City of Richmond

Report to Committee

To:	General Purposes Committee	**Date:**	June 30, 2016
From:	Mike Redpath Senior Manager, Parks	**File:**	06-2345-20-GCIT1/Vol 01
Re:	**Garden City Lands Park Development Plan**		

Staff Recommendation

That the Garden City Lands Park Development Plan, provided as Attachments 1 through 9 and as detailed in the staff report titled "Garden City Lands Park Development Plan," dated June 30, 2016, from the Senior Manager, Parks, be received for information.

Mike Redpath
Senior Manager, Parks
(604-247-4942)

Att. 9

REPORT CONCURRENCE			
ROUTED TO:	**CONCURRENCE**	**CONCURRENCE OF GENERAL MANAGER**	
Engineering Environmental Sustainability	☑ ☑		
REVIEWED BY STAFF REPORT / AGENDA REVIEW SUBCOMMITTEE	**INITIALS:** DW	**APPROVED BY CAO**	

5061956

Staff Report

Origin

On June 9, 2014, Council endorsed the Garden City Lands Legacy Landscape Plan (Attachments 1 and 2) as a framework for the future detailed planning and development of the Garden City Lands.

This report supports Council's 2014-2018 Term Goal 2: A Vibrant, Active and Connected City:

> *Continue the development and implementation of an excellent and accessible system of programs, services, and public spaces that reflect Richmond's demographics, rich heritage, diverse needs, and unique opportunities, and that facilitate active, caring, and connected communities.*
>
> *2.3. Outstanding places, programs and services that support active living, wellness and a sense of belonging.*

The purpose of this report is to provide information and summarize the recent Garden City Lands site investigations, the design process and consultation results. The result is the Park Development Plan which is an update to the Garden City Lands Legacy Landscape Plan and also describes the plan's various features.

Findings of Fact

The City-owned Garden City Lands (the Lands) are approximately 55.2 hectares (136.5 acres), located at 5555 No. 4 Road at the eastern edge of Richmond City Centre, between Westminster Highway, Garden City Road, Alderbridge Way and No. 4 Road. The Lands are located within the Agricultural Land Reserve (ALR) and Metro Vancouver's 2040 Regional Growth Strategy has designated the Lands as "Conservation and Recreation."

In the current 2041 Official Community Plan (OCP) Land Use Map, the Garden City Lands are designated as "Conservation," which is defined as being natural and semi-natural areas with important environmental values that may also be used for recreation, park, agricultural and food production purposes.

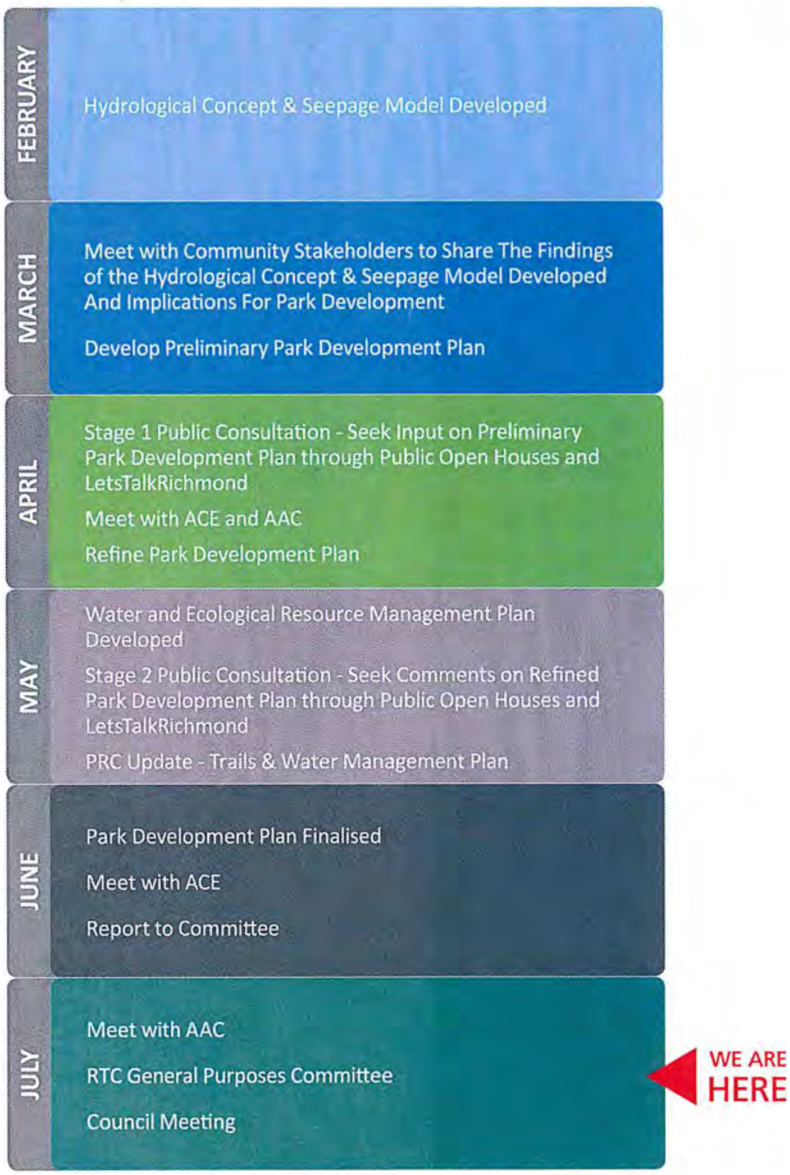
In 2015, Council adopted the Ecological Network Management Strategy to provide a "framework for managing and guiding decisions regarding the City-wide system of natural areas in Richmond and the ecosystem services they provide on City, public and private lands." In the Ecological Network Management Strategy the Lands are recognised as a "Special Study Area."

Analysis

The 2014 Garden City Lands Legacy Landscape Plan (Legacy Landscape Plan) described an overall conceptual plan for the Lands. It was the result of investigations into the site's existing environmental condition, the development of a vision and a set of principles, and consultations with the public and stakeholders about possible uses. In developing the Legacy Landscape Plan, the City also sought guidance from the Agricultural Land Commission (the ALC), the Scientific

Advisory Panel for Burns Bog, and a Faculty of Land and Food Systems representative from the University of British Columbia regarding site development, management and programming considerations. The synthesis of the consultation together with the key findings from the background inventory and analysis of the site provided a solid basis for the development of an overall vision and set of guiding principles. Refer to Attachment 1 for a summary of the Legacy Landscape Plan and Attachment 2 for the 2014 GCL Legacy Landscape Plan Development Zones.

Council's endorsement of the Legacy Landscape Plan included direction for staff to undertake further site analysis, detailed design investigations, and community consultation to generate a final Park Development Plan. To that end the following steps have been undertaken:



Site Analysis: Water and Ecological Resource Management Strategy

A consultant team with expertise in bog ecology, hydrogeological engineering and agrology was hired to undertake further analysis of the Lands with the goal of more fully understanding the current health of the bog, it's hydrology and plant communities, as well as to assess the potential implications of converting part of the site into agricultural land while conserving the bog. The consultant's work has been synthesised in the Garden City Lands Water and Ecological Resource Management Strategy (Attachment 9), which identified a number of management considerations to be addressed in the construction of the park.

One of the most notable considerations deals with the interface between the bog and proposed agricultural areas. The Water and Ecological Resource Management Strategy determined that it should be possible to maintain the ecological health of the core bog area while developing the western portion of the site for farming as long as the bog's water system was separated from the farming operation. To accomplish this, a hydraulic "barrier should be constructed with an impervious or low permeability material that extends from the bottom of the peat layer into the top of the surface berm. The subsurface portion of the barrier is intended to minimize ground water loss from the bog to the agricultural land to the west, drainage ditch to the south and utility trenches to the north and east.

The surface berm is intended to prevent surface water exchange between the bog and the adjacent land uses. The barrier will enhance the bog hydrology and preserve the water quality desired by a healthy bog ecosystem" (Attachment 9, pages 1-5). Different options for constructing the hydraulic barrier are described in the Water and Ecological Resource Management Strategy. Staff are reviewing, with the consultants, the suitability of these options in terms of methods and costs of construction, potential for phasing, monitoring protocols, and ecological impacts.

The Water and Ecological Resource Management Strategy also provides a discussion on soil amendments, drainage within the agricultural area, irrigation strategies for the agricultural areas, including how rainwater retention ponds could be integrated to provide sources of water for irrigation, and ecological management approaches throughout the park, in particular the bog, to maximize the environmental health of the park.

Soil amendment is proposed to be minimal utilizing amendment techniques to integrate the existing peat with quality mineral soil in keeping with the sustainability objectives of the Garden City Lands Legacy Landscape Plan.

Finally, the Water and Ecological Resource Management Strategy concludes with the importance of adopting an adaptive management approach to the development of the park elements. "It is not possible to provide detailed direction regarding management of the conservation area until there is a more confident understanding of the influence that the perimeter berms and hydrological barriers will have on the groundwater levels" (Attachment 9, page 19-1). To that end the Strategy describes a four year plan to monitor the bog's water systems, vegetation, habitat values to determine how the bog is responding to the introduction of the hydraulic barrier and berms and the perimeter pathways. It includes different approaches for managing invasive plant species within the bog that can be trialed to determine which approaches are most effective.

Site Design Investigations

Working in parallel with the Water and Ecological Resource Management Strategy team has been a team of consultants with expertise in site planning and engineering related to environmentally sensitive sites. This landscape team was tasked with the following two actions:

1. Update the Legacy Landscape Plan and its conceptual design elements to reflect the recommendations in the Water and Ecological Resource Management Strategy, the feedback from the public consultations and the farming strategies developed in concert with Kwantlen Polytechnic University; and

2. Determine a scope of work for Phase 1 that can be realised within the current capital funds available for the project.

The landscape team worked with City Parks, Environmental Sustainability and Engineering staff, and the Water and Ecological Resource Management Strategy team, to finalize the location and engineering of the central dyke, determine the final location and size of the rainwater storage ponds for irrigation, determine the requirements for utilities (e.g., power, water, sanitary and stormwater), explore options for the perimeter trails and park entries, describe planting design strategies throughout the Lands that could enhance the ecological values of the park, work with Kwantlen Polytechnic University in finalising the layout for the agricultural area and develop cost estimates for the different phases of the development plan. The design team's work resulted in the Park Development Plan (Attachment 4) which considered the following design elements:

Bog Conservation and Dike Location

The Water and Ecological Resource Management Strategy signals that it will be possible to separate the bog and its unique water retaining requirements, from the agricultural operations which seek to drain water freely through the soil. To that end the design team investigated different methods of constructing the dike/hydraulic barrier to isolate these water systems. The design team also evaluated the alignment of the dike as shown in the Legacy Landscape Plan and proposed some adjustments.

The Fields

Approximately 16 ha (40 acres) of the Lands is dedicated to agricultural production, most of which is expected to be configured into smaller plots (e.g., 1 to 2 acres) with intensive operations typical of the urban agriculture movement. The City has been working with Kwantlen Polytechnic University Institute for Sustainable Food Systems in preparing an overall Agricultural Management Plan for the Lands. The Agricultural Management Plan will apply sustainable agricultural practices that integrate environmental protection, social and economic equity, and economic profitability into all farm operations.

Perimeter Trails

Two different perimeter trail configurations were evaluated. One proposed a single four metre wide multi-use trail and the other proposed separate pedestrian and bicycle trails. Where the trails met the major road intersections and future pedestrian crossings of Alderbridge Way and Westminster Highway, the form and character of the 'entries' were evaluated. The perimeter trails are located primarily on land that has been previously disturbed due to roadway construction and are therefore expected to have no significant impact on the bog, nor impact farming operations.

Park Entries

The entries into the park are proposed to be kept simple and modest in size, and maintain the long views across the Lands. The entries will also provide opportunities for interpretive signage and maps of the park, quick access to the park's trails and public art.

The Rise

This is the area previously referred to as "the Mound." It is where a mix of fill material was placed decades ago and as a result it is at a higher elevation than the rest of the Lands and provides views across the farm fields and bog. The design team explored opportunities for informal recreation, agriculture and ecological enhancement.

Rainwater Collection Ponds for Irrigation

The design team evaluated the extent to which rainwater could be captured, stored and reused for irrigation of the farm fields. In addition these ponds are expected to provide a range of wildlife habitat.

Planting Design

Native trees and shrubs are proposed around the park's perimeter to enhance the ecological performance of the Lands. As well, along the Garden City Road and Westminster Highway frontages, rain gardens that include trees and wetland plants are proposed. Within the park, in open areas and along trails, fruit bearing trees and pollinator plants are proposed to reinforce the agricultural and habitat values of the Lands.

The Community Hub

The design for the community hub is not part of this phase of the design work and will be part of future discussions when funding becomes available. Nevertheless, the community hub will eventually become the Lands' main entry. It will host multi-functional agricultural buildings, community gardens, an event field and the primary parking area for the Lands.

Parking

As noted in the discussion of the Community Hub, the primary parking lot will be developed as part of the Community Hub. This parking area will support farming activities, farm and bog related events and provide parking for visitors to the Lands. It is expected to be constructed of permeable materials and be modest in size (70 to 80 stalls) to minimize its impact on the Lands. The small parking lot that was proposed in the Legacy Landscape Plan for mid-point along the Alderbridge Way frontage, close to the Rise and its informal recreation, was evaluated. The design team also assessed the possibility of adding parallel parking spaces along the west side of No. 4 Road. The latter two locations occur on previously disturbed locations and will not impact the bog.

The site design team's investigations formed the basis for the two stages of consultation.

Consultation Process

The community consultation focused on two streams. The first began with an invitation to key community groups (e.g., Richmond Food Security Society, Richmond Fitness and Wellness Association, Richmond Nature Park Society and Garden City Conservation Society) to meet with staff and consultants to discuss the preliminary Water and Ecological Resource Management Strategy analysis and its implications for the site development.

This meeting was then followed by Stage 1 Public Open Houses at which people were asked for their opinions regarding a series of design options including pathway locations and types, the treatment of entries into the park and the types of vegetation proposed. Public feedback was also received via LetsTalkRichmond.ca. The City received 179 responses to the survey and the majority of respondents were pleased to see the plan evolving as presented. In terms of the responses to the five questions, the public's preference was for separate pedestrian and bicycle paths, maximizing the use of native plants throughout the site, including perimeter plantings, keeping the entries into the park modest in size, using the Rise (Mound) as a location for informal recreation and orchards, and limiting parking to the community hub, with a small parking area off Alderbridge Way and parallel parking along No. 4 Road (Attachment 3).

Staff and the consultants reviewed these comments and refined the site plan to reflect the preferences. This refined plan was then presented at Stage 2 Public Open Houses for further feedback. The City received 40 responses through comment sheets provided at the open houses, and online through LetsTalkRichmond.ca. The majority of responses were supportive of the proposed development plan.

The other consultation stream that has informed the development plan is the participation of Kwantlen Polytechnic University. Since the early stages of the current design process, Kwantlen Polytechnic University has been actively involved in helping to refine the agricultural component of the Legacy Landscape Plan. They have provided input on proposed sizes of the various farm fields and the location of trails and drainage ditches. In addition, their proposed in-kind contribution to the project will be to develop a comprehensive Agricultural Management Plan for all the agricultural portions of the site. Kwantlen Polytechnic University also participated in the public open houses and community group meetings to share their interests in the project and answer questions regarding how the site would be farmed.

In addition, staff met with both the Advisory Committee on the Environment and the Agricultural Advisory Committee on two separate occasions. The first was to share the preliminary findings of the Water and Ecological Resource Management Strategy and the second was to provide the committee members with an opportunity to comment on the proposed development plan.

Agricultural Land Commission

A draft of the Legacy Landscape Plan was reviewed by the Agricultural Land Commission (ALC). The ALC provided preliminary comments regarding the plan and an initial positive review of the Garden City Lands vision and concept direction. More recently, City staff met with ALC staff to discuss the proposed Phase 1 scope of work within the Park Development Plan to determine what applications the City would be required to make to the ALC to gain approval to proceed. ALC staff confirmed that there would not be a requirement for a 'Non-Farm Use' application for the Phase 1 works as these are permitted within the ALR. Rather the components of the Park Development Plan can be addressed through the following two separate ALC application processes:

- Notice of Intent to Place Fill and/or Remove Soil; and
- Transportation, Utility, or Recreational Trail Uses within the ALR.

Garden City Lands Park Development Plan (Attachments 4 to 8)

The Garden City Lands Park Development Plan (Attachment 4) represents the synthesis of the original Legacy Landscape Plan with the new science-based recommendations that are part of the Water and Ecological Resource Management Strategy, as well as the feedback the City received from hundreds of Richmond residents and the contribution of Kwantlen Polytechnic University regarding agricultural production. The Park Development Plan continues with and elaborates upon the seven landscape zones that were illustrated in the 2014 GCL Legacy Landscape Plan Development Zones (Attachment 2):

1. The Bog: This ecologically important area remains the dominant feature of the Lands. The bog's ability to thrive will be enhanced by the construction of the barrier dike that separates its water system from the water dynamics associated with the agricultural area to the west, as well as an ongoing management plan to monitor water levels and control invasive plant species. The location of the hydraulic barrier and berm reflects the ratio of conservation land to farm land defined in the Garden City Lands Legacy Landscape Plan, and coincides with the transition from thicker to shallower depths of peat as well as maintaining the Fen and Bog relationship (Attachments 4 and 5).

   The alignment of the hydraulic barrier and berm as proposed in the Park Development Plan is straighter than the alignment shown in Legacy Landscape Plan based on the research within Water and Ecological Resource Management Strategy. Staff are reviewing the barrier and berm recommendation and will work with the consultant on finalising its location and construction methods.

2. The Fen: As described in the Water and Ecological Resource Management Strategy the Fen is an ecologically important associate of a bog ecosystem and is therefore important

to maintain. Consequently, the southern part of the dike has been located to the west of the core of the Fen to ensure its relationship with the bog continues (Attachment 4).

3. The Fields: A total of 16 ha (40 acres) are dedicated to farming as illustrated in the Landscape Development Plan. It is proposed the Kwantlen Polytechnic University will farm in the northern section while City will manage the southern 8 ha (20 acres), which will be adapted to farming activities as they surface. The rainwater storage ponds that are illustrated at the northwest and southwest of the site are sized to retain sufficient rainwater to provide supplemental water for irrigation purposes, thereby reducing reliance on potable water (Attachment 4). The majority of the farming zone will be open to the public via accessible trails that can also serve as farm service roads.

4. The Rise: This area represents a combination of passive recreation, agriculture and the establishment of a native forest. There are proposed to be orchard plantings to demonstrate different orchard planting and management techniques as part of a community education and outreach program. The meadows will be available for passive recreation such as picnicking, frisbee tossing and kite flying, and will include pollinator friendly wildflower plantings. The native forest will include a range of deciduous and evergreen plants native to the Lower Mainland and will provide a visual buffer to Alderbridge Way and the development to the north. This will ensure that distant views from the south and central part of the Lands will be to the North Shore Mountains (Attachment 4).

5. The Community Hub: The plan for this area remains illustrative and is not funded at this time. It serves as a 'placeholder' until the programming activities on the Lands have had a chance to mature and the requirements for this area can be more clearly determined. In the interim, the site can be used as a construction staging area as well as a temporary event space for harvest-themed activities (Attachment 4).

6. The Sanctuary: This area remains an important part of the site as it sits close to the middle of the Lands where noise from the surrounding roads is reduced and the experience of the Lands can be more fully appreciated. The Sanctuary also sits adjacent to a clump of cloudberry found on the east side of the dike (Attachment 4).

7. The Edges: The two primary design features of the "edges" are the pedestrian and bicycle trails, and the native plantings used to buffer the park from the busy streets. Based on public feedback and considering the future populations that will live in the adjacent neighbourhoods pedestrian and cyclists will have separate trails. Even though separated trails occupy more land, the footprint of these trails will largely remain in the previously disturbed areas and therefore have minimal impact on the bog ecosystem. The character of these trails would vary depending upon their location and would include a variety of surfaces including permeable paving, compacted crushed gravel, concrete, and wood boardwalks. All the trails will be accessible to people of all physical abilities. It is expected that lighting will be installed in the future along the perimeter walkways and will be designed to control light pollution and minimize the disturbance to wildlife (Attachments 6 to 8).

Phase 1 Implementation

The Park Development Plan provides an update to the approved Legacy Landscape Plan. It illustrates features that are not included in the current Capital submissions (e.g., Community Hub and Farm Centre, passive recreational elements on The Rise, wood boardwalks, entry nodes and public art) that will be the subject of future capital submissions. Implementation of Phase 1 of the Park Development Plan is estimated to be $4.4 million dollars which is funded from the existing 2015 and 2016 Council approved Capital funds.

City staff from Parks, Environmental Sustainability and Engineering will be working with the consultant team to develop the construction documents in preparation for the first stage of construction. The work is anticipated to commence in the summer of 2016 and continue through 2017 with works in the interior of the site limited to the dry season (June through October).

Financial Impact

There is no financial impact to implementing the Phase 1 works described in this report as sufficient funding is available through previously approved capital funds.

Conclusion

Since 2013, the public has expressed their support for a unique park to be located in the City Centre, one that has the potential to be a green oasis for residents and visitors as well as an important ecological and urban agriculture showcase site. As a result of the comprehensive planning and design that has occurred in the last three years, there is now a high level of interest from both Council and the community to begin using the land for agricultural and recreation. To that end, the Park Development Plan described in this report provides the direction to begin implementing the first phase of the plan.

As part of the 2015 and 2016 Council approved capital budgets, funding has been approved for the phased implementation of the 2014 Garden City Lands Legacy Landscape Plan. The Water and Ecological Resource Management Strategy and the Landscape Development Plan which are attached to this report will be used to guide the phased implementation. It is anticipated that construction mobilization on the site will occur in the summer of 2016 and is anticipated to continue through 2017. As work proceeds on the site, ongoing monitoring of the site vegetation and hydrology will continue as part of an adaptive management approach to park development. This approach will ensure that best practises for ecological and agricultural management are followed. The completion of the perimeter trail around the Garden City Lands will present to the community an accessible 3.0 km trail that will welcome and introduce residents and visitors of Richmond to the Garden City Lands.

Mike Redpath	Jamie Esko	Kevin Connery
Senior Manager, Parks	Manager, Parks Planning & Design	Research Planner 2
(604-247-4942)	(604-233-3341)	(604-247-4452)

Att. 1: Summary of the Legacy Landscape Plan
2. 2014 GCL Legacy Landscape Plan Development Zones
3: April 2016 Public Survey Results
4: 2016 GCL Park Development Plan
5: GCL Park Development Plan – The Central Dike
6: Park Development Plan – The Garden City Road Edge
7: Park Development Plan – The No. 4 Road Edge
8: Park Development Plan – The Westminster Hwy. Edge
9: Garden City Lands Water and Ecological Resource Management Strategy

Summary of the Legacy Landscape Plan

Vision (endorsed July 22, 2013)

The Garden City Lands, located in the City Centre, are envisioned as an exceptional legacy open space for residents and visitors. Visible and accessible from many directions, the Lands are an impressive gateway into Richmond's downtown, and a place of transition and transformation from the rural to the urban. Its rich, diverse and integrated natural and agricultural landscape provides a dynamic setting for learning and exploration. It is inclusive with a range of spaces, amenities and experiences that encourage healthy lifestyles, social interaction and a strong sense of community pride.

Guiding Principles (endorsed July 22, 2013)

- Encourage Community Partnerships and Collaboration
- Respect the Agricultural Land Reserve
- Foster Environmental Sustainability
- Promote Community Wellness and Active Living
- Maximize Connectivity and Integration
- Allow for Dynamic and Flexible Spaces
- Develop Science-based Resource Management Plans

The Legacy Landscape Plan envisioned the conservation of approximately 28 ha (70 acres) of the existing raised remnant peat bog, the cultivation of up to a maximum of 20 ha (50 acres) for food production and the remaining 7.2 ha (18 acres) set aside for trails and passive recreation. It identified seven landscape zones that delineate the site as follows:

1. The Bog;	2. The Mound;
3. The Community Hub;	4. The Fields;
5. The Sanctuary;	6. The Wetlands; and
7. The Edges.	

An essential requirement of the Legacy Landscape Plan was to meet the following four land use framework outcomes that were adopted on March 25, 2014:

1. Urban Agriculture – Provide a showcase for innovative and sustainable agriculture practices within a public park setting.

2. Natural Environment – Create a highly valued, biologically diverse and resilient natural environment that respects the inherent ecology of the Lands and contribute to the City's overall Ecological Network.

3. Community Wellness and Active Living – Ensure the park is accessible, safe and appealing, and that it promotes healthy lifestyles and community cohesiveness.

4. Cultural Landscape/Place-Making – Provide a rich and vibrant place that reflects and highlights the unique characteristics of the site and generates fond memories, community pride, and a deep appreciation of the agricultural and ecological values of the Lands.

Attachment 2: 2014 GCL Legacy Landscape Plan Development Zones

LANDSCAPE ZONES

- The Bog
- The Mound
- The Fields
- The Sanctuary
- The Wetland
- The Community Hub & Farm Centre
- The Edges

SURVEY RESULTS

At the public open houses held in April, people were asked to consider options for the design of the elements to be constructed during the first phase of development of the Garden City Lands. A survey, available in both paper form and on the City's Let's Talk Richmond site, allowed people to select their preferred design solutions. The results have been compiled and are shown below. They have been used to guide the refinement of the design, as illustrated on the boards presented at this open house.

If you would like to comment on any of the information provided at this open house, please use one of the provided comment sheets or visit: **www.letstalkrichmond.ca**.

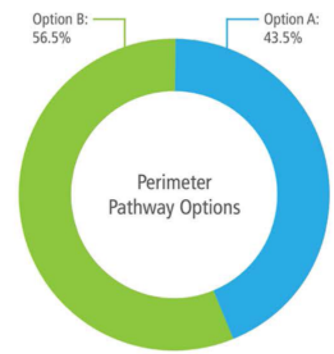
1. Perimeter Pathways

There are two options for perimeter pathways:

Option A: maintains existing bike lanes on streets that currently possess them (Garden City Road and Westminster Highway) and provides a 4-metre wide multi-use trail around the perimeter of the park.

Option B: proposes a dedicated off-street, two-way bike lane and a separate pedestrian pathway. This option results in a segregated pedestrian and cyclist network. However, the added width of these two separate pathways means trail development encroaches further into the park.

- Option A: **43.5%** prefer a single multi-use, 4m wide perimeter pathway and a dedicated bike lane as part of the road.
- Option B: **56.5%** prefer a dedicated 4m wide off-street bike lane and dedicated 3m wide perimeter pathway.



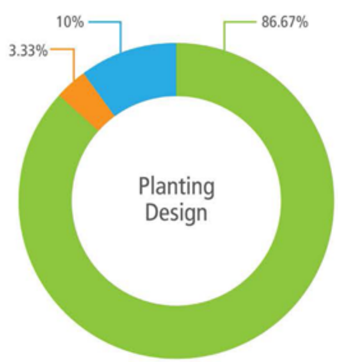
2. Planting Design

A combination of native trees and shrubs are proposed to be planted along the Alderbridge Way and No. 4 Road frontages to enhance the ecological performance of the Lands.

Along the Garden City Road and Westminster Highway frontages, rain gardens that include trees and wetland plants are proposed to replace the existing ditches and capture and treat stormwater runoff. These roads are unlike Alderbridge Way and No. 4 Road and do not have the curbs and catch basins typically found throughout the City.

Within the park, in open areas and along pathways, fruit bearing trees and pollinator plants are proposed to reinforce the agricultural and habitat values of the Lands.

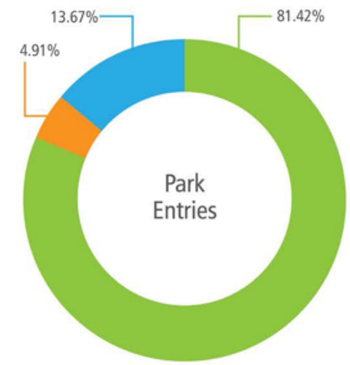
- Yes
- No opinion
- No. I would prefer to see...



3. Park Entries

The four main entries into the park have been kept simple and modest in size, and have been designed to maintain the long views across the Lands. The entries could also provide opportunities for information signage and maps of the park, quick access to the park's trails as well as public art. The planting designs associated with the entries are proposed to reflect the environmental and agricultural mission for the Lands.

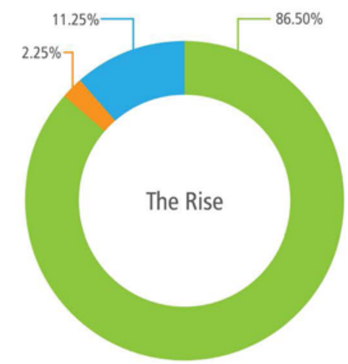
- Yes
- No opinion
- No. I would prefer to see...



4. The Rise

This is the area previously referred to as 'The Mound.' It is where a mix of fill material was placed decades ago and as a result, it is at a higher elevation than the rest of the Lands and provides views across the farm fields and bog. The Rise provides opportunities for informal recreation (e.g. picnicking, ball throwing, frisbee tossing, kite flying) and children's play. It is proposed to combine native trees, shrubs and wildflowers with orchard trees.

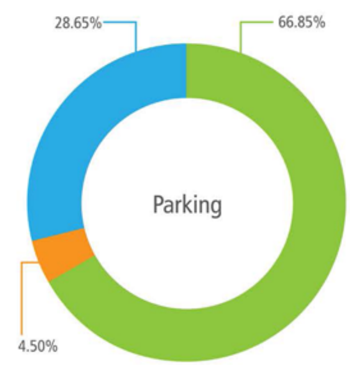
- Yes
- No opinion
- No. I would prefer to see...



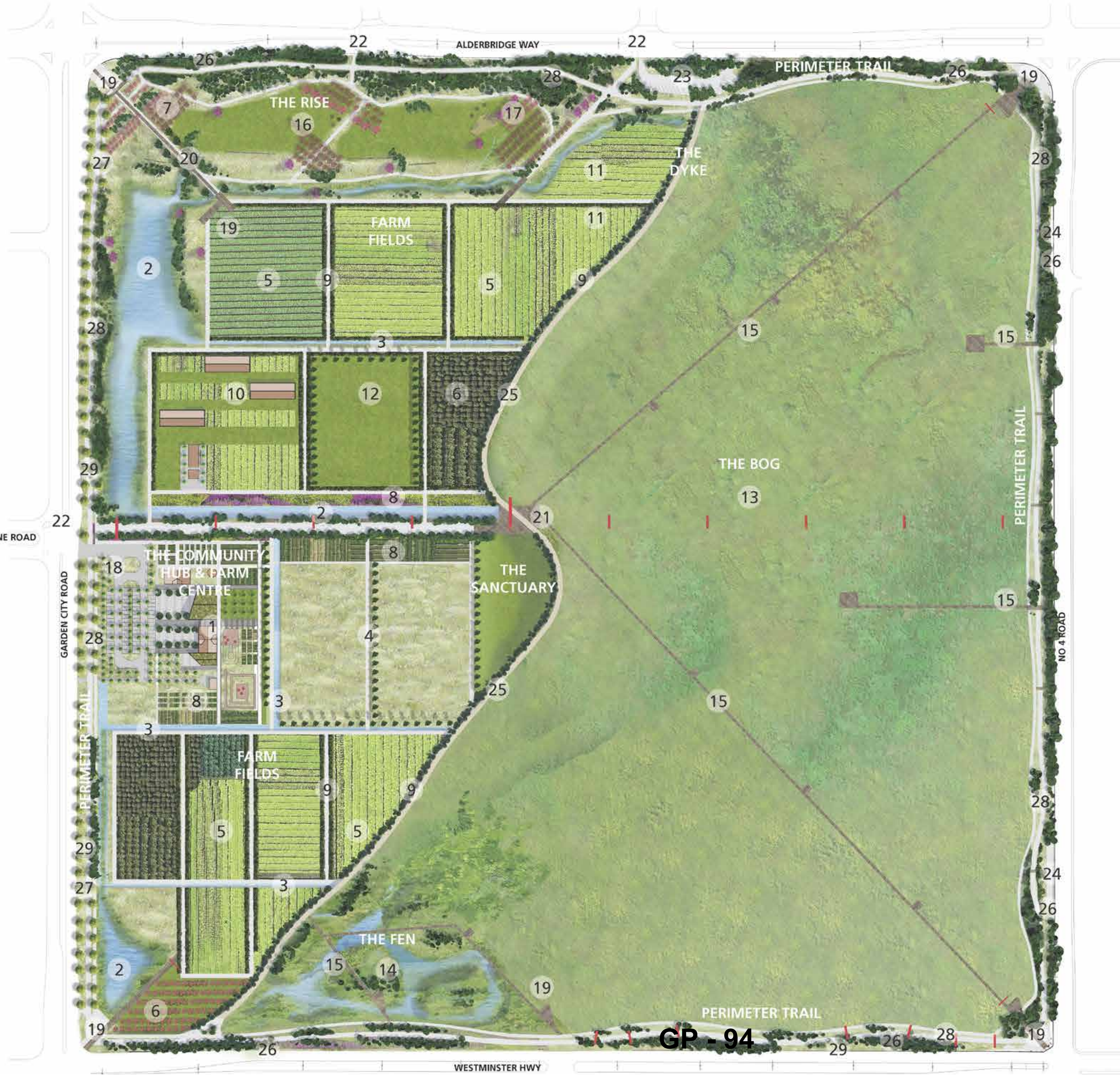
5. Parking

The Land's primary parking lot will be developed in concert with the development of the Community Hub and will support farming activities, farm and bog related events, and provide parking for the Lands' visitors. It is expected to be constructed of permeable materials and be modest in size (70-80 stalls) to minimize its impact on the Lands. A smaller parking lot is proposed for mid-point along the Alderbridge Way frontage, and the possibility of adding parallel parking spaces along the west side of No. 4 Road is being explored.

- Yes
- No opinion
- No. I would prefer to see...



Attachment 4: 2016 GCL Park Development Plan



LEGEND

THE AGRICULTURAL LANDS

1 Multi-Functional Building and Parking
2 Rainwater Storage for Agricultural Irrigation
3 Farm Drainage Ditch
4 Agricultural Event Field
5 Agricultural Fields
6 Orchard
7 Demonstration Orchard
8 Community Gardens
9 Hedgerows & Beetle Banks
10 Market Garden
11 Farm Fields
12 Soil Amendment Trials

THE BOG

13 Bog Conservation Area
14 The Fen
15 Boardwalk with Rest Points

THE RISE

16 Meadow / Informal Recreation
17 Children's Play

THE NODES

18 Garden City Lands Main Entrance
19 Entry Nodes
20 Entry Allée
21 Viewing Platform
22 Crosswalk
23 Parking Lot with Accessible Stalls
24 Parallel Parking with Accessible Stalls

THE DYKE

25 Multi-use Path with Farm Access

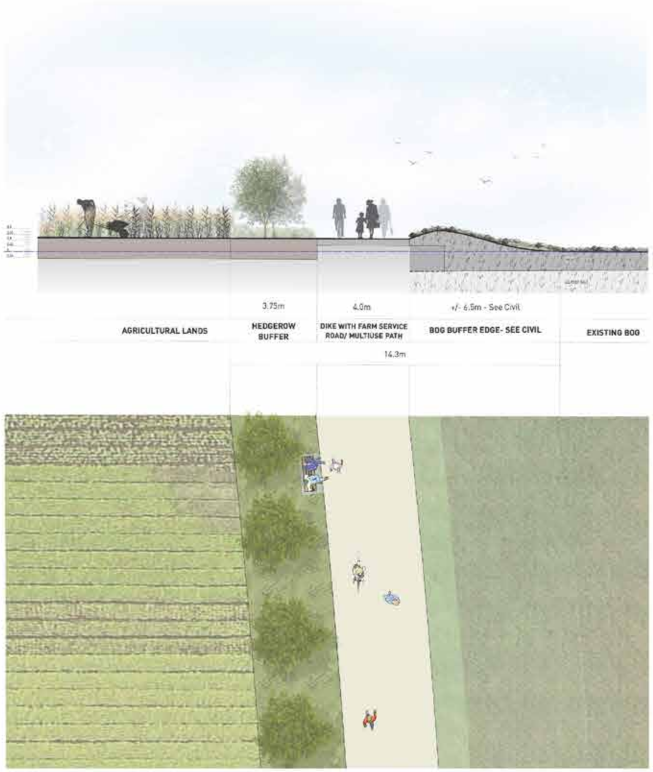
THE PERIMETER TRAILS

26 Native Forest Plantings
27 Street Trees
28 Perimeter Trails - Separated Paths
29 Rain Garden

Scale 1:1000

THE CENTRAL DIKE

The Central Dyke serves as a structure that will separate the flow of water between the bog and the agricultural fields. On one side, the water levels must be kept high for the health of the bog while on the other, the agricultural fields require good drainage. The dike top will have a broad pedestrian trail that will bring people into the centre of the park and afford views across The Lands from a slightly elevated perspective.

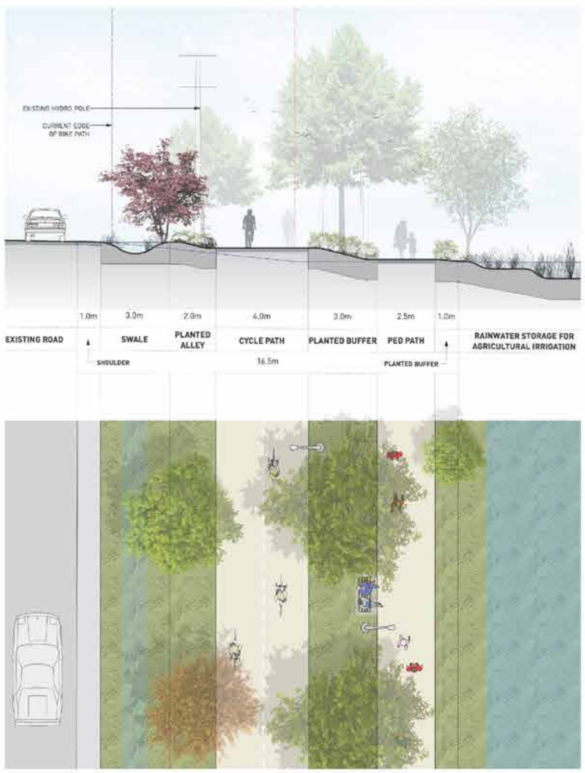


TYPICAL PLAN & SECTION SCALE 1:75

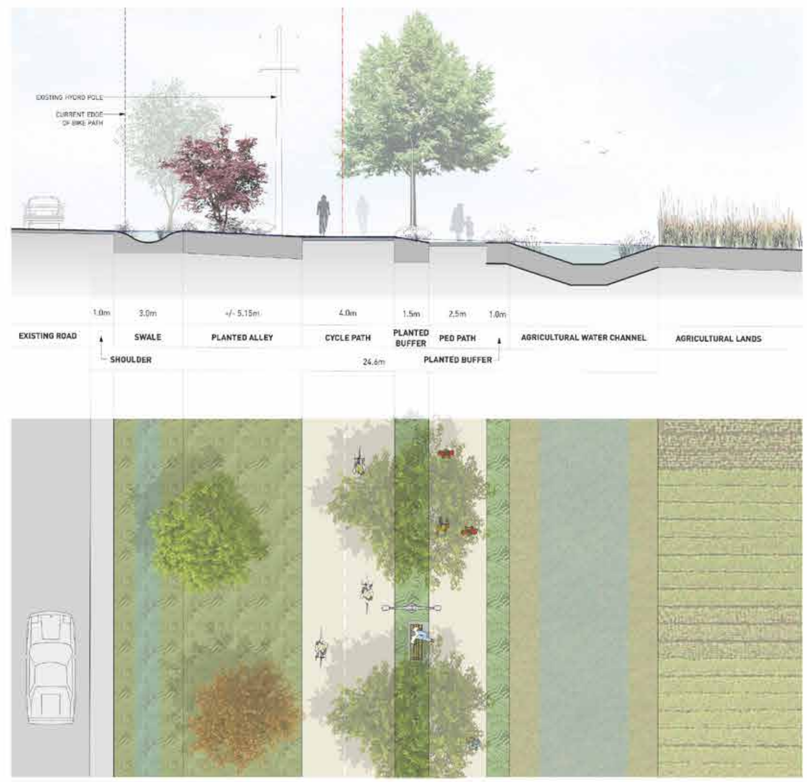
PERSPECTIVE Looking South across bog and farm fields NTS

KEY PLAN

DESIGN INSPIRATION



TYPICAL PLAN & SECTION - NORTH SCALE 1:75



TYPICAL PLAN & SECTION - SOUTH SCALE 1:75

KEY PLAN

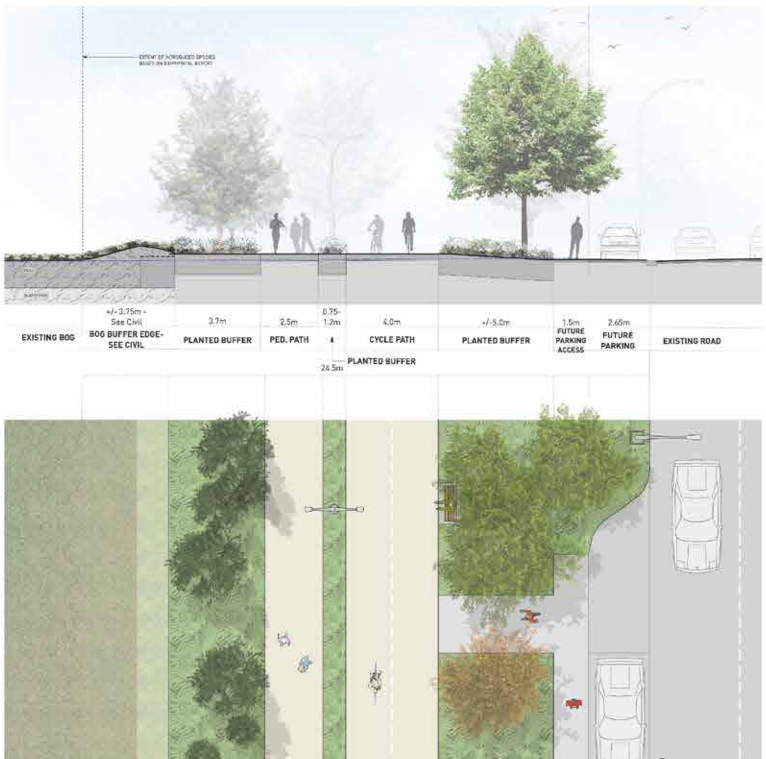
DESIGN INSPIRATION

DESIGN INSPIRATION

KEY PLAN

SITE PLAN - NORTH NODE SCALE 1:500

SITE PLAN - SOUTH NODE SCALE 1:500



TYPICAL PLAN & SECTION SCALE 1:75

PERSPECTIVE View from Alderbridge Way and No. 4 Road NTS

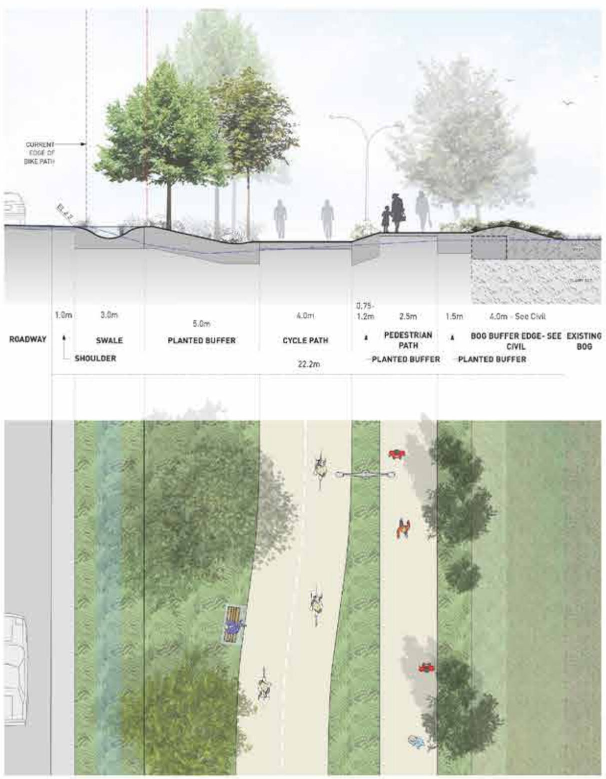
DESIGN INSPIRATION

KEY PLAN

SITE PLAN SCALE 1:500

THE PARK ENTRIES

This main entries into the park have been kept simple and modest in size, and have been designed to maintain the long views across The Lands. The entries are intended to provide opportunities for information signage and maps of the park, quick access to the park's trails as well as public art. The planting designs associated with the entries will reflect the environmental and agricultural mission for The Lands.



TYPICAL PLAN & SECTION SCALE 1:75

PERSPECTIVE Entry node at Garden City Road and Westminster Hwy NTS

Richmond

Final Draft Report

Garden City Lands Water and Ecological Resource Management Strategy

Water Resource Management Plan

July 2016
Our file 651.085-300

Submitted by:

KERR WOOD LEIDAL
consulting engineers

Contents

Figures

Tables

Executive Summary

The City of Richmond has engaged Kerr Wood Leidal Associates Ltd. (KWL) and a team of sub-consultants to prepare a Water and Ecological Resource Management Strategy. This project will support the Garden City Lands Legacy Landscape Plan (the Plan) by developing strategies to protect, restore and enhance important environmental values.

The Garden City Lands (GCL) is a 136.5 acre parcel owned by the City of Richmond. It is located within and at the eastern edge of Richmond's City Centre at 5555 No. 4 Road. The property boundaries are defined by Alderbridge Way along the north property line, No. 4 Road along the east property line, New Westminster Highway along the south property line, and Garden City Road along the west property line.

The Garden City Lands Legacy Landscape Plan is the guiding document for the GCL site development. The work of this project will develop methods to allow the creation and maintenance of the values and facilities that make up the Legacy Landscape Plan.

Site Assessment and Background Review

This part of the report summarizes the knowledge base of pertinent information available at the start of this project. It looks at the background information and literature available and indicates the basic understanding of the site from the perspective of the several disciplines contributing to this project.

Site Reconnaissance

A site visit was conducted on October 27, 2015. Members of the consulting team were accompanied by City staff from the Parks, Planning and Maintenance Departments. During the site reconnaissance, the GCL appeared to be dry without signs of saturation and surface ponding. Surface growth was freshly mowed to approximately 0.2 to 0.3 m in height across the site. Discussions and observation during the site visit covered topics including: site maintenance, site drainage and flooding, the mound, off-site inflow, the remnant bog, and wildlife and park uses.

Hydrogeological Site Assessment

Geotechnical and hydrological investigations conducted over the past several years have provided a wealth of information on the character, extent and thickness of near-surface native materials underlying the GCL and its immediate vicinity. The soils are characterised by a site-wide surficial layer of peat, averaging about 0.6 m in thickness, overlying about 3 m of overbank silt deposits that, in turn, overlie about 10 m to 20 m of fine to fine to medium grained sands. These deeper sands are referred to as the Fraser River Sand, and comprise a regional aquifer beneath the GCL and surrounding lands of Richmond and Delta that is hydraulically connected to the Fraser River. The upper part of the peat is fibrous and relatively permeable, and the water table beneath the GCL occurs very close to ground surface within this layer during the wetter parts of the year. In the drier summer months, the water drops into the underlying silts as water infiltrates downward into the deeper sand aquifer. The general groundwater flow direction in the peat appears to have been historically to the southwest.

Water quality within the peat is acidic, with relatively low concentrations of dissolved solids. This contrasts with the near-neutral minerotrophic water of the underlying sand aquifer and shallow groundwater near and beneath roadways where the peat layer has been removed. Locally, water quality in the peat appears to be influenced by mineral soils deposited for internal roadways or for other purposes.

The detailed hydrostratigraphic information gained through the previous investigations provide a good data set for building the physical features of the seepage and water balance model, and setting boundary conditions, flow characteristics and hydraulic properties for model calibration.

Ecological Site Assessment

The GCL property is located on the western edge of the Lulu Island Bog. This raised bog ecosystem once covered much of Lulu Island (and Richmond), but has now been greatly reduced due to agriculture, drainage and other human use and development. Bog ecosystems are unique and have specific challenges and opportunities associated with restoring them. The Garden City Lands bog is in a degraded condition and cannot be considered to be ecologically functional as a true bog, although it does contain regionally rare bog associated species and is potentially a good candidate for restoration. Although there has been considerable research into some aspects of bog ecology and restoration, there are some areas where the knowledge base is limited. One such area pertains to the lagg, which characterizes much of GCL.

Due to the different hydrological requirements of bog and lagg ecosystems (e.g., hydrochemical, pH, nutrient availability, stable versus fluctuating water table), and the relatively small size of the site, there is potential that they may have to be managed separately (i.e., isolated from one another) on GCL lands to support ecological integrity.

Another potential challenge is integrating agricultural activity and bog conservation on the same site. Many agricultural activities require drainage, which in large part has been responsible for the significant loss and degradation of bog and other wetland ecosystems. In addition, water requirements for agriculture are often highest during the summer, when bogs are particularly vulnerable to water drawdown. Water quality requirements for agricultural crops and bog ecosystems are sufficiently different that both their water inputs and outputs will have to be separated from one another.

The GCL must not be considered an isolated ecosystem, but rather a part of the Lulu Island Bog which includes DND lands and the Richmond Nature Park. Any proposed changes to the hydrology in GCL should consider potential effects to the greater whole.

Bog restoration typically follows a long-term outlook which must be kept in mind for all decisions on ecological management of the site and nearby areas. The Burns Bog Management Plan has ***a 100 year time horizon***. Future land use changes, adjacent development, and climate change may create conditions that further affect hydrology and bog/lagg ecosystems many years after development of the GCL.

Agricultural Site Assessment

The soils of the Garden City Lands are mixture of organic (peat) and mineral sols. These have previously been classified as Terric Mesisols and Rego Gleysols: saline and peaty phase. The main limitations are soil structure problems (mixture of peat and mineral soils) and high water tables (wetness).

The peat layer is found throughout the site and is underlain by fine-textured (silty) mineral subsoils. The rooting depth (typically 0 to 20 cm for most crops) is likely comprised of organic materials in varying stages of decomposition throughout.

Many similar soils exist in the immediate vicinity and have been cultivated. The practice usually involves the removal of the peat layer and development of the mineral layer. If the peat layer is not removed at the GCL site, then specific management steps may need to be followed.

The property has been assessed using the Canada Land Inventory (CLI) methodology as a mixture of organic (peat) and mineral soils with moderate to good agricultural capability. Limitations include high water tables, soil structure conditions, and potential salinity (to a lesser degree).

While there is no history of cultivation on the site, similar soils nearby the GCL are used extensively for berry and vegetable production and with proper management will produce an excellent diversity of crops. Special attention will need to be given to soil management if the peat is retained on site.

Any agricultural use will require some amount of land clearing and the incorporation of some plant vegetation. A list of agricultural activities that are highly or moderately suitable for the site includes:

- Garden vegetables such as root vegetables and green vegetables, corn and grains, and squashes;
- Berries including blueberries, raspberries, strawberries and cranberries;
- Field flowers, honey bees and botanical gardens;
- Hoop houses (small and medium);
- Poultry (very small scale) and large scale compost operations;
- Farm retail sales and agri-tourism as well as storing, packing, preparing, or processing foods;
- Passive uses (biodiversity conservation, wildlife viewing, parks, recreation); and
- Education and research including production and development of biological products used in Integrated Pest Management programs.

Surface Water and Drainage Assessment

The GCL site topography is relatively flat with elevation ranging from 1.5 m to 0.6 m. The site gently slopes down from the northeast to the southwest with an average slope of 0.08%. This is with the exception of the mound, which is about 2.5 m above ground level located at the northwest corner of the site. The GCL receives direct precipitation on the site and possibly receives off-site stormwater runoff that inflows to the site along Alderbridge Way. During the wet season, excess site runoff is collected by the south perimeter ditch that drains toward the west to the Garden City Road and toward the east to the No. 4 Road storm sewer system. A series of storm system inlets are located along the western edge of the site. However, the inlets were fully blocked by grass and sediment.

Historically, surface ponding has been observed at multiple locations. These topographic depression locations, as listed below, are also visible from the orthophoto due to vegetation changes.

- A large pool along the toe of the Mound.
- Multiple locations around the western edge and the southwest corner of the site.
- An area along the entrance from No. 4 Road.

The storm sewer pipes along Garden City Road and No. 4 Road are located along the edge of the road adjacent to the GCL. The storm sewer along Alderbridge Way is located in the middle of the road section, and the storm sewer along Westminster Highway runs along the South side of the road, not next to the GCL. The two pipes adjacent to the edge of the site will be easier to access either for discharge of water from the site or for accessing stormwater volumes to bring onto the site.

A MIKE URBAN model of the city's stormwater system was last updated in 2011 to assess the impacts of the 2041 development horizon for the Official Community Plan. The model identified surface flooding nearby the GCL site at all the major nodes located along Alderbridge Way and Garden City Road, attributable to inadequate capacity in the major storm sewer system for the modeled 10-year, 24-hour storm event. The limited capacity in the storm sewer network on Garden City Road may affect the drainage design for development of the site. Without upgrade of the receiving storm sewer pipes, detention on-site of the design rainfall event may be required.

This project presents a number of challenges for surface water and drainage considerations, including:

- Drainage will need to be provided to required elevations both for the bog and natural areas and for the agricultural and community use areas.
- There will be a need to retain water on the site to some minimum levels in order to support the bog and wetland natural areas of the Legacy Landscape Plan.
- Drainage may also be challenging due the very low gradients available in this area.
- There is a question whether the site can sustainably supply some or all of the water needs for on-site water uses with storage and re-use of on-site and/or off-site stormwater.

The source of water that enters the site along South side of Alderbridge Way is currently unknown and the volume of water will be difficult to estimate for storage or conveyance on GCL.

Water Resources Management Plan

This Water Resource Management Plan proposes recommended solutions to balance the water needs of the site and support the goals and features of the Legacy Landscape Plan.

Water Management Options for Bog Conservation

Subsurface and Surface Flow Barriers

It is proposed that a primary subsurface and surface flow barrier and perimeter barrier be constructed all the way around the bog area. A plan showing the berm alignment is provided in

Figure 10-2. The barrier should be constructed with an impervious or low permeability material that extends from the bottom of the peat layer into the top of the surface berm. The subsurface portion of the barrier is intended to minimize ground water loss form the bog to the agricultural land to the west, drainage ditch to the south, and utility trenches to the north and east. The surface berm is intended to prevent surface water exchange between the bog and the adjacent land uses. The barrier will enhance the bog hydrology and preserve the water quality desired by a healthy bog ecosystem. Construction options for the subsurface barrier are shown in Figure 10-3.

Fen Wetland

An outlet control structure will be installed at the southwest corner of the GCL, where a seasonal wetland exists. The outlet structure will be elevated above existing ground and provide various levels of control for management of the water level. The prolonged duration (winter into the spring) and extended area of ponding is expected to enhance the bog environment during the dry season. The fen wetland also provides nesting, perching, refuge and foraging habitat for wildlife. Examples of the type of outlet structure required to allow control of the water level in the fen wetland are provided in Figure 10-4. The extent of the wetland will be constrained by the primary and perimeter surface flow barrier berms.

The maximum ponding elevation for the fen is recommended to be 1.7 m. The surface berms should have minimum crest elevations of the higher of:

- 0.3 m above the maximum ponding elevation, or
- 0.3 m above existing ground for the perimeter berms, or
- 0.6 m above existing ground for the primary berm.

Bog Water Supply Option

In addition to the bog water conservation approach, including construction of hydraulic barriers and creation of a fen wetland, additional water supply sources were identified and assessed. Only the option of drawing water across No. 4 Road from the DND lands provides a source of water with the correct water chemistry to support and promote the health of the bog plant species. However, this option requires coordination with Federal Government and DND to negotiate access to the site and to conduct groundwater monitoring as soon as possible to further assess if this would be a viable option.

Agricultural Water Management Options

Agricultural Drainage System Design Recommendations

The agricultural drainage system will require the interconnectivity of several design components. The options for each component are found in Table 11-1 and the design recommendations are summarized in Table A - 1.

Table A - 1: Agricultural Drainage System Design Recommendations Summary

Items		Recommendation
Drain Pipe	**Spacing**	• Drain tile pipe spacing of should be a maximum of 22 m between pipes.
	Depth	• Drain tile pipe should be installed 1.0 to 1.2 m below final grade; and • The drainage outlet, i.e. ditch invert, will be lower than 1.0m deep (i.e. lower than the drain pipes).
	Size and Material	• 100 mm diameter is the standard pipe size for the lateral drains; • 150 mm diameter is required for the collector drain pipe; and • High density polyethylene (HDPE) pipes or rigid plastic pipes should be used in peat soils.
	Grading and Length	• For a 100 mm pipe diameter the minimum grade is 0.10% and the maximum grade is 2.00%. A 0.50% to 1.0% grade is recommended; • Lateral pipes should not exceed 600 m before connecting to a collector pipe or ditch outlet; and • A minimum clearance of 300 mm between the bottom of the drain outlet and the ditch bottom is recommended.
	Other Considerations	• Drainpipe should go at the base of the peat and not be cut into the clay-silt layer below. • The base of the peat layer, and invert of the tile drainpipes at the West edge of the site, should be at approximately 0.0 m elevation. • Significant fill material (up to 0.5 m), will be required at the northwest corner and along the western edge of the site.
	Alternatives	• If no drain tile pipes are installed then surface ditches should be spaced approximately 60 m apart.
Drainage Ditch	Alignment	• See Figure 11-1.
	Dimensions	• Minimum bottom width 0.6 m. • 4H:1V side slope for safety reason, 1.5H:1V side slope if needed and approved by geotechnical engineer.
	Invert	• Ditch invert should be 0.3 m below the tile drainpipe outlet, if possible. • Subject to geotechnical investigation, the ditch invert cut into clay layer 0.3 m below peat layer (to allow 0.3 m offset from the drain pipe outlet). • Peat depth is thinner on west side of site, about 0.6 to 1.0 m. • If base of peat layer is approximately elevation 0.0 m. the ditch invert along the West side of the site should be at approximately -0.3 m.
	Freeboard	• Maintain a minimum of 0.9 m elevation difference between the base flow water levels in the channel and the field surface elevation. This will provide a good outlet for tile drains.
	Slope	• Channel should have minimum slope at 0.5% to promote drainage if possible, but can be reduced to 0% if necessary.
	Outlet	• Flap gate or other device to prevent back flow from the storm sewer system flowing onto the site.
	Alternative	• Alternative to a drainage ditch, pipe could be used to convey the agriculture runoff to the storm sewer.

Irrigation Requirement and Water Sources

Based on data published by the Ministry of Agriculture through the Metro Vancouver Agricultural Water Demand Model (AWDM) and discussions with Kwantlen Polytechnic University, the estimated irrigation water requirement is 3000 m^3 per hectare per year for the GCL agriculture fields.

Table A - 2: Irrigation Water Sources Summary

Items	Pros	Cons
Groundwater	• Grounwater withdrawal of 3 L/s from up to two wells does not appear to significantly drawdown the water table in the bog area • On-site source of water.	• Possibility of high iron levels in the groundwater, which require treatment and maintenance of the treatment system • Actual pumping yield unknown at this time, would require test well
Rainwater Harvesting	• Sustainable source • Options include open pond and underground storage tank	• Requires significant area for storage • Seasonal availability if full irrigation volume needed cannot be stored • Limited to on-site rainwater and runoff only due to urban runoff water quality concerns • If surface storage, may require filtration before using in drip irrigation system
Fraser River Water	• Abundant volumes	• Issues of salinity and timing for drawing water • High infrastructure costs to transport water to the site, possible pumping
Municipal Water	• Due to flexibility, preferred for the short term	• Expensive • Less sustainable for the long-term

The development of agricultural fields will be a long term process due to phased soil amendment and drainage installations. The irrigation volume is expected to increase over time as field acreage is put into production. The final soil mix will affect crop selection and the ultimate irrigation water needs.

Potable water use is recommended in the short term until the irrigation needs are better defined and other irrigation source options can be implemented.

On-Site Stormwater Management

Stormwater BMPs

The constructed portions of the GCL site (building, parking, buildings, other impervious areas), applicable BMPs were selected based on the hydrologic regime, pre-development conditions, and proposed land use.

Table A - 3: On-site Stormwater BMPs

Items	Applicable BMPs
Community Hub	• Roof water should be drained to cistern/rain barrels and discharge excess to ground. The water collected can be used for irrigation of nearby plantings.

Items	Applicable BMPs
Path, Plaza and Parking Surfaces	• Pervious paving materials rather than impervious concrete or asphalt can reduce the runoff generated from parking areas. Pervious materials may include pavers, reinforced clean crushed gravel, reinforced turf, or engineered permeable pavements. • Oil and grit separators are suitable for spill control and removal of floatable petroleum-based contaminants as well as coarse grit and sediment from small areas such as parking lots, if the parking areas have impervious paved surfaces.
Road Drainage	• See road drainage servicing plan Figure 12-3

Road Drainage

The GCL site development requires modifications to some of the existing road drainage. A road drainage servicing plan is provided in Figure 12-3.

Alderbridge Way and No.4 Road

- Both roads are curbed with catch basins to drain road runoff. The catch basins will remain unchanged.
- Existing storm inspection chambers may stay to drain excess runoff from trail areas once the bog area is isolated; the storm system inspection chambers may need to be modified as discussed above.

Westminster Highway

- Westbound side of road drains to ditch on GCL site. The ditch remains and should stay on the south side of the perimeter hydraulic flow barrier.

Garden City Road

- Most of the drainage along Garden City Road is intercepted by inlets in the boulevard between the Northbound and Southbound lanes. Road drainage to inlets in the centre median should be maintained.
- Areas of Northbound Garden City Road with turn lanes at road junctions are crowned to drain to the GCL site. New catch basins are required to intercept runoff at these locations.
- The existing storm inspection chambers located along Garden City Road will no longer be needed when the perimeter trail and the agricultural drainage channels are built. These inlets should be closed or disconnected.

New Storm Drainage Connections

A minimum of two new connections to the storm sewer system are required for the development of the elements of the LLP.

One new storm sewer connection is required to drain the outlet from the bog conservation area. A new storm sewer pipe will be needed to connect the outlet structure to the storm sewer pipe on Garden City Road. The 10-year design flow for this connection is 0.8 m^3/s, based on the 10-year, 24-hour event peak runoff for this area from the City's MIKE Urban drainage model.

The other new storm sewer connection is required to drain the runoff from the farm areas of the GCL site to the storm sewer. This will involve connecting the drainage ditches from the GCL site to either the storm pipe under Garden City Road or to the storm box pipe under Lansdowne Road. It is recommended that the drainage connect from the GCL site to the Lansdowne Road storm box pipe, invert -0.853 m. The drainage invert for the ditch on the Western edge of the GCL site is expected to be -0.3 m. The 10-year design flow for this connection is 1.0 m^3/s, based on the 10-year, 24-hour event peak runoff for this area from the City's MIKE Urban drainage model.

Other Design Considerations

Climate Change

Climate change predictions to the GCL site were made using the regional analysis tool developed by the Pacific Climate Impacts Consortium (PCIC). The model uses 1961-1990 climate data as the baseline condition. The percentage maximum, minimum and mean precipitation departures for the Metro Vancouver region were estimated on an annual and a seasonal basis. The data describing project future climate conditions is provided in Table 12-1. In general, the future modelling conditions for 2020, 2050, and 2080 show a consistent pattern of increased annual total precipitation, and changed seasonal rainfall distribution. Increased winter precipitation suggests increased winter flooding and warmer drier summers suggests increased potential evaporation and transpiration.

Flood Construction Level and Building Elevation

The GCL site has a Flood Construction Level (FCL) of 2.9 m (GSC) however, as the proposed community buildings and facilities are within the ALR, farm buildings other than dwelling units are exempt from the FCL requirement.

If buildings will not be built above the FCL, it is recommended that all the structures are flood-proofed to minimize the damage of short-term flooding which must be expected to occur. In addition, all buildings are recommended to be constructed above the 10-year HGL to avoid the nuisance of frequent flooding. The 10-year HGL along the Western edge of the site on Garden City Road varies from approximately 0.8 m on the Northwest corner to 0.9 m on the Southwest corner. It is recommended that buildings be constructed with a minimum floor elevation of at least 0.3 m above the 10-year HGL, or above 1.2 m elevation.

Survey Elevation and Datum System

The majority of the GCL site is very flat with an average slope of 0.08% from the northeast to the southwest. Low drainage gradient on site and in the downstream stormwater drainage system makes design of infrastructure connections and flooding elevations more sensitive to the accuracy of elevation.

Some elevation data used in this work were not able to be verified to be geodetic. Therefore, it is recommended that all critical elevations be surveyed for design and construction purposes.

Ecological Management Plan

The 2014 Garden City Landscape Legacy Plan envisions restoration of a raised bog/lagg (fen) complex that drains to the southwest of the site. Currently the site is indicative of a semi-modified bog with a plant community that has been influenced by its urban setting. Concurrent with the Legacy Plan, a primary goal is to restore this ecosystem back to as natural a state as possible within the limitations of its location.

It is unclear how effective the perimeter hydrological barriers will be at retaining water in the conservation area, which is key to determining if a bog ecosystem can be restored over time. Efforts to restore a functioning bog will take significant resources and are dependent on the effectiveness of the perimeter subsurface hydraulic barriers and surface berms. Adaptive management on site will be important to develop a fuller understanding of the site's hydrogeology and its influence on plant communities.

Recreation Interface Zone

Areas around the perimeter of GCL have been subject to historical disturbance. This area is proposed to be redeveloped as perimeter berms to support recreational walkways, while at the same time isolating the hydrology on site. Landscaping is proposed as a vegetated buffer between the perimeter road and the conservation areas. These will be linear planted areas that are fragmented by walkways and/or bike lanes. These areas are expected to be raised above the bog and at the level of the adjacent roadways. The ecology is therefore expected to be moderately dry. It is recommended that only native tree and shrub species be planted in these areas.

Remnant Bog Zone

Plant communities found at the eastern edge of the GCL represent the closest plant community to natural bog conditions. This area is currently dominated by invasive species including a high percentage cover of Scotch heather; however, it also supports a number of species that are representative of bog ecosystems. This area has been historically mowed and, as a result, tall shrubs and trees have not established. The long term vision for this area includes establishing a stable shrub dominated plant community with wide-ranging hummocks and mats of sphagnum as well as scattered individual or small groupings of lodgepole pine trees. However, it is unclear based on our current understanding of the hydrological regime what effect the potential management interventions will have on existing vegetation communities or whether the restoration of a stable native bog ecosystem is even possible. The following four vegetation management options are presented with a range of outcomes, arranged in order of increasing cost to implement and manage:

1. No management - allow natural succession
- Expected outcome: invasive birch/blueberry dominated forest
2. Mowing to maintain a low shrub community
- Expected outcome: existing low shrub/herb plant community with a high cover of invasive Scotch heather
3. Manage invasive species - manual/mechanical removal
- Expected outcome: mosaic of shrub species and scattered pine
4. Remove invasive species and plant bog species
- Expected outcome: mosaic of shrub and herb species with pockets of sphagnum and scattered pine

After sufficient monitoring has provided a better understanding of the hydrological regime and plant communities, one of these strategies or a combination of these may be adopted.

Lagg Zone

The area to be managed as a lagg ecosystem exists to the southwest of the bog area where water naturally drains on site. The lagg is a transition zone that acts as an important buffer between a raised bog (and its acidic, nutrient poor environment) and the surrounding landscape which is influenced by more nutrient rich water inputs. As such, the lagg typically contains vegetation representative of both bogs and fens, and the hydrological conditions and soil type will influence the pattern of vegetation across the landscape.

Fen Wetland Zone

The marshland, situated in the southwest corner of the site, is the lowest point of GCL. The water table is high and almost entirely dominated by fireweed, Sitka sedge, hardhack and bracken fern. The goal for this area would be to support areas of standing water for most of the year. The area holds standing water through the wetter portions of the year, and has a natural drainage swale running south. Efforts required to enhance this area will be dependent on the effectiveness of the hydrological barriers.

Habitat Enhancement Opportunities

Habitat enhancement can support wildlife by improving the conditions (e.g. vegetation, ground cover, structural diversity) necessary to meet their individual needs. The following enhancement opportunities are expected to increase habitat value for a diversity of wildlife species.

Two stormwater channels are planned to drain the active agricultural area on the western portion of the Garden City Lands site. The final design of these storm water channels is dependent on predicted site stormwater runoff and on geotechnical limitations on the depth of channel excavation as discussed in this strategy. Wetland plant communities that could be planted in these channels to filter and treat agricultural runoff.

Targeted habitat enhancement strategies are recommended to support biodiversity, while mitigating human-wildlife conflicts that may be associated with additional agricultural use, recreational activity and traffic. The habitat features listed below mimic those found in healthy bog and lagg ecosystems and are appropriate regardless of the ecological management option pursued:

- Large woody debris - Large tree trunks that have fallen provide shelter, feeding sites, and movement pathways for wildlife;
- Standing wildlife trees - Dead standing trees or 'planted wildlife trees' are important habitat features for birds, mammals, amphibians and other organisms and provide forage, roosting and nesting sites for a diversity of bird species;
- Raptor perches - Raptors often use perch sites to act as vantage points when hunting prey; and
- Nest boxes/structures - Insect activity is expected to be high for birds and bats and nesting boxes and structures should be installed to support bird and bat species.

Ecological Implementation Framework – Adaptive management, maintenance and monitoring

A primary goal of this strategy is to re-establish a plant community that best represents a bog ecosystem. Towards this end, it is recommended that a vegetation monitoring program be undertaken for the first three years after buffers are installed to better understand groundwater conditions and plant community composition outside of the influence of mowing. The following monitoring schedule supports implementation of the most comprehensive option for managing vegetation in the conservation area - Option 4 – Remove Invasive Species and Plant/Promote Bog Species and Sphagnum, with installation of wildlife habitat features.

Figure: Proposed 10-year Treatment Schedule

Part A: Site Assessment and Background Review

1. Report Context

The City of Richmond engaged Kerr Wood Leidal Associates Ltd. (KWL) and a team of sub-consultants to prepare a Water and Ecological Resource Management Strategy. This project will support the Garden City Lands Legacy Landscape Plan (the Plan) by developing strategies to protect, restore and enhance important environmental values.

The Plan divides the site into broadly four areas, including remnant bog area, agricultural area, wetland area and community use area. Each land use area represents distinctive needs for surface and sub-surface water management on site.

The objectives of this Water and Ecological Resource Management strategy are:

- To develop methodologies for the protection of the sustainability of the bog including the provision of a buffer;
- To develop methodologies (drainage and irrigation) for enabling agricultural uses on the site; and
- To mitigate impacts of site development and public use on the site's ecological resources and to develop long-term maintenance strategies.

Due to the complex natural of the project, the project team consists of a group of multi-disciplinary specialists. The project work was broken down into the following six phases, each with the following deliverables:

- Phase 1 - Analysis of Current Conditions: Preliminary Site Assessment Report;
- Phase 2 - Hydrogeology Assessment: Draft Seepage Model Report;
- Phase 3 - Water Resource Management: Draft Water Resources Management Plan;
- Phase 4 - Ecological Resource Management: Draft Ecological Resource Management Plan;
- Phase 5 - Operations and Long Term Monitoring: Draft O&M and Long-Term Monitoring Plan; and
- Phase 6 - Final Water and Ecological Resource Management Strategy: Final Strategy.

This report is the deliverable for Phase 6, a preliminary site assessment report that summarizes the existing site conditions and a background literature review.

1.1 Project Background

The Garden City Lands (GCL) is a 136.5 acre parcel owned by the City of Richmond. It is located within and at the eastern edge of Richmond's City Centre at 5555 No. 4 Road. The property boundaries are defined by Alderbridge Way along the north property line, No. 4 Road along the east property line, New Westminster Highway along the south property line, and Garden City Road along the west property line.

The GCL is surrounded on three sides by urban neighbourhoods that are undergoing rapid redevelopment. It is one of four quarter sections that are the remnants of the Lulu Island Bog, the others being the Department of National Defense Lands and the two sections of the city –owned Richmond Nature Park that are bisected by Highway 99. Therefore, the GCL serves as an ecological connection between the natural lands to the east and Lansdowne commercial centre to the west. Over 33,000 people live in the adjacent quarter sections to the site, and the site represents a major addition to urban park area in the City of Richmond.

The GCL is located within the provincially designated Agricultural Land Reserve (ALR). The Lands are valued for the bog environment that existing on a portion of the site (approximately 70 acres) and also for their potential agricultural capability (approximately 50 acres). The GCL has recently been the subject of a planning and public consultation process that resulted in development of the Garden City Lands Legacy Landscape Plan to develop a green oasis in the City Centre for community wellness, agricultural and ecological conservation purposes.

GCL Legacy Landscape Plan

The Garden City Lands Legacy Landscape Plan is the guiding document for the GCL site development. The work of this project will develop methods to allow the creation and maintenance of the values and facilities that make up the Legacy Landscape Plan. The Legacy Landscape Plan divides the site into multiple sections to support four themes of use in different areas of the site, see Figure 1-1. Broadly, the site is divided into distinct but sometimes intertwined areas including:

- A remnant of the Lulu Island bog to be restored and supported as a viable bog community, including a sphagnum moss 'sanctuary area';
- A naturalized wetland area with stream and year-round open water areas, that could be used to support the hydrology of the bog and/or supply water for irrigation of the site;
- An agricultural area for Kwantlen Polytechnic University's Sustainable Agriculture Research and Education Farm as well as community gardening spaces; and
- Community use areas including activity fields and event spaces, the "mound", multi-function buildings and shelters, and water features.

The inherent challenge of the Legacy Landscape Plan is that these areas and uses represent up to four separate sets of needs for water management on the site. These separate surface water, groundwater and drainage needs for the site must be considered individually, as well as in proximity to the other uses, and the conflicts and competing needs reconciled in order to support the whole of the site.

This project, the Water and Ecological Resource Management Strategy, will build on the Legacy Landscape Plan to develop concept-level design options for implementation of the Plan. The team will balance the competing needs to the site and develop practical, feasible methods to achieve the vision for the site.

1.2 Report Organization

This report summarizes the knowledge base of pertinent information available at the start of this project. It looks at the background information and literature available and indicates the basic understanding of the site from the perspective of the several disciplines contributing to this project.

The report is organized in sections according to the expertise reviewing the background information. Each section summarizes the available information, the pertinent conclusions regarding the site, and discusses areas where unknown information will influence or affect the development of options and strategies in this project.

LANDSCAPE ZONES

- The Bog
- The Mound
- The Fields
- The Sanctuary
- The Wetland
- The Community Hub & Farm Centre
- The Edges

Source | From the City of Richmond Garden City Lands Legacy Landscape Plan - May 2014

651-085\501-Drawings\b_Figures\651085_Phase1_Fig1-1.cdr

Project No. 651-085

Date November 2015

Not to Scale

Garden City Lands - Legacy Landscape Plan | April 2014

KERR WOOD LEIDAL consulting engineers

Figure 1-1

Part A: Site Assessment and Background Review

2. Site Visit and Survey

2.1 Survey Plan and GIS Data

A site survey plan is shown in Figure 2-1. The plan, dated in January 2015, shows topographic survey points in an approximately 65 m x 35 m grid system all through the site. In addition, the edge of vegetation, abrupt elevation changes (the mound, ditches and swales), and site access path were included in the survey plan.

The City also supplied GIS data sets that contain administrative and utility data such as parcel boundary, address, road, water, sanitary and storm sewer data. The data covered the GCL site and 8 surrounding quarter sections. The only drainage system within the GCL is the south perimeter ditch along Westminster Hwy. The ditch, with a top width of 2.0 m, conveys site runoff westwards to the Garden City Road storm truck and eastwards to the No. 4 Road storm truck. A 900 mm steel culvert is shown along the middle section of the ditch.

2.2 Site Reconnaissance

A site visit was conducted on October 27, 2015. Members of the consulting team were accompanied by City staff from the Parks, Planning and Maintenance Departments. During the site reconnaissance, the GCL appeared to be dry without signs of saturation and surface ponding. Surface growth was freshly mowed to approximately 0.2 to 0.3 m in height. The group walked the site with discussions focusing on the following areas, as summarized in Table 2-1.

Table 2-1: Summary of Site Reconnaissance

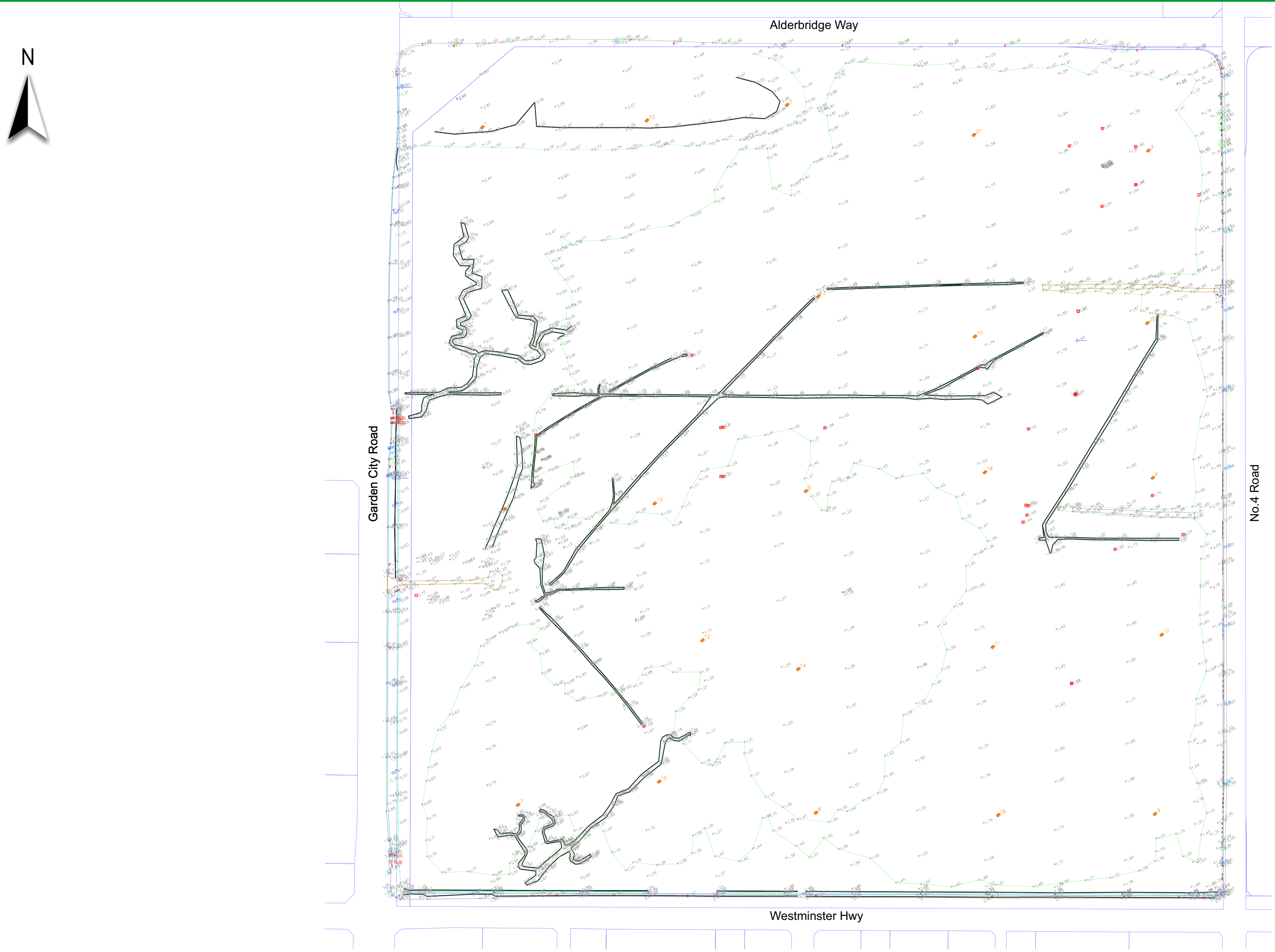
Items	Knowledge and Site Observation
Site Maintenance	The current maintenance activity is limited to mowing once per year. Regular mowing has somewhat conserved the bog ecosystem by controlling the growth of tall shrub and tress, as well as reduced invasive exotic weed species.
Site Drainage and Flooding	The site was dry without any signs of saturation and surface ponding. No overland flow path was identified on site at the time. Based on knowledge from the City maintenance department, the western edge of the site (north of the gravel parking lot) experienced flooding a few years ago. Surface ponding elevation approached the edge of Garden City Road. It was believed that a pipe inlet (or multiple inlets) drain the surface runoff into the storm sewer system along Garden City Road. Attempts were made to locate the inlet, but were not successful due to compacted clippings from the recent mowing activities. It is assumed that the outlet pipe, if it exists, would not drain well due to clogging.

Part A: Site Assessment and Background Review

Items	Knowledge and Site Observation
The mound	The mound area, about 2.5 m above ground elevation, is located along the northwest corner of the GCL. Discussions were focused on the reusability of the mound material for agriculture use. The agricultural consultant questioned the quality of the material as it is thought to be composed of waste from road construction. The City is going to conduct soil testing to better ascertain its composition. Vegetation along the south toe of the mound indicates that this area is a low-lying wet area.
Off Site Inflow	Parks Staff noted that the site received off-site runoff from Alderbridge Way through a possible outlet or abandoned pipe located just east of the mound. However, the site walkover did not find the noted drainage structure. The City Engineering Department will check record drawings to see if any abandoned infrastructure is recorded in the vicinity of this inflow.
Remnant Bog	The eastern part of the site was covered largely by sphagnum peat that resembles a raised bog ecosystem. The centre part of the remnant bog area appeared to be spongy with at least two types of living sphagnum moss.
Wild life and Park Use	The site has a visible diversity of plant communities and wild life habitat. A variety of blueberries, hardhack and sphagnum moss was found, as well as a heron, hawk and a coyote. The site is also used by the public, mainly for dog walking.
Richmond Nature Park	A walk in the Richmond Natural Parks was conducted by KWL staff after the site visit to the GCL site to gain familiarity adjacent remnant areas of the LuLu Island Bog in natural and un-mowed state. The bog portion of the Park is mainly covered by tall shrubs, many of them commercial (non-native) blueberries, approximately 1.5 m to 2.5 m in height. Besides, pine and birch trees are providing stiff competition. Typical bog plants, such as moss and low shrubs were visible but generally overgrown. Wild life such as mole and squirrels were spotted on site.

In summary, the GCL is experiencing a dryer than usual year in 2015. No surface drainage path or infrastructure was located on site. Annual mowing, as a management strategy, has kept the predominance of low growing plants, which preserve the GCL's resemblance to a bog ecosystem. In contrast, the Richmond Nature Park has transitioned into a forest-like ecosystem due to competition from pine, birch trees and tall bushes. Ideally, an additional site visit should be conducted during the wet season to further observe the site drainage patterns.

City of Richmond



Source | Survey plan from the City of Richmond.

651-085\501-Drawings\b_Figures\651085_Phase1_Fig2-1.cdr

Project No. 651-085

Date November 2015

Not to Scale

Garden City Lands Site Survey Plan

KERR WOOD LEIDAL consulting engineers

Figure 2-1

Part A: Site Assessment and Background Review

3. Hydrogeological Site Assessment

3.1 Available Information

A variety of technical reports and documents were identified that were likely to provide either direct, site-specific information concerning stratigraphic and hydrogeologic conditions underlying the GCL, or information for nearby sites. Documents obtained and reviewed as part of this preliminary assessment are itemized below:

Aerial Orthophotos

- 1922, 1930, 1949, 1954, 1963, 1969, 1980, 1986, 1991, 1997, 2002, 2009

Hydrogeological Assessment Reports

- SNC-Lavalin, 2015, Hydrogeological Investigation, Garden City Lands, Richmond, BC. Project No. 626827.
- SNC-Lavalin, 2013, Vancouver Landfill Hydrogeological Review. Ref: 511867.
- EGSL, 2006, Report on Hydrological Monitoring Program, MK Delta Lands Group Properties and Surrounding Area, Delta, BC. Project No. 06005.
- EGSL, 2010, Ecohydrological Overview of Surrey Bend Park, Surrey, BC. Project No. 01011.
- Golder Associates Ltd., 2004. McLennan Park Detention Pond Groundwater Characterization, Richmond BC. Project No. 03-1411-126

Geotechnical Reports

- Trow Associates, 2008, Preliminary Geotechnical Assessment for Garden City Lands, Richmond, BC. Ref: 071-03105.
- Trow Associates, 2004, Geotechnical Exploration and Report - Proposed Townhouse Development 9180-9220 Westminster Highway, Richmond, BC. Ref: 041-01522.
- GeoPacific, 2014, Geotechnical Investigation Report - Proposed Townhouse Development 9700 & 9740 Alexandra Road, Richmond, BC. Ref: 10913.
- GeoPacific, 2014, Geotechnical Recommendation for Proposed Central at Garden City Commercial/Retail Development (Bldings A-E, L, H) Garden City Road at Alderbridge Way, Richmond, BC. Ref: 12060.
- GeoPacific, 2014, Geotechnical Recommendation for Proposed Central at Garden City Commercial/Retail Development (Bldings East Anchor, J, K, M, N and Green Deck) Garden City Road at Alderbridge Way, Richmond, BC. Ref: 12060.
- GeoPacific, 2009, Geotechnical Investigation Report Proposed 18 Unit Townhouse Development 9460 and 9480 Westminster Highway, Richmond, BC. Ref: 8312.

Part A: Site Assessment and Background Review

Other Reports

- Diamond Head Consulting Ltd, 2013, City of Richmond Garden City Lands Biophysical Inventory and Analysis. Ref: None.
- Agricultural Land Commission, 2009, Exclusion Application – Garden City Lands (Letter and Minutes). Ref: O – 38099
- Schroeter Consulting, 2008, Agricultural Assessment of the GCL Lands, 55 No. 4 Road, Richmond. Ref: 07045.
- Davis, Neil and Klinkenburg, 2008, A Biophysical Inventory and Evaluation of the Lulu Island Bog, Richmond, British Columbia. Publisher: Richmond Nature Park Society.
- Agricultural Land Commission, 2006, Agricultural Capability Assessment (Memo). Ref: O – 36435.
- Lutmerding and Sprout, 1969, Soil Survey of Delta and Richmond Municipalities. Publisher: BC Department of Agriculture, Kelowna.

3.2 Previous Hydrogeology Work

Hydrogeological Investigation, SNC Lavalin, 2015

SNC Lavalin undertook a baseline hydrogeological investigation of the GCL in 2015. Their work included the following activities:

- Established groundwater instrumentation sites (18 piezometers at 10 locations);
  - four nested wells (shallow, intermediate, deep) at 15-01 through 15-04; and
  - six shallow wells completed within peat (15-05 through 15-10).
- Continuous water-level monitoring data obtained at hourly intervals over a period of six months (March to August 2015); data loggers installed in ten wells; and
- Water quality assessment completed in all piezometers. Background water quality was established based on indicator parameters only (i.e., temperature, pH, electrical conductance).

Piezometers 15-01 through 15-06 were drilled using solid and hollow stem augers, which provided samples for logging during drilling. Piezometers 15-07 through 15-10 were installed by hand using a slide hammer device, and no soil or peat samples were acquired for logging. Hydrographs were established documenting water levels within the peat, underlying clayey silt and underlying Fraser River Sand over time. Among observations made, the vertical hydraulic gradients were consistently downward, and water levels dropped over the course of the dry summer months, effectively dewatering the peat over the summer. Water within the peat was characterized as being acidic with relatively low dissolved solids (pH 3.8 to 4.8; electrical conductance less than 100 µS/cm), whereas waters within the underlying Fraser River Sand were near-neutral and minerotrophic (pH 6.3 to 7.0; electrical conductance about 300 µS/cm to 750 µS/cm). Minerotrophic, near neutral pH waters were also encountered in shallow soils nears roads, where peat had likely been removed a part of development.

Part A: Site Assessment and Background Review

Hydrogeological Assessment, McLennan Park, Golder Associates, 2004

In 2004, Golder completed a detailed hydrogeologic assessment of McLennan Park in Richmond to support construction of various water features in the park including a wetland and detention pond. The plans included construction of an on-site well to provide supplemental water to off-set predicted pond losses from the detention pond. The scope of work completed by Golder included:

- One cone penetrometer test (CPT) to develop a detailed stratigraphic profile at the test well site;
- Installation of three monitoring wells at varying distances from the test well site;
- Well development and sampling for a range of test parameters including pH, temperature, and electrical conductance on all wells, and chemical analysis of one well for a range of major ions, nutrients, metals, pesticides, herbicides and fungicides;
- Completion of an eight-inch diameter well within the Fraser River Sand aquifer, with a stainless steel well screen installed at 16.8 m to 18.3 m below ground surface;
- Completion of aquifer pumping tests, including a 3-hour variable rate pumping test followed by a 48-hour constant rate (3.1 L/s, or 50 USgpm) test;
- Water quality sampling from the test well, and
- Long-term water level monitoring using data loggers and manual measurements.

Golder used a computer model (AQTSOLV) using the Theis recovery solution to assess the data from the constant rate pumping test. The assessment indicated that the transmissivity of the aquifer was about 10-2 m2/s whereas the storativity was estimated to be about 2 x 10-3. The estimated long-term yield of the well was estimated to be about 3.1 L/s (50 USgpm), which would create water table drawdowns of at least 0.2 m at a radial distance of several hundred metres from the well. Water quality testing indicated the pumped water met all freshwater aquatic life guidelines with the exception of iron, which was significantly elevated (20.5mg/L vs 0.3mg/L).

Other Bog Monitoring, SNC and EGSL

EGSL undertook a detailed hydrological monitoring program of Burns Bog in Delta in 2006, and built upon the experience gained by SNC and others from monitoring of the City of Vancouver Landfill in Burns Bog. In addition, EGSL conducted an ecohydrological overview of the bog environment in Surrey Bend Park in Surrey, BC in 2010. Data gained from these programs includes information on the hydraulic properties of peat, including properties associated with vertical stratification (i.e., fibrous versus amorphous zones), which will be analogous to that encountered in the GCL. The peat properties provide a reality check for data generated at GCL. Further, the seepage and water balance model conducted for Burns Bog and the City of Vancouver Landfill has elements of seepage, recharge and interception by ditches that is analogous to the effort being undertaken for GCL.

Part A: Site Assessment and Background Review

3.3 Geotechnical Information

Geotechnical Investigation, Trow, 2008

Stratigraphic information, including borehole and cone penetrometer test (CPT) logs, was acquired by Trow Associates Inc. (Trow) in 2008 as part of a preliminary geotechnical assessment of GCL. The Trow study comprised the drilling and logging of soils at 22 locations across the GCL (AH7-1 through AH7-22), based on a nominal 150 m x 150 m grid pattern. Auger-hole depths ranged from 4.4 m to 15 m below grade. Nine CPTs were carried out (CPT07-1 through CPT07-9), with penetration depths ranging from about 30 m to 50 m below surface. Detailed borehole logs were prepared and stratigraphic cross sections were developed based on both visual log descriptions and CPT logs. In summary, the Trow study provides good spatial coverage of subsurface conditions and stratigraphy. A relatively good data set is provided on peat presence and thickness, although specific information on amorphous versus fibrous peat thickness is not provided.

Other Geotechnical Investigations

Relevant stratigraphic information has been made available for five geotechnical investigations of site developments undertaken in the vicinity of the GCL, which allows the seepage model layers to be expanded with greater confidence beyond the boundaries of the GCL. The geotechnical studies were undertaken at the following locations:

- 9280 – 9300 Westminster Highway, Trow Associates Inc. (2004);
  - Located west of GCL; and
  - Scope of work included drilling and logging six auger holes (AH04-1 through AH04-6) to depths of 6 m to 12 m, and four CPTs (CPT04-1 through CPT04-4) to 20 m depth.
- 9460 – 9480 Westminster Highway, GeoPacific Consultants Ltd. (2009);
  - Located immediately south of GCL; and
  - Scope of work included drilling and logging five auger holes (TH09-01 through TH09-05) to depths of 6.0 m to 9.1 m , and three CPTS (CPT09-01 through CPT09-03) to depths up to 30 m.
- Garden City Road at Alderbridge Way, GeoPacific Consultants Ltd. and Jacques Whitford/Stantec (2014); and
  - Located near northwest corner of GCL; and
  - Scope of work included drilling and logging of
    - 15 auger holes by Jacques Whitford (now Stantec) in 2004 (AH04-1 through AH04-15) to depths of 6.1 m to 9.1 m;
    - 28 auger holes by Stantec (AH12-1 through AH12-28) to depths of 6.1 m; and
    - three CPTS (CPT04-1, CPT04-02, CPT07-1 through CPT07-6, CPT 12-1 through CPT12-11) to depths up to 30 m.
- 9700 – 9740 Alexandra Road, GeoPacifc Consultants Ltd. (2014).
  - Located near northeast corner of GCL; and
  - Scope of work included drilling and logging four auger holes (TH12-01 through TH12-04) to depths of 4.6 m, and four CPTS (CPT12-01, CPT12-2, CPT09-04) to depths up to 30 m.

Part A: Site Assessment and Background Review

3.4 Hydrogeologic Understanding of the Garden City Lands

The Garden City Lands Legacy Landscape Plan involves developing strategies to protect, restore and enhance important environmental values. Key to this process is an understanding of current surface water and groundwater interactions, and the development of a predictive capability (i.e., a numeric model) to assess various strategies on achieving desired outcomes. Proposed development will require hydraulic isolation of bog from areas to be used for agriculture. A seepage and water balance model is required for the bog area that will include elements of recharge, seepage, and interception by ditches and underground utilities.

Based on information obtained and reviewed to date, the following items are of relevance to our understanding of hydrogeologic conditions at the GCL:

Hydrostratigraphy

- Native materials underlying the GCL comprise the following from ground surface down:
  - *Peat* – the peat is relatively thin, averaging about 0.6 m in thickness. It is thickest (about 1.4 m) in the eastern part of the site and thins to the west. The upper several centimetres of peat are relatively permeable (perhaps on the order of 10^{-4} m/s) with active plant and moss growth sphagnum), whereas the underlying few centimetres is characterized as amorphous and has a relatively low permeability (inferred to be on the order of 10^{-7} m/s).
  - *Clayey Silt* – this unit is continuous across the GCL and directly underlies the peat. It has a reactively low hydraulic conductivity and acts as a aquitard between the permeable peat unit and underlying Fraser River sand.
  - *Transitional Silt* – In several areas beneath the GCL, the clayey silt transitions into sand. The transitional zone is characterised by silt with thin interbeds of fine sand. The sand layers are unlikely to be laterally extensive and may occur as lenses.
  - *Sand* – beneath the clayey silt or transitional silt is a relatively thick unit composed of fine and fine to medium grained laterally extensive sands. The sand units collectively are referred to as the Fraser River sand aquifer that, beneath the GCL, is on the order of 10 m to 20 m in thickness. The sands extend several tens of kilometres to the east and south, are hydraulically connected to the Fraser River to the north, and extend to the marine environment to the west. The sustained yield from pumping a well installed in this aquifer to the south of GCL near Alberta Street is greater than 3.1 L/s (about 50 USgpm).
  - *Marine Silt* – the sand aquifer is underlain by a continuous layer of silt , inferred ot be of marine origin that is laterally extensive an is likely underlain by till. This silt unit behaves as an aquitard, and for purposes of the groundwater model, serves as the base of the model domain.

Water Quality

- Water within the peat was characterized as being acidic with relatively low dissolved solids (pH 3.8 to 4.8; electrical conductance less than 100 µS/cm), whereas waters win the underlying Fraser River Sands were near-neutral and minerotrophic (pH 6.3 to 7.0; electrical conductance about 300 µS/cm to 750 µS/cm). Minerotrophic, near neutral pH waters were also encountered in shallow soils nears roads, where peat had likely been removed a part of development. Based on water quality testing conducted south of the GCL near Alberta Street, groundwater is likely to meet current guidelines and criteria for various organic and inorganic constituents, with the exception of iron which is highly elevated as noted previously.

Part A: Site Assessment and Background Review

Water Levels and Groundwater Flow Direction

- Water levels in the peat and underlying silt units respond relatively rapidly to rainfall events, whereas water levels in the deeper sand unit are much more attenuated;
- Based on review of historic air photographs and current water level information, the general horizontal flow direction within the peat bog (and underlying sand aquifer) has historically been to the southwest; and
- Vertical flow is downward, from the peat through the silt aquitard and into the sand aquifer. Downward seepage occurs throughout the year. The quantity (i.e., flux) of downward flow is a key parameter to be define in order to assess various development alternatives, and will be assessed through the modeling effort.

Work currently underway is focused on resolving data gaps and supporting development of a 3-D finite element model of the hydrogeologic system. It is our understanding that the hydrogeologic work undertaken by SNC in 2015 includes on-going continuous water-level monitoring and hydraulic response tests (i.e., slug tests) at several locations to infer in situ hydraulic conductivity of the major stratigraphic units beneath the GCL. In addition to that work, specific items being addressed or soon to be addressed include the following:

- Verify the elevation datum used by each of the various consultants at and in the area of the GCL, and consolidate the data following conversion to a common datum (i.e., City of Richmond datum);
- Establish x, y, z coordinates for all borehole, cone penetrometer test (CPT), piezometer and monitoring wells completed at and in the vicinity of the GCL, and locate on a common GIS base map, suitable for presentation purposes and to serve as a base for the 3-D model;
- Compare water elevations in the Fraser Sand Aquifer with those in the Fraser River to the north, to characterize the hydraulic connection and provide data for 3-D model calibration. In particular, the assessment should focus on the effects of spring freshet on water levels and flow, and groundwater flow directions may reverse for several weeks in some areas along the Fraser during such events;
- Prepare at least two local and two regional hydrostratigraphic cross sections through the GCL – one trending North-South and the other East-West. The sections will include information from both on-site and off-site boreholes, and will show relevant peat profiles; and
- Probe the peat thickness, and install shallow small-diameter piezometers within the peat only, in the eastern part of GCL where peat thickness was not recorded by SNC (peat thickness was not recorded at hand-installed piezometers). In conjunction, install small diameter piezometers east of GCL, immediately east of No. 4 Road, and monitor shallow piezometers on either side of the road to establish differences, if any, in horizontal hydraulic gradients. This data will serve to better establish the benefits of hydraulically connecting shallow water beneath No-4 Road via, for example, horizontal drains.

Model development is currently underway, and will be refined as new information becomes available. It is currently envisages that the model will be calibrated to a summer water table condition (relatively low heads) and to a winter condition (relatively high heads). Once calibrated, scenarios to be assessed may include, the effects of various shallow water table cut-offs (i.e., along a line demarking the agricultural versus peat environments), and the effects of pumping the Fraser River Sand aquifer to maintaining a wetland on site and/or provide water supply for the agricultural lands. The data available from the extraction well to the south of GCL near Alberta Street provide relevant hydraulic parameters to infer the effects of a similar pumping well established at GCL.

Part A: Site Assessment and Background Review

4. Environmental Site Assessment

The GCL property is located on the western edge of the Lulu Island Bog, which also includes the Richmond Nature Park, the Richmond Nature Study Area, and the federal Department of National Defense Lands. Together, these properties (~200 hectares) represent the largest remnant bog ecosystem of what is historically referred to as the Greater Lulu Island Bog. This raised bog ecosystem once covered much of Lulu Island (and Richmond), but has now been greatly reduced due to agriculture, drainage and other human use and development.[1] Information in this section includes a summary assessment of biophysical information for GCL to date, a review of bog and wetland restoration options for the site, and next steps.

4.1 What is a Raised Bog Ecosystem?

Raised bogs are unique ecosystems associated with humid, temperate climates where precipitation exceeds evapotranspiration. They typically form in areas with flat topography and poor drainage and where the water table is at or near the surface for most of the year. The high water table creates anaerobic conditions which reduces the rate of decomposition and allows partly decayed plant matter (peat) to accumulate over a poorly-drained sediment layer (e.g., clayey-silt).[2] As organic matter accumulates over time, surface vegetation can no longer be fed by mineral rich groundwater and must instead rely primarily on precipitation for moisture. Because rainwater is nutrient poor and acidic, plants adapted to these types of conditions become established. One such plant that predominates in these conditions is *Sphagnum* moss, which is uniquely adapted to nutrient poor, water logged environments and can hold many times its weight in water. Ericaceous and other specialized plants are also able to take hold in these peat-substrate environments. Trees such as lodgepole pine can also persist, although their growth would be severely stunted.

Over time as peat builds up, the bog begins to form a dome (raised) shape, which is typically highest near its centre. The water table builds up and generally follows this domed profile, and water flows out radially from the centre of the bog to the peripheries.[1] Generally, the water table in raised bogs is stable and remains close to the bog surface (i.e., within a few centimetres) 95% of the time. The variable microtopography (e.g., small hummocks and depressions) combined with this stable water table create very small habitat niches for different species of vegetation.[3]

Towards the bog periphery, the depth of peat begins to diminish and vegetation communities begin to change. This is the transition (lagg) zone between the peat dominated bog ecosystem and surrounding mineral soil dominated landscapes. The lagg is the receiving zone where run-off from the bog mixes with groundwater and/or other water sources, resulting in unique hydrological and hydrochemical conditions.[4] Garden City Lands is positioned on the bog margin and shows evidence of both bog and lagg environments.

---

[1] Davis, Neil and Rose Klinkenberg (editors). 2008. A Biophysical Inventory and Evaluation of the Lulu Island Bog, Richmond, British Columbia. Richmond Nature Park Society, Richmond, British Columbia.
[2] Metro Vancouver. 2007. Burns Bog Ecological Conservancy Management Plan.
[3] Irish Peatland Conservation Council. Retrieved from http://www.ipcc.ie/a-to-z-peatlands/raised-bogs/. Accessed November 12, 2015.
[4] Howie, Sarah A. & Ilja Tromp-van Meerveld. The Essential Role of the Lagg in Raised Bog Function and Restoration: A Review. Wetlands (2011) 31:613–622

Part A: Site Assessment and Background Review

4.2 Previous Environmental Assessment

Biophysical Assessment

Disturbance

The Greater Lulu Island Bog has been degraded significantly from its natural ecological condition. An estimated 95% of the bog has been converted to agriculture or for other land uses. While the Lulu Island Bog (including GCL) represents the most significant remaining relict of this larger ecosystem, it too has been degraded considerably. Construction of drainage ditches, dumping of fill material, conversion to agricultural land, building of trails, introduction of non-native plants, and changes to the natural fire regime have affected ecosystem function.[1] Reduced water levels in the summer are considered the greatest threat to the bog. This has resulted in drier, acidic conditions which allow succession and the establishment of new vegetation communities.

Soil

Organic peat deposits within Lulu Island Bog are 0.4 to 6 metres thick.[1] GCL is on the bog margin and peat accumulation is lowest, as expected, measuring between 0.4 and 1.2 metres thick.[5] Based on a preliminary interpretation of Trow and SNC Lavalin data, the thickest peat deposits are on the northeast side of the property, and gradually lessen to the south and west. Shallow (thinner) deposits dominate in the bog margins are primarily composed of a mixture of decomposed reeds, sedges, and woody plants overlain by sphagnum moss.[6] As indicated in Section 3.3, the peat unit is underlain by a clayey silt sedimentary unitthen a transitional silt/discontinuous sand layer and then a relatively permeable sand unit.[7]

Water

Richmond's humid climate delivers 100-150 mm more precipitation than what is lost through evapotranspiration.[1] However, precipitation varies considerably throughout the year, resulting in seasonal variations in the water balance. Soil fertility test results of GCL soils indicate there is a mix of groundwater and precipitation feeding the site. In particular, available nitrogen levels were found to be higher than would normally be expected in a precipitation-fed bog.[11] This assertion is supported by the 2015 site investigation conducted on GCL. Direct precipitation was considered likely to be the main source of shallow water recharge away from edges and roads, whereas minerotrophic influences were observed on the site periphery and in lower clayey silt layers and sand.[10]

[5] SNC-Lavalin Inc. 2015. Hydrogeological Investigation of Garden City Lands. Prepared for City of Richmond.
[6] Diamond Head Consulting Ltd. 2013. City of Richmond Garden City Lands Biophysical Inventory and Analysis. Prepared for City of Richmond.

Part A: Site Assessment and Background Review

Vegetation

Plant communities on GCL are associated with bog and wetland ecosystems, the latter of which may also be considered the lagg. Significant, regionally rare bog species identified on GCL, closest to the DND lands, include cloudberry (Rubus chamaemorus), bog rosemary (Andromeda polifolia), Chamisso's cotton-grass (Eriophorum chamissonis), and velvet-leaved blueberry (Vaccinium myrtilloides). Other bog-associated plants include Labrador tea (Rhododendron groenlandicum), bog laurel (Kalmia microphylla), bog cranberry (Vaccinium oxycossos) and bog blueberry (Vaccinium uliginosum). Peat moss occurs sporadically on the east side of GCL. Spagnum pacificum, a species often associated with disturbed areas or areas with poor soils, is most common. There are minor occurrences of *Sphagnum capillifolium,* which is more frequently associated with raised bog ecosystems.[12]

A variety of introduced and invasive plants are also present, which can compromise ecological function through direct competition with native plants or by changing site conditions. Some examples include Scotch heather (*Calluna vulgaris*) and highbush blueberry (*Vaccinium corymbosum*), both of which are adapted to slightly acidic conditions. While the acidic nature and high water table of healthy bogs can hinder establishment of non-bog plant species (e.g., Himalayan blackberry), disturbances resulting in lower water tables or road construction can do the opposite. [5]

Many bog adapted species, such as cloudberry, are thought to persist in greater numbers on GCL than elsewhere in Lulu Island bog due to reduced competition from introduced plants. In the absence of annual mowing, it is likely that the bog associated plant community on the east side of GCL would gradually evolve to resemble the bog forest communities on DND lands and the Richmond Nature Park. Drainage in DND and RNP has led to conditions suitable for establishment of expansive stands of shore pine (*Pinus contorta* var. *contorta*) and hybrid birch (*Betula*) trees which dominate the tree canopy, and a dense understory of introduced non-native highbush blueberry. Although these species are present on GCL, regular mowing has controlled their expanse and allowed native bog species to persist. Scotch heather is the most pervasive introduced species on the east side of GCL. This species is adapted to bog conditions, and likely first established on DND lands following relatively recent fire events.[1] Heather has spread quickly in these natural areas and now dominates large portions of the east side of GCL.

Micro-topography is an important influence on plant occurrence in GCL. Plants such as *Sphagnum pacificum* and bog cranberry appear to persist in minor depressions and in larger areas with slightly lower surface elevations (10 cm) than the surrounding landscape. These lower elevation areas may be sufficient to allow these plants to persist, where those on ground slightly more elevated from the water table cannot. In addition to a generally lower water table in the summer, hummocks and slightly elevated ground provides a niche for plants less adapted to saturated conditions to exist. Scotch Heather, which is more adapted to drier heath conditions, is an example.

The west side of GCL is characterized by a transition to plants associated with wetlands or moist conditions, including common rush (*Juncus effusus*), Sitka sedge (*Carex sitchensis*), and reed canarygrass (*Phalarus arundinacea*), an introduced grass. Other dominant plants include hardhack (*Spiraea douglasii*), bracken (*Pteridium aquilinum*), and fireweed (*Chamerion angustifolium*). There are few signs of tree regeneration in the wetter, western portions of the site.[11] The sedge community in this area is expected to persist as long as there are no changes affecting the high water table. Again, annual mowing likely controls spread of some plant species (e.g., Himalayan blackberry), and reduces competition allowing low growing species to persist over time.

Part A: Site Assessment and Background Review

4.3 Recent Environmental Information

SNC Lavalin Groundwater Level Monitoring

Site investigations conducted by SNC Lavalin in 2015 determined that the water table is in the peat from March to mid/July, but then drops into the underlying clayey silt from mid-June/July through to August.[12] Data for the September to February period was either not collected or was not available at the time of writing; however, field observations in October indicated that the water table is likely reduced through late summer and early fall. Seasonally low precipitation and increased evapotranspiration in the summer is largely responsible for the lower water table.[10] Drainage ditches may also be factor contributing to reduced water table in the summer.

Local Bog Restoration Literature Review

Burns Bog in Delta and Camosun Bog in Vancouver offer two examples of bog environments that have been subject to significant study and restoration efforts. Therefore, it is prudent to look to them as important case studies for Garden City Lands and Lulu Island Bog.

Burns Bog is considered to exist at the climatic limits for raised bogs in North America; the water table is 27-39 cm below the lawn microtopographic surface in late summer.[7] The ecological integrity of Burns Bog is threatened by several factors:[2,7]

- changes to hydrology through reduced bog area and excessive drainage (ditching);
- loss of natural lagg (the buffer between bogs and mineral rich waters);
- forest encroachment (loss of peatland leading to drier conditions); and
- climate change (expected longer, drier summers and drought conditions which can affect hydrology).

Activities that lower the water table can cause irreversible damage to functional bog ecosystems. The moisture regime must be sufficient to maintain suitable conditions for *Sphagnum* establishment through spore germination and early growth. Sphagnum grows most actively in the shoulder seasons (Spring and Fall), while going dormant in the summer.[8] However, maintaining moist conditions is also important during the summer drought period, which may be exacerbated by future climate change.[7] A lower water table dries out the peat andencourages establishment of plants adapted to lower moisture regimes and forest encroachment. Trees further reduce water loss by intercepting rainfall and through evapotranspiration.

Restoration strategies for Burns Bog include offsetting water loss through drainage by blocking ditches (leaving evapotranspiration as main output), removing trees, and retaining winter precipitation to make it through the summer drought period. Maintaining and improving storage capacity in the acrotelm is also a critical factor.[7]

Camosun Bog is considerably smaller than Burns Bog, but many of the conditions that affect this ecosystem are similar. Residential development and storm drain installation surrounding the site potentially reduces the catchment area for the bog and increase drainage. Other factors degrading the bog included forest succession due to lower summer water levels and human disturbances including berry picking, garbage and off-leash dog activity.[9]

---

[7] Chantler, A. [edt] Water under Pressure. Proceedings of the CWRA Conference Vancouver October 2006. pp 58-70.
[8] Hebda, R. Pers.com. 2015.
[9] Baker, Nadia et al. 2000. Investigation of Options for the Restoration of Camosun Bog, Pacific Spirit Regional Park. University of British Columbia Thesis.

Part A: Site Assessment and Background Review

A key restoration strategy for Camosun Bog was to raise the relative summer water table. Optimal *Sphagnum* establishment occurs where the mean annual water table is approximately 5 cm below the surface, and the water table should not be below 40 cm. The relative water table was lowered in Camosun by removing the top forest layer and some of the underlying peat, thereby lowering the soil surface 10-15 cm.[9] Other restoration and management strategies enacted or recommended at Camosun include:

- transplanting bog species and establishing *Sphagnum* using diaspores;
- removing non-bog associated plants (e.g. salal) and reducing tree cover. Tree removal was not found to affect summer water levels, but could lead to faster recovery times in the fall water table;
- ensuring effects of berms are fully understood prior to implementing, due to potential that berms may raise water levels in some areas and reduce water levels elsewhere;
- blocking ditches (fully or partially) while recognizing need to mitigate flooding and potential for sub-surface drainage;
- avoiding irrigation as method to raise water level due to water conservation and efficacy concerns;
- implementing ecologically sensitive zones to limit public access;
- expanding boardwalks for education and nature appreciation, while managing access;
- continuing water monitoring program (water table levels and soil chemistry) to help evaluate bog condition; and
- investigating potential increases in mosquito populations.[9]

Landscape Legacy Plan Ecological Aspects

The GCL Landscape Legacy Plan focuses on two components of the natural environment ('The Bog' and 'The Wetland'), in addition to a semi-natural area ('The Edge') that should be integrated with the restoration plan due to potential ecological connectivity. The following sections provide a brief summary of relevant literature and issues related to the natural areas and features associated with the Bog, Wetland (i.e., Lagg), and Edge.

Bog

Due to its location on the margins of Lulu Island Bog, there is a strong likelihood that the GCL is representative of both bog and lagg ecosystems and that a transitional plant community exists. The east side of GCL is currently considered a semi-natural bog ecosystem, dominated by introduced Scotch Heather, but also having a diversity of native bog-associated plants, some of which are regionally rare.

There are five conditions that must be met for bog restoration to be considered as a possibility for a site[10]

1) There should be a large area of peat where the drainage does not cut into the mineral substrate;
2) There should be at least 50-100 cm of compressed, humified peat;
3) It should be possible to exclude all sources of nutrient enrichment (air and water borne);
4) There should be a buffer zone between the site and agricultural land; and
5) A source for plant colonization should exist locally.

[10] Charman, D. 2002. *Peatlands and environmental change.* Wiley, New York.

Part A: Site Assessment and Background Review

Garden City Lands meets (or potentially meets) these five conditions.

Wetland (Lagg)

The Legacy Landscape Plan envisions creation of an open water complex in the southwest corner of Garden City Lands. The ecology of this area indicates that it may be considered the transition or lagg zone for the Lulu Island bog. These zones receive water from both the bog and surrounding mineral ground[4], and thus may be considered an important buffer or mixing area. Lagg characteristics include slightly higher pH and nutrient levels than bogs, and fluctuating water table in these zones resulting from high winter runoff and low summer water levels.[4] This results in slightly different plant communities, which is evident in the increased abundance and dominance of hardhack (*Spiraea douglasii*), sitka sedge, bracken fern, rush, and reed canarygrass on the west side of GCL.[11]

Unfortunately, despite their importance, these lagg systems have received relatively little attention in bog restoration.[4] Therefore, while creation of a marsh (wetland ecosystem) is a primary objective, maintaining representative vegetation components and chemistry gradient in the lagg should also be a focus of restoration efforts.

Treed Perimeter

A landscaped treed perimeter for portions of the GCL is envisioned in the Legacy Landscape Plan. While offering a clear aesthetic value and visual barrier, there are some issues associated with trees and bogs. The acidic, nutrient poor conditions of bogs are not suitable for many tree species. Trees can also affect water balance by intercepting precipitation and through transpiration. Where the water table is reduced through drainage, trees can establish quickly. This is evident on the adjacent DND property and RNP where birch and pine have established in fill areas, along roads and ditches, and elsewhere with reduced water tables. Therefore, landscape tree planting on the periphery of GCL will need to be carefully considered in coordination with natural areas restoration to ensure tree planting is done where it does not pose adverse impact to the survival and restoration of the natural areas. Ecologically suitable trees will be selected for recommended treed areas that will not compromise the ecological integrity of the bog.

Part A: Site Assessment and Background Review

4.4 Environmental Understanding of the Garden City Lands

Bog ecosystems are unique and have specific challenges and opportunities associated with them, many of which are based on existing and potential site conditions. Garden City Lands is in a degraded condition and cannot be considered to be ecologically functional, although it does contain regionally rare bog associated species and is potentially a good candidate for restoration. Although there has been considerable research into some aspects of bog ecology and restoration, there are some areas where the knowledge base is limited. One such area pertains to the lagg[7], which characterizes much of GCL.

Detailed topographical information and a comprehensive understanding of the water table (and seasonal fluctuations) on both GCL and DNC lands is required to determine potential for restoration of bog and lagg ecosystems. With this information, modeling can be performed to infer potential increases to the water table that may result from establishment of a berm (as an example of one intervention), and whether this would support active *Sphagnum* growing conditions or if the site is more suited to a semi-modified bog ecosystem. The exact location of the berm may not coincide with that envisioned in the Landscape Legacy Plan.

Due to the different hydrological requirements of bog and lagg ecosystems (e.g., hydrochemical, pH, nutrient availability, stable versus fluctuating water table), and the relatively small size of the site, there is potential that they may have to be managed separately (i.e., isolated from one another) on GCL lands to support ecological integrity.

Another potential challenge is integrating agricultural activity and bog conservation on the same site. Many agricultural activities require drainage, which in large part has been responsible for the significant loss and degradation of bog and other wetland ecosystems. In addition, water requirements for agriculture are often highest during the summer, when bogs are particularly vulnerable to water drawdown. Water quality requirements for agricultural crops and bog ecosystems are sufficiently different that both their water inputs and outputs will have to be separated from one another.

Off-site considerations must also be included. As a bog ecosystem requires water to be retained on site, seasonal fluctuations in the water table must be addressed. Flooding concerns in surrounding urban areas, which may arise due to limiting drainage and retaining more water in the bog, must be mitigated. In addition, the GCL must not be considered an isolated ecosystem, but rather a part of the Lulu Island Bog which includes DND lands and the Richmond Nature Park. Any proposed changes to the hydrology in GCL should consider potential effects to the greater whole.

Bog restoration typically follows a long-term outlook. The Burns Bog Management Plan has ***a 100 year time horizon***. Future land use changes, adjacent development, and climate change may create conditions that further affect hydrology and bog/lagg ecosystems many years after development of the GCL. For example, if DND lands were at some point considered to be surplus, and subsequently acquired for re-development, there could be significant repercussions to GCL and the Lulu Island Bog. However, if these lands were protected as park there is potential that expanded management could be implemented to improve ecological function of the larger bog.

Part A: Site Assessment and Background Review

5. Agricultural Site Assessment

5.1 Previous Agricultural Work

A number of previous reports and analyses regarding agricultural capability and potential have been completed for the Garden City Lands[11,12,13,14]. These reports note that while the bog may be somewhat debilitated due to previous uses as a rifle range and radio antenna installation array (and associated fill placement), the overwhelming conclusion is that the Garden City Lands are comprised of lands with good to moderately-good agricultural potential. There has been no cultivation on the site historically, however vegetation management in the form of mowing has been conducted by the City of Richmond to control growth height and manage the intrusion of certain types of plants.

Garden City Lands Biophysical Inventory and Analysis

A *Garden City Lands Biophysical Inventory and Analysis*[15] was developed as part an initial phase for the creation of the Garden City Lands Legacy Landscape Plan. This *Biophysical Inventory and Analysis* contained a number of observations and conclusions regarding the agricultural capability and suitability of specific agricultural activities for the site. It built on the previous research and provided a deeper level of analysis regarding the agricultural suitability of the site, including a small number of soil samples that were analyzed for fertility indicators (pH, organic matter, nutrients). CLI classification of agricultural soils were in alignment with the ALC's 2006 report: the assessment noted a mix of Class O3 and Class 3 soils. A small corner of the site was listed as Class 7 (no agricultural capability) due to fill being placed, driveways, and a few naturally-occurring drainage areas. The main limitations to cultivation that were noted were soil structure (peat depth) and high water tables (need for drainage).

5.2 Recent Agricultural Information

Since the Biophysical Assessment (2013) and the Legacy Lands Plan (2014) were produced there has been relatively little progress regarding the agricultural development of the site. No large-scale soils sampling, peat depth analysis, or drainage planning has been conducted. However, Kwantlen Polytechnic University has expressed interest in partnering with the City of Richmond to develop a farm school at the GCL site. As such they have prepared a preliminary proposal for a Sustainable Agriculture Research and Education Farm[16], and have begun collection soil samples for analysis at a later date[17].

[11] Garden City Lands Exclusion Application and Agricultural Land Commission Decision, 2009.
[12] Agricultural Assessment of the CLC Lands, 555 No. 4 Road, Richmond. Dan Schroeter Consulting Inc., 2008.
[13] Soil Survey of Delta and Richmond Municipalities. Preliminary Report No. 10. H.A. Luttmerding and P.N. Sprout, 1969.
[14] Agricultural Land Commission Agricultural Capability Assessment File #: O-36435. T. Murrie, 1996.
[15] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.
[16] Sustainable Agriculture Research and Education Farm: Preliminary Proposal for the City of Richmond. Kwantlen Polytechnic University, 2013 (revised 2015).
[17] During 2015, KPU collected soil samples from the west side of the GCL site on a 100 m grid line. A total of 60 samples are being stored in the freezer for future physical and chemical analysis (Dr. R. Harbut, personal communication, November 2015).

Part A: Site Assessment and Background Review

Kwantlen Polytechnic Agricultural Plan

Kwantlen Polytechnic University's (KPU) goals for the farm are to provide students with an educational opportunity to learn how to:

- Grow fruit and vegetable crops within a sustainable, ecologically-sound context (there is no mention of livestock, poultry, or egg production in their proposal);
- Develop business, sales, marketing skills;
- Develop problem-solving and research skills;
- Understand the layers of government and associated policies; and
- Incorporate short-term outreach education (workshops, field days) for industry and the public.

The KPU proposal is for a fully operational farm that would include market crops and research, orchard/perennial crops, outbuildings including a barn and tool shed, a composting facility, and cold storage.

The farm would be developed over several years, using a phased approach. For example:

- Year 1: 5 acres (2 acres of market crop production);
- Year 2: Infrastructure installment: high tunnels, irrigation systems, perennial crops; and
- Year 3: Regular farm operations in full effect.

KPU has expressed interest in using a section of the site as an experimental farm to test agricultural best practices for organic (peat) soils.

KPU is also interested in participating in a Project Advisory Committee or Panel to guide the short, medium, and long-term goals of the agricultural development of the Garden City Lands[18].

5.3 Agricultural Understanding of the Garden City Lands

Agricultural Management Conclusions

Soils

The soils of the Garden City Lands are mixture of organic (peat) and mineral sols. These have previously been classified as Terric Mesisols and Rego Gleysols: saline and peaty phase. The main limitations are soil structure problems (mixture of peat and mineral soils) and high water tables (wetness)[19].

The peat layer is found throughout the site and is underlain by fine-textured (silty) mineral subsoils. Previous studies measured this peat depth to be 16 to 39 cm[20], however these results are based on a limited number of samples, and therefore variations likely occur. The rooting depth (typically 0 to 20 cm for most crops) is likely comprised of organic materials in varying stages of decomposition throughout.

---

[18] Dr. R. Harbut, personal communication, November 2015.

[19] Agricultural Land Commission Agricultural Capability Assessment File #: O-36435. T. Murrie, 1996.
[20] Agricultural Land Commission Agricultural Capability Assessment File #: O-36435. T. Murrie, 1996.

Part A: Site Assessment and Background Review

Many similar soils exist in the immediate vicinity and have been cultivated. The practice usually involves the removal of the peat layer and development of the mineral layer. If the peat layer is not removed at the GCL site, then the following management steps may need to be followed:

- Ensure that any drainage system installed works in conjunction with the sponginess of peat (to avoid wet surfaces);
- Ensure that the plant's ability to grow a good root system and absorb nutrients is optimized (to neutralize pH); and
- Provide adequate soil aeration (to avoid subsidence and compaction).

Subsidence and compaction, and resulting mixture of organic and mineral soils, is noted as a key potential challenge to the long term cultivation of these soils[21]. The removal of the peat layer would largely eliminate this challenge.

Capability

In 2006, Trevor Murrie, PAg, ALC Staff Agrologist, assessed the property using the Canada Land Inventory (CLI) methodology during a site visit and and previous soil reports[22] as a mixture of Class O4WL (O3LW) and 4W (3WN). A follow-up assessment by Upland Agricultural Consulting[23] determined the soils to be a mix of these along with O3WL (O2LW) and 3W (2WN). This can be interpreted as a mixture of organic (peat) and mineral soils with moderate to good agricultural capability. Limitations based on high water tables, soil structure conditions, and potential salinity (to a lesser degree).

The two assessments agreed that while there is no history of cultivation on the site, similar soils nearby the GCL are used extensively for berry and vegetable production and with proper management will produce an excellent diversity of crops. It was noted that special attention will need to be given to soil management if the peat is retained on site.

Suitable Agricultural Activities

Any agricultural use will require some amount of land clearing and the incorporation of some plant vegetation. The following agricultural activities were listed as highly or moderately suitable for the site[24]:

- Root vegetables and green vegetables;
- Corn and grains;
- Blueberries, raspberries, and strawberries;
- Pumpkins, zucchinis, squash;
- Cranberries;
- Field flowers;
- Honey bees;
- Hoop houses (small and medium);
- Poultry (very small scale);
- Farm retail sales and agri-tourism;
- Passive uses (biodiversity conservation, wildlife viewing, parks, recreation);

[21] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.
[22] Soil Survey of Delta and Richmond Municipalities. Preliminary Report No. 10. H.A. Luttmerding and P.N. Sprout, 1969.
[23] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.
[24] Ibid.

Part A: Site Assessment and Background Review

- Education and research;
- Botanical gardens;
- Storing, packing, preparing, or processing foods;
- Large scale compost operations; and
- Production and development of biological products used in Integrated Pest Management programs.

Agricultural Management Unknowns

Several gaps in knowledge remain and need to be filled in order to move agricultural production on the site from conception to reality.

Baseline data on soil fertility

Any agricultural production will require a detailed level of soil fertility analysis. This can be done by collecting samples in a concentrated area (where agricultural production is likely to occur) or across the site in a gridlike fashion. The samples should be tested for a full suite of physical and chemical parameters such as: pH, EC, nutrients (available and total), CEC, salinity, organic matter, and particle size analysis. This detailed level of analysis is outside the scope of this project. KPU has collected 60 samples that are being stored for future analysis, however they are in need of funds to complete the testing by an external laboratory[25].

Baseline soil data on heavy metals

It is important to check soils for contamination prior to cultivating crops for human consumption. Analysis of heavy metals in soil can provide a relatively cost-effective indicator of toxicity problems. There are many sources of metal contaminants that can accumulate in soils. These include the burning of fossil fuels, use of additives in gasoline, use of insecticides, metal plating, domestic sewage sludge, industrial waste, and air pollution. Based on the GCL's previous use as a rifle range and radio antenna installation array (and associated fill placement), soil toxicity remains a possibility. The greatest human health problems usually arise from Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Lead (Pb), and Zinc (Zn). Cd and As are extremely poisonous to humans; Hg, Pb, and Ni are moderately so; and Boron (B), Cu, Manganese (Mn), and Zn are relatively lower in mammalian toxicity[26].

While it is outside the scope of this project, soil samples should be analyzed in the lab for a suite of trace metals[27] and results should be compared to two commonly-used health and safety guidelines: BC's Organic Matter Recycling Regulation (OMRR) Class A Compost[28] and the Canadian Council of Ministers for the Environment (CCME)'s Canadian Environmental Quality Guidelines (CEQG): Soil Quality Guidelines for Human Health[29]. It may be possible (and cost effective) to use the samples

[25] Dr. R. Harbut, personal communication, November 2015
[26] The Nature and Properties of Soils. 11th Ed. 1996. Brady, N.C. and R.R. Weil. Prentice Hall, Upper Saddle River, NJ.
[27] The samples were tested for trace metals using the following techniques: Inductively Coupled Plasma (ICP) for the majority of elements, Hydride Generation Atomic Absorption Spectrometry (HGAAS) for As and Se, and Cold Vapour Atomic Absorption Spectrometry (CVAAS) for Hg.
[28] Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice. Best Management Practices. March 2008. BC Ministry of Environment. http://www2.gov.bc.ca/assets/gov/environment/waste-management/recycling/landappguidelines.pdf
[29] CCME Canadian Environmental Quality Guidelines. Factsheets. http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/index.html

Part A: Site Assessment and Background Review

previously collected by KPU and currently being stored to test for both soil fertility and heavy metal parameters at the same time.

Detailed data on peat depth

The Biophysical Inventory and Analysis included an initial survey of peat depth across the site based on a survey following a grid pattern[30]. Three linear transects running east to west were established 190 metres apart. Peat depth was measured every 50 metres by either excavating a soil pit or using a metal probe. Depending on the agricultural methods chosen at the time of planting, more detailed information regarding peat depth may be required. It would be beneficial to use these results as a starting point and obtain a more detailed analysis of peat depths within the sections of the site specifically allocated to future agricultural development. Unfortunately, this further analysis is outside the scope of this project.

On site water plans for drainage and irrigation

While it is expected that final plans will involve separating agricultural drainage water from bog water by a dyke, more information will be required to determine appropriate crop-based drainage plans. Data on groundwater depth appears to be largely missing and without it, it will be difficult to complete appropriate agricultural drainage plans for the site. With respect to agricultural drainage, and in particular drain tile spacing, a full drainage assessment based on water table depths measured during the wet seasons is required. We expect a key part of this investigation, the Hydrogeology Assessment, will help to answer some of these questions.

Questions also remain about best sources of irrigation water for crop cultivation on the site. Groundwater could be used as a source, however without more knowledge regarding quantity and quality of this water resource it remains challenging to include groundwater in irrigation plans. Rainwater harvesting could be an option, however many organic certification programs discourage the use of rainwater for certain edible crops due to potential human health concerns. Therefore, without further details regarding groundwater, all irrigation plans associated with agricultural development of the site will need to rely on municipal water sources.

Some of these outstanding questions regarding drainage and irrigation may be answered throughout the course of this project, through the Hydrogeology Assessment and associated modelling. The level of detail provided regarding drainage and irrigation will depend largely on the results of this analysis.

Climate change

It is worth noting that climate change remains an important unknown for agriculture. In particular, changes to the hydrologic and temperature regimes may impact crop selection, irrigation requirements, and potential yields. Throughout this project, efforts will be made to include climate change forecasting and modelling results at every level of analysis.

[30] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013. P73.

Part A: Site Assessment and Background Review

6. Surface Water and Drainage Site Assessment

The GCL site topography is relatively flat with elevation ranging from 1.5 m to 0.6 m. The site gently slopes down from the northeast to the southwest with an average slope of 0.08%. This is with the exception of the mound, which is about 2.5 m above ground level located at the northwest corner of the site. The GCL receives direct precipitation on the site and possibly receives off-site stormwater runoff that inflows to the site along Alderbridge Way. During the wet season, excess site runoff is collected by the south perimeter ditch that drains toward the west to the Garden City Road and toward the east to the No. 4 Road storm sewer system. A series of catch basins are located along the western edge of the site that drains to the west. However, most of the catch basins were fully blocked by grass and sediment.

Historically, surface ponding has been observed at multiple locations. These topographic depression locations, as listed below, are also visible from the orthophoto due to vegetation changes.

- A large pool along the toe of the Mound.
- Multiple locations around the western edge and the southwest corner of the site.
- An area along the entrance from No. 4 Road.

A map showing the historic ponding locations is provided in Figure 6-1.

6.1 Previous Drainage Work

Drainage Modelling of Richmond Stormwater System

The Richmond city-wide MIKE URBAN drainage model was updated by KWL in 2011[32]. The model assessed the effect of the 2041 Official Community Plan land use on the 2010 existing drainage system. In the model, the GCL was divided into two sub-catchments, with the western half contributing to the Garden City Road storm sewer system and the eastern half contributing to the No. 4 Road storm sewer system. Under the 10-year, 24-hour design storm, the model identified surface flooding at all the major nodes located along Alderbridge Way and Garden City Road. As shown in Figures 6-2 and 6-3, the flooding was due to inadequate capacity in the major storm sewer system.

The existing model of the City's storm sewer network is intended to be utilized in this project to assess available off-site stormwater volumes that may be available for on-site uses on the GCL. The model will also be used to assess the impact of development of the GCL for its intended park uses on the existing adjacent storm sewer system, as well as connection options for drainage from the site to the storm sewers. Assessment of whether this flooding can be mitigated by incorporation of stormwater detention and storage in the GCL site will be part of the further work on this project.

[32] KWL, 2011. Drainage Modelling and Capital Plan for the Proposed 2041 OCP

Part A: Site Assessment and Background Review

In addition, the limitations of the storm sewer network highlighted by the 2011 modelling may pose a problem for drainage design for the GCL for implementation of the Landscape Legacy Plan. The undersized storm sewers on Garden City Road will be unable to accept additional peak runoff flow for the design event from the GCL. While the development of the GCL will not require significant increases in impervious area on the site, there will be additional impervious area and reduced overall permeability on the Western side of the site, relative to the existing condition, as well as reduction in total vegetative cover. These will contribute to increase peak runoff from the site. If the undersized pipes will not be upgraded for development of the GCL, then all increases in peak runoff would need to be mitigated on-site. This would be a highly sustainable approach and as the increase in peak runoff is expected to be small relative to the size of the site, this may be possible. This will be investigated as part of later work on this project.

Surface Water and Drainage from the 2013 Biophysical Assessment[33]

The main surface drainage features on the GCL site are drainage ditches, stormwater catch basins, swales and natural depressions. A ditch runs along the south boundary of the site, draining from the middle of the site toward both the west and east with an average slope of 0.2% in either direction. Considerable debris blockage was identified at each end of the ditch outlet. A series of ten stormwater inlets is located along the west boundary of the site. Many of the inlets were noted to be partially or fully blocked by grass and sediment, with pooled water found in adjacent areas.

A system of meandering swales is located on the northwest portion of the site, between Landsdowne Road and the Mound. They are assumed to be remnant channels from pre-settlement times, as Lulu Island grew from the deposition of Fraser River sands and gravels, and water moved across the surface.

At the time of the biophysical inspection, the western half of the site was noticeably wetter than the eastern half. A large area of pooled water was present in the northwest part of the site, extending from near the toe of the Mound reaching southward for about 50 m. Without management, the western half of the site will have excess soil moisture for agriculture use. Poor drainage would damage perennial crops during wet winter months and affect annuals. Therefore, farming practices, as envisioned for the western portion of the GCL, will require site drainage, such as perimeter ditches or mole drains, to remove water from the peat soils.

During the dry summer months, farms require irrigation, which may be able to be obtained from drainage ditches and on-site water storage. Irrigation water taken from pumped wells is not recommended because it is likely to be saline, especially after extended periods of pumping.

On the eastern half of the site, the envisioned peat bog restoration favors high precipitation and restricted drainage. From a bog restoration point of view, the water table should be kept high nearly year round and drainage must be restricted to support the bog and any associated hydrophilic ecosystem components.

A simplified hydrologic analysis using rational method estimated 0.05 m^3/s of surface water flow from the GCL. This value was calculated using a runoff coefficient of 0.1 during a 10-year 24-hour storm event under saturated conditions.

[33] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.

Part A: Site Assessment and Background Review

6.2 Recent Drainage Information

Limited recent drainage information is available post the 2011 citywide drainage study. Much of the following is descriptive understanding of the site climate and drainage.

Precipitation Data and Climate Change

According to the 1981-2010 climate normal data on the Environment Canada website, the mean annual precipitation at the Vancouver International Airport station (ID 1108447) is 1189 mm (1153 mm of rainfall and 38 cm of snowfall). Rainfall occurs throughout the year, with most occurring from October to March. Most snowfall occurs during November to February. The rainfall intensity frequency data at YVR climate station for various return periods are shown in Table 6-1.

Table 6-1: Local Rainfall Intensity Frequency Data

Return Period (Years)	24-Hour Rainfall Total (mm)
2	51.5
5	65.0
10	73.9
25	85.1
50	93.4
100	101.7

In 2015, GCL experienced an exceptionally dry spring and summer. As shown in Table 6-2, the 2015 monthly precipitation only account for 6% to 58% of the average amount from the Climate Normals. In contrast, the precipitation receive in August 2015 exceeds the average amount by 85%.

Table 6-2: 2015 Precipitation Data

Month	2015 Precipitation (mm)	Climate Normal (1980-2010) Precipitation (mm)	% (2015/Climate Normals)
April	51.4	88.5	58%
May	4.2	65.0	6%
June	11.0	53.8	20%
July	20.8	35.6	58%
August	67.8	36.7	185%

Extreme weather conditions are expected to occur more frequently in the future. Both CGM1 and HADCM2 climate projection models predicted increasing precipitation during winter months and decreasing precipitation in the summer months.[34] Increased winter precipitation suggests increased winter water supply and warmer drier summers suggests increased potential evaporation and transpiration. Development of options for the GCL Water Resource Management Strategy will consider the impacts of changing weather patterns to the site hydrology over time. As bog ecology depends on rainfall for water supply, it will be sensitive to changes in both the timing and amount of precipitation. Agricultural uses of the park and community amenities that incorporate stormwater re-use would also be affected by climate change over time and these considerations will be incorporated to the extent

[34] Paul H. Whitfield and Richard J. Hebda, 2006. Restoring the Natural Hydrology of Burns Bog, Delta, BC – The Key to the Bog's Ecological Recovery.

possible. However, climate change predictions are generally based on average annual conditions, and often do not address seasonal rainfall variation or changing storm intensity.

Site Visit and GIS Data

As noted in Section 2, a site visit was done by the consulting team to walk the site and understand the topography, drainage, and other site characteristics. Information obtained during the site visit, from observations and from City staff, combines with the GIS infrastructure data provided by the City to understand the existing drainage and infrastructure on the site.

Besides direct precipitation, the GCL also receives runoff from offsite. Westminster Highway, along the South side of the site, and Garden City Road, along the West side of the site, are not curbed along the GCL site. Runoff from the adjacent half of both roads flows onto the GCL for collection and drainage into the municipal storm sewer system.

In addition, City staff indicate that there is a source of off-site water that enters the site from the road bank of Alderbridge Way, near the center of the North side of the site. While no visible discharge point was identified in this area during the site visit, there may be an abandoned pipe or other infrastructure that discharges in this location. At this time the source of the water has not been determined, therefore the volume of water that is discharged here is not known.

Information from staff and GIS data obtained from the City indicate that multiple stormwater system inlets along the West edge of the site are primarily responsible for draining excess surface water from the site. The GIS data indicate that there are inspection chambers, which may also be inlets (this will be confirmed at a later site visit and check with operations staff), located approximately every 20 m along the base of the road bank of Garden City Road. These connect to two storm pipes that runs along the edge of the road right-of-way. The storm pipes connect to a storm trunk sewer at Lansdowne Road, which drains toward the West to the Gilbert Road North pump station on the Fraser River.

There is also a storm inlet at the Southeast corner of the site that drains the East half of the ditch along Westminster Highway. In the 2011 modelling report, the catchment for this discharge point includes more than half of the GCL site. This inlet drains to a trunk storm sewer along No. 4 Road that drains to the North, to the No. 4 Road pump station on the Fraser River.

City staff report that the storm inlets (which were un-observable during the site visit) are open pipe inlets and are prone to clogging. Except when inlets are clogged, the existing drainage infrastructure appears to be adequate for draining excess water from the site during normal conditions. Site flooding that encroached upon Garden City Road in the recent past is considered to be due to clogging of the storm inlets along Garden City Road.

The storm sewer pipes along Garden City Road and No. 4 Road are located along the edge of the road adjacent to the GCL. The storm sewer along Alderbridge Way is located in the middle of the road section, and the storm sewer along Westminster Highway runs along the South side of the road, not next to the GCL. These two pipes would be more difficult to connect to for either bringing offsite stormwater to the site or for discharging stormwater from the due to the necessity of crossing part or all of the roadway to connect to the pipe.

Part A: Site Assessment and Background Review

Water Quality Information

Water quality testing of water from the on-site well at Garden City Park was conducted by KWL in January and March 2005. Among the tested parameters (temperature, turbidity, pH, TSS, conductivity, dissolved oxygen, sulphide, ammonia, sulphate, chloride, total hardness, BOD and trace metal), the Al, Cr, Fe and Ti level was above the BC Guidelines for Protection of Aquatic Life. It should be noted that the samples were taken during the excavation of the stormwater pond, and they were a mixture of groundwater and surface water, so are not reliable evidence for the levels in either surface water or groundwater alone.

According to the meeting minutes of the Environment Advisory Committee[35], groundwater monitoring has also been conducted by the City since 2008 at the Southwest corner of the GCL, directly across from the Esso gas station and oil change facility. To date, there is no indication of any contamination at this location. Ongoing monitoring will take place as long as the gas station and oil change facility is there.

Runoff from paved surfaces, particularly roads, carries sediment and other contaminants. The quality of off-site stormwater has not been characterised and will not be as part of this project. This work will need to assume that stormwater runoff from roads and other off-site sources carries sediment and other contaminants consistent with literature values. Generally, in the urban environment these include significant levels of heavy metals, and may include dissolved nutrients from landscaping management operations or agriculture though the nutrient contaminants vary seasonally[36]. These contaminants will be considered in evaluating the use of road and offsite runoff water on the GCL, such as water supply for wetlands.

6.3 Drainage Understanding of the Garden City Lands

Existing Site Drainage Conclusions

The GCL site receives water from the following sources:

- Precipitation – direct precipitation onto the site;
- Discharge coming from road embankment along Alderbridge Way; and
- Road runoff from adjacent roadways on the South (Westminster Highway) and West (Garden City Road) sides of the site.

There are two general existing flow routes identified across the site. One allows water to drain from the central and east portions of the site toward the South edge of the site. Along the South edge, drainage in the ditch flows from the center toward the East and West to storm sewer system inlets. The Southwest corner of the site appears to drain poorly, as ponding frequently occurs during the wet season. By the early fall timing of the site visit for this project, there was no standing water or wet ground on site. The other flow route generally, drains water across the Northwest quadrant of the site, from the center of the North side of the site to the North half of the West side of the site.

[35] Advisory Committee on the Environment – Garden City Legacy Landscape Plan, April 16, 2014.
[36] Minton, Gary. Stormwater Treatment: Biological, Chemical, and Engineering Principles. 2010.

Part A: Site Assessment and Background Review

Information from staff and GIS data obtained from the City indicate that multiple stormwater system inlets along the West edge of the site are primarily responsible for draining excess surface water from the site. There is also a storm inlet at the Southeast corner of the site that drains the East half of the ditch along Westminster Highway.

City staff report that the storm inlets (which were un-observable during the site visit) are open pipe inlets and are prone to clogging. Except when inlets are clogged, the existing drainage infrastructure appears to be adequate for draining excess water from the site during normal conditions. Site flooding that encroached upon Garden City Road in the recent past is considered to be due to clogging of the storm inlets.

However, the 2011 modelling of the storm system indicates that the storm sewers along Garden City Road and Alderbridge Way are undersized for the 10-year, 24-hour design event. Some flooding in the GCL could be due to limited capacity in the storm sewer system, though the duration of ponding on the site after storms have ended indicates that poor drainage of the site is an issue regardless.

The limited capacity in the storm sewer network on Garden City Road, in particular, may have an impact on the drainage design for development of the site. Without upgrade of the receiving storm sewer pipes, detention on-site of the design rainfall event may be required. The storm sewer pipes will not be able to receive any increase in runoff from the site due to development of the park.

Surface Water Challenges

This project presents a number of challenges for surface water and drainage considerations. Drainage will need to be provided to required elevations both for the bog and natural areas and for the agricultural and community use areas. The levels of drainage for those four uses will be determined as part of the work of this project, but they may all be different elevations and are likely to require separate drainage infrastructure to achieve the different drainage levels.

While drainage may be required to multiple different levels, there will also be a need to retain water on the site to some minimum levels in order to support the bog and wetland natural areas of the Legacy Landscape Plan. This will require careful consideration and balancing of flooding, safety, drainage, and ecological needs.

Drainage may also be challenging due the very low gradients available in this area. The site itself is mostly very flat, and there is minimal gradient from surface drainage from this location to the Fraser River. As drainage conveyance capacity is partly dependent on gradient, the grades are expected to make design of drainage solutions more challenging for this site.

There is also a question whether the site can sustainably supply some or all of the water needs for irrigation and possibly other on-site water uses with storage and re-use of on-site and/or off-site stormwater. The viability of this will be investigated in the course of the Water and Ecological Resource Management Strategy project. Infrastructure to provide storage and re-use of stormwater will also have to be provided with overflow and drainage infrastructure for safe conveyance and discharge of excess flows.

Part A: Site Assessment and Background Review

Existing Site Drainage Unknowns

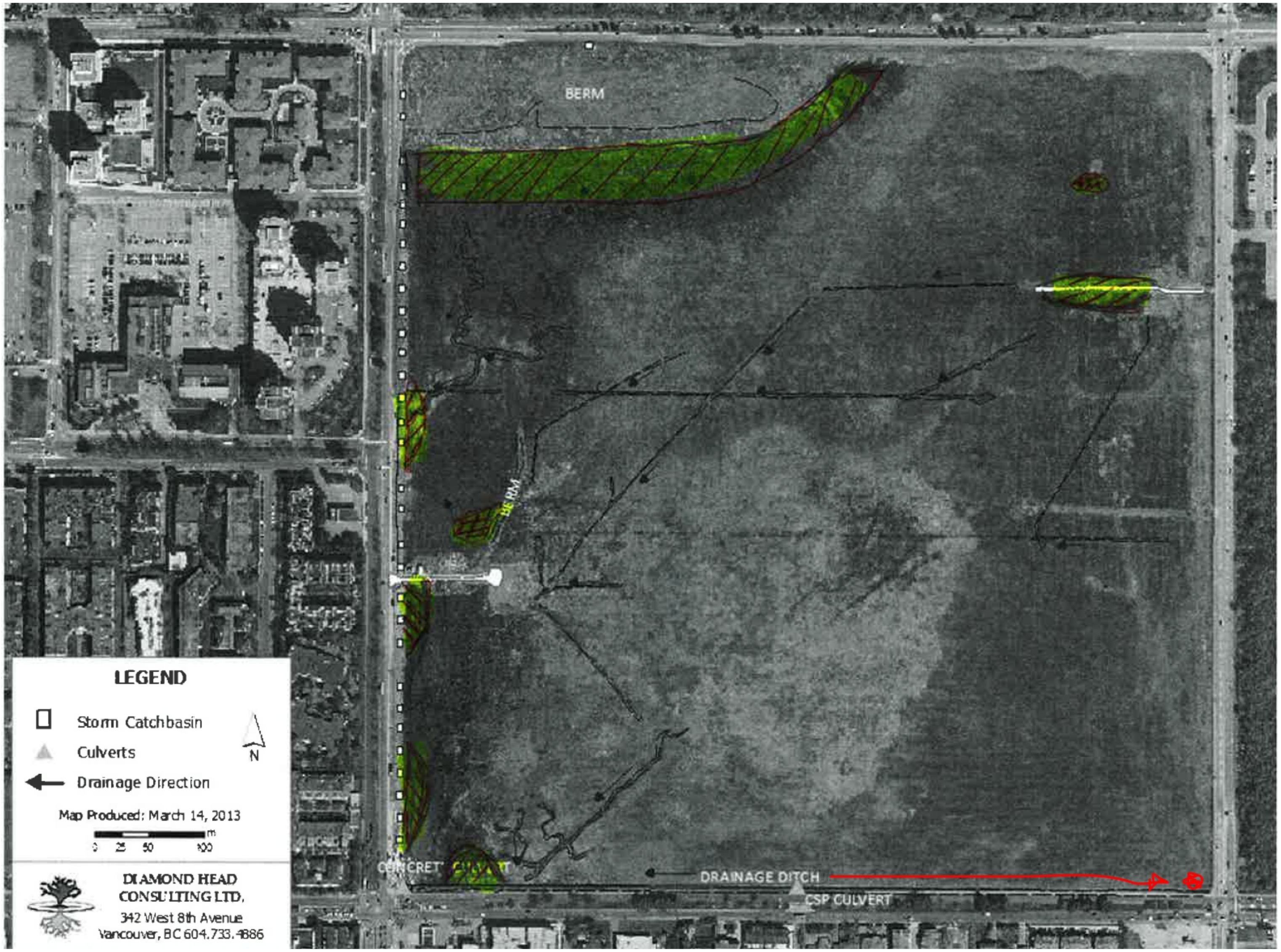
The water quality or water chemistry of the stormwater from on-site as well as from off-site must be considered for use and contribution to the natural areas for the park and for use in irrigation or other on-site water uses. The water chemistry of on-site water has been sampled as part of the Biophysical Asessment, but the off-site stormwater water quality has not been characterised and will not be as part of this project. This work will need to assume that stormwater runoff from roads and other off-site sources carries sediment and other contaminants consistent with literature values.

In addition, the water quality of onsite water that has been in contact with groundwater may be of concern. Groundwater in Richmond is known (see Section 3 of this report) to carry high levels of iron, such that iron staining can occur on surfaces and vegetation that have been in contact with the groundwater. As there may be some existing groundwater contribution to the site[37], as well as there is a possible option developing a groundwater source for on-site irrigation, the possibility of iron contamination is a concern but is not quantifiable at this time.

The source of water that enters the site along South side of Alderbridge Way is currently unknown and may not be able to be identified with certainty. The affects the stormwater management options and design as the volume of water will be difficult to estimate for storage or conveyance on GCL.

[37] City of Richmond Garden City Lands Biophysical Inventory and Analysis. Diamond Head Consulting, 2013.

City of Richmond



Ponded Water

Source | from Diamond Head Consulting Ltd.

Project No. 651-085

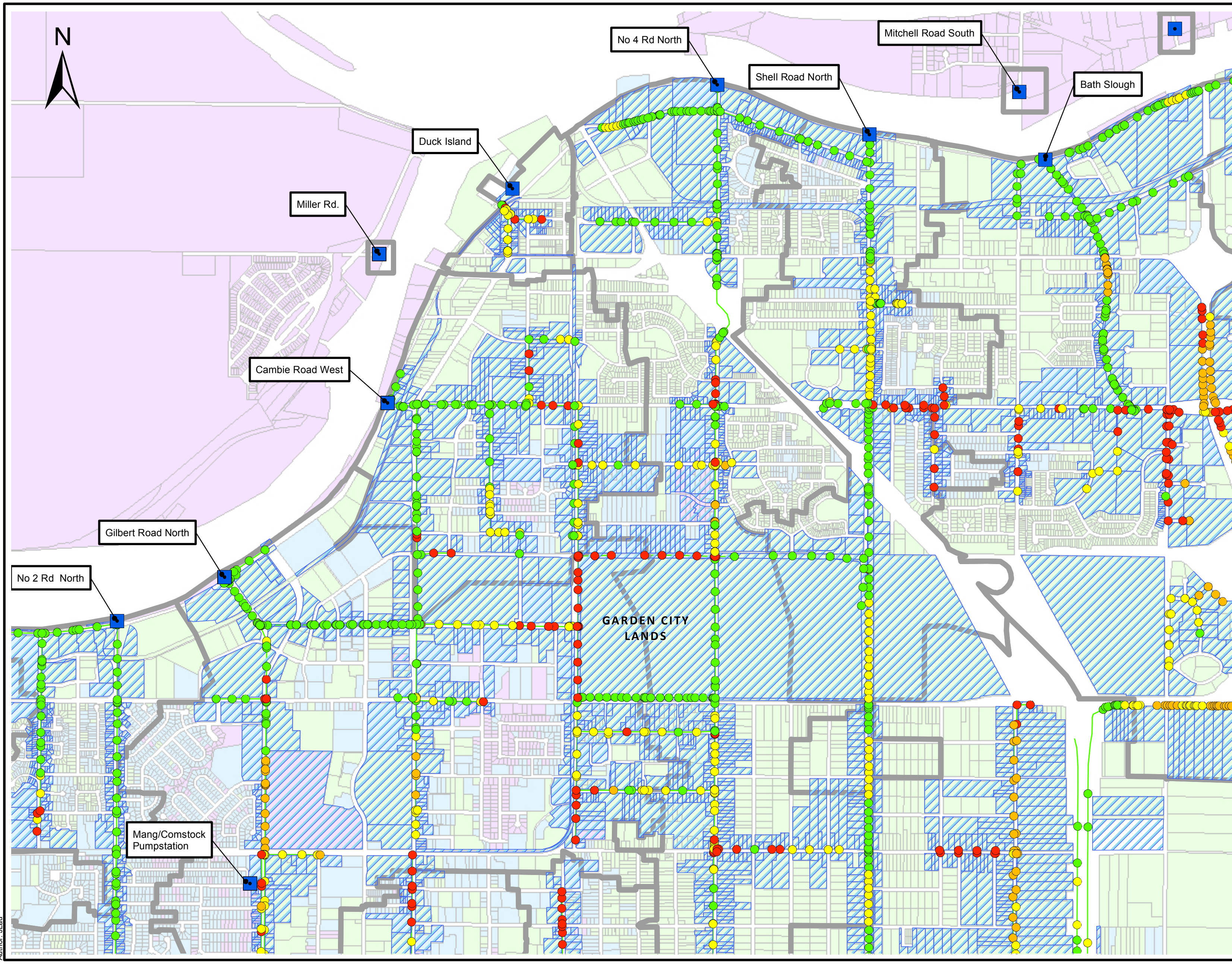
Date November 2015

Not to Scale

KERR WOOD LEIDAL consulting engineers

Garden City Lands Ponded Water

Figure 6-1



Path: O:\0600-0699\651-085\430-GIS\MXD-Rpt\Phase1\651085_Phase1_Fig6-2.mxd Date Saved: 24/11/2015 11:42:58 AM
Author: JLau

Richmond

Garden City Lands Water and Ecological Resource Management Plan

Legend

- Catchment Boundary
- Pump Station

Parcel Elevation (m)

- < 0.5
- 0.5 - 1.0
- > 1.0

Max Water Levels (Min El)

- Surface Flooding
- Surface Flooding (No IC)
- Inadequate Freeboard (< 0.45 m)
- Acceptable
- Lots Adjacent to Major System

Note:
Parcel elevations based on lowest inspection chamber elevation where available and DEM elsewhere. Inspection chamber elevations and DEM as provided by the City of Richmond, February 2011. DEM reported accuracy is 0.6 m ±.

Peak water levels compared to minimum parcel elevations.

Model results of existing infrastructure without improvements.

Pump stations on along western dyke.

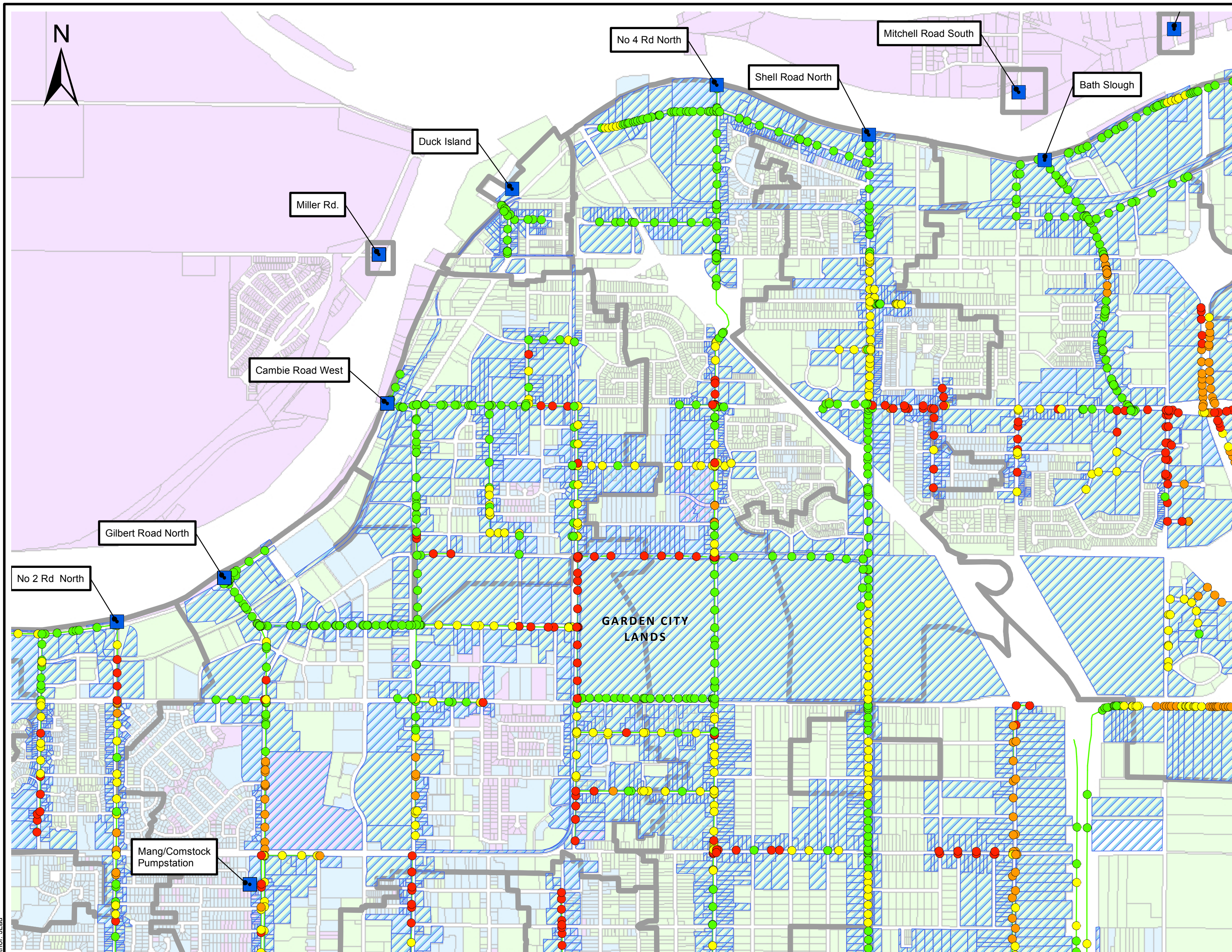
KERR WOOD LEIDAL
consulting engineers

500 0 500 (m)
1:20,000

Project No.	Date
651-085	November 2015

Major System Flooding
2041 OCP Condition
Without Improvements
10-Year, 24 Hour
Free Outfall

Figure 6-2



Path: O:\0600-0699\651-085\430-GIS\MXD-Rp\Phase1\651085_Phase1_Fig6-3.mxd Date Saved: 24/11/2015 11:40:42 AM
Author: JLau

Richmond

Garden City Lands Water and Ecological Resource Management Plan

Legend

- Catchment Boundary
- Pump Station

Parcel Elevation (m)

- < 0.5
- 0.5 - 1.0
- > 1.0

Max Water Levels (Min El)

- Surface Flooding
- Surface Flooding (No IC)
- Inadequate Freeboard (< 0.45 m)
- Acceptable
- Lots Adjacent to Major System

Note:
Parcel elevations based on lowest inspection chamber elevation where available and DEM elsewhere. Inspection chamber elevations and DEM as provided by the City of Richmond, February 2011. DEM reported accuracy is 0.6 m ±.

Peak water levels compared to minimum parcel elevations.

Model results of existing infrastructure without improvements.

KERR WOOD LEIDAL
consulting engineers

500 0 500 (m)
1:20,000

Project No.	Date
651-085	November 2015

Major System Flooding 2041 OCP Condition Without Improvements 10-Year, 24 Hour Constant 2 m Outfall

Figure 6-3

Part A: Site Assessment and Background Review

7. Site Assessment Conclusions

The conclusions from the preliminary site assessment are summarized below.

7.1 Site Groundwater Management Conclusions

Based on information obtained and reviewed to date, the following items are of relevance to our understanding of hydrogeologic conditions at the GCL:

Hydrostratigraphy

- Native materials underlying the GCL comprise the following from ground surface down:
  - *Peat* – the peat is relatively thin, averaging about 0.6 m in thickness. It is thickest (about 1.4 m) in the eastern part of the site and thins to the west. The upper several centimetres of peat are relatively permeable (perhaps on the order of 10^{-4} m/s) with active plant and moss growth sphagnum), whereas the underlying few centimetres is characterized as amorphous and has a relatively low permeability (inferred to be on the order of 10^{-7} m/s).
  - *Clayey Silt* – this unit is continuous across the GCL and directly underlies the peat. It has a reactively low hydraulic conductivity and acts as a aquitard between the permeable peat unit and underlying Fraser River sand.
  - *Transitional Silt* – In several areas beneath the GCL, the clayey silt transitions into sand. The transitional zone is characterised by silt with thin interbeds of fine sand. The sand layers are unlikely to be laterally extensive and may occur as lenses.
  - *Sand* – beneath the clayey silt or transitional silt is a relatively thick unit composed of fine and fine to medium grained laterally extensive sands. The sand units collectively are referred to as the Fraser River sand aquifer that, beneath the GCL, is on the order of 10 m to 20 m in thickness. The sands extend several tens of kilometres to the east and south, are hydraulically connected to the Fraser River to the north, and extend to the marine environment to the west. The sustained yield from pumping a well installed in this aquifer to the south of GCL near Alberta Street is greater than 3.1 L/s (about 50 USgpm).
  - *Marine Silt* – the sand aquifer is underlain by a continuous layer of silt, inferred to be of marine origin that is laterally extensive and is likely underlain by till. This silt unit behaves as an aquitard, and for purposes of the groundwater model, serves as the base of the model domain.

Water Quality

- Water within the peat was characterized as being acidic with relatively low dissolved solids (pH 3.8 to 4.8; electrical conductance less than 100 µS/cm), whereas waters win the underlying Fraser River Sands were near-neutral and minerotrophic (pH 6.3 to 7.0; electrical conductance about 300 µS/cm to 750 µS/cm). Minerotrophic, near neutral pH waters were also encountered in shallow soils nears roads, where peat had likely been removed a part of development. Based on water quality testing conducted south of the GCL near Alberta Street, groundwater is likely to meet current guidelines and criteria for various organic and inorganic constituents, with the exception of iron which is highly elevated as noted previously.

Part A: Site Assessment and Background Review

Water Levels and Groundwater Flow Direction

- Water levels in the peat and underlying silt units respond relatively rapidly to rainfall events, whereas water levels in the deeper sand unit are much more attenuated;
- Based on review of historic air photographs and current water level information, the general horizontal flow direction within the peat bog (and underlying sand aquifer) has historically been to the southwest; and
- Vertical flow is downward, from the peat through the silt aquitard and into the sand aquifer. Downward seepage occurs throughout the year. The quantity (i.e., flux) of downward flow is a key parameter to be define in order to assess various development alternatives, and will be assessed through the modeling effort.

Work currently underway is focused on resolving data gaps and supporting development of a 3-D finite element model of the hydrogeologic system.

7.2 Site Environmental Management Conclusions

Due to its location on the margins of Lulu Island Bog, there is a strong likelihood that the GCL is representative of both bog and lagg ecosystems and that a transitional plant community exists. The east side of GCL is currently considered a semi-natural bog ecosystem, dominated by introduced Scotch Heather, but also having a diversity of native bog-associated plants, some of which are regionally rare.

There are five conditions that must be met for bog restoration to be considered as a possibility for a site[38]

1. There should be a large area of peat where the drainage does not cut into the mineral substrate;
2. There should be at least 50-100 cm of compressed, humified peat;
3. It should be possible to exclude all sources of nutrient enrichment (air and water borne);
4. There should be a buffer zone between the site and agricultural land; and
5. A source for plant colonization should exist locally.

Garden City Lands meets (or potentially meets) these five conditions for restoration of the bog on the Eastern portion of the site.

The Legacy Landscape Plan envisions creation of an open water complex in the southwest corner of Garden City Lands. The ecology of this area indicates that it may be considered the transition or lagg zone for the Lulu Island bog. These lagg systems have received relatively little attention in bog restoration, therefore, while creation of a marsh (wetland ecosystem) is a primary objective, maintaining representative vegetation components and chemistry gradient in the lagg should also be a focus of restoration efforts.

The acidic, nutrient poor conditions of bogs are not suitable for many tree species and trees can also affect water balance by intercepting precipitation and through transpiration of groundwater. Therefore, landscape tree planting on the periphery of GCL will need to be carefully considered in coordination with natural areas restoration.

[38] Charman, D. 2002. *Peatlands and environmental change.* Wiley, New York.

Management considerations for bog restoration on the GCL site include:

- Creating hydrological conditions sufficient to support active *Sphagnum* growth and prevent peat from drying out during summer months, thereby encouraging establishment of plants more suited to these conditions;
- Management control of invasive plants which are outcompeting native bog species;
- Isolating bog and lagg ecosystems due to their different hydrological and hydrochemical requirements;
- Isolating hydrological inputs and outputs separately in the agriculture zone and wetland zone;
- Ensuring any management action taken on GCL does not negatively affected the greater Lulu Island bog ecosystem (DND lands and RNP), and that potential future changes in adjacent land use will not compromise restoration efforts on the GCL site;
- Potential impacts of climate change (e.g. longer, drier summers) are appropriately considered in water balance models for the site to ensure wetland requirements can be met over the long-term; and
- Restoration of the bog and lagg ecosystem will require a long-term vision and adaptive management to achieve objectives. For comparison, the Burns Bog Management Plan has a 100 year outlook.

7.3 Site Agricultural Management Conclusions

The Garden City Lands offer a wealth of opportunity for a diverse range of agricultural activities. The breadth and scope of farming that will occur will depend on how the following factors are managed:

- The cultivation of the organic (peat) and mineral soils;
- The sophistication of drainage incorporated into the water management plan;
- The source of water for irrigation (quality and quantity of water available); and
- The operation of the site itself (either solely by the City of Richmond, in partnership with KPU, or through land use agreements with other individuals and/or agencies).

There are no serious limitations to farming the Garden City Lands and those that do exist (e.g., high water tables, organic soil layers) can be overcome with minimal to moderate levels of amendments and modifications to the site.

7.4 Site Drainage Management Conclusions

The GCL site receives water from the following sources:

- Precipitation – direct precipitation onto the site;
- Discharge coming from road embankment along Alderbridge Way and
- Road runoff from adjacent roadways on the South (Westminster Highway) and West (Garden City Road) sides of the site.

Part A: Site Assessment and Background Review

There are two general existing flow routes identified across the site. One allows water to drain from the central and east portions of the site toward the South edge of the site. Along the South edge, drainage in the ditch flows from the center toward the East and West to storm sewer system inlets. The Southwest corner of the site remains wet with standing water on site through the winter season. The other flow route generally drains water across the Northwest quadrant of the site, from the center of the North side of the site to the North half of the West side of the site.

There are multiple stormwater system inlets along the West edge of the site are primarily responsible for draining excess surface water from the site. There is also a storm inlet at the Southeast corner of the site that drains the East half of the ditch along Westminster Highway. The existing storm inlets are thought to be open pipes (unconfirmed at this time) and are prone to clogging.

This project presents a number of challenges for surface water and drainage considerations, including:

- Drainage will need to be provided to required elevations both for the bog and natural areas and for the agricultural and community use areas.
- There will be a need to retain water on the site to some minimum levels in order to support the bog and wetland natural areas of the Legacy Landscape Plan.
- Drainage may also be challenging due the very low gradients available in this area.
- There is a question whether the site can sustainably supply some or all of the water needs for on-site water uses with storage and re-use of on-site and/or off-site stormwater.

Among the unknown information that will affect the development and selection of water management options for the site, the water quality of off-site stormwater will be assumed based on typical values.

The source of water that enters the site along South side of Alderbridge Way is currently unknown and the volume of water will be difficult to estimate for storage or conveyance on GCL.

Storm system modelling indicates that existing storm sewer pipes on Garden City Road and Alderbridge Way are undersized for the design storm event. The limited capacity in the storm sewer network on Garden City Road, in particular, may have an impact on the drainage design for development of the site. Without upgrade of the receiving storm sewer pipes, detention on-site of the design rainfall event may be required. The storm sewer pipes will not be able to receive any increase in runoff from the site due to development of the park.

Part B: Water Resources Management Plan

This part of the project is an effort to develop a Water Resource Management Plan to inform the implementation of the LLP and the long-term operation of the site.

Key objectives for the Water Resource Management Plan include:

- Evaluate the proposed water management methodology shown in the LLP to achieve conservation and enhancement of the bog area and develop alternative methodologies if required;
- Investigate surface water drainage methodologies to accommodate agricultural and community wellness uses; and
- Make recommendations for the retention of surface water for irrigation purposes and managing.

8. Water Resource Management Objectives

The water management on the GCL site incorporates the ecological needs for water from the natural areas, as well as the needs of the agricultural areas of the site. The objectives regarding water conservation within the LLP will be balanced in conjunction with desired uses to ensure that recommendations are developed that will allow for food production goals to be met within the parameters of conservation and health. Key objectives for the water management plan are discussed in the following sections.

8.1 Guiding Principles from City of Richmond and Landscape Legacy Plan.

In discussions with the City staff regarding the goals and priorities for this project, staff indicated that the guiding principles from the LLP continue to hold true for development of the options for water and ecological management on the site. This work is intended to determine to what extent the Vision and themes selected for this site can be developed in the process of creating the GCL as a long term investment for the community's needs. The guiding principles shown below were used to inform the priorities for different uses and amenities on the site in development of options and evaluation of their relevance and importance for the future build-out of the site.

Landscape Legacy Plan Vision Statement

In the LLP, an overall Vision Statement for the GCL was developed and adopted by City Council. The statement was based on community and stakeholder aspirations, as well as key findings from the biophysical inventory and hydrological and geological analyses. It states:

- The Garden City Lands located in the City Centre is envisioned as an exceptional open space legacy for residents and visitors.
- Visible and accessible from many directions, the Lands are an impressive gateway into Richmond's downtown and a place of transition and transformation from the rural to the urban.
- It's rich, diverse, and integrated natural and agricultural landscape provides a dynamic setting for learning and exploration.
- It is inclusive, with a range of spaces, amenities, and uses that encourage healthy lifestyles, social interaction, and a strong sense of shared community pride

Part B: Water Resources Management Plan

Landscape Legacy Plan - Seven Guiding Principles

To ensure that future development of the GCL is consistent with the Vision Statement, seven principles were established, as follows:

1. Encourage Community Partnerships and Collaboration – coordinated efforts and commitment by many stakeholders to achieve a common vision.
2. Respect Agricultural Land Reserve – encourage viable and sustainable agricultural uses that benefit the community. Incorporate agro-ecology, wildlife, culture, economics, and society with agricultural production.
3. Strive for Environmental Sustainability – conserve and enhance bog areas and wildlife. Develop green infrastructure and establish ecological connections with surrounding areas.
4. Promote Community Wellness and Active Living – foster access to year round activities to encourage discovery and learning. The amenities and infrastructure should be designed to reflect the unique landscape and history of the lands.
5. Maximize Connectivity and Integration – provide safe and clear access from the surrounding neighborhoods. Integrate recreation, ecological areas and agriculture functions on the site.
6. Allow for Dynamic and Flexible Spaces – provide spaces that are dynamic and adaptable depending upon seasons, community interests and needs over the years, new innovative programs and cultural opportunities.
7. Develop Science-Based Resource Management Plans – the preservation of sensitive bog environment, construction of a wetland, and integrated eco-systems will require careful considerations and-on going monitoring. Scientific research and adaptive management will be required in the long term.

Landscape Legacy Plan Land Use Themes

In 2007, Richmond City Council endorsed three major land use themes for the 65 acres of land for potential uses and amenities. Since the acquisition of the whole 136.5 acre parcel, an additional theme of Cultural Landscapes Peacemaking was added in consideration to GCL's location within the urban City centre. The four land use themes are:

- **Urban Agriculture** - A showcase for innovative and sustainable agricultural practices with community benefits within a public park setting.
- **Natural Environment** - A highly valued, biologically diverse, and resilient natural environment that reflects the inherent ecology of the Lands and is a vital contribution to the City's overall Ecological Network and community health.
- **Community Wellness and Active Living** - An accessible, safe, and appealing public open space that promotes healthy lifestyles and community cohesiveness through a unique richness of adaptable social, environmental, agricultural, and recreational amenities and programs.
- **Cultural Landscape/Placemaking** - A rich and vibrant place with a distinct identity that reflects and highlights the unique characteristics of the site and generates fond memories, community pride, and a deep appreciation of the agricultural and ecological values of the GCL.

Part B: Water Resources Management Plan

8.2 Proposed Land Uses

The LLP has been designed to respond to the existing knowledge of the site, the community input, and the vision statement adopted by Council and the land use framework.

As shown on Figure 8-1, the plan features seven landscape zones as detailed below. The landscape zones serve the base plan to develop the water and ecological resource management strategy.

- The Bog - The existing raised remnant peat bog area and its critical plant species in the eastern half of the site will be protected as a natural area. Raised earth dikes with trails will be considered as a bog conservation strategy.
- The Mound - The existing raised mound along the north edge provides excellent views over the Lands. Dense planting of trees along Alderbridge Way will create a buffer and backdrop to the Lands. If required, this flexible space could be farmed in the future.
- The Community Hub - This will be a multi-functional community gathering area located along Garden City Road at the terminus of Lansdowne Road. It will be comprised of flexible gathering and festival spaces, stormwater features, play elements, community and demonstration gardens, and a cluster of buildings that will serve community, educational, and agricultural needs.
- The Fields - Agricultural fields are located predominately in the central and western part of the site and will allow for the cultivation of crops, horticultural plants, tree nursery, art crops, and flex-fields. Flex-fields are intended to be flexible and adapt to community needs over time.
- The Sanctuary - Located near the centre of the site, this is an ecologically important and sensitive area within the bog environment with a large patch of moss that relies on the high water tables of the bog.
- The Wetlands - A wetland area will be created along the south edge of the GCL, allowing for year round standing water to serve as wildlife habitat, an aesthetic recreational amenity and as potential storm water retention and filtering ponds. This area will be used to help regulate water levels to protect the bog environment and potentially be a water source for irrigation.
- The Edges - The Garden City Road edge will be designed as a significant greenway that is part of the regional and City cycling network. All of the perimeter trails will provide for off-street walking and cycling and ensure safe connections to surrounding areas.

Elements for Water Management Focus

The different land use elements of the LLP require a variety of water management considerations for water supply, drainage, and the groundwater table. From a water management perspective, the two most critical aspects of the LLP are the bog, on the eastern side of the site and the farm area on the western side of the site. These two land uses and their juxtaposition on the site, require multiple assessments and consideration of on- and off-site interactions and implications. Much of the discussions and recommendations in this study are focussed on the bog and the farm area.

Additional elements that are part of the water management plan include drainage for trails, plazas and parking areas on the site, potential storage, and integration options for on-site water features.

City of Richmond
Garden City Lands
Water and Ecological Resource Management Strategy

Legend

Study Boundary

Note: Garden City Legacy Landscape Plan, 2014

Reference: J2013 Orthophoto and GIS background from the City of Richmond.

KERR WOOD LEIDAL
consulting engineers

100 0 100 (m)
1:4,000

Project No.	Date
651-085	July 2016

Garden City Lands Landsape Zones

Figure 8-1

Path: O:\0600-0699\651-085\430-GIS\MXD-Rp\651085_Fig8-1.mxd Date Saved: 11/07/2016 4:26:51 PM
Author: SScott

Part B: Water Resources Management Plan

9. Proposed Water Management in the LLP

9.1 Proposed Major Drainage Elements

Lansdowne Terminus Water Feature

The Lansdowne terminus water feature is proposed to be multifunctional (see Figure 3-1, item 13). Functions include aesthetic water feature, irrigation water reservoir, stormwater education, and community gathering place. It is intended to store excess water from the stormwater channel and the developed areas adjacent to the GCL. In addition, it allows overflow from the bog side through a local depression of the seepage barrier/berm.

A number of challenges have been identified regarding the proposed functions of the water feature:

- Aesthetic: it is challenging to maintain the water feature as a wet pond if solely fed by stormwater runoff. The water feature will dry up during the dry season and will need municipal water supply to top up.
- Water quality: agriculture runoff carries soil and dissolved compounds from the fields, including pesticides, fertilizers and manure. Therefore, high turbidity and odor may be expected during the growing season.
- Water quantity: a stormwater storage facility to relieve capacity in the storm sewer system would require significant storage volumes. The footprint area of the water feature, and the depth of water in it, are likely limited. It should be noted that the storage volume in the water feature would only cover a small fraction of the irrigation need.
- Public health: a permanent pool of untreated stormwater runoff may increase mosquito populations if not properly designed and maintained, which raises public health concerns about West Nile Virus.

These challenges are addressed in the Strategy as described in the following sections of this report.

Stormwater Channel

The proposed stormwater channel runs through an existing low-lying area frequently flooded following winter storms. (see Figure 9-1, item 15). The channel begins on the east side of the mound near Alderbridge Way. It flows westward along the south toe of the mound, then turns south and flows parallel to Garden City Road, flowing into the terminus water feature, and overflowing off site into the Lansdowne Road storm sewer. In addition to drainage and irrigation, the stormwater channel was envisioned to promote learning and exploration, viewing, education, and bird watching opportunities.

Challenges and opportunities present with the stormwater channel include:

- Location: the proposed stormwater channel is well positioned as an agriculture drainage channel. The location takes advantage of the natural topography to use existing low-lying areas for channel locations. There is space available at the northwest corner of the site to enlarge the channel locally to increase detention storage.
- Drainage: the average gradient along the 600 m long channel will be very low . Low gradient reduces the drainage capacity of the channel, increasing the required channel cross section size.

Part B: Water Resources Management Plan

- Receiving system: The stormwater channel receives agricultural runoff that is rich in TSS and nutrients. It present risks to the receiving water body, if discharged to the Lansdowne Rd storm sewer system without treatment.

Water Retention Wetland

The southwest edge of the site has the lowest elevation within the extent of GCL site. Under current conditions, on site runoff collects in this area forming a seasonal water pool. The LLP proposes to turn this area into a permanent wetland, which can be accomplished by establishing an elevated control structure at the outlet. The wetland not only serves as wildlife habitat and aesthetic recreational amenity, but also as a potential storm water retention and filtering pond, that can be used to regulate water levels in the bog and for irrigation.

Challenges and opportunities for the water retention wetland are summarized as follows:

- Function: it makes sense to have a wetland at a natural low-lying area of the site. Surface topography provides opportunity to maximize the detention volume. By adding a perimeter berm around the remnant bog and wetland area, the wetland will have the capacity to retain more water than under current conditions. However, the idea of having a permanent wetland is challenging as it may not be possible to maintain year-round standing water.
- Vegetation: this would not be a lush wetland with typical aquatic plants, such as water lilies, herbaceous and willow trees. To fit the ecology of a bog and preserve the desired water chemistry, the wetland would mimic as much possible a natural Lagg plant community. There would be a mosaic of wetland species building on the existing plant types, such as sedges and hardhack. It is possible to have scattered islands of tall shrubs for diversity.
- Water quality: with the presence of the proposed berms, water in the wetland would come only from the bog portion of the GCL. The unique water chemistry such as low PH, low dissolved oxygen, etc., would limit its use as irrigation water for the agricultural areas of the GCL.
- Outlet control: It is feasible to construct an elevated outlet structure that will regulate water levels and encourage increased ponding depth and surface area. The elevated water levels will likely enhance the bog environment by reducing water loss by drainage off the site.

City of Richmond
Garden City Lands
Water and Ecological Resource Management Strategy

Legend

Study Boundary

Note: Garden City Legacy Landscape Plan, 2014

Reference: J2013 Orthophoto and GIS background from the City of Richmond.

KERR WOOD LEIDAL
consulting engineers

50 0 50 (m)
1:3,250

Project No.	Date
651-085	July 2016

Garden City Lands Proposed Land Use

Figure 9-1

Path: O:\0600-0699\651-085\430-GIS\MXD-Rp\651085_Fig9-1.mxd Date Saved: 11/07/2016 4:28:41 PM
Author: SScott

Part B: Water Resources Management Plan

9.2 Preservation of the Remnant Bog

The GCL site is located on the west edge of the Greater Lulu Island Bog. It was once part of the Greater Lulu Island Bog ecosystem. As shown in Figure 9-2, this raised bog once covered a much greater area of Richmond prior to European Settlement (*Davis, N. and R. Klinkenberg, 2008. A biophysical inventory and evaluation of the Lulu Island bog, Richmond, BC*). However, much of this bog has been lost due to urbanization, agriculture, and peat mining. Today, the most significant tract of remnant bog habitat remains in the Department of National Defense (DND) property and the Richmond Nature Park (RNP) to the east of the GCL. The GCL site is considered a transitional zone with only the eastern portion being a part of this bog ecosystem. Peat depth across the site ranges from 0.2 m to 1.4 m which is thinner than that of a typical bog. For many years, annual mowing has been conducted on the GCL site, with the aim of controlling the establishment of tree and large shrub species which has helped to preserve the remaining low-growing bog species. More information on the remnant bog and options for its restoration may be found in the *Draft Garden City Lands Ecological Resource Management Plan* (separate report).

Some critical factors need to be considered to preserve and promote bog health:

- Water table: In order for sphagnum moss and other bog plant species to thrive, the ideal water table in the peat needs to be within 0.4 m of the surface of the bog. This means the ground water level should be at the surface in the wet season and should drop but remain close to or within 0.4 m of the surface in the dry season.
- Water chemistry: Bog water is acidic (low pH), low in nutrients and mineral content. It is sometimes referred as “sterile” compared to water in other ecosystem environments. Because of this it is very difficult to add water to a bog, because other sources of water, that are not a bog, are likely to have incompatible water chemistry which would harm the bog ecosystem. The primary source of water for a bog is rainwater falling directly on the bog.
- Restoration of bog plant community and removal of invasive species are also important. They will be addressed in the *Draft Garden City Lands Ecological Resource Management Plan*.

Part B: Water Resources Management Plan

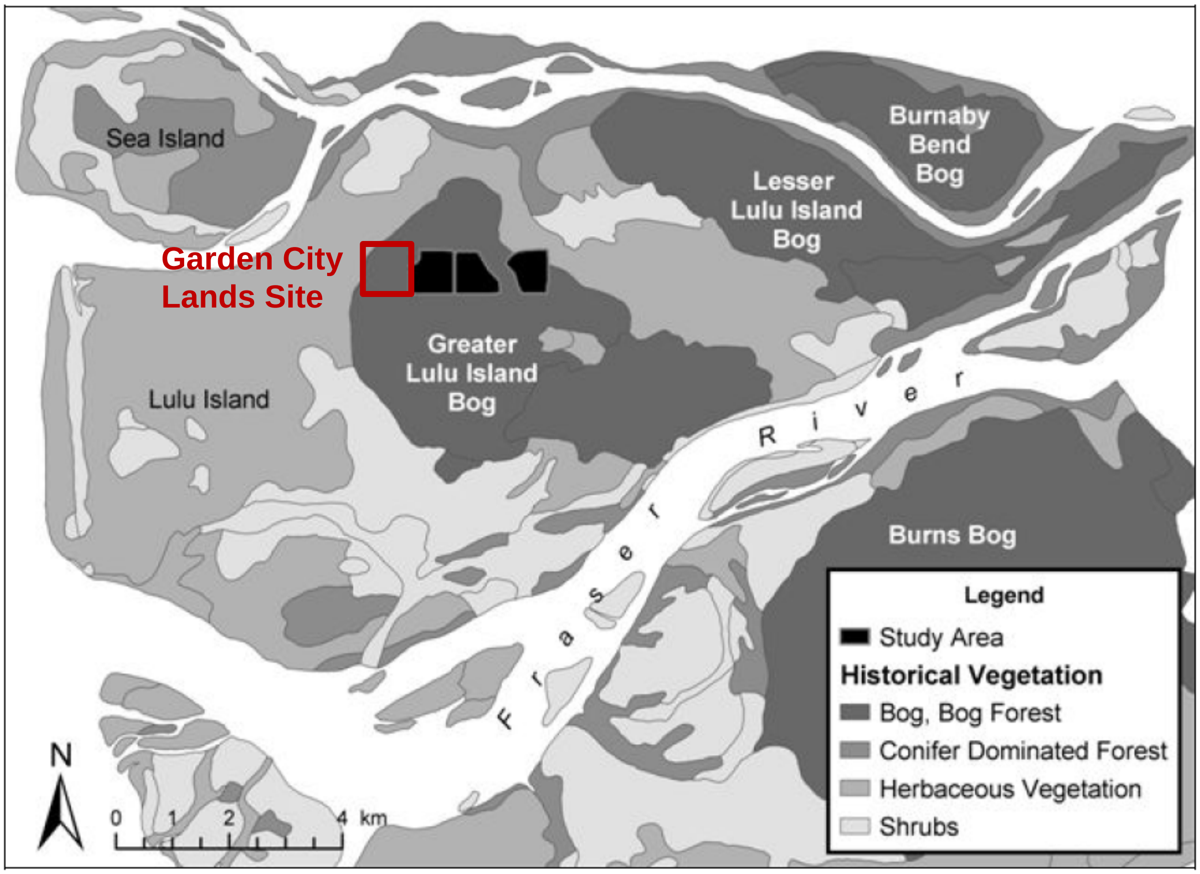


Figure 9-2: Illustration of Garden City Lands location in the Historical Greater Lulu Island Bog[39]

9.3 Enabling Agricultural Uses

Identifying and evaluating suitable options to support long term sustainable agriculture on the GCL site requires research and assessment of the existing conditions as well as identifying the range of requirements for crop production and agricultural management of the western portion of the site. On-site water management for drainage and irrigation to enable successful agricultural production scenarios to be considered and assessed for integration into the site includes.

- Site drainage: Drainage provisions are required in the agricultural fields to drain the groundwater table to below root depth during the growing season to provide aerobic soil and prevent root rot. The GCL site topography is a particular challenge to the site drainage because the gradient (slope) is very flat across the site.

[39] Davis, Neil and Rose Klinkenberg, Editors. *A Biophysical Inventory and Evaluation of the Lulu Island Bog, Richmond, British Columbia*. Richmond Nature Park Society, Richmond, British Columbia.

Part B: Water Resources Management Plan

- Irrigation requirement: During the dry summer, irrigation will be required for the crops. As GCL is located in the centre of the urban area, it does not have access to the existing agricultural irrigation network which transports water from the Fraser River to farm fields via low-gradient ditches. Drawing water from Fraser River near the GCL site may not be feasible due to increasing salinity closer to the mouth of the river. Other options including rainwater reuse, on site storage and municipal water supply must be considered for irrigation.

In addition, soils meeting minimum requirements for agricultural production will be critical to the success of agriculture on the GCL site. Soil amendment will be required to augment the existing on-site soils in order to allow a range of crops to be gown.

Part B: Water Resources Management Plan

10. Water Management Options for Bog Preservation

10.1 Hydrogeology Assessment

The full Hydrogeology Report for the Garden City Lands may be found in Appendix A. The following paragraphs summarize critical information, conclusions, and recommendations extracted from the report that provide part of the basis for development of water management options and recommendations.

On-Site Ground Water Table

Hydrogeological investigation was performed by SNC-Lavalin from March 2 to August 26, 2015. The GCL soil stratification was defined by 0.4 m to 1.2 m of peat, followed by a clayey silt unit 2.3 to 3.8 m thick, a transitional silt and a discontinuous sand unit of 0.2 m to 1.5 m underlain by sand to the maximum depth of the investigation. The water table was observed to occur within the peat layer from March to mid-June/July and within the underlying clayey silt layer from mid-June/July to the end of August (i.e. the end of monitoring period).

The site drainage concepts were developed based on March – August groundwater data from 2015 (SNC, 2015).

As the proposed agricultural activities are to be conducted within the peat layer, focus was placed on the seasonal groundwater variation measured by the shallow wells that were installed through the peat and top of the underlying clayey silt. To define the boundary conditions, maximum and minimum groundwater level at the four corners of the GCL are listed in Table 10-1 and used for the site drainage design. Figure 10-1 provides the location plan for all the wells installed on site.

Table 10-1: Max and Min Groundwater Levels at the GCL Monitoring Sites

Location	Nearest Well ID	Peat Level Elevation (m)		Water Table (m)	
		Top	Bottom	2015 April (Max)	2015 Aug (Min)
Northwest Corner	15-6	0.4	-0.06	0.8	N/A
Southwest Corner	15-2S	1.2	0.61	1.0	0.6
Northeast Corner	15-5	1.3	0.23	0.9	0.3
Southeast Corner	15-3S	1.5	0.63	1.4	0.0

Part B: Water Resources Management Plan

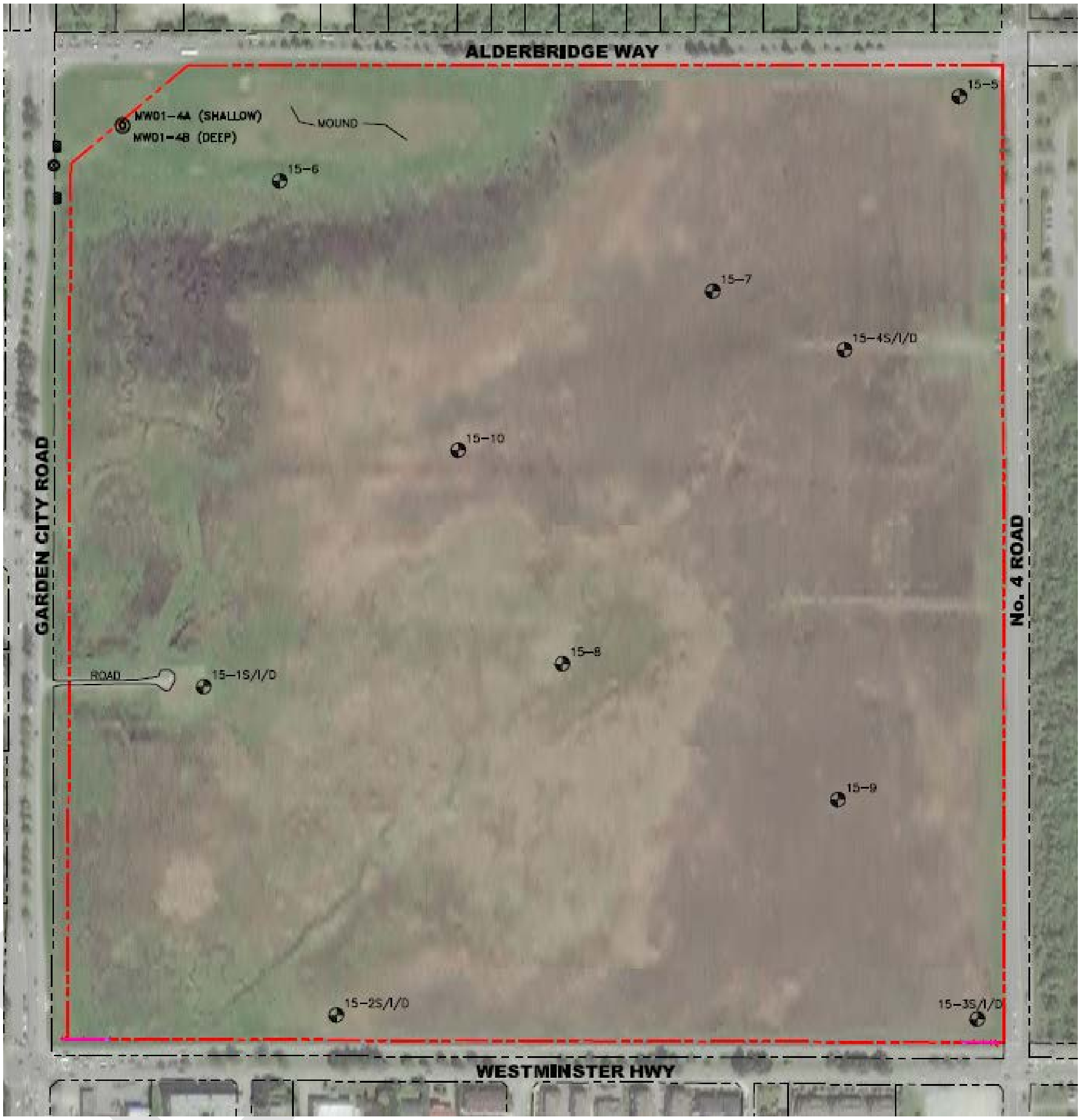


Figure 10-1: Location Plan of the Groundwater Monitoring Wells (SNC Lavalin, 2015)

It should also be noted that 2015 was an exceptionally dry year, particularly through the summer period, relative to historical climate normals for Richmond, BC. The mean annual condition is expected to be wetter than the 2015 monitoring would indicate, though dry years must be expected to occur and may occur with increasing frequency with the predicted changing climate. At this time, the site water management options are based on the limited 2015 on-site seasonal groundwater levels.

Part B: Water Resources Management Plan

Subsurface Seepage Model and Conclusions

To investigate the feasibility of the proposed land use concept, which features co-existence of the farmland and functioning peat bog, a 3-dimensional seepage model was developed. The model simulates downward seepage losses from the peat to the sand aquifer. Options for site drainage, seepage barriers, and groundwater pumping were incorporated into the model to test their impact on the downward and lateral seepage movement in the peat, silt/clay and sand aquifer layers.

The following conclusions were drawn from the seepage model:

- Incorporating a hydraulic barrier between the farm and bog area will be effective at minimizing the impact of draining the farm land on water levels in the bog area;
- Development of No. 4 Road and a deep box culvert appears to have diverted the historical flow of seepage from peat lands on the DND site to the east of GCL, reducing the water table in the peat on the GCL;
- Incorporating hydraulic barriers across the peat layer along the north and south sides of the bog will reduce seepage losses from the peat to ditches and utility trenches, but the impact will be relatively small; and
- The vast majority of seepage losses from the peat under current conditions are vertically downwards to the sand aquifer. Groundwater pumping from the sand aquifer for irrigation does not appear to significantly increase these losses.

Further details of the hydrogeological modelling are provided in the report in Appendix A.

10.2 Subsurface and Surface Flow Barriers

Based on the seepage modelling, a subsurface flow barrier is needed to prevent water from flowing out of the bog peat layer in the subsurface toward the farm area and the surrounding road fill material and to instead maintain that groundwater as much as possible in the bog. As predicted by the hydrogeological model, a hydraulic barrier through the entire depth of the peat layer and keyed into the clayey silt layer is needed to disconnect the drainage of the upper soil layer on the agricultural side of the site from the groundwater level in the bog side of the site and minimize the impact of the agricultural drainage on the bog.

Primary Flow Barrier Alignment

A primary barrier is proposed in the North-South direction separating the agricultural and bog areas of the GCL site. It includes both a subsurface barrier to minimize groundwater flow within the peat layer and a surface berm to prevent surface flows and hydrochemical contamination between bog and agricultural areas. The surface berm also serves as a base for a pedestrian and vehicle access trail through the centre of the GCL site.

Figure 10-2 shows two alignment options for the primary barrier. Option 1 is the original alignment proposed in the LLP, which follows the edge of the bog and its critical plant species extents.

Option 2 is a revised alignment that deviates slightly from the bog species in the south half of the site. The deviation is intended to minimize local ponding against the berm and to promote effective drainage to the fen wetland area in the Southeast corner of the site. The south end of the primary berm was moved further east to avoid any abrupt elevation drop from the berm crest to the plaza at the southwest corner of the site for the access road. With this Option 2 alignment, the berm and subsurface barrier

Part B: Water Resources Management Plan

can curve down to the South perimeter trail location and connect at a less acute angle. Either of these options would be acceptable from an engineering and ecological management perspective and it will be up to the Design Team to work with the City staff to come to consensus about the preferred route.

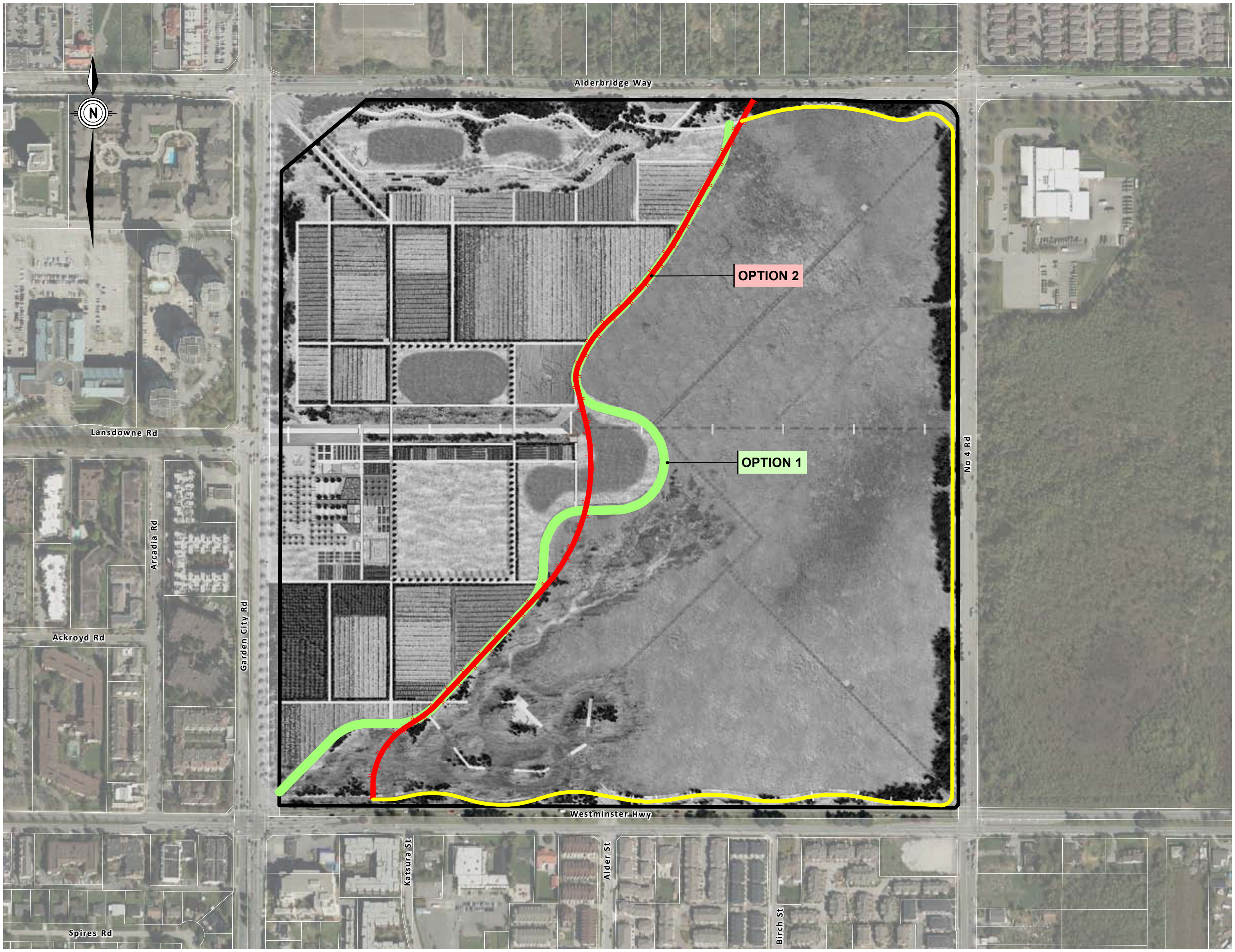
An additional consideration for the primary barrier and trail location is that the trail bump into the bog side in of the site in Option 1 reduces the undisturbed width of the bog area in the lower half of the site. This affects the ability of wildlife to use this area as a wildlife refuge as the trail encroaches into the conservation area[40]. It is recommended that the trail be located as far to the west in this area as possible to support the wildlife uses of the bog area.

Additional Flow Barriers

Additional subsurface barriers and surface flow barriers are recommended along the north, south, and east edges of the bog to reduce seepage losses from the bog to the ditch and utility trenches and planned trees and other plantings around the perimeter of the site, and to prevent or reduce intrusion of runoff from roads, plazas, and perimeter trails from entering the bog site. These will completely isolate the flows in the bog conservation area to retain as much rain water as possible in the bog area and prevent contamination from other water sources. A possible alignment of the perimeter barriers is shown in Figure 10-2. The location of the perimeter berms can be next to or underneath the perimeter trails.

[40] Comment from Richard Hebda in meeting, April 5, 2016.

City of Richmond
Garden City Lands
Water and Ecological Resource
Management Strategy



Legend

- Study Boundary
- Legacy Plan (Option 1)
- Revised Alignment (Option 2)
- Perimeter Hydraulic Barrier

Reference: 2013 Orthophoto and GIS background from the City of Richmond.

KERR WOOD LEIDAL
consulting engineers

100 0 100 (m)
1:4,000

Project No.	Date
651-085	July 2016

Alignments of the Primary and Perimeter Hydraulic Barriers

Figure 10-2

Path: O:\0600-0699\651-085\430-GIS\MXD-Rp\651085_Fig10-2.mxd Date Saved: 11/07/2016 4:29:26 PM
Author: SScott

Part B: Water Resources Management Plan

Construction Options

The subsurface barriers should be built using impermeable or low permeability material. The barriers should extend from the ground surface through the peat layer and be keyed into the top of the clay-silt layer below. The required depth of the barrier varies with location, depending on the thickness of the peat layer.

Three construction options for the subsurface barriers are listed in Table 10-2 and shown in Figure 10-3.

Table 10-2: Subsurface Barrier Construction Options

Options	Descriptions	Pros	Cons
HDPE Wrapped Soil	• Excavate peat and backfill with HDPE or other flexible material wrapped compact soil fill. • The barrier will be covered with soil on the farm side and with excavated peat on the bog side to avoid contact with mineral soil.	• Flexibility on barrier width to fit any trail requirement. • Cost effective. • Watertight.	• Possibility of puncture and leakage during construction or maintenance activities.
Sheet Pile Wall	• Drive sheet pile wall on the outside of the bog. • Trail would be located on fill outside the sheet pile relative to the bog. • Plastic sheet pile wall is preferred over steel to minimizing chemical reaction with acidic bog water.	• No excavation is required. • Easy construction.	• Relatively high in cost. • Not perfectly watertight.
Clay Fill	• Excavate peat down to the clay-silt layer and replace with compacted clay fill.	• Lowest cost. • Provides a solid clay base for the trail construction without the drawback of subsidence in peat	• Placing mineral fill directly against peat poses a risk of altering the water chemistry in the peat and harming the bog health. • May be more acceptable for the perimeter barriers as the perimeter of the bog is already in contact with mineral fills.

Part B: Water Resources Management Plan

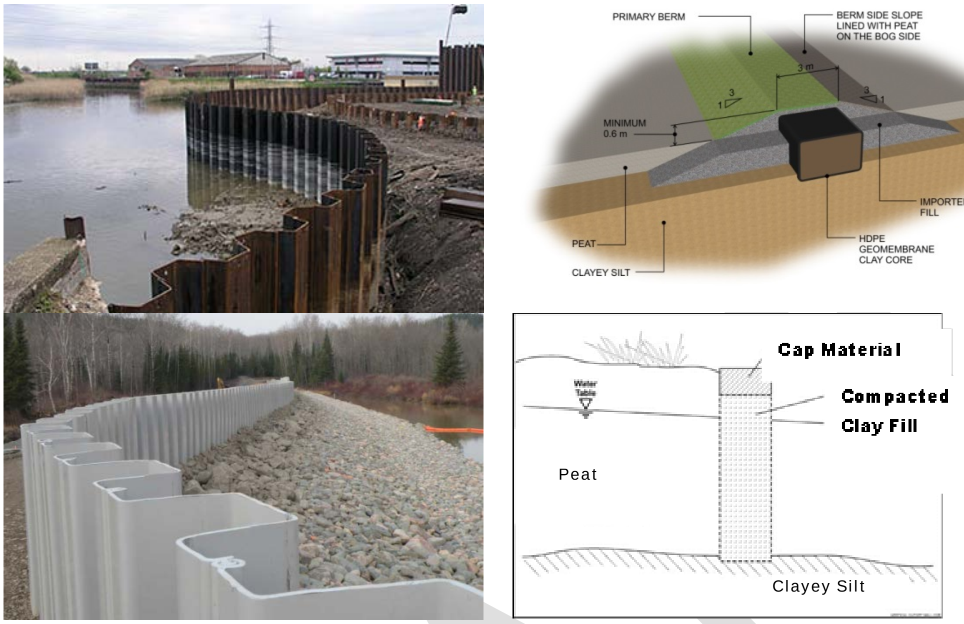


Figure 10-3: Subsurface Barrier Construction Options

10.3 Fen Wetland

As a result of natural topography on site, pooled water areas are found in the southwest corner of the site throughout the winter season. This forms a seasonal fen wetland that provide nesting, perching, refuge, and foraging habitat for wildlife. The LLP proposed to preserve and extend this wetland feature, allowing standing water to serve as potential stormwater retention and filtering pond, as wildlife habitat, and an aesthetic amenity. The current understanding of the ecology of this area supports the idea of a fen wetland for this part of the site, as discussed in the ecological resource sections of this report. A fen wetland in this location would be part of the lagg, which is the peripheral area surrounding a bog, as a transitional element between the bog and other ecosystems adjacent to the bog conservation area.

To enhance hydrological conditions for the benefit of the bog and lagg areas, the outlet of the existing wetland will be regulated. The elevated water level will increase the amount of rainwater that is retained in the bog side of the site, supporting the groundwater table to enhance the health of the bog plant species. The water in the fen wetland will be less acidic and more nutrient rich compared to the bog water chemistry, and thus will not be a good water source for adding water to the bog by irrigating the higher areas of the bog with this water.

The water level in the fen wetland should be allowed to be high, but the intent is to pond water around the periphery of the bog, not cover the whole bog in standing water. A maximum ponding elevation was selected that provides for the ability to manage the water level on the conservation area to near the top of the peat mound but ensure that the whole area will not be underwater. The maximum ponding elevation is 1.7 m, whereas the highest point in the bog is approximately 2.0 m.

Part B: Water Resources Management Plan

Outlet

The proposed wetland will have a controlled outlet near the southwest corner of the site, within the bog conservation area. The outlet will allow excess water from the bog conservation area to flow into the stormwater sewer system under Garden City Road. An outlet structure will be elevated above the existing ground to promote the ponding volume. The ability to adjust the outlet should be provided to allow management of the water level. The prolonged duration (winter into the spring) and extended area of ponding is likely to enhance the bog environment during the dry season. Examples of the outlet structure are shown in Figure 10-4. The important elements of the structure are listed in the following page.

- The structure should have a vertical inlet section with slots to for stop logs allow a variable elevation for the spill level. Multiple boards or stop logs should be created for use with the structure to allow adjustment of the spill elevation.
- The top of the structure should be open such that it will always spill at the maximum ponding elevation. The top may be covered with a sturdy grating, if desired, to reduce the likelihood of personal injury and unauthorized access into the structure.
- The riser of the structure should be constructed of concrete or PVC, rather than steel or other metal as metals will be subject to higher than normal rates of corrosion in the acidic water from the bog.

Figure 10-4: Examples of the Wetland Outlet Structures

Berm Elevation

The proposed minimum berm elevations are shown in Figure 10-5. Principles guiding the determination of the berm elevation include:

- The maximum ponding depth is to the existing ground elevation at the centre of the bog area of the site;
- The primary berm is a minimum of 0.6 m above the existing ground elevation and a minimum of 0.3 m above the maximum ponding elevation;
- The perimeter berm is a minimum 0.3 m above the existing ground and 0.3 m above the maximum ponding elevation for the southwest corner of the site; and

Part B: Water Resources Management Plan

- Special considerations will be given to areas where the berms tie into the plazas (at the SW, NE and SE corners) to avoid abrupt changes in elevation. The crest elevation of the berms should not dip below the minimum elevations shown as that would provide a path for concentrated flow, potentially affecting the maximum ponding elevation.

10.4 Bog Water Supply Options

The previous sections discussed bog water conservation strategies such as building of hydraulic barriers to minimize losses from the groundwater table, and creating a fen wetland to increase groundwater levels in the bog conservation area. If monitoring of groundwater levels in the bog conservation area shows that these strategies are not sufficient to support and maintain the bog ecology on the site, additional water supply sources may need to be considered.

A potential water source for the enhancement of the bog is a challenge due to the unique bog hydrochemistry. Under natural conditions, a true bog is supported only by a rain fed water table that is perched above the surrounding terrain. Three options have been assessed and summarized in Table 10-3.

Table 10-3: Bog Water Supply Options

Options	Discussion
Draw water from DND lands under No. 4 Road	• Draw water from the adjacent bog area to the east by intercepting and utilizing Department of National Defense (DND) groundwater losses into the road fill and box storm pipe on No. 4 Road (minimal impact to the existing state of bog on the DND land). • Directional drilling could be used to insert 3 or 4 pipes connecting the shallow groundwater layer on both sides of No. 4 Road with flexible pipe such as corrugated HDPE. • Both inlet and outlet would be below ground surface within the peat layer. • LiDAR shows possible positive drainage gradient from DND to GCL (to be verified). • Drainage pipe maintenance may be problematic as pipes may become clogged with vegetation or roots and maintenance activities may be destructive to the nearby bog. • Lack of information on the DND land (high uncertainties on the DND groundwater conditions, both volumes and chemistry) is a concern. • Most preferred option as the water chemistry of the water table on the DND lands is thought to be the best possible match for the bog on the Garden City Lands.
Pump water from fen wetland area	• Fresh bog runoff to the fen wetland should have similar water chemistry to the bog. • Wetland water chemistry is likely to change over time with increased levels of nutrient and biological activities. • Wetland water quality testing would be required for 1 or 2 years after the construction of the subsurface and surface flow barriers to assess the differences in water chemistry across the site. • Pumping of water to another portion of the site would likely add oxygen; bog water is typically very low in oxygen. • Fen wetland water would not be available in the dry period.

Part B: Water Resources Management Plan

Options	Discussion
Irrigation with municipal water	• Potable water contains chlorine, minerals and nutrient from the reservoir. • The water quality would not be likely to improve the overall health of the sphagnum and other bog species. • Least preferred option.

Of the three identified options, only the option of drawing water across No. 4 Road from the DND lands provides a source of water with the correct water chemistry to support and promote the health of the bog plant species. However, this option requires significant coordination with the Federal Government and DND to gain access to the site and to conduct groundwater monitoring before it could be determined whether this approach is worth pursuing. The data collection process would confirm the groundwater gradient from the DND lands to the GCL site and identify if there is likely to be any negative impact to the DND lands. As the monitoring process would be expected to require multiple years, it is recommended that discussion of this possibility should be initiated between the City of Richmond and the DND as soon as possible such that the monitoring and pipe installation could move forward quickly if needed.

City of Richmond
Garden City Lands
Water and Ecological Resource Management Strategy

Legend

- Study Boundary
- Proposed Berm
- Perimeter Hydraulic Barrier
- Proposed Berm Elevation

Proposed Berm Elevations based on:

- Maximum Ponding Elevation 1.7 m
- Minimum Berm Elevation 0.3 m Above Max Ponding
- Primary Berm Minimum 0.6 m Above Existing Ground
- Perimeter Berms Minimum 0.3 m Above Existing Ground

Reference: 2013 Orthophoto and GIS background from the City of Richmond.

KERR WOOD LEIDAL
consulting engineers

100 0 100 (m)
1:4,000

Project No.	Date
651-085	July 2016

Proposed Berm Minimum Crest Elevations

Figure 10-5

Path: O:\0600-0699\651-085\430-GIS\MXD-Rp\651085_Fig10-5.mxd Date Saved: 11/07/2016 4:30:01 PM
Author: SScott

Part B: Water Resources Management Plan

11. Agricultural Water Management Options

Agriculture practices on a remnant bog site require infrastructure to provide adequate drainage. The typically high water table, high winter precipitation and relatively flat topography pose unique challenges to the site drainage, which is the primary focus of the agricultural water management options. In addition, soil amendment and irrigation options have also been considered as part of the work on this project.

It should be noted that the recommendations for agricultural drainage and irrigation for the GCL are based on the assumption that surface water and groundwater will be separated from the bog water table and runoff by subsurface and surface hydrologic barriers. Results from the Hydrogeology Assessment component of this project were used to inform this section. The recommendations are also based entirely on management of the water table that results from precipitation, rather than on use and/or management of the groundwater in the aquifer that lies below the silty clay lens under the peat soil layer.

It is worth noting that the agricultural water management options were prepared based on limited information on how agricultural activities will be undertaken on the site as the farm management plan was not completed at the time of writing. Some outstanding questions regarding drainage and irrigation remain and some may not be fully resolved until agriculture is initiated on the site and the agricultural conditions and challenges are more fully known. Therefore, the options chosen towards drainage and irrigation for the site will likely require adjustments once the agricultural production of crops is more thoroughly planned and/or initiated.

11.1 Drainage Assumptions

Assumptions regarding soil, crop production, and associated drainage goals were made in order to provide a basis for recommendations regarding various aspects of the agricultural site drainage.

Soil and Crop Assumptions

While soil definition and amendment is not strictly part of the water management plan, it is a critical part of the agriculture requirement for successful farming activities. The existing surface layer on the GCL site is peat, which is acidic and low in mineral content and unsuitable for most crop production. Therefore, mineral soil amendment will be necessary in order to grow a variety of crops.

Soil assumptions include:

- Peat depth throughout the agricultural portion of the site is generally 0.5m – 1.0m deep, meaning that the primary growing layer of the existing soil is poor in mineral content and soil structure;
- Peat depth becomes shallower towards the northwest corner of the site;
- To prepare the site for agriculture, approximately 0.3m – 0.5m of peat would be removed, mixed with mineral soils and other amendments as needed to create an optimal growing medium, and would be returned to cover the remaining peat;
- This peat may be so coarse and woody in places that it may require some grinding, crushing, or milling to break down large pieces of organic material before it is combined with other soil amendments;

Part B: Water Resources Management Plan

- The depth of the soil may need to be manipulated so that small depressions or pockets are filled, creating a more consistently flat topography throughout the agricultural portion of the site; and
- Some degree of settling or subsidence is expected to occur during the first few years as the peat and/or amended peat decomposes and subsides. Some effectiveness of the tile drains may be compromised as the land settles and therefore the drainage installation and maintenance programs should plan for this settling.

Crop assumptions include:

- Crops grown on the site will be a combination of root vegetables, leafy greens, strawberries, and fruit trees. It is not expected that cranberries or significant areas of blueberries will be grown. If they are then crop-specific adjustments to this plan will need to be made;
- Growing season is March 1 to October 31. During the growing season, water has to be removed quickly to prevent damage to root development for most crops. Plants breathe through their roots therefore it is important that there is air in the soil and that the soil is not saturated for long periods of time;
- For perennial crops that have a deep established root system, the roots of the crop should not be saturated for more than five days. The water level must be below the root zone by the end of five days;
- For shallow rooted crops, the crop roots may not be affected until the water level has risen within 0.9 m of the land surface. Inadequate drainage is considered to begin when the water level remains above this level for significant periods of time; and
- While the site is wet generally, once the dry season comes there are few rain events in this climate and most crops will require additional water through the growing season to do well. While the City has quite a lot of farming in the Eastern part of Lulu island and those farms get their irrigation water through ditches from the Fraser River, this site on the western side of the island, in the middle of the urban part of the island, and does not have ready access to the irrigation network that eastern Richmond utilizes.

Drainage Assumptions

The following drainage assumptions have been made:

- The water being drained from the site is primarily from precipitation and associated soil surface ponding, rather than related to groundwater level management;
- The overall drainage goals are to have the surface water table lowered to 0.3m – 0.5m below the surface 24 hours after rain stops;
- Ditches will provide the primary means of surface water removal;
- Subsurface drainage in the form of drain tile will support water removal and help to control the water table; and
- Subsurface drainage will require routine maintenance.

Part B: Water Resources Management Plan

11.2 Agricultural Drainage System Design Recommendations

The drainage system requires the coordination of several design components, namely ditch requirements, drain tile depth and spacing, pipe size, and pipe grading & length. The recommendations for each component are discussed below.

Tile Drain Requirements

Pipe Depth

- A minimum depth of about 1.0m should be used to offset the settling/subsidence of the peat soil over time. Placing the drain pipe just at the bottom of the peat layer would be ideal. It is possible that the depth of drain tiles may need to vary between 0.8m and 1.2m depth depending on peat depth and terrain. This can be adjusted at the time of installation;
- As it is expected that the soils will be amended and built up by 0.3 m or more it should be possible to achieve the minimum of 1.0 m of soil over the invert elevation of the drain tiles across most of the site;
- It is assumed that the drainage outlet for the tile drains will be lower than the drain tile pipes to allow positive drainage; and
- Using a tile plow or chain trencher to install the tile drains is efficient and recommended.

Pipe Spacing

- A tile drain pipe spacing of 22 m is estimated to be adequate for the GCL site. These calculations required using proxies for saturated hydraulic conductivity because that data was unavailable for the site, therefore the numbers are estimates. A more robust system would use 10 – 15 m spacing. The tile drain pipes will be installed parallel to one another, such that the pipes in a single field are connected to a collector pipe along one side that connects to the outlets or to ditches; and
- If no tile drains are installed then surface ditches should be spaced approximately 60 m apart.

Pipe size and Material

- 100 mm diameter perforated pipe is the standard pipe size for the lateral drains;
- Initial calculations for the GCL site suggest that a cumulative lateral pipe length of 1,000 m would result in the need for a 150 mm collector drain pipe diameter; and
- High density polyethylene (HDPE) pipes or rigid plastic pipes can be used in peat soils, these won't shift or become misaligned due to uneven settling/subsidence.

Pipe grading and length

- If the drain pipes are installed too flat then they have a tendency to quickly fill with sediment, however if they are installed too steep then the excessive velocity and pressure of water within the pipe can cause it to fail and can cause erosion of soil particles around the pipe;
- For a 100 mm pipe diameter the minimum grade is 0.10% and the maximum grade is 2.00%. A 0.50% to 1.0% grade is therefore recommended for the GCL site. Some variation can be tolerated;

Part B: Water Resources Management Plan

- As a guide, the grade should not deviate more than 15% of the internal diameter of the pipe (e.g. 15 mm) and must be a gradual variation over 10 m or more;
- To reduce the negative impact of potential failures lateral pipes should not exceed 600 m before connecting to a collector pipe or ditch outlet; and
- A minimum clearance of 300 mm between the bottom of the drain outlet and the ditch bottom invert is recommended.

Other Design Considerations

- Drain tile pipe should go at the base of the peat and not be cut into the clay-silt layer below for two reasons: fine clay material would increase the chance of tile drains clogging; and significant damage to the clay aquitard layer could risk allowing iron-rich groundwater to come up from below the aquitard and mix with surface water in the agricultural areas (though this is a fairly low risk based on hydrogeological modelling);
- Between storm events during the growing season, the 1.2 m freeboard is especially important. In the spring and fall when heavy machinery must be used to plant and harvest crops soils needs to be relatively dry. If the soils are too wet the soil structure will be damaged by compaction and erosion, sometimes permanently;
- Significant fill material (up to 0.5 m), will be required in low spots to achieve the drainage depth above the bottom of the drainage system at the base of the peat layer. The low spots include areas at the northwest corner area and along the western edge of the site; and
- Even though the ground rises toward the east from the western edge, in some areas the slope may be less than ideal for the tile drains, and that places a limitation on the depth of the drain tile or requirement for soil fill.

Drainage Ditch Options

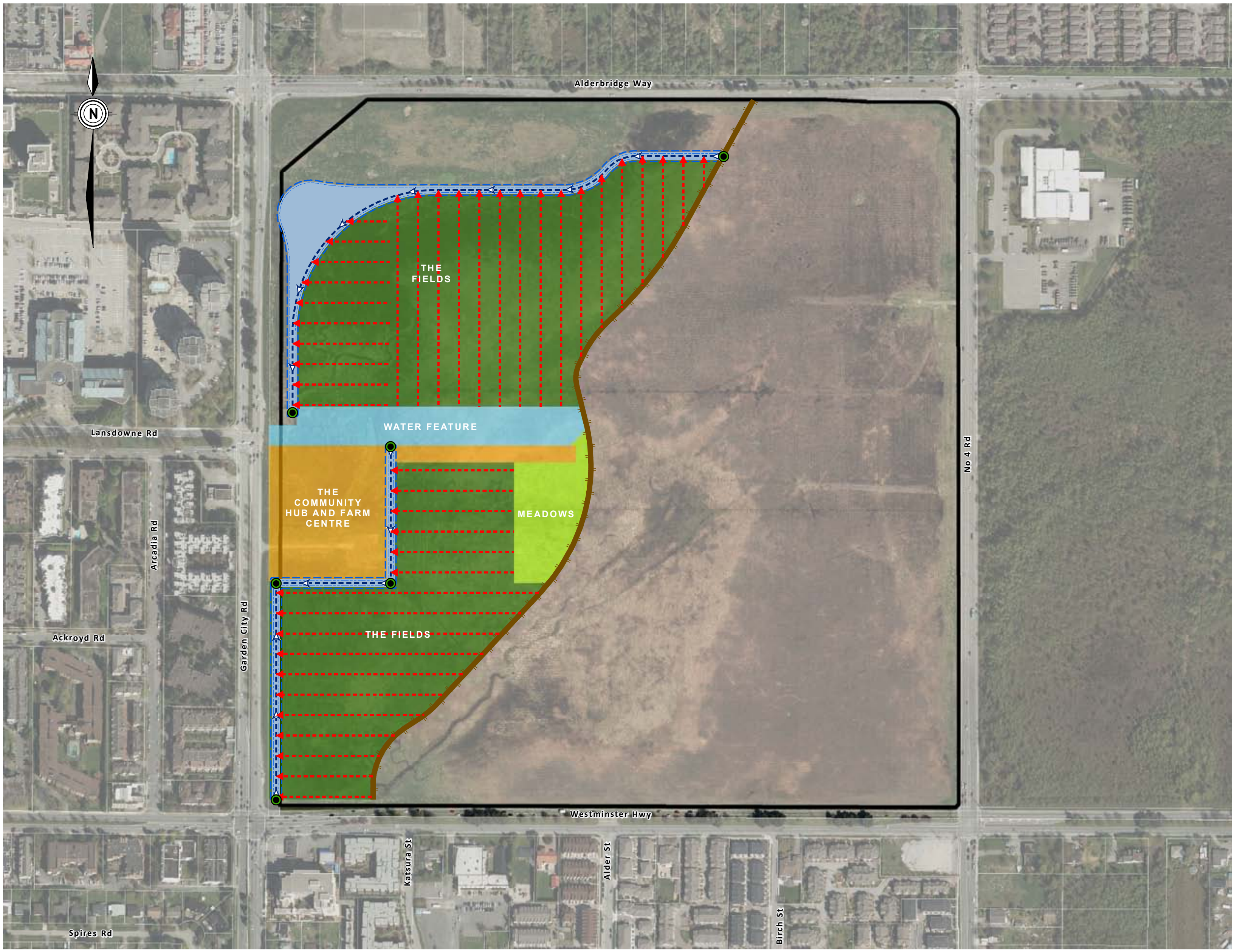
Primary Ditch Locations and Alignment

- North Drainage Ditch

  Under the existing conditions, site runoff pools along the south toe of the mound. Following winter storm events, the natural depression forms a continuous water feature that can be converted to a drainage channel along the south toe of the mound and along the west edge of the field. The drainage ditch would collect runoff from the agricultural fields located to the north of the main entrance, as shown in Figure 11-1.

- South Drainage Ditch

  The southern half of the agricultural fields are located to the east and south of the community hub. The natural topography this area gently slopes down to the west. Therefore, the ideal location of the drainage ditch is located along the western edge of the agriculture fields (Figure 11-1).



City of Richmond
Garden City Lands
Water and Ecological Resource
Management Strategy

Legend

- Study Boundary
- Proposed Drainage Tile (22m Spacing)
- Surface Berm and Subsurface Flow Barrier
- Proposed Ditch

Proposed Land Use

- Meadows
- The Community Hub and Farm Centre
- The Fields
- Water Feature

Reference: 2013 Orthophoto and GIS background from the City of Richmond.

KERR WOOD LEIDAL
consulting engineers

100 0 100 (m)
1:4,000

Project No.	Date
651-085	July 2016

Agriculture Field Drainage Plan

Figure 11-1

Path: O:\0600-0699\651-085\430-GIS\MXD-Rpt\651085_Fig11-1.mxd Date Saved: 11/07/2016 4:30:32 PM
Author: SScott

Part B: Water Resources Management Plan

Design Considerations

The drainage ditches are proposed to convey and store stormwater runoff from the agricultural field before discharging to the storm sewer system.

The ditches locations are partly dependent on the field layouts for the agricultural portion of the GCL site, and the field layouts have not been determined at this time. Therefore, the locations and configurations of the ditches are likely to change from those depicted in Figure 11-1.

In addition, there is the question of whether the drainage channels will also potentially function for storage for irrigation in addition to drainage of runoff. If they are needed to provided storage for irrigation, the outlet configuration and control on the discharge to the storm sewers would be more complex, requiring a flow control manhole and the ability to manage the water level in the channels. There may also be a need to bypass the stored water volume to provide drainage during the growing season while maintaining the volume of stored water. The drainage channels would also need to be lined to retain water during the dry season, similar to the pond design as discussed in Section 5.4.

In their simplest form, the drainage ditches will function as conveyance for runoff that is kept dry between storm events to prevent odor and biological growth issues. Cross-sections of the north and south drainage ditches are provided in Figure 11-2 and Figure 11-3.

A summary of the drainage ditch design parameters is shown in **Table 11-1**.

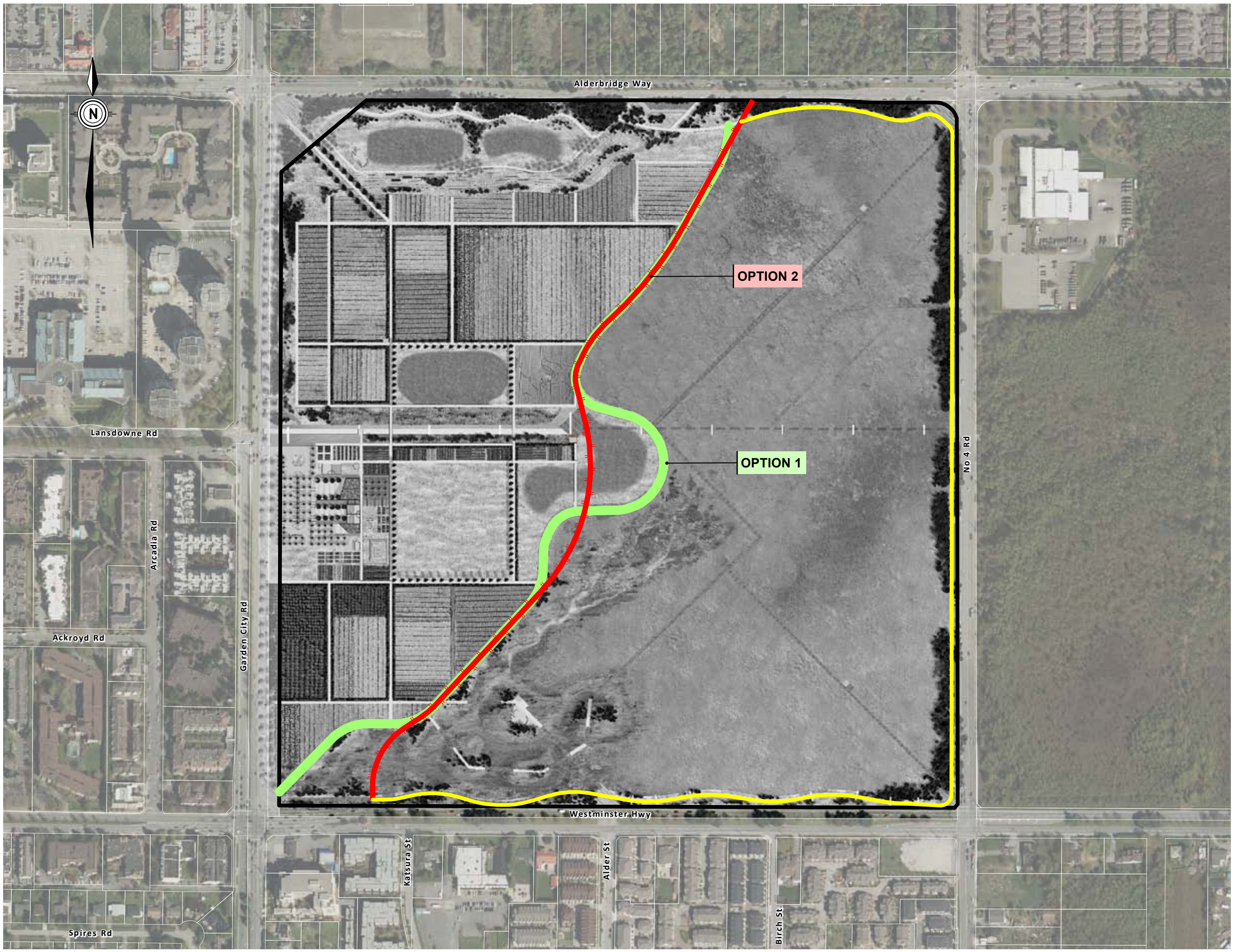
Table 11-1: Agriculture Drainage Ditch Design Parameters

Items	Ideal Configurations	Design Options
Ditch Dimension	• Minimum bottom width 0.6 m. • 4H:1V side slope for safety reasons.	• Minimum side slopes, pending geotechnical requirements: 1.5:1.
Ditch Invert	• Ditch invert at or above the base of the peat layer and not breaching into the clayey silt layer below. • Invert elevation approximately 1.0 m along the West side of the site • Ditch invert 0.3 m below the tile drain pipe outlet.	• Invert at same elevation as tile outlet and at base of peat layer on west edge of site. • Subject to geotechnical recommendation, the ditch invert may be cut into the clayey silt layer 0.3 m below the base of the peat layer (to allow 0.3 m offset from the drain pipe outlet). Invert elevation approximately -0.3 m • peat depth is thinner on west side of site, about 0.6 to 1.0 m.

Part B: Water Resources Management Plan

Items	Ideal Configurations	Design Options
Freeboard	• Maintain 1.2 m elevation difference between the base flow water levels in the channel and the field elevation. This will provide a good outlet for tile drains.	• For shallow rooted crops and grasses the crop roots may not be affected until the water level has risen within 0.9m of the land surface. Inadequate drainage is considered to begin when it rises above this level and end when it falls below this level. • In some situations where the crops grown are uniform and do not have deep roots a determination of inadequate drainage can be defined depending on the crop types. The field elevation can be designated where 95% of the land in the field lies above the determined elevation.
Ditch Slope	• Minimum slope 0.5% to promote drainage.	• Minimum slope 0% to minimize fill and to provide an irrigation storage volume. • An in-between value of 0.2% would be preferred to a value of 0%
Ditch Outlet	• Flap gate or other device to prevent back flow from the storm sewer system flowing onto the site.	• Pumping drainage from the GCL site would allow the discharge to be at a level near the top of the box storm sewer pipe on Lansdowne road.

City of Richmond
Garden City Lands
Water and Ecological Resource Management Strategy



Legend

- Study Boundary
- Legacy Plan (Option 1)
- Revised Alignment (Option 2)
- Perimeter Hydraulic Barrier

Reference: 2013 Orthophoto and GIS background from the City of Richmond.

KERR WOOD LEIDAL
consulting engineers

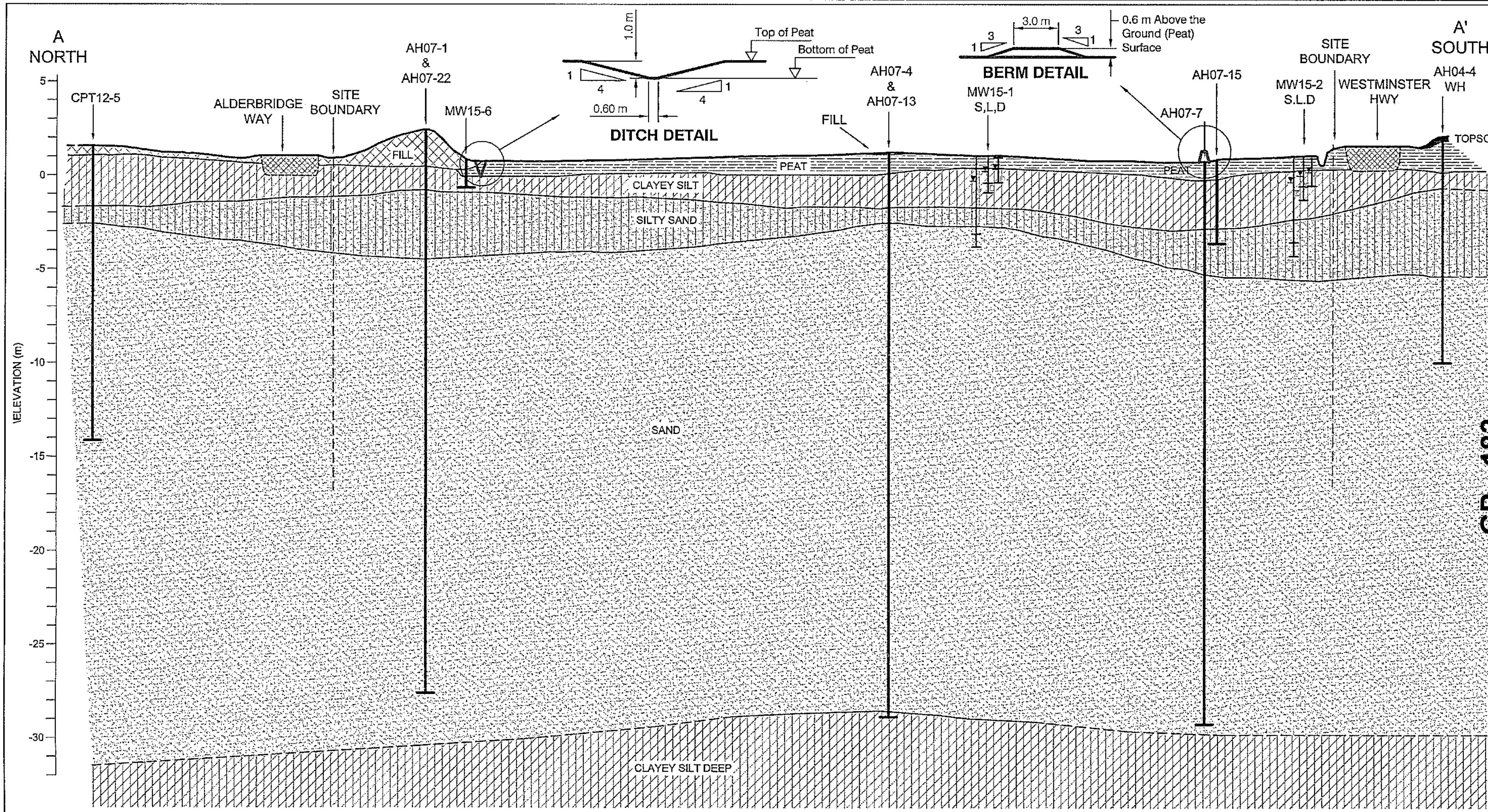
100 0 100 (m)
1:4,000

Project No.	Date
651-085	July 2016

Alignments of the Primary and Perimeter Hydraulic Barriers

Figure 10-2

Path: O:\0600-0699\651-085\430-GIS\MXD-Rp\651085_Fig10-2.mxd Date Saved: 11/07/2016 4:29:26 PM
Author: SScott



12.5X VERTICAL EXAGGERATION

SCALE 1:2500

20 0 20 60 100m

MW BOREHOLE WATER LEVEL DETAIL

BLUE = WINTER WATER LEVEL

GREEN = SUMMER WATER LEVEL

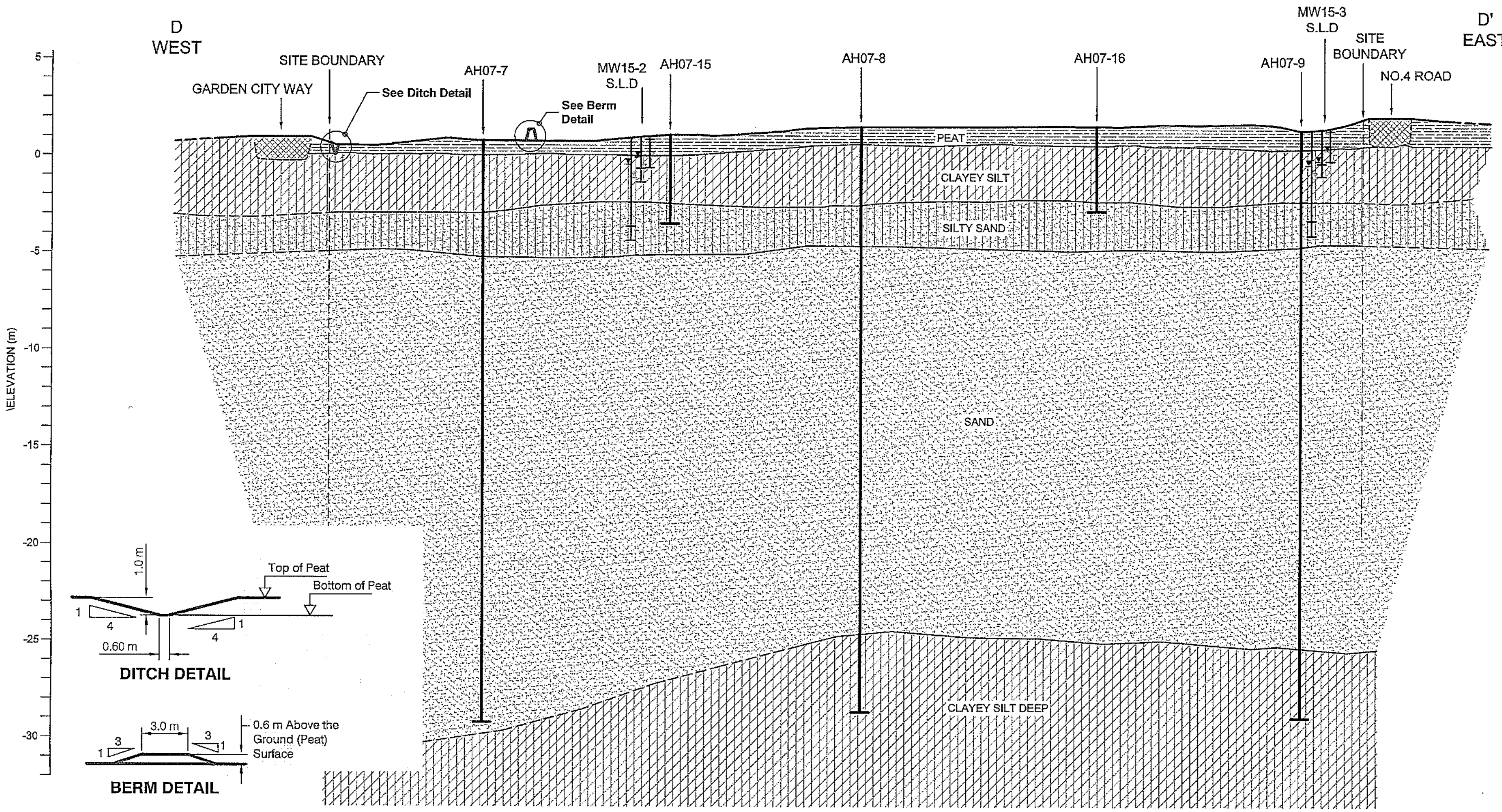
RED = SCREEN & SAND PACK LENGTH

D DENOTES DRY

Enterprise Geoscience Services Ltd.
203 - 2902 West Broadway
Vancouver, BC, V6K 2G8

CLIENT:	City of Richmond
PROJECT:	Garden City Lands
TITLE:	Agriculture Drainage Cross Section A-A'
DRAWN BY: YL	CHK BY: JB
DATE: 2016/02/08	REVISED:
PROJ #: 201507	Figure 5-2

O:\0600-0699\651-085\501-Drawings\b_Figures\651085_HydrotechnicalSections.dwg 4/25/2016 9:40 AM



12.5X VERTICAL EXAGGERATION

SCALE 1:2500

MW BOREHOLE WATER LEVEL DETAIL

BLUE = WINTER WATER LEVEL

GREEN = SUMMER WATER LEVEL

RED = SCREEN & SAND PACK LENGTH

D DENOTES DRY

Enterprise Geoscience Services Ltd.
203 - 2902 West Broadway
Vancouver, BC, V6K 2G8

CLIENT:	City of Richmond
PROJECT:	Garden City Lands
TITLE:	Agriculture Drainage Cross Section D-D'
DRAWN BY: YL	CHK. BY: JB
DATE: 2016/02/08	REVISED:
PROJ #: 201507	Figure 5-3

Part B: Water Resources Management Plan

Meeting ARDSA Drainage Criteria

The agriculture drainage criteria were developed under the Agricultural and Rural Development Subsidiary Agreement (ARDSA). The ARDSA drainage criteria for the growing season (March 1 to October 31) is to remove the runoff from the 10 year 2 day storm, within 2 days. Prolonged periods of soil saturation deprives air in the soil and damages crop development.

To ensure adequate drainage for the proposed fields, a 10-year, 2-day ARDSA storm event was developed using a scaled design storm from Pitt Meadows. The storm, with a total rainfall amount 84 mm was simulated in the City of Richmond's MIKE Urban model of the storm drainage system using a conservative boundary condition of 2.0 m constant water level at the outfall into the Fraser River. The hydraulic grade line in the storm drainage system immediately downstream of the GCL site is shown in Figure 11-4. The plot indicates that ground elevation above -0.3 m would be flooded for less than 2 days. For the on-site agricultural drainage design, proposed field surface elevations should be checked against this elevation.

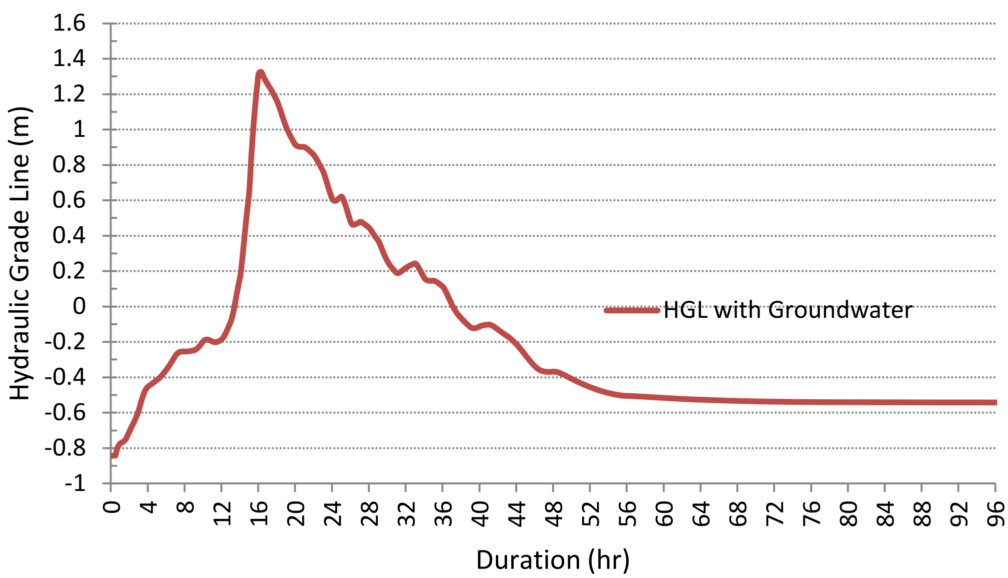


Figure 11-4: Hydraulic Grade Line at the Outlet of the GCL Site

11.3 Irrigation Requirement

Estimates of Crop Water Needs

The following estimates are calculated based on data published by the Ministry of Agriculture through the Metro Vancouver Agricultural Water Demand Model (AWDM) and through discussions with Rebecca Harbut, the lead faculty in Sustainable Agriculture at Kwantlen Polytechnic University. The AWDM was developed to provide current and future estimates of agricultural water demands. Crop, irrigation system type, soil texture, and climate data parameters are used to calculate water demand estimates. Climate data from 2003 was used to present information on one of the hottest and driest years on record, and 1997 data was used to represent a wet year.

Part B: Water Resources Management Plan

Conservative parameters were used in determining irrigation needs. This was done in order to potentially provide an overestimation of water needs rather than an underestimation, so that water planning can be done in a cautious manner. AWDM results may therefore be higher than what may actually be used.

The following assumptions were made:

- Average irrigation management techniques (e.g. mixture of drip, sprinkler, and handheld) were used in the determination of irrigation needs. It is possible that better management would provide a lower estimate.
- A 2003 climate data was used, which represents a relatively dry year. By comparison, ADWM calculations using 1997 data (a relatively wet year) indicates only 60% of water used compared to a dry year. Climate change modelling predicts an average increase of 10% water use required over and above current conditions.
- The default soil texture used in these calculations is a sandy loam. Water percolation may be slower in a peat-based soil. Therefore, if minimal amendments are made to the current soils the actual water use may be lower than calculated.

Based on the above assumptions and using the water demand model, the crop demand estimates are listed in Table 11-2. The irrigation volume in the last two columns indicates total annual demand for 20 acres as the ultimate requirement for the 20 acres that KPU expects to have in production under the agreement with the City of Richmond.

Table 11-2: Estimates of Crop Water Demands

Crop	m^3 per hectare	Millions of US gallons per hectare	m^3 per acre	Millions of US gallons per acre	m^3 per 20 acres	Millions of US gallons per 20 acres
Apple	7,275	1.92	2,945	0.78	58,900	15.55
Blueberry	3,305	0.87	1,338	0.35	26,760	7.06
Greenhouse	10,754	2.84	4,354	1.15	87,080	23.00
Raspberry	4,220	1.11	1,709	0.45	34,180	9.02
Strawberry	3,402	0.90	1,377	0.36	27,540	7.27
Vegetable	3,478	0.92	1,408	0.37	28,160	7.43
Range	**3,305 – 10,754**	**0.87 – 2.84**	**1,338 – 4,354**	**0.35 – 1.15**	**26,760 – 87,080**	**7.06 – 23.00**

The biggest water user is greenhouse production. This is likely because the growing season is extended and also because the higher temperatures within the greenhouse (whether poly or glass) cause higher rates of evapotranspiration. Apples are the second highest water users. This is typically true for all tree fruits especially when the trees are becoming established. Older plants tend to require less irrigation because their roots are more established and can tap deeper soil moisture.

Given the high amount of organic matter that the soil will have and the associated high levels of water retention, there is a strong likelihood that the lower end of the volume range will be required. Furthermore, there will likely be times when certain fields are left fallow, or crops are rotated, and therefore it is unlikely the entire site will be watered all at the same time. Therefore, planning for the availability of 3,000 m^3 or irrigation water per hectare per year should provide ample water for the site's needs.

Part B: Water Resources Management Plan

11.4 Irrigation Water Sources

Groundwater Source

As discussed in a previous section, subsurface seepage modelling included adding pumping wells for agriculture irrigation. Groundwater pumping from the sand aquifer at a rate of 3 L/s does not appear to significantly drawdown the water table in the bog area. The pumping rate is limited based on previous work that recommended a maximum pumping rate of 50 US gal/min to limit the risk of subsidence for nearby building foundations (see Appendix A).

Model results support groundwater pumping as a viable source of irrigation. However, there is a significant drawback to groundwater as a source of irrigation as it is expected that the water in the aquifer has high levels of iron content. If this groundwater were to be used for irrigation it would require treatment. Treatment would increase the cost and complexity of supplying irrigation water on-site. There are standard approaches for removing iron from a water supply and treatment options include oxidation and filtration, and ion exchange resins. A treatment system would require monitoring and regular operation and maintenance procedures by trained operations personnel.

Rainwater Runoff Harvesting from Storm Drainage System

Rainwater harvesting and storage during the wet season for irrigation during spring and summer could be another option for a source of irrigation water. The idea of harvesting water from the storm sewer system was proposed during development of the LLP and is investigated here. The existing MIKE Urban stormwater model (2011, KWL) was used to determine surcharging volumes around the GCL site.

Typical Year Condition

To assess the performance of the stormwater drainage system adjacent to the GCL site, a “typical year” was selected to reflect the mean annual condition. Seventy-six years of rainfall data was obtained from the Vancouver International Airport Climate Station (ID 1108447). The mean annual rainfall and mean wet season rainfall (October - March) were determined to be 1,086 mm and 780 mm, respectively.

The objective was to select a year with total rainfall depth, rainfall intensity, as well as seasonal distributions best matching the long-term mean annual conditions. Based on statistical analyses, a twelve-month period, from August 1, 2009 - July 31, 2010, was selected to represent the “Average Year” conditions. The characteristics of the selected year are listed in Table 11-3 and compared to those of the long-term rainfall record.

Part B: Water Resources Management Plan

Table 11-3: Characteristics of the Typical Year Rainfall

	Selected Typical Year (2009-2010)	Long Term Mean (1973-2013)	Difference
Mean Annual Rainfall Total	1052 mm	1086 mm	3%
Mean Wet Season Rainfall Total	807	780	-3%
24hr Rainfall Average Intensity	2.1 mm/hr	2.1 mm/hr	0%

Rainfall depth amounts for the selected year (August 1, 2009 - July 31, 2010) were input to the MIKE Urban model at a time step of 15-minutes. Results from continuous simulation indicated that the storm drainage system along the perimeter of the GCL has sufficient capacity of convey the flow under typical year conditions.

Rainwater harvesting can be accomplished by extracting flow from the downstream stormwater sewers system. Under an average year condition, approximately 9000 m^3 of water is expected to be conveyed in April and 4000 m^3 of water to be conveyed in each month of May and June. Conveyance volumes in the Garden City Road storm pipes are shown in Table 5-4, below. These typical volumes would allow harvesting and storage of water during the winter months as well as re-charge of 4000 m^3 (in typical year conditions) of storage through June.

Table 11-4: Typical Year Flow Volumes in Garden City Road Storm Sewer Pipes

Year	Month	Monthly Total Volume (m^3)
2009	October	32217
2009	November	52569
2009	December	10318
2010	January	53211
2010	February	11024
2010	March	11841
2010	April	9691
2010	May	4332
2010	June	4496
2010	July	0

Potential storage options that are applicable to the GCL include surface storage pond and underground storage tank. Details on each storage option are summarized in Table 11-5.

Part B: Water Resources Management Plan

Table 11-5: On-site Irrigation Storage Options

Options	Design Parameters
Surface Storage Pond	**Pond Storage - General** • Approximately 1 m deep at design water elevation • The entrance water feature can be used as part of the surface storage, with limited volume • Pond would go dry when water used up • Open-stored water requires filtration prior to use in distribution system such as drip irrigation because the drip nozzles clog easily • Storage volume must account for evaporation losses • Pond would need to be lined with impermeable material to prevent losses into surrounding peat soils which would allow stored water to seep away. **Pond storage for full irrigation need for 20 ha** • 3,000m^3 of irrigation water per hectare per year • Irrigation for 20 ha • Pond would require approximate 60,000 m^2 (6 ha) surface area to irrigate 20 ha – up to 1/3 of land area • Less expensive than underground storage to construct **Pond storage to irrigate 1 ha (or scale to irrigate larger area)** • Irrigate 1 ha, or irrigate several ha for part of the growing season • Can refill 3000 m^3 storage monthly except July/August, so can irrigate more than 1 ha depending on timing of water needs for crops • Lowest up-front cost for storage as less expensive than underground and smaller than full irrigation volume required
Underground Storage Tank	**Underground storage tank to irrigate 1 ha (or scale to irrigate larger area)** • Only practical for partial irrigation – available stormwater can refill 3000 m^3 storage monthly except July/August • No evaporative losses to be accounted for, so smaller volume of storage required for same irrigation volume compared to pond storage • Similar size as surface storage for partial irrigation but can be located beneath parking area rather than occupying space that could otherwise be farmed • Concrete in-ground tank 0.8 m to 1.5 m depth, depending on the allowable depth into clay layer • Tank must have anti-flotation slab or collar to prevent floating in high water table • Expensive up-front costs for construction of tank

Limitations of Rainwater Harvesting from Storm System

Many organic certification programs discourage the use of harvested runoff for certain edible crops due to potential human health concerns, including:

- toxins leading from roads; and
- bacterial contamination from rodent feces in gutters and rooftops.

Part B: Water Resources Management Plan

On-Site Rainwater Harvesting

If the harvesting of rainwater runoff is not desirable due to water quality concerns, rainwater could be harvested on-site such that there would be no road or roof runoff in the harvested and stored water. The KPU staff indicated[41] that this option may be desirable for irrigation of a 5 acre vegetable garden on the site, which is used as an example to assess this storage option, below.

There are two options for this:

1. Rainfall that falls on a pond is collected through the winter and not allowed to drain away; or
2. Rainfall that falls on a pond and on-site runoff is collected in the drainage features through the winter and the storage volume is not allowed to drain away.

In both options, excess rain and runoff, for example from a large storm event, would be drained to the storm drainage system.

First, just the volume that could be collected and held in a pond based on rainfall distributions and average rainfall in typical years was considered. For comparison, the typical yearly rainfall is:

- 1086 mm – based on the YVR rainfall record 1937 -2012
- 1040 mm – based on the last five years of record 2007 – 2012
- 1013 mm – 2015, as an example of a record dry year

The value of 1040 mm rainfall as a typical year was used, and rainfall into a pond as well as pan evaporation from the pond surface through the growing season were accounted for in water balance calculations. It is estimated that the needs of a 5 acre vegetable-focused market garden could be irrigated with a pond area of:

- 2.16 ha – for an irrigation volume of 7290 m^3, supplying 3600 m^3/ha/year – typical irrigation application rates
- 1.20 ha – for an irrigation volume of 4047 m^3, supplying 2000 m^3/ha/year – high water efficiency irrigation measures

These volume calculations assume vertical sides, with no slope accounted for, and a maximum depth of 0.6 m based on typical rainfall patterns and evaporation values.

Second, runoff from on-site areas can be incorporated into the volume calculations, but the routing of runoff will work differently depending on the location of the pond. At the time of this work, proposed pond locations based on field layout planning were not available, so general calculations were done assuming that water could be routed to a pond from neighbouring areas.

If runoff from the nearby site areas is directed to the storage pond, then an additional 200-300 mm of water from the catchment area could be added to the storage volume. The additional amount is variable dependent on the rainfall distribution for a given year, as the winter excess runoff will vary with the intensity of rainfall events. A maximum pond depth of 1 m is assumed based on the depth of the clayey-silt aquitard and the assumption that the pond bottom should at or near the surface of that soil layer. If 250 mm runoff is available from adjacent areas, then a 0.73 ha pond area (vertical sided) with at least 1.16 ha of catchment area draining to it, would provide the 7290 m^3 of storage needed to irrigate 5 ac. at 3600 m^3/ha/year.

[41] Email from Kevin Connery, City of Richmond, to KWL, 11-05-2016

Part B: Water Resources Management Plan

The general pond design requirements shown in Table 5-5 would be necessary for storage of on-site rainwater and runoff as well as off-site runoff. If the drainage channels were to be used for storage for irrigation they would also have the same design considerations as a pond.

Fraser River Water Source

Many farms in Richmond rely on the conveyance of water from the south arm of the Fraser River water to provide irrigation water for agricultural land. For some farmers it is their only source of irrigation water. The majority of the farms using Fraser River water, however, are in the eastern part of the City of Richmond. Salt wedges occur in estuaries like the Fraser River delta where ocean water meets fresh water. This denser salt water pushes up the estuary and the distance where the mixing occurs depends on tides, precipitation, and the time of year (such as the spring freshet). The City has indicated that Fraser River irrigation water is being drawn from the river as far west as No. 6 Rd, which is only about 3.2 km east of the CGL.

The Fraser River could be a viable irrigation water source option for the future, however significant infrastructure would need to be built to draw water from the Fraser to the GCL site. The ditch network that supplies river water to Eastern Lulu Island does not extend to the GCL site and several kilometres of pipe or ditches would need to be constructed to bring water to the site. Depending on the location on the river where water is drawn, pumping may be needed to river water into the distribution system. If this option is deemed of interest once the GCL farming irrigation needs are better defined, it will require further investigation to determine its feasibility. At this stage the level of infrastructure required indicates This option would be too expensive to implement in the first phases of development for the GCL.

Municipal Water Source

Without ideal alternatives in place in terms of water quality and quantity, it is recommended that irrigation of the Garden City Lands rely on municipal water sources, at least in the short term. This has the combined benefit of providing confidence in water quality, as well as measurement of water use through metering. Sub-metering could be a part of the irrigation system design such that specific fields and/or crops are monitored to determine volumetric use over the course of the growing season. This will provide additional information if and when the possibility of switching to stored water or another water source becomes a feasible option. This data would also be useful if and when a sub-irrigation system is developed for the site. Sub-irrigation is discussed in more detail in the following section.

11.5 Controlled Drainage and Sub-irrigation

Dual Purpose Drainage and Sub-irrigation Systems

Sub-irrigation is an irrigation technique that uses open ditches and drain tile lines to apply water to the root systems by raising the water table sufficiently to wet the soil, usually by adding water with a pump. Dual-purpose drainage/sub-irrigation systems can be installed such that during wet periods the system operates as a drainage system and excess water is removed from the field. When a structure (such as a flashboard riser) is used in the outlet ditch to regulate the drainage rate, the system may operate either as controlled drainage or sub-irrigation (Figure 11-5).

In controlled drainage, a weir is placed in the control structure so that the water level in the drainage outlet has to rise higher than the weir crest before the water will flow out of the drain pipe. This helps conserve water by reducing drainage outflows, without pumping additional water into the system. The drawback is that there may not be sufficient soil moisture during peak demand of the growing season.

Part B: Water Resources Management Plan

Subirrigation is essentially a drainage system that is set up so that water can be pushed back into the drain pipes to raise and maintain the water table to a certain depth. When the water table is higher than normal because of subirrigation or controlled drainage, the storage available for infiltrating rainfall is reduced and excessive soil moisture may result. For this reason, it is imperative that the system be designed for both drainage and irrigation conditions, typically requiring that the irrigated lands be at nearly the same elevation, and that it is monitored vigilantly.

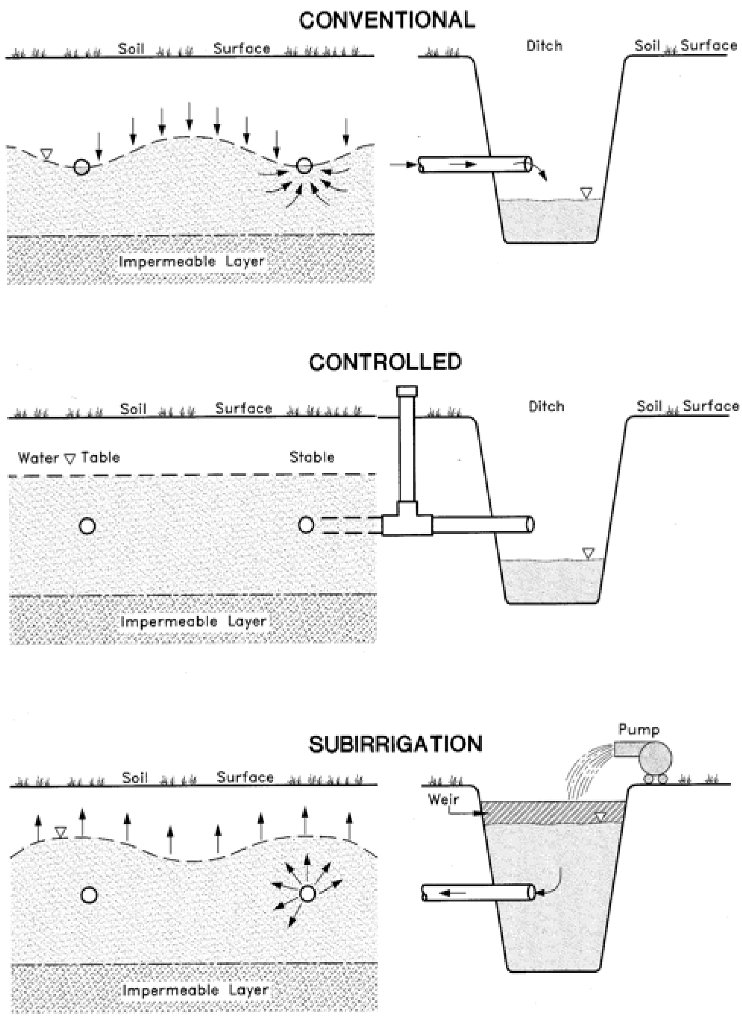


Figure 11-5: Differences Between Conventional Drainage, Controlled Drainage, and Sub-irrigation (from Lalonde and Hughes-Games, 1997).

Part B: Water Resources Management Plan

Advantages of sub-irrigation include:

- Both drainage and irrigation needs are satisfied by one system;
- Less energy, labour, and maintenance required than conventional irrigation;
- Operational costs may be lower than for conventional irrigation;
- Evaporation is reduced; and
- Plants stay dry during water application.

Disadvantages of sub-irrigation include:

- Not all soils or topography are suitable;
- A source of water that can be pumped into the system must be available; and
- Maintenance and system controls must be closely monitored, especially during the first year.

A dual-purpose system will normally fluctuate between the drainage, controlled drainage and sub-irrigation modes several times during one cropping season. However, water tables may be difficult to manage optimally due to imperfect topography, unpredictability of the distribution, timing, and rainfall intensity. Therefore, the management of these systems is more difficult than conventional drainage. As a result, intensive monitoring and management of the system is necessary for effective operation.

Sub-irrigation Design Considerations

Many factors will influence the size and design of sub-irrigation and drainage systems, including precipitation patterns, soil type, crop rooting depth, and tolerance to water stress. Several soil properties such as water-holding capacity, hydraulic conductivity, and profile depth will also influence site design.

Sub-irrigation sites should have the following characteristics:

- Topography: The field surface should be uniform, where the difference in elevation between small depressions and bumps is no greater than 300 mm (0.3 m);
- Water table relationship to drain depth: The natural water table before drainage should be close to or above the drain depth;
- Water supply: The system must have adequate access to water supply capacity for sub-irrigation to meet required plant use and compensate for the water loss due to seepage. Water requirements can be roughly estimated at 0.6 to 0.9 L/sec/hectare during the irrigation period. It is difficult to judge whether this will be more or less than tradition irrigation volume requirements until sub-irrigation is tested for the site soil conditions;
- Pipe sizing: Size of pipes will need to be adjusted so that the largest pipe size is selected for each section and the collector size doesn't just increase towards the outlet as is the case in conventional drainage (see Figure 11-6);
- Grade: When the water is added for sub irrigation the gradient of the pipe is negative (the grade is rising) and gravity flow cannot occur. The system must provide the necessary hydraulic head to compensate for the grade gained, as well as the friction along the pipe. Generally speaking, the field should be flat or have a constant slope that is less than 0.5%; and
- The soil profile should be uniform and relatively deep with a good hydraulic conductivity.

Part B: Water Resources Management Plan

The simplest design approach for controlled drainage or sub-irrigation is to control the water level of the outlet ditch. This can be done with small weirs or culverts. This method is inexpensive but precise water table control is a challenge. The water table design depth is the most difficult part of designing an effective sub-irrigation system.

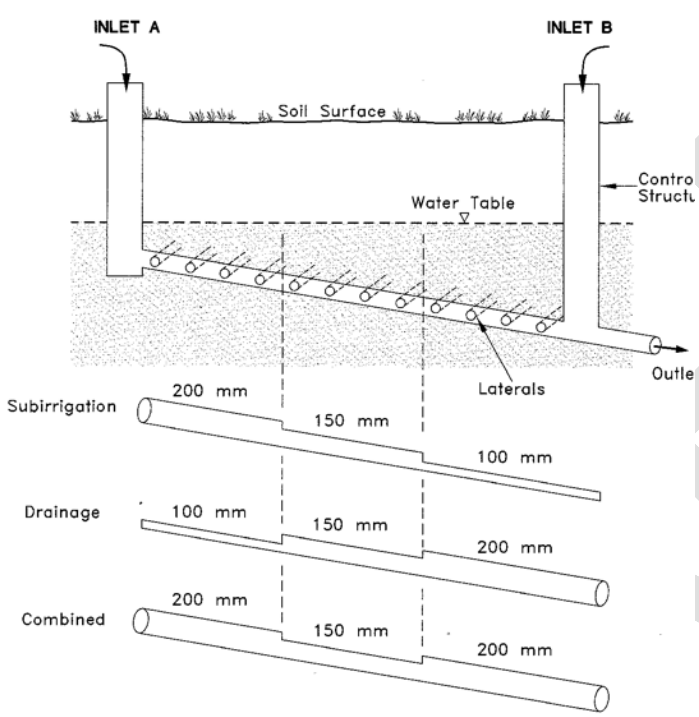


Figure 11-6: Example of Pipe Sizing Requirements in a Sub-irrigation System (from Lalonde and Hughes-Games, 1997).

Maintenance and Management of Controlled Drainage and Sub-irrigation Systems

Once the system is installed the water table variations and soil moisture levels will need to be monitored to fine tune the design. During the first year after installation, water table observation wells and soil tensiometers should be installed throughout the site to monitor the relationship between water table depth and available soil moisture for a particular site.

Management decisions will likely include questions related to:

- when to raise/lower the control structure;
- how high to maintain the weir in the control structure;
- when to add water to the system; and
- how much water to add.

If additional water supply is not available, then conserving water by controlled drainage is critical. If dry conditions are anticipated, raising the weir soon after planting to conserve as much water as possible will be important. However, the long-term growing season production net benefit of controlled drainage

Part B: Water Resources Management Plan

and/or sub-irrigation must also be considered when managing the system. Raising the water table too soon or too high will discourage deep root growth, an effect which could make the crop more susceptible to drought later in the season. It may also encourage denitrification which could result in a nitrogen deficiency later in the season.

Ideally, the water table could be monitored daily or weekly during first year by using observation wells. Once experience has been gained, and the water table's response to rainfall and control structure level adjustments have been observed, monitoring intensity can be reduced. For the first season of operation, records of rainfall, water table depth, control structure level, pumping rate and crop performance should be maintained. This data will indicate how the system responds to precipitation and pumping. Several years of system operation may be required before the right balance between drainage, controlled drainage, and sub-irrigation is achieved.

A dual-system of controlled drainage and sub-irrigation is feasible for the Garden City Lands based on topography and soil depth, however key concerns remain. With controlled drainage it is unclear if the ditch depth and drainage pipe grade will be sufficient to provide the soil with enough water to significantly raise the water table throughout the site. For sub-irrigation needs, the lack of an identified water source to supply into the pumped system remains a critical gap. Therefore, the cost of installing and maintaining a sub-irrigation system at the Garden City Lands will depend largely on the viability of identifying a suitable water source.

Part B: Water Resources Management Plan

12. On-Site Stormwater Management

12.1 Stormwater Management for Impervious Areas

There are many stormwater best management practices (BMPs) commonly used to reduce the runoff by managing the water balance at the site level. For the construction portions of the GCLs site (building, parking, buildings, other impervious areas), applicable BMPs were selected based on the hydrologic regime, pre-development conditions, and proposed land use.

Community Hub

The community Hub is a multi-functional gathering area located along Garden City Road at the terminus of Landsdowne Road. It will be comprised of gathering space, community garden, stormwater features and a cluster of buildings that will serve community, educational and agricultural needs.

For site building stormwater management, buildings can drain roof water to cistern/rain barrels, and discharge excess to ground. Rain barrels are effectively small retention facilities for roof runoff. The water collected can be used for watering and irrigation of small areas of nearby gardens or landscaping.

Figure 12-1: Example of Rain Barrel and Cistern

The limitation of rain barrels is that rainfall is seldom a reliable source for water during the drier seasons and rain barrels are not large enough to store a significant volume of rainwater to provide irrigation through dry periods.

Other than roof areas, ground impervious areas near the Hub are expected to be relatively small. These areas should be sloped to drain away from buildings to pervious ground area.

Path, Plaza, and Parking Surfaces

Use of pervious paving materials rather than impervious concrete or asphalt can reduce the runoff generated from parking areas. Pervious materials may include pavers, reinforced clean crushed gravel, reinforced turf, or engineered permeable pavements.

Impervious surfaces can be sloped to drain to swales or the existing adjacent storm system inlets (storm inspection chambers). The existing storm inlets may need to be modified to accommodate new grades and elevations and to fit grated inlets appropriate to the surrounding surface and material.

Part B: Water Resources Management Plan

Figure 12-2: Example of reinforced clean crushed gravel and Geogrid

In general the expected treatments for these surfaces are:

- Trails and paths should be constructed with permeable surfaces and/or should be sloped to drain to adjacent pervious areas.
- Plaza areas should be constructed with permeable surfaces and/or sloped to drain to adjacent permeable surfaces, if available. If that is not possible, impervious plaza area runoff should be picked up with central grated inlets and conveyed to the nearest storm sewer. Note that there is no available storm sewer along Westminster Highway, but the existing ditch along the South side of the GCL can receive runoff from adjacent plaza areas.
- Parking areas at the Hub and around the perimeter of the site should be constructed with permeable surfaces if possible. If the parking areas cannot be permeable, they should be equipped with water quality treatment units such as oil and grit separators to treat the runoff prior to discharge into the storm sewer system.

Road Drainage

The GCL site development requires modifications to some of the existing road drainage. A road drainage servicing plan is provided in

Part B: Water Resources Management Plan

Figure 12-3.

Alderbridge Way and No.4 Road

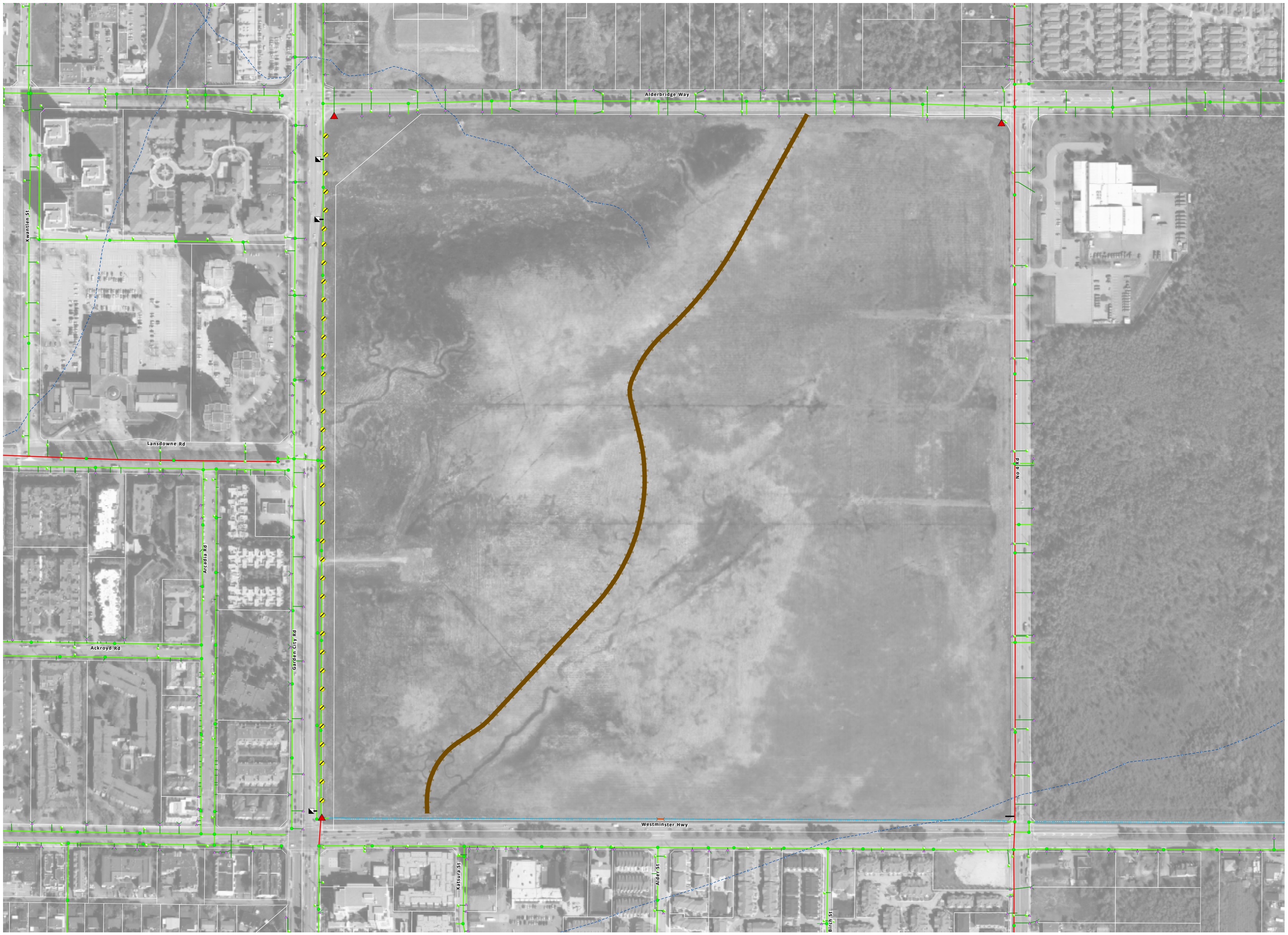
- Both roads are curbed with catch basins to drain road runoff. The catch basins will remain unchanged.
- Existing storm inspection chambers may stay to drain excess runoff from trail areas once the bog area is isolated; the storm system inspection chambers may need to be modified as discussed above.

Westminster Highway

- Westbound side of road drains to ditch on GCL site. The ditch remains and should stay on the south side of the perimeter hydraulic flow barrier.

Garden City Road

- Most of the drainage along Garden City Road is intercepted by inlets in the boulevard between the Northbound and Southbound lanes. Road drainage to inlets in the centre median should be maintained.
- Areas of Northbound Garden City Road with turn lanes at road junctions are crowned to drain to the GCL site. New catch basins are required to intercept runoff at these locations.
- The existing storm inspection chambers located along Garden City Road will no longer be needed when the perimeter trail and the agricultural drainage channels are built. These inlets should be closed or disconnected.



City of Richmond
Garden City Lands
Water and Ecological Resource Management Strategy

Legend

- Existing Drainage Catch Basin
- Existing Drainage Inspection Chambers
- Existing Drainage Manholes
- Existing Drainage Outlets
- Existing Drainage Box
- Existing Drainage Culvert
- Existing Drainage Ditch
- Existing Drainage Laterals
- Existing Drainage Pipe
- Existing Drainage Slough
- Surface Berm and Subsurface Flow Barrier

Site Servicing Plan

- Existing Drainage Inspection Chamber to be Disconnected
- Existing Drainage Inspection Chamber to be Upgraded
- New Catch Basin
- New Drainage Inspection Chamber

KERR WOOD LEIDAL
consulting engineers

REVISION INFORMATION

Rev. No.	Date	Drawn	Checked	Description of Revisions

Date July 2016

Project Number 651-085

N

25 0 25 (m)
1:2,000

Reference: 2013 Orthophoto and GIS data from the City of Richmond.

Road Drainage Servicing Plan

Figure 12-3

Part B: Water Resources Management Plan

12.2 New Storm Drainage Connections

A minimum of two new connections to the storm sewer system are required for the development of the elements of the LLP.

One new storm sewer connection is required to drain the outlet from the bog conservation area. The outlet will be located near the Southwest corner of the site, within the bermed area of the bog. The outlet structure, as described in Section 4.3, will have a vertical riser structure on top, with a manhole-type structure in the ground below. A new storm sewer pipe will be needed to connect the outlet structure to the storm sewer pipe on Garden City Road. The 10-year design flow for this connection is 0.8 m^3/s, based on the 10-year, 24-hour event peak runoff for this area from the City's MIKE Urban drainage model.

The other new storm sewer connection is required to drain the runoff from the farm areas of the GCL site to the storm sewer. This will involve connecting the drainage ditches from the GCL site to either the storm pipe under Garden City Road or to the storm box pipe under Lansdowne Road. As the City's MIKE Urban model indicates that the Garden City Road storm sewer is at or below capacity for the design 10-year 24-hour storm event, it is recommended that the drainage connect from the GCL site to the Lansdowne Road storm box pipe. The invert of the box pipe is -0.853 m (based on record drawings). The drainage invert for the ditch on the Western edge of the GCL site is expected to be -0.3 m. Depending on the configuration chosen for the drainage and the use of the drainage channels for stormwater storage, the drainage from the site may be pumped to the storm sewer system rather than drained by gravity. If the drainage system is pumped, the connection to the sewer may be at a higher elevation. The 10-year design flow for this connection is 1.0 m^3/s, based on the 10-year, 24-hour event peak runoff for this area from the City's MIKE Urban drainage model.

12.3 Other Design Considerations

Climate Change

Extreme weather conditions are expected to occur more frequently in the future. Effects of climate change to the bog environment and agriculture activities should be considered and monitored as the changing weather patterns may affect the site hydrology and vegetation over time.

Climate change predictions to the GCL site were made using the reginal analysis tool developed by the Pacific Climate Impacts Consortium (PCIC). This tool was developed using data collected by Environment Canada, several BC ministries, RioTinto Alcan, and BC Hydro. It is selected due to its regional specific option and its ability to select a standard set of multiple climate models.

Climate models covers a wide range of key future characteristics, namely CGCM3-A1B, CGCM3-A2, CGCM3-B1. Each model reflects distinctly different direction of future demographic change, economic development, and technological change. The model uses 1961-1990 climate data as the baseline condition. The percentage maximum, minimum and mean precipitation departures for the Metro Vancouver region were estimated on an annual and a seasonal basis. The data describing project future climate conditions is provided in Table 12-1.

Part B: Water Resources Management Plan

Table 12-1: Climate Change on Precipitation

Metro Vancouver		Predicted Climate Change on Precipitation				
		Annual	Spring	Summer	Fall	Winter
Region Min	2020	4.1%	4.2%	-4.9%	4.8%	2.0%
	2050	8.9%	9.5%	-11.5%	12.1%	7.9%
	2080	12.0%	13.3%	-14.9%	17.1%	10.5%
Region Max	2020	7.4%	11.3%	4.1%	11.3%	6.3%
	2050	11.9%	17.6%	-2.0%	18.5%	12.9%
	2080	16.0%	22.8%	-3.1%	24.1%	16.8%
Region Mean	2020	5.5%	7.5%	0%	8.4%	4.1%
	2050	10.5%	13.2%	-5.7%	15.3%	10.1%
	2080	14.1%	17.7%	-6.9%	20.5%	13.4%

Note:
SRES AR4 – CCCMA _CGCM3 (average of all 15 scenarios)
CGCM3 A1B-run1 (SRES AR4)
CGCM3 A1B-run2 (SRES AR4)
CGCM3 A1B-run3 (SRES AR4)
CGCM3 A1B-run4 (SRES AR4)
CGCM3 A1B-run5 (SRES AR4)
CGCM3 A2-run1 (SRES AR4)
CGCM3 A2-run2 (SRES AR4)
CGCM3 A2-run3 (SRES AR4)
CGCM3 A2-run4 (SRES AR4)
CGCM3 A1-run5 (SRES AR4)
CGCM3 B1-run1 (SRES AR4)
CGCM3 B1-run2 (SRES AR4)
CGCM3 B1-run3 (SRES AR4)
CGCM3 B1-run4 (SRES AR4)
CGCM3 B1-run5 (SRES AR4)

The future modelling conditions for 2020, 2050 and 2080 show a consistent pattern of increased annual total precipitation, and changed seasonal rainfall distribution. Increased winter precipitation suggests increased winter flooding and warmer drier summers suggests increased potential evaporation and transpiration.

The changing weather patterns present challenge to the GCL site. Bog ecology depends on rainfall for water supply. It will be sensitive to the decreased groundwater level in the drier summer. Agricultural uses of the park and community amenities that incorporate stormwater re-use would also be affected by climate change over time.

Flood Construction Level and Building Elevation

All lands within the City boundaries are designated as floodplain. The GCL site has a Flood Construction Level (FCL) of 2.9 m (GSC) according to the Floodplain Designation and Protection Bylaw (No. 8240, 2008), which is the minimum elevation of the lowest habitable floor of a structure in a floodplain. However, as the proposed community buildings and facilities are within the ALR, farm buildings other than dwelling units are exempt from the FCL requirement.

Stormwater management within ALR is governed by the BC Agricultural Land Commission (ALC). Relevant criteria cover agriculture field drainage and residential development in the ALR, but do not regulate buildings and facilities for community use.

It may not be practical to build the community buildings on the site above the FCL, as they would be higher than all the surrounding site and roads and require significant amounts of fill to achieve the FCL. If buildings will not be built above the FCL, it is recommended that all the structures are flood-proofed to minimize the damage of short-term flooding which must be expected to occur. In addition, all buildings are recommended to be constructed above the 10-year HGL to avoid the nuisance of frequent flooding.

Part B: Water Resources Management Plan

10-Year Flood Level

The City's drainage bylaw requires sufficient drainage for the 10-year, 24-hour and 10-year, 2-hour design rainfall events. The existing MIKE Urban stormwater model (2011, KWL) was used to assess the 10 year hydraulic grade line in the stormwater drainage system immediately downstream of the GCL site.

The model identified surface flooding near the GCL site at all the major nodes along Alderbridge Way and Garden City Road for the modeled 10-year, 24-hour storm event. To estimate the total flooding volume, Hydraulic Grade Line (HGL) was extracted from each flooding node. The depth of HGL above ground elevation was multiplied by the flooding area assumed by the model to compute the max instantaneous flooding volume at each node. The volumes were then summed to a total volume of 2,707 m^3. This is the maximum amount of surface ponding expected near the GCL site for the 10-year event. While it has been noted that the MIKE Urban model has a tendency to over-predict flooding for the 10-year, 24-hour event, such that the predicted flood levels are not observed during actual 10-year return period events, the model results are the best information available about the performance of the storm system for the design event.

Figure 12-4 shows the node locations where flooding was identified under the 10-year 24-hr design storm. The 10-year hydraulic grade lines at the four corners of the GCL site are also provided in Figure 12-5.

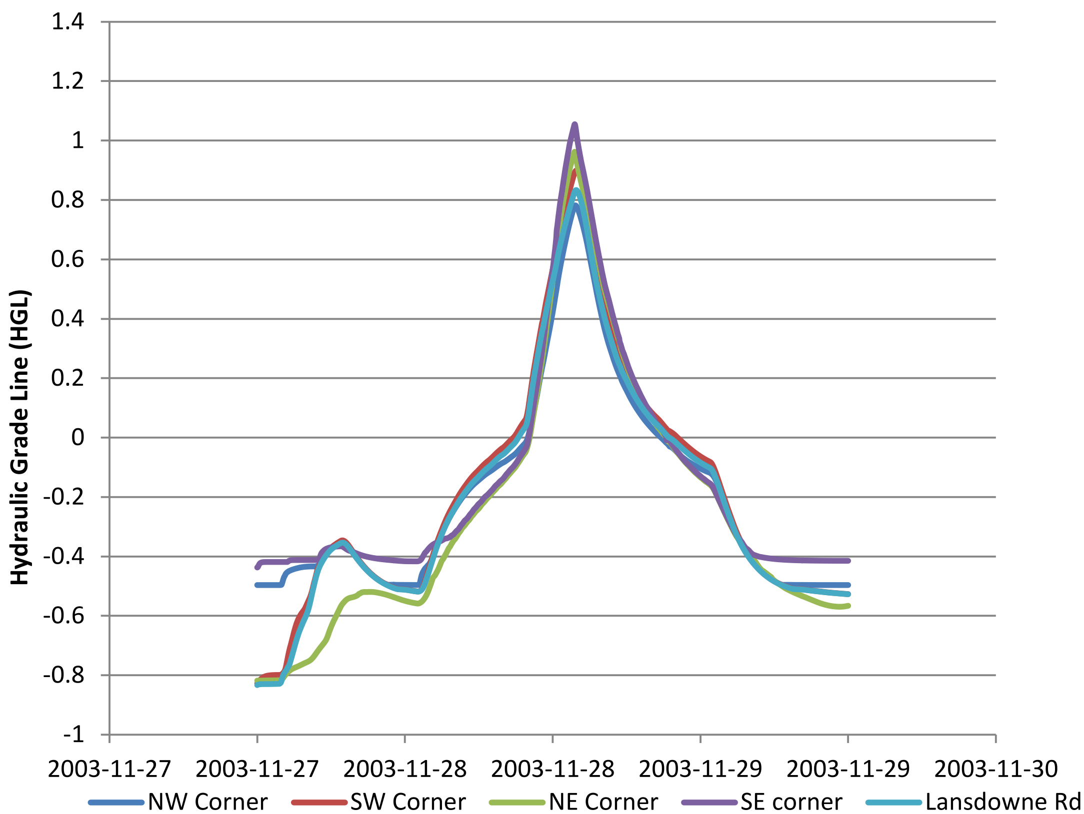


Figure 12-4: Hydraulic Grade Line Elevations for the 10-Year 24-Hour Storm

Part B: Water Resources Management Plan

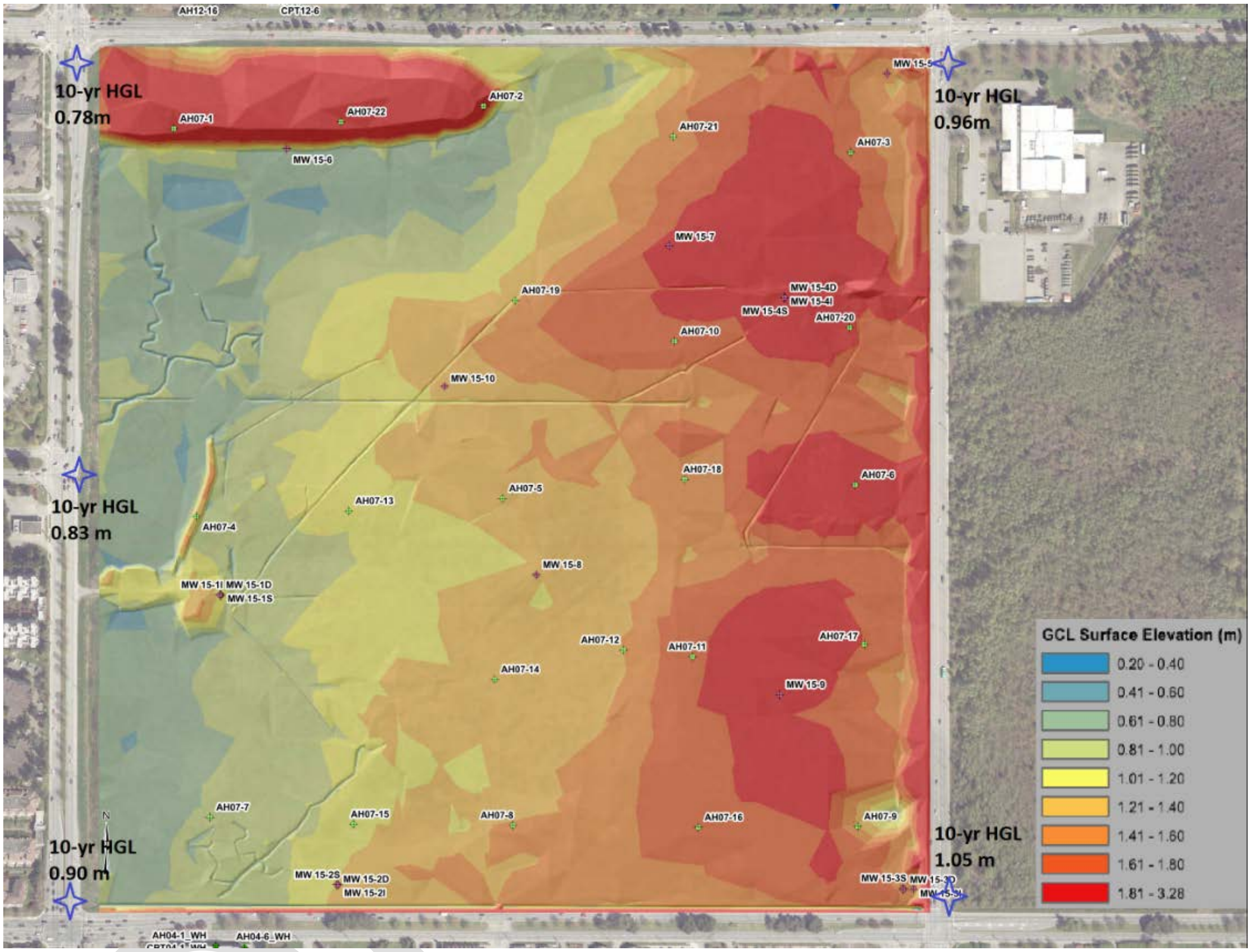


Figure 12-5: 10-year hydraulic grade lines at the four corners of the GCL site

The 10-year HGL along the Western edge of the site on Garden City Road varies from approximately 0.8 m on the Northwest corner to 0.9 m on the Southwest corner. It is recommended that buildings be constructed with a minimum floor elevation of at least 0.3 m above the 10-year HGL, or above 1.2 m elevation. As shown in the Figure above, the existing grade on the site near the terminus of Lansdowne Road is mostly in the range of 0.6 m – 0.8 m, so some fill would still be required to establish minimum floor elevations above 1.2 m.

A geotechnical engineer should be consulted on the foundation design for any buildings on the site as the predominance of peat in the near-surface soils may require special considerations for building foundation design.

Part B: Water Resources Management Plan

Survey Elevation and Datum System

The majority of the GCL site is very flat with an average slope of 0.08% from the northeast to the southwest. Low drainage gradient on site and in the downstream stormwater drainage system makes design of infrastructure connections and flooding elevations more sensitive to the accuracy of elevation.

Over the course of this study, the following data have been verified to be geodetic datum:

- LiDAR DEM of 9 quarter sections surrounding Garden City Lands site (by McElhanney).
- Piezometer readings (by SNC Lavalin).
- Storm system water level monitoring (by City of Richmond staff).

However, some elevation data were not verified to be geodetic. They include:

- Ground survey of GCL site; and
- City infrastructure elevations (i.e. inverts) in the GIS system. GIS information of City infrastructure was taken from record drawings, which do not provide datum information. Minor elevation discrepancies, were found between the GIS data base and the LiDAR and the monitoring data.

Therefore, it is recommended that all critical elevations be surveyed for design and construction purposes.

Construction Best Practices

Measures must be taken to prevent the release, from any work site, of silt, sediment, sediment-laden water, raw concrete, concrete leachate, or any other *deleterious substance* into any ditch, watercourse, stream, or storm sewer system. The work area should be isolated from flowing water as much as possible and diversions around the site should be provided for overland flow paths. Ensuring that all equipment used on-site is in good working order, and having a ready spill containment kit and staff trained in its use, are also critical measures.

Part B: Water Resources Management Plan

13. Draft Water Resource Management Plan

This Draft Water Resource Management Plan proposes recommended solutions to balance the water needs of the site and support the goals and features of the Legacy Landscape Plan.

13.1 Water Management Options for Bog Conservation

Subsurface and Surface Flow Barriers

It is proposed that a primary subsurface and surface flow barrier and perimeter barrier be constructed all the way around the bog area. A plan showing the berm alignment is provided in Figure 10-2

Figure 10-2. The barrier should be constructed with an impervious or low permeability material that extends from the bottom of the peat layer into the top of the surface berm. The subsurface portion of the barrier is intended to minimize ground water loss form the bog to the agricultural land to the west, drainage ditch to the south, and utility trenches to the north and east. The surface berm is intended to prevent surface water exchange between the bog and the adjacent land uses. The barrier will enhance the bog hydrology and preserve the water quality desired by a healthy bog ecosystem. Construction options for the subsurface barrier are shown in Figure 10-3.

Fen Wetland

An outlet control structure will be installed at the southwest corner of the GCL, where a seasonal wetland exists. The outlet structure will be elevated above existing ground and provide various levels of control for management of the water level. The prolonged duration (winter into the spring) and extended area of ponding is expected to enhance the bog environment during the dry season. The fen wetland also provides nesting, perching, refuge and foraging habitat for wildlife. Examples of the type of outlet structure required to allow control of the water level in the fen wetland are provided in Figure 10-4. The extent of the wetland will be constrained by the primary and perimeter surface flow barrier berms.

The maximum ponding elevation for the fen is recommended to be 1.7 m. The surface berms should have minimum crest elevations of the higher of:

- 0.3 m above the maximum ponding elevation, or
- 0.3 m above existing ground for the perimeter berms, or
- 0.6 m above existing ground for the primary berm.

Bog Water Supply Option

In addition to the bog water conservation approach, including construction of hydraulic barriers and creation of a fen wetland, additional water supply sources were identified and assessed. Only the option of drawing water across No. 4 Road from the DND lands provides a source of water with the correct water chemistry to support and promote the health of the bog plant species. However, this option requires coordination with Federal Government and DND to negotiate access to the site and to conduct groundwater monitoring as soon as possible to further assess if this would be a viable option.

13.2 Agricultural Water Management Options

Agricultural Drainage System Design Recommendations

The drainage system will require the interconnectivity of several design components. The options for each component and the design recommendations are summarized discussed below in Table 13-1.

Table 13-1: Agricultural Drainage System Design Recommendations Summary

Items		Recommendation
Drain Pipe	**Spacing**	• Drain tile pipe spacing of should be a maximum of 22 m between pipes
	Depth	• Drain tile pipe should be installed 1.0 to 1.2 m below final grade; • The drainage outlet, i.e. ditch invert, will be lower than 1.0m deep (i.e. lower than the drain pipes).
	Size and Material	• 100 mm diameter is the standard pipe size for the lateral drains; • 150 mm diameter is required for the collector drain pipe.

Items		Recommendation
		• High density polyethylene (HDPE) pipes or rigid plastic pipes should be used in peat soils
	Grading and Length	• For a 100 mm pipe diameter the minimum grade is 0.10% and the maximum grade is 2.00%. A 0.50% to 1.0% grade is recommended. • Lateral pipes should not exceed 600 m before connecting to a collector pipe or ditch outlet; and • A minimum clearance of 300 mm between the bottom of the drain outlet and the ditch bottom is recommended.
	Other Considerations	• Drain pipe should go at the base of the peat and not be cut into the clay-silt layer below. • The base of the peat layer, and invert of the tile drain pipes at the West edge of the site, should be at approximately 0.0 m elevation. • Significant fill material (up to 0.5 m), will be required at the northwest corner and along the western edge of the site.
	Alternatives	• If no drain tile pipes are installed then surface ditches should be spaced approximately 60 m apart.
Drainage Ditch	Alignment	• See Figure 11-1.
	Dimensions	• Minimum bottom width 0.6 m • 4H:1V side slope for safety reason, 1.5H:1V side slope if needed and approved by geotechnical engineer.
	Invert	• Ditch invert should be 0.3 m below the tile drain pipe outlet, if possible • Subject to geotechnical investigation, the ditch invert cut into clay layer 0.3 m below peat layer (to allow 0.3 m offset from the drain pipe outlet) • Peat depth is thinner on west side of site, about 0.6 to 1.0 m • If base of peat layer is approximately elevation 0.0 m. the ditch invert along the West side of the site should be at approximately -0.3 m.
	Freeboard	• Maintain a minimum of 0.9 m elevation difference between the base flow water levels in the channel and the field surface elevation. This will provide a good outlet for tile drains.
	Slope	• Channel should have minimum slope at 0.5% to promote drainage if possible, but can be reduced to 0% if necessary
	Outlet	• Flap gate or other device to prevent back flow from the storm sewer system flowing onto the site
	Alternative	• Alternative to a drainage ditch, pipe could be used to convey the agriculture runoff to the storm sewer

Irrigation Requirement and Water Sources

Irrigation requirement

Based on data published by the Ministry of Agriculture through the Metro Vancouver Agricultural Water Demand Model (AWDM) and discussions with Kwantlen Polytechnic University, the estimated irrigation water requirement is 3000 m^3 per hectare per year for the GCL agriculture fields.

Part B: Water Resources Management Plan

Water Sources

Table 13-2: Water Sources Summary

Items	Pros	Cons
Groundwater	• Grounwater withdraw of 3 L/s from up to two wells does not appear to significantly drawdown the water table in the bog area • On-site source of water	• Possibility of high iron levels in the groundwater, which require treatment and maintenance of the treatment system • Actual pumping yield unknown at this time, would require test well
Rainwater Harvesting	• Sustainable source • Options include open pond and underground storage tank	• Requires significant area for storage • Seasonal availability if full irrigation volume needed cannot be stored • Limited to on-site rainwater and runoff only due to urban runoff water quality concerns • If surface storage, may require filtration before using in drip irrigation system
Fraser River Water	• Abundant volumes	• Issues of salinity and timing for drawing water • High infrastructure costs to transport water to the site
Municipal Water	• Due to flexibility, preferred for the short term	• Expensive • Less sustainable for the long-term

Short-Term Irrigation Plan

The development of agricultural fields will be a long term process due to phased soil amendment and drainage installations. The irrigation volume is expected to increase over time as field acreage is put into production. The final soil mix will affect crop selection and the ultimate irrigation water needs.

Potable water use is recommended in the short term until the irrigation needs are better defined and other irrigation source options can be implemented.

13.3 On-Site Stormwater Management

Stormwater BMPs

The constructed portions of the GCL site (building, parking, buildings, other impervious areas), applicable BMPs were selected based on the hydrologic regime, pre-development conditions, and proposed land use.

Table 13-3: On-site Stormwater BMPs

Items	Applicable BMPs
Community Hub	• Roof water should be drained to cistern/rain barrels and discharge excess to ground. The water collected can be used for irrigation of nearby plantings.
Path, Plaza and Parking	• Pervious paving materials rather than impervious concrete or

Part B: Water Resources Management Plan

Surfaces	asphalt can reduce the runoff generated from parking areas. Pervious materials may include pavers, reinforced clean crushed gravel, reinforced turf, or engineered permeable pavements. • Oil and grit separators are suitable for spill control and removal of floatable petroleum-based contaminants as well as coarse grit and sediment from small areas such as parking lots, if the parking areas have impervious paved surfaces.
Road Drainage	• See road drainage servicing plan. • Figure 12-3.

Road Drainage

The GCL site development requires modifications to some of the existing road drainage. A road drainage servicing plan is provided in

Figure 12-3.

Alderbridge Way and No.4 Road

- Both roads are curbed with catch basins to drain road runoff. The catch basins will remain unchanged.
- Existing storm inspection chambers may stay to drain excess runoff from trail areas once the bog area is isolated; the storm system inspection chambers may need to be modified as discussed above.

Westminster Highway

- Westbound side of road drains to ditch on GCL site. The ditch remains and should stay on the south side of the perimeter hydraulic flow barrier.

Garden City Road

- Most of the drainage along Garden City Road is intercepted by inlets in the boulevard between the Northbound and Southbound lanes. Road drainage to inlets in the centre median should be maintained.
- Areas of Northbound Garden City Road with turn lanes at road junctions are crowned to drain to the GCL site. New catch basins are required to intercept runoff at these locations.
- The existing storm inspection chambers located along Garden City Road will no longer be needed when the perimeter trail and the agricultural drainage channels are built. These inlets should be closed or disconnected.

New Storm Drainage Connections

A minimum of two new connections to the storm sewer system are required for the development of the elements of the LLP.

One new storm sewer connection is required to drain the outlet from the bog conservation area. A new storm sewer pipe will be needed to connect the outlet structure to the storm sewer pipe on Garden City Road. The 10-year design flow for this connection is 0.8 m^3/s, based on the 10-year, 24-hour event peak runoff for this area from the City's MIKE Urban drainage model.

The other new storm sewer connection is required to drain the runoff from the farm areas of the GCL site to the storm sewer. This will involve connecting the drainage ditches from the GCL site to either the storm pipe under Garden City Road or to the storm box pipe under Lansdowne Road. It is recommended that the drainage connect from the GCL site to the Lansdowne Road storm box pipe, invert -0.853 m. The drainage invert for the ditch on the Western edge of the GCL site is expected to be -0.3 m. The 10-year design flow for this connection is 1.0 m^3/s, based on the 10-year, 24-hour event peak runoff for this area from the City's MIKE Urban drainage model.

13.4 Other Design Considerations

Climate Change

Climate change predictions to the GCL site were made using the reginal analysis tool developed by the Pacific Climate Impacts Consortium (PCIC). The model uses 1961-1990 climate data as the baseline

Part B: Water Resources Management Plan

condition. The percentage maximum, minimum and mean precipitation departures for the Metro Vancouver region were estimated on an annual and a seasonal basis. The data describing project future climate conditions is provided in Table 12-1. In general, the future modelling conditions for 2020, 2050 and 2080 show a consistent pattern of increased annual total precipitation, and changed seasonal rainfall distribution. Increased winter precipitation suggests increased winter flooding and warmer drier summers suggests increased potential evaporation and transpiration.

Flood Construction Level and Building Elevation

The GCL site has a Flood Construction Level (FCL) of 2.9 m (GSC) however, as the proposed community buildings and facilities are within the ALR, farm buildings other than dwelling units are exempt from the FCL requirement.

If buildings will not be built above the FCL, it is recommended that all the structures are flood-proofed to minimize the damage of short-term flooding which must be expected to occur. In addition, all buildings are recommended to be constructed above the 10-year HGL to avoid the nuisance of frequent flooding. The 10-year HGL along the Western edge of the site on Garden City Road varies from approximately 0.8 m on the Northwest corner to 0.9 m on the Southwest corner. It is recommended that buildings be constructed with a minimum floor elevation of at least 0.3 m above the 10-year HGL, or above 1.2 m elevation.

Survey Elevation and Datum System

The majority of the GCL site is very flat with an average slope of 0.08% from the northeast to the southwest. Low drainage gradient on site and in the downstream stormwater drainage system makes design of infrastructure connections and flooding elevations more sensitive to the accuracy of elevation.

Some elevation data used in this work were not able to be verified to be geodetic. They include:

- Ground survey of GCL site; and
- City infrastructure elevations (i.e. inverts) in the GIS system. GIS information of City infrastructure was taken from record drawings, which do not provide datum information. Minor elevation discrepancies, were found between the GIS data base and the LiDAR and the monitoring data.

Therefore, it is recommended that all critical elevations be surveyed for design and construction purposes.

Part C: Ecological Resources Management Plan

The ecological resource component of the Strategy includes a review of proposed land uses and recommendations for managing ecological value within differing land uses, as proposed, with particular focus on the sensitive bog ecosystem and other ecological resources. Prioritized opportunities for ecological restoration and enhancement are identified as means to best restore and protect the existing bog ecosystem and other ecological values in perpetuity as a valued component of Richmond's Ecological Network. Potential cumulative effects of adjacent land use, storm water drainage, recreation and invasive plant species are considered. Strategies are also recommended to ensure GCL optimizes the 'free benefits' that intact natural systems can provide. Finally, an adaptive management framework is proposed to learn and develop a better understanding of wetland (bog, fen, marsh) ecosystems and for monitoring the outcomes of specific management actions to support future decision-making.

14. Ecological Management

The 2014 Garden City Landscape Legacy Plan envisions restoration of a raised bog/lagg (fen) complex. that drains to the southwest of the site. Currently the site is indicative of a semi-modified bog with a plant community that has been influenced by its urban setting. Concurrent with the Legacy Plan, a primary goal is to restore this ecosystem back to as natural a state as possible within the limitations of its location.

It is unclear how effective the perimeter hydrological barriers will be at retaining water in the conservation area because monitoring of the groundwater was done during a spring and summer that were very dry in comparison to typical seasonal conditions., which is key to determining if a bog ecosystem can be restored over time. Efforts to restore a functioning bog will take significant resources and are dependent on the effectiveness of the perimeter subsurface hydraulic barriers and surface berms. Therefore, it is recommended that, in conjunction with the groundwater monitoring program, a long term adaptiveAdaptive management approachon site will be taken for managingimportant to develop a fuller understanding of the site's hydrogeology and its influence on plant communities within the conservation area. .

The following issections provide a summary of current ecological conditions on site, as identified in the 2014 Biophysical Inventory and potential vegetation management objectives.

14.1 Existing Conditions: Ecological Conservation Area

The 2014 Biophysical Inventory identified 7 vegetation types on GCL. The area that has been envisioned for conservation supports types V1, V3, V4, V5 and V6. Vegetation types V2 and V7 are areas that are proposed for agricultural development and are not discussed in this report. For the purposes of framing the restoration options on site, the area has been divided into four conservation zones based on vegetation types. These zones are outlined in Table 14-1 and illustrated in Figure 14-1. Discussion of management options for each conservation zone is presented in Sections 14.2 through 14.5.

Table 14-1: GCL Conservation Zones as Related to the Biophysical Inventory Vegetative Polygons

Conservation Zones	Vegetation Polygon ID	Comments
Recreation Interface	V1 and edge of Westminster	The highly disturbed area forms the northern and eastern boundaries of the conservation areas, and includes elevated fill

Part C: Ecological Resources Management Plan

Conservation Zones	Vegetation Polygon ID	Comments
	Hwy	that support a diversity of mostly introduced plant species, including grasses which are most dominant. No species of significance or peat is present. In addition, the narrow edge along the south edge of the conservation area has been included in this zone. This area includes the fill slope associated with Westminster Hwy. Due to its low environmental value, the areas will likely be converted into berms and recreation walkways.
Remnant Bog	V3	Plants associated with this area are more tolerant of acidic conditions typical of bog ecosystems. This area provides the best opportunity to preserve and enhance species that represent the remnant bog.
Lagg (fen)	V4, V6	The lagg area has a high water table providing site conditions suitable for plant species that are more tolerant of hydrophilic conditions. This area has poor drainage and low plant species diversity and is almost entirely dominated by fen associated species, including native Sitka sedge and hardhack.
Marsh	V5	The marsh area has a high water table but has had some disturbance in the past. Species present include almost entirely native species including Sitka sedge with pockets of hardhack and bracken fern.

Part C: Ecological Resources Management Plan

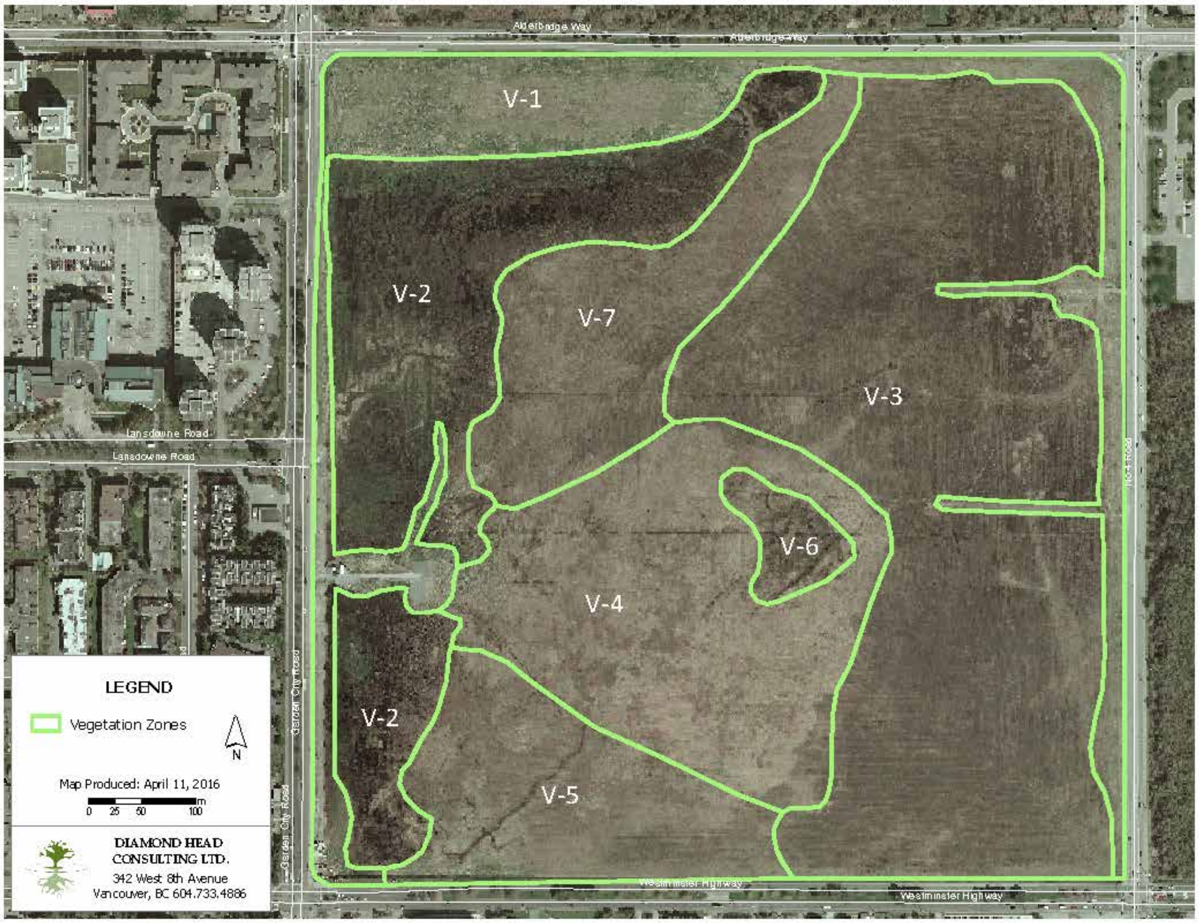


Figure 14-1: Vegetation Polygons As Designated In the Biophysical Inventory

Part C: Ecological Resources Management Plan

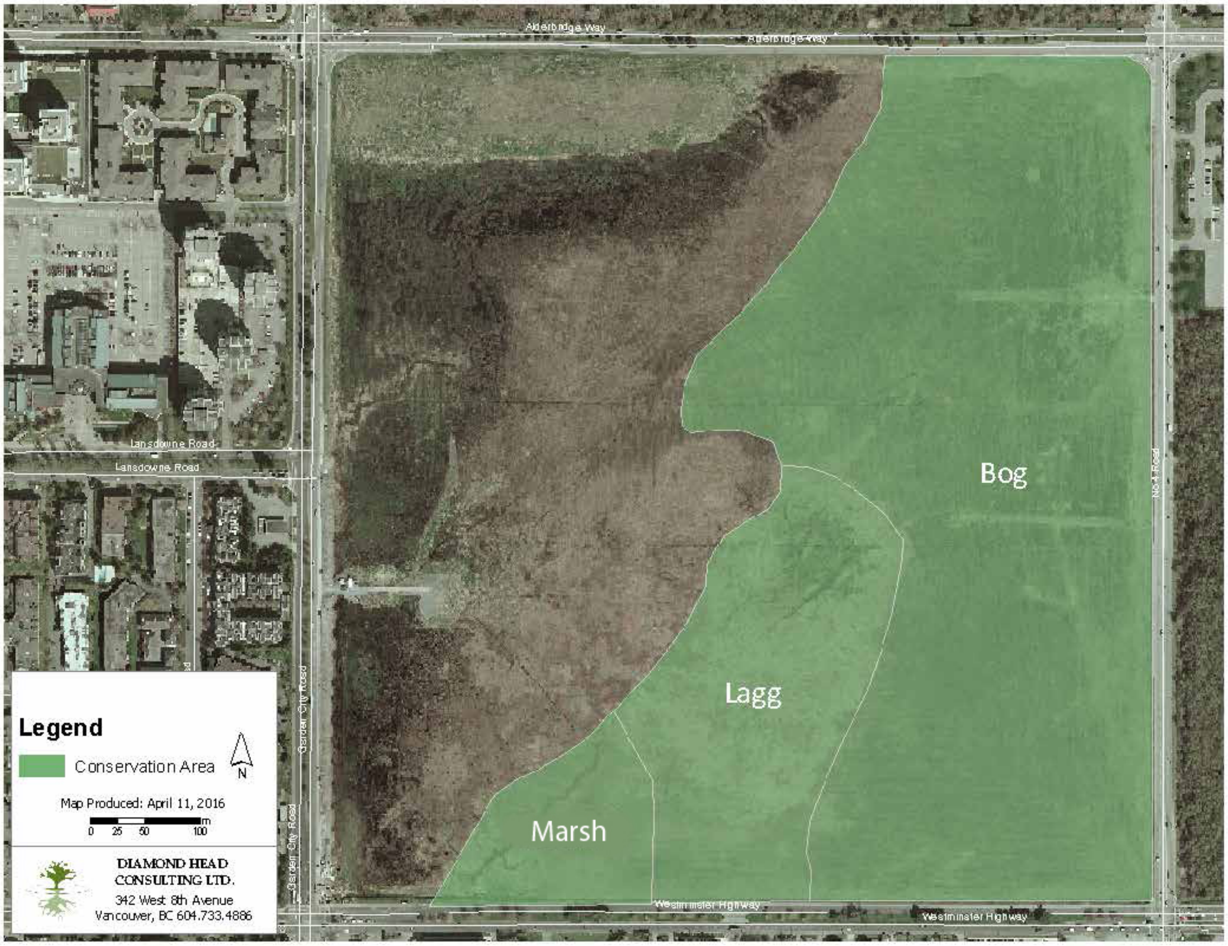


Figure 14-2: Proposed Conservation Zones

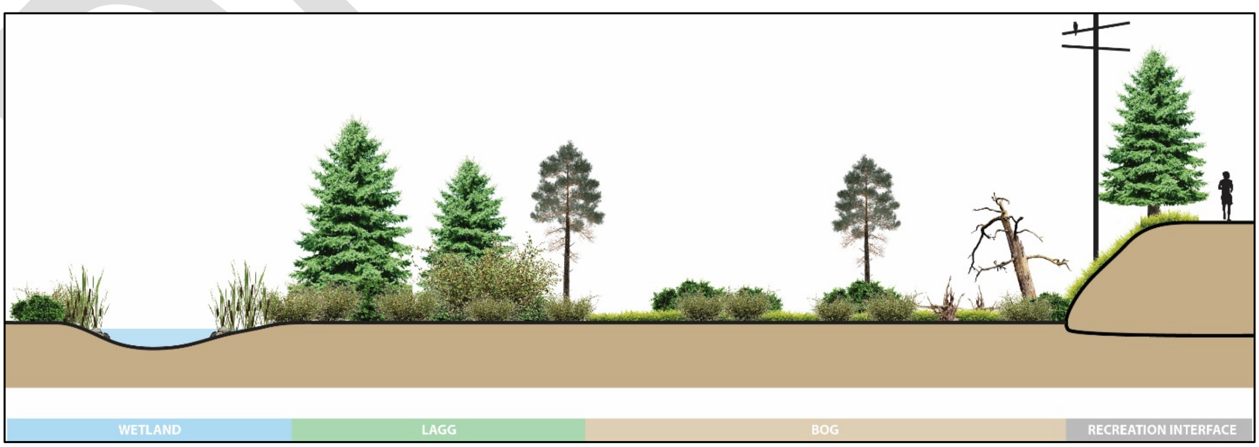


Figure 14-3: Concept Restoration For The Conservation Area

Part C: Ecological Resources Management Plan

14.2 Recreation Interface Zone

Areas around the perimeter of GCL have been subject to historical disturbance. These areas are associated with fill that was placed during construction of the perimeter roads, including two spur roads off of No.4 Road that lead to former radio tower sites. There is a high diversity of plant species found in these areas; however, most are non-native, invasive species that aggressively colonize disturbed sites. The south edge of the conservation area consists of a short fill slope and ditch constructed as part of Westminster Highway.

This area is proposed to be redeveloped as perimeter berms to support recreational walkways, while at the same time, isolating the hydrology on site. Design of the berms will include an impermeable membrane that will isolate the fill from the peat topsoil in the bog. These features will prevent on-site water from draining off-site as well as isolating the bog from off-site water that has the potential to threaten the integrity of the bog's ecology.

Landscaping is proposed as a vegetated buffer between the perimeter road and the conservation areas. These will be linear planted areas that are fragmented by walkways and/or bike lanes. These areas are expected to be raised above the bog and at the level of the adjacent roadways. The ecology is therefore expected to be moderately dry. It is recommended that only native tree and shrub species be planted in these areas.

The two spur roads that extend from the east edge of the site may be incorporated into the future trail system for the site. If not, restoration of these areas should target upland native plant communities. Species to be considered for the perimeter walkways and the two spur roads should be limited to species listed in Table 14-2. Paper birch (*Betula papyrifera)* has the potential to naturally seed into the Bog Zone but is not preferred for that plant community; as a result this species should not be planted in the Recreation Interface Zone.

Table 14-2: Trees and Plants Shrubs Species to be Considered For the Recreation Interface Zone

Shrubs		Trees	
Scientific Name	**Common Name**	**Scientific Name**	**Common Name**
Gaultheria shallon	Salal	*Pinus Contorta*	Lodgepole pine
Rubus parviflorus	Thimbleberry	*Pseudotsuga menziesii*	Douglas-fir
Rubus spectabilis	Salmonberry	*Thuja plicata*	Western redcedar
Rosa nutkana	Nootka Rose	*Tsuga heteropphylla*	Western hemlock
Rosa gymnocarpa	Baldhip Rose	*Picea sitchensis*	Sitka spruce
Symphoricarpos albus	Snowberry		
Sambucus racemosa	Red elderberry		
Holodiscus discolor	Oceanspray		
Amelanchier alnifolia	Saskatoon		
Ribes sanguineum	Red-flowering currant		
Acer circinatum	Vine Maple		
Corylus cornuta	Beaked hazelnut		

Part C: Ecological Resources Management Plan

14.3 The Remnant Bog Zone

Plant communities found at the eastern edge of the GCL represent the closest plant community to natural bog conditions. This area is currently dominated by invasive species including a high percentage cover of Scotch heather; however, it also supports a number of species that are representative of bog ecosystems. This area has been historically mowed and, as a result, tall shrubs and trees have not established.

The long term vision for this area includes establishing a stable shrub dominated plant community with wide-ranging hummocks and mats of sphagnum as well as scattered individual or small groupings of lodgepole pine trees. However, it is unclear based on our current understanding of the hydrological regime what effect the potential management interventions will have on existing vegetation communities or whether the restoration of a stable native bog ecosystem is even possible. Therefore, interim measures to manage the existing modified bog ecosystem focus primarily on vegetation management, specifically: reducing competition to sphagnum and regionally rare plants (cloudberry, velvet-leaved blueberry, bog rosemary) that exist on site; and managing invasive/introduced plant species (European birch, highbush blueberry and Scotch heather).

Photo 14-1: View East from the Centre of the GCL Site Towards the Bog Zone

The following four vegetation management options are presented with a range of outcomes, arranged in order of increasing cost to implement and manage (and discussed in further detail in the following subsections):

1. No management - allow natural succession
   - Expected outcome: invasive birch/blueberry dominated forest
2. Mowing to maintain a low shrub community
   - Expected outcome: existing low shrub/herb plant community with a high cover of invasive Scotch heather
3. Manage invasive species - manual/mechanical removal
   - Expected outcome: mosaic of shrub species and scattered pine

Part C: Ecological Resources Management Plan

4. Remove invasive species and plant bog species
    - Expected outcome: mosaic of shrub and herb species with pockets of sphagnum and scattered pine

Because it is unclear at this time how effective the perimeter hydrological barriers will be at retaining water in the conservation area, efforts to restore a functioning bog will take significant resources and are dependent on the effectiveness of the man-made systems. Therefore, it is recommended that, in conjunction with the groundwater monitoring program, a long term adaptive management approach be taken for managing plant communities within the conservation area. After sufficient monitoring has provided a better understanding of the hydrological regime and plant communities, one of these strategies or a combination of these may be adopted. Recommended timelines are provided in the Implementation section of this report.

Option 1: No Management (Natural Succession)

If the plant community is left to develop without any intervention, it would likely evolve to resemble many areas of the Richmond Nature Park (RNP). The non-native and invasive European birch (*Betula pendula*) would likely establish and become the dominant tree species. The shrub layer would likely be quickly taken over by the non-native and invasive highbush blueberry (*Vaccinium corymbosum*). Many of the ground level plants would likely be outcompeted and would slowly disappear, including the regionally rare bog-rosemary, cloudberry and velvet-leaved blueberry. This process of succession is expected to occur over 10-20 years.

Table 14-3 specifies the plant species that would be expected to establish if the site was left unmanaged. These include invasive species of concern (in red). In this scenario, it is likely that many of the bog indicator species would be outcompeted by the invasive plant species regardless of the effectiveness of the hydrological barriers.

Table 14-3: Plants Expected to Dominate the Site Through Natural Succession

Scientific Name	Common Name	Percent Cover
Vaccinium corymbosum	High bush blueberry	>25
Betula pendula	European birch	>25
Calluna vulgaris	Scotch heather	10-20
Gaultheria shallon	Salal	<5
Vaccinium myrtilloides	Velvet-leaved blueberry	<5

Note:
black = native species; red = invasive species

Part C: Ecological Resources Management Plan

Photo 14-2: Invasive Species Scotch Heather

Photo 14-3: Invasive Species European Birch

Option 2: Mowing to Maintain the Existing Plant Community

The site could be maintained as it is today with continued annual mowing. The resulting plant community is expected to remain more or less the same. Some of the species that prefer high water tables including sphagnum are expected to expand if hydrological barriers prove to be effective. Table 14-4 specifies the plant species that are found to dominate the site, invasive species of concern (in red), and species that are indicators of bog ecosystems (in green). Mowing would continue to effectively control the two highest risk invasive species (European birch and highbush blueberry). Non-native Scotch heather would predominate.

Table 14-4: Plants Expected to Dominate the Site Through Regular Mowing

Scientific Name	Common Name	Percent Cover
Calluna vulgaris	Scotch heather	20-40
Vaccinium myrtilloides	Velvet-leaved blueberry	5-10
Gaultheria shallon	Salal	<5
Vaccinium corymbosum	Highbush blueberry	<1
Betula pendula	European birch	<1
Sphagnum capillifolium	Sphagnum	<1
Andromeda polifolia	Bog rosemary	<1
Rubus chamaemorus	Cloudberry	<1
Eriophorum chamissonis	Chamisso's cotton-grass	<1
Rhododendron groenlandicum	Labrador tea	<1
Note: *black = native species; green = native bog indicator species; red = invasive species*		

Part C: Ecological Resources Management Plan

Photo 14-4: View North Across the Bog Zone.

Option 3 : Remove Invasive Species

One of the greatest risks to this ecosystem is invasive plant species that have already proven to aggressively establish in the adjacent natural areas to the east. Highbush blueberry and European birch have established on site and pose a high risk of dominating the site if they are not managed. This option proposes manually and/or mechanically removing these species, allowing other existing native plant species to grow. Scotch heather is invasive and covers a significant portion of the site. It would be very difficult to eradicate without significant soil disturbance. These plants produce high numbers of seeds. Manual removal is expected to loosen soil and release a high number of seeds, which will then re-establish on the site. All Scotch heather should be cut as close to the ground as possible to reduce its vigour and to prevent seed development. This should take place between April and May while flowers are developing. It is expected that Scotch heather will be naturally reduced over time due to shade cast by taller shrubs. Himalayan blackberry and Evergreen blackberry are starting to establish around the edge of the GCL adjacent to the roadways. These pose a high risk of invading the interior portions of the site and their roots should be excavated by hand.

The response to these mitigation efforts would be assessed in the first 5 years through the monitoring period. It is expected that there will be some natural regeneration of tree species, including Lodgepole pine (*Pinus contorta*).

Table 14-5: Plants expected to dominate the site through management of invasive species

Scientific Name	Common Name	Percent Cover
Calluna vulgaris	Scotch heather	10-15
Vaccinium myrtilloides	Velvet-leaved blueberry	5-15
Pinus contorta	Lodgepole pine	<5
Gaultheria shallon	Salal	5-10
Sphagnum capillifolium	Sphagnum	<1
Andromeda polifolia	Bog rosemary	<1

Rubus chamaemorus	Cloudberry	<1
Eriophorum chamissonis	Chamisso's cotton-grass	<1
Rhododendron groenlandicum	Labrador tea	<1
Note: *black = native species; green = native bog indicator species; red = invasive species*		

Photo 14-5: Non-native Blueberry

Photo 14-6: Invasive Evergreen Blackberry

Option 4 : Remove Invasive Species and Plant/Promote Bog Species and Sphagnum

Historical annual mowing has prevented tall shrubs and trees from establishing and as a result it is unclear whether the restoration of a stable native bog ecosystem is possible due to the hydrological regime. However, with existing site hydrology, ongoing commitment to restore a plant community that best represents a bog ecosystem could be pursued. Requiring a higher level of effort and resources than Options 1 -3, Option 4 proposes removal of invasive species, management of existing bog species, and replanting of additional bog plant species.

Establishment of a bog-like ecosystem would require that the invasive highbush blueberry and European birch be manually and/or mechanically removed annually. Scotch heather is invasive but covers a large area and would be very difficult to eradicate without significant soil disturbance. Efforts should be made to reduce its cover over time and replace it with native bog species. Patches should be cut strategically to reduce its vigor and prevent seed dispersal. It is expected that Scotch heather will be naturally reduced over time due to shading by taller shrubs.

Areas that support sphagnum should be identified, and competition managed to promote its growth. Trials are recommended to spread sphagnum propagules in trial plot areas to monitor establishment.

In addition to promoting growth of sphagnum, select native species, including lodgepole pine and salal should be planted in small groups to mimic a native bog plant community. These species should be planted away from existing areas supporting sphagnum. Depending on the level of commitment and resources available, other plant species that are representative of a bog could also be planted and maintained. The viability of transplanting bog species should be tested through select vegetation monitoring plots in the first 3-5 years.

Part C: Ecological Resources Management Plan

Table 14-6: Plants Expected to Dominate the Site Through Removal of Invasive Species and Planting of Bog Species

Scientific Name	Common Name	Percent Cover
Pinus contorta	Lodgepole pine	10-25
Calluna vulgaris	Scotch heather	10-15
Gaultheria shallon	Salal	10-15
Vaccinium myrtilloides	*Velvet-leaved blueberry*	5-10
Sphagnum capillifolium	Sphagnum	5-10
Rubus chamaemorus	Cloudberry	<1
Eriophorum chamissonis	Chamisso's cotton-grass	<1
Andromeda polifolia	Bog rosemary	<1
Kalmia microphylla	Bog Laurel	<1
Vaccinium uliginosum	Bog blueberry	<1
Oxycoccus oxycoccus	Bog cranberry	<1
Rhododendron groenlandicum	Labrador tea	<1

Note:
black = native species; green = native bog indicator species; red = invasive species

Photo 14-7: Bog Blueberry

Photo 14-8: Lodgepole Pine

Part C: Ecological Resources Management Plan

14.4 The Lagg Zone

The area to be managed as a lagg ecosystem exists to the southwest of the bog area where water naturally drains on site. The lagg is a transition zone that acts as an important buffer between a raised bog (and its acidic, nutrient poor environment) and the surrounding landscape which is influenced by more nutrient rich water inputs. As such, the lagg typically contains vegetation representative of both bogs and fens, and the hydrological conditions and soil type will influence the pattern of vegetation across the landscape.

The existing plant community supports low plant species diversity, and is almost entirely dominated by fen associated plants such as Sitka sedge and hardhack; however, bracken fern is also quite common. This area has been historically mowed and therefore tall shrubs have not been able to establish. To increase the diversity of vegetation, recommended enhancement includes planting clusters of tall shrub species typical of Fraser Lowland bog margins. The target plant community would be diverse in species and structure. It would create a patchwork of plants varying from low growing sedge dominated areas to pockets of tall shrubs and single to small groupings of trees. Table 14-7 specifies the target plant species in the lagg ecosystem.

Table 14-7: Plant/Promote Species Recommended for a Lagg Zone

Scientific Name	Common Name	Percent Cover
Picea sitchensis	Sitka spruce	10-25
Alnus rubra	Red alder	10-25
Carex sitchensis	Sitka sedge	>50
Spiraea douglasii	Hardhack	10-25
Salix Sp	Willow	<5 in clusters
Cornus sericea	Red-osier dogwood	<5 in clusters
Rubus spectabilis	Salmonberry	<5 in clusters
Malus fusca	Pacific crabapple	<5
Lonicera invoilucrata	Black twinberry	<5
Sambucus racemosa	Red elderberry	<5

Part C: Ecological Resources Management Plan

Photo 14-9: View West of the Lagg Zone

14.5 The Fen Wetland Zone

The fen wetland area, situated in the southwest corner of the site, is the lowest point of GCL. The water table is high and almost entirely dominated by fireweed, Sitka sedge, hardhack and bracken fern. Less acidic and more nutrient rich compared to the bog and lagg ecosystems as a result of higher water flows, this area could be enhanced to support a greater diversity of vegetation and provide habitat characteristics that are not provided by the bog or lagg areas. Installation of a buffer between zones with differing hydrological requirements will help to support establishments of a healthy fen wetland zone.

The goal for this area would be to support areas of standing water for most of the year. The area holds standing water through the wetter portions of the year, and has a natural drainage swale running south. Efforts required to enhance this area will be dependent on the effectiveness of the hydrological barriers. If after 3 years there is no standing water in this area, test sites should be treated to excavate swales and ponds that are 0.5 to 0.7 m below the current ground level. Excavation should not extend below the existing peat layer and should not include any portion of the clay aquitard. The excavated peat should be mounded to create small islands between these open water features or used to top dress the fill slopes of berms. The islands could be planted with taller shrubs and low growing trees. Wetland species could be planted along the wetted edges of the water features. Table 14-8 specifies the target plant species for the fen wetland ecosystem.

Table 14-8: Plant Species Suitable for a Fen Wetland Ecosystem

Scientific Name	Common Name	Percent Cover
Carex sitchensis	Sitka sedge	>50%
Spiraea douglasii	Hardhack	10-25%
Salix sp	Willow	<5% in clusters
Cornus sericea	Red-osier dogwood	<5% in clusters
Typha latifolia	Common cattail	<5% on water's edge
Scirpus americanus	American bulrush	<5% on water's edge
Juncus effusus	Common rush	<5% on water's edge

Part C: Ecological Resources Management Plan

Photo 14-10: View South of the Wetland Zone. The Natural Drainage Swale is Visible.

Part C: Ecological Resources Management Plan

15. Habitat Enhancement Opportunities

A variety of wildlife inhabits Garden City Lands. Although some small mammals (e.g. rodents) may be present year round, most species will use GCL either seasonally or as part of a larger home range, including DND lands and the Richmond Nature Park (RNP). Richmond is located along the coastal bird migration corridor and many bird species make use of the area for forage and/or nesting. GCL also supports two species at risk: Barn Swallow (Hirundo rustica) and Barn Owl (Tyto alba).

Habitat enhancement can support wildlife by improving the conditions (e.g. vegetation, ground cover, structural diversity) necessary to meet their individual needs. The following enhancement opportunities are expected to increase habitat value for a diversity of wildlife species.

15.1 Agricultural Stormwater Channels

Two stormwater channels are planned to drain the active agricultural area on the western portion of the Garden City Lands site. These can be designed to capture and filter runoff using natural processes before entering the City's stormwater system. There is little grade change through these features, however, shallow chambers could be designed to ensure that water is filtered through pervious soils and dense native wetland plant communities. The objective of these features is to remove any toxins and reduce nutrient loading that originates from farming. The final design of these storm water channels is dependent on predicted site stormwater runoff and on geotechnical limitations on the depth of channel excavation as discussed in this strategy. Recommended wetland plant communities that could be planted in these chambers are summarized in Table 15-1.

Table 15-1: Plant Species Suitable for Stormwater Treatment Wetlands

Scientific Name	Common Name
Carex obtupta	Slough sedge
Carex sitchensis	Sitka sedge
Spiraea douglasii	Hardhack
Salix Sp	Willow
Cornus sericea	Red-osier dogwood
Typha latifolia	Common cattail
Scirpus americanus	American bulrush
Juncus effusus	Common rush

15.2 Structural Habitat Features

GCL currently lacks structural habitat features that are of value to a diversity of wildlife such as raptors and small mammals. Targeted habitat enhancement strategies are recommended to support biodiversity, while mitigating human-wildlife conflicts that may be associated with additional agricultural use, recreational activity and traffic. The habitat features described below mimic those found in healthy bog and lagg ecosystems and are appropriate regardless of the ecological management option pursued. Machinery should not be permitted to travel over the bog area due to its sensitivity to compaction. Therefore, these habitat features should be installed close to the perimeter berms within reaching distance of an excavator. To improve efficiency, these habitat structures should be installed during construction of the perimeter berms and hydrological barriers.

Part C: Ecological Resources Management Plan

Large Woody Debris

Large tree trunks that have fallen are often called downed wood or large woody debris. These features provide shelter, feeding sites, and movement pathways for wildlife. They also act as nurse logs for plants and add organic matter and nutrients to the soil. Large woody debris cover is generally low in natural bog ecosystems and consists of smaller diameter stems. Therefore, only a small number of pine stems should be placed on site to best replicate natural conditions. In the initial stages of the restoration program this would be limited to the edges of the recreation pathways/berms where excavators could easily reach in to the bog area and avoid compaction:

- Target density is 200 pieces per hectare (two per 100 m^2);
- Preferred source is native lodgepole pine. Other native conifers are acceptable if pine is not available. Use of western redcedar should be limited due to the amount of auxins (plant hormone) present in the wood; and
- Logs should be a minimum of 20 cm in diameter and 4 m long.

Photo 15-1: Examples of CWD Placement on Restoration Sites at KM4 in the Lower Seymour Conservation Reserve (District of North Vancouver) and in Tynehead Regional Park (City of Surrey).

Standing Wildlife Trees

Dead standing trees or 'planted wildlife trees' are important habitat features for birds, mammals, amphibians and other organisms. They provide forage, roosting and nesting sites for a diversity of bird species. They are also a source of organic nutrient inputs. While excavators are being used to install the perimeter berms and hydrological barriers, wildlife trees should be installed on the fill slope extending down to and including the bog area:

- Logs should be native conifer species;
- One third to one half the length of a wildlife tree should be buried to ensure stability;
- Trees should be placed leaning away from structures and people;
- Logs should be a minimum of 40 cm in diameter and 6 m long; and

Part C: Ecological Resources Management Plan

- Wildlife trees should be installed at variable spacing with an average of one per linear 50m around the perimeter of the bog and lagg area.

Photo 15-2: Examples of Standing Wildlife Tree Placement on Restoration Sites at Lynn Creek and in Tynehead Regional Park

Raptor Perches

Barn owl, red-tailed hawk, and northern harrier have been observed on Garden City Lands. The site is considered ideal hunting location for these species due to its open terrain. Raptors often use perch sites to act as vantage points when hunting prey; however, there is a distinct lack of these structures in GCL. Raptor perches should be installed along the edges of the bog area, away from trails and roads (to reduce the risk of getting hit by cars while hunting). Preferred locations are along the central berm and one at the end of each of the spur roads. Perches can be metal or wood poles with a platform or nesting structure at the top.

Nest Boxes/Structures

If vegetation communities are allowed to develop naturally there will be a good diversity of ground cover and forage for wildlife. Insect activity is expected to be high for birds and bats. Nesting boxes and structures should be installed to support bird and bat species. Target species should include barn owl and barn swallow, purple martin, and other cavity nesters. Nest boxes/structures should be installed along the east edge of the central berm within the marsh and lagg (fen) areas. Nest boxes and structures should be monitored and managed in coordination with local stewardship groups. Educational signage may also be erected to help support these initiatives.

15.3 Protection of Habitat for Wildlife

The conservation zone is located within a highly urbanized area and has different habitat types to support a diversity of wildlife species. Establishment of the conservation zone supports the objectives of the Ecological Network Management Strategy (ENMS) and will promote biodiversity within the city's highly urbanised areas.

Some wildlife species are more sensitive to human disturbance, particularly during certain periods of the year (e.g. breeding season). Establishing a wildlife viewing area with controlled access that limits

Part C: Ecological Resources Management Plan

disturbance from humans and pets can support biodiversity, while also providing opportunities for nature appreciation.

An optimal location for the wildlife viewing area is in the southern portion of the conservation zone (Figure 15-1). Ideally the designated areas would include some of the wetland, portions of the lagg and the south end of the remnant bog. Together these areas provide a diversity of habitat. Standing water in the southeast corner of the site in combination with the sedges available for forage are likely to attract waterfowl in the winter months. Thickets of taller shrubs in the lagg area and clusters of trees will provide cover for nesting birds.

This area should support a lower density of trails that are designed to support wildlife viewing. Educational signage should specifically limit human or pet disturbance of wildlife, and trails should be designated as on-leash areas for dogs.

Figure 15-1: Proposed Location of The Wildlife Viewing Area

Part D: Operations and Long-Term Monitoring

This part of the report includes recommended operations, maintenance and monitoring activities for the Garden City Lands in accordance with the recommendations and preferred options for development of the site.

16. Agricultural Monitoring and Maintenance Activities

This is an adaptive management framework that includes best practices, monitoring, and maintenance recommendations for drainage and irrigation on the Garden City Lands. These steps will allow the City and the agricultural producer(s) to obtain the data necessary to determine if conditions are changing (positively or negatively), and whether particular actions need to be taken to repair any problems that may arise. Periodic evaluation of farm water use will also provide an opportunity to reassess water needs over time.

16.1 Drainage Ditches

Drainage Ditch Management Best Practices

- The freeboard in major ditches should be maintained at 1.2m, or the maximum possible based on the actual ditch inverts and the field surface elevations. Between storm events during the growing season the freeboard is especially important to allow drainage of the fields in production.
- When ditch cleaning operations are underway it is recommended that silt barriers be put in place to intercept sediment if water is flowing through the ditch during cleaning.
- Ensure protective plant cover is present along the stream/ditch banks to prevent erosion. There are several erosion control methods outlined the in the BC Ministry of Agriculture's Drainage Manual (1997).
- Mark all outfalls and surface water inlets for reference and for future maintenance.
- Confirm that all surface water inlets are fitted with a proper guard or grate to keep debris and trash out of the subsurface drainage system.
- Ensure that a grate or rodent guard is installed on all outfall pipes to prevent unwanted entry by burrowing animals.

Drainage Ditch Monitoring

- Inspect all surface water inlets twice a year (spring and fall), and ensure that all of the markers are still in place and clearly visible.
- Make thorough inspections of all outfalls in the spring, fall and after severe storm events when the soil is wet and the subsurface drains are running. Make sure that all of the markers are still in place and clearly visible.
- Remove any trash, debris or plant material that has accumulated around any inlets and end pipes to ensure that they continue to function properly.
- Look for any signs of reddish-orange gelatinous sludge coming from the outfall. This may indicate the presence of iron ochre, which may be coming from the aquitard and can plug the drainage system.

Part D: Operations and Long-Term Monitoring

- Look for signs of sediment in drain discharge and in the receiving ditch. Sediment at the drain outfall indicates that there is soil entering the drainage system from bad joints, crushed pipe or the need for a drain envelope. Quite a bit of sediment may come out of the system in its first year, but this should not persist.
- Under normal conditions, the outfall should flow free and clear from any sediment or debris.
- Monitor bank stability to ensure erosion is minimized and outflow area for drainpipes are free and clear.

Drainage Ditch Maintenance

- Repair or replace grates or rodent guards if necessary to prevent unwanted entry by burrowing animals.
- Clean the receiving drain if it has accumulated sediment and is negatively affecting the outfall.
- Maintain (mow) vegetation in the drainage ditches to minimize impacts on water flow.

16.2 Subsurface Drain Pipes

Drain Tile Best Practices

- The ideal times to inspect the system are in the spring, late fall and after a significant rainfall event – when the soil is wet and the drains are running.
- Drain tiles should be installed at a depth between 0.8m and 1.2m depth depending on peat depth and terrain. At least 1.0m depth will also help to offset land settling;
- The initial period following the installation of the new subsurface drainage system is critical to ensuring it functions properly over the long term. The soil around and above the drains will still be loose and should be left alone to settle naturally with time and rain.
- Avoid the use of equipment to pack down the soil over the drains, as any heavy pressure on the loose soil could damage or collapse the pipes.
- Minimize traffic on the field for as long as possible, and straddle the laterals and mains with equipment or work across (not parallel to) the drains when working the field in the first year after installation.
- Keep records of any maintenance/repairs and changes to the system on the drainage plan. This will ensure that there is always an accurate plan of the system for future inspection and maintenance.

Drain Tile Monitoring

- Some degree of settling or subsidence is expected to occur during the first few years as the peat and/or amended peat decomposes and subsides. Some effectiveness of the tile drains may be compromised as the land settles and therefore the drainage installation and maintenance programs should plan for this settling.

Part D: Operations and Long-Term Monitoring

- Check for any signs of erosion of the drainpipe trench following rain events, especially in the first few years.
- Inspect the mains and laterals a couple of days after a heavy rainfall to look for any signs of ponding or excessive wet spots in your field. This may indicate that a blocked drain exists and will need to be repaired.
- Uniformity of crop growth is another good indicator of a properly functioning drainage system. Ideally, the field should dry evenly and produce similar yields.
- Take periodic aerial photographs of the farm to get an overview of the drainage system and to identify potential drainage problems.
- Check the settlement of backfill along the trench especially after the first winter. Deep holes may indicate a section of broken drainpipe requiring repair.
- Check for any signs of wash-ins and blow-outs, which can indicate that there is a broken drain pipe, and surface water has entered the drain. Repair the damage before too much sediment enters the subsurface drainage system and reduces its hydraulic capacity. Observe vegetation growth along drain lines and remove small bushes and trees that are close to the drainage lines before their roots enter and block the drain.
- Check for silt deposits in the pipe at the outlet, which can indicate a failure of filters, collapse of a drain, or a loose connection.

Drain Tile Maintenance

- Cleaning subsurface drains involves digging holes down to the drain at intervals of 10–25 m, removing a short section of the drain, and inserting a steel rod with a hook or corkscrew end, or short-jointed sewer rods. The steel rod with the corkscrew end is inserted from the lower end of the drain until resistance is encountered. The rod is screwed into the sediment and removed several times.
- Flushing the drain is also recommended. To flush and clean a drain, a reasonable supply of water must be available. High-pressure cleaning will not clean a significant distance down the drain.
- Silt boxes and catch basins may be installed at critical points in the system to capture sediment. They should be inspected and cleaned out annually.
- Persistent wet spots may indicate a leaky pipe. Dig up the drain at the wet spot and repair it or discard and replace it. If the fields are wet, it may be better to wait for drier conditions to make the repairs to avoid damaging the soil structure.

16.3 Irrigation System

Irrigation Management Best Practices

- In the short term, potable water use is recommended until the need for an irrigation water source is better defined. This has the combined benefit of providing confidence in water quality, as well as measurement of water use through metering.

Part D: Operations and Long-Term Monitoring

- Sub-metering could be a part of the irrigation system design such that specific fields and/or crops are metered to determine volumetric use over the course of the growing season. This will provide additional information if and when the possibility of switching to stored water or another water source becomes a feasible option. This data would also be useful if and when a sub-irrigation system is developed for the site.
- The development of agricultural fields will be phased and the irrigation volume is expected to increase as field acreage is put into production.
- Use of automated systems to apply the amount of water required for the crop during that time period is recommended, to reduce over and under watering. This may include setting up a controller, housed in a cabinet or other storage space, that is connected to the irrigation system electronically.
- Use of trickle / drip irrigation systems are preferred as they are more efficient than other irrigation systems, however sprinklers may need to be used from time to time.
- A water budget method should be calculated to determine when and how long to irrigate.
- It is important to determine the moisture content throughout the root zone to make an educated decision on when to start irrigating by using tensiometers or other equipment.
- A 'winterization' plan should be established to put the system to rest at the end of the growing season. This may include draining the system and reprogramming the automatic controller.
- A 'return to normal service' plan should be established to bring this system back into operation at the start of the growing season. This may include ensuring there is no damage to the system and reprogramming the automatic controller.

Irrigation System Monitoring

- Check irrigation equipment for leaks. Common faults include leaking gaskets, defective sprinkler bearings, and uneven pressure due to incorrect pipe sizes.
- Sprinklers: Check nozzles annually for wear. Worn, oversized nozzles will apply excess water to the crop. Check for missing, broken, or clogged heads. Check to see if the spray is covering the area uniformly and is targeting the appropriate area.
- Drip system: Check trickle/drip emitters annually for signs of clogging. Plugged emitters cause uneven water distribution. Ensure flush valves are operating, confirm operations water pressure.
- Controller (if applicable): Ensure the cabinet housing the controller is clean, and no wires are loose or worn. Check to see if the battery needs changing. Ensure the controller is programmed properly for the time of day, season, and any water conservation measures.
- Inspect valves and valve boxes, ensure electrical connections are intact.
- Conduct a peak flow rate check for water withdrawal rate (see BC Ministry of Agriculture worksheets).
- Conduct an annual water use check for total water use (see BC Ministry of Agriculture worksheets).

Part D: Operations and Long-Term Monitoring

Irrigation System Maintenance

- Sprinkler: replace missing or broken heads as needed, remove and clean clogged heads, adjust or replace tilted heads. Replace leaky valves and check for drainage problems. Trim vegetation or other obstructions around the sprinkler heads.
- Drip emitter: replace emitters that are no longer working efficiently. Replace tubing as needed. Change the filter periodically.
- Controller: Clean the cabinet out (remove cobwebs, dirt) and replace the battery seasonally. Reprogram to ensure the correct time and day is displayed. Tighten and replace wires as needed.

Part D: Operations and Long-Term Monitoring

17. Other Drainage Infrastructure Monitoring and Maintenance

17.1 Storm System Connections

Routine Operations and Maintenance

Primary storm system connections to drain runoff from the site will be located at or near the entrance to the Garden City Lands Site at the junction with Lansdowne Road on the West side of the site, and in the southwest corner of the bog preservation area, see Figure 2-1. These two connections are critical for maintaining drainage of excess water from the site and staff should check on them routinely, on a daily basis as part of a general site check. The daily check need only be a visual observation of whether or not there is anything unusual at or near the storm system connections, and whether they appear to be draining normally or abnormally. If anything unusual about the storm system connections is observed during a routine check, they should be further investigated to determine if the unusual conditions indicate that there is a problem requiring attention.

Additional storm system connections are located at various points around the periphery of the site, see Figure 2-1. These drain the perimeter trail areas and plazas at entry points. These storm system connections each drain less area and do not required to be checked as frequently. However, during times of heavy rainfall the City staff should plan to check on drains to observe whether they are functioning normally.

Fen Wetland Outlet Management

The outlet structure for the fen wetland will have a variable level control requiring manual operation and control. The outlet will be controlled by manual insertion and removal of stop logs (boards) that incrementally raise and lower the spill elevation of the outlet between the minimum and the maximum elevations. The maximum ponding level for the fen wetland is recommended to be 1.7 m. This will be the maximum spill elevation for the fen wetland. The variation in weir elevation for the outlet will be from existing ground level to 1.7 m.

Initially, the outlet elevation should be set to ground elevation, the lowest spill level for the outlet. The spill elevation of the outlet should not be raised until the construction of all subsurface hydraulic barriers and above-ground berms are complete all the way around the bog conservation area.

Once construction of the hydraulic barriers and berms is complete, the spill elevation may be raised. The typical spill elevation for the outlet will be determined over time.

- When the spill level is first raised, it is recommended that the outlet be set at approximately 1.5 m elevation, and not higher, until the site has experienced wet-season heavy rains and the City has chance to observe and monitor how the site behaves with that raised outlet elevation.
- If the site does not appear to be retaining water for a sufficient length of time into the spring, the spill elevation of the outlet should be raised the following year.
- If the site appears to be retaining water too well, and a lower level of ponding, or less area of inundation, is desired on the site, then the spill elevation of the outlet should be lowered the following year.

Part D: Operations and Long-Term Monitoring

- If at any time there appears to be leakage in the berms surrounding the bog conservation area and repairs are necessitated, the ponding elevation on the site can be temporarily lowered to allow repairs and/or drainage of the ponded volume of water to relieve the hydraulic pressure on the berms. Ideally repairs would be done during the late summer when the site would tend to be drier. If possible, draining of the ponded water should be delayed until late July/August to allow the bog to utilize retained water during the growing season for the bog vegetation. Also, if the ponded volume needs to be drained to a lower elevation but not to the minimum elevation, the spill elevation should be maintained above the minimum elevation.

Part D: Operations and Long-Term Monitoring

18. Groundwater Monitoring

The existing monitoring wells that were installed on the site in 2015 should remain in place to monitor the effects of changes to the site over time. It will take multiple years for the Garden City Lands site to be developed, and it is recommended that the monitoring wells should be maintained and the data recorded through the development of the site and after development.

The monitoring of the existing wells is expected to revert to the City at some point. Whether the monitoring is performed by City staff or by a contractor, the monitoring wells should be maintained in situ if possible through the development of the site and post-construction. There is no timeframe for which it is certain that monitoring is not needed, and monitoring of on-site groundwater levels is expected to be valuable for the long-term. In this case, a minimum of ten years of monitoring of groundwater should be planned after development of the GCL is complete.

The current instrumentation has continuous recording of groundwater levels and the data is downloaded from each well manually at intervals. In order to be aware of the functioning of the instrumentation, it is recommended that each monitoring well should be checked and the data downloaded quarterly, if possible, and no less than semi-annually if quarterly is not possible.

Part D: Operations and Long-Term Monitoring

19. Ecological Monitoring and Maintenance Activities

This report provides a number of recommendations and options for managing the natural areas to be conserved at Garden City Lands. It is not possible to provide detailed direction regarding management of the conservation area until there is a more confident understanding of the influence that the perimeter berms and hydrological barriers will have on the groundwater levels.

A primary goal of this strategy is to re-establish a plant community that best represents a bog ecosystem. Towards this end, it is recommended that a vegetation monitoring program be undertaken for the first three years after hydrologic barriers are installed to better understand groundwater conditions and plant community composition outside of the influence of mowing. It is expected that after this monitoring period, more informed decisions can be made regarding whether it is possible to support a natural bog ecosystem on-site or not. Moreover, because of the large scale and associated costs of the potential treatments and maintenance, the options presented must be considered carefully by the City before committing to an approach and an outcome.

The following monitoring schedule supports recommendations based on implementation of the most comprehensive option for managing vegetation in the conservation area - Option 4 – Remove Invasive Species and Plant/Promote Bog Species and Sphagnum, with installation of wildlife habitat features.

19.1 YEAR 0 (2016)

Monitor Groundwater

- Continue monitoring program to better understand groundwater levels, water quality and chemistry.

Monitor Plant Species Composition - Vegetation Sample Plots

- Conduct surveys to identify and locate native bog-associated plants, including species such as Sphagnum, cloudberry, bog-rosemary, velvet-leaved blueberry Labrador tea, bog laurel, bog blueberry, Chamisso's cotton-grass. Occurrences of rare and sensitive plant species on site should be highlighted.
- Establish permanent sample plots within the remnant bog area for monitoring vegetation development and understanding vegetation response on a yearly basis:
    - Plots should consist of 20 m x 20 m areas identified by permanent stakes, established every 100 m in a grid pattern, targeting approximately 28 plots in total.
    - Micro plots measuring 1 m x 1 m should also be established within each monitoring plot.
    - Initial assessment of each plot should occur in late spring, and should include an inventory of key vegetation species and a visual estimate of species ground cover. Ideally a baseline sampling should be completed prior to construction of any berms.
    - Point monitoring should be established via photo stations at each plot corner with photos taken at a height marked on the stake and facing each cardinal direction.
    - As visual estimates can be subjective, it would be ideal if the same individual assess the plots every year.

Part D: Operations and Long-Term Monitoring

Invasive Species Management

- Invasive species should be aggressively removed by hand, particularly those in proximity to rare or sensitive native bog-associated plant species,.

Vegetation/Habitat Management

- Competitive vegetation should be cleared from around existing critical bog species including the remaining pockets of sphagnum. After 3 growing seasons, it is expected that there will be a better understanding of the groundwater hydrology after the installation of the hydrological barriers and the plant community composition that can establish under the new site conditions. This will allow for the development of a more refined strategy for long term management of the plant communities.
- Plant vegetation within Recreation Interface Area as listed in Section 4.3 and maintain according to BCSLA guidelines.
- Install habitat features as described in Section 5.

19.2 YEARS 1-2 (2017-2018)

Monitor Groundwater

- Ongoing monitoring of groundwater levels, water quality and chemistry**.**

Monitor Plant Species Composition - Vegetation Sample Plots

- Each plot area should be inventoried every year in late spring, with key vegetation species and a visual estimate of species ground cover completed, per steps recommended above.
- Partnerships with stewardship groups already active in the area should be promoted, in partnership with the City. Tasks may include initial monitoring of plant communities, and identification and maintenance of specific bog species.

Invasive Species Management

- Invasive species should be aggressively removed for first three years.

Vegetation/Habitat Management

- Healthy bog species, including the remaining sphagnum pockets, should be protected, and competitive vegetation removed.
- Replace any plants that failed to establish within the Recreation Interface Area and maintain per BCSLA guidelines.
- Continue to install, or replace or re-establish habitat features as described in Section 5.

Part D: Operations and Long-Term Monitoring

19.3 YEAR 3 (2019)

Monitor Groundwater

- Analyze findings from monitoring of groundwater levels, water quality and chemistry**.**

Monitor Plant Species Composition - Vegetation Sample Plots

- Continue to inventory sample plots every year. Analyze findings from first three years and recommend an approach to managing the conservation areawith key vegetation species and a visual estimate of species ground cover completed, per steps recommended above.
- Work with stewardship groups where feasible, including monitoring of plant communities, and identification and maintenance of specific bog species.

Invasive Species Management

- Continue annual maintenance of invasive plant species.

Vegetation/Habitat Management

- Actively protect significant bog species and remove competitive vegetation.
- Assuming that the perimeter berms and hydrological barriers are installed within the first two years, vegetation should be restored within each of the conservation areas, as determined by the results of the monitoring program.
- With a better understanding of the plant community dynamics based on the hydrological regime, plant bog, lag and/or wetland vegetation within respective areas.
- A variety of bog plant species should be transplanted within some of the permanent sample plots and monitored for survival and growth. Recommended species include indicators of healthy bog ecosystems, such as sphagnum, bog cranberry, cloudberry, Labrador tea and western bog laurel.

19.4 YEARS 4-10 (2019 – 2025)

Monitor Groundwater

- Depending on the confidence of findings from the first three years, potentially continue the groundwater monitoring program**.**

Monitor Plant Species Composition - Vegetation Sample Plots

- Depending on the confidence of findings from the first three years, potentially continue to inventory sample plots in Years 4 and 5.
- Continue to work with stewardship groups where feasible, including monitoring of plant communities, and identification and maintenance of specific bog species.

Invasive Species Management

- Continue annual maintenance of invasive plant species.

Part D: Operations and Long-Term Monitoring

Vegetation/Habitat Management

- Actively protect significant bog species and remove competitive vegetation for Years 4 and 6 at least.
- Re-plant any plant species that failed to establish, per BCSLA guidelines. Plants should be maintained carefully for at least 3 years.

Figure 19-1 provides a schedule of recommended treatments over the next 10 years, and can be updated once there is a greater understanding of the groundwater function and plant community dynamics.

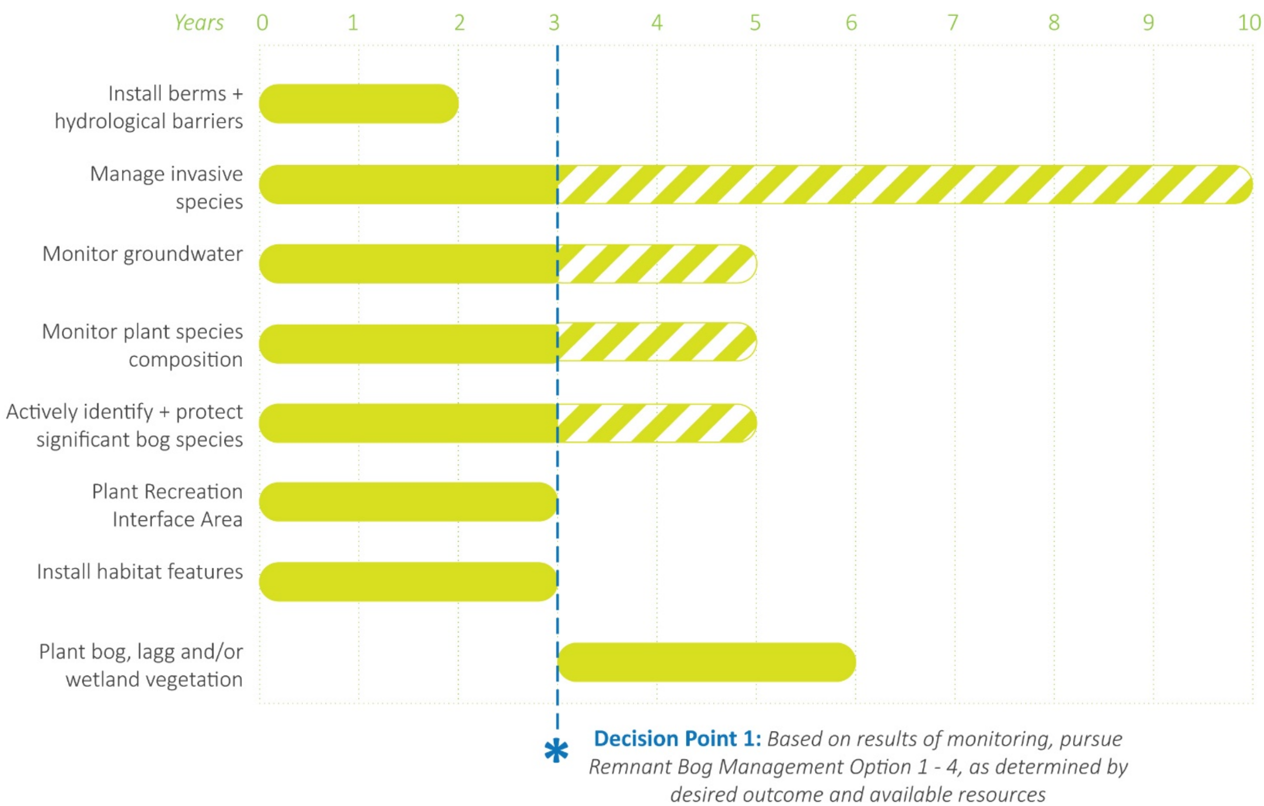


Figure 19-1: Treatment Schedule

20. References

BC Ministry of Agriculture, 2002. Agricultural Drainage Criteria Factsheet.

City of Richmond, 2008. Engineering Design Specifications.

City of Richmond, 2008. Green Roofs & Other Options Involving Industrial & Office Buildings Outside the City Centre. Bylaw # 8385.

City of Richmond, 2008. Flood Plain Designation and Protection Bylaw # 8204.

City of Richmond, 2011. Subdivision and Development Bylaw # 8751.

Davis, Neil, and Rose Klinkenberg, 2008. A biophysical Inventory and Evaluation of the Lulu Island Bog, Richmond, BC.

Diamond Head Consulting Ltd., 2013. City of Richmond Garden City Lands Biophysical Inventory and Analysis.

Evans, R. and W. Skaggs, 1996. Operating controlled drainage and subirrigation systems. North Carolina Cooperative Extension Service. Publication Number AG 356.

Franzmeier, D.P., Hosteter W.D., and R.E. Roeske, 2001. Drainage and Wet Soil Management. University of Purdue, Indiana.

Harbut, R. Faculty, Sustainable Agriculture and Food Systems, Kwantlen Polytechnic University (Pers. Comm.), 2015 and 2016.

Hughes-Games, G. Manager, Resource Management, BC Ministry of Agriculture (Pers. Comm.), 2016.

Kidd, Thomas, 1927. History of Lulu Island and Occasional Poems.

KWL, 2011. Drainage Modelling and Capital Plan for the Proposed 2041 OCP.

KWL, 2015. Integrated Rainwater Resource Management Strategy.

Lalonde, V. and G. Hughes-Games, BC Agricultural Drainage Manual, 1997.

National Engineering Handbook, Section 16. Drainage of Agricultural Land. Chapter 8: Drainage of Organic Soils.

Pacific Climate Impacts Consortium, 2016. Climate Change – Regional Analysis Tool. https://www.pacificclimate.org/analysis-tools

PWL Partnership, 2014. Garden City Lands Legacy Landscape Plan.

SNC-Lavalin, 2015. Hydrogeological Investigation Garden City Lands.

Stephens, J.C., 1955. Drainage of peat and muck lands. Yearbook of Agriculture.

Whitfield, Paul H., and Richard J Hebda, et al., 2006. Restoring the Natural hydrology of Burns Bod, Delta, BC – The Key to the Bog's Ecological Recovery.

21. Report Submission

Prepared by:

Laurel Morgan, P.Eng. Project Manager **KERR WOOD LEIDAL ASSOCIATES LTD.**	Chris Johnston, P.Eng. Technical Reviewer **KERR WOOD LEIDAL ASSOCIATES LTD.**
John Balfour, P. Eng. Senior Hydrogeologist **Enterprise Geoscience Services**	Mike Coulthard, RPF, RPBio Principal **Diamond Head Consulting**
Ione Smith, P.Ag. Principal Agrologist **Upland Consulting**	

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of City of Richmond for the Garden City Lands Water and Ecological Resource Management Strategy. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

Copyright Notice

Revision History

Revision #	Date	Status	Revision	Author
1	July 11, 2016	Final Draft	Submission to City for review and comment	ALL
0	June 6, 2016	Draft	Submission to City for review and comment	ALL

OQM | Organizational Quality Management Program