The University of British Columbia | Okanagan Campus

Integrated Rainwater Management Plan

Final Report | Part 3: Interim Reports

a place of mind

THE UNIVERSITY OF BRITISH COLUMBIA

Prepared for

UBC Okanagan Campus Planning and Development, Sustainability Office
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Attention: Leanne Bilodeau, Associate Director, Sustainability Operations
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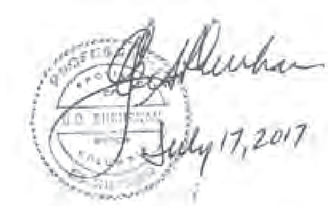

Glen Shkurhan, P.Eng.

Date Issued: July 2017

Project NO.: 1332.0327.01

ACKNOWLEDGEMENT

The University respectfully acknowledges the traditions and customs of the Okanagan Nation and its people in whose territory the campus is situated. The Syilx (Okanagan) people have been here since time immemorial. In September 2005, the Okanagan Nation Alliance officially welcomed UBC to traditional Syilx (Okanagan Nation) territory in an official ceremony, Knaqs npi'lsmist, where UBC signed a Memorandum of Understanding with the Okanagan Nation.

As they have been stewards of this traditional territory since time immemorial, UBC works with the Okanagan Nation to ensure they are partners in the pursuit planning at the Okanagan Campus.

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MEMORANDUM

Date:	October 5, 2016
To:	Leanne Bilodeau
cc:	
From:	Glen Shkurhan
File:	1332.0327.01
Subject:	Arrival Plaza and Transit Exchange

Leanne, as requested we offer the following guidance regarding rainwater management for the Arrival Plaza and Transit Exchange.

The existing site is shown to the left below, the proposed concept to the right as we received from UBC. The red line boundary in the image to the right has been used as the basis for a current to future catchment comparison. The area is approximately 1 hectare in size.

Currently the site is largely paved as a parking lot with a total impervious surface of 76%. The site is heavily used by automobiles today, and subject to the variety of pollutant that go with it – largely oils and greases, heavy metals, and sediment. There are no catch basins or pipes within the site, rather runoff sheds overland to the east, north east, with discharge ultimately to the grassed swale along University Boulevard. This drainage does not currently enter the existing pond located to the south based on our understanding of the site.

The proposed concept is to add a building and reconfigure the remainder of the site, particularly for a transit exchange. Based on the concept below the total impervious surface is estimated to be 80%, very similar to the current condition. The site will likely be used less by private automobiles, but more by transit vehicles. The site will still be heavily exposed to pollutants such as oils and greases, heavy metals, and sediment.

Current site

Future Site

As such, from both a water quality risk perspective and a runoff quantity perspective, the future condition is generally equal to what exists today, just in a different form. To satisfy the minimum criteria of “no net impact”, very little is required for this site, however we understand UBC wishes to stretch beyond this minimum where possible.

One item of significant note is that the grassed swale along University Way represents a very import feature today – not only is it the management feature for this parking lot, but it represents a major flow path for the upstream campus when the capacity of the storm sewer system is exceeded. Placing the building at the location shown will interrupt that management feature and flow path. If at all possible we recommend the building be set back to not interrupt the major flow path. Alternatively a pipe will need to be installed in the roadway, and that pipe should be sized for a 100 year flow since it is the major flow path.

We also note in the future concept there are a number of green spaces on either side of the building and integrated into the transit exchange area. These provide a good opportunity to create all these green spaced into a depressed vegetated swale / rain garden type facility, with runoff from the paved surfaces and roof top into these facilities. They represent about 20% of the site and the analysis shows that an average depression storage of 100 mm, preferably 200 mm, over 20% of a site can offer significant management opportunity. In this case, we suggest UBC strive for 200 mm of depression storage. Runoff from the hard surfaces should be directed into these green spaces in a way that evenly distributes between them. Attempt to achieve a consistent relationship of hard space to green space; and develop a grading scheme accordingly.

You will need to give consideration to the building design, and in particular the roof drainage. Ideally the roof drainage would also discharge to surface into these green areas. If connections to a storm sewer are required, existing storm sewers are readily available to connect to, however that is not water currently felt by the pipes or pond. Ideally some form of control - roof storage, planter boxes or using the green areas - would be used first, with overflow into a piped connection. All the green space facilities will require a spill point. So long as attention is given the site grading, we anticipate that an overland spill system could be achieved rather than installing piping; however this is a detail for the site designer. Particularly with site controls added to the site, we would foresee the overflow continuing to University Way.

The pollutants associated with this area do warrant a filtration / biological type treatment. If properly designed, the vegetated green spaces can serve this function too, however we suggest that maintenance and the interval for a major overhaul will be higher. Also, depending on the concentration of pollutants, when the soils need to be replaced they may be deemed hazardous and require special disposal. It is hard to say, however, as this is highly dependent on the maintenance and traffic load of the transit vehicles. In years past the transit exchange at the UBC Vancouver campus had a heavy load of pollutants. Urban Systems worked with UBC about 10 years ago to design an engineered water quality treatment system for that exchange, but we are not aware of it every being installed.

Another challenge will be snow management. These green spaces will be vulnerable to increased maintenance if snow is piled into them and if sand is used. This could impede drainage as well, so we suggest that if piping is not integrated, there will need to be very particular attention to site grading. Preferably, UBC switches to brine and piles snow in other areas (to the east) not designated for rainwater management.

Aside from using the green spaces integrated within the site, we see the vacant space to the east as a large opportunity. Either in addition to, or in exchange for using the smaller green spaces within the site as management features, the site could be graded to the east or a very significant centralized management facility built. We have noted this potential with the blue circle in the image below. We anticipate this vast area could support a substantial facility for retention and water quality treatment. Although grading will need a closer look, we anticipate the ability to intercept the University Way system and route any overflow into this centralized system to serve as an overflow basin to lessen impact further down University Way. Perhaps an area to the south of this facilities could also be used as the snow stockpile location?

Let me know if you have any further questions at this time.

Sincerely,

URBAN SYSTEMS LTD.

Glen Shkurhan, P.Eng.
Project Leader

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MEMORANDUM

Date:	October 9, 2016
To:	Leanne Bilodeau
cc:	Abigail Riley
From:	Glen Shkurhan
File:	1332.0327.01
Subject:	Synergies Between Future Projects

In previous memos and emails we had provided commentary on stormwater management needs for some individual Future Project sites. As discussed in our October 6, 2016 we agreed to offer guidance on potential synergies between future projects that are in close proximity to each other. These three clusters include the following:

1. Figure A - University Way Pedestrianization with The Learning Centre (TLC), the Arrival Plaza, Future Academic Building and the Transit Exchange.

As previously communicated, University Way represents a critical major flow path (flood route) for high flows when the storm sewer system surcharges. Accommodating high flows through this corridor should continue, which includes continuing east through the Arrivals Plaza and Transit Exchange area. As previously reported, the location of the proposal building at the Arrivals Plaza is currently positioned overtop of the flow path. Unless the proposed building is repositioned, the drainage corridor will need to be rerouted. One option is to locally reroute around the proposed building and return to the existing University Way drainage course further to the east. This would generally maintain existing flow patterns. This is expected to be the lowest cost option purely from the perspective of drainage infrastructure. Another option would be to direct this water north down the pedestrian pathway into Lot H and Innovation precinct. This option would be costlier.

The University Way Pedestrianization project will offer more green space than current, therefore in itself represents a net benefit. There has been discussion about bringing in roof drainage from adjacent buildings and discharging it into the green space within University Way. Existing buildings do not require disconnection, so this opportunity would be optional. We also anticipate that redirecting the roof drainage from existing building will require costly building retrofits, but is something that UBC will need to explore if interest remains. The future academic building on north side of University Way will result in a modest increase in impervious area and should be controlled to the extent that the impervious surface in increasing. It appears that only a small amount of green space will exist adjacent to this future building. One option would be to use all available greenspace within this site for SWM, and / or drain water into the University Way site. The challenge, however, is that the building is on the north side and the proposed rainwater system within the University Way is currently proposed on the south side, therefore a drainage system from the academic building site would need to drain overland across University Way which may not be desirable.

The TCL is in a favourable position to direct into University Way because it is on the south side. However, the TLC site will result in a significant increase in impervious surface and will require significant control to compensate. Due to positioning and topography, the Future Academic building and the TLC building can only rely on the eastern block of the University Way Pedestrianization project for stormwater management. There is insufficient greenspace proposed within University Way to meeting the management needs of these two adjacent sites. While definitely an asset and something to promote, the rainwater management systems proposed for University Way are still limited in size. So, while the opportunity exists to route these adjacent sites into University Way, it will be insufficient in itself, and they will still require controls within each site. To account for future climate change impacts (full ensemble IDF) the recommended on-site control is to retain 25 mm of precipitation from all impervious surfaces that exceed current levels, or 250 m3 for each additional hectare of impervious surface. This is to achieve a “no net impact” over current conditions.

If site planning for the TLC and Future Academic building determines that sufficient controls cannot be integrated on-site, another option is to create a flow diverter as noted in Figure A to direct excess water east on University Way past the Arrivals Plaza and Transit Exchange sites to a new centralized dry basin immediately to the east of the Transit Exchange site. This was also discussed in the memo of October 5, 2016 for the Arrivals Plaza and Transit Exchange.

In summary, our recommendation would be as follows:

- University Way must be designed to continue providing an overland flow path. We recommend the layout of the Arrivals Plaza needs to be thought through to ensure that a major flow path is maintained.
- The proposed landscape rainwater systems within University Way are encouraged. The final sizing of these will dictate their management capacity. Any capacity provided is considered a net benefit to compensate for other areas. The concept should be refined and the storage potential measured in the eastern block and compared to the amount of storage required for the Future Academic building and TLC site. Based on current concepts, the Future Academic building requires a minimum of 23 m3 of retention storage and the TLC site requires a minimum of 76 m3. These volumes are based on a 1:5 year event and assuming that University Way continues to function as a major overland flow route during a 1:100 year event.
- Further evaluate the opportunity to integrate controls in the TLC and Future Academic Building site – can the minimum management target be achieved on site or not?
- The two existing buildings in the western block would preferably not be redirected into University Way – there is no advantage and it is expected to be very expensive, if not impractical, to retrofit the buildings. However, UBC will need to review these buildings in detail to confirm this.
- Decisions on the above will influence the design flow that needs to be accommodated within University Way. The portion which cannot be managed by the existing storm sewer and pond system would overflow east. IF these flows are higher than current levels, you would first conduct an impact assessment for University Way, and depending on the outcome of that assessment may need to develop a new storage facility to the east of the transit exchange site, or redirecting flow north into Innovation Precinct. These alternate approaches would be more costly and complex than managing water on-site.

In closing, while there are synergy opportunities between these sites, we suggest that best solution from the perspective of cost, complexity, and implementation flexibility is for each project site to meet the minimal management target with on-site controls, with an overflow into the existing drainage system.

2. Figure B - Purcell Courts with Innovation Precinct and the GEID Emergency Overflow

From UBC's review of the Options Report, it is understood that UBC is supportive of draining the Purcell Courts expansion into Innovation Precinct. In addition, the GEID emergency overflow needs to be accommodated. Both Purcell Courts and the GIED overflow are expected to interface with what is referred to as Innovation Cell C; the most westerly development cell as noted in Figure B attached.

In the Options Report we identified a natural catchment upstream (west) of Purcell Courts that would also generate some amount of runoff that would also need to be intercepted and managed. This catchment is shown in Figure B. The predicted runoff from this area is very modest with a peak flow estimated around 0.1 m3/s depending on the precipitation event applied. While modest, it is still prudent to construct an interception channel providing positive drainage around Purcell Courts. Other than an interception channel with positive drainage, nothing else should be necessary for the natural upland slope. The available topographic information is not accurate enough at this time to say for certain which direction this channel is best drained, but available contours suggest the vast majority would also drain to the north east towards Innovation Precinct. A concept flow network is also shown in Figure B, and will need to be resolved through a preliminary design process.

To meet broad objectives, it is assumed that on-site controls will be applied within Purcell Courts, with an overflow system. But simply discharging overflow from onto the adjacent slope downstream is not recommended. Rather, a formal channel or pipe should be installed to take runoff down slope in a safe manner. There is existing drainage from the existing phase of Purcell Courts for which UBC had to construct some armouring to protect the slope from erosion. During the design process, it should be explored if this existing system can be merged with that for the future phases of Purcell Courts.

Fundamentally a channel or pipe could both be used and are likely similar in cost. This selection is a detailed decision for a design process. A grading scheme will need to be developed for Purcell Courts to identify an accurate discharge point and route for this drainage, but it is predicted at this time that it would intersect with the south edge of Innovation Precinct Cell C as shown in Figure B. This development cell will expectedly also apply on-site controls as defined in the Options Report, also with some overflow being generated.

The GEID overflow routing is flexible, and again, may never activate as it will only happen in the event of mechanical failure of the supply pump controls or human error. Possible, but low probability. We understand there are new plans for GEID to increase the size of the reservoir. The size of the reservoir will not in itself change the risk, flow rates, or volume that needs to be accommodated by the overflow. The overflow capacity is a function of the pump rate to fill the reservoir. We recommend UBC ask GEID whether the rate of filling the reservoirs will increase. Past study assumed 221 L/s.

Topography suggest there is flexibility on the alignment the GEID overflow could have, but it is also noted that the existing topography of Cell C is highly irregular and we anticipate that significant regrading will be required to accommodate development. As such, we cannot offer succinct guidance at this time on how flow should be accommodated through Cell C, but we offer a high level concept in Figure B. Resolution of routing will need to be done by those preparing the functional design of Cell C and its access road. For this area to be pipeless, a functional layout and grading scheme will be critical. The functional layout will need to accommodate a network of surface flow paths. The frequency and extent of flow in this network will depend on the extent of rainwater controls applied locally with each building / parking lot. As noted in Figure B, existing topography is undulating, but appears to generally fall to the south-east. It would appear that Cell B is the lowest area. A detailed grading scheme will be required to identify the optimal location of the communal recharge basin, but two potential locations are shown in Figure B. If serviced by a single basin, a culvert will be required across Innovation Precinct. Alternatively, one basin could be provided in Cell An, and a second dedicated for Cell B. Again, these are options that will need to be explored as part of a functional plan for Innovation Precinct.

We recommend that the existing parking lot H ditch be maintained, generally, as a snow disposal and pretreatment facility, however with some minor modifications to address slope erosion issue. This ditch would then overflow into a new water quality treatment / habitat facility which would then overflow into the final recharge basin.

Once UBC has expressed their support of the fundamental concept, we will provide flows and volumes to feed into the Functional Plan for Innovation Precinct.

3. Figure C - Nonis Neighbourhood East and West (divided by Alumni Avenue).

The Nonis Neighbourhood is divided into the three cells. Nonis West on the west side of Alumni Avenue, Nonis East on the east side of Alumni Avenue, but divided into a northern and a southern cell. Each of these three cells are noted in the top image of Figure C attached. We understand that Nonis West drains to the storm sewer on Alumni Avenue, whereas both cells of Nonis East drain to natural depressions. However, our interpretation of the 2015 Campus Plan is that one significant natural depression will be infilled to accommodate a parking lot in Nonis East. We suggest consideration that the fill be a free draining material along with the application of dry wells in the parking lot in attempt to largely maintain the natural drainage characteristics of the area. This is a general recommendation only and will need to be evaluated by a geotechnical engineer during the design process.

Development on the west side of Alumni Avenue will result in a considerable increase in impervious surface. Direct discharge without controls is expected to have a negative consequence on the storm sewer system within Alumni Avenue. To account for future climate change impacts (full ensemble IDF) the recommended on-site control is to retain 25 mm of precipitation from all impervious surfaces that exceed current levels, or 250 m3 for each additional hectare of impervious surface. This is to achieve a “no net impact” over current conditions. Based on the concept layout for Nonis West, a minimum retention volume of 175 m3 appears required for the increased impervious surface. It would appear that such storage could be accommodated within the greenspace immediately south of the existing sports field, but will need to be confirmed by UBC through a functional design process. An overflow would be provided to the existing storm sewer.

Our understanding of the 2015 Campus Plan is that the existing parking lot of Nonis East will be converted into a second sports field, whereas a new building and parking lot will be built to the east, as shown in the bottom image of Figure C attached. Assuming the new sports field will be built as a permeable surface that can infiltrate into the ground, this conversion should result in a net neutral change hydrologically. However, if the new sports field is built with rapid drainage into a piped underdrain system this would have a net negative effect. As such, the design and drainage of the field is important to consider. Given the apparent decent infiltration capacity of soils in this area, we will assume that it will be a naturally draining field at this time, in which case the hydrologic impact remains neutral for this area. Even thought that this southern portion of Nonis East would appear to be a net neutral impact, it is still recommended that site controls be integrated with new buildings and parking lots to the degree possible given the infilling of the natural depression. Otherwise, the doubling of the water inputs to the single remaining natural depression will likely effect it negatively, despite it having storage capacity.

The question for the south cell of Nonis East is whether rainwater management features can also be integrated around the future sports field, or by using the sports field itself? This will provide an opportunity for Nonis West if insufficient controls can be integrated into Nonis West.

For the north cell of Nonis East, the proposed building concept would appear to increase the total impervious surface over current conditions by approximately 2,400 m2. Again, applying a 25 mm retention depth criteria, this cell should be providing a retention volume of at least 60 m3 for a no net increase in a 1:5 year event; 120 m3 for a 1:100 year event. We also note that the existing building may have a conflict with an existing storm sewer draining into the natural depression. It should be field verified UBC that this site currently drains to the natural depression. If so, we do suggest this continue, with appropriate controls, because rerouting the site to the existing storm sewer system on Alumni Avenue would be a detriment.

In summary, Nonis West and the northern Cell of Nonis East should be providing retention facilities to manage their respective increases in impervious surface. A functional design is required to determine if adequate storage can fit within their respective boundaries. If yes, then it's expected that Nonis West would continue to overflow to Alumni Avenue. However, if not, there appears to be an opportunity to direct surplus water across Alumni Avenue into the south cell of Nonis East for management, assuming of course that management facilities can be integrated into Nonis East. Again, assuming the proposed sports field will be a free draining field via infiltration and not with an underdrain system, then hydrologically the southern cell should be net neutral. However, because of the infilling of the natural depression, we still recommend that controls be integrated with the building and parking lots in an attempt to maintain the current hydrologic process given the apparent good infiltration capacity. The single remaining natural depression is expected to continue being the discharge point for the Nonis East north cell, and should also serve as an overflow from the southern cell.

Sincerely,

URBAN SYSTEMS LTD.

Glen Shkurhan, P.Eng.
Project Leader

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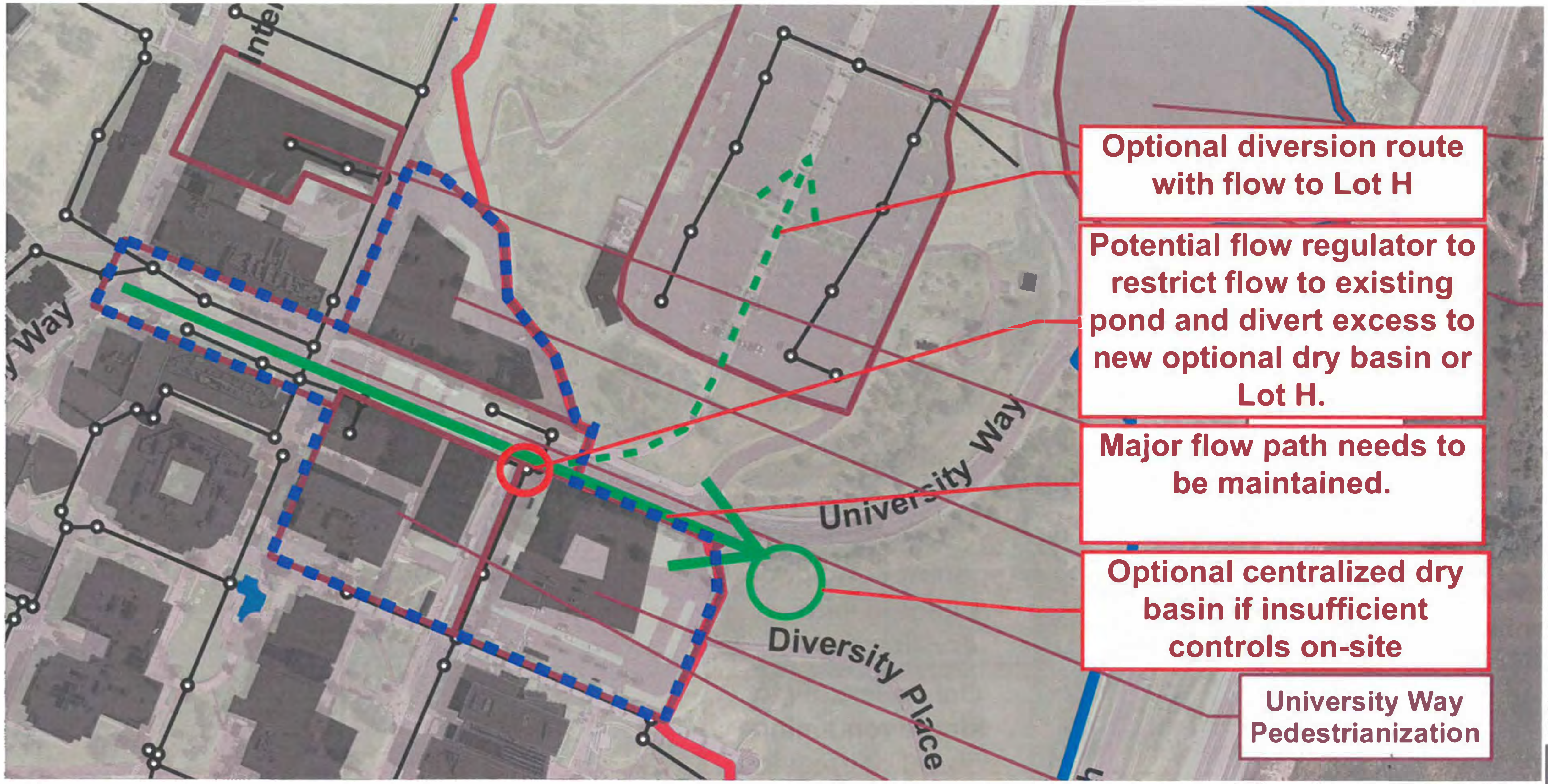

OKANAGAN

IRMP

University Way Project Cluster

Legend

- Development Areas
- Existing Manholes
- Existing Storm Sewers

0 30 60 120 180
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332 0327 01
Author:	SQ
Checked:	GS
Status:	~ DRAFT ~
Revision:	A
Date:	2016 / 9 / 16

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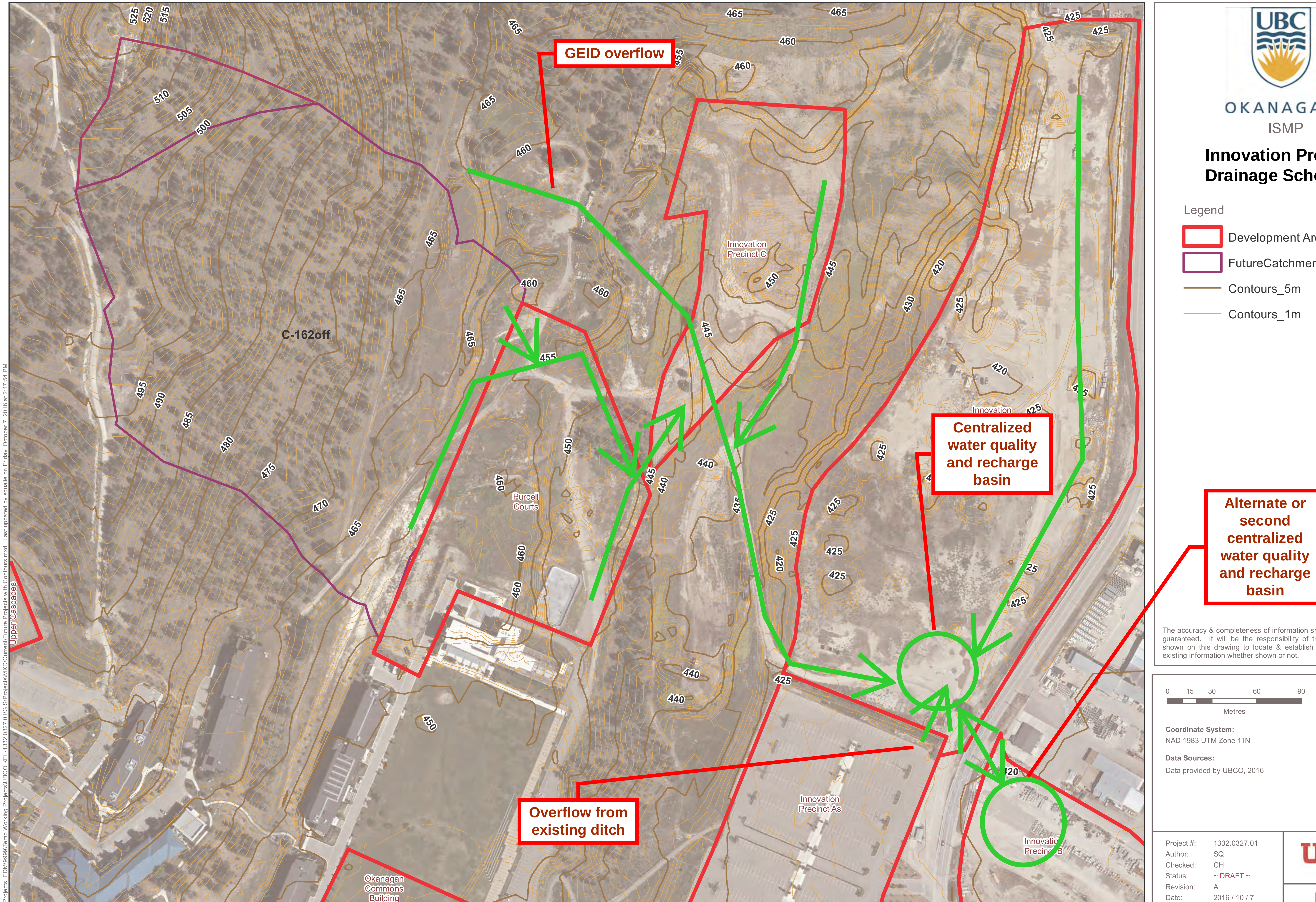
FIGURE A



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ISMP

Innovation Precinct Drainage Schematic

Legend

- Development Areas
- FutureCatchments
- Contours_5m
- Contours_1m

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 15 30 60 90
Metres

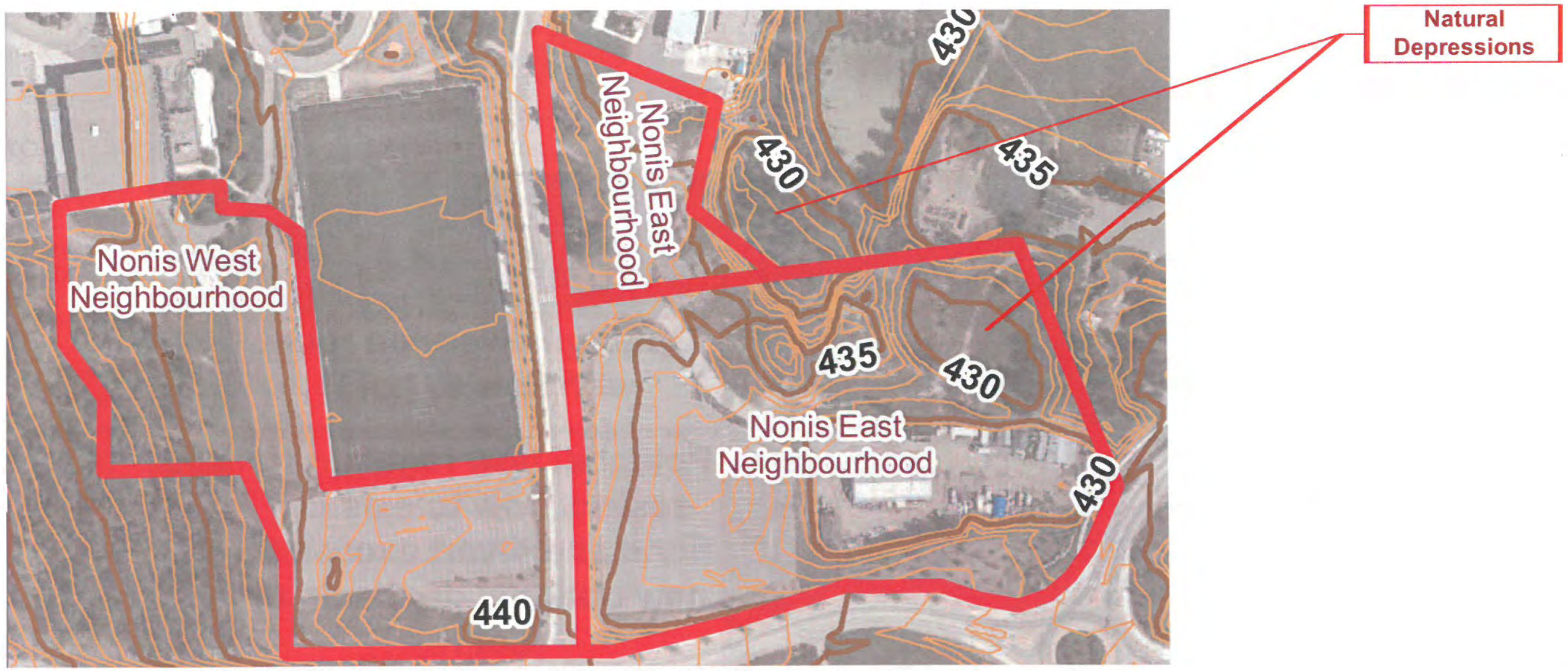
N

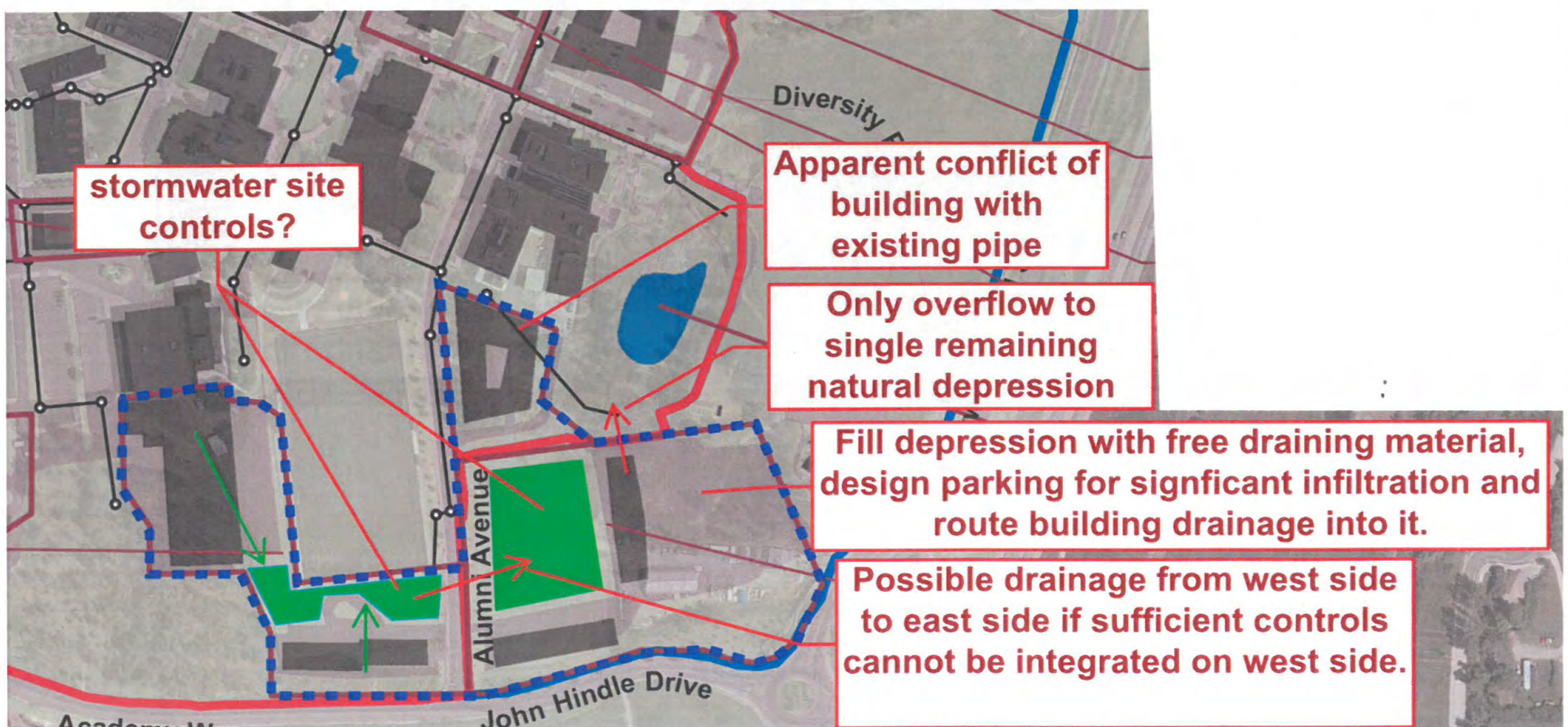
Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	CH
Status:	~ DRAFT ~
Revision:	A
Date:	2016 / 10 / 7

FIGURE B





UBC OKANAGAN

IRMP

Nonis Cluster

Legend

- Development Areas
- Existing Manholes
- Existing Storm Sewers

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0 30 60 120 180
Metres

N

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #: 1332 0327 01
Author: SQ
Checked: GS
Status: ~ DRAFT ~
Revision: A
Date: 2016 / 9 / 16

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FIGURE C

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University of British Columbia

Integrated Rainwater Management Plan

Revised Options Report

October 28, 2016

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UBC OKANAGAN

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University of British Columbia
Integrated Rainwater Management Plan
Revised Options Report

Client: UBC-Okanagan
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Attention: Leanne Bilodeau, Director, Sustainability Operations
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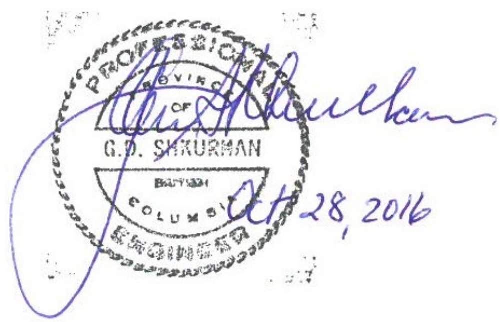

REVISED

Prepared by: Glen Shkurhan, P.Eng.

Date issued: October 28th, 2016

Project No.: 1332.0327.01

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Figures

Graphs

Tables

1 Introduction

The University of British Columbia (UBC) is undertaking an Integrated Rainwater Management Plan (IRMP) for its Okanagan campus to guide campus growth in a way that respects natural hydrologic processes, protects existing environmental values, and manages risk. This Plan is limited to the portion of UBC lands draining to the east, as shown in Figure 1. With new information about campus growth, and new objectives and goals on how growth should occur, this IRMP is an update to the earlier UBCO Stormwater Management Plan prepared in 2011.

The Plan area is divided into two primary catchments of interest; the established campus covering the southern portion of the lands, and the northern portion of the lands in which Innovation Precinct will be located. For ease of reference, these two areas are referred herein as "Main Campus" and "Innovation Precinct".

The Main Campus has an established storm sewer system that ultimately drains to an existing pond located in the south east corner of the campus. This pond has no defined outlet. This pond is identified as an important feature to UBC, both environmentally and socially, and is to be protected. The existing storm sewer system has a history of flooding at some locations during heavy rainfall, therefore, increased runoff rates and volumes pose a concern of increased flood risk.

Within the Main Campus there are a number of planned projects that will result in site transformation. Each project will have a different hydrologic affect from what currently exists; in some case an improvement in other cases a potential detriment. These projects represent both a need and an opportunity to how rainwater is managed.

The Innovation Precinct is largely undeveloped and was a former gravel mining operation. Beneath a relatively thin veneer of lower permeable soils is a highly permeable aquifer. This highly permeable aquifer offers an opportunity for disposal of rainwater, but requires pre-treatment to avoid pollution of the aquifer. Unused production wells currently owned by the Glenmore Ellison Irrigation District (GEID) exist at the northern end of the property. These wells represent a potential constraint; however, it is understood that GEID has intent to decommission them. We also understand that UBC has some interest to take ownership of them from GEID for non-potable use. The future of these wells will need to be a consideration in how rainwater in the Innovation Precinct is managed and disposed.

There is no significant drainage infrastructure downstream of UBC property; therefore rainwater must be fully managed within UBC property, up to and including the 1:100 year return period, in accordance with City of Kelowna standards.

1.1 Objectives and Goals

Prior to the Plan getting underway, UBC developed a number of objectives and goals that establishes the studies foundation. These include:

1.1.1 Project Goals

1. Develop a comprehensive ISMP, including supporting geo-tech soils analysis and stormwater modelling, that reduces life-cycle costs and supports and advance the Campus Plan, Design Guidelines, and WSIP
2. Develop an ISMP companion operations and maintenance manual for the campus.
3. Provide building and landscape design recommendations to inform the UBC Okanagan Design Guidelines (presently under review) and new/concurrent development projects on campus.
4. Develop an ISMP phasing plan to address stormwater infrastructure requirements for new development projects on campus and to ensure an integrated stormwater system across campus
5. Supply the model for the campus' integrated stormwater system to inform future infrastructure investment and development projects, with relevant design criteria, and which can be maintained and updated by UBC staff over time.

1.1.2 Project Objectives

1. Environmental Sustainability – Whole Systems Integration
2. Green Infrastructure and LID (Low Impact Development)
3. Placemaking and Quality Public Realm
4. User Experience and Educational Programming
5. Adaptability
6. Operational Effectiveness
7. Cost Effectiveness

1.2 Report Scope

This document is an interim report that presents the technical analysis that has been undertaken, and presents infrastructure options available to UBC for how rainwater may be fundamentally managed. While this study identifies the general type and extent of rainwater management that is to be achieved, it does not specifically define rainwater management features at each site, as that selection requires site design beyond the scope of the IRMP.

This report explores the following questions and options to help UBC arrive at a preferred strategy.

Within the Main Campus;

Option 1 - Should management techniques be applied at the source to avoid increased runoff, or will UBC prefer to upgrade the storm sewer network?

Option 2 - Should management techniques be applied at the source to only those projects requiring it to avoid increased risk, or should they be applied to all future Projects where opportunity exists?

Option 3 - In the face of climate uncertainty, what extent of climate change considerations should be given to the design and sizing of management facilities?

Option 4 - Should expansion of Purcell Courts drain as previously planned into the Main Campus, or should the expansion area be directed into the Innovation Precinct area?

Within Innovation Precinct;

Option 1 – Should centralized stormwater management facilities be applied, or should smaller, highly distributed facilities be created?

Option 2 – What is the preferred combination between disposal facilities and temporary storage?

Option 3 – Should Innovation Precinct use injection wells, or recharge basins, for disposal to ground?

Option 4 – Should the existing infiltration ditch adjacent to Lot H be retrofitted, or left as is and supplemented?

Option 5 – What are the options for how the GEID Reservoir Emergency Overflow can be integrated into Innovation Precinct?

1.3 Performance Criterion

The following performance criterion has been applied:

1. For established drainage systems, the minimum criterion is to avoid increased flood risk over current conditions.
2. Storm sewers are evaluated for a 1:5 year return period event, with consideration for climate change.
3. Major flow routes are evaluated for a 1:100 year return period event, with consideration for climate change.
4. Management techniques applied to lands within the catchment of the existing pond will be assessed based on the potential impact to the existing pond (i.e. Increased flood risk, or decreased annual water supply).
5. Rainwater disposal is required for all events up to and including the 1:100 year event, with consideration for climate change.

2 Land Use and Project Definition

2.1 Existing Conditions

To represent the existing land use condition, existing topographic mapping and available engineering records from UBC were used to delineate catchment boundaries. Aerial photographs and GIS tools were used to delineate and measure land cover types, such as roof tops, paving, and landscaping. For analysis, refined delineations are used; however, for the purposes of reporting herein only a summary of existing land uses and primary catchments are presented in Figure 1. There is particular interest in the potential effect on the hydrology of the existing pond; therefore, the catchment area to the existing pond is specifically noted separate from those lands not tributary to the existing pond.

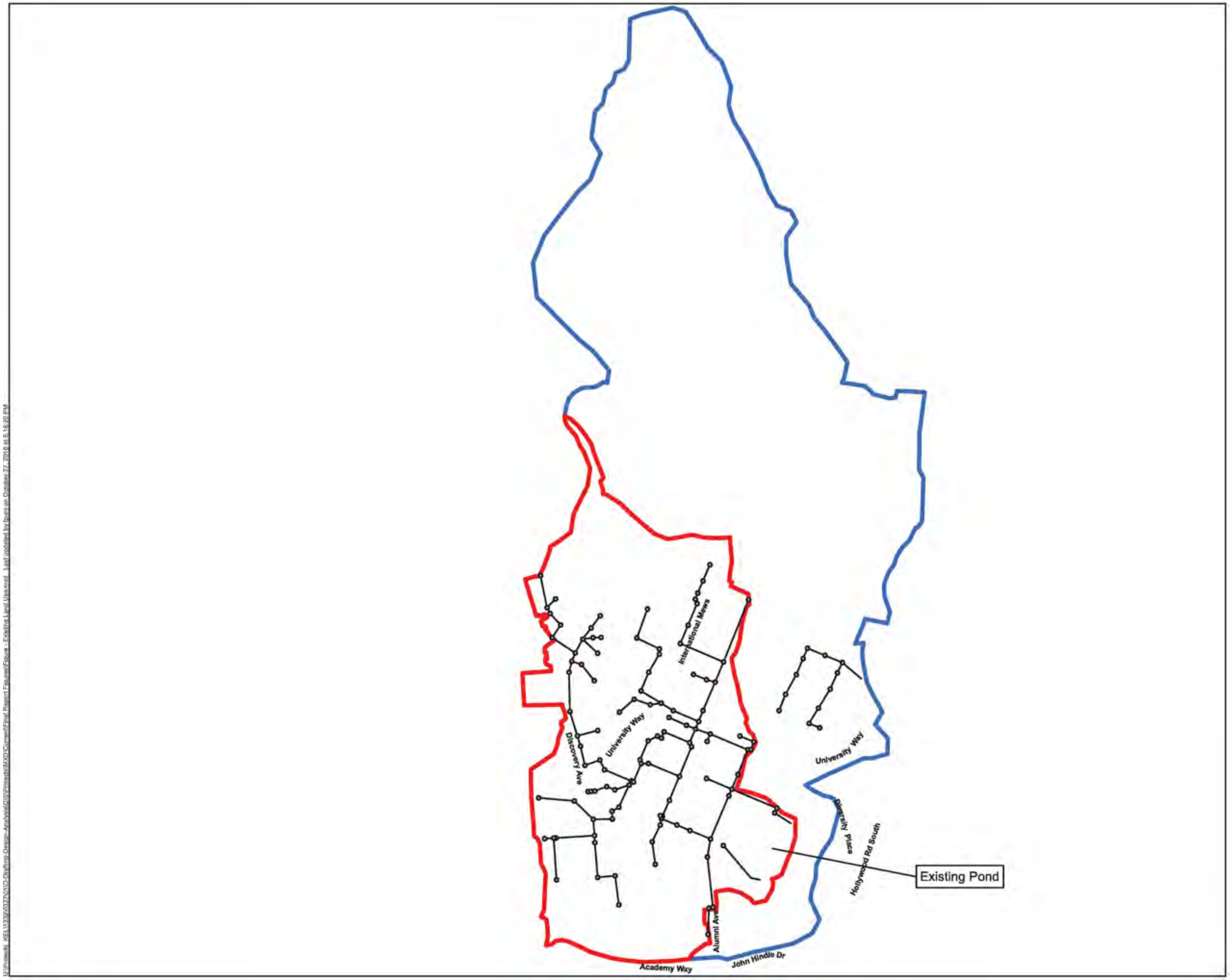
The offsite golf course to the north has been included in the catchment area because topography suggests the potential for runoff to enter UBC property, and there is no known drainage infrastructure that would direct runoff elsewhere. However, analysis conducted does not identify any significant runoff from the golf course entering UBC property, therefore will not influence infrastructure decisions.

It is known that dry wells exist in the Upper Campus Parking Lot and in Parking Lot H; however, quantifying the performance of these dry wells is not possible without conducting field tests. There are no other known rainwater management features at the site level. For the purposes of assessment, it has been assumed that all existing impervious surfaces are directly connected to the storm sewer system. Storm sewer performance is highly sensitive to catchment delineation and the assumed location where each catchment enters the system. Best available information has been used, but assumptions had to be made which may result in some irregularities against true conditions. Extensive field work beyond the scope of this study would be required to validate or refute assumption. That effort is perhaps warranted only if the results presented herein for the existing system show patterns that are significantly not consistent with observations during heavy rainfall events.

2.2 Future Projects

UBC has identified a number of future Projects across the main campus, as well as future growth in the northern portion of the property referred to Innovation Precinct. The location and boundaries of each Project is presented in Figure 2. In most cases, UBC has previously developed concept figures of each Project. Where they exist, they have been integrated into Figure 2 and used to estimate future impervious and pervious areas. We understand that these are preliminary and may be subject to change; however, it is the best available information at this time.

UBC is yet to undertake a land use planning process for the Innovation Precinct area, however has identified the anticipated boundaries of the development cells, which are also shown in Figure 2. Specific land use within each cell is not yet known, however it is expected to have a high impervious area. For the



IRMP

Existing Land Use & Primary Catchments

Legend

- Existing Manholes
- Existing Storm Sewers
- Catchment External to Existing Pond
- Catchment to Existing Pond
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 50 100 200 300
Metres

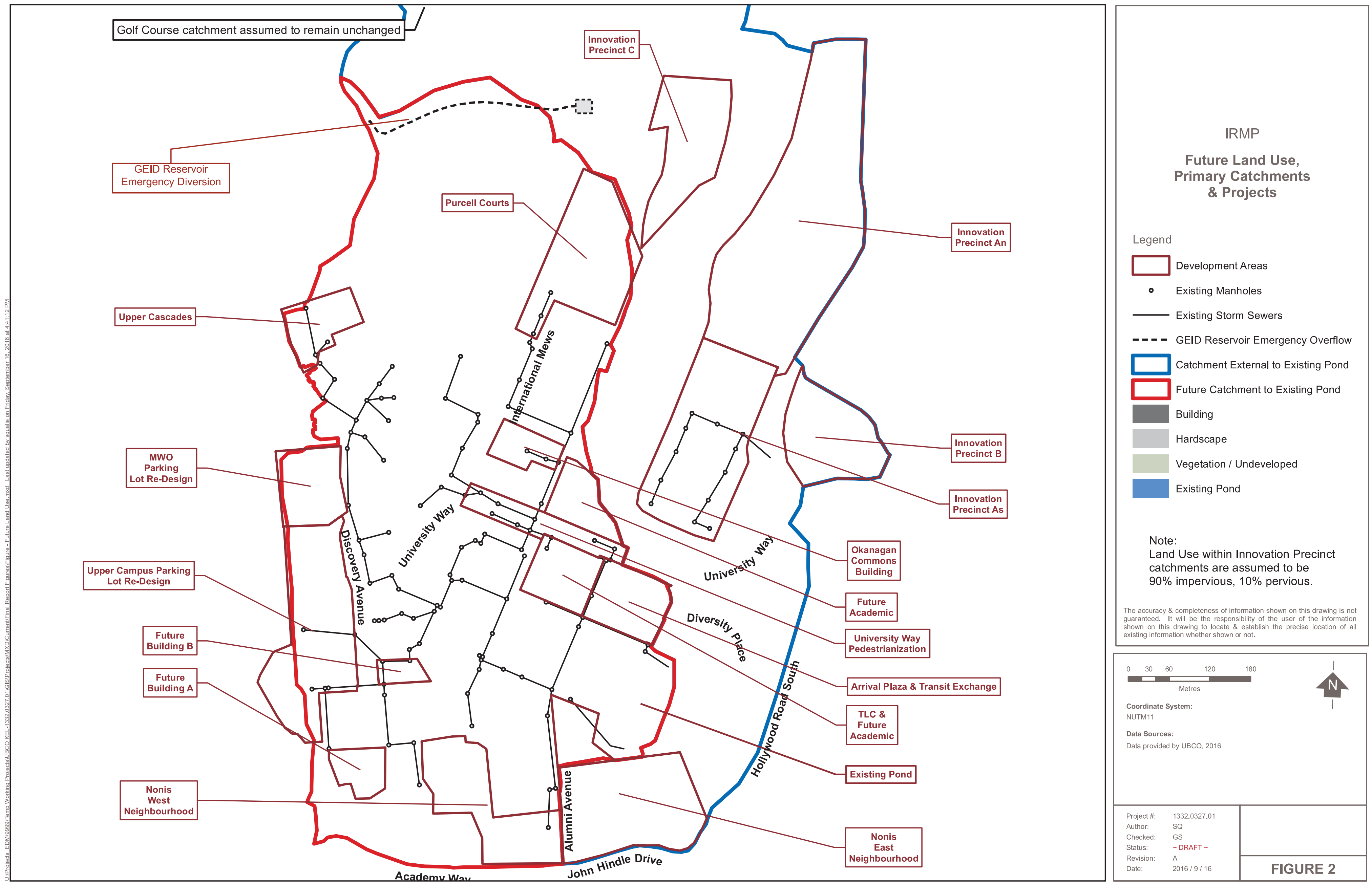
N

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ DRAFT ~
Revision:	A
Date:	2016 / 10 / 27

FIGURE 1



Golf Course catchment assumed to remain unchanged
Innovation Precinct C
GEID Reservoir Emergency Diversion
Purcell Courts
Innovation Precinct An
Upper Cascades
International Mews
MWO Parking Lot Re-Design
Innovation Precinct B
Innovation Precinct As
University Way
Discovery Avenue
Upper Campus Parking Lot Re-Design
Okanagan Commons Building
University Way
Future Academic
Diversity Place
University Way Pedestrianization
Future Building B
Future Building A
Arrival Plaza & Transit Exchange
Hollywood Road South
TLC & Future Academic
Existing Pond
Alumni Avenue
Nonis West Neighbourhood
Nonis East Neighbourhood
Academy Way
John Hindle Drive
IRMP
Future Land Use, Primary Catchments & Projects
Legend
Development Areas
Existing Manholes
Existing Storm Sewers
GEID Reservoir Emergency Overflow
Catchment External to Existing Pond
Future Catchment to Existing Pond
Building
Hardscape
Vegetation / Undeveloped
Existing Pond
Note:
Land Use within Innovation Precinct catchments are assumed to be 90% impervious, 10% pervious.
The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.
0 30 60 120 180
Metres
N
Coordinate System:
NUTM11
Data Sources:
Data provided by UBCO, 2016
Project #: 1332.0327.01
Author: SQ
Checked: GS
Status: ~ DRAFT ~
Revision: A
Date: 2016 / 9 / 16
FIGURE 2

purposes of analysis, it is assumed at this time that all development future cells of Innovation Precinct will have 90% impervious cover and 10% pervious cover.

2.3 Initial Screening of Future Projects in Main Campus

Rainwater management requirements for Future Projects within the Main Campus are varied and different than required in the Innovation Precinct.

As noted in Section 1.3 Performance Criteria, for established drainage systems the minimum criterion is to avoid increased flood risk over current conditions. This is the baseline on which to determine if a minimum level of site management techniques must be applied, or whether they are deemed optional.

Whether or not a Project is anticipated to result in a negative impact on existing systems is determined by whether or not the Project area currently drains to the established drainage system, and the degree to which directly connected impervious surface changes. If the catchment area increases, it can be expected that additional runoff will be generated. If the future Project condition results in a higher degree of directly connected impervious surface than the current condition, then it can be expected that additional runoff will be generated.

Prior to conducting detailed analysis, an initial screening of future Projects in the Main Campus was undertaken, a summary of which is presented in Table 2.1. In some cases, a Future Project is represented by a single sub-catchment, but in other cases a Future Project is represented by a series of sub-catchments. The cumulative effect of each Project is highlighted in bold text and shaded grey in Table 2.1. So, while Table 2.1 does present the results for each sub-catchment of each Project, focus should be placed on the cumulative totals.

The boundary of each Future Project, and therefore the sub-catchment area, is selected by Urban Systems for assessment purposes and does not necessarily match UBC's concept. The assessment is based on a "current" to "future" comparison within the defined boundaries presented herein.

There are 14 Projects identified within the Main Campus (excluding Innovation Precinct), and 13 of these are tributary to the existing pond (excluding most of Nonis Neighbourhood East).

Based on interpretation and measurement of available concept figures, the following Projects are expected to yield a **smaller** impervious surface over existing conditions, and deemed to not result in a negative impact even if the impervious surfaces are directly connected to the drainage system (assuming again that the current impervious surface is directly connected):

- Upper Cascades
- Upper Campus Parking Lot (subject to maintaining the existing catchment boundaries. A northern portion of the existing parking lot current drains off campus to the west. In addition, the drainage divide of the John Hindle Drive has not been specified in the concepts provided to date.)
- University Way Pedestrianization
- Nonis Neighbourhood East (potion not tributary to existing pond)

Table 2.1
Initial Screening of Projects in Main Campus for site management requirements

Project Area	Future Sub-Catchment	Future Sub-Catchment Area (ha)	%Impervious		Does this area currently connect to the ponds drainage system?	Potential net impact? (assumes existing impervious area is directly connected)	Is site management techniques mandatory to avoid no increased impact?	Estimated pervious area of Sub-Catchment (m2)	Apparent sufficient pervious area for no net impact (assumes 100% utilization of pervious)?	Apparent sufficient pervious area for no net impact (assumes 50% utilization of pervious)?
			Existing	Future						
Upper Cascades	C-93	0.46	75	62	yes	no	no	1,747	yes	yes
Upper Cascades	C-91	0.26	93	95	yes	no	no	133	yes	yes
Upper Cascades		**0.71**	**82**	**74**	**yes**	**no**	**no**	**1,880**	yes	yes
Mountain Weather Office	**C-103**	**1.00**	**37**	**72**	**indirectly**	**yes**	**yes**	**2,846**	yes	**no**
Upper Campus Parking Lot	C-104	1.63	95	82	partially	yes	yes	2,981	yes	yes
Upper Campus Parking Lot	C-151	0.77	80	74	yes	no	no	1,999	yes	yes
Upper Campus Parking Lot	C-121s	0.18	38	53	yes	yes	yes	854	yes	yes
Upper Campus Parking Lot	C-121	0.48	29	29	yes	no	no	3,378	yes	yes
Upper Campus Parking Lot		**3.06**	**78**	**70**	**partially**	**no**	**yes (see note 4)**	**9,212**	yes	yes
Nonis Neighbourhood West	C-146	0.81	54	46	yes	no	no	4,381	yes	yes
Nonis Neighbourhood West	C-146a	0.32	9	64	yes	yes	yes	1,150	yes	no
Nonis Neighbourhood West	C-156	0.65	10	100	yes	yes	yes	12	no	no
Nonis Neighbourhood West		**1.78**	**30**	**69**	**yes**	**yes**	**yes**	**5,543**	yes	**no**
Nonis Neighbourhood East (portion tributary to existing pond)	**C-171**	**0.40**	**19**	**79**	**yes**	**yes**	**yes**	**829**	yes	yes
Future Building B	**C-155**	**0.20**	**4**	**94**	**yes**	**yes**	**yes**	**113**	**no**	**no**
TLC & Future Academic	C-39	0.25	85	98	yes	yes	yes	61	yes	no
TLC & Future Academic	C-149	0.20	43	99	yes	yes	yes	20	no	no
TLC & Future Academic	C-141	0.14	2	95	yes	yes	yes	64	no	no
TLC & Future Academic	C-77	0.16	69	91	yes	yes	yes	146	yes	yes
TLC & Future Academic	C-142	0.35	64	66	yes	no	no	1,184	yes	yes
TLC & Future Academic		**1.09**	**58**	**86**	**yes**	**yes**	**yes**	**1,475**	yes	yes
Okanagan Commons Building	**C-78**	**0.50**	**8**	**83**	**yes**	**yes**	**yes**	**864**	yes	**no**
Future Academic - Building Surround	C-71	0.36	82	92	yes	yes	yes	269	yes	yes
Future Academic - Building	C-71a	0.34	84	100	yes	yes	yes	0	no	no
Future Academic		**0.70**	**83**	**96**	**yes**	**yes**	**yes**	**269**	yes	yes
Arrival Plaza & Transit Exchange	**C-165**	**0.94**	**76**	**80**	**partially**	**yes**	**yes**	**1,848**	yes	yes
Purcell Courts (future expansion)	C-163	0.80	1	64	no	yes	yes	2,883	yes	yes
Purcell Courts (future expansion)	C-162	1.49	1	63	no	yes	yes	5,477	yes	yes
Purcell Courts		**2.29**	**1**	**63**	**yes**	**yes**	**yes**	**8,360**	yes	yes
University Way Pedestrianization	C-131w	0.40	73	60	yes	no	no	1,630	yes	yes
University Way Pedestrianization	C-131e	0.46	74	71	yes	no	no	1,330	yes	yes
University Way Pedestrianization		**0.86**	**73**	**66**	**yes**	**no**	**no**	**2,960**	yes	yes
University Centre Building	C-21	0.28	100	100	yes	no	no	0	**n/a**	**n/a**
Fipke Centre Building	C-22	0.32	100	100	yes	no	no	0	**n/a**	**n/a**
Future Building A	**C-147**	**0.49**	**36**	**62**	**yes**	**yes**	**yes**	**1,836**	yes	yes
Nonis Neighbourhood East (portion not tributary to existing pond)	**C-164**	**2.97**	**43**	**43**	**no**	**no**	**no**	**16,794**	yes	yes

Note 1: The estimated pervious area is measured from concept drawings provided by UBC. They are understood to be preliminary and subject to change.

Note 2: The Fipke Centre and University Centre buildings are noted because of the potential interest to reroute the roof drainage into the University Way Pedestrianization.

Note 3: The assessment of whether there is sufficient pervious surface is based on applying 200 mm of depression storage. 200 mm of storage on 50% of the pervious area is hydrologically equivalent to 100 mm of storage on 100% of the pervious area.

Note 4: For the Upper Campus Parking Lot, only those portions of the project that are proposed to be redirected into the established main campus drainage system is required to apply site management.

Therefore, there requirement for site specific management techniques is considered optional. However, should new concepts suggest an impervious surface greater than the existing condition, site specific management techniques will be required to the degree that impervious surface exceeds existing levels.

The remaining 10 Projects are expected to yield a larger impervious surface over existing conditions, and therefore are deemed to results in a negative impact if the impervious surface were to be directly connected to the drainage system. These Projects require site specific management techniques to the degree that the impervious surface exceeds existing levels. Projects requiring site management versus those that may be deemed optional are highlighted in Figure 3.

Still referring to Table 2.1, the pervious area for each future Project was estimated and gauged whether or not if it is apparent that the area would be sufficient to achieve the minimum "no-net-impact" criterion. This was determined based on the relative change in impervious area from existing to future, and also based on the effective utilization of the available pervious area. It is often not practical to design a site for 100 % utilization. While listed in theory, an assessment is also conducted assuming 50% utilization. We suggest that 50% utilization be the most likely scenario for planning purposes. Site specific design is required to demonstrate that more can be achieved. Note 3 at the bottom of Table 2.1 describe the assumption of the evaluation.

Based on initial screening, and assuming practical utilization of only 50% of the sites pervious area for rainwater management, the following four Future Project sites are anticipated to be insufficient to avoid increased rainwater runoff during a 1:5 year and/or 1:100 year design event:

Mountain Weather Office – In this case a portion of the Mountain Weather Office does connect to the drainage system of the Main Campus, but the impervious surface does not connect directly to the storm sewer. It is understood that current concepts for the site involve directing runoff into the existing system. In order for the site to avoid any negative impact this site will need to apply site controls to prevent direct connection of impervious surface. Initial screening suggests there is sufficient pervious space available provided more than 50% of it is used for LID.

Nonis Neighbourhood West - Concepts suggest a significant increase in impervious area and the assessment suggests there is insufficient pervious area if only 50% is effectively used.

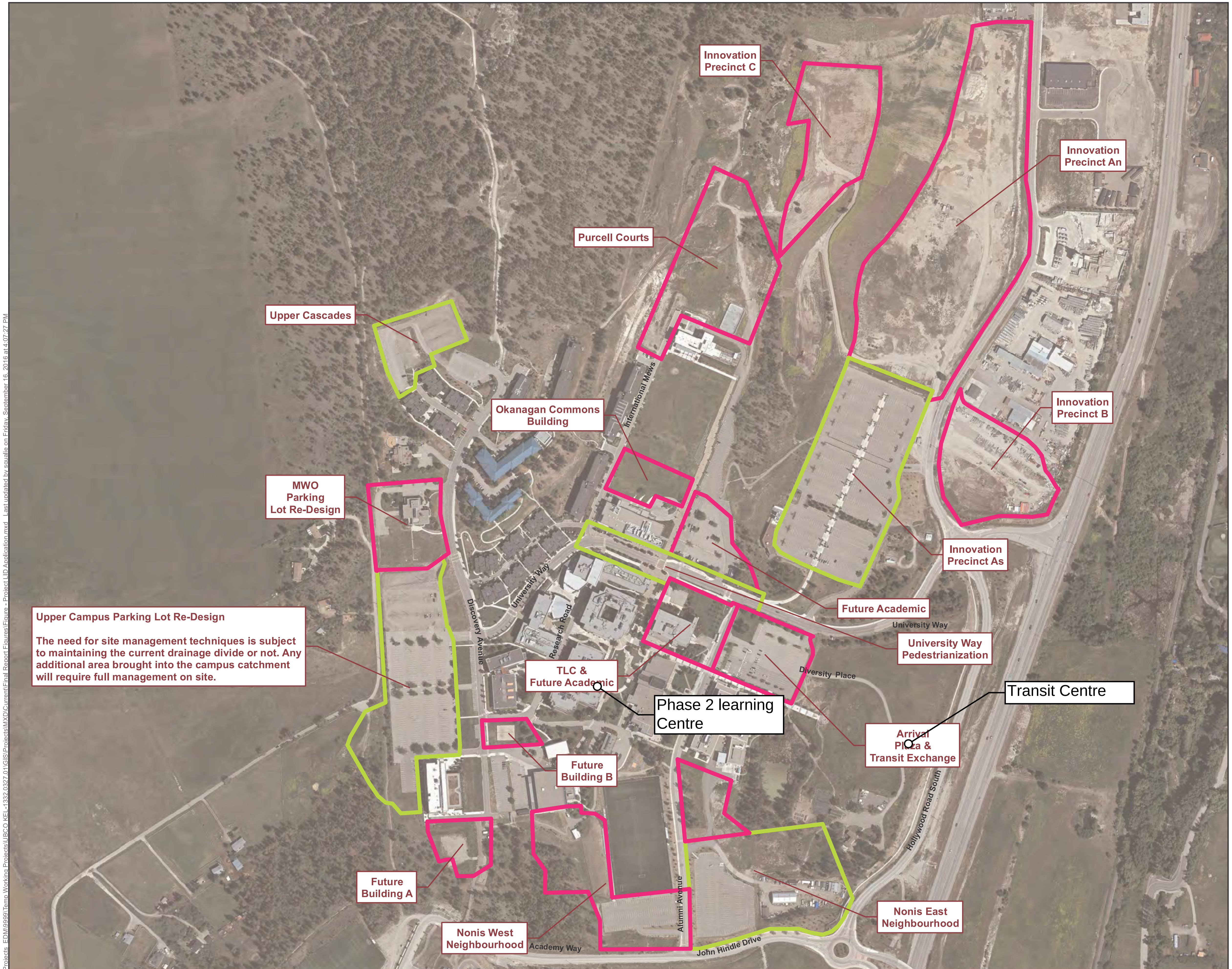
Future Building B - Concepts suggest a significant increase in impervious area and the assessment suggests there is insufficient pervious area if only 50% is effectively used.

Okanagan Commons Building - Concepts suggest a significant increase in impervious area and the assessment suggests there is insufficient pervious area if only 50% is effectively used.

Note that the initial screen assessment is based on utilization of pervious area within the boundary of the Project. The option exists to look to additional pervious area adjacent to the Project area to supplement that available within the Project boundary.

2.4 Initial Screening of Disposal Options in Innovation Precinct

A figure depicting the Innovation Precinct area is presented in Figure 4. Innovation Precinct is unique from the Main Campus in that it is largely undeveloped (with exception to Parking Lot H), and it has significantly different soil infiltration parameters. In particular, it has an accessible aquifer with



OKANAGAN

IRMP

Application of Site Management Techniques to Future Projects

Legend

Future Projects

These Project sites require site management techniques to avoid impact over current conditions

These Project sites do not require site management techniques to avoid impact over current conditions

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information before shown or not.

0 30 60 120 180

Metres

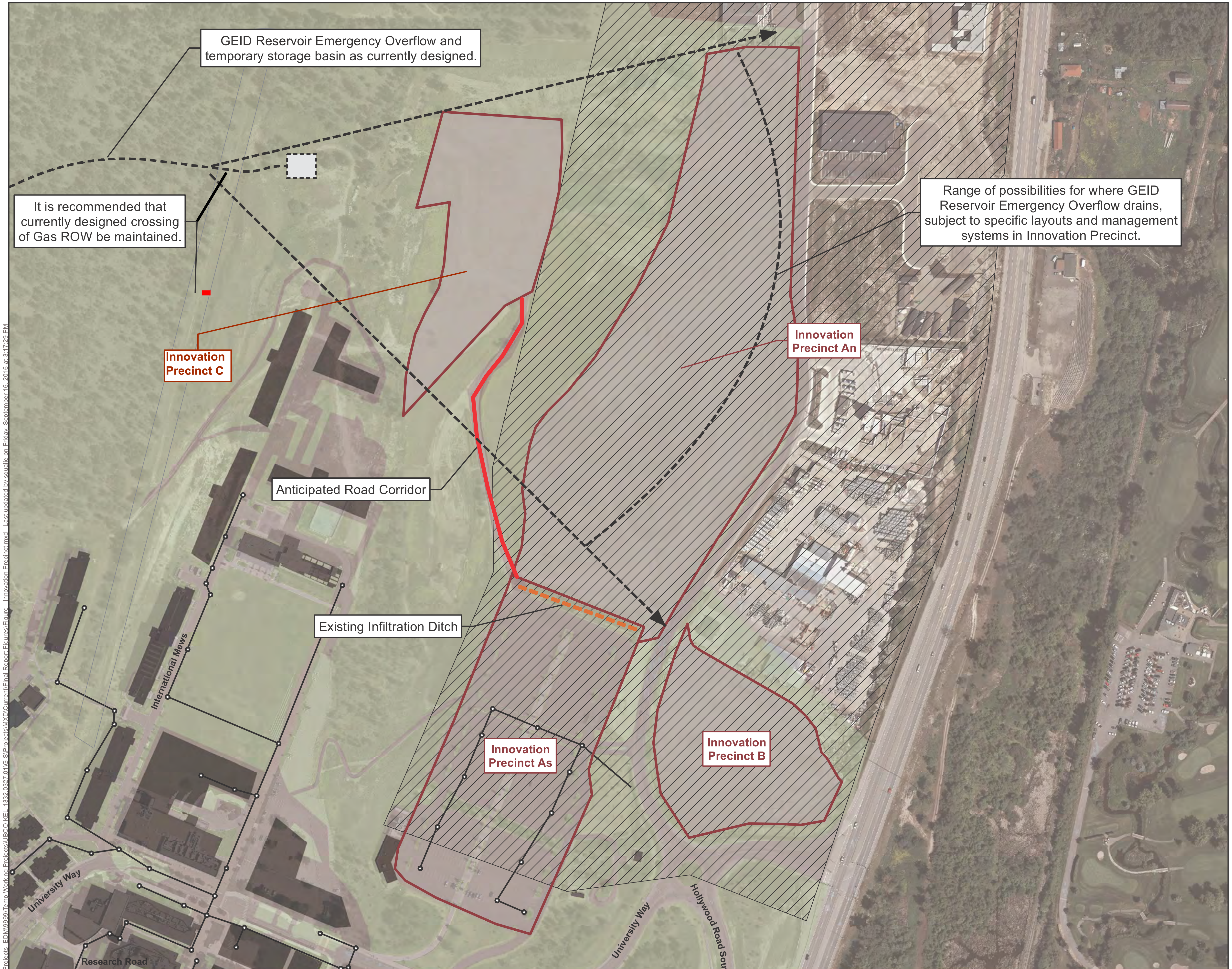
N

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #: 1332.0327.01
Author: SQ
Checked: GS
Status: ~ DRAFT ~
Revision: A
Date: 2016 / 9 / 16

FIGURE 3



UBC OKANAGAN

IRMP

Innovation Precinct

Legend

- Development Areas
- Existing Manholes
- Existing Storm Sewers
- Building
- Hardscape
- Vegetation / Undeveloped
- Zone of Rapid Infiltration

Note:
Innovation Precinct Developed cells are assumed to be 90% impervious and 10% pervious.

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 20 40 80 120
Metres

N

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
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Checked:	GS
Status:	~ DRAFT ~
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Date:	2016 / 9 / 16

URBAN systems

FIGURE 4

exceptional recharge capacity provided that the top three meters of less permeable soils are penetrated. Piteau has recommended a design rate of 7,000 mm (vertical) per day for the underlying aquifer.

Parking Lot H is a 3.4 hectare paved area which is partially served by a series of dry wells, and supplemented with an “infiltration ditch” located along the northern edge of the parking lot. This “infiltration ditch” is known to overtop its bank and is slow draining. In fact, portions of the ditch hold water for extended periods and do not infiltrate. In general, this “infiltration ditch” is undersized for the area it services and is not functioning as intended. It is anticipated that its performance is influenced by soils being less permeable than perhaps thought by the designers, and sealing off of the soils due to fine particles contained within the parking lot runoff and from snow removal processes.

Also shown in Figure 4 is an emergency overflow from the GEID reservoir. It was previously proposed that an HDPE overflow pipe be installed down the slope to a temporary basin excavated at the location shown in Figure 4 until such time that planning of Innovation Precinct got underway. Now with development plans advancing for Innovation Precinct, there is an opportunity to integrate that overflow and disposal into the Plan area. The recommended basin volume in Urban Systems August 9, 2011 memo was 1,150 m^3. The pipe alignment to the point where is crosses the existing GAS right-of-way remains to be the recommended location, however once east of the GAS right-of-way there is flexibility in where this system flows. We recommend that a conveyance system continue east, either in the pipe or a properly designed open channel system, to a storage and disposal facility ultimately identified for development of Innovation Precinct. There is a lot of flexibility in how and where that occurs. It is only constrained by topography; to make sure that the route selected flows downhill, and the discharge point can manage and dispose of 1,150 m^3 of water at a maximum flow rate of 0.19 m^3/s. This is further explored in Section 5 of this report.

Piteau Associates conducted analysis as part of their dedicated geotechnical study to identify two approaches to stormwater disposal to the underlying aquifer in Innovation Precinct; a recharge basin and an injection well. Both approaches require penetration of the lower permeability surface soils. The depth of these surface soils varies, but in general they are estimated to be 3 meters thick. This is a realistic thickness to excavate, however it can amount to a significant volume of spoil and cost if this excavation occurs over a large area. Within a 24 hour period, each square meter of exposed aquifer can dispose of 7 m^3 of water, which is the design value to be used in sizing a recharge basin.

The second method of disposal is through injection wells, and Piteau has recommended a design recharge rate of 0.035 m^3/s per 200 mm diameter well. Piteau has also recommended a minimum spacing of 50 meters between wells to prevent groundwater mounding and potential negative effects.

Despite the aquifers high infiltration rate, it is still far below peak runoff rates generated by impervious surfaces during design storms. One approach would be to size and position recharge systems capable of matching the peak runoff rate from the impervious surfaces. The second approach would be to size and position recharge systems capable of disposing the runoff volume within a reasonable time frame, and to provide temporary storage when runoff rates exceed the recharge rate. For the temporary storage option this initial assessment has assumed that disposal of the runoff volume would occur over a 24 hour period.

An initial screening assessment of the noted disposal options is presented in Tables 2.2 and 2.3 for the Injection Wells and Tables 2.4 and 2.5 for the Recharge Basin on the following pages. The observations reached from this initial screening is as follows:

Table 2.2 - 1:5 Year Injection Well Disposal

Development Cell	Development Area (ha)	Assumed Future Impervious Fraction (%)	Precipitation Depth (mm)	Precipitation Volume (m3)	Future Runoff Coefficient	Future Runoff Volume (m3) (note 3)	Future Peak Runoff Rate (m3/s)	Maximum number of injection wells (see note 1)	Area required for wells (2500 m2 per well) (see note 2)	Disposal volume in 24 hours per injection well	Number of wells with temporary storage	Temporary Storage Volume (see note 5)	Pond Area assuming average 1.5 m deep (m2)	Pond area as percent of catchment
Existing Kelowna IDF														
Innovation Precinct An	6.5	90	17.91	1,166	0.83	968	0.45	13	32,143	3,024	1	488	325	0.5%
Innovation Precinct As - Lot H	3.4	95	17.91	603	0.88	528	0.35	10	25,000	3,024	1	253	168	0.5%
Innovation Precinct B	1.7	90	17.91	305	0.83	252	0.16	5	11,429	3,024	1	128	85	0.5%
Innovation Precinct C	1.8	90	17.91	326	0.83	269	0.22	6	15,714	3,024	1	137	91	0.5%
Totals	**13.4**			**2,401**	**0.84**	**2,017**	**1.18**	**34**	**84,286**	**3,024**	**1**	**1,005**	**670**	**0.5%**
Full Ensemble IDF												(see note 6)		
Innovation Precinct An	6.5	90	23.63	1,538	0.85	1,314	0.71	20	50,714	3,024	1	814	542	0.8%
Innovation Precinct As - Lot H	3.4	95	23.63	796	0.89	712	0.52	15	37,143	3,024	1	421	281	0.8%
Innovation Precinct B	1.7	90	23.63	403	0.85	342	0.23	7	16,429	3,024	1	213	142	0.8%
Innovation Precinct C	1.8	90	23.63	431	0.85	366	0.31	9	22,143	3,024	1	228	152	0.8%
Totals	**13.4**			**3,168**	**0.86**	**2,734**	**1.77**	**51**	**126,429**	**3,024**	**1**	**1,676**	**1,117**	**0.8%**
MICRO5 IDF												(see note 7)		
Innovation Precinct An	6.5	90	27.73	1,805	0.87	1,574	0.89	25	63,571	3,024	1	1,041	694	1.1%
Innovation Precinct As - Lot H	3.4	95	27.73	934	0.91	848	0.63	18	45,000	3,024	1	539	359	1.1%
Innovation Precinct B	1.7	90	27.73	473	0.87	411	0.28	8	20,000	3,024	1	273	182	1.1%
Innovation Precinct C	1.8	90	27.73	505	0.87	439	0.38	11	27,143	3,024	1	292	194	1.1%
Totals	**13.4**			**3,717**	**0.88**	**3,272**	**2.18**	**62**	**155,714**	**3,024**	**2**	**2,145**	**1,430**	**1.1%**

Table 2.3 - 1:100 Year Injection Well Disposal

Development Cell	Development Area (ha)	Assumed Future Impervious Fraction (%)	Precipitation Depth (mm)	Precipitation Volume (m3)	Future Runoff Coefficient	Future Runoff Volume (m3) (note 3)	Future Peak Runoff Rate (m3/s)	Maximum number of injection wells (see note 1)	Area required for wells (2500 m2 per well) (see note 2)	Disposal volume in 24 hours per injection well	Number of wells with temporary storage	Temporary Storage Volume (see note 5)	Pond Area assuming average 1.5 m deep (m2)	Pond area as percent of catchment
Existing Kelowna IDF														
Innovation Precinct An	6.5	90	47.66	3,102	0.90	2,801	1.14	33	81,429	3,024	1	1,432	955	1.5%
Innovation Precinct As - Lot H	3.4	95	47.66	1,605	0.93	1,493	0.91	26	65,000	3,024	1	741	494	1.5%
Innovation Precinct B	1.7	90	47.66	813	0.90	731	0.37	11	26,429	3,024	1	375	250	1.5%
Innovation Precinct C	1.8	90	47.66	869	0.90	783	0.56	16	40,000	3,024	1	401	267	1.5%
Totals	**13.4**			**6,389**	**0.91**	**5,825**	**2.98**	**85**	**212,857**	**3,024**	2	**2,949**	**1,966**	**1.5%**
Full Ensemble IDF												(see note 6)		
Innovation Precinct An	6.5	90	50.53	3,289	0.91	3,000	1.61	46	115,000	3,024	1	1,953	1,302	2.0%
Innovation Precinct As - Lot H	3.4	95	50.53	1,702	0.95	1,624	1.26	36	90,000	3,024	1	1,010	674	2.0%
Innovation Precinct B	1.7	90	50.53	862	0.91	784	0.47	13	33,571	3,024	1	512	341	2.0%
Innovation Precinct C	1.8	90	50.53	921	0.91	842	0.61	17	43,571	3,024	1	547	365	2.0%
totals	**13.4**			**6,774**	**0.92**	**6,232**	**3.95**	**113**	**282,143**	**3,024**	**2**	**4,022**	**2,681**	**2.0%**
MICRO5 IDF												(see note 7)		
Innovation Precinct An	6.5	90	75.7	4,928	0.95	4,701	2.62	75	187,143	3,024	3	4,882	3,255	5.0%
Innovation Precinct As - Lot H	3.4	95	75.7	2,550	0.97	2,473	2.40	69	171,429	3,024	2	2,526	1,684	5.0%
Innovation Precinct B	1.7	90	75.7	1,291	0.95	1,226	0.74	21	52,857	3,024	1	1,279	853	5.0%
Innovation Precinct C	1.8	90	75.7	1,380	0.95	1,311	0.93	27	66,429	3,024	2	1,367	911	5.0%
totals	**13.4**			**10,148**	**0.96**	**9,742**	**6.69**	**191**	**477,857**	**3,024**	**6**	**10,054**	**6,703**	**5.0%**

Notes:

1. Gravity Well capacity (for 200 mm diameter) estimated at 0.035 m3/s per Piteau memo report dated July 29, 2016. This column assumes no temporary storage.
2. The area required for a well network is based on recommended 50 m spacing (2500 m2 per well)
3. Temporary storage area is based on a maximum depth of 1.5 meters and based on NO LID applied.
4. Soils overlying the aquifer in North East has an estimated K ranging from 0.09 m/day to 4.3 m/day. A huge range. For disposal facilities it is recommended that this material be removed.
5. Based on an estimated storage rate of 75 m3/ ha for 5 year and 220 m3/ha for 100 year.
6. Based on an estimated storage rate of 125 m3/ha for 5 year and 300 m3/ha for 100 year.
7. Based on an estimated storage rate of 160 m3/ha for 5 year and 750 m3/ha for 100 year.

Table 2.4 - 1:5 year Recharge Basin Disposal

Development Cell	Development Area (ha)	Assumed Future Impervious Fraction (%)	Precipitation Depth (mm)	Precipitation Volume (m3)	Future Runoff Coefficient	Future Runoff Volume (m3) (note 7)	Future Peak Runoff Rate (m3/s)	Temporary Storage Volume (see note 3)	Minimum recharge footprint area (m2) (see note 1)	Minimum temporary storage basin area (m2) (see note 6)	Total basin area as a percent of catchment
Existing Kelowna IDF											
Innovation Precinct An	6.5	90	17.91	1,166	0.83	968	0.45	488	138	187	0.5%
Innovation Precinct As - Lot H	3.4	95	17.91	603	0.88	528	0.35	253	75	93	0.5%
Innovation Precinct B	1.7	90	17.91	305	0.83	252	0.16	128	36	49	0.5%
Innovation Precinct C	1.8	90	17.91	326	0.83	269	0.22	137	38	53	0.5%
Totals	**13.4**			**2,401**	**0.84**	**2,017**	**1.18**	**1,005**	**288**	**382**	**0.5%**
Full Ensemble IDF								(see note 4)			
Innovation Precinct An	6.5	90	23.63	1,538	0.85	1,314	0.71	814	188	355	0.8%
Innovation Precinct As - Lot H	3.4	95	23.63	796	0.89	712	0.52	421	102	179	0.8%
Innovation Precinct B	1.7	90	23.63	403	0.85	342	0.23	213	49	93	0.8%
Innovation Precinct C	1.8	90	23.63	431	0.85	366	0.31	228	52	100	0.8%
Totals	**13.4**			**3,168**	**0.86**	**2,734**	**1.77**	**1,676**	**391**	**727**	**0.8%**
MICRO5 IDF								(see note 5)			
Innovation Precinct An	6.5	90	27.73	1,805	0.87	1,574	0.89	1,041	225	469	1.1%
Innovation Precinct As - Lot H	3.4	95	27.73	934	0.91	848	0.63	539	121	238	1.1%
Innovation Precinct B	1.7	90	27.73	473	0.87	411	0.28	273	59	123	1.1%
Innovation Precinct C	1.8	90	27.73	505	0.87	439	0.38	292	63	132	1.1%
Totals	**13.4**			**3,717**	**0.88**	**3,272**	**2.18**	**2,145**	**467**	**962**	**1.1%**

Table 2.5 - 1:100 Year Recharge Basin Disposal

Development Cell	Development Area (ha)	Assumed Future Impervious Fraction (%)	Precipitation Depth (mm)	Precipitation Volume (m3)	Future Runoff Coefficient	Future Runoff Volume (m3) (note 7)	Future Peak Runoff Rate (m3/s)	Temporary Storage Volume (see note 3)	Minimum recharge footprint area (m2) (see note 1)	Minimum temporary storage basin area (m2) (see note 3)	Total basin area as a percent of catchment
Existing Kelowna IDF											
Innovation Precinct An	6.5	90	47.66	3,102	0.90	2,801	1.14	1,432	400	554	1.5%
Innovation Precinct As - Lot H	3.4	95	47.66	1,605	0.93	1,493	0.91	741	213	281	1.5%
Innovation Precinct B	1.7	90	47.66	813	0.90	731	0.37	375	104	146	1.5%
Innovation Precinct C	1.8	90	47.66	869	0.90	783	0.56	401	112	156	1.5%
Totals	**13.4**			**6,389**	**0.91**	**5,825**	**2.98**	**2,949**	**832**	**1,134**	**1.5%**
Full Ensemble IDF										(see note 4)	
Innovation Precinct An	6.5	90	50.53	3,289	0.91	3,000	1.61	1,953	429	873	2.0%
Innovation Precinct As - Lot H	3.4	95	50.53	1,702	0.95	1,624	1.26	1,010	232	442	2.0%
Innovation Precinct B	1.7	90	50.53	862	0.91	784	0.47	512	112	229	2.0%
Innovation Precinct C	1.8	90	50.53	921	0.91	842	0.61	547	120	244	2.0%
Totals	**13.4**			**6,774**	**0.92**	**6,232**	**3.95**	**4,022**	**890**	**1,791**	**2.0%**
MICRO5 IDF										(see note 5)	
Innovation Precinct An	6.5	90	75.7	4,928	0.95	4,701	2.62	4,882	672	2,583	5.0%
Innovation Precinct As - Lot H	3.4	95	75.7	2,550	0.97	2,473	2.40	2,526	353	1,331	5.0%
Innovation Precinct B	1.7	90	75.7	1,291	0.95	1,226	0.74	1,279	175	677	5.0%
Innovation Precinct C	1.8	90	75.7	1,380	0.95	1,311	0.93	1,367	187	724	5.0%
Totals	**13.4**			**10,148**	**0.96**	**9,742**	**6.69**	**10,054**	**1,392**	**5,311**	**5.0%**

Notes:

1. Recharge basin is based on capacity of 7 m/day per Piteau memo report dated July 29, 2016. This assumes infiltration over 24 hours. However, assume an average 1.5 meters of ponding depth.
2. Soils overlying the aquifer in North East has an estimated K ranging from 0.09 m/day to 4.3 m/day. A huge range. For disposal facilities it is recommended that this material be removed.
3. Based on an estimated storage rate of 75 m3/ha for 5 year and 220 m3/ha for 100 year.
4. Based on an estimated storage rate of 125 m3/ha for 5 year and 300 m3/ha for 100 year.
5. Based on an estimated storage rate of 160 m3/ha for 5 year and 750 m3/ha for 100 year
6. Size of temporary storage basin based on an average of 1.5 meters deep and excludes the area of the recharge area. The recharge basin volume counts towards temporary storage.
7. Runoff volume assumes NO LID is applied to the development cells.

1. The anticipated high impervious surface within Innovation Precinct is expected to generate significant peak runoff rates and volumes. It is possible to apply site controls to lessen the runoff, which will be discussed in later sections of this report. Lessening the runoff rates and volumes will have a direct effect on the temporary storage and disposal systems and associated costs.
2. It is not practical to install injection wells or a recharge basin that can keep pace with the peak runoff rate. To some degree temporary storage of runoff should be provided and disposed over time. Sizing will be governed by the 1:100 year 24 hour storm event.
3. The disposal capacity of a 200 mm diameter injection well is equivalent to a recharge basin that is 432 m^2 in area. Both offer a disposal rate of 0.035 m^3/s (3,024 m^3 per day). A recharge basin requires stripping the less permeable surface soils that are estimated to be 3 meters thick. Therefore, a basin of this size will require the stripping and disposal of 1,300 m^3. This would result in a basin 3 meters deep, which may be deeper than desired. As such, import of coarse granular material may be desired to shallow up the basin somewhat. It is anticipated that perhaps 1 meters of infill be used (432 m^3), leaving an open basin that is 2 meters deep.
4. The area required for the temporary storage is also directly related to the maximum storage depth and bank geometry (if an open basin), which are variables UBC is free to choose. However, for an open basin, storage depths are typically in the range of 1 to 2 meters. Sizing herein is based on an average depth of 1.5 meters.
5. It would appear reasonable to suggest 2 to 3 recharge wells could be used to service the total area provided temporary storage is used. The optimal combination and the choice as to whether to use a single communal facility or multiple will be explored further in Section 4 and 5 of this report.
6. Climate change predictions appear to have a significant impact on the runoff rates and volumes, and therefore the sizing of the disposal facilities. Climate change predictions applied are conservative, in particularly the MICRO5. There also remains uncertainty in those predictions. Unlike established systems in the main campus, Innovation Precinct is planning from scratch which offers a more costs effective opportunity to accommodate the future. The decision for UBC is to determine what level of conservatism to apply today for uncertain predictions of 50+ years into the future.

Based on the above, comprehensive hydrodynamic modeling was undertaken as described in Section 3.

3 Hydrodynamic Modeling

3.1 Defining Single Event Storms

Design storms for single-event modeling were generated from IDF (Intensity Duration Frequency) curves. Each of these single-event storms (duration, pattern, and return period) were generated based on historic values and then re-generated using IDF curves that reflect projected climate change. The IDF curves were created using the IDF CC Tool[1].

The IDF CC Tool uses an historical IDF data set in combination with results from one or more (Global Climate Model) GCMs to generate IDF curves for select future conditions. For the purposes of this study, curves were generated for the following conditions:

- Historical IDF data from ECCC Station “Kelowna A” (ID 1123970) for the period 1969-2004
- RCP 8.5 (no expected reduction in greenhouse gas emissions)
- Time horizon of 2040 to 2070

Two sets of IDF curves were generated for climate change sensitivity analyses using:

- the average values generated from all 24 GCMs used by the tool, and
- the MIROC5 Run 1 values (GCM that produced the highest intensity results)

Note that “Run 1” of the MIROC5 GCM was used for this purpose since it represents the highest intensities of the three runs used by the IDF CC Tool. Tables 3.1 through 3.3 summarize the statistical IDF equations for all three sets of IDF curves – historical, Full Ensemble Average, and MIRCO5 Run 1. Graph 3.1 shows the comparison between the curves from each scenario.

<u>Historical</u>

$$I = AT^b$$

Where: I = rainfall intensity [mm/hr]
T = rainfall event duration [hours]
A and b are as shown below

[1] http://www.idf-cc-uwo.ca

Table 3.1 - Historical (Existing) Kelowna IDF

Return Period (Years)	2	5	10	25	50	100
Coefficient (A)	8.9	12.2	14.5	17.3	19.3	21.4
Exponent (b)	-0.685	-0.723	-0.738	-0.753	-0.761	-0.767

Future

$I = A(T+t_0)^b$

Where: I = rainfall intensity [mm/hr]

T = rainfall event duration [hours]

A, b, and t_0 are as shown below

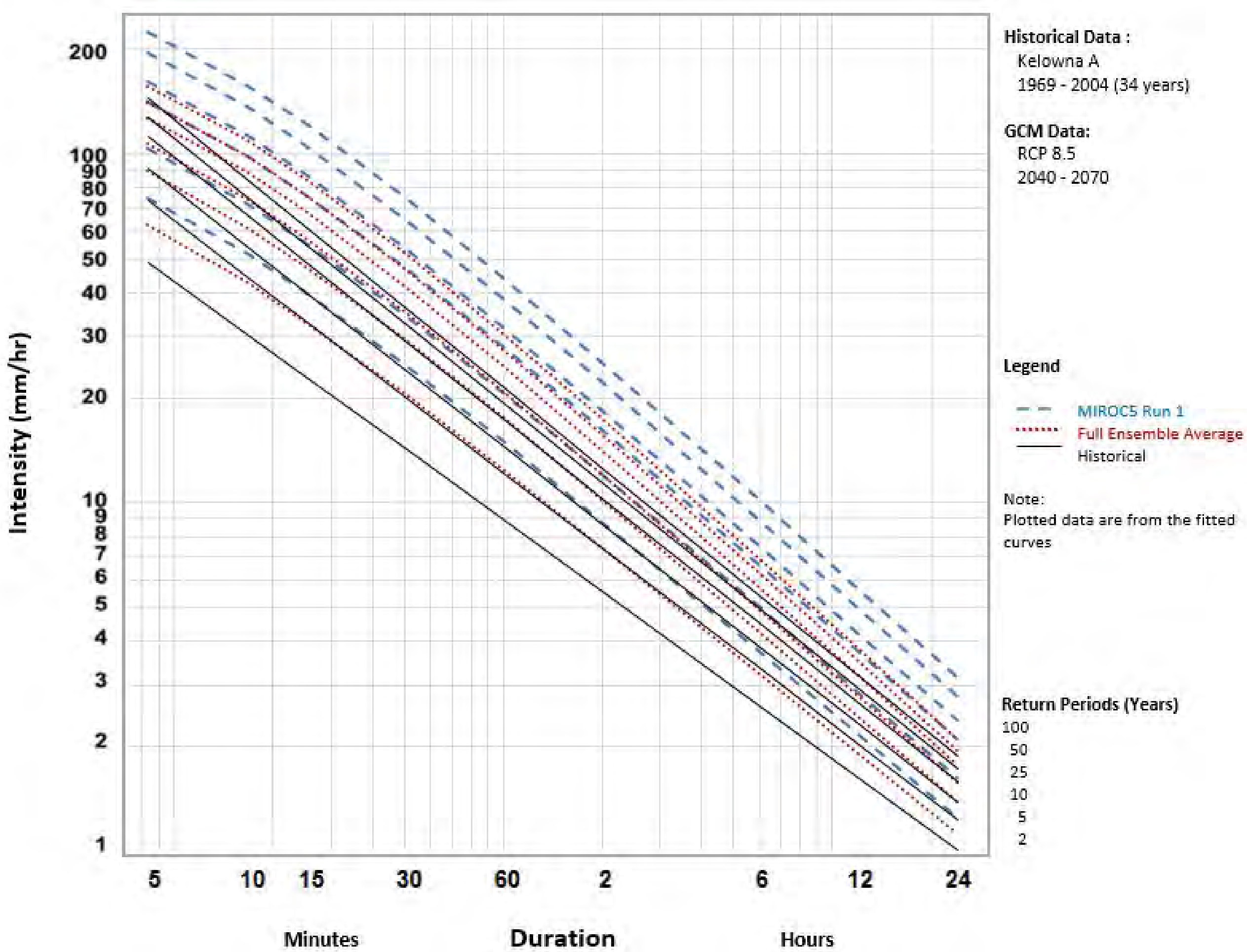
Table 3.2 - Full Ensemble Average IDF

Return Period (Years)	2	5	10	25	50	100
Coefficient (A)	12.9	18.4	22	26.2	29.4	32.7
Exponent (b)	-0.768	-0.811	-0.83	-0.846	-0.854	-0.862
Coefficient t_0	0.044	0.059	0.065	0.071	0.076	0.079

Table 3.3 - MIROC5 Run 1 IDF

Return Period (Years)	2	5	10	25	50	100
Coefficient (A)	15.7	21.7	29.7	33.9	41.1	47.3
Exponent (b)	-0.795	-0.814	-0.834	-0.836	-0.846	-0.851
Coefficient t_0	0.057	0.063	0.071	0.071	0.075	0.077

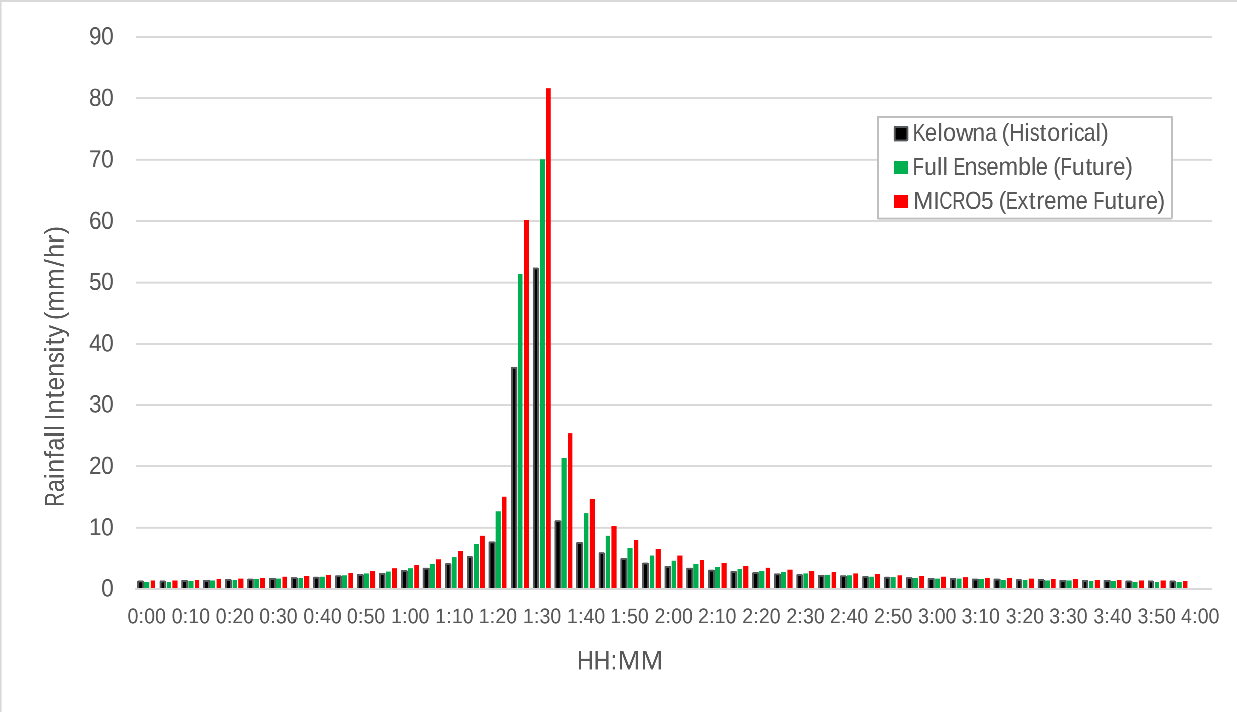
Graph 3.1 - Historical and Projected IDF Curves Comparison



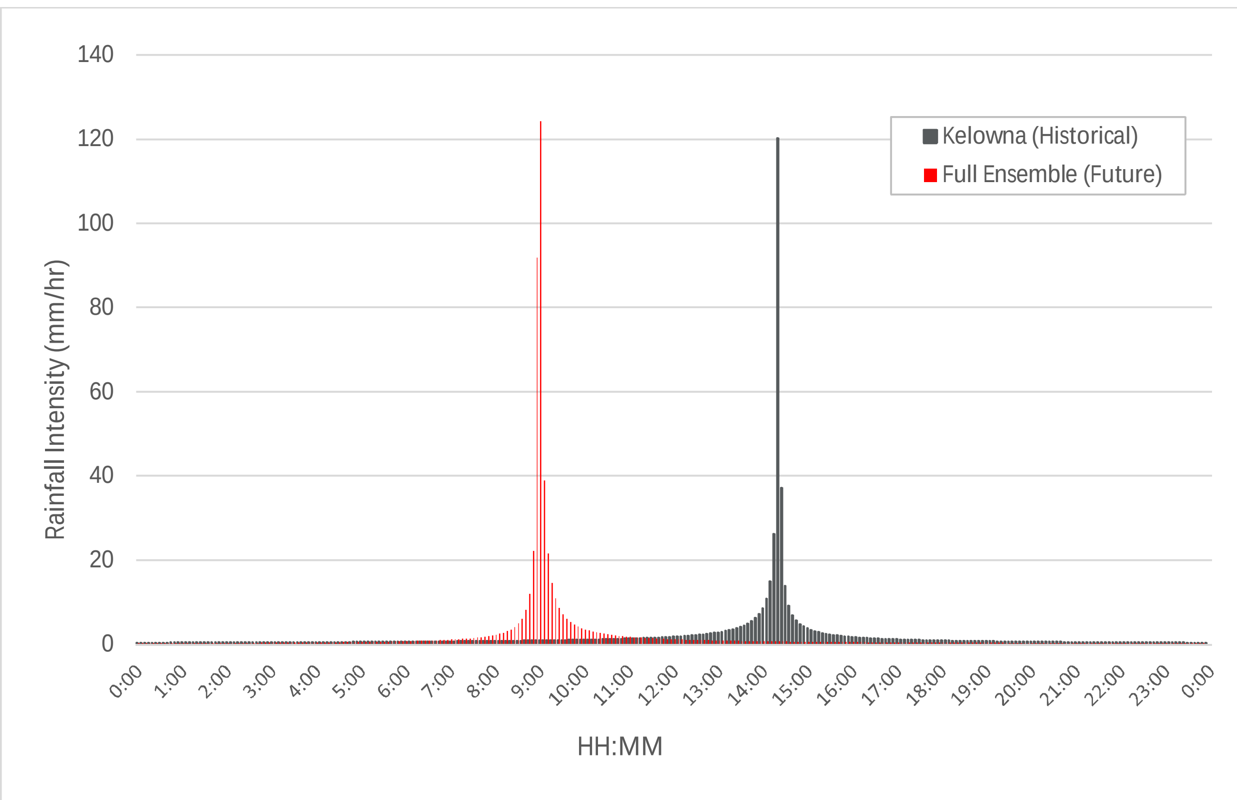
3.1.1 Single Event Design Storms

Single event (SE) storms were used to primarily analyze and size conveyance systems, but they were also used to analyze storage performance during extreme events. Single Event storms were generated by combining total storm rainfall with a temporal distribution. The total storm rainfall was determined from the IDF curves (both historical and projected future which include climate change). Each storm's total rainfall is dependent on the storm duration and selected frequency (return period). For example, the piped system was analyzed using a 4 hour storm with a return period of 5 years. The Modified Chicago temporal distribution was selected for this storm since it includes the full spectrum of rainfall intensities found in the IDF curves from 10 minutes to 4 hours. This ensures that the sub-catchments, which each have different times-of-concentration, are subjected the rainfall intensity which generates the highest peak runoff from each sub-catchment. Graph 3.2 shows the 5 year, 4 hour storm using total rainfall from the historical and projected future IDF curves – Kelowna, Full Ensemble, and MICRO5. Graphs 3.3 and 3.4 show the 100 year, 24 hour storms.

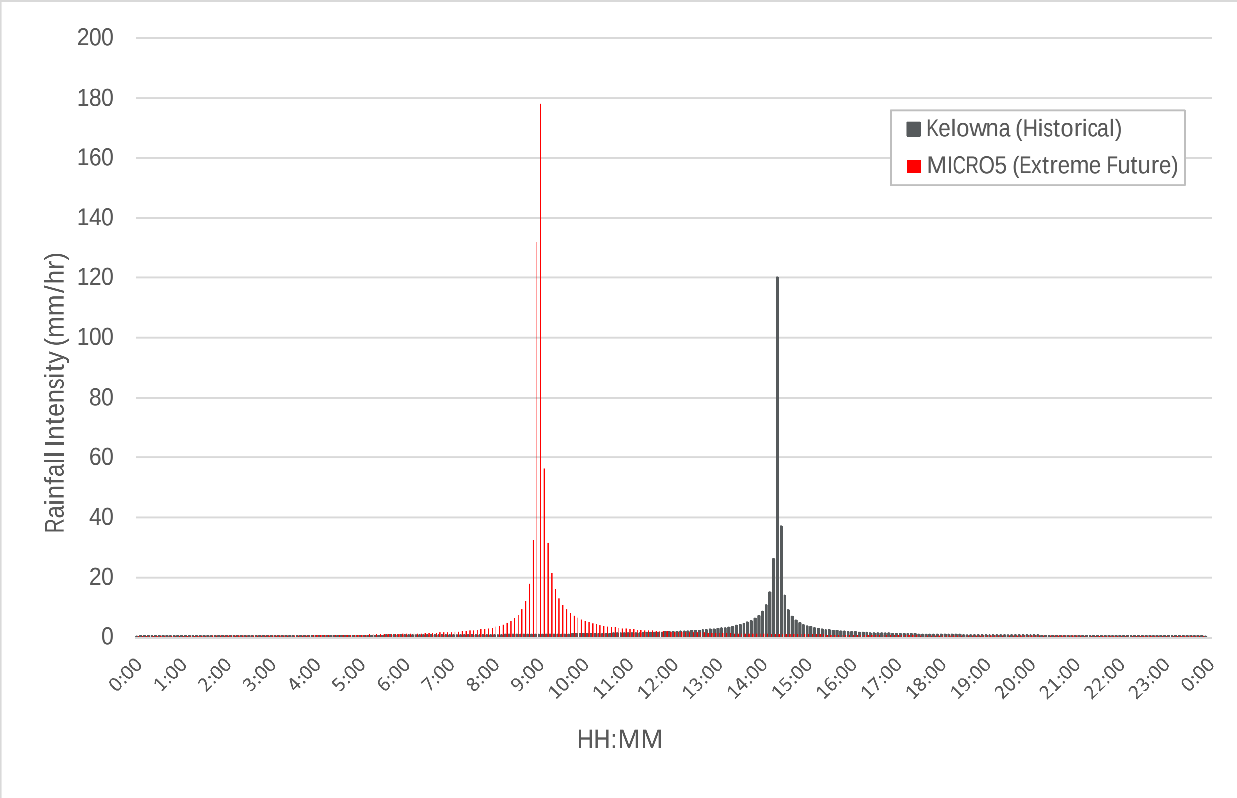
Graph 3.2 - 5 Year 4 Hour Hyetographs



Graph 3.3 - 100 year 24 hour hyetographs



Graph 3.4 - 100 year 24 hour hyetographs



3.2 Continuous Precipitation Time Series

Continuous modeling was completed using historical 1 hour climate data. The continuous time series was used to evaluate the long-term performance of the existing pond, and in particular, to determine how well it functions under multi-day rainfall events. This latter point is important since the total rainfall, and therefore total runoff that occurs over several days, can be significantly greater than any single rainfall event. It is desired to understand if existing and proposed retention/disposal systems have sufficient capacity to store runoff until it can be infiltrated and evaporated.

Currently, it is not possible to download future climate time series with a time interval less than 24 hours. While it is possible to synthesize an hourly time series using daily values, this work was beyond the project scope.

In order to determine if future climate, and in particular precipitation, could negatively impact the retention capacity of the existing pond, and since future hourly data are not available for continuous modeling, we completed the following analysis to qualitatively assess this risk.

1. Downloaded daily data from PCIC for the GCM that generated the greatest rainfall values during summer (when most high-volume rainfall events occur). This was the MIROC5 Run 1 data.
2. Downloaded daily data from PCIC for the GCM that generated the least annual rainfall values (driest year). This was the INM_CM4 data.
3. For each future data set (2040-2070):

a. Calculated “rolling sums” of precipitation over three periods – 7 days, 14 days, and 21 days. Determined the maximum total precipitation for each rolling period.

b. Calculated the maximum total precipitation for each series of contiguous days of rainfall (2 days of contiguous rainfall, 3 days of contiguous rainfall, etc.). Determined the maximum total precipitation for each contiguous series.

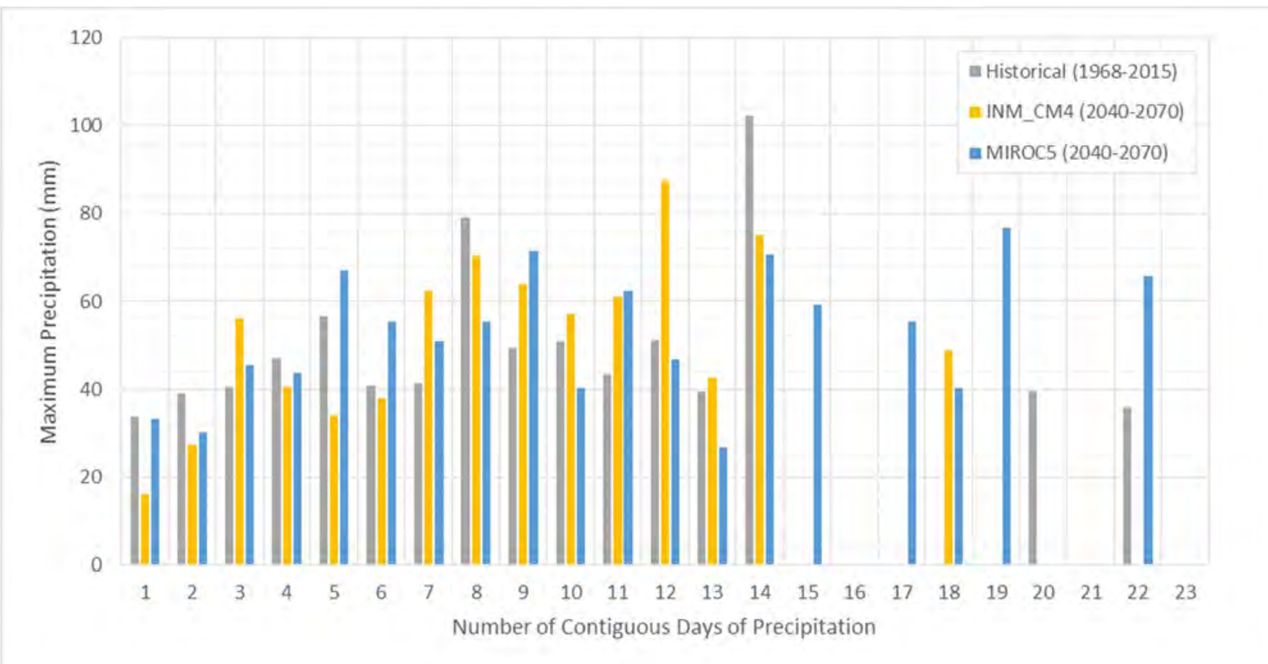
4. Completed step 3 above using historical rainfall data (1968 to 2015).

5. Compared the future and historical values. These are summarized in Table 3.4 and Figure 3.2 below.

Table 3.4 - Maximum Rolling Period Precipitation

Rolling Period (days)	Total PPT (mm)		
	Historical (1968-2015)	INM_CM4 (2040-2070)	MIROC5 (2040-2070)
7	72.9	76.1	75.8
14	128.6	90.2	112.8
21	165.2	99.3	125.2

Graph 3.5 - Maximum Contiguous Multi-Day Precipitation



Note that for the 7 day rolling period, there is little difference (less than 5%) between the historical and the future maximum total precipitation, although the future values are slightly higher. Historically, however, the 14 and 21 day maximum total values exceed future values by a significant amount.

Comparison between historical and future contiguous days of precipitation is a bit more complex. Each of the data sets (historical, INM_CM4, and MIROC5) generates the maximum total rainfall for some series (1, 2, 4, 8, and 14 contiguous days for historical for example), but not all. However, two of the three highest precipitation totals (for 8 and 14 contiguous days) were recorded historically. This means that the performance of the existing retention pond has already been modeled under high volume, multi-day rainfall events.

These two sets of results suggest that if the existing and proposed retention systems function adequately (that is, they have sufficient capacity to store and infiltrate/evaporate collected runoff) during continuous simulation using historical climate data, they are likely to perform at least as well using future climate projections.

3.3 Soil Parameters

A dedicated soil classification and infiltration study was undertaken by Piteau Associates as a component of this IRMP study in order to identify infiltration potential of both near surface soils and the underlying aquifer in the north east portion of the lands. Based on the recommendations by Piteau Associates, the saturated infiltration rates shown in Table 3.5 have been applied.

Table 3.5 - Saturated Infiltration Rates

Zone	m per day	mm per day	Average mm per hour
Main Campus (altered)	0.04	40	1.7
Native Ground	0.1	100	4.2
North East Campus (Undeveloped near surface soils)	1.0	1,000	41.7
North East Campus (Developed near surface soils) (see note below)	0.1	100	4.2
North East Campus (Underlying Aquifer)	7.0	7,000	292
Eastern Campus	0.1	100	4.2

Note: Because of the criticality of sizing the storm water storage and disposal facilities to avoid downstream impact, a conservative near surface infiltration rate has been assumed for the pervious areas of the developed cells of Innovation Precinct.

A detailed description of all soils and depression storage values, and a copy of the dedicated geotechnical study, will be appended to the future IRMP report, but are not attached to this interim report.

3.4 Depression Storage

Nominal depression storage has been assigned to all surfaces, however for the purposes of assessing site specific management techniques an average depression values of 100 mm is applied to all pervious areas within a given Project area. As discussed in Section 2.3 above, it is not expected that substantially depression storage can be achieved on all pervious surfaces. It has been assumed that it is realistic to target 50% utilization of the pervious area, and achieving 200 mm of depression storage over that 50%. From a volumetric storage perspective, this is equivalent to an average of 100 mm of depression storage over 100% of the area. This approach has been applied because modeling routines do not permit the redirection of rainwater to only a portion of the sub-catchments pervious area. A more discretized model requires more detailed site information and extends beyond the scope of this study.

3.5 Pipe Modeling

Storm and manhole attributes were extracted from the models previously prepared for the UBCO Stormwater Management Plan (CTQ, 2011). We understand that manholes across the campus are unbenched and have projecting pipes, which represent hydraulically inefficient junctions. We have assigned junction losses accordingly which can yield poor junction performance despite the capacity of the downstream pipes. Assigned junction losses are summarized in Table 3.6 below.

Table 3.6 - Entry and Exit Loss Coefficients

Element	Entry Loss Coefficient	Exit Loss Coefficient
Culvert	0	0.5
Pipe (inlet to system)	0	0.1
Pipe (outfall)	0.1	0.5
Pipe (straight run)	0.1	0.1
Pipe (bends or laterals)	0.5[(1)]	0.5[(1)]

[(1)] *Applied to only the end of the pipe at the manhole under consideration.*

Modeling has been conducted using PCSWMM software as previously agreed with UBC staff. Systems have been analysed under the following land use, site management, and precipitation scenarios, not all of which have been presented herein:

Land Use and Site Management Condition Scenarios:

- Existing condition
- Future Project with no site controls and all impervious area directly connected to the storm sewer system.
- Future Project with site controls applied only to the Project, or portion of Project requiring it to avoid impact over existing conditions (see Table 2.1)
- Future Project with site controls applied to all Projects.

Precipitation Scenarios (see Section 3.1)

- Existing (Historic) Kelowna IDF
- Future Ensemble Climate Change IDF
- Micro5 Run 1 IDF
- Continuous Simulation (1968 to 2015)

3.6 Storage and Disposal Modelling for Innovation Precinct

Based on the initial screening assessment presented in Section 2.4 above, estimated temporary storage basins were developed with an assumed outlet. It is suggested at this time to consider a single centralized storage and disposal facility to serve Innovation Precinct Catchments An, As, and C combined. And a second facility may service Innovation Precinct Catchment B. Storage and discharge relationships applied are as shown in Table 3.7 and 3.8 below.

Table 3.7 – Storage for Innovation Precinct An, As, C

Depth (m)	Area (m2)	Cumulative Volume (m3)
0.00	5,871	0
0.25	6,182	1,507
0.50	6,500	3,092
0.75	6,826	4,758
1.00	7,161	6,506
1.25	7,503	8,339
1.50	7,854	10,259

For the basin shown in Table 3.7, performance was analyzed based on an assumed discharge rate of 0.07 m3/s, which is equivalent to two injection wells, or a recharge basin 864 m2 in area.

Table 3.8 – Storage for Innovation Precinct B

Depth (m)	Area (m2)	Cumulative Volume (m3)
0.00	763	0
0.25	878	205
0.50	1,000	440
0.75	1,130	706
1.00	1,269	1,006
1.25	1,415	1,342
1.50	1,570	1,715

For the basin shown in Table 3.8, performance was analyzed based on an assumed discharge rate of 0.035 m^3/s, which is equivalent to one injection wells, or a recharge basin 432 m^2 in area.

The combination of temporary storage to discharge will be discussed further in Section 4 and 5 of this report.

4 Modeling Results

4.1 Main Campus Hydrology

Systems within the Main Campus were modelled and assessed multiple ways. First, each Future Project was modelled against the design single events (5 year and 100 year) to determine the Project runoff characteristics (peak flows and volumes) under three management scenarios; no LID (site controls), LID applied to mandatory sites (see Table 2.1), and LID applied to all Projects. In this case, analysis was first only conducted using the Existing Kelowna IDF rainfall parameters as the focus of this assessment is to understand the relative effect of applying site controls to the available pervious space. Site controls at this time have only been assigned to Future Projects. It has been assumed that all portions of the established campus that are not planned for redevelopment will remain status quo.

A summary of Project hydrology is presented in Table 4.1 on the following page. Runoff values have been listed for the Fipke Centre Building and the University Centre Building only because there has been discussion on the possibility of redirected roof drainage from these buildings into the University Way Pedestrianization Project. So for these buildings there will be no site controls applied to them directly, hence why runoff values are the same for all three scenarios presented. These are the potential runoff rates and volumes that will need to be considered by University Way Pedestrianization should roof interception be pursued.

Table 4.1 demonstrates that in most cases, the application of site controls can offer a significant reduction in both peak flow and runoff volumes, particularly if applied to all Project areas. In fact, in many cases analysis suggested that many Projects have the ability to be zero discharge for the 5 year event. In a few cases, analysis suggests the possibility for full retention even for the 100 year event. Maximizing site retention is highly advantageous from the perspective of storm sewer performance and flood risk. This is also beneficial in terms of UBC meeting its ecology and biodiversity goals and aspirations. However, retaining water on site will reduce the water inputs to the existing pond. While reducing high flows would be a benefit to the pond, reducing low flows may be detrimental. Site controls will be more effective at reducing low flows than high flows, and it is the low flows during drier periods of the year that are most critical to the health of the existing pond.

A summary of runoff parameters for the existing pond is provided in Table 4.2 below.

Table 4.1
Summary of Project Area Performance
(Existing Kelowna IDF)

Development Area	Future Sub-Catchment	Future Catchment Area (ha)	Future Impervious (%)	5 Year Runoff Coefficient			5 Year Peak Flow Rate (m3/s)			5 Year Runoff Volume (m3)			100 Year Runoff Coefficient			100 Year Peak Flow Rate (m3/s)			100 Year Runoff Volume (m3)		
				No LID	LID applied to Mandatory Areas	LID applied to Full Area	No LID	LID applied to Mandatory Areas	LID applied to Full Area	No LID	LID applied to Mandatory Areas	LID applied to Full Area	No LID	LID applied to Mandatory Areas	LID applied to Full Area	No LID	LID applied to Mandatory Areas	LID applied to Full Area	No LID	LID applied to Mandatory Areas	LID applied to Full Area
Upper Cascades	C-93	0.46	62	0.73	0.73	0.00	0.05	0.05	0.00	60	60	0	0.80	0.80	0.00	0.14	0.14	0.00	170	170	0
Upper Cascades	C-91	0.26	95	0.98	0.98	0.75	0.04	0.04	0.03	40	40	30	0.98	0.98	0.84	0.08	0.08	0.08	120	120	100
Upper Cascades		**0.71**	**74**	**0.82**	**0.82**	**0.27**	**0.09**	**0.09**	**0.03**	**100**	**100**	**30**	**0.86**	**0.86**	**0.30**	**0.22**	**0.22**	**0.08**	**290**	**290**	**100**
Mountain Weather Office	**C-103**	**1.00**	**72**	**0.80**	**0.00**	**0.00**	**0.09**	**0.00**	**0.00**	**150**	**0**	**0**	**0.85**	**0.21**	**0.21**	**0.22**	**0.02**	**0.02**	**430**	**100**	**100**
Upper Campus Parking Lot	C-104	1.63	82	0.88	0.00	0.00	0.16	0.00	0.00	260	0	0	0.90	0.47	0.47	0.40	0.20	0.20	700	360	360
Upper Campus Parking Lot	C-151	0.77	74	0.82	0.82	0.00	0.09	0.09	0.00	110	110	0	0.86	0.86	0.24	0.24	0.24	0.03	320	320	90
Upper Campus Parking Lot	C-121s	0.18	53	0.65	0.00	0.00	0.02	0.00	0.00	20	0	0	0.75	0.00	0.00	0.06	0.00	0.00	60	0	0
Upper Campus Parking Lot	C-121	0.48	29	0.50	0.50	0.00	0.02	0.02	0.00	60	60	0	0.66	0.66	0.00	0.07	0.07	0.00	210	210	0
Upper Campus Parking Lot		**3.06**	**70**	**0.79**	**0.28**	**0.00**	**0.29**	**0.11**	**0.0**	**450**	**170**	**0**	**0.85**	**0.57**	**0.31**	**0.77**	**0.51**	**0.23**	**1290**	**890**	**450**
Nonis Neighbourhood West	C-146	0.81	46	0.79	0.68	0.00	0.12	0.07	0.00	250	140	0	0.85	0.86	0.38	0.35	0.27	0.12	920	820	370
Nonis Neighbourhood West	C-146a	0.32	64	0.91	0.25	0.25	0.11	0.01	0.01	160	40	40	0.90	0.64	0.64	0.25	0.17	0.17	410	300	300
Nonis Neighbourhood West	C-156	0.65	100	1.00	1.00	1.00	0.09	0.09	0.09	120	120	120	1.00	1.00	1.00	0.22	0.22	0.22	310	310	310
Nonis Neighbourhood West		**1.78**	**69**	**0.89**	**0.72**	**0.41**	**0.32**	**0.17**	**0.10**	**530**	**300**	**160**	**0.91**	**0.87**	**0.65**	**0.82**	**0.66**	**0.51**	**1640**	**1430**	**980**
Nonis Neighbourhood East (portion tributary to existing pond)	**C-171**	**0.40**	**79**	**0.86**	**0.00**	**0.00**	**0.05**	**0.00**	**0.00**	**60**	**0**	**0**	**0.89**	**0.44**	**0.44**	**0.13**	**0.10**	**0.10**	**170**	**80**	**80**
Future Building B	**C-155**	**0.20**	**94**	**0.96**	**0.61**	**0.61**	**0.01**	**0.01**	**0.01**	**30**	**20**	**20**	**0.96**	**0.81**	**0.81**	**0.03**	**0.03**	**0.03**	**90**	**80**	**80**
TLC & Future Academic	C-39	0.25	98	0.99	0.87	0.87	0.02	0.02	0.02	40	40	40	0.99	0.92	0.92	0.06	0.05	0.05	120	110	110
TLC & Future Academic	C-149	0.20	99	1.00	0.94	0.94	0.02	0.02	0.02	40	30	30	0.99	0.97	0.97	0.05	0.05	0.05	90	90	90
TLC & Future Academic	C-141	0.14	95	0.98	0.75	0.75	0.01	0.01	0.01	20	20	20	0.98	0.86	0.86	0.03	0.03	0.03	60	60	60
TLC & Future Academic	C-77	0.16	91	0.94	0.41	0.41	0.02	0.00	0.00	30	10	10	0.95	0.72	0.72	0.04	0.04	0.04	70	50	50
TLC & Future Academic	C-142	0.35	66	0.75	0.75	0.00	0.04	0.04	0.00	50	50	0	0.81	0.81	0.01	0.11	0.11	0.00	140	140	0
TLC & Future Academic		**1.09**	**86**	**0.90**	**0.76**	**0.52**	**0.11**	**0.09**	**0.05**	**180**	**150**	**100**	**0.93**	**0.86**	**0.60**	**0.29**	**0.28**	**0.17**	**480**	**450**	**310**
Okanagan Commons Building	**C-78**	**0.50**	**83**	**0.88**	**0.00**	**0.00**	**0.04**	**0.00**	**0.00**	**80**	**0**	**0**	**0.91**	**0.49**	**0.49**	**0.10**	**0.05**	**0.05**	**220**	**120**	**120**
Future Academic (Building surround)	C-71	0.36	92	0.96	0.53	0.53	0.04	0.02	0.02	60	30	30	0.96	0.77	0.77	0.10	0.09	0.09	160	130	130
Future Academic (Roof top)	C-71a	0.34	100	1.00	1.00	1.00	0.04	0.04	0.04	60	60	60	1.00	1.00	1.00	0.08	0.08	0.08	160	160	160
Future Academic		**0.70**	**96**	**0.98**	**0.76**	**0.76**	**0.08**	**0.06**	**0.06**	**120**	**90**	**90**	**0.98**	**0.88**	**0.88**	**0.18**	**0.17**	**0.17**	**320**	**290**	**290**
Arrival Plaza & Transit Exchange	**C-165**	**0.94**	**80**	**0.86**	**0.00**	**0.00**	**0.09**	**0.00**	**0.00**	**150**	**0**	**0**	**0.90**	**0.43**	**0.43**	**0.23**	**0.10**	**0.10**	**400**	**190**	**190**
Purcell Courts	C-163	0.80	64	0.64	0.00	0.00	0.06	0.00	0.00	90	0	0	0.74	0.00	0.00	0.17	0.00	0.00	280	0	0
Purcell Courts	C-162	1.49	63	0.64	0.00	0.00	0.12	0.00	0.00	170	0	0	0.74	0.00	0.00	0.31	0.00	0.00	520	0	0
Purcell Courts		**2.29**	**63**	**0.6**	**0.00**	**0.00**	**0.18**	**0**	**0**	**260**	**0**	**0**	**0.74**	**0.00**	**0.00**	**0.48**	**0.00**	**0.00**	**800**	**0**	**0**
																			0	0	0
University Way Pedestrianization	C-131w	0.40	60	0.67	0.67	0.00	0.04	0.04	0.00	50	50	0	0.77	0.77	0.00	0.13	0.13	0.00	150	150	0
University Way Pedestrianization	C-131e	0.46	71	0.80	0.80	0.00	0.05	0.05	0.00	70	70	0	0.85	0.85	0.14	0.14	0.14	0.01	180	180	30
University Way Pedestrianization		**0.86**	**66**	**0.74**	**0.74**	**0.00**	**0.09**	**0.09**	**0**	**120**	**120**	**0**	**0.81**	**0.81**	**0.07**	**0.27**	**0.27**	**0.01**	**330**	**330**	**30**
University Centre Building	C-21	0.28	100	1.00	1.00	1.00	0.03	0.03	0.03	50	50	50	1.00	1.00	1.00	0.07	0.07	0.07	140	140	140
Fipke Centre Building	C-22	0.32	100	1.00	1.00	1.00	0.04	0.04	0.04	60	60	60	1.00	1.00	1.00	0.09	0.09	0.09	150	150	150
Future Building A	**C-147**	**0.49**	**62**	**0.63**	**0.00**	**0.00**	**0.04**	**0.00**	**0.00**	**50**	**0**	**0**	**0.74**	**0.00**	**0.00**	**0.15**	**0.00**	**0.00**	**170**	**0**	**0**
Nonis Neighbourhood East (portion not tributary to existing pond)	**C-164**	**2.97**	**43**	**0.45**	**0.45**	**0.00**	**0.17**	**0.17**	**0.00**	**240**	**240**	**0**	**0.64**	**0.64**	**0.00**	**0.50**	**0.50**	**0.00**	**900**	**900**	**0**

Note 1: For simplicity, the term "LID" (Low Impact Development) has been used to denote the application of rainwater site controls.

Note 2: Mandatory areas are those portions which would result in a negative impact over the existing condition. Refer to Table 2.1 for a preliminary screening of where mandatory LID is required to avoid no negative impact.

Note 3: Where site management techniques area required, a pervious depression storage of 100 mm was applied, and is assumed to represent an average over all pervious areas. It is also assumed that all impervious areas is routed to the pervious area and not directly connected to the storm sewer system.

Note 4: The results presented in this table represent the "Existing Kelowna IDF" precipitation.

Table 4.2 - Summary of Annual Average Runoff Coefficients to Existing Pond

	Existing Condition	Future Projects with no LID	Future Projects with LID applied to Mandatory Sites	Future Projects with LID applied to All Sites
Contributing Catchment Area (ha)	41.5	51.3	51.3	51.3
Average Annual Runoff Coefficient (1968-2015)	0.37	0.44	0.28	0.25
Average Annual Runoff Coefficient – Wettest Year (1982)	0.39	0.47	0.30	0.28
Average Annual Runoff Coefficient – Driest Year (2010)	0.34	0.42	0.27	0.23

Concepts of the Weather Mountain Office and Upper Campus Parking lot suggest a comparatively small additional area may be brought into the established system, whereas the future expansion of Purcell Courts would see a significant change in the ponds catchment area, particular when considering that any drainage from the upslope area to the west of Purcell Courts would also need to be intercepted. The potential change in catchment boundary can be seen by comparing Figure 1 and Figure 2. In combination, these potentially add 10 hectares to the total catchment of the existing system. On an annual basis, this increased area is not detrimental, provided that the areas are managed at the site. However, as will be discussed below, this additional area can be detrimental to the performance of the piping system during a design event.

To further evaluate the potential effect of site controls on the existing pond, the Main Campus and existing pond was modeled using continuous simulation to develop a pond water level frequency analysis as presented as Graph 4.1 on the following page. The graph shows that without the application of site controls (Full development with no LID), Future Projects would cause the water level in the pond to rise approximately 0.1 m over the vast majority of time. If the Future Projects are completed with the application of site controls to all projects (LID applied to all projects), the graph shows that the water level in the pond will decrease by about 0.05 m over the vast majority of time. And finally, the graph shows that if Future Projects are completed with only applying site controls that require it to avoid a negative impact to the storm sewer system (LID applied to mandatory sites), the pond water levels virtually match the existing pattern, confirming no net change.

The graph also indicates that all scenarios are similar under significant flow events. The application of site controls does not significantly affect the extent and frequency of the pond filling and spilling.

4.2 Main Campus Storm Sewer Performance

The existing storm sewer system is understood to have been sized for the 1:5 year return period. Surcharging and surface flooding is known to occur during heavy precipitation events. UBC has concern for the overland flow paths and potential risk it poses to buildings and other high risk infrastructure. UBC would like to better understand overland flow paths and flood risks, however insufficient topographic information currently exists, and conducting such a review extends beyond the scope of this current study. It is recommended to UBC as a dedicated complimentary assignment to this IRMP study.

UBC also has a desire to reduce the reliance on “grey infrastructure”. Therefore, particularly when combined with existing flood risk, there is a need to reduce loading on the storm sewer system wherever possible. There are three significant aspects that will alter the long range design flows in the storm sewer system; land use, how development is managed, and climate changes in precipitation. The former are more readily predictable and managed, while the last is not.

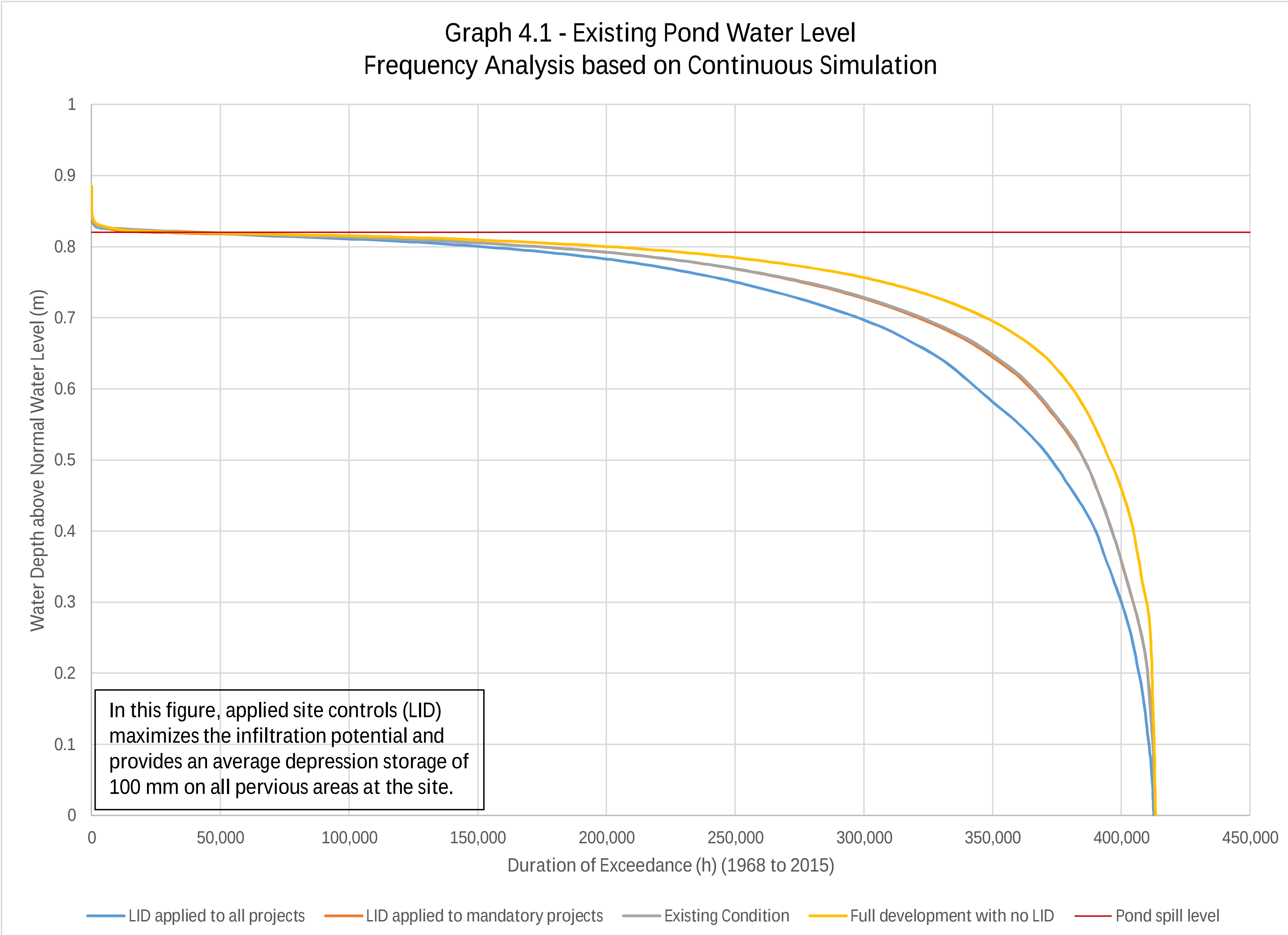
Given that the storm sewer system is only designed for the 1:5 year event, comparative performance results have only been compiled and presented for the 1:5 year events. However, a number of 1:5 year event scenarios have been assessed, including:

1. Existing Land Use Condition
2. Future Land Use Condition with no site controls
3. Future Land Use Condition with site controls applied to mandatory Project sites
4. Future Land Use Condition with site controls applied to all Project sites

All four scenarios have been modelled with the Existing Kelowna IDF precipitation and the Full Ensemble climate change precipitation. The MICRO5 precipitation has not been included because of its extreme nature and uncertainty, and the very significant impact it will have on the existing system. We suggest that there is insufficient information and certainty to make critical infrastructure retrofit decisions around that event. We suggest that other forms of management be applied near term along with a monitoring program to better understand performance. Over time predictions about climate change will also improve and provide more confident guidance on the need for infrastructure changes. Our suggestion is that decisions around retrofitting the storm sewer system for long range climate change is premature, however this is an option available to UBC. We also suggest that decisions around retrofitting the existing storm sewer system be risk based, which would be better informed by UBC conducting a detailed overland flow path assessment.

Allowing Future Projects to proceed without site controls will create two negative affects; it will result in increased flows and risk to flooding in the storm sewer system, and it will increase the typical water level in the existing pond. As such, allowing Future Projects to proceed without site controls would require a near term commitment to increase storm sewer capacity and acceptance of increased water levels in the existing pond.

A comparison of storm sewer performance for the noted eight scenarios (four land use / management scenarios and two precipitation scenarios) are presented in Figures 5 through Figure 12.



Graph 4.1 - Existing Pond Water Level
Frequency Analysis based on Continuous Simulation
Water Depth above Normal Water Level (m)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
450,000
Duration of Exceedance (h) (1968 to 2015)
In this figure, applied site controls (LID) maximizes the infiltration potential and provides an average depression storage of 100 mm on all pervious areas at the site.
LID applied to all projects
LID applied to mandatory projects
Existing Condition
Full development with no LID
Pond spill level

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1:5 Year Storm Sewer Performance
Existing Condition
Current Kelowna IDF Curves

Legend

Manholes

- No Surface Flooding
- Surface Flooding

Pipe Surcharging

- None
- Minor
- Significant

Pipe sizes are existing.

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
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FIGURE 5

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1:5 Year Storm Sewer Performance Development of All Project Sites With No Site Controls Current Kelowna IDF Curves

Legend

Manholes

- No Surface Flooding
- Surface Flooding

Pipe Surcharging

- None
- Minor
- Significant
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

Pipe sizes are existing.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
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FIGURE 6

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1:5 Year Storm Sewer Performance Future Development With Site Controls at Mandatory Project Sites Current Kelowna IDF Curves

Legend

Manholes

- No Surface Flooding
- Surface Flooding

Pipes Surcharging

- None
- Minor
- Significant
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

Pipe sizes are existing.

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

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Author:	SQ
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FIGURE 7

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1:5 Year Storm Sewer Performance Future Development With Site Controls at All Project Sites Current Kelowna IDF Curves

Legend

Manholes

- No Surface Flooding
- Surface Flooding

Pipes Surcharging

- None
- Minor
- Significant
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

Pipe sizes are existing.

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
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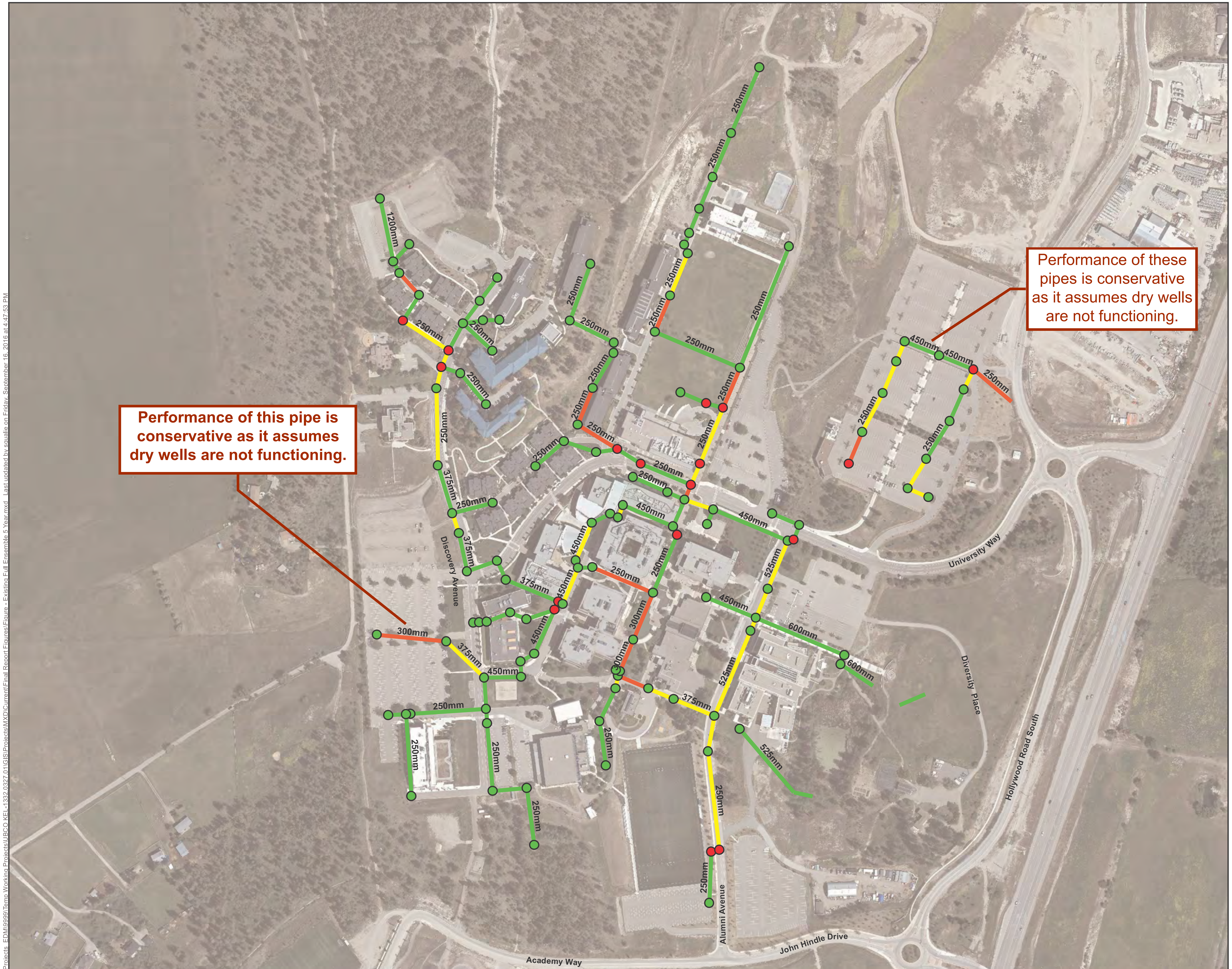
FIGURE 8



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1:5 Year Storm Sewer Performance
Existing Condition
Full Ensemble
Climate Change Prediction

Legend

Manholes

- No Surface Flooding
- Surface Flooding

Pipe Surcharging

- None
- Minor
- Significant

Pipe sizes are existing.

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

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Author:	SQ
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FIGURE 9

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IRMP

1:5 Year Storm Sewer Performance
Development of All Project Sites
With No Site Controls
Full Ensemble
Climate Change Prediction

Legend

Manholes

- No Surface Flooding
- Surface Flooding

Pipes Surcharging

- None
- Minor
- Significant
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

Pipe sizes are existing.

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

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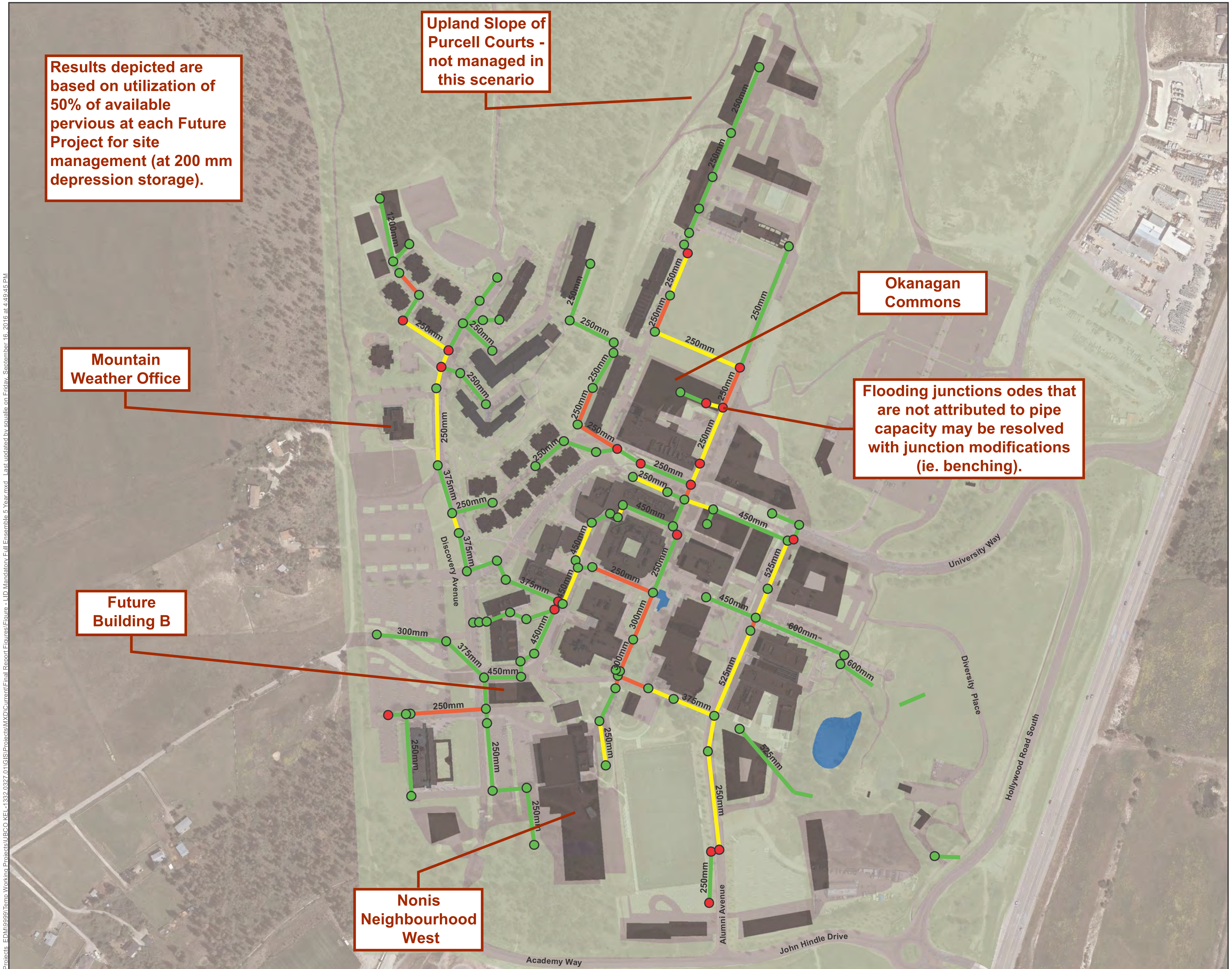
FIGURE 10



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IRMP

1:5 Year Storm Sewer Performance Future Development With Site Controls at Mandatory Project Sites Full Ensemble Climate Change Prediction

Legend

Manholes

- No Surface Flooding
- Surface Flooding

Pipes Surcharging

- None
- Minor
- Significant
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

Pipe sizes are existing.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
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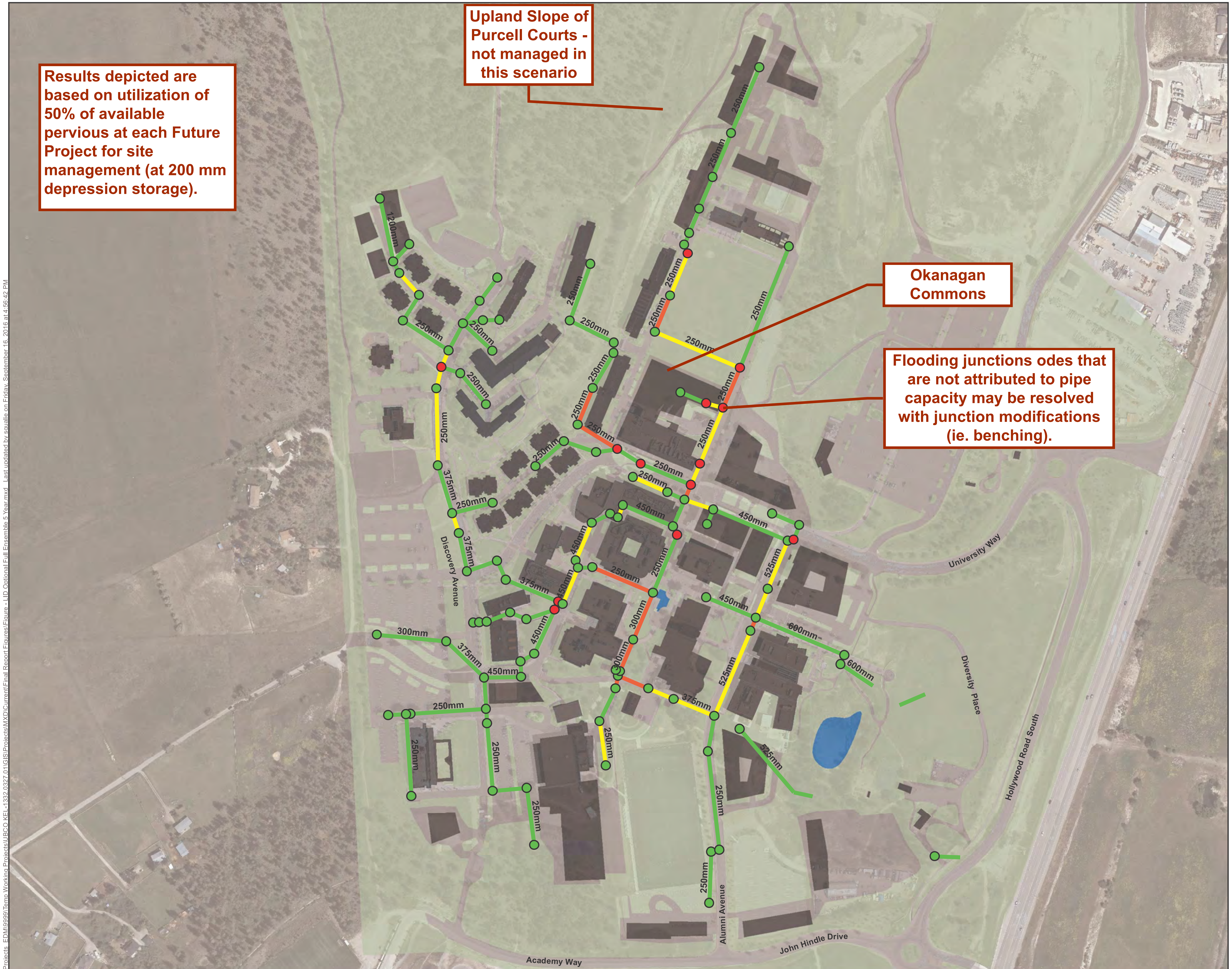
Date:	2016 / 9 / 16

URBAN systems

FIGURE 11



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IRMP

1:5 Year Storm Sewer Performance Future Development With Site Controls at All Project Sites Full Ensemble Climate Change Prediction

Legend

Manholes

- No Surface Flooding
- Surface Flooding

Pipes Surcharging

- None
- Minor
- Significant
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

Pipe sizes are existing.

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150 Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

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FIGURE 12

A synopsis of the preceding figures is as follows:

- All figures demonstrate manhole flooding to surface at some locations, despite at times the pipes not demonstrating significant surcharging. This is a result of the default loss coefficients assigned to the manholes (see Table 3.6) based on the understanding that they are not benched and have projecting pipes into the manholes. The results have validated manholes with a known history of flooding, however the analysis is also indicating flooding at manholes which do not exhibit a history of flooding. There are many complex factors that will ultimately govern the junction hydraulics that cannot be fully captured within the scope of this study. As such, the results of manhole performance should be interpreted cautiously; as an indicator of *potential* performance, and not the absolute performance. Observed performance history should be more strongly considered. We encourage the reader to focus more on the pipe performance results, which have few uncertainties.

- Without the application of site controls, completion of the Future Projects will increase flows and have detrimental effects on pipe performance, thereby increasing the risk of flooding.

- The application of site controls at the mandatory sites (see Table 2.1) shows pipe performance returns close to the existing condition, but not fully in all cases. In the initial screening assessment, it appeared that 4 Future Projects did not have adequate pervious surface to fully meet the retention requirements for “no net impact” assuming only 50% of that pervious space is effectively utilized. Three of the four sites demonstrate sufficient pervious space provided that more than 50% of the pervious area can be utilized. One site, Future Building B, is the only site that would not appear to offer sufficient pervious space. Either additional pervious space will need to be integrated into the site design, or other forms of retention (e.g. planter boxes, green roof, subsurface infiltration galleries) may be applied. The modeling has verified this is the case, therefore in a few locations there is an indication that pipe performance will diminish somewhat. We anticipate the impact is likely low relative to current condition, but impact nonetheless.

- One of the specific impact areas is downstream of the Purcell Courts expansion area. A significant portion of this expansion area, and the upland slope, currently does not contribute to the existing pond, but currently drains eastward downslope towards the Innovation Precinct area. It is expected that Purcell Courts will need to make provision to intercept any runoff from the upland slope. At this time, analysis has assumed any intercepted upland runoff would not be provided retention control. This is a conservative assumption, and if this is the case, analysis is indicating it would be detrimental. Analysis suggests that Purcell Courts should have sufficient capacity to manage itself, and perhaps it has sufficient capacity to also manage runoff from the upland slope. Therefore, this becomes a decision for how the expansion of Purcell Courts and the upland slope is managed. The options are: 1) Factor in the upland slope runoff in the sizing of site controls for Purcell Courts, 2) Create a cut off channel to capture upland slope runoff that forces it to drain north east and not into the existing storm sewer system, or 3) drain the Purcell Courts expansion area and the upland slope into Innovation Precinct and not into the established drainage system. These options are discussed further in Section 5 of this report.

- The application of site controls at all Future Project sites compensates for the 4 mandatory sites which may not have adequate control opportunity. In this scenario pipe performance is largely returned to existing condition or better.

- Climate change influences are predicted to worsen pipe performance whether site controls are applied or not. However, the application of site controls at all Future Projects offers significant benefit. Again, the projections for climate change are still uncertain and the values applied to this analysis are for several decades out. As such, the results herein are a window into the possible long range future, and maybe premature to make critical decisions with at this time, depending on the strategy that UBC ultimately selects. One major benefit of applying site controls is that it defers the need to upgrade storm sewers, with exception of course to storm sewer upgrades that may be required to address conditions that are deemed unacceptable today.

4.3 Innovation Precinct

Based on the assumed storages and controls described in Section 3 above, Table 4.3 below describes the required storage volumes. In this case, however volumes are determined both with and without the application of site controls. Again, this assumes that 50% of the available pervious area is used for rainwater retention, 200 mm deep. With an assumed pervious fraction of 0.10, retention storage would be provided at 100 m^3 per hectare. The site design challenge will be to effectively disperse runoff from the impervious area across the available pervious area. However, as shown below, the effective utilization of the pervious area for retention can offer a significant reduction in centralized storage for the 1:5 year event, however has only modest reduction for the 1:100 year event. Sizing of infrastructure must be provided for the 1:100 year event. For the established Main Campus, we suggest caution in making significant retrofit decisions based on climate change predictions, however in the case where new infrastructure is required we suggest that future climate change predictions should be accounted for now. Table 4.3 below presents the influence of climate change projections. The extreme intensity of the MICRO5 IDF's triples the storage requirement over today's design rainfall. Alternative to increased storage, the disposal rate could be increased by the same factor. The relationship between the disposal rate and temporary storage is a strategy decision that is further explored in Section 4 below.

Table 4.3 – Temporary Storage Basin Requirements

	5 Year, 4 Hour Single Event				**100 Year, 24 Hour Single Event**			
	Peak Inflow (m^3/s)		**Maximum Storage Volume (m^3)**		**Peak Inflow (m^3/s)**		**Maximum Storage Volume (m^3)**	
Storage / Disposal System	Future No LID	Future with LID	Future No LID	Future with LID	Future No LID	Future with LID	Future No LID	Future with LID
Historical Kelowna IDF								
Storage for IP An, As, C	0.798	0.163	898	73	2.050	1.644	2,758	2,372
Storage for IP B	0.158	0.013	81	3	0.369	0.326	232	238
Full Ensemble IDF								
Storage for IP An, As, C	1.221	0.380	1460	556	2.871	1.967	3,816	3,061
Storage for IP B	0.233	0.066	152	27	0.475	0.399	363	285
MICRO5 IDF								
Storage for IP An, As, C	1.516	0.540	1907	1006	5.024	4.210	9,372	8,730
Storage for IP B	0.281	0.117	195	71	0.743	0.700	605	573

Note: Storage for IP An, As, C is based on a discharge rate of 0.07 m3/s (2 injection wells). Storage for IP B is based on a discharge rate of 0.035 m3/s (1 injection well).

5 Options and Discussion

5.1 Costs

For the decisions that need to be made at this time, there are only four key facilities to consider, for which the following unit costs are suggested. All capital costs below include 35% for engineering and contingencies.

1. **Shallow Landscape Based Low Impact Development (LID) Techniques:**
   At this time the generic term of "LID" or "site controls" is being used to represent a wide range of techniques that may be applied. However, for the purposes of this study analysis has assumed that LID is represented by depressed landscape facilities integrated into the available pervious area of a given site. The facility would provide depression storage in the order of 100 to 200 mm deep, a layer of topsoil sufficient for the desired planting scheme (likely in the order of 300 to 450 mm thick), possibly an underdrain connected to the storm sewer, and an overflow also connected to the storm sewer. Drainage from pervious surfaces of the site, including building roof drains, would discharge as disbursed as possible to these landscaped areas. At this time, more costly structures such as porous pavements, green roofs, etc., have not been considered. Choosing site specific LID features and determining how they will integrate into the sites is a future steps for UBC beyond the scope of this study.

   As described in sections above, the extent of site management varies extensively at each Project. It is highly dependent on the current land use condition of the site relative to what is proposed. UBC has established baseline performance criteria that future projects must not increase risk. Optionally, future projects can do better than existing conditions. Analysis suggests that if 10% of a site can be effectively used for rainwater management, significant control can be achieved. If 20% of the site can be effectively used with sufficient depression storage, with the remaining 80% being impervious, analysis suggests that a site can be virtually zero discharge.

   Climate change influences may over time precipitate the need for UBC to retrofit existing systems, however at this time we suggest that there is insufficient information about the future that warrants consideration for retrofitting existing systems for future conditions. We suggest that decisions should focus on opportunities through planned redevelopment and campus expansion. Retrofitting existing systems is suggested as the last resort, and based on historic performance and a risk assessment.

In the Main Campus, 14 different Future Projects have been defined with a total area of approximately 17 hectares. Based on available concept images for these Projects, they have a total pervious area of 55,000 m^2, or 5.5 hectares. This represents 32% of the total development area. This is more than what is required to meet management objectives, so the opportunities appear to exist. The question is how these opportunities are distributed across the campus. Let us assume at this time that 10% of all pervious area is allocated to rainwater management, which is approximately 1.7 hectares (17,000 m^2). We would argue, however, that there is relatively little difference between a standard landscaping and a landscape feature purposed for rainwater management. The key difference is shape (creating a shallow depression), a basic overflow device, and possibly an underdrain. Landscape designers in Urban Systems apply a planning level capital cost of about $90 per square meter for conventional mixed landscaping and suggest a premium of perhaps 10% if no special controls or under-drains are required, and perhaps 20% if underdrains are required. This puts the capital cost premium over conventional landscaping at $9.00 to $18.00 per m^2. For this discussion, let us consider a capital cost premium of $18 per m^2

Similarly, with operation and maintenance costs, annual maintenance is expected to be similar to a conventional landscaping and a major rehabilitation is likely every 15 to 20 years. For this discussion, let us consider an annual maintenance cost premium of $2 per m^2. The life cycle duration is not dissimilar from conventional landscaping; therefore, the rehabilitation costs are considered neutral.

For all Projects identified in the established campus, and with LID features applied to 17,000 m2, the capital cost premium is estimated at $306,000, and the annual maintenance premium estimated at $34,000. The capital costs premium could be higher for more structural solutions such as green roofs, planter boxes integrated with building architecture, etc.

2. **Storm Sewers –** For planning purposes, Urban Systems suggests a unit capital cost of $1.50 per mm perm of sewer in new areas, and $2.00 per mm per m when retrofitting existing areas due to increased impact and restoration required. Most storm sewer maintenance is associated with poor installations and debris when cleansing velocity is not achievable. In most cases UBC offers good topography which should allow decent flow velocities. It would be hoped that any new sewers would be built to high standard. Some maintenance costs are associated with cleaning drains, periodic flushing, and camera inspections, however overall the maintenance costs associated with a properly installed system are minimal. For planning purposes, we suggest considering $10,000 per year.

   Figures 13 and 14 present the required pipe upgrades resulting from future development without the application of any site controls. In this case, we have presented results based on the full ensemble climate change precipitation set. If new pipes are installed, we suggest consideration for climate change be given since the life cycle of a storm sewer should be 75+ years. However, we feel that the MICRO5 is extreme and therefore we have not considered it.

   Figure 13 describes the required pipe upgrades to generally maintain existing pipe performance, which totals $2.2M and can be compared against the cost of applying site controls, discussed in item 1 above.

   Figure 14 describes the required pipe upgrades to generally eliminate surface flooding, which totals $2.9M. The upgrades are extensive.

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IRMP

Minimum Upgrades Required To Maintain Flooding at Existing Level

Future Development with NO LID with 1:5 year Full Ensemble

Legend

- Pipe Upgrades
- Manholes
- Existing Pipes
- 300mm Existing Pipe Size
- 300mm Upgrade Pipe Size

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ DRAFT ~
Revision:	A
Date:	2016 / 9 / 16

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FIGURE 13

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IRMP

Upgrades Required To Eliminate Flooding

Future Development with NO LID with 1:5 year Full Ensemble

Legend

- Pipe Upgrades
- Manholes
- Existing Pipes

300mm Existing Pipe Size

300mm Upgrade Pipe Size

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System:
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FIGURE 14

3. **Temporary Storage (Dry Pond) –** In Innovation Precinct, it appears that temporary detention will be required to reduce the installation of disposal facilities. In this case detention should include provisions for water quality treatment upstream of the disposal facility. We suggest a capital cost of \$200 per m^3 of storage; however, the costs can vary depending on the extent of landscaping and finishing elements. Annual maintenance is suggested at \$15 per m^3 of storage and should have a life span of 15 to 20 years before major overhaul.

4. **Recharge Basin –** This is an optional approach for rainwater disposal in Innovation Precinct. It is similar to the temporary storage basin noted above, however additional native soil must be removed and disposed to expose the high permeability aquifer. The overburden material to be removed is approximately 3 meters thick, but it is typical for a basin to be in the order of 2 meters deep with freeboard. As such, an additional 1 meter of material will need to be removed and disposed. It is assumed this material can be spoiled locally on the property for general landscaping; however its specific application as structural fill will require the assessment of a geotechnical engineer. It is also assumed that coarse import clear crush material with be imported to prevent the basin from being excessively deep. If so, we suggest an added premium of \$60 per m^3. A recharge basin does not require the same water quality treatment features as the temporary storage facility, but can have landscape finishing on the side slopes similar to the storage basin. So, a recharge basin has some less complexities and more complexities over the temporary storage basin, and on average we suggest using the same \$200 per m3. Recharge basins are sized based on their bottom area, so assuming the basin has storage depth of 1.5 meters, the unit cost is \$300 per m^2. The life cycle duration should also be 15 to 20 years if properly maintained and designed, however it will require regular maintenance in the form of debris removal and vacuuming the base to prevent it from clogging. However, it is assumed that there is a water quality treatment system immediately upstream of the basin (likely in the form of a forebay) to minimize that need. It is suggested that an annual maintenance cost of \$20 per m^2 be applied. A recharge basin of 432 m^2 has equivalent capacity as one injection well, having an estimated capital cost of \$129,000 and annual maintenance of \$8,600. The benefit of a recharge basin is that it is accessible and can be rejuvenated. The other benefit of a recharge basin is that its volume can be counted as part of the temporary storage, so assuming storage of 1.5 meters deep, a basin 432 m2 offers 648 m3 of storage which an injection well does not.

5. **Injection Well –** The estimated capital cost for a single injection well can range between \$100,000 and \$165,000. For planning purposes, we suggest applying \$150,000. This excludes the cost of any pre-treatment systems upstream of it. Similar to the recharge basin approach, the temporary storage could be applied as the water quality treatment facility immediately upstream of the well (likely in the form of a constructed wetland). Alternatively, an oil grit separator should be applied, with a capital cost of about \$75,000 combined with a small constructed wetland or other form of filter, with an estimated capital cost of about \$500 per m^2. We have suggested a higher than usual unit rate because of the small size and economy of scale. It is assumed that each constructed wetland would be approximately 100 m^2 in size, for a capital cost of \$50,000. The total capital cost for this system is \$275,000 per well. However, if the well is coupled with the temporary detention basin, it can serve as the treatment system and the capital cost of the well alone, at \$150,000, is comparable to that of the recharge basin (\$129,000) with equal capacity.

   Annual maintenance will be similar to that of a temporary storage basin and recharge basin. \$1,000 per year for cleaning the OG separator, \$20 per square meter of the wetland. Life cycle duration is also expected to be 15 to 20 years before major works, provided it is well designed and maintained. The difficulty with an injection well is that it is very difficult to rejuvenate if clogged. If it clogs, it is likely that the well will need to be abandoned and a new one drilled. The land area required for a well alone is virtually nothing, compared to a recharge basin which requires 432 m^2 for an equal capacity. However, the provision of temporary storage will govern the land area necessary, which is common to both an injection well and recharge basin. An injection well offers no storage, therefore the combination of an injection well and temporary storage will cost $150,000 higher than the combination of a recharge basin and temporary storage (capital cost difference of $21,000 plus the value of 648 m3 of basin storage ($130,000)).

Finally, for recharge wells it is recommended that water testing and monitoring be done of water entering the well in order to manage liability around aquifer contamination. The specifics of this program would need to be developed in the future should UBC wish to consider wells, as the program will be influenced by many factors not yet defined.

5.2 Options and Discussion

As previously introduced, this interim report is to assist UBC in discussing and making decisions around the following options. Urban Systems offers its professional opinion to each option for consideration. Costs presented below are introductory indicators and are not based on a full life cycle cost analysis.

5.2.1 Within the Main Campus;

Option 1 - Should management techniques be applied at the source to avoid increased runoff, or will UBC prefer to upgrade the storm sewer network?

The application of site controls satisfies many of UBC's objectives and goals. Analysis demonstrates that effective utilization of pervious spaces for rainwater management are significantly beneficial in managing runoff rates and volumes. For the main campus in particular, this is very meaningful to manage flood risk. However, to achieve a no net impact over today's condition, application of site controls at all Future Project sites is required, or alternatively, ensure sufficient controls can be integrated into each Future Project that will have an impervious fraction or catchment area greater than the site has today. If successfully done, Future Projects can proceed without upfront costs of storm sewer upgrades (other than perhaps addressing pipe deficiencies that are unacceptable in the current condition).

Assuming site controls are successfully applied to all Future Projects, analysis suggests that the typical water level in the existing pond could drop in the order of 50 mm from the current water level pattern. We don't anticipate this to be measurably detrimental to the pond. We would caution, however, against consideration to retrofit all areas of the Main Campus with site controls. Applying site controls beyond the Future Project areas may result in more detrimental effects.

It is argued that the costs of site controls are only incremental over traditional landscaping, estimates to be a total of $306,000 of capital and $34,000 per year. Assuming 50 years of remaining service life in the existing storm sewer system, the total value in 2016 dollars is $2M. This cost is spread incrementally over 50 years.

The alternative is to forgo site controls and begin replacing piping infrastructure. However, to manage risk full replacement will need to occur parallel with each Future Project. In this case new infrastructure shown does include for climate change predictions. It is questionable whether to plan for the MICRO5 scenario, but we suggest the Full Ensemble at a minimum. Only addressing the 1:5 year event, capital cost is estimated at $2.2 to $2.9M (near term dollars). Assuming again a 50 year service life to compare against site controls, the estimated maintenance cost is $500,000. The 2016 cost that would compare to the site control option, is $2.7M for storm sewer replacement, putting it significantly higher than the site control option at $2M.

All things considered, Urban Systems suggest there is high value to apply site controls that will prevent, or at least minimize and defer, storm sewer replacement. As part of the comprehensive IRMP yet to come, pipe upgrades necessary to address current deficiencies that are deemed unacceptable (e.g. flooding of the Fipke Building on August 2, 2016) will be explored and defined. Identifying pipe upgrades need to be done thoughtfully as to not transfer a flood risk problem from one location to another. Pressure relief points may still be required to avoid wholesale changes to the piping system, but these pressure relief points will be positioned where overland flow paths are available (or can be created) and where resulting impacts are deemed acceptable. As part of this review process, recommendations will be made on specific pipe upgrades along with a statement on when these upgrades should be undertaken relative to future projects. However, in theory, with the application of adequate site controls, no future project should increase risk. There is some potential risk during construction of a future project that a significant rain may fall prior to its site controls being in place; however this risk is considered reasonably low for each individual site. This risk increases if numerous construction sites are active at the same time.

Option 2 - Should management techniques be applied at the source to only those projects requiring it to avoid increased risk, or should they be applied to all future Projects where opportunity exists?

If UBC wishes to accept a no-net-impact over current condition criteria, analysis indicates that not all Future Project sites require it. Site controls will need to be applied differently at each site to the degree necessary to manage the increase in impervious area or catchment area. Current concepts for each project suggest that sufficient pervious space is available at most sites, however may not be at 4 project sites. Resolving this issue requires site specific planning that extends beyond the scope of this study.

Analysis also suggests that applying site controls at all Future Projects, even with potential short comings at some sites, can provide equal or better performance than currently. Urban Systems does not anticipate quantifiable impact to the existing pond if site controls are limited to the Future Projects, but we would caution against broader application of site controls beyond currently defined Future Project sites for fear of impact to the existing pond due to starvation of low flows. An option, however, is to install under-drains connected to the storm sewer system in site controls for non-Project sites to still capture the base flow, but rely on detention alone to reduce peak flows.

Urban Systems suggest that site controls be only for Future Project sites at this time and that a monitoring program be established near term to measure the outcomes of each project in order for Adaptive Management decisions to be made in the future. Monitoring can come in many forms, depending on the performance parameter UBC is interested to track and to suit the implementation plan, however we suggest that the most significant parameter to track is flow rate within the established storm sewer system and pond to provide more information on current performance and to track the impacts of future projects as they build. Our early recommendations for monitoring are as follows:

1. Install a permanent water level gauge in the existing pond. Ideally this will collect data in 5 minute time steps, but 1 hour would be adequate.
2. Install a permanent flow rate gauge in the existing storm sewer trunk system immediately upstream of the existing pond. Data should be recorded in 5 minute increments.
3. Install temporary flow rate gauges for one year on the service connection / overflow from each future project immediately upon implemented (to measure the effectiveness of the site controls applied). Data should be recorded in 5 minute increments.
4. Install permanent water level monitoring gauges in both the water quality treatment forebay and recharge basin in Innovation Precinct. These should collect data in 5 minute time steps, but 1 hour would be adequate.
5. Conduct periodic water quality monitoring within the existing pond and future recharge basin.

Monitoring of flow rates in Innovation Precinct will be subject to UBC's decision on the system being pipeless or not. More specific recommendations for monitoring will be provided in the comprehensive IRMP.

Option 3 - In the face of climate uncertainty, what extent of climate change considerations should be given to the design and sizing of management facilities?

Science about future precipitation remains uncertain, and recommended application of global models are based on a pessimistic view on the worlds ability to reduce GHG's adequately, therefore are conservative. As demonstrated in this report, this conservative outlook will yield significant increases in precipitation intensities. We recommend that infrastructure decision do consider some climate changes, but we suggest considering the Full Ensemble as the minimum consideration. APEGBC guidelines suggest that in the absence of site specific trend data, design flows should be increased 10% to account for climate change. The Full Ensemble exceeds that amount base line recommendation by APEGBC. The MICRO5 grossly exceeds it.

Urban Systems suggests consideration for the Full Ensemble condition in infrastructure decisions at this time.

Option 4 - Should expansion of Purcell Courts drain as previously planned into the Main Campus, or should the expansion area be directed into the Innovation Precinct area?

Much of the Purcell Courts expansion area appears to drain north-east to the Innovation Precinct area. Draining Purcell Courts to Innovation Precinct would be in keeping with existing drainage patterns and reduce the criticality to ensure sufficient site controls are provided to avoid any additional risk to the existing systems.

If Purcell Courts is drained into the established system of Main Campus, it needs to be verified that there is sufficient ability to fully manage this increased area of the development cell and any uphill slope that drains to it. Preliminary information suggests this is possible, but verification requires detailed site design that extends beyond the scope of this study. Purcell Courts is in close proximity to a steep slope, and based on Piteau's investigation it warrants site controls having an under-drain to avoid risk of seepage impacts on the downhill slope.

The proximity of Purcell Courts to Innovation Precinct development cell C is convenient to integrate systems with relatively little infrastructure, however a more advanced look at topography and grading is recommended as part of the planning process for Innovation Precinct. Discharge from Purcell Courts downslope into Innovation Precinct could likely be done either with a pipe or an open channel system, however if open channel it should be lined to limit seepage and erosion. The geometry of the slope and the required channel will also dictate the options. Generally speaking, anticipating a pipe within the steep slopes is likely the most practical approach.

Ideally, the infrastructure within Innovation Precinct will be in place prior to the development of Purcell Courts, however we don't believe it is mandatory provided that some temporary infrastructure be applied as necessary. To some degree Purcell Courts is expected to generate some amount of runoff at a concentrated discharge point. This water will need to be directed to a location that does not cause an erosion risk, and ultimately needs to be recharged to the ground. The timing and duration between Purcell Courts and Innovation Precinct will need to be considered, as will the phasing of Innovation Precinct itself. It is always preferable to construct from the downstream up, but in this case we suggest a temporary channel and recharge basin could be applied if UBC requires that Purcell Courts proceeds in advance of Innovation Precinct.

The relative cost of sending water from Purcell Courts into Innovation Precinct is considered low relative to redirecting flows into the main campus given the apparent impacts that may result. This is considering both tangible costs (i.e. pipe infrastructure) and intangible costs (i.e. costs of repair if something goes wrong). We suggest that directing water from Purcell Courts into Innovation Precinct is more a risk management decision than it is an infrastructure decision.

Management and disposal of rainwater within Innovation Precinct does not appear limited, therefore any additional runoff from Purcell Courts should be easily accommodated. It is still recommended, however, that site controls be implemented.

Urban Systems suggests that the Purcell Courts expansion area should drain into Innovation Precinct to eliminate uncertainty and risk to the existing system of Main Campus.

The use of active park facilities (ball courts, skate parks, etc.) could be used as temporary storages, however these "hard court" facilities do not provide retention, but only temporary detention that only assist in reducing peak flows, but not meet other environmental and social objectives. There is also the potential that regularly flooding these active hard court services may decrease user satisfaction and increase maintenance. Particularly in Purcell Courts is drained to Innovation Precinct, we suggest not using active hard court facilities for stormwater management, but apply landscape / infiltration based site controls and then designing conveyance systems to accommodate minor and major design flows.

5.2.2 Within Innovation Precinct;

Some suggestions to managing Innovation Precinct is portrayed in Figure 15 on the following page. It shows that Innovation Precinct development Cell C is outside what Piteau has identified as the rapid infiltration zone. It is therefore not anticipated that this cell will be fully self-managed and will require an overflow, storage, and disposal further downstream. This is also the case for Purcell Courts, should UBC agree to drain it into Innovation Precinct.

Option 1 – Should centralized stormwater management facilities be applied, or should smaller, highly distributed facilities be created?

As noted above, it is expected that some amount of overflow, at least for a 1:100 year event, will occur for from Purcell Courts and development cell C. This overflow is expected to route down the future road corridor into cell An for further management and disposal.

It is envisioned that flow along the future road corridor from Cell C to Cell A would be a swale, however may alternatively be a pipe. We first suggest a swale because of an aspiration to be a “pipeless” neighbourhood, but also as a showcase of more natural systems and processes. However, this road will have a significant longitudinal grade and therefore will require particular considerations for a swale to be successful, as follows:

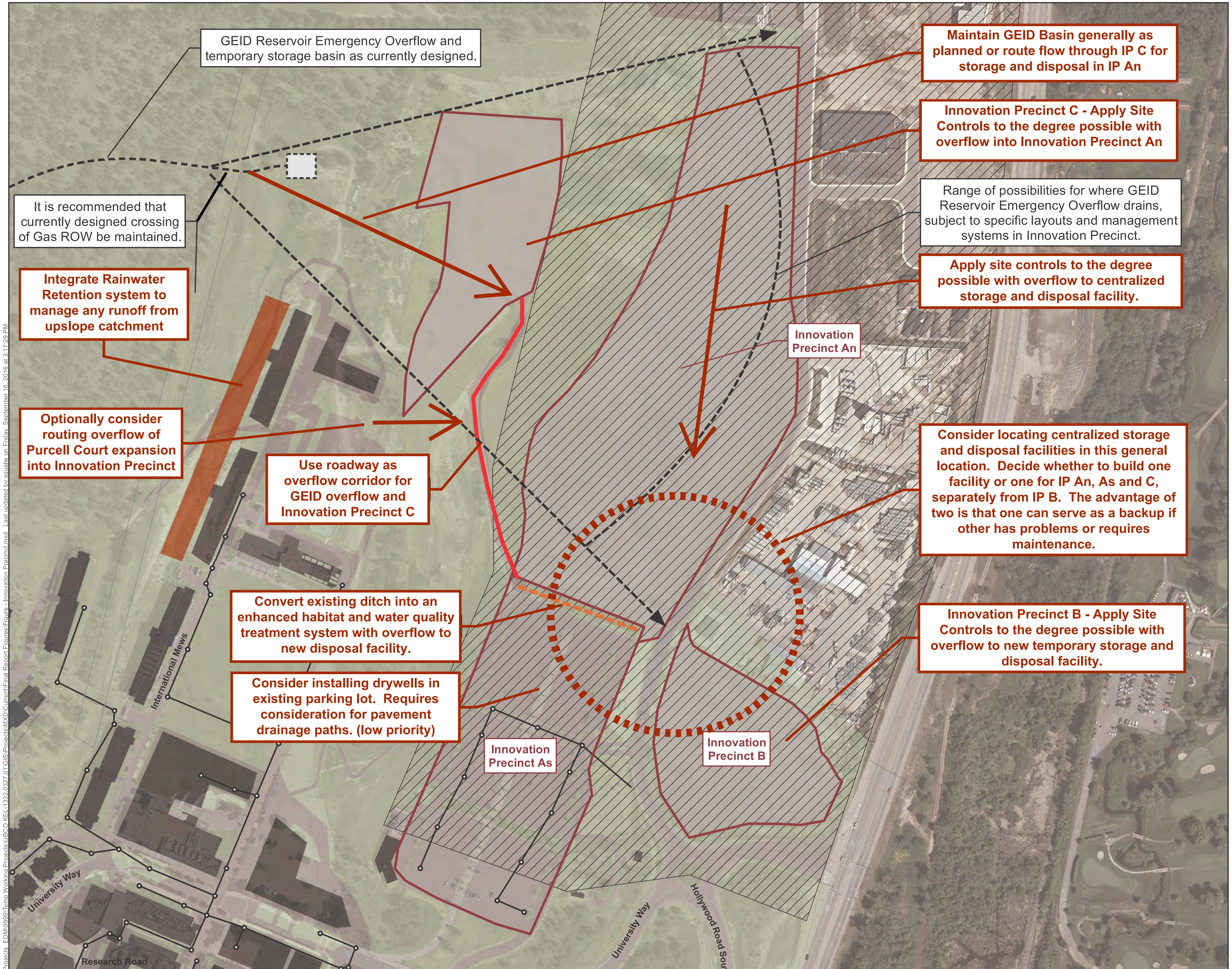
1. A cross section of the road will need to be developed to ensure that sufficient space in the corridor is secured, and to understand the overall roadway geometry.
2. The swale will need to be lined in order to prevent seepage failures and erosion.

The capital costs are likely not dissimilar to a pipe, however the swale will require somewhat more maintenance (litter cleaning, vegetation management) compared to a pipe which should be virtually maintenance free. In addition, a piped solution will be more space efficient. A swale will likely involve a wider corridor and more embankment fill.

So, a centralized system to some extent will be required for these areas. However, for development within the rapid infiltration zone, the opportunity exists for highly distributed controls. Without question, it is recommended that shallow landscaped based site controls be applied to the degree possible, just like as discussed for the Main Campus. The option of centralized or disbursed lies with the ultimate water disposal system for runoff that cannot be managed by the shallow site controls.

If adequately planned and designed, and through the effective application of site controls for small storms, it should be possible to largely have Innovation Precinct pipe free provided there is acceptance for overland flow paths for high flows to a centralized storage and disposal facility. Again, this determination should be explored through the planning process for Innovation Precinct as a separate initiative. Site grading and building form will be critical to the need for underground piping infrastructure.

As indicated elsewhere in this report, it is not practical to dispose of runoff at the peak rate it is generated, therefore for large events temporary storage is required. Also, the cost of disposal facilities is high,



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IRMP

Innovation Precinct Suggested Management Approach

Legend

- Development Areas
- Existing Manholes
- Existing Storm Sewers
- Building
- Hardscape
- Vegetation / Undeveloped
- Zone of Rapid Infiltration

Note:
Innovation Precinct Developed cells are assumed to be 90% impervious and 10% pervious.

0 20 40 80 120
Metres

N

Coordinate System: NUTM11

Data Sources: Data provided by UBCO, 2016

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FIGURE 15

therefore there are economies of scale; not only for capital cost, but long term operation and maintenance.

Centralized facilities also offer the opportunity as a more substantial focal point in the community. Urban Systems suggests wide distribution of shallow landscape based site controls to the degree possible, with identified overflow routes to a centralized storage and disposal facility.

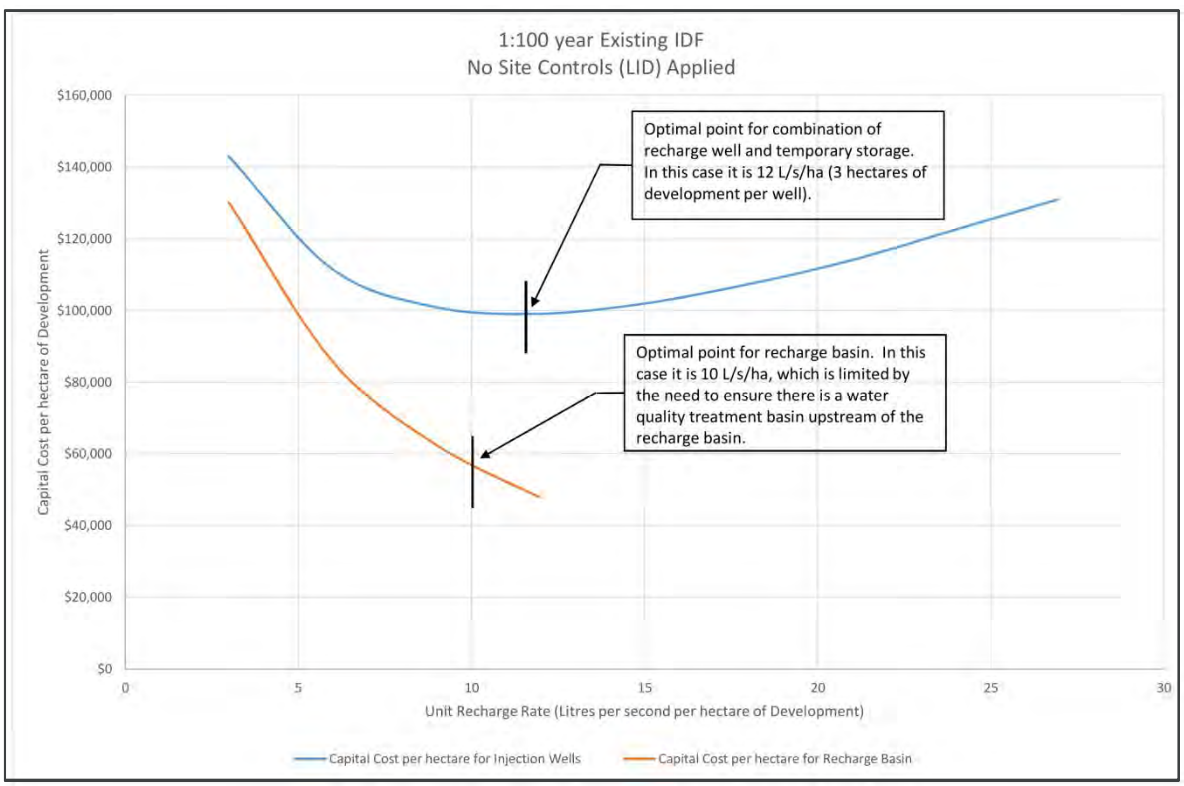
Option 2 – What is the preferred combination between disposal facilities and temporary storage?

This is the most challenging of all the questions raised. To answer this question, we must consider the cost relationships between storage and disposal. Given the expected impervious area and the likely peak runoff generated during a 100 year event, analysis has indicated it not practical to dispose of water at the rate it's generated, so some amount of storage is required.

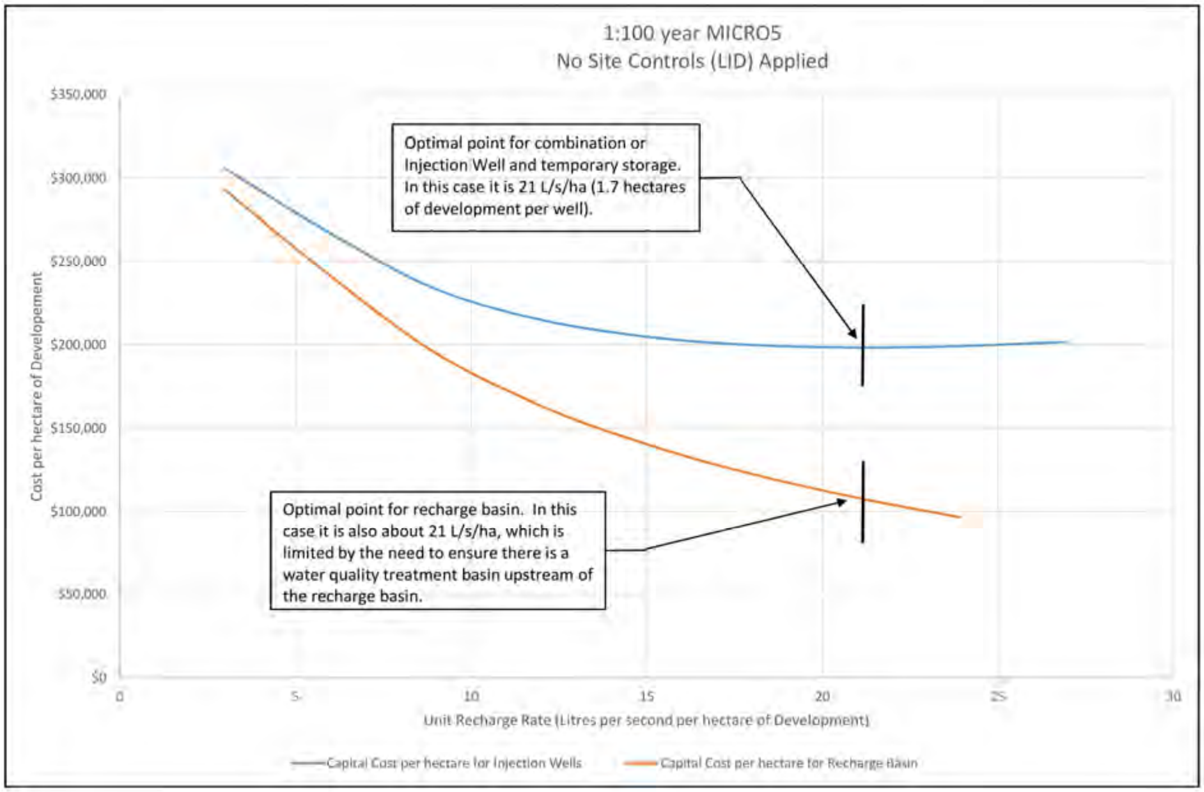
Two comparative capital cost profiles have been developed as presented in Graphs 5.1 and 5.2. Two sets of rainfall parameters have been selected to understand the two extremes; the 1:100 year Existing Kelowna IDF in Graph 5.1 and the extreme 1:100 year MICRO5 IDF in Graph 5.2. In both cases the curve is based on capital cost alone because maintenance and life expectancy are considered similar for both disposal systems, and therefore have a neutral effect on the comparison.

There are a number of variables that will affect the absolute cost per hectare of development, therefore for comparative purposes certain variables were selected and held constant such that a relative comparison could be achieved.

Graph 5.1 – Capital Cost Profile (Existing IDF)



Graph 5.2 – Capital Cost Profile (MICRO5)



These graphs validate early discussion that the use of recharge basins is more cost effective than recharge wells, and this pattern is consistent regardless of the design storm applied. So long as development design is high enough, and the design storm large enough that temporary storage is required, a recharge basin offers greater cost efficiency, and simply lower cost because of the efficiency of the recharge basin also providing temporary storage.

As shown in the graphs above, there is definitive optimal relationship between temporary storage and number of injection wells confirming that some amount of temporary storage should be provided. For the recharge basin, the lowest cost will be to make the entire basin capable of rapid recharge; however the optimal point is limited by the need to have a water quality treatment facility, which can be a primary treatment basin (e.g. constructed wetland) ahead of the recharge basin. It is suggested that the primary treatment basin be approximately 20 to 25% of the total required storage volume. The graphs above locate that optimal point for each of the scenarios applied. The optimal point shifts depending on the design storm and total storage required, therefore some other decisions first need to be made before a single optimal point can be provided. However, it appears clear that a recharge basin offers greater cost effectiveness regardless.

In addition, the total footprint area is approximately the same between the options since the optimal cost was achieved with the same amount of temporary storage for each option: the volume of storage is largely what defines the size of the area required. Similarly, regular annual O&M requirements are expected to be generally similar, however if a problem develops the recharge basin will be far easier to deal with.

The recharge well option requires that wells be spaced a minimum of 50 meters apart and from a cost perspective the optimal well solution requires a minimum of 4 wells in total for current precipitation and up to 7 for future precipitation. These wells will require piping to connect them together, and to the storage basin, and will also require a well head protection zone around each well. However, this protection zone should not significantly encumber the land. In other words, the land base and maintenance for the two options is generally similar, however the recharge basin is far cheaper to implement and has lower risk associated with aquifer contamination and is easier to manage if a performance issue develops.

The cost analysis also reaffirms the recommendation to use centralized storage and disposal facilities rather than numerous small facilities because of greater geometric efficiencies and utilization of space. Also, it will be most cost effective to operated and maintain fewer facilities. Flow routing, the topographic grading scheme, and the phasing program of implementation for Innovation Precinct will have a significant influence on the number and location of recharge basins. What appears to be the most efficient location for siting a centralized recharge basin is circled in Figure 15. This should be explored as part of the planning process getting underway for Innovation Precinct.

Option 3 – Should Innovation Precinct use injection wells, or recharge basins, for disposal to ground?

The answer to this question is largely answered with Option 2 above. The cost comparison indicates that a recharge basin is cheaper and more cost effective.

In addition, there are greater risks of aquifer contamination with the injection wells. The fate and use of the existing GEID wells in the area should influence the decision on whether to consider injection wells or not. It is suggested not if there is any chance of these existing wells being used for potable water or food supply irrigation.

We understand that one of the vector wells has a pump that extracts water while the other 16 inch well is a casing and screen. Assuming they are abandoned, it may be possible to repurpose them as injection wells; however this will require detailed review by a qualified hydrogeologist. In addition, the optimal configuration indicates that 7 wells are required, so even if these two can be used, an additional 5 are needed.

Injection wells, if fouled by lack of maintenance will not be readily rejuvenated and will likely need to be abandoned, whereas a recharge basin can be designed with an accessible filter layer that can be rejuvenated.

Regardless of which option is selected, given that Innovation Precinct will form a gateway into the University it is encouraged that the recharge basin and temporary storages be designed in a way that serve as a visual amenity, and not solely as a utility.

In summary, Urban Systems suggest using recharge basins rather and injection wells for the following reasons:

- Both options require a similar encumbered land base, but wells require a greater gross area with well head protection.
- Both options have similar annual O&M however if a problem develops a recharge basin is much more easily addressed.
- Recharge basins are cheaper and more cost effective because the recharge basin component also serves as temporary detention.
- Recharge basins do not offer the same degree of contamination risk to the aquifer.

Option 4 – Should the existing infiltration ditch adjacent to Lot H be retrofitted, or left as is and supplemented?

Simply put, Urban Systems suggests that UBC can do better. This existing ditch is not functioning as intended, is unsightly, and despite the Spadefoot toad inhabiting it, could be improved to provide better habitat. At a minimum, Urban Systems suggests that this ditch be rehabilitated to address bank instability and erosion issues. If it is confirmed through Innovation Precinct planning that the ideal location for a centralized storage and recharge basin is as circled in Figure 15, an option would be to maintain this existing ditch purely as a snow retention and sediment trap ditch for the parking lot, with an overflow into an adjacent, enhanced water quality treatment and Spadefoot Toad habitat feature followed by the temporary storage and recharge basin for disposal of water.

Option 5 – What are the options for how the GEID Reservoir Emergency Overflow can be integrated into Innovation Precinct?

Urban Systems feels there are many options to consider. Some options are suggested in Figure 15, but it is recommended that the piping design remain as is to the point where it crosses the Gas right-of-way, which we believe is the optimal point. However, from that point east there are options.

The activation of this overflow system is going to be rare, if ever. Extending piping and building separate storage and disposal facilities certainly adds cost that may never be used. However, some provision must be given should it be needed. While the risk associated with placing a storage basin upstream of Innovation Precinct development may be low, it is still not preferable. Urban Systems suggests extending the conveyance system, either with a pipe or an erosion resistance channel, to the western limit of development cell C. At this point an overland flow path can be integrated into the design of the development cell C to receive any overflow safely. An overland flow path through the development cell will be required regardless to serve the development itself, continue down the roadway corridor, and through the lower development cell to the centralized storage facility for Innovation Precinct. It is highly unlikely that the reservoir will overflow at the same time as a significant storm event, therefore it is not suggested that systems within Innovation Precinct need to be oversized to accommodate the reservoir overflow.

For comparison, the design flow rate from the GEID overflow is 221 L/s. Assuming LID is applied to the development of Innovation Precinct, the anticipate peak 1:5 year discharge rate from Cell C alone is approximately 120 L/s, and 600 L/s for the 1:100 year event, both using the Full Ensemble climate change precipitation. The 1:100 year flow will govern the design of major flow paths, so assuming that the GEID overflow could be accommodated in a surface flow path, the GEID overflow add no addition requirement to the design of Innovation Precinct. It is therefore suggested that accommodating the GEID overflow through the development area creates no impact, but is simply an added component to be accommodated.

We do understand that GEID is adding a third cell to the reservoir that the overflow services. Adding more storage in itself does not require additional overflow capacity because the overflow is only provided to compensate if the supply pumps do not shut off. We recommend that UBC speak to GEID to determine whether or not the supply rate has increased above 221 L/s.

5.3 Decision Making Criteria

UBC have expressed that the primary decision making criteria are as follows:

- Reduced total cost of ownership
- Potential to avoid upgrades to grey infrastructure
- Reduced O&M
- Spatial footprint and impacts
- Contribution to enhancing public realm
- Contribution to teaching, learning and research

Table 5.1 – Decision Matrix

Criteria	Apply Site Controls to all Future Projects (including Innovation Precinct)	Do not apply Site Controls to Future Projects (including Innovation Precinct)	Apply Recharge Basins in Innovation Precinct	Apply Recharge Wells in Innovation Precinct
Reduced total cost of ownership	Yes	No	Yes	No
Potential to avoid upgrades to grey infrastructure	Yes	No	n/a	n/a
Reduced O&M	No	Yes	Neutral	Neutral
Spatial footprint and impacts	See note below	See note below	See note below	See note below
Contribution to enhancing public realm	Yes	No	Yes	Yes
Contribution to teaching, learning and research	Yes	No	Yes	Yes

Although there are several options, or questions, discussed above, the primary decisions to be made are; 1) whether or not to apply controls at Future Project sites (including Innovation Precinct), and 2) whether to use injection wells or recharge basins in Innovation Precinct. UBC staff will need to make their own interpretation of how each item measures against the expressed criteria, but Urban Systems offers its views in Table 5.1 above.

Note: The cost analysis presented in sections above has factored in land base requirements. It generally demonstrates that Future Projects and Innovation Precinct offer sufficient pervious space to provide significant benefit if it can be effectively used for rainwater management. At this time analysis has assumed only effective application of 50% of the available pervious space at each Project site. As such, it does not appear that the development plans at each site will be compromised to meet performance targets. However, UBC will need to go through a design exercise for each Future Project site to determine how and in what form site controls can be integrated. This level of investigation is beyond the scope of this IRMP study.

Similarly, for Innovation Precinct analysis has identified that temporary storage cannot be avoided. As such, a defined land base of equal size needs to be provided for storage regardless of disposal choice. A centralized system will require less total land than several smaller storages. Underground storage may be considered, which would allow active facilities (e.g. Parking lot, but not buildings) to be built over top of them, however the unit cost of buried storage is approximately 5 times that of an open basin. UBC will need to weigh the cost of land use lost opportunity (by providing land base for an open basin) against the substantial premium cost for buried storage. However, buried storage does not meet many environmental, social, and “avoid grey infrastructure” objective expressed.

5.3.1 Low Impact Development Feature Operational Considerations

LID features are anticipated to largely consist of depressed landscaped area that receives surface runoff from surrounding pervious areas. It is anticipated that these LID features will have either a piped overflow or a surface overflow graded toward an accepted surface flow path or nearby drainage inlet (e.g. catch basin). As would happen in a natural state, ground will freeze to some extent during the winter, and snow will accumulate. During periods of thaw, runoff will generate to various degrees. LID features should be used for snow disposal from pervious areas, and a commitment is required to keep outlets clear of snow and debris such that overflows is not impeded.

The application of LID also requires special attention during construction to prevent damage. The single largest risk is fine sediments from a construction site washing into, and plugging, infiltration based LID features. Not only can the sediment impact infiltration capacity, but it can damage the landscape finishing. This risk will be highest for features integrated into Innovation Precinct where performance is heavily governed by infiltration. The recharge basin or recharge wells will be particularly vulnerable and therefore very strict sediment and erosion control measures will need to apply. An implementation strategy should also consider temporary facilities during the bulk of the construction process, with ultimate infrastructure being implemented once the bulk of the construction risk is passed. The implementation strategy would be contingent on many factors which are not yet known and will need to unfold as part of the Innovation Precinct Plan process.

There are a number of established best practices for controlling sediment and erosion on construction sites. If one does not already exist for UBC, it is recommended that a sediment and control criteria manual be developed. It is also recommended that as part of the design process for each future development the total annual maintenance hours be estimated such that appropriate decisions can be made around staff and equipment, not just cost.

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The University of British Columbia would like to acknowledge the work carried out by the UBCO Leadership Team, Technical Working Group and Urban Systems' consultant team, in the development of the *UBC Okanagan Integrated Rainwater Management Plan (IRMP, 2017)*.

The *IRMP* was developed from 2016-2017 by Urban Systems' interdisciplinary consultant team in collaboration with UBC. It was developed to support the *UBC Okanagan Campus Plan (2015)* and *UBC Okanagan Whole Systems Infrastructure Plan (2016)* by providing an update to the *2011 Stormwater Master Plan*. The *IRMP* responsibly manages the rainwater that falls on campus in a way that respects natural hydrological processes, protects existing environmental values, and manages risk.

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