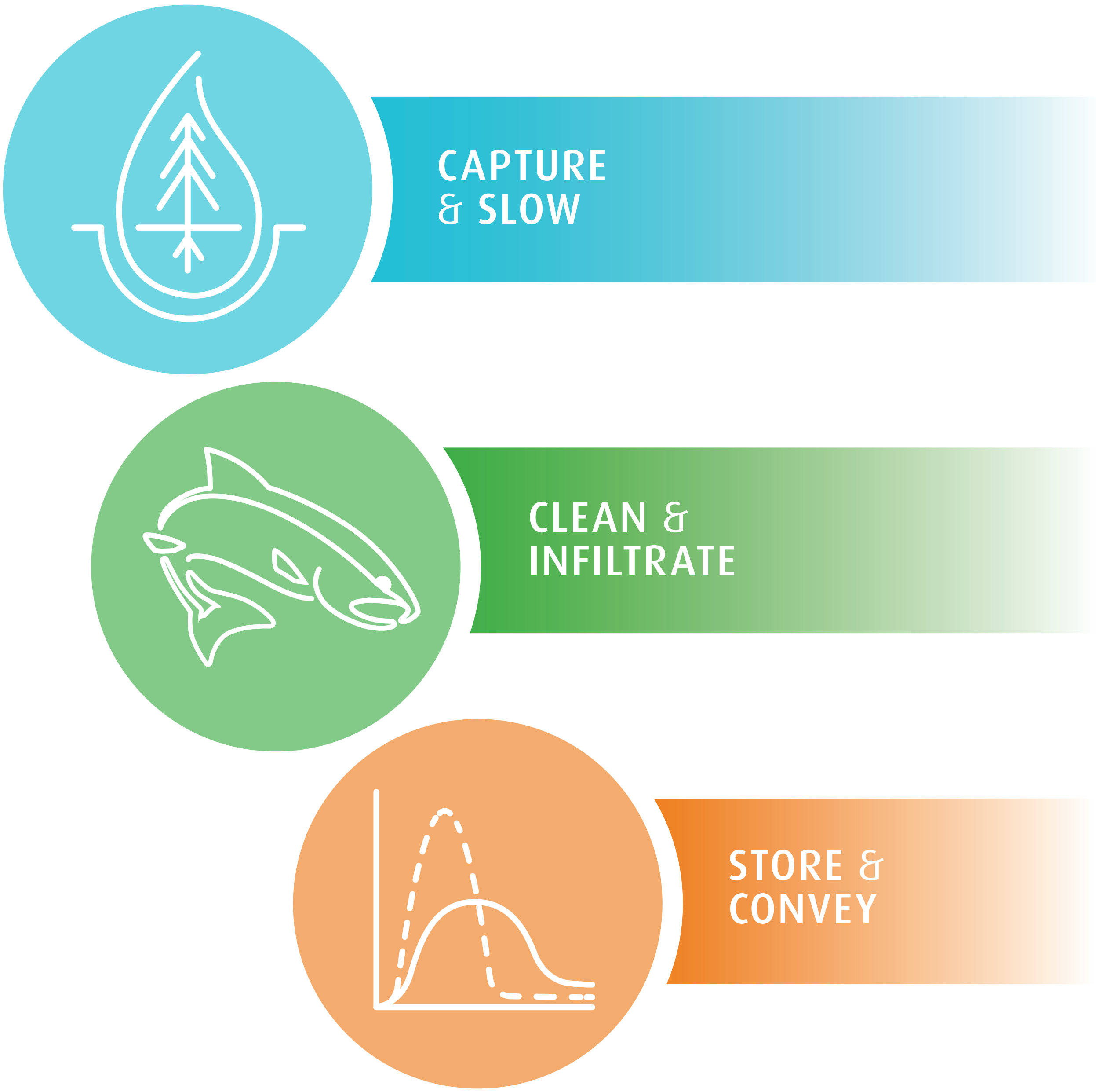
Green Stormwater Infrastructure Common Design Guidelines

FOR THE CAPITAL REGION



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APPENDICES AND SUPPLEMENTAL

Note: The appendixes and supplemental documents, will be periodically updated to keep up with advances in research and practice by adding additional GSI facility design guidelines appropriate for the region.

Forward

This resource was created at the request of the Capital Regional District's Integrated Watershed Management – Inter-Municipal Group. The purpose is to present a breadth of regionally appropriate design guidelines and considerations to build Green Stormwater Infrastructure (GSI) facilities on public, private and institutional lands. The primary audience of this resource is local governments and those qualified professionals, developers and building contractors considering or building GSI facilities. With permission from Metro Vancouver Regional District much of this document is based on Metro Vancouver's Stormwater Source Control Design Guidelines 2012 and has been modified and enhanced to be updated and regionally appropriate.

Disclaimer

The design guidelines contained in this resource are not to be used as design standards – before starting please check with the respective local government for design specifications, regulations and jurisdictional authority. These guidelines do not supersede any applicable laws, bylaws, criteria or regulations. At all times, the designer remains responsible for detailed design and satisfactory operation and performance and must meet all Federal, Provincial and Local government requirements.

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Acknowledgments

The technical design guidelines presented in the resource were written, or with permission modified and adapted, by **Opus International Consultants Limited**. **Kerr Wood Leidal Associates Ltd**. provided the technical drawings. **Colquitz Engineering** provided guidance with Part 1, Part 2 and Appendix A.

The CRD and the CRD's Integrated Watershed Management – Inter-Municipal Group would like to thank the following consultants and governments for granting permission to compile, adapt and modify their stormwater management documents for this collaborative document.

- Metro Vancouver - Stormwater Source Control Design Guidelines 2012, written by Lanarc Consultants Ltd., Kerr Wood Leidal Associates Ltd. & Goya Ngan, Landscape Architect.
- District of Saanich Stormwater Management Guidebook (2011, Unpublished Draft), technical aspects by Kerr Wood Leidal Associates Ltd. and Murdoch de Greeff Inc.
- City of Victoria, Rainwater Management Standards – Professional addition (June 2015)

Thank you to RBC Blue Water Project grant for in part funding the creation of this document.

Executive Summary

This resource presents a variety of regionally appropriate Green Stormwater Infrastructure (GSI) design guidelines and implementation considerations. GSI offers local governments an innovative stormwater management tool to help meet legislative responsibilities to protect natural receiving environments from impacts of stormwater, and can also be utilized as a climate change adaptation tool to protect property and infrastructure, while creating climate resiliency.

Working in conjunction with grey infrastructure, GSI can allow for replenishing of groundwater and interflow; reduction of property damage caused by flooding; protect waterways from storm events and summer low flows; protect aquatic habitat; and improve water quality in receiving environments.

GSI facilities are designed to:

Capture & Slow > the flow of stormwater by re-directing it to naturalized facilities with safe dispersion.

Clean & Infiltrate > stormwater runoff before it reaches the natural receiving environments.

Store & Convey > stormwater to minimize peak flows in heavy rain events and for safe conveyance in the piped and natural storm drain system.

Part 1 – Background – Solving Stormwater: Introduces the purpose and intended audience, along with GSI regional implementation considerations, drivers, principles, benefits, jurisdictional roles and tools.

Part 2 – GSI Application: Outlines the application of GSI via the design process, selection of the GSI drivers, and provides the rainfall targets required for proper sizing of a facility with other design resources to be considered.

Appendices and Supplementals: Numerous appendices make up the bulk of this document with design guidelines for a breadth of regionally appropriate GSI facilities for application on road-right-of-way, private, institutional and public properties. Each GSI design guideline presents design, siting, sizing, contaminant and runoff reduction, and maintenance considerations that are required for properly functioning facilities that work to clean, infiltrate or detain for the safe delayed or slowed conveyance of stormwater. The appendices also include a planting resource for vegetated GSI facilities and regional considerations for potential unintentional interactions with sanitary sewers.

The common design guidelines contained in this resource are not to be used as design standards.

Before starting, please check with the respective local government for design specifications, regulations and jurisdictional authority. The appendices will be periodically updated to keep up with advances in research and practice by adding additional GSI facility design guidelines appropriate for the region. The most up-to-date version of this document found at: www.crd.bc.ca/education/green-stormwater-infrastructure

Part 1 – Background – Solving Stormwater

1.0 Introduction

Solving stormwater is about better management of stormwater volume and quality. As the communities across the capital region continue to grow, densify and become more connected by roads, there is a mounting loss of forest and wetland, with impervious surfaces becoming a larger percentage of the land use cover. This has altered the natural hydrology of the watersheds and has a negative impact on the proper function and health of the fresh and marine aquatic systems that function as natural receiving environments of stormwater.

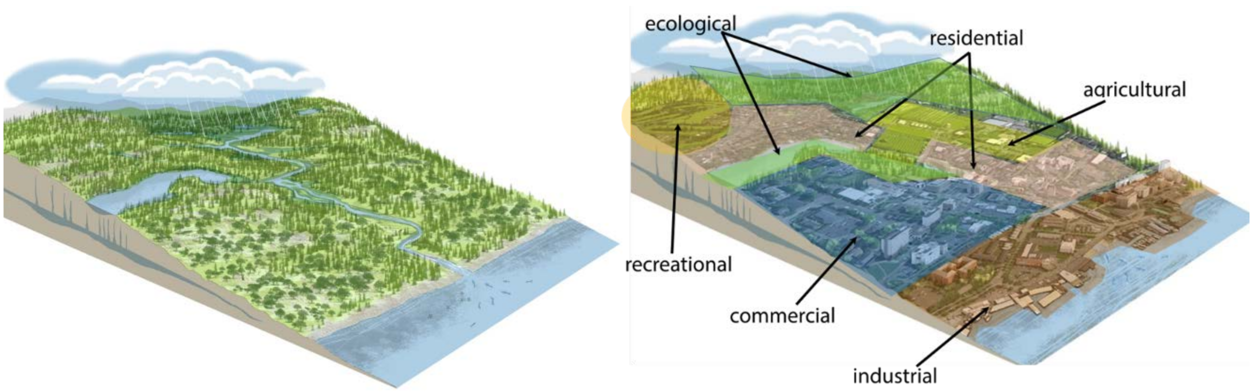

Figure 1 Natural Watershed vs. Developed Multi-Use Watershed

In addition, aging infrastructure and the impacts of climate change are expected to amplify the current stressors on stormwater drainage systems and overall watershed health and function. Because watersheds cross local government borders, how each respective community is designed has a direct effect on the health of shared waterways and marine environments through stormwater runoff quality, quantity and rate of discharge.

This resource presents a wide selection of regionally applicable design guidelines for Green Stormwater Infrastructure (GSI) facilities that are suitable for road Right-Of-Ways (ROW), or on public, commercial, residential or institutional properties of various parcel sizes. GSI can be integrated as a retrofit, re-build or in new developments. Where appropriate, GSI facilities may be considered as standalone facilities, or as part of a treatment train system (sequence of multiple treatment facilities) integrated into a fully green or traditional grey storm drain system. It is the responsibility of the Qualified Professional (i.e., Professional Engineer, Professional Landscape Architect) to insure that techniques utilized are appropriate for a given situation.

1.1 About this Resource

GSI offers local governments an innovative stormwater management tool to better meet legislation to protect the aquatic receiving environment and human health from stormwater impacts, and prepare for the impacts of climate change. GSI facilities should be designed to address volume reduction (capture and slow), water quality (clean and infiltrate) and rate control (store and convey) design drivers, via proper sizing of GSI facilities. This resource showcases an array of regionally specific common design guidelines for GSI facilities.

The design guidelines for each facility in this resource identifies design, siting, sizing, contaminant and runoff reduction, and maintenance considerations required for properly functioning facilities that work to clean, infiltrate or detain for the safe delayed or slowed conveyance of stormwater.

Please refer to www.crd.bc.ca/education/green-stormwater-infrastructure for the most current version of each appendix, as dated on the front page.

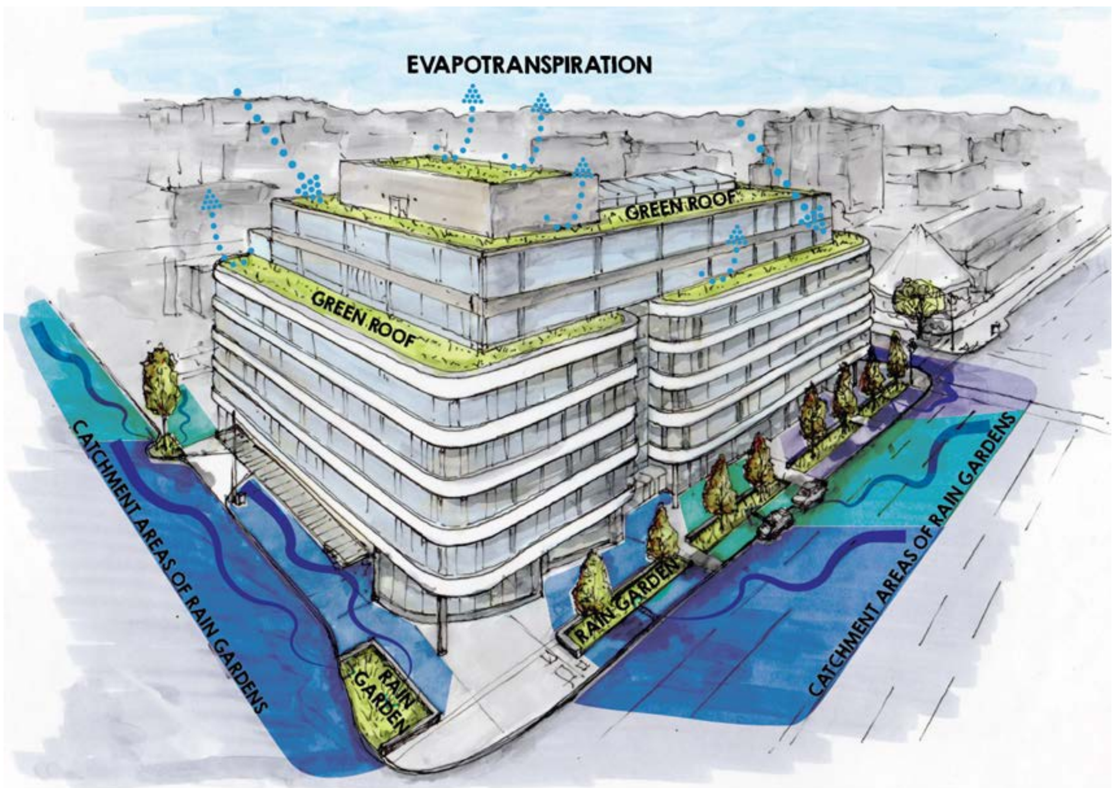

Figure 2 Illustration of GSI Implemented at the Atrium, Victoria, BC

1.2 Intended Audience

1.2.1 Primary Audience

1. Local Governments – involved in funding and making decisions about municipal infrastructure and stormwater management including: elected officials, municipal managers, planners, engineers, technical and maintenance staff, and community associations.
2. Qualified professionals, developers, building contractors and maintenance workers – involved in planning, designing, constructing and maintaining GSI facilities on public or private lands.

1.2.2 Secondary Audience

1. Commercial, Institutional & Multi-Residential property owners, managers and operations staff interested in GSI on their property – small to large properties, urban to rural parcels.
2. Residential Land Owners interested in GSI on their property – small to large properties, urban to rural parcels, interested in GSI on their property.

1.3 Solving Stormwater

How communities in the capital region develop and manage stormwater volume, rate and quality, has a direct effect on the ecological health and function of the region's shared watersheds, waterways and shorelines.

Whether at a property, neighbourhood, urban catchment or watershed scale, land development negatively alters the natural hydrological cycle. When trees, other natural vegetation and soils are replaced with storm drain pipes and impervious surfaces (rooftops, paved roads, parking lots and compacted and waterlogged soils), less rain infiltrates into the ground and more runs off becoming stormwater.

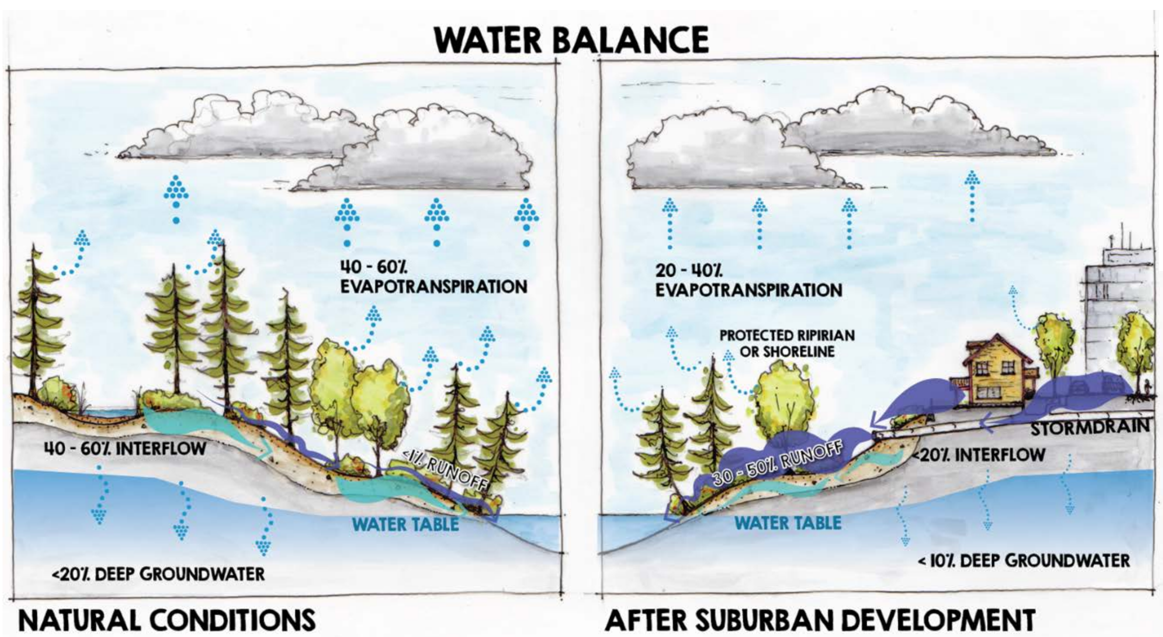

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Figure 3 Water Balance

This alteration of the hydrological cycle results in less water infiltrating into the landscape and too much stormwater too quickly being conveyed by storm drains directly into waterways and shorelines. The volume and speed and contaminants carried within the stormwater causes degradation of these natural receiving environments. The traditional grey (piped) infrastructure is designed to move stormwater off the impervious surfaces and away from the built environment as quickly as possible. Much of this piped (grey) system typically provides only minimal removal of contaminants captured by catch basin and oil/grit separators (when well maintained) throughout the catchments. Much less common are proprietary end-of-pipe stormwater treatment devices. Thus, most contaminants in stormwater are transported to the natural receiving environments, further impacting water quality for aquatic species and human recreational values.

1.4 What is Green Stormwater Infrastructure?

GSI facilities are designed to intercept, slow, treat and store stormwater runoff directed from impervious surfaces. By design, these facilities primarily work by mimicking natural (undeveloped) hydrology through bioretention (soil-water-plant interactions), infiltration or detention.

GSI facilities presented in this guidebook are generally smaller, decentralised, site-specific alternative stormwater management facilities for public lands such as parks and ROW, private, commercial and institutional lands in the ultra-urban to rural setting. Depending on the site-specific conditions and municipal requirements, these GSI facilities may or may not be required to be connected to the piped storm drainage system. Opportunistically, GSI may be designed for new development and retrofitted into existing or redevelopments.

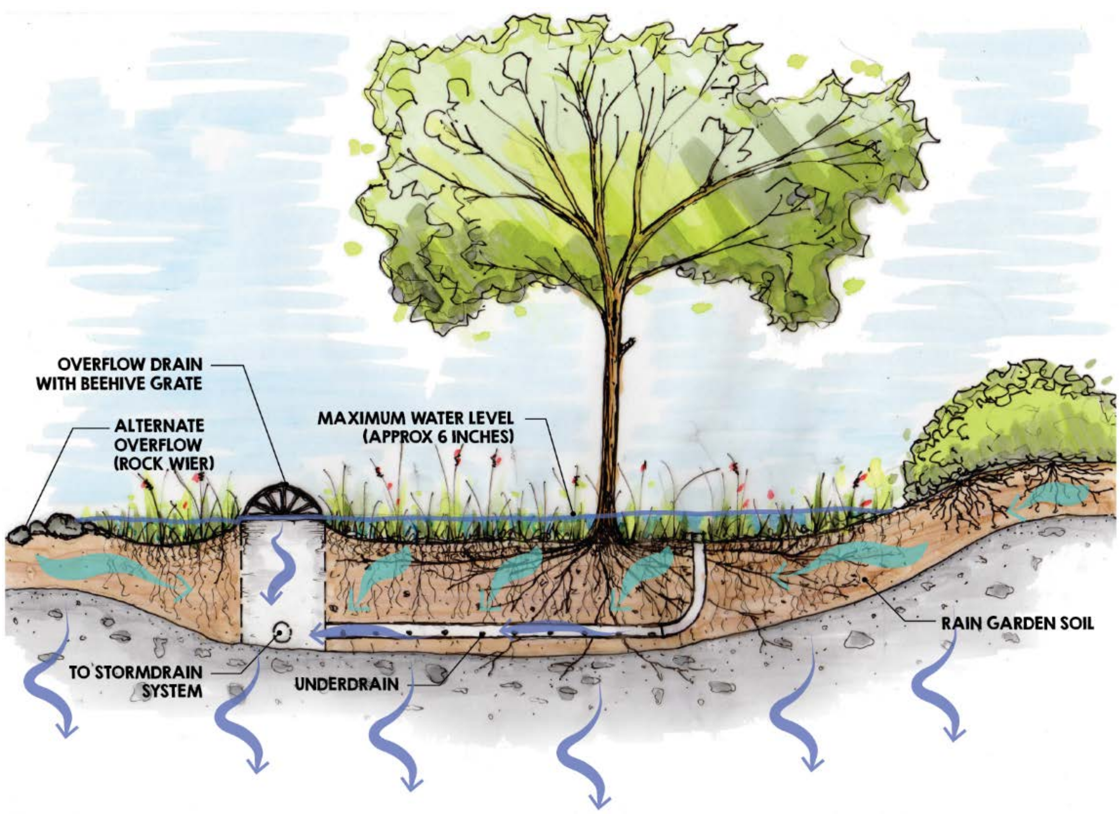

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Figure 4 Cross Section of a Rain Garden

1.5 Objectives of Green Stormwater Infrastructure

The objective of using GSI facilities as a part of a stormwater or integrated watershed management strategy is to effectively protect local watersheds, and ultimately the marine receiving environment, through reducing stormwater contamination and improving overall watershed function. GSI facilities strategically placed throughout communities and watersheds can effectively remove nutrients, pathogens and trace metals from stormwater, and reduce the volume, rate, duration and intensity of stormwater flows as close to the source as possible (i.e., where rain falls on impervious surfaces). Careful selection and placement of a GSI facility many have significant social, economic and environmental benefits.

1.6 Design Drivers of Green Stormwater Infrastructure

On a site-by-site, neighbourhood or watershed scale, GSI aims to address the impacts of stormwater by better managing stormwater where it is being generated. Working in conjunction with, or an alternative to, grey infrastructure, GSI can provide green space, allow for reduction in potential property damage caused by flooding, protection of waterways and aquatic habitat from high flow storm events and seasonal low flows, and replenish groundwater. GSI drivers can help address stormwater stressors on both the natural environment and grey infrastructure through site-specific design.

GSI facilities are designed to:

Capture & Slow the flow of stormwater by re-directing it into naturalized facilities with safe dispersion;

Clean & Infiltrate stormwater runoff before it reaches natural receiving environments; and

Store & Convey stormwater to minimize peak flows in heavy rain events and for safe conveyance in the piped and natural storm drain system.

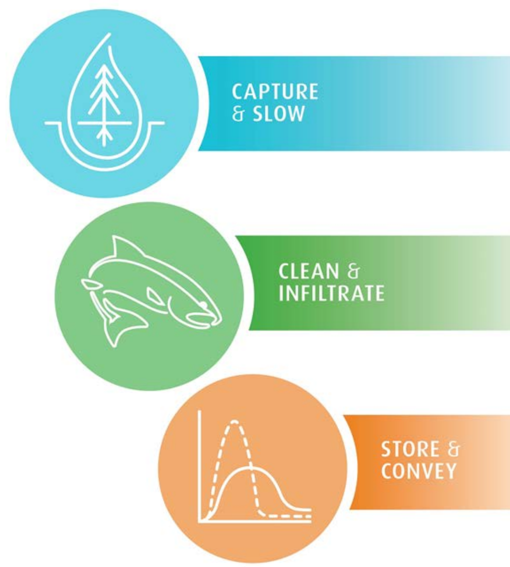

Figure 5 GSI Design Drivers

1.7 Principles for Effective Planning of GSI Facilities

1. Mimics Natural Hydrology
2. Integrates Facility into Overall Site Design
3. Provides Reliable Pollutant Removal Performance
4. Manageable Maintenance
5. Attractive Community Amenity
6. Delivers Multiple Community Benefits
7. Provides Learning Opportunity for Future Improvement
8. Recognizes Accumulative Environmental Benefits
9. Reduces Infrastructure Costs
10. Acceptable Life Cycle

1.8 Benefits of GSI

- Reduce water quality guidelines exceedances
- Reduce levels of contaminants
- Reduce risk of erosion in receiving environments
- Increase protection of sensitive aquatic ecosystems
- Reduce sewer overflows
- Increase climate change resilience
- Expand green amenities
- Increase protection of human health
- Reduce flood risk
- Cost effective when opportunistically implemented
- Visually raises awareness of stormwater

1.9 Land Use Cover

Percentage of land use cover, such as forest/trees, agriculture, open green spaces and impervious surfaces in a watershed is a good indicator of the health and function of the watershed and aquatic environments. Regional land use cover data (http://hat.bc.ca/our-blog/urban-forest-stewardship-initiative) indicates that the region is trending towards a continued increase in impervious cover and a decrease in forest cover, at all scales - regional, municipal, watershed, urban catchment, neighbourhood and property scale. Without GSI, the result of development will be an increase in peak runoff rates and a decrease in the ecological health of watercourses. Learn more at:

https://www.crd.bc.ca/education/our-environment/watersheds/watershed-maps-flow-diagrams/watershed-land-cover-maps.

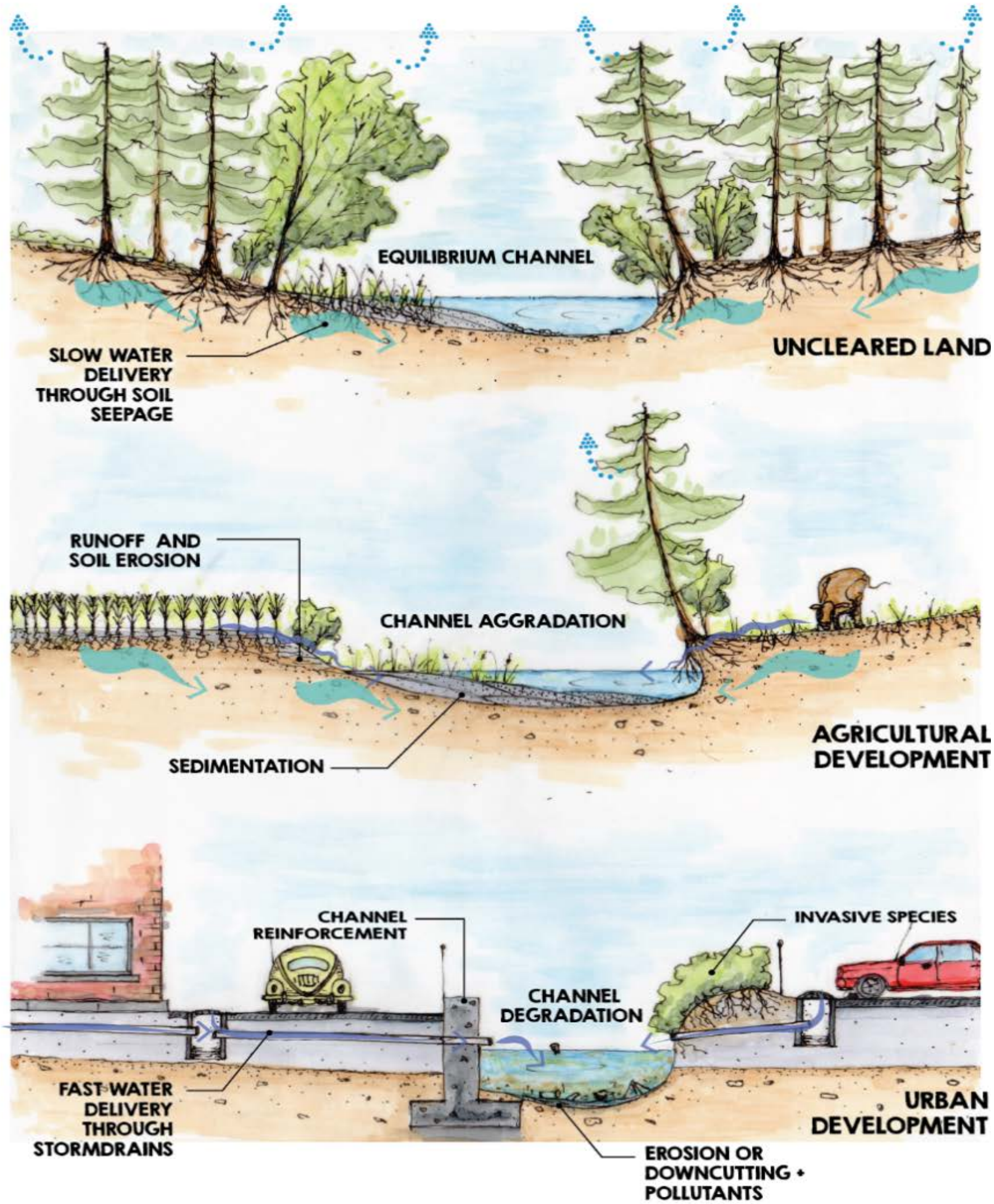

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Figure 6 Impacts of Land Use Cover On a Watershed and Creek

1.10 Climate Change Impacts and Adaptation

In April 2017, the CRD released 2 key resources to assist the numerous stakeholders across the region to prepare for climate change:

- *Taking Action on Climate Change Capital Regional District - Regional Climate Action Strategy*[1], is a region-wide strategic planning document that recognizes the importance of our region's natural environment and the necessity of taking strategic action on climate change to strengthen the resilience of our region as we face uncertainty and;
- *Climate Projections for the Capital Region* (April 2017)[2], is a data-rich technical document with high-resolution regional projections to understand the details of how the region's climate may change by the 2050s and 2080s. The report indicates that climate change is expected to bring increased rainfall volume, frequency and intensity throughout the fall, winter and spring. In the summer, there is an expected decrease in rain with longer duration of dry spells and hotter temperatures. These climate projections will most likely amplify current stressors on the traditional storm drain system and the natural receiving environment. GSI that utilize these projected climate changes can best be implemented opportunistically at site, catchment and watershed scale, as part of a cost effect climate adaptation strategy for stormwater infrastructure that also protects the natural environment from the impacts of stormwater. Appendix A, Table 1 provides regionally specific rainfall capture target amounts required when sizing typical GSI facilities.

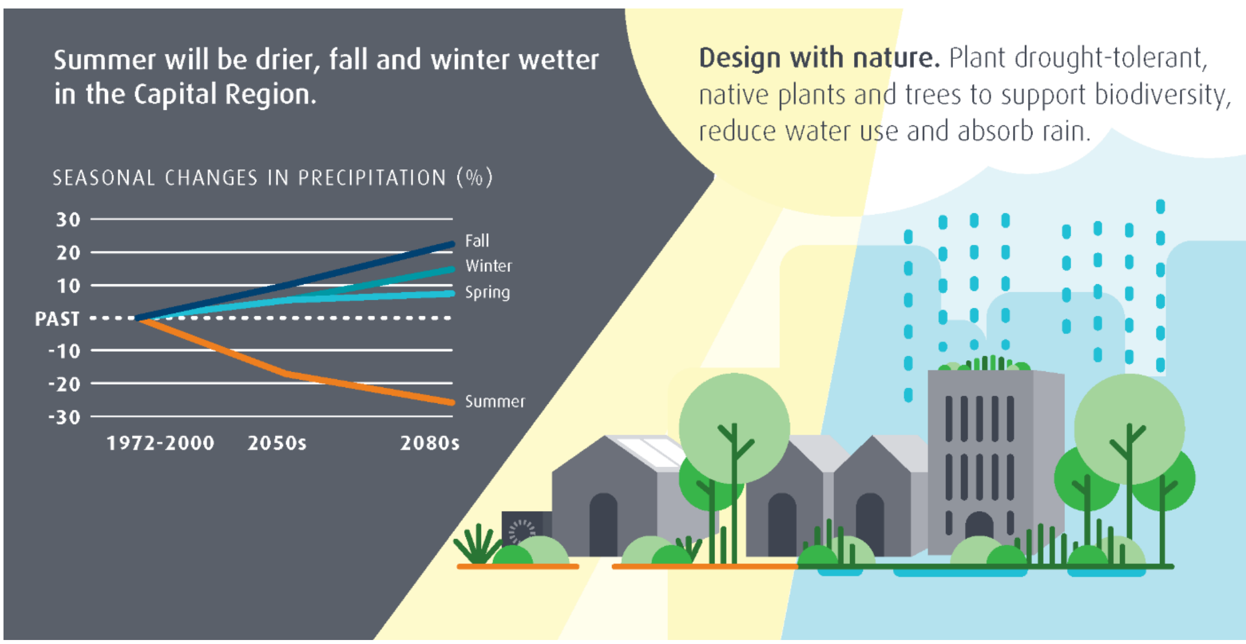

Figure 7 Season Rainfall Projection Illustration

[1] https://www.crd.bc.ca/project/climate-action

[2] https://www.crd.bc.ca/about/data/climate-change

1.11 Stormwater Monitoring

Many common contaminants in stormwater are non-point source pollution from deposits on impervious surfaces and the land, such as metals, nutrients, hydrocarbons, soils and bacteria. These contaminants are transported in stormwater from impervious areas into the storm drain system to natural water bodies and shorelines. A summary of typical stormwater sourced contaminants in freshwater and marine receiving environments are summarized in Table 1.

The CRD's Environmental Protection Division works alongside local governments and Island Health Authority to plan, promote and coordinate the management of stormwater quality with the goal to minimize the impacts from stormwater on the natural receiving environment. Program staff monitor, identify and track the sources of contamination in stormwater, creeks, lakes, harbours and the ocean through bacterial and chemical sampling to ensure that provincial water quality guidelines are met for sensitive aquatic ecosystems and recreational use. In the summer, Island Health Authority monitors public beaches for bacterial contamination. GSI implementation and evaluation is an important tool in contaminant reduction.

CRD annual stormwater quality monitoring reports can be found at:

https://www.crd.bc.ca/about/document-library/Documents/annual-reports/environmental-protection/integrated-watershed-management

The CRD stormwater monitoring program uses the following water quality guidelines:

Sensitive Ecosystem Health Water Quality

British Columbia Ambient Water Quality Guidelines are developed to promote healthy ecosystems and protect human health. Water quality guidelines are science-based levels of physical, biological and chemical parameters for the protection of water uses such as aquatic life, wildlife, agriculture, drinking water and recreation. Learn more at: http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines

Canadian Water Quality Guidelines for the Protection of Aquatic Life provides science-based goals for the quality of aquatic ecosystems. These water quality guidelines are intended to provide protection of freshwater and marine life from anthropogenic stressors such as chemical inputs or changes to physical components (e.g., pH, temperature, and turbidity). Learn more at:
http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/

Recreational Water Quality

British Columbia Recreational Water Quality for Human Health provides science-based goals for the quality of recreational waters used for exercise, play and relaxation to protect people's physical exposure to pathogens and contaminants. Health authorities may sample the water quality of recreational beaches or create reports on recreational water quality concerns to help inform them of any public health risks. At their discretion, they may decide to close beaches, issue public advisories or post warning signs based on these sampling results until the water samples indicate that it is safe to resume swimming in these waters. Learn more at:

http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/recreational-water-quality

Water Quality Objectives

British Columbia Water Quality Objectives are used to manage fresh and marine water quality. Water quality objectives may be developed for specific water bodies to protect water uses in that watershed. Attainment monitoring is used to determine if water quality objectives are being met. Learn more at:

http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives

Flow Monitoring

Several permanent and temporary flow monitoring stations have been installed on creeks throughout the capital region's core area. Once these stations have been installed for sufficient time to develop flow trends, the data will be interpreted and made available upon request.

Table 1 Typical Stormwater Contaminants in Natural Receiving Environments

Contaminant	Parameter Monitored by CRD staff	Typical Source
Solids	Total suspended solids (TSS) Turbidity	sand, silt, soils, decomposing organics, garbage/trash, cooking oil and grease
Bacteria	Fecal coliform *Escherichia coli* (*E. coli*) *Enterococcus*	Cross contamination from domestic sewage system, wild, farm and domestic animal waste, plant or soil material
Metals	Arsenic (total) Aluminum (total and dissolved) Cadmium (total) Chromium (total) Copper (total) Iron (total) Lead (total) Nickel (total) Zinc (total)	Vehicle parts and fluids, industrial waste, domestic waste, naturally occurring and leaching from soils, mineral leaching from metals exposed to weather
Nutrients	Total phosphorus Orthophosphate Nitrate (NO3) Nitrate plus nitrite (NO3 + NO2) Nitrite (NO2)	Fertilizers, farm-animal waste, faulty septic systems, vegetation decomposition
Physical	Temperature Conductivity Salinity Dissolved Oxygen pH	Indicates changes in land-based activities
Organics	Polycyclic aromatic hydrocarbons (PAH)	Combustion engines, petroleum based products, wood stoves

1.12 Jurisdictional Responsibilities for Protection of Stormwater Quality

GSI offers local governments an innovative stormwater management tool to help meet their responsibilities to protect natural receiving environments from impacts of stormwater, and can also be utilized as a climate change adaptation tool to protect property and infrastructure, while creating climate resiliency.

1.12.1 Key Federal and Provincial Legislation

The jurisdictions involved in protection of stormwater quality, either directly or indirectly, include all municipalities, districts, electoral areas, the Capital Regional District, Island Health Authority, the BC Ministry of Transportation and Infrastructure, the BC Ministry of Forests, Natural Resource Operations and Rural Development, the BC Ministry of Environment and the Department of Fisheries and Oceans Canada (DFO). These agencies set guidelines and administer protection of groundwater and surface water for proper ecological function, protection of water quality for the environment, sensitive ecosystem habitat and public health recreational contact.

Table 2 Key Federal and Provincial Legislation Related to Stormwater Management Impacts

Key Federal and Provincial Legislation	Section relevant to stormwater management impacts
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Check with the respective local governments for local bylaws which meets or beats the below regulations.	
Fisheries Act (Federal R.S.C., 1985, c. F-14 – updated 2012)	
Fisheries Protection and Pollution Prevention	35 – Serious harm to fish 36 – Deposit of deleterious substance prohibited 37 – Minister may require plans and specifications if a person carries on or proposes to carry on any work, undertaking or activity that results or is likely to result in serious harm to fish or in the deposit of a deleterious substance in water frequented by fish, ecological significant areas etc. 38 – Duty to notify
Regulations	43 – 1) The Governor in Council may make regulations for carrying out the purposes and provisions of this Act and in particular, but without restricting the generality of the foregoing, may make regulations: (b) respecting the conservation and protection of fish; (h) respecting the obstruction and pollution of any waters frequented by fish; (i) respecting the conservation and protection of spawning grounds; (n) establishing a list of aquatic invasive species; (o) respecting the control of aquatic invasive species, including regulations respecting the prevention of the spread of such species, etc.
Riparian Areas Protection Act (BC – updated 2014)	
	2-11, 36 Repealed 12 – Provincial directives on streamside protection 13 – Regulation-making authority

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Key Federal and Provincial Legislation	Section relevant to stormwater management impacts
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Check with the respective local governments for local bylaws which meets or beats the below regulations.	
Riparian Areas Protection Act Riparian Areas Regulation (B.C. Reg. 376/2004– updated 2014)	
	2 – Purposes of this regulation (a) to establish directives to protect riparian areas from development so that the areas can provide natural features, functions and conditions that support fish life processes, and (b) to facilitate an intergovernmental cooperation agreement between the ministry, Fisheries and Oceans Canada and the Union of British Columbia Municipalities including the ability for individual intergovernmental cooperation agreements with local governments. 3 – Application – this regulation applies within the geographic boundaries of the CRD. 4 – Assessment reports required before development 5 – Development of strategies for monitoring, enforcement and education 6 – Use of local government powers for protection and enhancement of areas 7 – Preparation of assessment report by qualified environmental professional 8 – Transitional – "former regulation" means the Streamside Protection Regulation, B.C. Reg. 10/2001
Water Sustainability Act (BC – new 2016)	
Part 2 — Licensing, Diversion and Use of Water	11 – Changes in and about a stream 15 – Environmental flow needs 16 – Mitigation measures 17 – Sensitive streams mitigation 22 – Precedence of rights 26 – Amendment or substitution of authorization, change approval or permit 30 – Beneficial use 39 – Water reservations
Part 3 — Protecting Water Resources	43 – Water objectives 46 – Prohibition on introducing foreign matter into stream 47 – Remediation orders in relation to foreign matter in stream

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Key Federal and Provincial Legislation	Section relevant to stormwater management impacts
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Check with the respective local governments for local bylaws which meets or beats the below regulations.	
	59 – Prohibition on introducing foreign matter into well 60 – Remediation orders in relation to foreign matter in well Division 4 — Water Sustainability Plans (64-85) Division 5 — Temporary Protection Orders (86-88)
Part 6 — Regulations (124-136)	126 – Regulations respecting administration and governance 127 – Regulations respecting licensing, diversion and use of water and related matters 128 – Regulations respecting sensitive streams 129 – Regulations respecting streams and stream protection 130 – Regulations respecting groundwater and groundwater works 131 – Regulations respecting measuring, testing and reporting 132 – Regulations respecting water sustainability plans
Part 8 — Consequential and Related Amendments	See various
Water Sustainability Act Water Sustainability Regulation (B.C. Reg. 36/2016)	
Division 2 — Sensitive Streams	17 – Sensitive streams designated 18 – Applications respecting sensitive streams 19 – Mitigation requirements 20 – Mitigation measures 21 – Compensatory mitigation measures
Division 4 — Exemptions from Section 6 (1) of Act	31 – Exemption — corridor drainage 32 – Exemption — local government drainage works 33 – Exemption — agricultural drainage

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Key Federal and Provincial Legislation	Section relevant to stormwater management impacts
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Check with the respective local governments for local bylaws which meets or beats the below regulations.	
	34 – Exemption — building perimeter drainage 35 – Exemption — wells 35.1 – Diversion and use of water for firefighting
Part 3 — Changes in and about a Stream	37 – Authority to make changes in and about a stream 38 – Notice to habitat officer 39 – Authorized changes 40 – Limitation on making authorized changes under this Part 41 – Obligations of persons making authorized changes under this Part 42 – Failure to comply with this Part when making authorized change 43 – Protection of water quality 44 – Protection of aquatic ecosystem 45 – Protection of other water users

1.12.2 Local Government Regulatory Tools, Authority and Responsibilities

As watersheds cross jurisdictional borders it is important that upstream and downstream communities work together to minimize the ecological, health, social and financial impacts of stormwater. It is the local governments or respective jurisdictions (e.g., provincial ministries) that own, operate and maintain the storm drain systems that carry stormwater from roads, public or private to the nearest waterway. Within First Nation communities it is a responsibility of the Band Council, in cooperation with Indigenous and Northern Affairs Canada (INAC) and Health Canada, to build and manage stormwater infrastructure and protect receiving environments from the impacts of stormwater. These jurisdictions are responsible for the management of stormwater runoff and to meet the requirements of federal and provincial legislation related to stormwater impacts.

The regulatory tools, authority and responsibility of stormwater management in British Columbia occurs at the municipal level under authority of the Provincial Local Government Act (LGA). Under authority of the LGA, the local governments and the CRD have Liquid Waste Management Plans (LWMP) or area based stormwater quality bylaws or service agreements. These LWMP and bylaws set out a cooperative framework to protect the aquatic ecosystems and public health from the impact of stormwater through stormwater quality monitoring, education, engagement and enhancement. Across the capital region, there are also unique cooperative initiatives between First Nations, neighbouring local governments and the CRD for the management and protection of watersheds and shorelines.

The LGA contains development planning, servicing, financing and approval provisions applicable to stormwater management (e.g., enacting bylaws that encourage more natural drainage or implementation of GSI). Table 3 outline sections of the LGA that can be utilized by local governments as tools to implement GSI and other stormwater management activities.

Table 3 Tools Available Under the LGA for Implementation of GSI and Other Stormwater Management Initiatives

Relevant Sections of the BC Local Government Act Revised 2015	Tools available under the LGA for Implementation of GSI
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Where applicable, check with the respective local governments for enacted local bylaws.	
Part 9: Regional Districts: Specific Service Powers Drainage	Division 3 — Drainage, Sewerage and Related Matters 306 – Special drainage and sewerage authority May, by bylaw, (a) regulate and prohibit the design and installation of drainage works provided by persons other than the regional district, and (b) require owners of real property to connect their buildings and structures to the appropriate drain connections in the manner specified in the bylaw. 306-313 – Defines special drainage authority including: watercourse may be included in drainage system; works for controlling drainage; watercourse agreements between adjoining municipalities or land owners; requirements respecting drainage works and; appropriation of stream channel or bed. 314 – authority subject to *Water Sustainability Act* Division 7 — Other Specific Service Powers 327 – If the regional district provides a service in relation to the control of the deposit and removal of soil and the control of the deposit of other materials, it may regulate removal and deposit of soil or other material on any land in the regional district or in any area of the regional district.
Soil and Fill	The Soil Conservation Act gives local government permitting authority for soil removal and placing of fill. Continued on next page

Relevant Sections of the BC Local Government Act Revised 2015	Tools available under the LGA for Implementation of GSI
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Where applicable, check with the respective local governments for enacted local bylaws.	
Part 10- Regional Districts: Service Structure and Establishing Bylaws	The CRD, on behalf of the participants, provide area based stormwater quality monitoring, watershed based initiatives and education. These services are provided for under: Liquid Waste Management Plans (LWMP) Stormwater Quality Management Establishing Bylaws Harbours Environmental Action Service Establishing Bylaw
Part 13: Regional Growth Strategy	426, 428, 429 – Provides for goal statements that promote human settlement that is socially, economically and environmentally healthy and that makes efficient use of public facilities and services, land, water and other resources. Including reducing water pollution and protecting the quality and quantity of ground and surface waters.
Part 14: Planning and Land Use Management Official Community Plans (OCP)	**Division 4 — Official Community Plans (OCP)** 473 – Content and process must include statements on the restrictions on the use of land that is subject to hazardous conditions or that is environmentally sensitive to development, and the approximate location and phasing of any major road, sewer and water systems. 474 – Policy Statement that may be included may include policies relating to the preservation, protection, restoration and enhancement of the natural environment, its ecosystems and biological diversity.
Development Approval	**Division 6 – Development Approval Information Requirements** 484-487 – by bylaw, may make requirements for development approval information regarding potential impacts of a proposed development on local infrastructure and the natural environment of the area affected. Continued on next page

Relevant Sections of the [BC Local Government Act](#) Revised 2015	Tools available under the LGA for Implementation of GSI
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Where applicable, check with the respective local governments for enacted local bylaws.	
Development Permits	**Division 7 – Development Permits** 488-491 – by bylaw, may designate areas for protection of the natural environment, ecosystems and biological diversity, development from hazardous conditions and protection of farming. Establishment of objectives for the form and character of intensive residential, commercial, industrial or multi-family residential development. This may include requirements and conditions or sets standards within designated development permit area.
Other Permits and Permit Matters	**Division 10 – Other Permits and Permit Matters** 500 – by bylaw, may require tree cutting permits in relation to areas affected by flooding or other hazards
Drainage Collection Systems for Subdivision and Development	**Division 11 — Subdivision and Development: Requirements and Related Matters** 506-510 – by bylaw, may require, regulate and prescribe standards for a drainage collection system or a drainage disposal system be provided, located and constructed in accordance with the standards established in the bylaw. Requirements for excess or extended services means a provision may be requested of developer to provide park land or portion of the costs of the drainage system that will serve land other than the land being subdivided or developed may be required. 506-508 – requires that a drainage collection or management system be provided, located and constructed for subdivisions in accordance with standards established in a bylaw.
Runoff control requirements	523 – by bylaw, may (1) require that an owner of land who carries out construction of a paved area or roof area, manage and provide for the ongoing disposal of surface runoff and stormwater in accordance with the requirements of a bylaw, (2) establish the maximum percentage of the area of land that can be covered by impermeable material and, (3) make different provisions for different zones, uses, areas, sizes of impervious surfaces, terrain, surface water or groundwater conditions.

Continued on next page

Relevant Sections of the BC Local Government Act Revised 2015	Tools available under the LGA for Implementation of GSI
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Where applicable, check with the respective local governments for enacted local bylaws.	
Flood Plains Areas	524 – by bylaw, may designate the land as a flood plain, specify the flood level for the flood plain, and the setback from a watercourse, body of water, etc.
Landscaping	527 – by bylaw, may require, set standards for and regulate the provision of screening or landscaping for preserving, protecting, restoring and enhancing the natural environment, and/or preventing hazardous conditions.
Farming Areas	514 – Land Title Act, and Agricultural Land Commission Act regulates subdivision of lands and minimum parcel size. 552 – local governments, with approval of the Minister of Agriculture and Lands, make bylaws with respect to farm operations, however, this section does not expressly provide for stormwater management. Other relevant Provincial Acts: Farm Practices Protection (Right to Farm) Act Water Sustainability Act
Drainage Service Delivery and Cost Recovery	559 sets out the general requirements under which local governments may charge DCCs which enables local governments to providing, constructing, altering or expanding drainage to service, directly or indirectly, the development for which the charge is being imposed. 570 – Municipal development works agreements with private developers, including works such as drainage.
Part 16 — Municipal Provisions Drainage Works	**Division 4 — Municipal Irrigation Services and Drainage Works** 639 – District/municipal drainage works: District/municipality may collect the water from any highway by means of drains or ditches, and convey the water to, and discharge the water in, the most convenient natural waterway or watercourse. When proposing to construct drains or ditches must publish in a newspaper once a week for 4 consecutive weeks. All claims for damages or compensation arising out of the construction, maintenance, operation or use of the works must be filed with the municipality within 1 month from the date of the 4th publication of the notice. Continued on next page

Relevant Sections of the BC Local Government Act Revised 2015	Tools available under the LGA for Implementation of GSI
This table is for quick reference only and may not be exhaustive. Refer to original legislation. Where applicable, check with the respective local governments for enacted local bylaws.	
Part 18: Legal Proceedings in Relation to Local Governments and Other Authorities Drainage Works	735 – indicates that there is a 6-month statute of limitations in which to lay claim to any damages form the works done. 736 – states that notice must be delivered to the municipality in writing within 2 month from the date on which the damage was sustained. 744 – Immunity in relation to certain nuisance actions, a municipality or regional district, is not liable in any action based on nuisance if the damages arise, directly or indirectly, out of the breakdown or malfunction of a water or drainage facility or system.

Part 2 – Green Stormwater Infrastructure – Application

2.0 GSI Design Drivers

Solving stormwater is about managing stormwater volume and quality from a site to watershed scale.

GSI may be designed for new development and retrofitted into existing or redevelopments. Working in conjunction with, or an alternative for, grey infrastructure, GSI can allow for replenishing of groundwater and interflow, reduction of property damage caused by flooding, protect waterways from storm events and summer low flows, protect aquatic habitat and improve water quality in receiving environments.

GSI facilities are designed to:

Capture & Slow > the flow of stormwater by re-directing it to naturalized facilities with safe dispersion.

Clean & Infiltrate > stormwater runoff before it reaches natural receiving environments.

Store & Convey > stormwater to minimize peak flows in heavy rain events and for safe conveyance in the piped and natural storm drain system.

2.1 GSI Design Process

In any new development, redevelopment or retrofit project on public, private, commercial or institutional lands the design of GSI should be considered as an integrated component early in the design process. This section outlines a design process for GSI facilities – identifying key steps and their arrangement in a typical development process from early planning through to field reviews and monitoring.

The attached appendices present design guidelines with more specific details of design considerations and process for the respective GSI facility.

Table 4 GSI Design Process

Design Stage	Objective
1. Pre-design/early stages of any construction, development, or re-development	Find synergies and save money in public or private new, redevelopment or retrofit projects (i.e., private redevelopment installing a GSI on the ROW, integrating bike lanes with GSI facilities). Determine what documentation and process is required from start to finish.
2. Planning & Stormwater Related Requirements for Site	Identify requirements (respective local government) of a local bylaw or guidelines for design are applicable (i.e., limits to percentage of impervious area or pre-/post-stormwater flow, qualified professional input or design, GSI-related design targets or criteria, etc.) or stormwater management plans for the watershed or catchment area, or as required by jurisdiction (i.e., oil grit separator may be required by your local municipal stormwater bylaw).
3. A. Drivers for GSI B. Stormwater Capture Targets for Site C. Simplified Sizing Approach for GSI facilities	How could implementation of GSI assist in achieving better stormwater management at a site, catchment, watershed and receiving environment scale? Prioritize the 3 drivers for GSI specific to the site. **> Slow – Reduce piped volume with safe dispersion** **> Clean – Provide water quality treatment and infiltration** **> Store – Provide rate control/detention for safe conveyance** Determine expected site rainfall and stormwater capture targets for simplified sizing approach for GSI facility. Identity the current or potential (for new/retrofit developments) "effective" impervious area as the target runoff area for the GSI facility.
4. A. Site Analysis B. Design Considerations & Site Constraints C. Strategies for Dealing with Limited Space	Gather critical data for site: expected rainfall for site, infiltration potential and constraints (depth to ground water, site sloping, proximity to steep slopes, existing vegetation cover, soil mapping, infiltration tests, potential soil contaminants due to historical use of site). Determine the receiving waters and pollutants of concern for that aquatic ecosystem. Analyse the current and proposed land use(s) draining to the GSI facility should also be used to determine the stormwater pollutants of concern. Qualified Professional (i.e., experienced Professional Engineer, Professional Landscape Architect) is advised and may be required. Continued on next page

Design Stage	Objective
5. GSI for Contaminant Reduction & Treatment Trains	Examine performance of GSI facilities for site-specific-receiving water body contaminant reduction. Would the site benefit from stormwater treatment trains (i.e., sequence of multiple stormwater treatments)?
6. Detail Design of GSI	Design and size GSI facilities. Create technical details in plan, cross section and profile. Incorporate GSI facilities in construction and maintenance specs. The GSI design guidelines in this resource are not to be used as design standards – before starting please check with the respective local government for design specifications, regulations and jurisdictional authority. Check with respective local governments for rainfall capture targets specific to design standards that they may have that have been adjusted for predicted climate change.
7. Construction Staging of GSI	Schedule the installation of GSI facilities to optimize on synergies of project or other related or unrelated projects, avoid problems with severe rainfall events and other potential disturbances.
8. Field Review & Monitoring of GSI	Provide critical field inspections to ensure performance. Use post-construction monitoring and adaptive management to reduce costs.

3.0 Design Resources

3.1 Rainfall Amounts and Capture Targets

REFER TO: Appendix A, Table 1 Typical GSI Facility Design Guideline Rainfall Capture Targets to determine the rainfall required for sizing a given GSI facility. This table will be periodically updated to keep up with advances in research and practice.

In this resource, design guidelines for each GSI facility utilize a 'simplified sizing approach'[3] of the optimal rainfall or stormwater runoff capture volume is 72% of the 2-year, 24-hour event rainfall volume. For each GSI facility this is expressed in the sizing equation as millimeters of rainfall. The region can be divided up in to 5 climate zones throughout using rainfall data supplied from provincial rain gauges, or provided by the respective local government. Any updates provided by the local governments for rainfall capture targets will be updated periodically in Appendix A.

Consideration should be given to using climate adjusted rainfall capture targets for GSI. *Climate Projections for the Capital Region (April 2017)*[4]. This climate change report outlines that the Single-Day Maximum Precipitation will increase by 20% (2% to 37% range, 10% to 90% percentile values) for year 2050 and 35% (11% to 54% range) for year 2080.

3.1.1 Volume Reduction

The typical target for GSI is to capture and retain 72% of the 2-year, 24-hour event volume, which is roughly equivalent to the 6-month, 24-hour post development flow volume.

These rainfall capture targets are used to calculate the volume of rainfall that falls on the given impervious surface (thus generating stormwater runoff) to be captured, infiltrated, treated and/or detained by the GSI facility. Because rainfall patterns differ around the capital region, this rainfall capture target is area specific. Check with respective local governments for rainfall capture targets specific to design standards that they may have and ensure that they are based on the current climate projections.

3.1.2 Water Quality Treatment

Stormwater capture, volume reduction, water quality treatment, infiltration and rate control, go hand in hand. To protect the natural receiving environments (creeks, shorelines, and harbours) from the impacts of stormwater discharges. Regional climate projections predict that the region will be receiving less rain for longer periods in the summer and more rain during the winter. During the dry summers contaminants accumulate on the land and impervious surfaces, increasing the contaminant loading potential when heavy rains begin in the fall, known

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[3] Modelling for the collection and treatment for 90% of the total rainfall from impervious areas can be determined using continuation simulation modelling. This modelling can take a significant amount of time and there is limited availability of long-term precipitation gauges. Modelling in Metro Vancouver has shown that 72% of the 2-year, 24-hour event is roughly equivalent to 90% of average annual rainfall. Therefore, using the R mm for the volume reduction and rate control are likely suitable for most sites.

[4] https://www.crd.bc.ca/about/data/climate-change

as "first flush". Maximizing infiltration will also aid in groundwater recharge and ensure interflow continues to provide adequate seasonal flow rates in creeks.

3.1.3 Rate Control

Local governments typically use Intensity-Duration-Frequency curves to represent the relationship between rainfall intensity, rainfall duration, and return period (or its inverse, probability of exceedance) of rainfall events. Developing a hyetograph for hydrologic modelling using the Soil Conservation Service Type 1A rainfall distribution is generally accepted in this region. Designers should check with the local jurisdiction for the hyetograph development and hydrologic modelling availability and requirements. In this resource, design guidelines for each GSI facility utilises a 'simplified sizing approach' of the optimal rainfall or stormwater runoff capture volume is 72% of the 2-year, 24-hour event rainfall volume.

3.2 Requirements for Site

Many municipalities have included requirements for stormwater management within their subdivision and development bylaws. Traditionally, these requirements have been focussed on conveyance and flood protection requirements, but many have now included GSI principles. Furthermore, many municipal official community planning documents include general provisions for stormwater management either at the municipal level or catchment-specific requirements. Some municipalities have developed watershed-specific plans which may identify specific stormwater targets based on the constraints and opportunities in that watershed. The developer, planner and designer should familiarize themselves with these requirements at the early stages of a project.

In the absence of specific site requirements, the generally accepted GSI guidelines are as follows:

Table 5 Generally Accepted GSI Drivers and Targets

Design Driver		Rainfall Capture Target*
Capture & Slow >	the flow of stormwater by re-directing it into naturalized facilities with safe dispersion.	• Retain the 6-month/24-hour post-development volume from impervious areas on site and infiltrate to ground. If infiltration is not possible, the rate-of-discharge from volume reduction GSI will be equal to the calculated release rate of an infiltration system.
Clean & Infiltrate >	stormwater runoff before it reaches natural receiving environments.	• Collect and treat the volume of the 24-hour precipitation event of the total rainfall from impervious areas suitable GSI.
Store & Convey >	stormwater to minimize peak flows in heavy rain events and for safe conveyance in the piped and natural storm drain system.	• Reduce post-development flows (volume, shape and peak instantaneous rate) to pre-development levels for the 6-month/24-hour, 2-year/24-hour, and 5-year/24-hour precipitation events.

*Note: Refer to the local jurisdiction requirements for management of flood events.

For sites that discharge directly to receiving bodies not impacted by runoff rates from a specific site (e.g., tidal waters, large lakes), consideration should be given to focus on water quality and not on volume control and runoff rates.

3.3 Selecting GSI Facility

REFER TO: Appendix A – Table 2 GSI Information Table to assist in the selection of the GSI based on stormwater management drivers, land use application, site constraints, peripheral benefits and cost criteria.

Selecting the optimal GSI facility or facilities for a retrofit or a new development is an art as well as a science. Different factors must be considered when selecting GSI facilities that are appropriate for the site conditions, project budget and GSI drivers for a particular site. A traditional Stormwater Rehabilitation Unit (SRU) may also be required by the local government in order to meet water quality guidelines, bylaw or planning policy. Where a SRU is required, GSI may still be part of a treatment train.

3.4 Various GSI Facility Common Design Guidelines

REFER TO: various appendices for common design guidelines for a variety of GSI facilities (i.e., Swale, Rain Garden, Cisterns & Detention Tanks)

3.5 Planting Templates and Plant Lists

REFER TO: Supplemental 1, Planting Templates & Plant Lists as a design companion resource for any vegetated GSI facility. Recommendations for planting templates and plant lists are presented. Plant selection principles of design include: plants and trees should fit into the existing natural and built environment; utilize native species indigenous to southern Vancouver Island; use of a columnar variety of tree is recommended for urban streetscapes as they require less maintenance costs and have less interaction with overhead transmission lines, neighbouring buildings and vehicle traffic; select plant species based upon an understanding of hardiness and habitat requirements; design planting plans with an appropriate mix of trees and shrubs as well as native perennials, wildflowers and aquatics.

3.6 Overcoming Challenges and Constraints

Each site will have its own unique site challenges and constraints. This section offers some design resources to assist planners and GSI designers with selecting a suitable GSI facility, sizing and overcoming site challenges and constraints.

3.6.1 Soil Infiltration

There are a wide variety of soil conditions across the capital region, and infiltration rates will vary considerably seasonally at the same site. Depending on soil conditions and other site constraints, various GSI designs for full or partial infiltration source controls are appropriate. Much of the populated area in the capital region has low infiltration rates due to clay soils. Resources such as Addressing Green Infrastructure Design Challenges in the

Pittsburgh Region – Clay Soils (EPA, Jan 2014) (https://www.epa.gov/sites/production/files/2015-10/documents/pittsburgh-united-clay-soils-508.pdf) may provide helpful insights.

Regional Infiltration Potential Resource

Site-specific soils and infiltration information should be obtained by a geotechnical engineer at the design phase if at all possible. However, for generalized information only, a recent report and set of regional infiltration potential maps can aid in understanding the native soil infiltration potential of a given watershed. This resource can be found at: https://www.crd.bc.ca/education/our-environment/watersheds/watershed-maps-flow-diagrams

On-site infiltration testing

Infiltration tests have their limitations, as they may be difficult to perform or interpreted due to historic site disturbance or alteration, existing impervious cover, seasonal variation in soil saturation, etc. For all GSI facilities that utilize infiltration, on-site infiltration testing is required at the elevation (depth) of the proposed infiltration facility. The BC Environment Percolation Test Requirements recommend using the double ring infiltrometer testing methodology. Infiltration rates should be reported in mm/hr. Ideally, the test would be performed in the wet season (or simulate the wet season conditions) and testing results would be available when the GSI facility is designed, but testing may not be performed until the site is under construction and the design has been finalized. In the absence of test results, literature values for saturated hydraulic conductivity are often used in conjunction with an appropriate "correction" or "safety" factor. A correction factor can be applied to the determined infiltration rate to allow for average soil variability, degree of long-term facility maintenance, and total suspended sediments reduction through pre-treatment. Selection of a correction factor is based on the judgement of the Qualified Professional.

Strategies to Deal with Limited Infiltration Rates

All sites in the capital region can incorporate some form of GSI, even though in some poor drainage soil or site conditions the choices will be limited to constructed solutions like green roof, flow-through planters or infiltration techniques with flow restrictors. The most cost- and space-effective techniques will be those that rely on significant infiltration into site soils. To determine if infiltration based GSI facilities are advisable on the development site, professional geotechnical engineers, hydrogeologists, and designers should identify site or neighbourhood features that may act as constraints.

Table 6 provides general guidance on the match between source control type and infiltration rate. Use these as guidelines, not rules.

Table 6 Tentative Match: GIS Facility to Soil Infiltration

Soil Infiltration Rate tested at the site of proposed infiltration	Full Infiltration	Full Infiltration with Reservoir	Partial Infiltration with Reservoir and Subdrain*	Partial Infiltration with Flow Restrictor
High infiltration rate >30 mm/hr	x	x		
Moderate infiltration rate 15-30 mm/hr	x	x	x	
Low infiltration rate 1-15 mm/hr		x	x	x
Very low infiltration rate <1 mm/hr			x	x
*Note: In some cases, bioretention facilities with subdrains have the potential to export Phosphorus and Nitrogen at a higher rate than contained in the stormwater they are receiving. See Low Impact Development Technical Guidance Manual for Puget Sound 2012 (chapter 6.1.2 Bioretention Design) for nutrient management suggestions.				

Infiltration Constraints

The Infiltration Constraints discussion below provides a partial list of site-specific considerations to be considered to help determine what GSI may or may not be suitable. The BC Ministry of Environment publication Underground Stormwater Infiltration Best Practices for Protection of Groundwater Resources in British Columbia (Nov. 2014) (http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/library/underground_stormwater_infiltration-2014.pdf), is an important guidance document to review for the protection of groundwater when considering GSI infiltration facilities.

Historical or Current Land Uses that are Pollutant Hot Spots: Infiltration should not be undertaken from historical or current land uses that present a high risk of groundwater pollution e.g., historical industrial sites, automobile service yards, wrecking yards, public works yard, sites storing industrial chemicals or wastes, unless appropriate pre-treatment is included.

Drinking Water Wells: Infiltration should be separated from drinking water wells, against both surface water intrusion and ground water pollution. Standards for separation may vary by municipality, soil conditions, and well operation, but should, at a minimum, equate the separation required between septic fields and drinking water wells by BC Ministry of Health. At time of writing, this separation was a minimum of 30.5 m horizontally.

Contaminated Soils: Sites that have previously contaminated soils will need geotechnical analysis to determine if they can be remediated and if they are suitable for infiltration once remediated.

Seasonally High Water Table: For infiltration to be effective, the bottom of the infiltration facility should be at least 600 mm above seasonally high water table. Site test holes and mapping should be completed if areas of high water table are indicated.

Shallow Bedrock: Infiltration may be constrained by shallow bedrock or by cemented layers in soils. The infiltration facility bottom should be at least 600 mm above monolithic, unfractured bedrock. Note, however, that many types of bedrock including fractured sandstone are highly pervious and suitable for infiltration. Some other types of bedrock (e.g., karst limestone) are excessively permeable, and infiltration directed at them may need careful pre-treatment for water quality. Some cemented layers in soils are underlain by highly permeable strata, and facilities can be designed to remove pollutants from surface water and then infiltrate it to these deeper permeable soils.

Steep Slopes: Existing or proposed steep slopes can be a constraint to infiltration. Designers must consider the stability of the slope, and the interaction of deep and shallow groundwater interflow on the stability of the slope. Infiltration designs within 30 m (or greater in some areas) of steep slopes, or that direct surface or groundwater at a steep slope area are prohibited unless reviewed and deemed acceptable by engineers with experience in geotechnical engineering.

Unstable Soils: The stability of soils for foundation conditions or against mass slumping may be affected by infiltration. If expandable clays are present on a site, geotechnical advice should be sought on setbacks from infiltration facilities to foundations – 3-5 m setback distances are common. Other unstable soils, such as peat or organic muck, may be affected by increased water content related to infiltration, and geotechnical advice should be sought.

Riparian Area or other Protected Habitat: Infiltration techniques that require excavation are commonly restricted in areas of protected habitat. However, non-invasive techniques that provide drain/soil/compost check dams to create vernal pools, or facilities outside the protected area that allow treated runoff to distribute and slowly flow through the protected area are appropriate.

3.6.2 Strategies to Deal with Limited Space

A key advantage of integrating GSI into the overall design of a project is to avoid requirements for additional land. Strategies to minimize the requirement for extra land for GSI include:

- ✓ Use required landscape areas as GSI – make concave landscape areas at the site periphery and in parking lot islands and courtyards, rather than berms.
- ✓ Consider that even formal, rectilinear urban planters can be designed as rain gardens.
- ✓ Design roadside boulevards and medians as infiltration areas rather than raised landscaping.
- ✓ Infiltrate into tree wells and structural soils. The use of structural soils for tree planting in paved areas is a well-established technique. Drainage of small paved areas into these structural soils should be considered where the infiltration rate of the subsurface soils will allow the removal of the water within 24 hours, or where adequate under drainage is provided.
- ✓ Increase the depth and organic matter content of landscape soils. Good growing medium soils will be capable of storing water in up to 20% of their volume. Greater soil depth allows the storage of additional surface runoff. Sufficient organic matter maintains soil percolation rates.
- ✓ Create hydraulic disconnects – that is, drain small paved areas into absorbent landscape rather than to the storm drain system. A good example is draining sidewalks to boulevard rather than directly to curb and gutter. Another example is allowing small roof areas to drain from roof leaders to the surface of absorbent landscape. When the ratio of impervious area to pervious area remains small, this absorbent landscaping can absorb the runoff from disconnected areas and reduce the area of impervious surface that must be accommodated in separate source control facilities or that runs off to the storm drainage system.

- ✓ Install pervious paving. Pervious paving of several types is highly suitable for pedestrian areas, overflow parking, and main parking areas.
- ✓ Place infiltration trench or soak-a-way manhole under paved areas. For example, the drain rock reservoir under infiltration swales can extend under driveways, thus increasing the infiltration area.
- ✓ Allow surface storage. Temporary ponding on the surface of infiltration swales or rain gardens is approximately 3x more efficient than underground storage in a drain rock reservoir, due to the volume of space taken up by the rock.
- ✓ Provide underground storage. Temporary storage of rainfall, and slow release into infiltrating soils, can greatly increase the effectiveness of limited infiltration capacity or area. Underground storage can be by cisterns and detention tanks.
- ✓ Install a green roof, either intensive or extensive, to provide rainfall capture above buildings and parkades.
- ✓ Consider rainwater, for flushing toilets, irrigation and/or laundry uses. This technique is with "purple pipe" building systems for non-potable water. NOTE: this is not discussed in this resource. For more information see the British Columbia Building and Plumbing Code.

3.6.3 GSI Facilities and Contaminant Removal

GSI facilities can significantly reduce stormwater contaminants through sedimentation, filtration, adsorption, vegetative uptake, and infiltration. However, nutrient removal efficiencies vary greatly due to the complex chemical processes involved. GSI facilities can be effective at capturing the "first flush" of runoff from impervious surfaces and this is where pollutant loadings are most concentrated. Proper operation and maintenance of the GSI facilities is crucial for long term contaminant removal performance. It is important to note that in some studies, phosphorus levels may increase in Vegetated and Grassy Swales.

When choosing a GSI facility to reduce a specific contaminant, volume reduction or detention/reduction volume, the following webpages are excellent resources. The basic contaminant reduction table in each appendix is for quick reference only. Here are more comprehensive resources:

1. The International Stormwater Best Management Practices (BMP) Data Base (www.bmpdatabase.org) has compiled research and monitoring programs of both GSI and proprietary devices performance for runoff reduction and suspended and dissolved contaminant removal for solids, bacteria, nutrients, and metals. This website features a database of over 600 studies, performance analysis results, tools for use in performance studies and summaries, monitoring guidance and other study-related publications looking at GSI and manufactured devices.

2. The Center for Watershed Protection has numerous resources, including the document: National Pollution Removal Performance Data Base (Version 3, September 2007). http://www.stormwaterok.net/CWP%20Documents/CWP-07%20Natl%20Pollutant%20Removal%20Perform%20Database.pdf

3. The Minnesota Stormwater Manual outlines typical stormwater contaminants, sources of stormwater contamination and mechanisms of contaminant removal. These can be found at: https://stormwater.pca.state.mn.us/index.php?title=Pollutant_fate_and_transport_in_stormwater_infiltration_systems

3.6.4 Stormwater Treatment Trains

The term 'Stormwater Treatment Train' represents a multi-level approach to managing the quantity and quality of stormwater runoff. Treatment trains utilize operational or behavioural source control BMP and grey or structural source control facilities such as oil grit separators, along with green infrastructure. On a watershed or catchment scale, the treatment train sequence often starts with pollution prevention and progresses through source control BMP, green infrastructure facilities, and may require end-of-pipe treatment such as hydrodynamic separators before the runoff water is discharged to receiving waters, when these approaches are linked it is known as a stormwater treatment train.

It can be effective to distribute GSI facilities on a site such that a single GSI facility treats a single impervious or portion of impervious area. This makes for a site design that is easy to map in a stormwater management plan for construction that shows how each area is treated by each facility. Designers are also encouraged to think about combinations of GSI facilities, if needed, to improve and maximize the benefits for the site. A 'Stormwater Treatment Chain' is a group of source controls that are arranged in series, flowing from 1 facility to another. It should be noted that the term is used generically to refer to a series of facilities, and water quality treatment may or may not be part of the function of the series.

3.6.6 Sanitary Sewers and GSI

REFER TO: Supplemental 2, Leaky Sanitary Sewers & Green Stormwater Infrastructure Management Considerations

Like all infrastructure, sanitary sewers deteriorate over time. This can result in leakiness, which municipalities refer to as "inflow and infiltration". Leaky sewers can unintentionally drain groundwater into the sewer system or leak sewage out to the environment. Installing green infrastructure in areas with leaky sewers may result in positive, negative, or neutral impacts. Therefore, it is important to understand the site-specific interactions between proposed green infrastructure and existing sewers, which may or may not be leaky. It is also important for municipalities and homeowners to inspect their sewer pipes and to maintain/repair them to address sewer leakiness as appropriate.

3.7 Detail Design of GSI Checklists

The following checklists provide items to include or consider for inclusion on detailed design drawings.

	Plan Checklist GSI Detailed Design
☐	Extent of effective impervious surface
☐	Outline of Stormwater Source Control
☐	Edge treatment at the Stormwater Source Control e.g., drop curb, flush curb, bollards, border, etc.
☐	Piping and drainage diagrams, sizes and slopes
☐	Overflow location to drainage system
☐	Utility crossings and seepage cut-off details
☐	Spot elevations, slope arrows and/or contours to show grading design, including pipe inverts, catch basin elevations, breaks in grade
☐	Proposed weir locations limiting slope to no more than 2%
☐	Extent of proposed growing medium installation
☐	Extent of proposed drain rock reservoir installation
☐	Erosion control and runoff dispersion features at steep slopes and inlet points
☐	Planting plan showing trees, shrubs, ground covers, and use of grasses as applicable
☐	Watering or irrigation plan showing provisions for establishment watering

	Cross Section Checklist GSI Detailed Design
☐	Depth to ground water
☐	Surface grades
☐	Paving or base course layers, if included in design
☐	Extent of proposed growing medium installation, layering of growing medium types
☐	Extent of proposed drain rock reservoir installation
☐	Piping and drainage locations in relation to growing medium and reservoir
☐	Erosion control and runoff dispersion features at steep slopes and inlet points
☐	Edge treatment at the Stormwater Source Control e.g., drop curb, flush curb, bollards, border, etc.
☐	Front view of proposed weirs
☐	Typical cross section of planting and mulching treatment
☐	Specialty materials for green roof, such as lightweight soils, root barrier, drainage layer

	Profile Checklist for GSI Design
☐	Surface grades
☐	Extent of proposed growing medium installation
☐	Extent of proposed drain rock reservoir or drainage layer installation (top and level bottom)
☐	Undisturbed native soil or check dam details between discrete reservoir or infiltration trench cells
☐	Piping locations in relation to soil and reservoir, pipe gradients
☐	Side view of proposed weirs

3.8 Construction Sequencing and Oversight

Appropriate oversite of construction sequencing, erosion and sediment control measures for more rain than expected can avoid additional stormwater pollution being generated from the work site.

A person trained and experienced in the construction, operation and maintenance of infiltration devices shall be responsible for construction of the device. The following apply:

- **Schedule** – Installation of GSI facilities should optimize on synergies of project or other related or unrelated projects, avoid problems with severe rainfall events and other potential disturbances.
- **Construction Site Stabilization** – Construction site runoff from disturbed areas shall not be allowed to enter the GSI facility. Runoff from pervious areas shall be diverted from the device until the pervious areas have undergone final stabilization.
- **Suitable Weather** – Construction shall be suspended during periods of rainfall or snowmelt. Construction shall remain suspended if ponded water is present or if residual soil moisture contributes significantly to the potential for soil smearing, clumping or other forms of compaction.
- **Compaction Avoidance** – Compaction and smearing of the soils beneath the floor and side slopes of the GSI facility, and compaction of the soils used for backfill in the soil planting bed, shall be minimized. During site development, the area dedicated to the GSI facility shall be cordoned off to prevent access by heavy equipment. Acceptable equipment for constructing the GSI facility includes excavation hoes, light equipment with turf type tires, marsh equipment or wide-track loaders.

3.9 Field Review and Monitoring of GSI

Post-construction monitoring and adaptive management is suggested to ensure performance of GSI facilities. Designers, land owners/managers and municipalities may find it beneficial to conduct both short and long term performance monitoring to ensure adequate maintenance requirements and future design considerations.