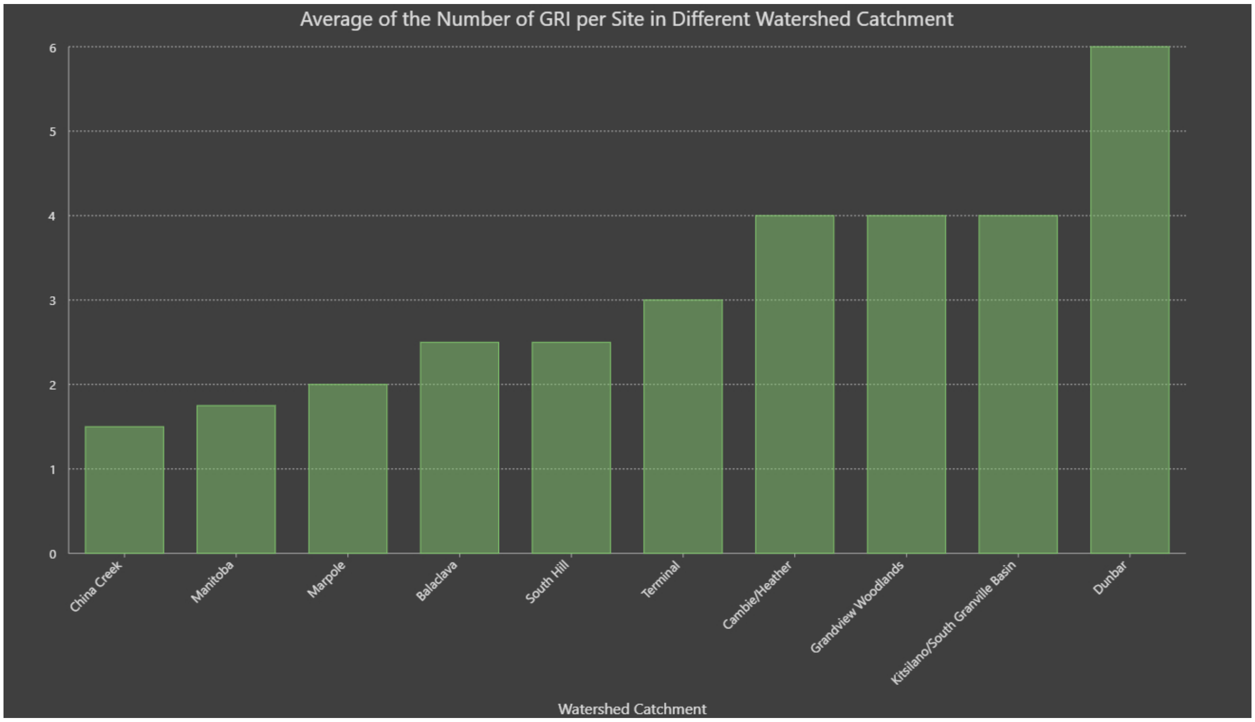


Figure 12. The average of the number of GRI per site in each watershed catchment.

The highlights are the BPs with the highest and lowest numbers of GRI. The highest one is St. George's Senior School, which includes lawn, planters, vegetative areas, on-grade planters, rain gardens and green roof. Of all the BPs reviewed, five sites only have one GRI, which is absorbent landscaping for all five. The total lot area for each of these five sites is relatively small which may be the reason why only one GRI was proposed per site. The larger a site is the more space and opportunities there are for developers to reserve spaces for GRI.

5.8 Total Rainwater Captured Through Tier 1 & 2 versus Total Rainwater Capture Required

Figures 13 and 14 below show the total volume of rainwater captured through Tier 1 and 2 approaches versus the total volume of rainwater capture required onsite.

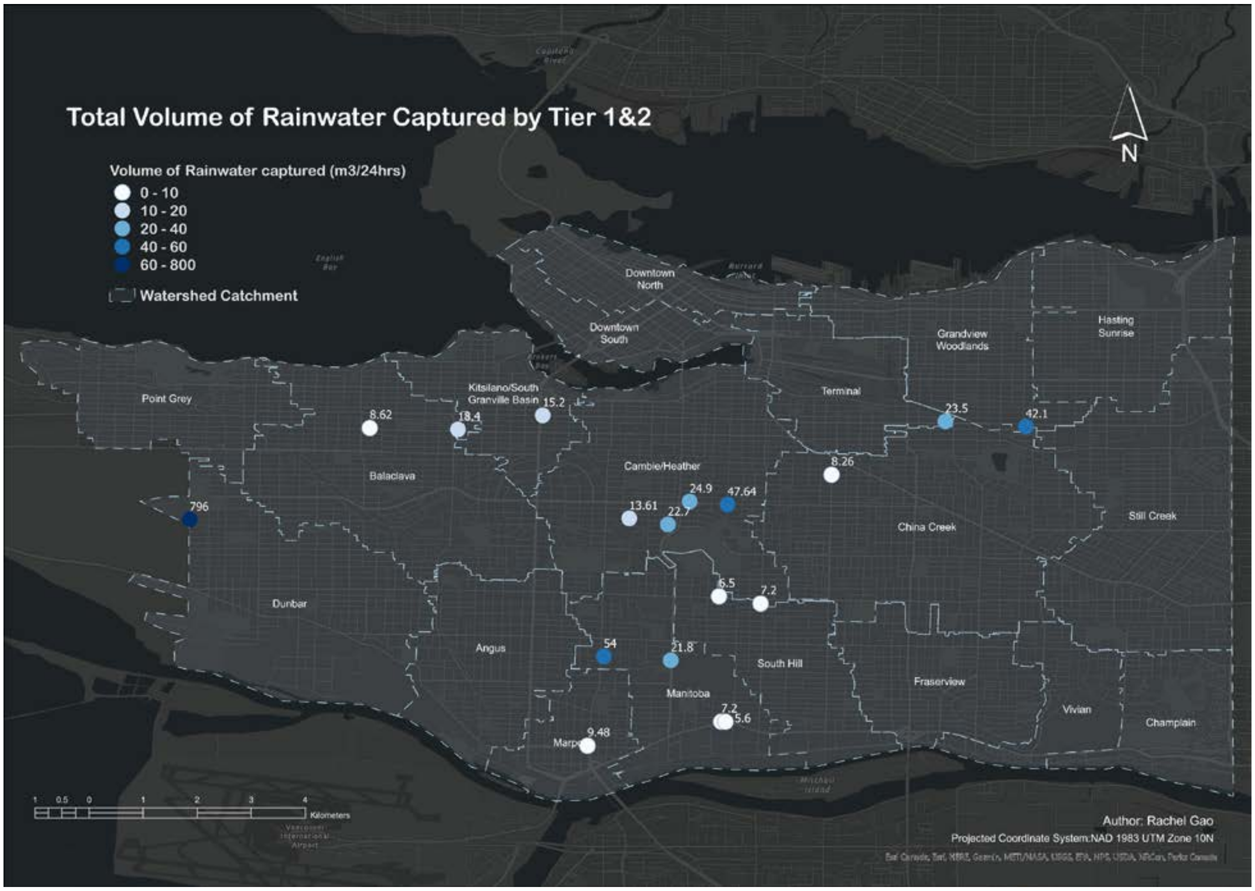


Figure 13. A point overlay that illustrates the total volume of rainwater captured by Tiers 1 and 2 GRI for BP sites.

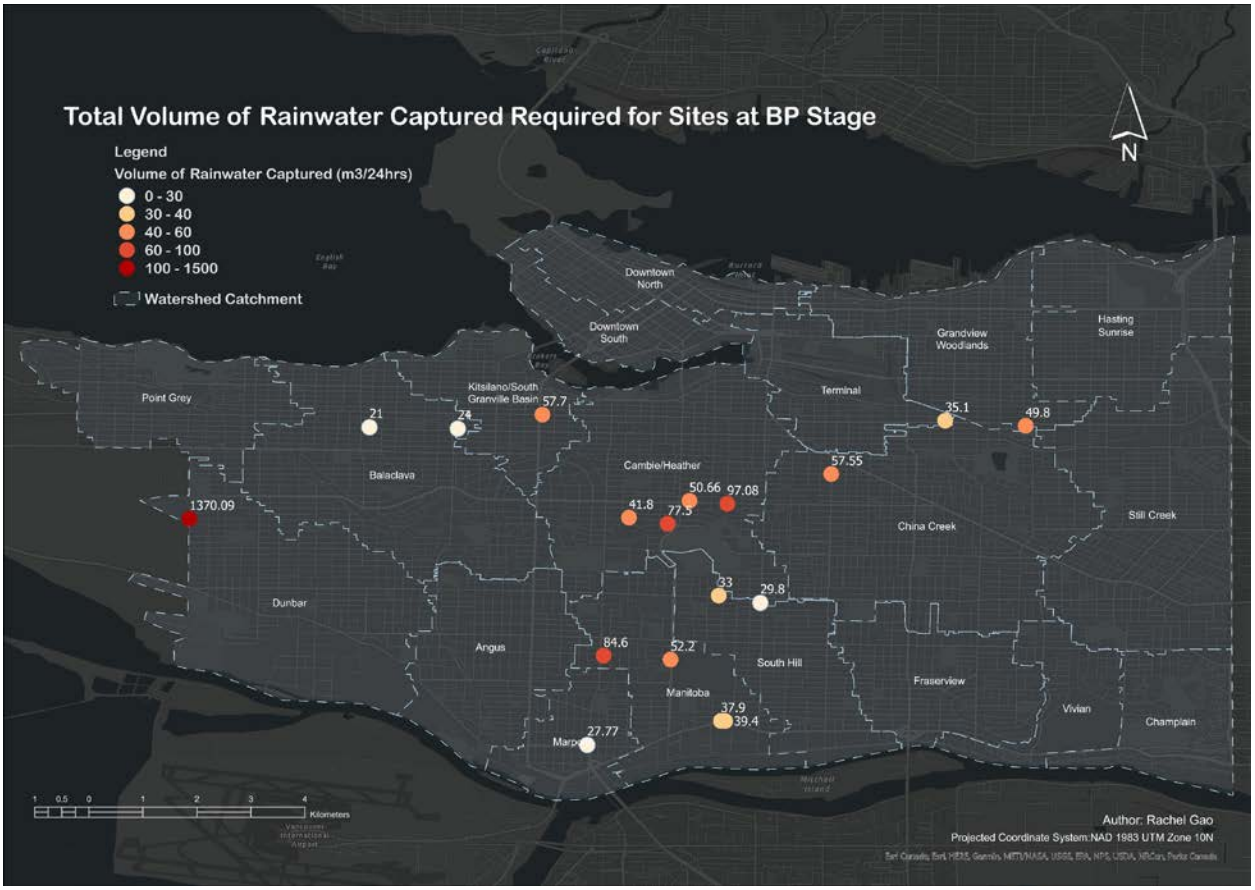


Figure 14. A point overlay that illustrates the total volume of rainwater captured required for BP sites, which is capturing first 24mm of rainfall onsite, as per the *Rainwater Management Bulletin*.

Display Method and Rationale

Both volumes of rainwater captured were displayed as graduated colour points using the number of different types of GRI in each site.

Both total volumes of rainwater captured were shown from high to low using a dark to light blue and red colour scheme. This display method allows users to visualize the general comparisons of the rainwater captured for each site at BP stage.

Figure 15 below shows the percentage of total rainwater captured by Tier 1&2

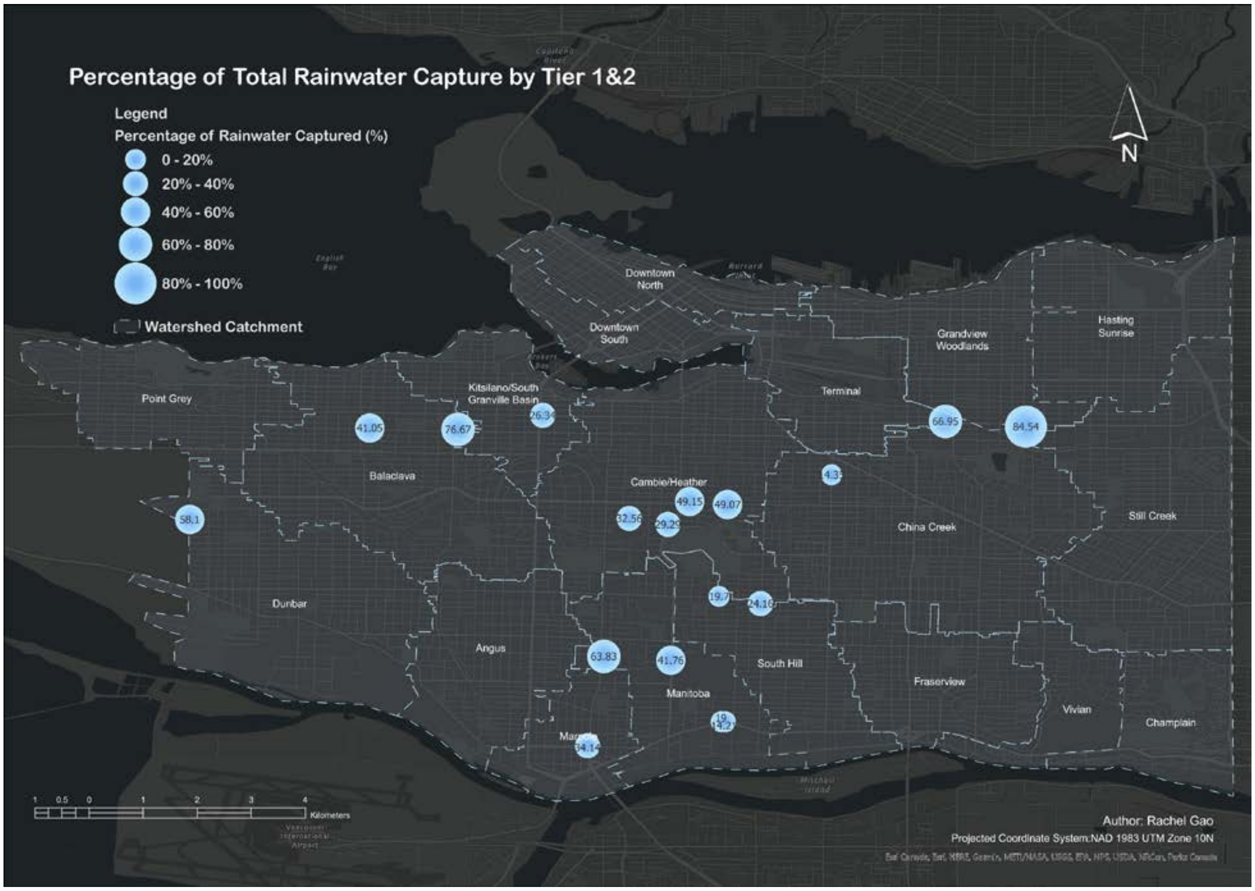


Figure 15. A point layer that represents the percentage of total rainwater captured by Tiers 1 and 2 GRI for BP sites. The percentage of total rainwater captured is calculated by taking the total volume of rainwater captured by Tiers 1 and 2 for a site and dividing it by the total volume of rainwater captured required for that site.

Display Method and Rationale

This layer is displayed as graduated size points based on the percentage of rainwater captured by Tiers 1 and 2 out of the total required rainwater captured for each site. This display method could help people see the differences in the percentage among the sites.

Findings and Highlights

Figure 16 below shows the comparison between the rainwater captured by Tiers 1 and 2 and the rainwater captured by Tier 3. The blank sites in the bar chart are the ones that have no related data. Approximately half of the sites utilize Tiers 1 and 2 capture to collect over 50% of the rainwater. As a general trend, the sites with larger areas have more GRI proposed and can capture more rainwater through Tiers 1 and 2 than the sites with smaller areas, as they generally have less GRI onsite that can infiltrate (partially and/or fully). However, St. George's Senior School is a special case. This site has the largest lot area but only has a 50% of rainwater captured by GRI. This may because the majority of the site area will be used for buildings and as hard surface amenity space (i.e. playground). Even though the total number of GRI types in St. George's Senior School is the highest, the total area of the GRI is still a small portion relative to the total site area.

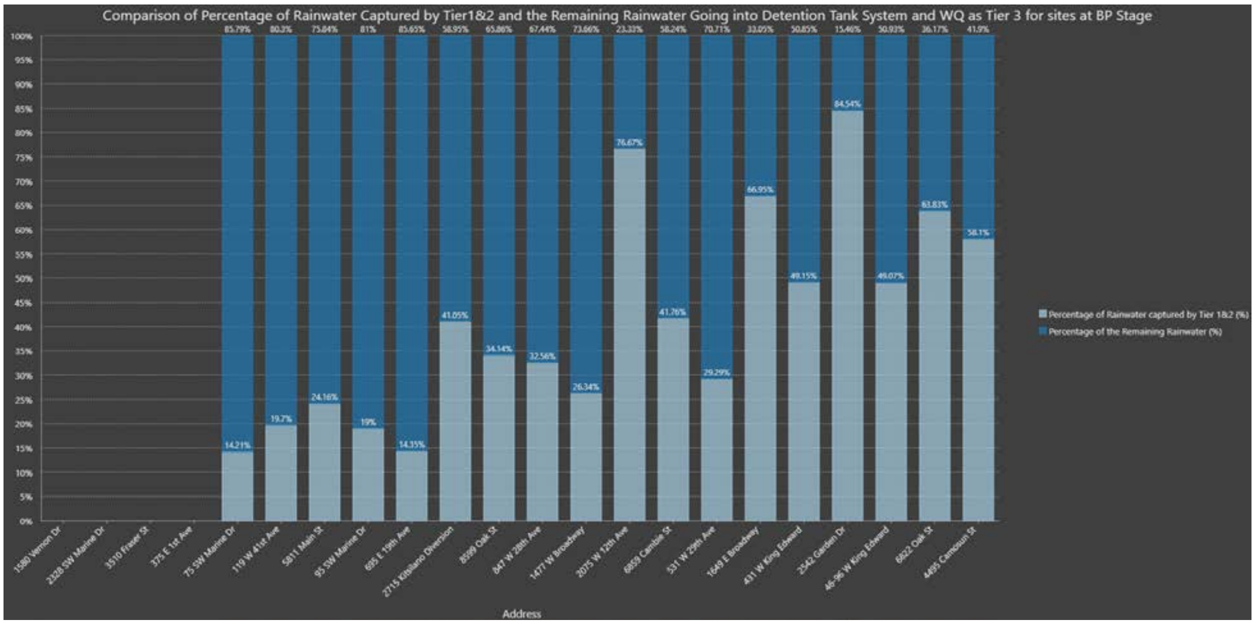


Figure 16. The percentage of rainwater captured by Tiers 1 and 2 against the percentage captured by Tier 3.

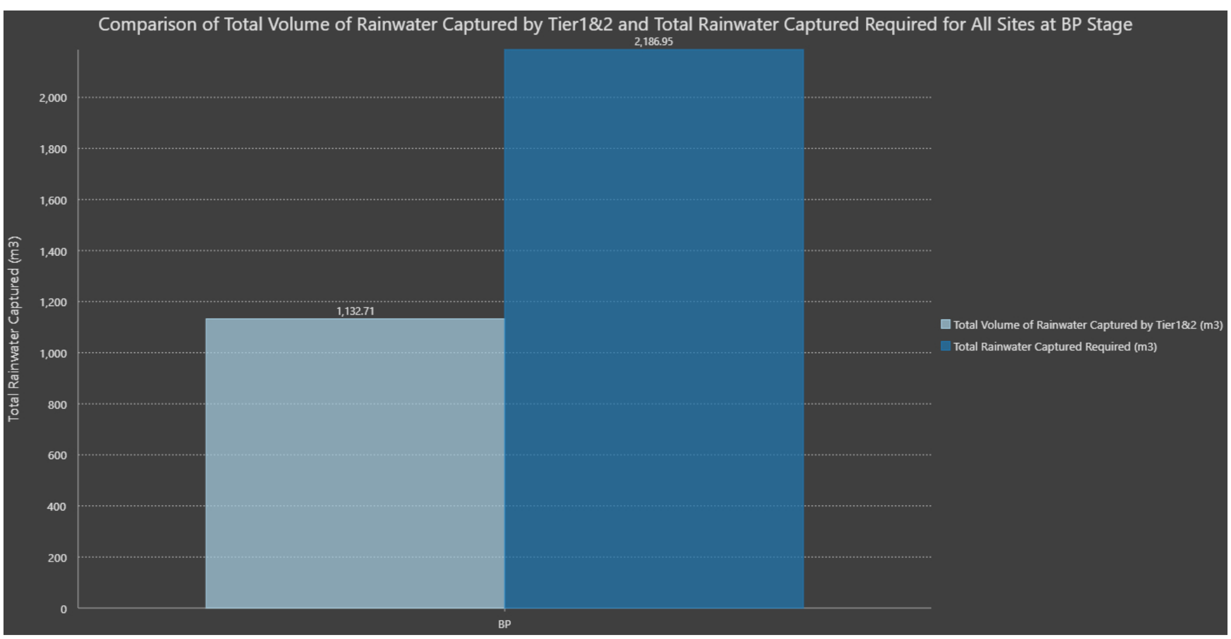


Figure 17. The percentage of rainwater captured by Tiers 1 and 2 compared to the total rainwater capture required as per the *Rainwater Management Bulletin*.

Figure 17 shows the total capture required as per the *Rainwater Management Bulletin* for all twenty-two sites in comparison to the total volume retained using Tiers 1 and 2 for these sites. The chart shows that on average developers have proposed to capture only about half of the required rainwater captured volume.

Figure 18 and 19 below show charts that indicate relationships between the averages of the total rainwater captured by Tiers 1 and 2 and the land uses and building typologies.

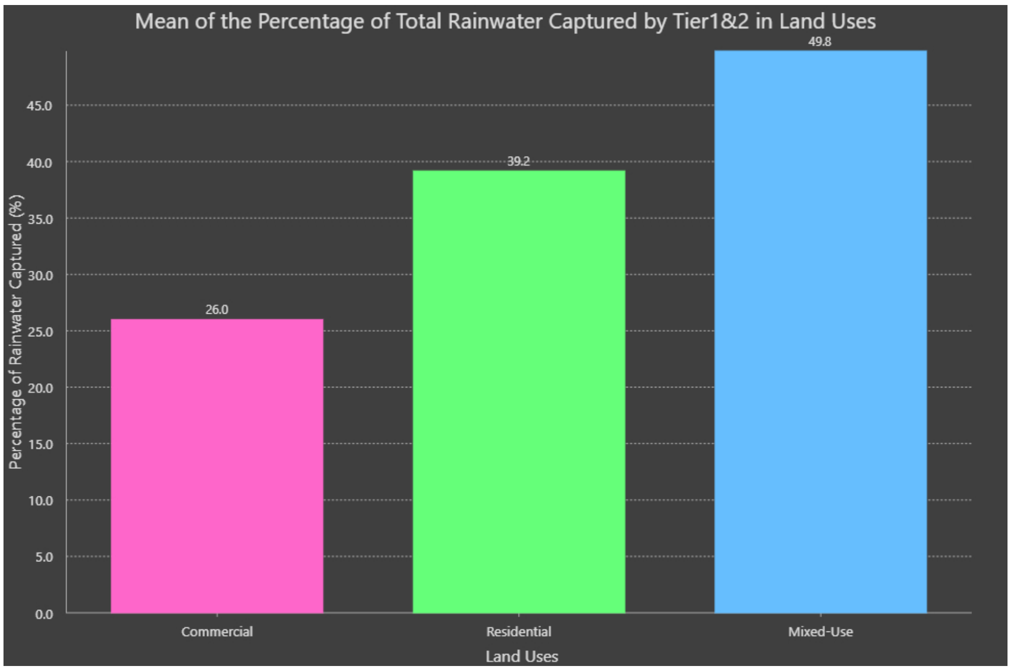


Figure 18. The mean of the percentage of total rainwater captured by GRI in land uses.

Figure 18 demonstrates that mixed-use sites have the highest average percentage (49.8%) of the volume of rainwater captured by Tiers 1 and 2, followed by the residential land uses sites (39.2%). The commercial site has the lowest percentage (26.0%).

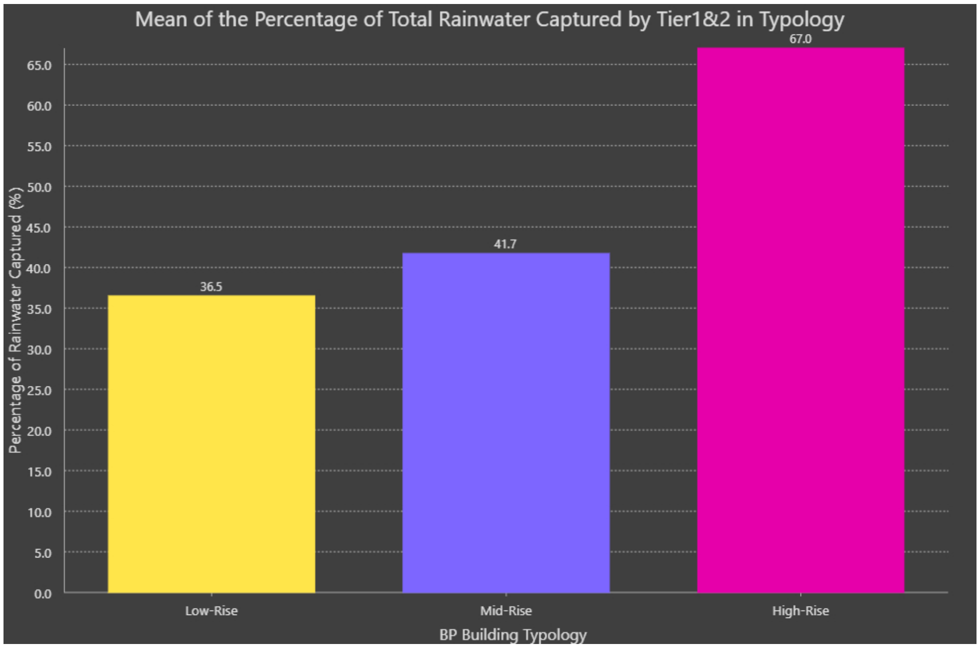


Figure 19. The mean of the percentage of total rainwater captured by GRI in typologies.

Figure 19 shows a similar relationship between the average percentage of total rainwater captured by Tiers 1 and 2 and their building typologies. The high-rise building has the highest average percentage (67.0%), with mid-rise (41.7%) and low-rise buildings (36.5%) having relatively similar values.

The commercial land use is showing only 26%. This may be because there is only one site observed as commercial land use (see Figure 6), and there are also only two sites identified as high-rise buildings (see Figure 8). Therefore, it can be inferred that these two factors lack an adequate sample size and as a result the mean percentage for each is skewed in comparison to other types of land uses and building typologies. However, it is anticipated that these numbers or trends will change as more reviews are completed and added to the database in future.

5.9 Pre-development versus Post-development Site Condition.

The comparisons of pre-development and post-development conditions for sites at the BP stage are shown below. Note that the application for 2328 SW Marine Drive was withdrawn so there is no related data for this site.

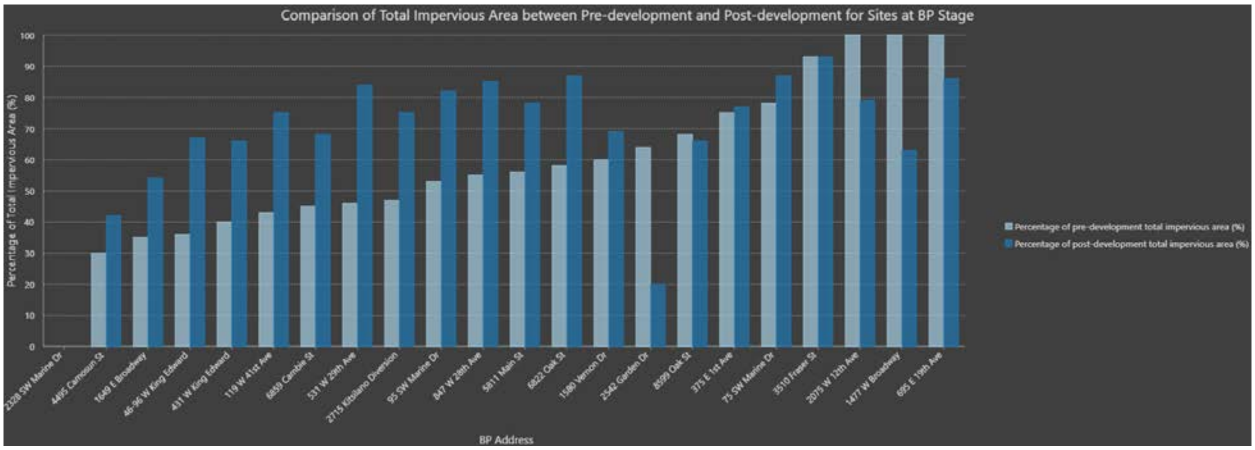


Figure 20. A comparison of the impervious area between pre-development and post-development for BP sites.

Figure 20 illustrates the differences in the total impervious area between pre- and post-development condition. As per the figure above, there are five sites that have decreased impervious area for proposed development, in which three in particular have 100% impervious for pre-development condition. This is due to the fact that the sites consist of all buildings and parking lot with little to no space for landscape area. Only one site (3510 Fraser St) has retained the percent perviousness and majority of the sites have increased the impervious areas for proposed development.

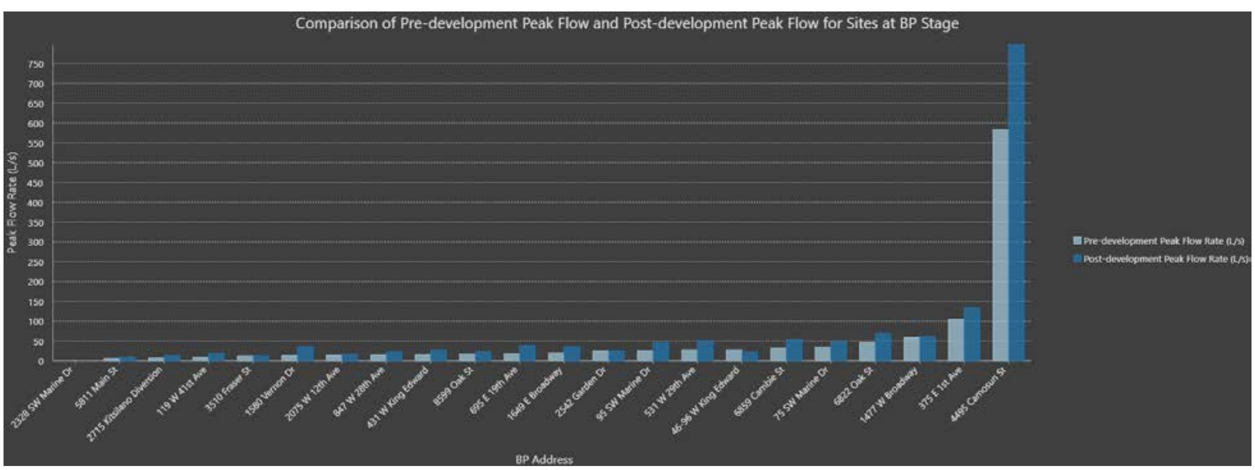


Figure 21. A comparison of the peak flow rate between pre-development and post-development for BP sites.

According to Figure 21, the post-development peak flow rates are always greater than the pre-development peak flow rates at all sites. Pre- and post-development peak flow rates are calculated for each site based on site-specific parameters. The peak flow rates calculated provide an understanding of how intense the runoff discharge would have been at post-development condition if rainwater is not managed onsite through GRI implementation.

5.10 Special Attributes

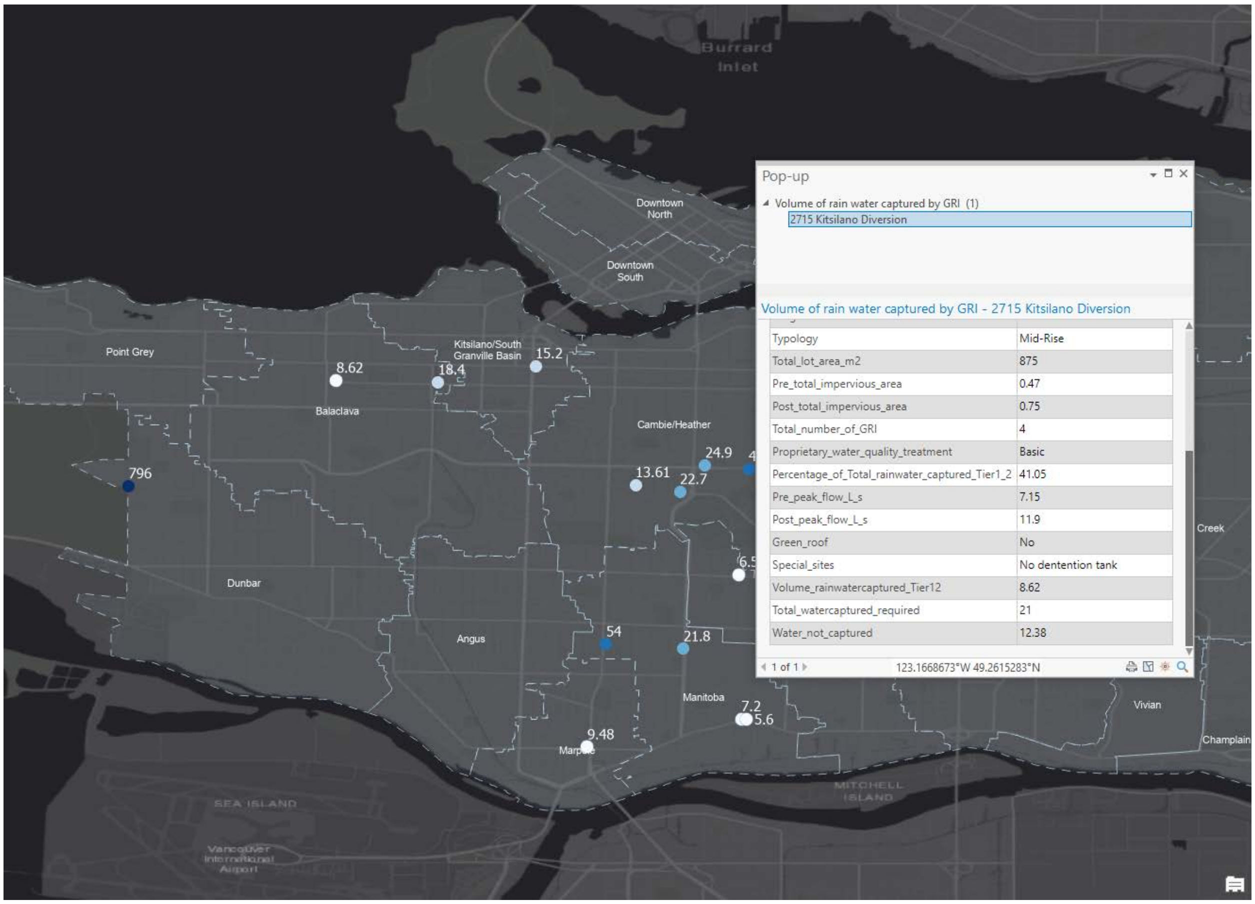


Figure 22. An example of the pop-up table within the mapping overlay.

Besides the main metrics of the analysis discussed above, there are also some special and unique characteristics for certain sites, which have collectively been identified as special sites.

There are a total of fifteen special sites: one application that was withdrawn; one site that is a temporary modular building; two sites with no detention tank; four sites with no Tier 1 GRI proposed; and eight sites that have proposed a green roof on-site. All of these special sites include unique information that is of interest to City staff.

Display Method and Rationale

The pop-up table enables people to have quick access to all the information related to the site, including all of the metrics that have been discussed in previous sections.

6.0 Summary

In conclusion, based on the analysis of the twenty-two BP applications with GRI on-site, it can be stated that the number of GRI proposed for a site are correlated to the site's characteristics, and can be either restricted or promoted by the sizing of a lot, the land uses proposed, and the specific building typology. The findings indicate that more GRI on-site leads to less impervious area, more rainwater being captured on-site, and lower overall flow rate when being discharged.

Based on the twenty-two building permits that have been studied in this project, it can be said that in general:

- low-rise buildings have more GRI proposed;
- commercial and mixed-use buildings have a higher average number of GRI proposed;
- sites with larger lot areas have a greater number of GRI that are bigger in size; and
- Cambie Corridor has the greatest number of GRI assets when compared to other watersheds in the southeast and northwest Vancouver.

Provided this, it is the author's opinion that the increase in GRI assets in private sites will help the City to lower the amount of water entering combined sewers, which in turn will reduce the outflow of stormwater into the urban watershed and ocean from potential overflow events.

It is important to note that this project also has some limitations in its findings. As previously mentioned, this project only focuses on the twenty-two BPs since May 3, 2021, which in turn may influence the resulting information due to the limited number of datasets that were tracked. It is expected that these results will change when more permits are added into the database and tracked in ArcGIS, which will then provide more accurate and representative trends for the analysis. By continuing to track the data in ArcGIS, the City will be better positioned to manage future policies. If this work is to continue, the GIS overlay can be used as a mapping tool for cataloguing and visualizing GRI assets on private sites, in addition to an engagement piece for communicating the benefits of GRI to both internal and external stakeholders. There is also a potential for this project to be incorporated into a future update of VanMap as a layer for information-sharing purposes.

7.0 References

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