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PART B:

WATER RESOURCES MANAGEMENT PLAN

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 is 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.

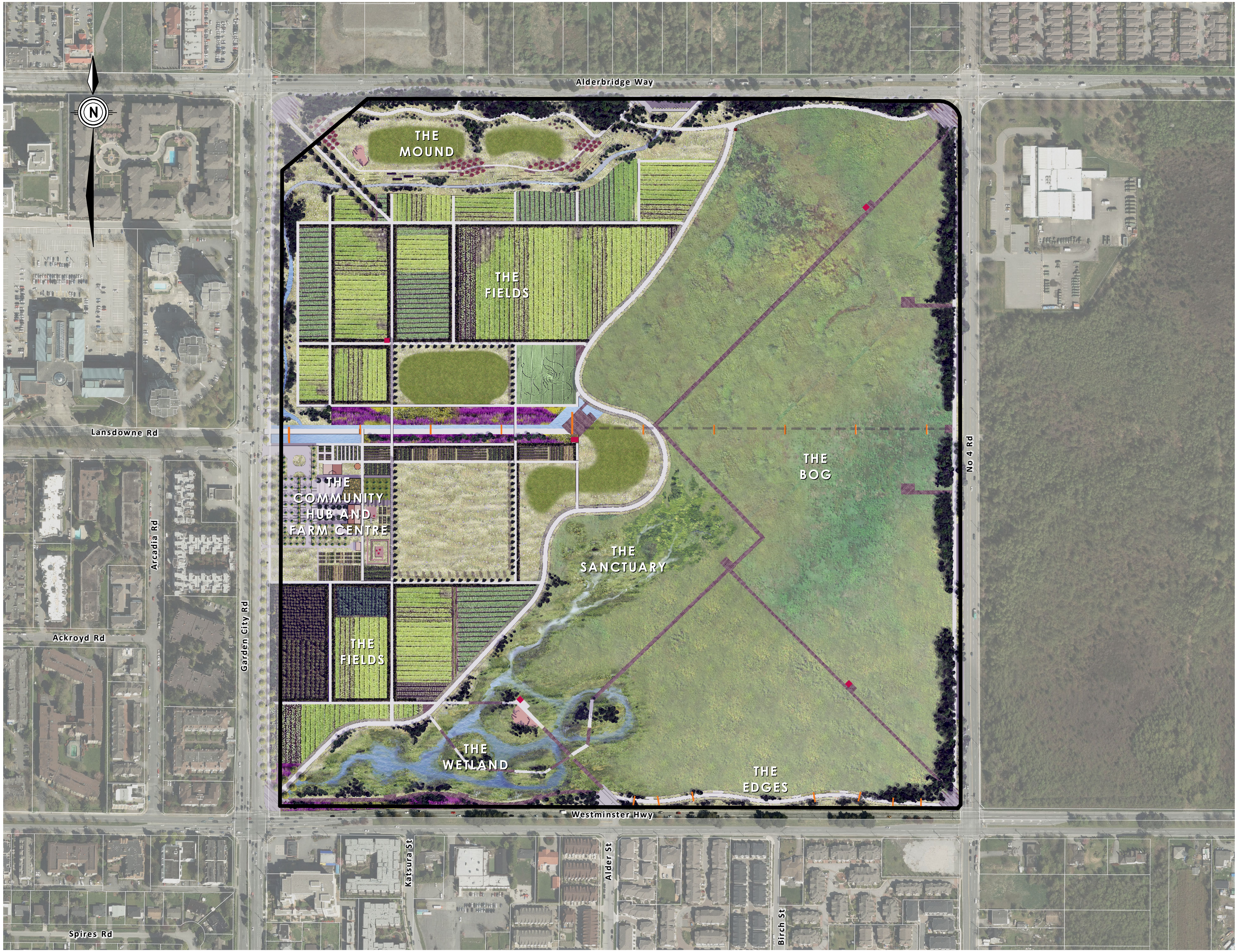
As shown on Figure 8-1, the plan features seven landscape zones as detailed below. The landscape zones serve the base plan to develop the water and ecological resource management strategy.

- 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.

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Garden City Lands Landsape Zones

Figure 8-1

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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, is 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.

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Legend

Study Boundary

Note: Garden City Legacy Landscape Plan, 2014

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

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Project No.	Date
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Garden City Lands Proposed Land Use

Figure 9-1

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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

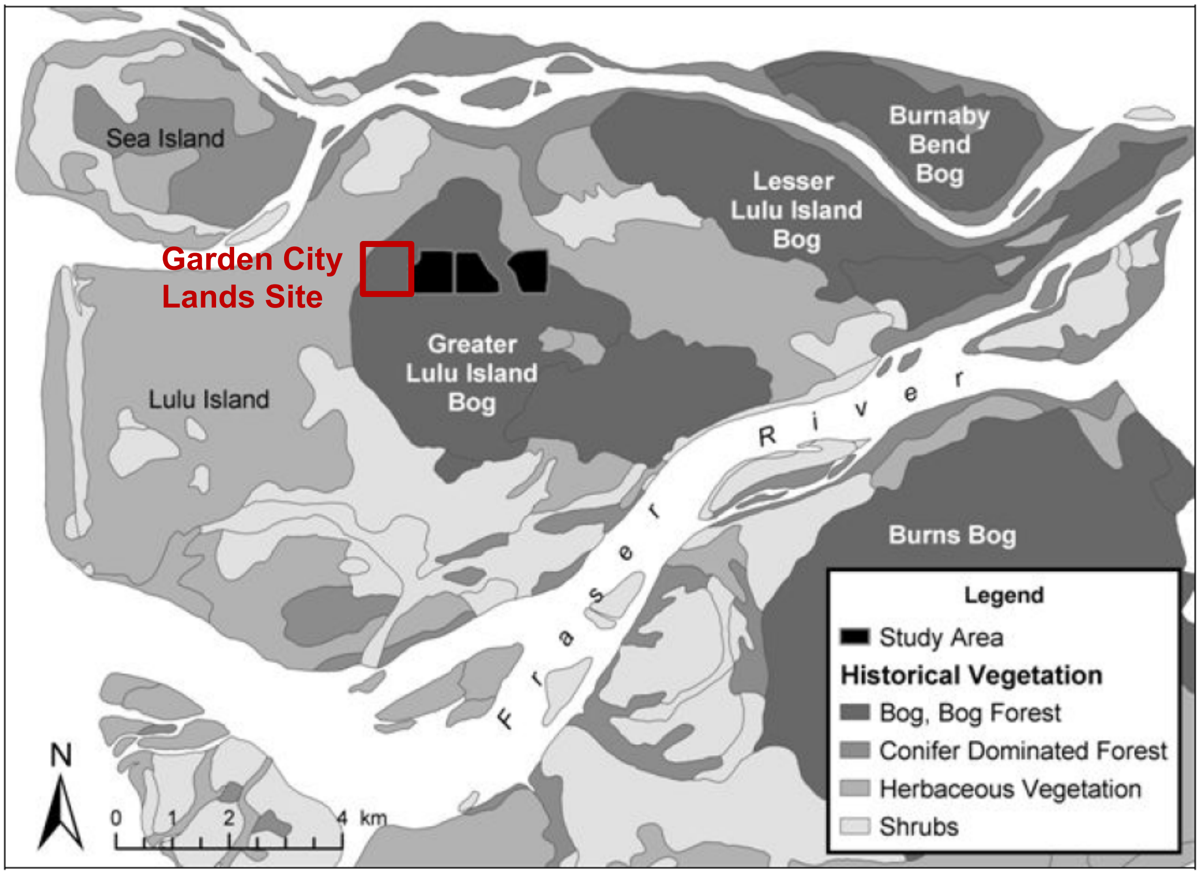


Figure 9-2: Illustration of Garden City Lands location in the Historical Greater Lulu Island Bog[38]

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.

[38] 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 preliminary hydrogeology results for the Garden City Lands may be found in Appendix A. The following paragraphs summarize critical information, conclusions, and recommendations extracted from the results 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

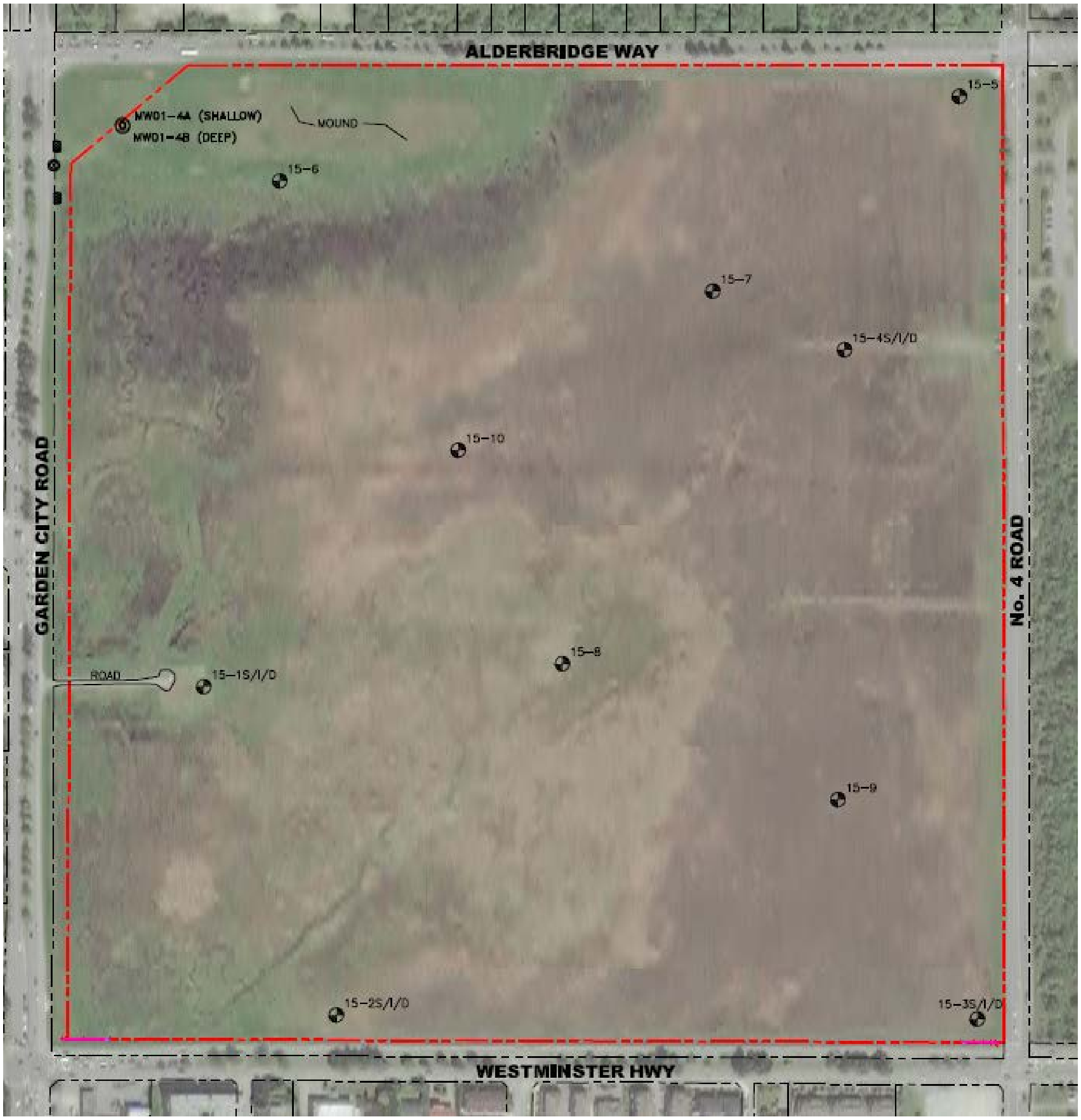


Figure 10-1: Location Plan of the Groundwater Monitoring Wells (SNC Lavalin, 2015)

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 preliminary hydrogeology results 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 mixing 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.

Part B: Water Resources Management Plan

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 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.

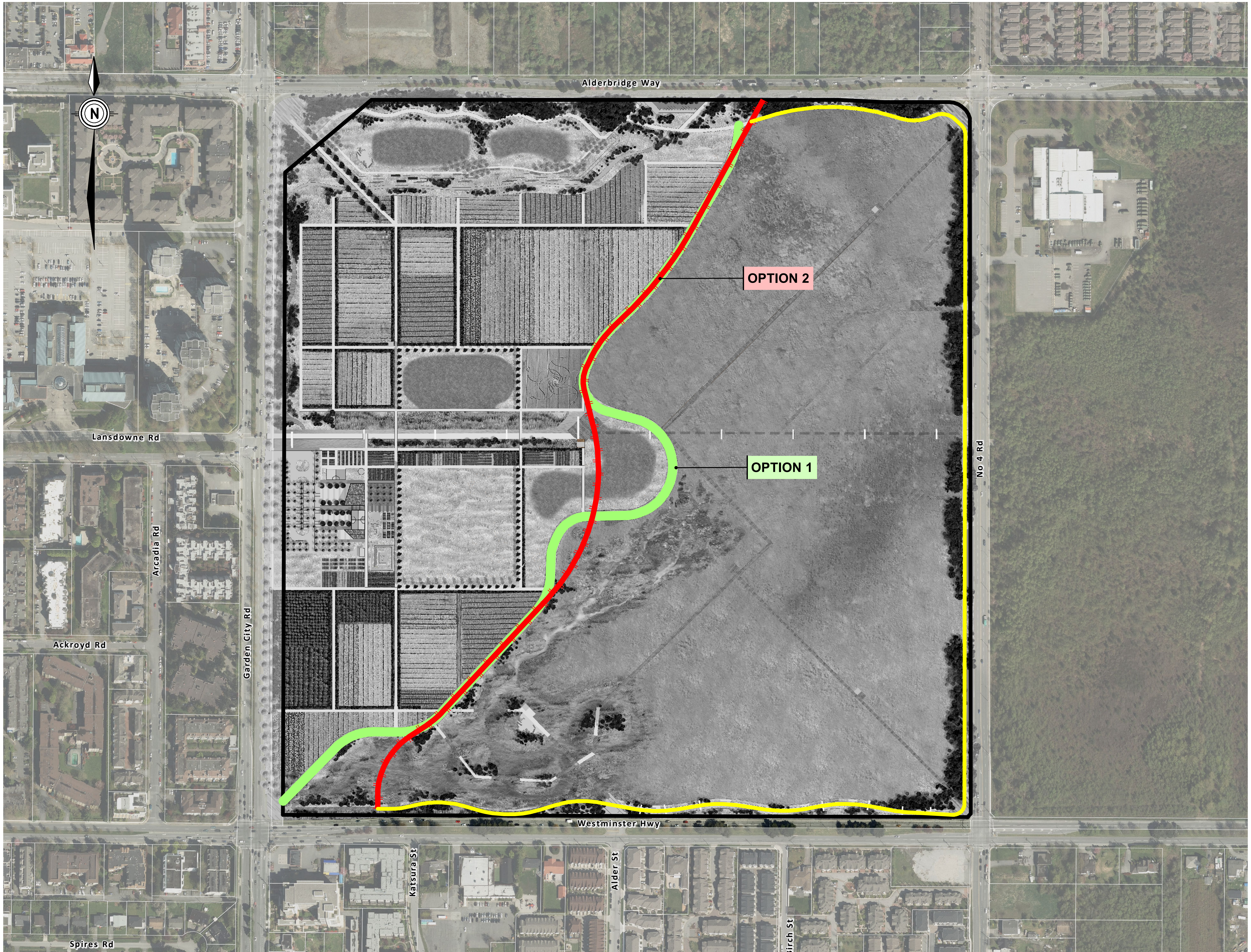
An additional consideration for the primary barrier and trail location is that the trail bump into the bog side in of the site in Option 1 reduces the undisturbed width of the bog area in the lower half of the site. This affects the ability of wildlife to use this area as a wildlife refuge as the trail encroaches into the conservation area[39]. 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.

[39] 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.

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Project No.	Date
651-085	July 2016

Alignments of the Primary and Perimeter Hydraulic Barriers

Figure 10-2

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Author: SScott

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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

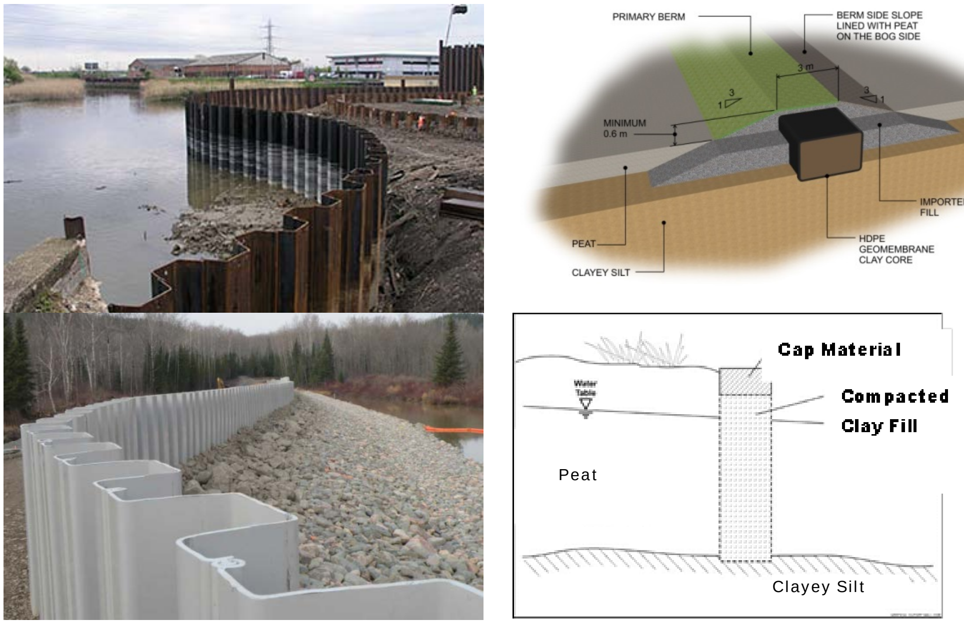

Figure 10-3: Subsurface Barrier Construction Options

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 provides 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

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- 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
Divert water from DND lands under No. 4 Road	• Divert 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.

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Options	Discussion
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.
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.

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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.

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Project No.	Date
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Proposed Berm Minimum Crest Elevations

Figure 10-5

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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, low in mineral content, and unsuitable for most crop production. Therefore, mineral soil amendment will be necessary 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;

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- 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.

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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 and length. The recommendations for each component are discussed below.

Tile Drain Requirements

Pipe Depth

- A minimum depth of about 1.0 m 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 will need to vary between 0.8 m and 1.2 m 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 will not 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;

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- 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

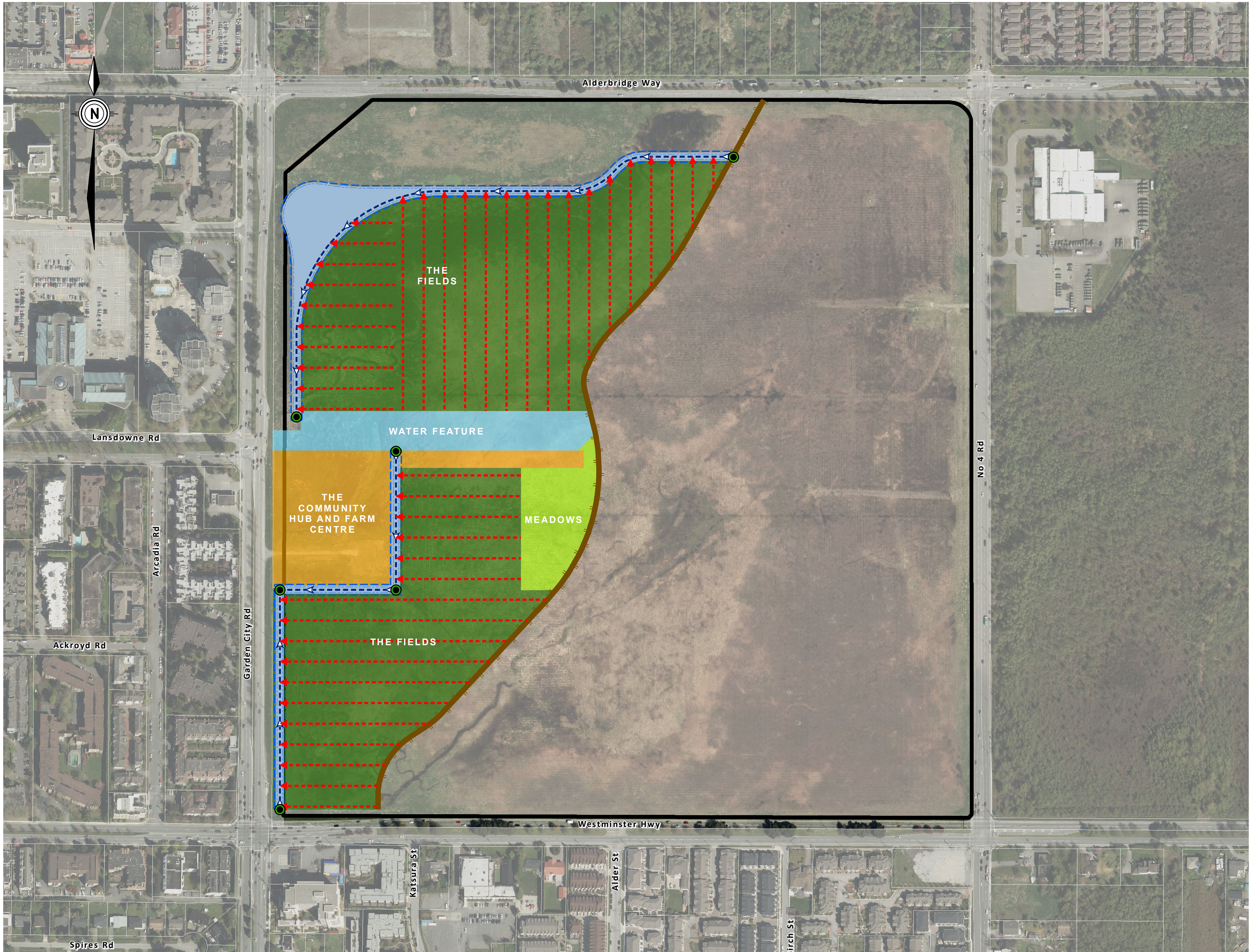
Primary Ditch Locations and Alignment

- 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 is 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
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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.

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Project No.	Date
651-085	July 2016

Agriculture Field Drainage Plan

Figure 11-1

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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 were needed to provide 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 no more than 0.3 m below the base of the peat layer and not breaching through clayey silt layer below. • Invert elevation approximately 0.0 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.

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Table 11-1: Agriculture Drainage Ditch Design Parameters (*cont.*)

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. The storm sewer has an invert of approximately -0.8m, which is lower than the proposed ditch however, peak water levels in the storm sewer may be as high as the road surface.	• 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.

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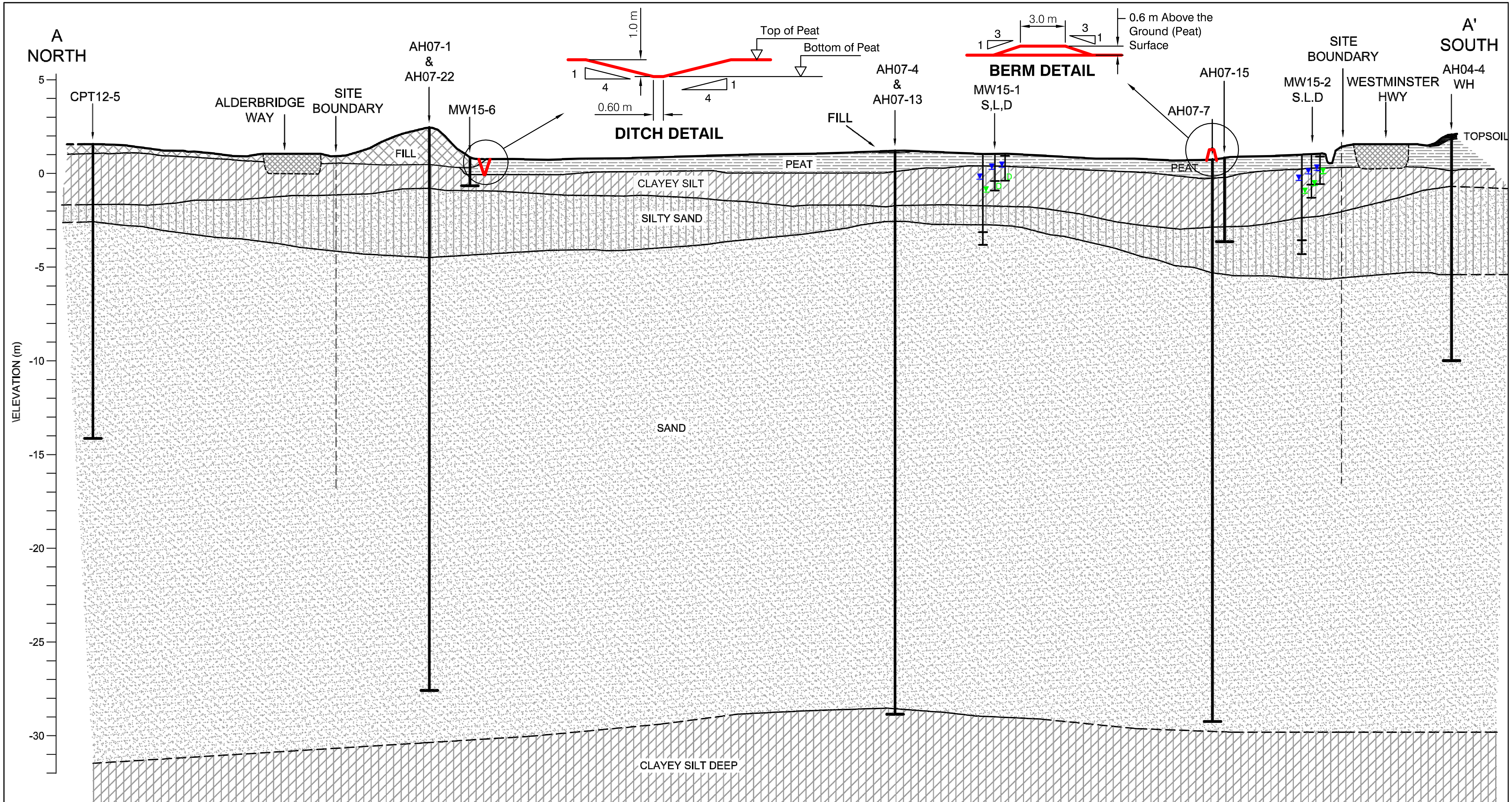

12.5X VERTICAL EXAGGERATION

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MW BOREHOLE WATER LEVEL DETAIL

BLUE = WINTER WATER LEVEL

GREEN = SUMMER WATER LEVEL

D DENOTES DRY

RED = SCREEN & SAND PACK LENGTH

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

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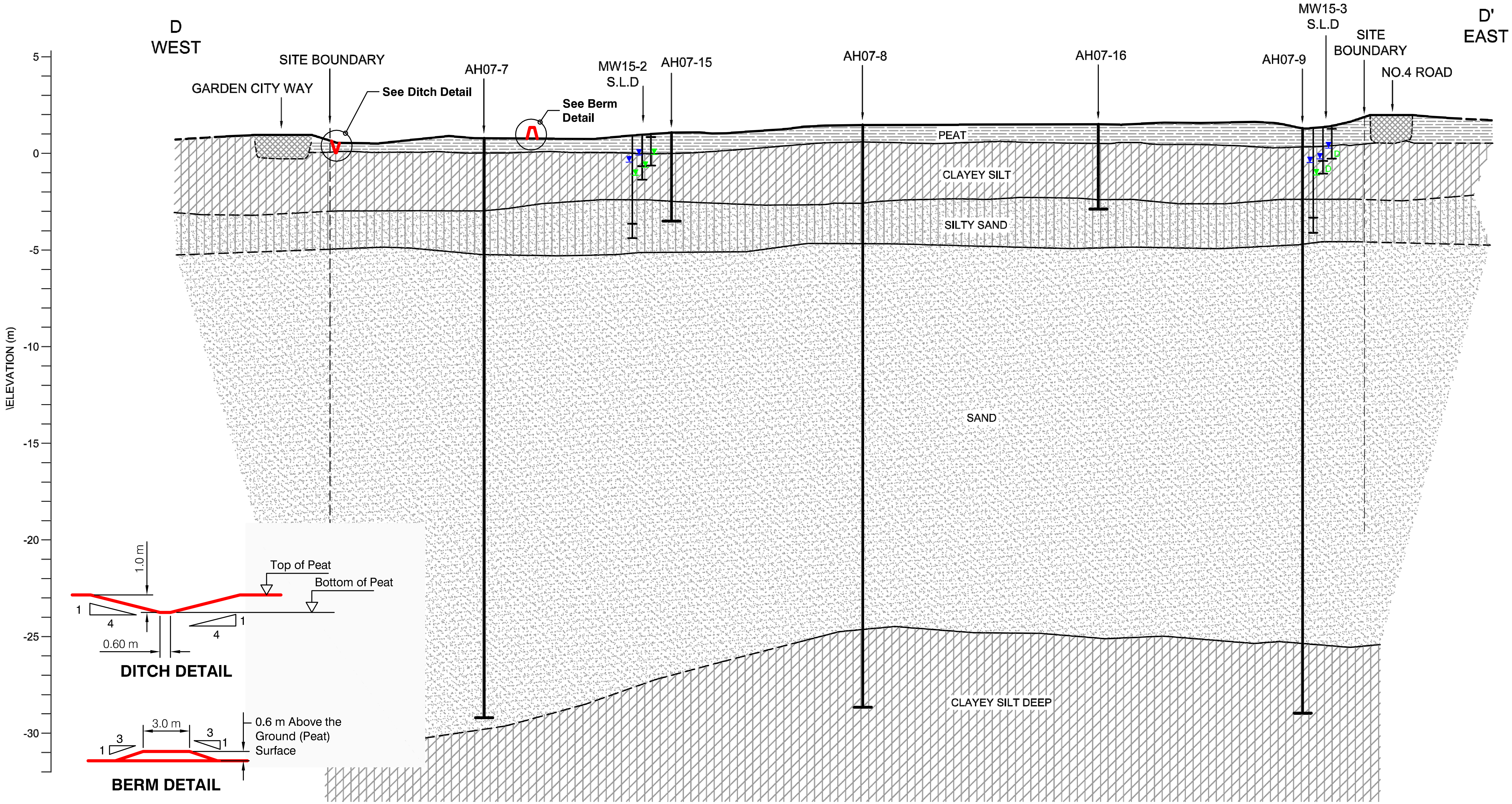

12.5X VERTICAL EXAGGERATION

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 D-D'
DRAWN BY: YL	CHK. BY: JB
DATE: 2016/02/08	REVISED:
PROJ #: 201507	Figure 5-3

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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.

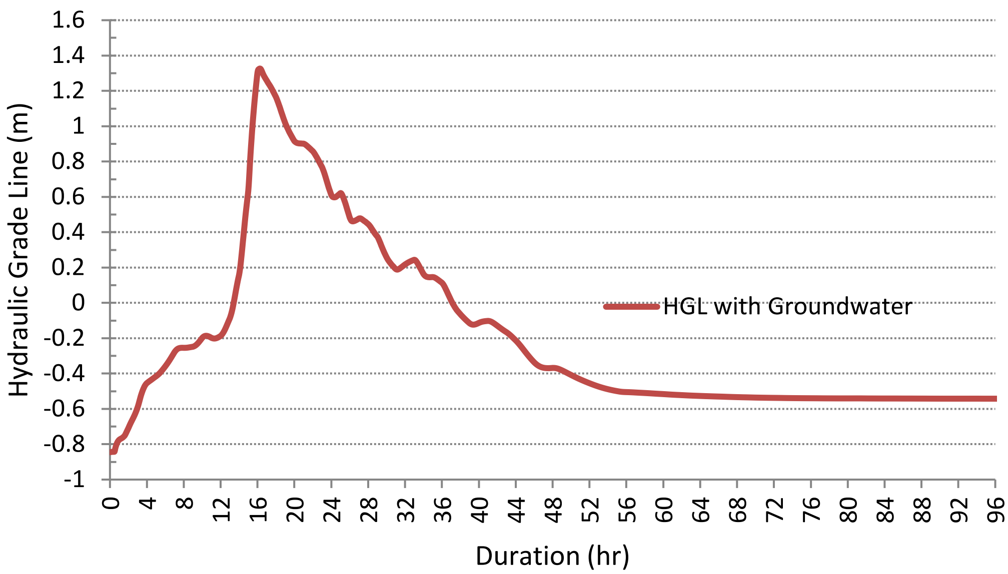

Figure 11-4: Hydraulic Grade Line at the Outlet of the GCL Site

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.

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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 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.

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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.

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 11-4, 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.

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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

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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.

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[40] that this option might 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.

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

Part B: Water Resources Management Plan

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.

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 bring 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.

Part B: Water Resources Management Plan

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.

Sub irrigation 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 sub irrigation 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.

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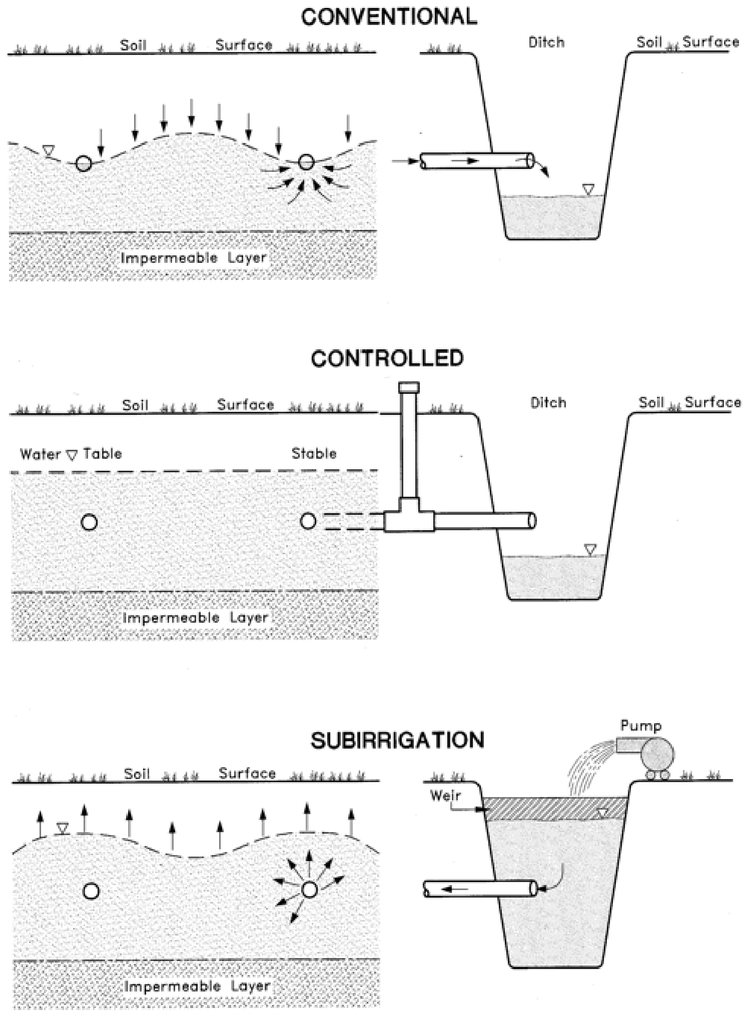

Figure 11-5: Differences between Conventional Drainage, Controlled Drainage, and Sub-irrigation (from Lalonde and Hughes-Games, 1997).

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.

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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.

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.

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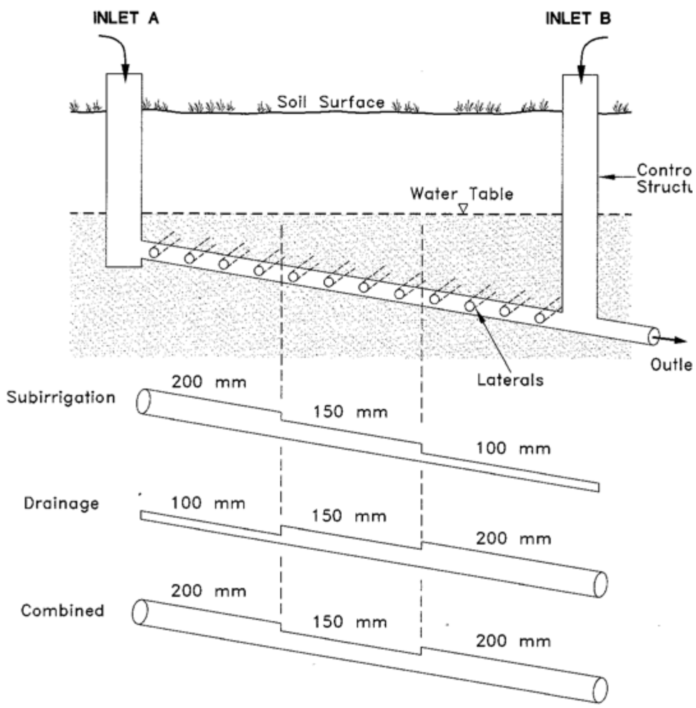

Figure 11-6: Example of Pipe Sizing Requirements in a Sub-Irrigation System (From Lalonde and Hughes-Games, 1997).

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 the following:

- 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.

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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 and/or sub-irrigation must also be considered when managing the system. Rising 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.

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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.

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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 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.

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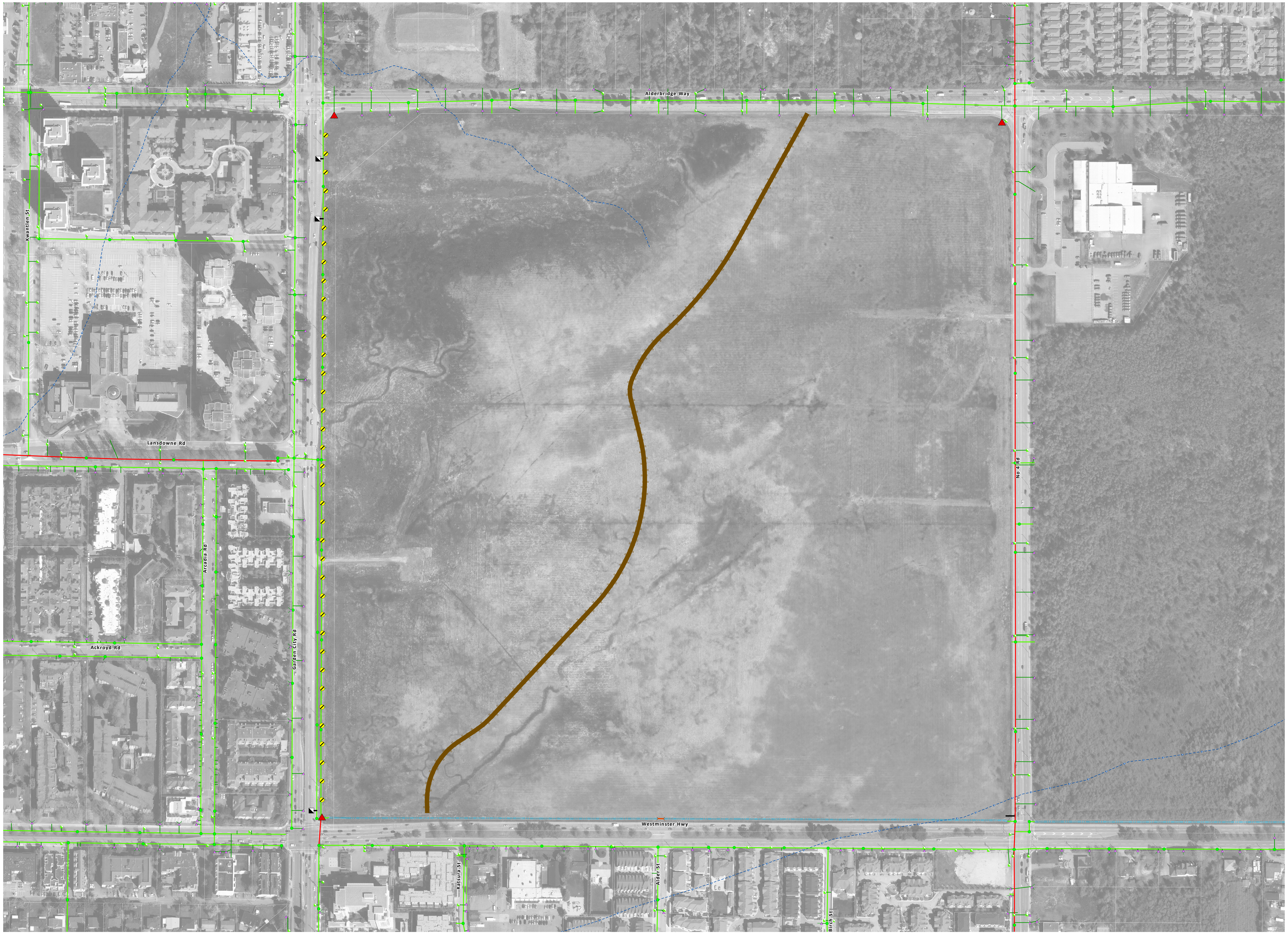
Garden City Road

- 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

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

Road Drainage Servicing Plan

Figure 12-3

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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 0.65 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 either to 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 0.44 m^3/s, based on the 10-year, 24-hour event peak runoff from the farm areas from the City's MIKE Urban drainage model.

The design flows above are intended only for design of the storm connections to the receiving storm conveyance system. These flows are conservative flows based on the 10-year, 24-hour design event occurring in the winter when the soils and are saturated and a high proportion of the rainfall becomes runoff. These flows do not account for any storage benefits from retaining and ponding rain on the bog portion of the site to support the growth of the bog or any on-site retention and storage of runoff on the agricultural portion of the site.

The MIKE Urban model was modified to evaluate the benefit of on-site storage to the storm flows from the site. Storage nodes were added to the model to store runoff from both the bog and agricultural portions of the site prior to runoff being discharged to the storm sewer system. If on-site storage is considered, the flows from the GCL site are significantly reduced, as shown in Table 12-1. This indicates that if the proposed options for storage of runoff were implemented and the storage volumes were managed to retain runoff during significant storm events, the runoff from the site could be reduced to very low levels for the 10-year return period design event.

Table 12-1: Outflows from Garden City Lands Reduced By Managed Storage

Storage Location	Max Storage Volume (m^3)	10-year 24-hour Storm Outflow (m^3/s) with Managed Storage	Difference to Design Flow (%)
Bog Area	10,035	0.001	- 99.9 %
Farm Area	4035	0.01	- 97.7 %

Part B: Water Resources Management Plan

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 cover 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 12-2.

Table 12-2: 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.

Part B: Water Resources Management Plan

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.

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.

Part B: Water Resources Management Plan

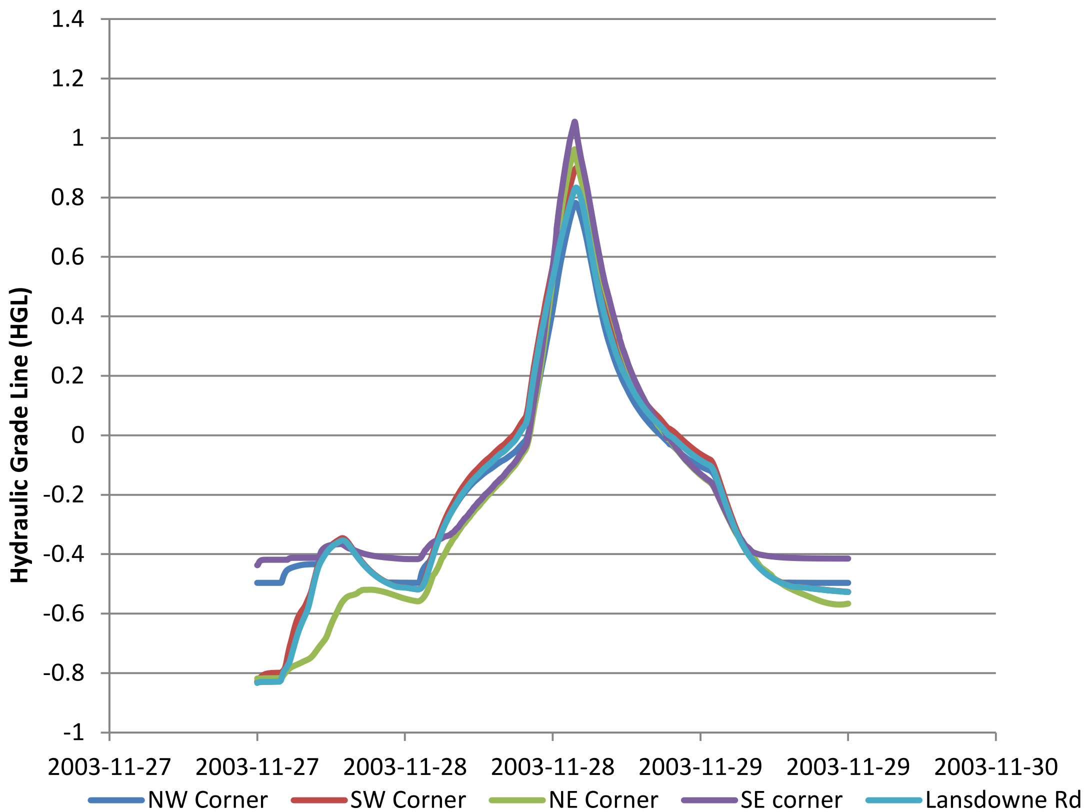

Figure 12-4: Hydraulic Grade Line Elevations for the 10-Year 24-Hour Storm

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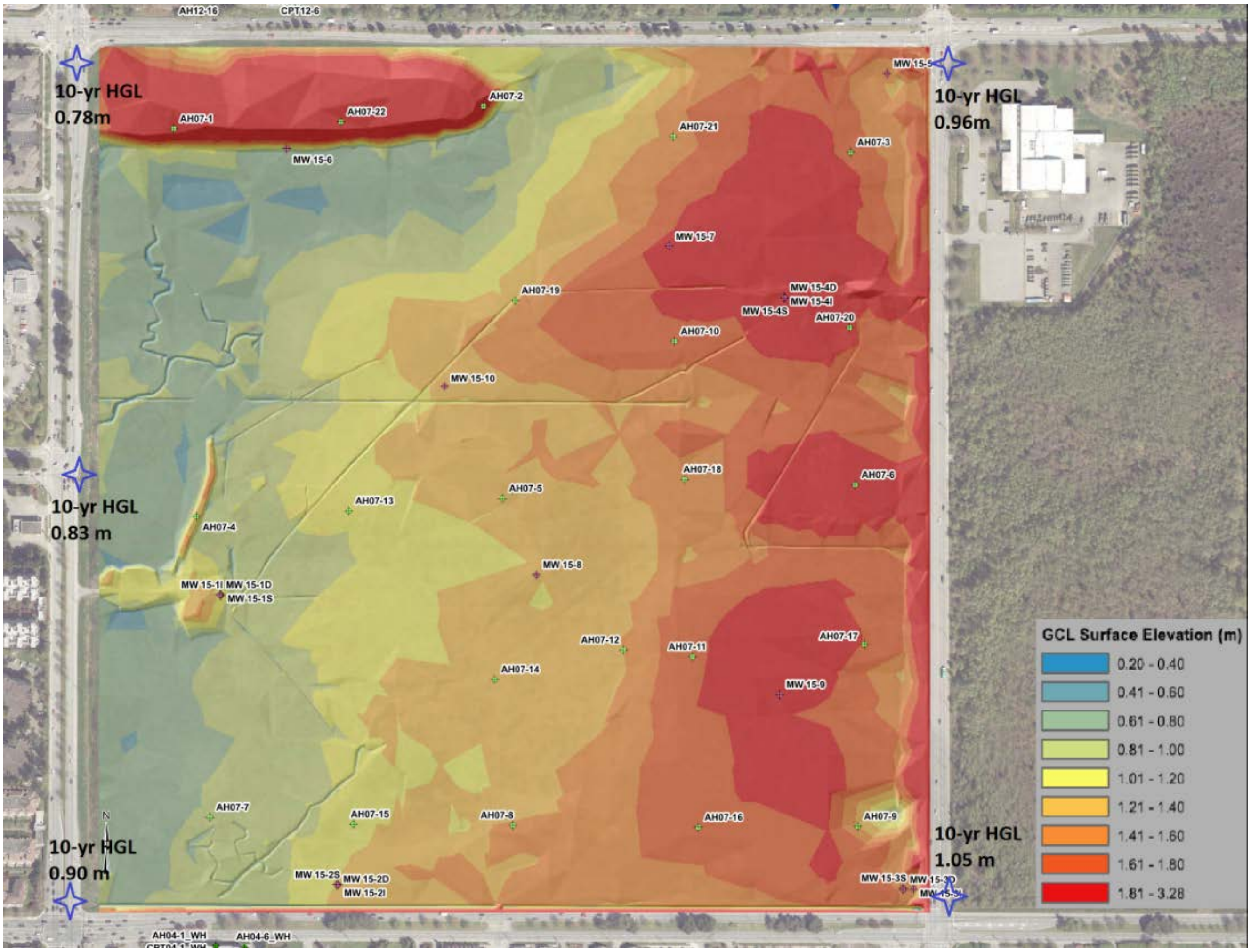

Figure 12-5: 10-year hydraulic grade lines at the four corners of the GCL site

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.

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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 database, 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. Water Resource 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.

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 10-20-2. 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.

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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. • 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.

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Table 13-1: Agricultural Drainage System Design Recommendations Summery (*cont.*)

Items		Recommendation
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.

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Water Sources

Table 13-2: Water Sources Summary

Items	Pros	Cons
Groundwater	• Groundwater 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.

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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 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.

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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 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 12-2. 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.

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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, the LiDAR, and the monitoring data.

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