The University of British Columbia | Okanagan Campus

Integrated Rainwater Management Plan

Final Report | July 2017 | Part 1: Vision, Principles, Actions

a place of mind

THE UNIVERSITY OF BRITISH COLUMBIA

Prepared for

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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.

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table of contents

ubc okanagan campus integrated rainwater management plan

1 VISION, GOALS, AND CONTEXT PLANS 1

ACKNOWLEDGEMENT 2

TERMINOLOGY CLARIFICATION 3

HOW TO USE THE IRMP 3

EXECUTIVE SUMMARY 4

1.1 IRMP FRAMEWORK 10

1.2 SETTING CONTEXT 11

1.3 IRMP GOALS 14

1.4 IRMP OBJECTIVES 15

1.5 STORMWATER MANAGEMENT PLAN (2011) 17

1.6 WHOLE SYSTEMS INFRASTRUCTURE PLAN 18

1.7 SUMMARY OF PUBLIC CONSULTATION 23

2 LOW IMPACT DEVELOPMENT AND SITE CONTROL 27

2.1 TECHNICAL ANALYSIS AND OPTIONS REPORT 28

2.2 EXISTING CONDITIONS 28

2.3 GEOTECHNICAL CONDITIONS AND SOIL PERMEABILITY 31

2.4 FUTURE PROJECTS 35

2.5 SITE MANAGEMENT REQUIREMENTS FOR FUTURE PROJECTS 40

2.6 LOW IMPACT DEVELOPMENT (LID) CONTROL OPTIONS 45

3 COMMUNAL INFRASTRUCTURE 49

3.1 MAIN CAMPUS 50

3.2 OVERLAND FLOW PATH ROUTING AND FLOOD MITIGATION ASSESSMENT 56

3.3 MAIN CAMPUS INFRASTRUCTURE IMPROVEMENTS 66

3.4 INNOVATION PRECINCT (NORTH CAMPUS) 69

4 ENVIRONMENTAL CONSIDERATIONS AND SUPPLEMENTAL RECOMMENDATIONS 87
4.1 EXISTING POND IN MAIN CAMPUS 88
4.2 EXISTING DITCH SERVICING LOT H 89
4.3 CONSTRUCTED WETLAND AND RECHARGE BASIN 90
4.4 SUPPLEMENTAL RECOMMENDATIONS 91

5 IMPLEMENTATION AND LIFE CYCLE COSTS 94
5.1 MAIN (SOUTH) CAMPUS IMPLEMENTATION STRATEGY 95
5.2 INNOVATION PRECINCT IMPLEMENTATION STRATEGY 95
5.3 LIFE CYCLE COSTS 96

APPENDICES
APPENDIX 1 MODELING SCHEMATICS AND PARAMETERS
APPENDIX 2 STORM SEWER HYDRAULIC PROFILES

CREDITS

list of figures

FIGURE 1 EXISTING LAND USE AND PRIMARY CATCHMENTS 29
FIGURE 2 SOIL GROUP AND INFILTRATION RATES 33
FIGURE 3 FUTURE LAND USE, PRIMARY CATCHMENTS AND PROJECTS 37
FIGURE 4A SEWER PERFORMANCE 1:5 YEAR HISTORIC IDF 51
FIGURE 4B STORM SEWER PERFORMANCE 1:5 YEAR, CLIMATE CHANGE 52
FIGURE 4C STORM SEWER PERFORMANCE 1:100 YEAR HISTORIC IDF 53
FIGURE 4D STORM SEWER PERFORMANCE 1:100 YEAR CLIMATE CHANGE 54
FIGURE 5 1:100 YEAR PREDICTED FLOOD LOSSES 57
FIGURE 6 OVERLAND FLOW PATH ROUTING 58
FIGURE 7 PROFILE OF UNIVERSITY WAY AT DISCOVERY AVENUE 61
FIGURE 8A OVERLAND FLOW PATHS IN PROXIMITY TO CREATIVE STUDIES BUILDING (SITE 1) 62
FIGURE 8B OVERLAND FLOW PATHS IN PROXIMITY TO THE ARTS BUILDING (SITE 2) 63
FIGURE 8C OVERLAND FLOW PATHS IN PROXIMITY TO CAMPUS ADMINISTRATION (SITE 3) 64
FIGURE 9 POTENTIAL STORM SEWER IMPROVEMENTS 67
FIGURE 10 PROPOSED INFRASTRUCTURE SOUTH CAMPUS 68
FIGURE 11 PROPOSED INFRASTRUCTURE SCHEMATIC NORTH CAMPUS 71
FIGURE 12A INNOVATION PRECINCT OPTION 1 81
FIGURE 12B INNOVATION PRECINCT OPTION 2 82
FIGURE 13A CENTRALIZED TREATMENT WETLAND AND RECHARGE BASIN LINEAR CONFIGURATION WITH BI-DIRECTIONAL INPUTS 83
FIGURE 13B CENTRALIZED TREATMENT WETLAND AND RECHARGE BASIN COMPACT CONFIGURATION WITH SINGULAR INPUT 84
FIGURE 13C CENTRALIZED TREATMENT WETLAND AND RECHARGE BASIN SECTION 85

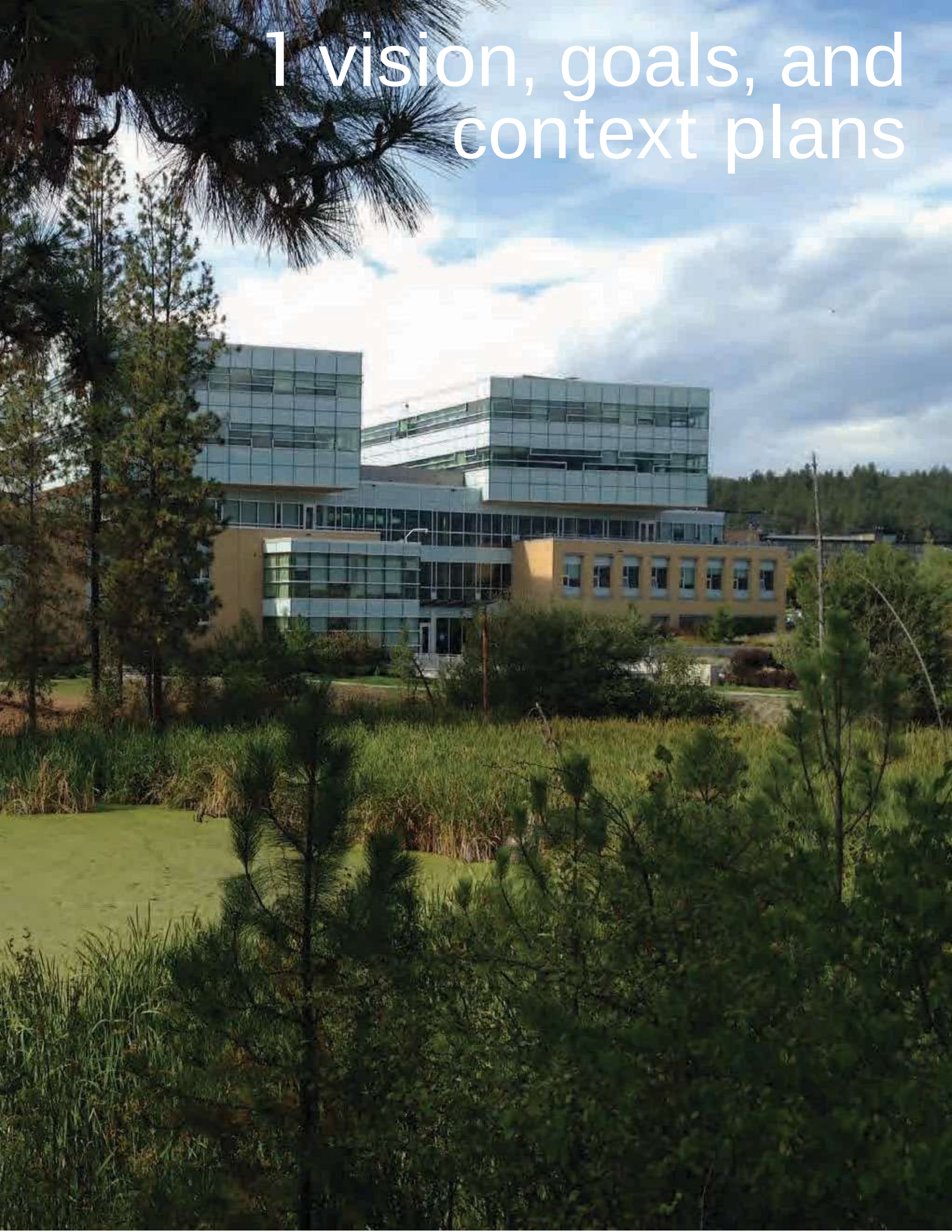
list of tables

TABLE ES-1 SUMMARY OF RECOMMENDATIONS 7
TABLE 1 FUTURE PROJECT AREA STATISTICS 39
TABLE 2 DAILY (24 HOUR) PRECIPITATION DEPTHS 40
TABLE 3 FUTURE PROJECT HYDROLOGY AND HYDRAULICS 43
TABLE 4 APPLICATION OF LID TECHNIQUES 47
TABLE 5 INNOVATION PRECINCT PROPOSED INFRASTRUCTURE 70
TABLE 7 TREATMENT REMOVAL PERFORMANCE 75
TABLE 8 COMPARISON OF TREATMENT EFFECTIVENESS 77
TABLE 9 LIFE CYCLE COSTS 99

Companion Documents

PART 2 – RAINWATER MANAGEMENT OPERATION AND MAINTENANCE MANUAL
PART 3 – INTERIM REPORTS
PART 4 – GEOTECHNICAL INVESTIGATION
PART 5 – PUBLIC CONSULTATION PROCESS

1 vision, goals, and context plans



The UBC Okanagan Campus Plan (2015) sets out a vision and a long-term planning framework for the physical development of the campus in support of the University's strategic plan and academic mission. It provides for a potential doubling of the campus population and academic and residential facilities, based on historical city, regional and university growth patterns. A key principle is to manage campus growth through a whole systems (environmental, economic and social sustainability) lens to achieve net-positive impact on the well-being of the campus community and ecology, and in manner that is responsive and resilient to current and future conditions. Key strategies to implement the Plan's vision and this principle include implementing rainwater management strategies that enhance ecosystem assets; addressing life-cycle costs/benefits and treating rainwater as a resource, not a waste product; shifting towards renewable and regenerative energy, water and waste systems; and incorporating indigenous landscapes that are characteristic of the Okanagan climate.

A companion to the Campus Plan is the 2015 Whole Systems Infrastructure Plan (WSIP), which provides a comprehensive blueprint and implementation framework for the whole systems principle, including rainwater and biodiversity measures. The WSIP supports the implementation of low impact development (LID) rainwater strategies to manage future rainwater loads as the campus grows over the next 35 years in manner that also supports campus ecology and biodiversity. It sets out conceptual approaches for improving rainwater management with the goal of diverting 100% of rainwater from the municipal system through capture, re-use, infiltration and storage.

The WSIP recommended that an earlier 2011 Stormwater Master Plan be updated based on new management principles, and that this document be supported by geotechnical analysis to better define conditions and opportunities of the properties for infiltration. This Integrated Rainwater Management Plan (IRMP) is the result of those recommendations.

Acknowledgement

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1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
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Terminology Clarification

Historic guiding documents and the public consultation process applied the term "stormwater" management, as such this term is applied herein when referencing those past documents and processes. However, in the development of this Plan, the term "stormwater" was replaced with "rainwater" in recognition that it is not only storms that are to be managed. One could also argue that "precipitation" is also appropriate for recognition of snowfall, however "rainwater" was chosen appropriate at this time. Although both terms are applied herein, they are to be interpreted synonymously.

How to Use the IRMP

The purpose of the IRMP is to provide direction for 100% rain water management on campus up to and including the 1:100 year return period, in a way that responds to natural hydrologic processes, protects environmental values and manages risks; in compliance with relevant City of Kelowna standards. It has been developed to support the successful implementation of the Campus Plan (2015) and the Whole Systems Infrastructure Plan (2016).

The IRMP is intended to provide project teams with specific guidance on all UBCO owned projects for the design and maintenance of rainwater management site controls and low impact development for UBCO-owned projects, facilities, landscape and infrastructure. The IRMP provides specific site control and retention storage requirements, peak discharge rates, and discharge volumes for future development sites on campus.

The IRMP is intended for use by:

- Project teams including, design consultants, project managers and UBC Properties Trust;
- UBC staff undertaking project reviews, including Campus Planning and Development and Campus and Community Planning;
- UBC staff undertaking project implementation, operations and maintenance, including Campus Operations and Risk Management Services.

The IRMP's recommendations should be applied to the design and construction of all new capital and civil projects, substantive additions/renovations, and applicable cyclical maintenance and renewal work. Implementation should be supported by UBC's investments in public realm and capital projects at the building scale.

The IRMP should be used as a companion document to the Campus Plan (2015), the Whole Systems Infrastructure Plan (2016) the Campus Plan Design Guidelines and the UBC Technical Guidelines. Project teams should reference all relevant UBC policy and guidance documents along with the IRMP.

Further information if required may be obtained by contacting:

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Executive Summary

A rainwater management strategy has been formulated in response to the goals and objectives identified in the Campus Plan and the Whole Systems Infrastructure Plan (WSIP). The strategy has a strong focus toward managing rainwater at the source through the application of Low Impact Development (LID) techniques to all future projects and development.

Minimum rainwater retention targets have been established to achieve, at minimum, a "no-net impact" to existing infrastructure. Where opportunity exists, future projects and development are asked to stretch beyond this minimum standard and provide additional retention storage.

Rainwater management systems have been assessed in accordance with both 1:10 year and 1:100 year criteria, with consideration for both historic precipitation and future precipitation resulting from predicted climate change. The sizing of new infrastructure herein is to suit climate change predictions.

The capital cost associated with LID techniques is highly variable depending on the type selected. In general, it is anticipated that LID retention requirements can be met by capitalizing on the available landscape area of each future project. Available landscaped areas are to be designed as depressed rain gardens, vegetated swales, or the like, to capture precipitation runoff from the site's building rooftops, parking lots, and other hard surfaces.

Referencing the existing campus alone (excluding Innovation Precinct), to achieve a "no-net impact" objective, the estimated capital cost of storm sewer replacements (grey infrastructure) that would need to occur to facilitate future projects without the application of LID is roughly estimated at between $1.5M and $2M. UBC intends to implement quality, intense landscaping at future projects regardless of whether it is designed for LID purposes or not. So when comparing the cost of landscaped LID against grey infrastructure improvements, only the incremental cost over-and-above conventional landscaping should be considered. Again, for future projects only within the existing established campus, the total incremental cost associated with the minimum LID requirements is estimated at roughly $140,000, and an increased annual maintenance cost of $1,800 per year. If all future projects apply LID that stretch beyond the minimum requirements, the total incremental cost for LID increases to approximately $325,000, and an increased annual maintenance cost of $4,200 per year. These incremental costs are significantly less than required grey infrastructure improvements, noted above. Additionally, the application of LID allows for site specific, incremental application of controls, whereas grey infrastructure improvements will need to be front-ended ahead of redevelopment. LID also permits UBC to implement a monitoring and adaptive management program before infrastructure replacements need be considered.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

While LID is expected to effectively manage most precipitation events, soil infiltration potential is insufficient to manage high volume (rare) precipitation events. As such, despite the application of LID, the established main campus will continue to rely on grey infrastructure and the existing pond. As noted above, successful application of LID should prevent the need to replace storm sewers to facilitate future projects; however, with the existing storm sewer system having only been sized for a 1:5 year event, there are known storm sewer deficiencies and occasional flooding is observed. An overland flow path analysis has identified the potential risk to three buildings on campus; Creative Studies, Arts, and Campus Administration. Resolving this risk with piping solutions will require considerable storm sewer improvements with a capital value of approximately $400,000 at minimum. Alternatively, flood risk can be mitigated with alterations to surface landscaping to redirect potential overland flows away from these buildings.

Overland flow is also observed at the intersection of University Way and Alumni Avenue. The existing swale to the east of this intersection along University Way is a critical flood route that must be maintained and requires consideration in the planning of the Arrivals Plaza and Transit Exchange project. At this time, no additional management facility has been recommended downstream of this location. This decision was based on a recent storm event of reference; a storm occurring on August 2, 2016 having a return period of approximately 1:50 years. While extensive flows were observed, no impact was observed.

Substantial new development is proposed in the north campus, an area referred to as Innovation Precinct. This land is largely undeveloped today, therefore will experience a significant change in land use and hydrology. While upslope portions of this area also have somewhat limited soil infiltration capacity, the lower portions overlie an aquifer with rapid infiltration potential. Similar to the established main campus, all future developments in Innovation Precinct are expected to meet minimum rainwater retention targets through application of LID at the source.

Due to the limitations of the existing system in the established main campus, and the opportunities for new infrastructure in Innovation Precinct, it is proposed that all future growth of Purcell Courts be routed into Innovation Precinct for treatment and disposal. In addition, UBCO's commitment to providing an emergency overflow from the GEID reservoir will also be accommodated into the Innovation Precinct management system. Specific infrastructure to accommodate Purcell Courts and the GEID overflow must be identified through the Innovation Precinct site planning process; only conceptual alignments for them can be identified within the scope of this IRMP.

With thoughtful site planning, there is the potential for Innovation Precinct to be "pipeless", but to supplement LID a communal conveyance, treatment, and disposal system is still required. Disposal of rainwater into the aquifer will require pre-treatment. LID applied at the source will be the first form of treatment.

Excess runoff spilling from those LID's will be collected and conveyed to a centralized constructed wetland for secondary treatment. This constructed wetland will satisfy many identified goals and objectives, including water quality treatment; a community amenity, ecological diversity, and serve as a "living lab". In combination with this constructed wetland will be a recharge basin that will provide temporary storage and ultimate disposal of runoff spilling from the constructed wetland. For various reasons, a centralized recharge basin is preferred over a network of recharge wells. The communal management system is to be sized for 100% retention of the 1:100 year design storm, including an allowance for climate change impacts. The siting and design of critical communal infrastructure must be thoughtfully considered as part of the Innovation Precinct design process. Sizing of infrastructure within this document is to solely serve currently owned UBCO lands as defined herein, and will not accommodate further development east of Innovation Drive.

From an ecology perspective, both the existing pond servicing the main campus and the ditch north of Lot H are home to at risk species (Western Painted Turtle and Spadefoot Toad, respectively). Through the public consultation process, many voiced their desire for these habitats to be protected. For the existing pond, the primary recommendation is to manage nutrient loading through landscape and snow management practices. If those acts are insufficient to prevent the expansion of vegetation growth in the pond, more advanced forms of treatment within the pond could be considered. Near term, regular maintenance cleaning should focus on the pond forebay. Given the residency of the Western Painted Turtle, cleaning of the main pond can do harm to their habitat, but so will expansive growth of vegetation. The growth of vegetation within the main pond should not negatively affect the ponds hydraulic performance. With actions to first manage nutrient loading, UBCO should continue to monitor the health of the pond. Only if expansion of the rushes continues should other actions be explored.

The ditch north of Lot H now provides habitat to the Spadefoot Toad, but is largely ineffective at infiltrating; its originally intended function. While this ditch could be rejuvenated to achieve its intended function, that action will compromise the habitat of the Spadefoot Toad. As such, it is recommended that the ditch be largely maintained, however actions should be taken to arrest localized bank erosion, and an overflow from the ditch should be provided to the future construction wetland treatment facility and recharge basin for Innovation Precinct.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

TABLE ES-1 SUMMARY OF RECOMMENDATIONS

Recommendation		Report Reference Section
Low Impact Development (LID) Techniques		
.1	All future projects must provide a minimum on-site retention storage of 25 mm from all increases in impervious surfaces (over current conditions). Future projects are encouraged to provide 25 mm of retention storage for all impervious surfaces.	2.5, 2.6
.2	For any lands that are proposed to drain into the existing campus drainage system that do not currently drain to the existing campus drainage system, the on-site retention storage requirement is 50 mm for the total additional area proposed.	2.5, 2.6
.3	All LID facilities are to be provided an overflow into the existing storm sewer system. In close proximity to steep banks, LID should be provided an underdrain also with connection to the storm sewer.	2.5, 2.6
Overland Flow Path Routing		
.1	The overland flow path on the south side of University Way east of Alumni Avenue must be maintained. Site planning of the Arrivals Plaza and Transit Exchange must accommodate it.	3.2
.2	Site planning should be undertaken to explore landscape solutions to redirect potential flood flows away from three vulnerable buildings; Creative Studies, Arts, and Campus Administration.	3.2
Storm Sewers		
.1	Upgrade the existing 250 mm storm sewer crossing University Way near Lot F to a 450 mm diameter.	3.3
.2	Add benching to numerous manholes that exhibit high turbulence.	3.3
Existing Pond (south campus)		
.1	Review landscape maintenance and snow management practices to reduce, to the greatest extent possible, nutrient loading into the pond.	4.1
.2	Continue with annual water quality monitoring.	4.1
.3	Periodically remove sediment excessive vegetation from the forebay, as required.	4.1

Recommendation		Report Reference Section
.4	Monitor vegetation growth. Do not dredge the main pond unless vegetation continues to consume the south portion of the pond and other forms of water quality management fail.	4.1
.5	Undertake a detailed survey of Western Painted Turtle to better understand their use of the wetland habitat.	4.1.2
.6	Preserve or create essential habitat features, including basking rocks and logs, in shallow water areas with emergent and floating vegetation.	4.1.2
Innovation Precinct		
.1	All further development of Purcell Courts should be drained to Innovation Precinct rather than the established south campus.	3.4
.2	All development must provide a minimum on-site retention storage of 25 mm from all impervious surfaces.	3.4
.3	The GEID reservoir overflow shall be accommodated through IP cell C, however the specific routing and design must be explored through the IP planning process.	3.4
.4	A communal conveyance system will be required, sized to the 1:100 year event. UBCO is encouraged to use over flow systems wherever possible, striving for Innovation Precinct to be "pipeless".	3.4
.5	Create a centralized Constructed Wetland and Recharge Basin. The constructed wetland is to be sized to treat the 1:2 year event, but pass the 1:100 year event flows without impact. The recharge basin is to be sized for the 1:100 year event, including an allowance for climate change impacts.	3.4.1
.6	Provide pretreatment upstream of the constructed wetland using oil/grit separators (OGS), or similar.	3.4.1
.7	Undertake a dedicated infrastructure planning exercise as part of the Innovation Precinct planning process to identify the optimal location and configuration for how the construction wetland and recharge basin will integrate.	3.4.1.3
Lot H Existing Ditch		
.1	Largely maintain the existing ditch north of Lot H, but provide armoring where necessary to arrest bank erosion. UBCO is encouraged to not use this ditch for snow storage.	3.4, 4.2
.2	Add planting to enhance habitat	4.2
.3	Provide an overflow into the communal constructed wetland and recharge basin for Innovation Precinct.	3.4

	Recommendation	Report Reference Section
Monitoring		
.1	Install a permanent water level gauge in the existing pond and the proposed constructed wetland.	4.4.1
.2	Install a permanent staff gauge with a recording float mechanism in the recharge basin that can be manually read.	4.4.1
.3	Install a permanent flow rate gauge in the existing storm sewer trunk system immediately upstream of the existing pond.	4.4.1
.4	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)	4.4.1
.5	Conduct periodic water quality monitoring within the existing pond and future constructed wetland. Testing is recommended for a minimum of total suspended solids, petroleum hydrocarbons, fecal coliforms, total copper, total zinc, and nitrogen.	4.4.1
.6	Install a 2" PVC observation well immediately to the east of the recharge basin to sample downgradient groundwater quality.	4.4.1
General		
.1	Within the established south campus, service connections for new buildings should connect to the storm sewer at lowest possible point. Roof drainage is recommended to discharge to a LID facility, and be completely separate from foundation drains or internal drains (but in accordance with BC Plumbing and Building Codes). Where significant surcharge is predicted (refer to Figures 4a-d) backflow preventers should be considered on service connections. Ideally, new buildings will be slab on grade, or at least be planned such that all critical infrastructure and contents are above grade. Future buildings should be flood proofed.	4.4.2
.2	Detailed design should be conducted with site specific testing of soil infiltration rates at the location of proposed LID facilities.	4.4.3
.3	UBCO to develop rigorous sediment and erosion control guidelines for all future development and construction activity.	4.4.4

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

Recommendation		Report Reference Section
.4	Consult with pertinent faculty to discuss "living lab" opportunities when preparing designs and monitoring programs.	3.4.1

1.1 irmp framework

The IRMP is comprised of five parts, as follows:

Part 1 – Vision, Principles and Actions is Provided Within This Parent IRMP Document.

- Introduces the Vision, Objectives and Goals outlined in the 2015 Campus Plan and 2016 Whole Systems Infrastructure Plan.
- Sets the context and setting of land use, environment, and issues.
- Summarizes the technical work that supports the recommendations and actions.
- Provides an executive summary of the public consultation process.
- Recommends actions, their sizing, and design consideration (the "strategy")
- Presents associated life cycle costs of various infrastructure.
- States implementation, monitoring, and Adaptive Management steps.

Part 2 – LID Operation and Maintenance Manual

This is a companion document to the Part 1 IRMP, presenting the following:

- A description of either prescribed or likely Low Impact Development (LID) techniques to be applied. This is not to dismiss others LID techniques that may be applied, but the document has focussed on the most likely short list.
- Sample graphics and photos of the LID features described.
- A description of routine maintenance tasks and the anticipated frequency.
- A description of typical troubleshooting problems that may arise and how to address them.

Part 3 – Interim Reports

The formulation of the IRMP stemmed from a series of interim reports, which have been assembled as reference documents. These include the following:

1. Arrival Plaza and Transit Exchange, memo dated October 5, 2016.
2. Synergies Between Future Projects, memo dated October 9, 2016.
3. Revised Options Report, report dated October 28, 2016. This Revised Options Report was an interim document that guided the ultimate strategy defined in the IRMP. This document presents the:
   » Description of the study area; existing and future
   » Applied criteria
   » Preliminary hydrodynamic modeling and results
   » Options review and discussion

Part 4 – Geotechnical Investigation

To support the technical development of the IRMP, a geotechnical investigation was conduction to more clearly define soils conditions, near surface infiltration potential, and deeper recharge potential. This companion document reports that investigation.

Part 5 – Public Consultation Process

UBCO undertook a two-part public consultation process, soliciting input from staff, faculty, and students. Part 1 of the consultation process occurred in spring 2016 to explore fundamental values about environmental and water management. Part 2 was conducted in fall 2016 following the completion of the IRMP Options Report. A synopsis of these events are provided in Section 2.2 of this IRMP, while the detailed reports are provided in Part 5.

1.2 setting context

1.2.1

TOPOGRAPHICAL, ECOLOGICAL AND CLIMATIC CONTEXT

UBC's Okanagan Campus is located in Kelowna, British Columbia, within the city's northeast quadrant, on the west side of Highway 97. The Main Campus lands are the focus of the consultancy and consist of 105 hectares (260 acres). Located immediately west of the Main Campus and in the Agricultural Land Reserve (ALR) are an additional 103.6 hectares (256 acres) of agricultural lands purchased by the University in 2010. These lands are separated from the Main Campus by a narrow legal parcel (approximately 3m wide) owned by the Glenmore Ellison Irrigation District (GEID) that runs along the entire length of the campus's western boundary. Known as the West Campus lands, they are not included in the scope for this IRMP. Those lands are unique and will require a dedicated strategy to be developed in the future in concert with a land use review.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

The Okanagan Campus is situated along the McKinley Escarpment where north-south-aligned ridges and valleys formed during the last glaciation of the Okanagan Valley. Positioned along the ridgeline, the campus has three distinct benches and slopes ranging up to 30% in angle (3 vertical to 1 horizontal). The campus also has several low-lying areas that have developed into rainwater retention areas and wetlands and that are valued as natural and ecological features on campus.

The UBC Okanagan campus is located in the ecological setting of the Okanagan Very Dry Hot Ponderosa Pine zone, which represents the driest woodland regions in BC, with hot, dry conditions in summer and cool conditions with little snow in winter. Mean annual precipitation (Kelowna Airport) is 298 mm, of which 102 mm (34%) falls as snow; however these values are expected to change over time with the influences of climate change. Trends for the Okanagan Region are expected to include increased annual temperature, increased annual precipitation (likely in shorter and more intense rainfall events), and decreased snowfall and snow pack leading to an overall decline in groundwater recharge and glacier-fed water systems.

Approximately 25% of the campus has high environmental sensitivity, representing primarily woodland and wetland ecological communities. With a diverse landscape of pine woodland and open grassland, the campus contains several ecosystems and has plants and wildlife identified as being species at risk. Among those documented on campus are the Great Basin Spadefoot Toad and the Western Painted Turtle, which have been observed in certain rainwater features making maintenance more challenging and costly.

The University is required to undertake wildfire management on campus to prevent the occurrence and spread of wildfire. Understanding potential changes to the Okanagan climate resulting from climate change will need to be considered in planning the IRMP for the campus. Within the context of the IRMP, how precipitation is expected to change is most important.

1.2.2

EXISTING INFRASTRUCTURE SYSTEMS

The current Okanagan campus infrastructure systems consist of:

- District Energy System (DES) used for heating and cooling by academic buildings
- Central Heating Plan (CHP) used for heating of 5 buildings (Admin, Library, Science, Arts, Gym)
- Natural gas distribution system
- Power distribution system

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

- Potable water distribution system
- Sewage water conveyance system
- Storm sewer system
- Sanitary sewer system

The DES operates as a closed ambient loop system and serves most of the academic buildings on campus. The system extracts groundwater and injects it back into an unconfined aquifer underlying the campus lands using a series of wells and an infiltration basin. Under the Environmental Assessment Act, UBC must meet Environmental Assessment Office (EAO) requirements regarding groundwater levels, quality and rates of extraction.

There are a number of easements and right-of-ways (ROWs) registered in favour of independent service providers on campus, and in 2009 UBC completed a Utility Corridor Strategy to identify campus servicing corridors for appropriate and accessible utility siting. Significant existing utility ROWs on campus include FortisBC's regional high-pressure gas transmission line, which bisects the westside of campus, and the Glenmore Ellison Irrigation District (GEID) trunk main, which traverses the campus under University Way.

1.2.3

CURRENT CAMPUS DEVELOPMENT PROJECTS

There are several campus development projects underway, some of which proceeded in tandem with the creation of this IRMP. These include: University Way "Main Street" pedestrianization, the Teaching and Learning Centre, Transit Exchange expansion, the new west campus access road and parking lot reconfiguration, and the lower campus Research / Innovation Precinct. Other projects will follow in time. Subsequent sections of this IRMP describe each project and speak to their required rainwater management.

Additionally, UBC is responsible to provide an emergency spillway on its lands for the Glenmore Ellison Irrigation District (GEID) reservoir located at the University's northern boundary. UBC had previously commissioned a report to determine the optimal location for this infrastructure. The IRMP now considers and makes recommendation on the proposed spillway relative to proposed rainwater systems (e.g., spillway relocation, shared infrastructure).

1.3
irmp goals

In order to guide the development of the IRMP, UBCO identified a number of goals to be considered.

1.3.1
GOAL 1

Develop a comprehensive Integrated Rainwater Management Plan (IRMP), including supporting geotechnical soils analysis and rainwater modelling, that reduces life-cycle costs and supports and advances of The UBC Okanagan Campus Plan, Design Guidelines, and WSIP to accommodate expected campus growth in balance with implementing UBC's whole systems and sustainability objectives, and that demonstrates best practice in the following:

- Environmental Sustainability – Whole Systems Integration
- Green Infrastructure and Low Impact Development (LID)
- Placemaking and Quality Public Realm
- User Experience and Educational Programming
- Adaptability
- Operational Effectiveness
- Cost Effectiveness

1.3.2
GOAL 2

Develop an IRMP companion operations and maintenance manual for the UBC Okanagan campus.

1.3.3
GOAL 3

Provide building and landscape design recommendations to inform the UBC Okanagan Design Guidelines (presently under review) and new/concurrent development projects on campus.

1.4
irmp objectives

Complementary to the goals stated in the sub-section above, the following objectives were created by UBCO prior to the IRMP launch. The IRMP has since been formulated in a way that best achieves the stated project objectives through further evaluation.

1.4.1
OBJECTIVE 1: ENVIRONMENTAL SUSTAINABILITY - WHOLE SYSTEMS INTEGRATION

- Optimize rainwater as a resource and amenity for the social, environmental and economic well-being of the campus and its community.
- Support campus landscape and ecology to enhance ecosystem services and biodiversity.
- Collect and filter rainwater to enhance wetlands.
- Contribute to the campus's resilience to climate change.

1.4.2
OBJECTIVE 2: GREEN INFRASTRUCTURE AND LOW IMPACT DEVELOPMENT (LID)

- Demonstrate best practice in and maximize use of green infrastructure and low-impact development (LID) rainwater strategies.
- Promote the natural hydrologic cycle and a natural systems approach as part of a long-term plan for rainwater management on the campus.
- Identify rainwater systems appropriate to existing soil conditions.
- Optimize rainwater quality[1] prior to discharge and re-entering natural water systems (e.g. ponds, aquifer, streams).
- Seek practical opportunities to daylight[2], natural rainwater and ecological systems.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

[1] British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Summary Report: http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines

[2] To "daylight" is to remove a closed pipe system and create an exposed channel or creek.

1.4.3

OBJECTIVE 3: PLACEMAKING AND QUALITY PUBLIC REALM

- Identify potential synergies to celebrate rainwater management as an integrated component of the public realm, buildings and site landscapes that provides a progressive image of sustainability while also using rainwater as a resource.

1.4.4

OBJECTIVE 4: USER EXPERIENCE AND EDUCATIONAL PROGRAMMING

- Incorporate rainwater within the framework of the "Living Lab" and "Learning Landscape" of the academic university.
- Make recommendations for educating the university public and raising awareness of rainwater on campus as part of the implementation strategy including making facilities visible, accessible and educational.

1.4.5

OBJECTIVE 5: ADAPTABILITY

- Address opportunities and constraints of the campus and surrounding context.
- Identify systems and infrastructure improvements to be implemented with future development sites and projects.
- Optimize flexibility for system and infrastructure expansion and change.
- Provide infrastructure resiliency in the face of changing climate, more severe and intense storms, and summer droughts.

1.4.6

OBJECTIVE 6: OPERATIONAL EFFECTIVENESS

- Retain rainwater on-site and achieve 100% diversion of rainwater from the municipal system and compliance with City of Kelowna rainwater requirements;
- Safeguard human life and property from flooding and erosion.
- Provide clear direction to UBC staff groups on their roles and responsibilities regarding campus rainwater with an operations and maintenance manual and schedule.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

1.4.7
OBJECTIVE 7: COST EFFECTIVENESS

- Reduce overall life-cycle costs of the rainwater infrastructure and system
- Use topography and natural systems to avoid earth works and minimize rainwater infrastructure costs.
- Provide guidance that allows for a minimal level of long-term maintenance and avoidance of high-maintenance facilities.

1.5 stormwater management plan (2011)

Prior to this IRMP, the historic Stormwater Management Plan (CTQ Consultants, 2011) provided recommendations on how stormwater was to be managed. That Plan became misaligned with some of the redefined goals and objectives of UBCO.

That Plan addressed future development based on the earlier 2009 UBCO Master Plan. It focused on addressing deficiencies and future growth to meet the requirements of the City of Kelowna's Subdivision, Development, and Servicing Bylaw, which state that rainwater runoff cannot exceed predevelopment rates and the use best practices for rainwater management. It identifies areas on the campus that need to be modified to meet the University's guidelines to control and retain all rainwater on-site.

That Plan identified that stormwater released into existing systems may need to be controlled to accommodate current pipe capacity. It recommends nine specific upgrades along with additional stormwater wetlands to ensure adequate storage.

The existing pond, located at the southeast side of campus, close to the Engineering Management Building, manages rainwater from the main campus area. The Pond, which is currently identified as a wetland habitat area, was reported to have a maximum storage capacity of 3,570 m^3 and is designed to overflow into a second natural depression directly adjacent to the south end of the pond with an additional capacity of 5,070 m^3 [3].

As part of this IRMP process, overflow of the pond on occasion has been reported by UBC staff. Overflow has also been predicted with hydrodynamic modeling for this IRMP. However, overflow is rare and most water entering the pond is lost to infiltration, evaporation, and wetland plant evapotranspiration. The pond is considered an "ecological hotspot" on campus, providing habitat to many different species.

[3] As reported in the Stormwater Management Plan (CTQ Consultants, 2011).

The infiltration ditch immediately to the north of parking lot (Lot H) has reported issues with build-up of sand and snow sediments. UBCO staff are needing to clean this ditch each year. The 2011 Stormwater Management Plan recommended that snow storage in these rainwater features should be discontinued to maintain adequate infiltration and reduce the cost of maintenance; an action that is also supported by this IRMP. Of note, this ditch is also identified as an "ecological hotspot", providing habitat to the Spadefoot Toad.

1.6 whole systems infrastructure plan

Also a precursor to the IRMP, the Whole Systems Infrastructure Plan (WSIP) discussed several aspirations and strategies which formed a framework for this IRMP. The following italicized content was extracted from the WSIP.

> *"The Whole Systems Infrastructure Plan builds upon existing stormwater planning efforts to provide a framework that integrates low impact development (LID) strategies that will enable the campus continue to divert 100% of stormwater from municipal systems between now and 2030:*
>
> 1. *Collect and filter stormwater to an enhanced and expanded wetland network;*
> 2. *Where conditions permit on campus, infiltrate runoff from buildings and impervious surfaces in the campus core;*
> 3. *Implement specific stormwater improvements relative to the 2011 Stormwater Management Plan by placing a higher priority on using LID stormwater management methods where site conditions are suitable; and*
> 4. *Update the stormwater management plan to reflect the 2015 Campus Plan and incorporate LID strategies."*
>
> ***Water and Water Quality Monitoring -*** *Low Impact Development (LID) methods are recommended to help address both water quality and water quantity of the rainwater runoff on the campus. However, as identified in the 2011 Rainwater Management Plan, a rainwater monitoring program should be implemented to ensure the proper functioning of the overall rainwater system and water quality.*
>
> ***Ecological Values -*** *Rainwater sustains wetlands that are important for the campus from a biodiversity, educational, and recreational point of view. Indeed, some of the species at risk[4], such as Great Basin spadefoot toad, colonize ditches and other small rainwater features which make maintenance more challenging and costly.*

[4] Ecological Analysis, Ecoscapes, commissioned to support the Campus Plan and WSIP, available on-line under Campus Plan (2015) Attachments/Reference Materials Here: http://campusplanning.ok.ubc.ca/policies-plans/plans-guidelines/campus-plan-2015.html

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

The Whole Systems Infrastructure Plan does not provide an updated rainwater management plan. Rather it referenced the 2011 Stormwater Management Plan and provides additional guidance for how low impact development (LID) rainwater strategies could be implemented on campus to manage future rainwater loads associated with campus growth.

1.6.1

ACHIEVING 100% RAINWATER DIVERSION

Managing Rainwater - There were several general approaches proposed in the WSIP to address rainwater on campus:

1. Conventional pipe systems to drain precipitation captured by impervious surfaces and convey it into storage areas or the municipal drainage system;
2. Reduced impervious areas and / or infiltration strategies including LID rainwater measures to slow runoff such as green roofs; and
3. Capture, storage, and re-use system for building use, irrigation, or ecological features.

Proposed Approach - Given the existing rainwater infrastructure on campus, projected development growth, and sustainability goals, the following measures were suggested in the WSIP to build upon the campus system and continue to divert 100% of rainwater from municipal or off-site drainage systems:

1. Collect and filter rainwater in parking lots and other large impervious areas to enhance an expanded network of wetlands;
2. Infiltrate runoff, where possible, from buildings and impervious surfaces in the campus core; and
3. Implement specific rainwater improvements relative to the 2011 Stormwater Management Plan but giving a higher priority to using LID rainwater management methods where site conditions are suitable.

More so, these measures are to work together in enhancing the ecological landscape of the campus.

1.6.2

COLLECT AND FILTER RAINWATER TO ENHANCE WETLANDS

This measure is based on the approach of collecting and filtering rainwater runoff to enhance and expand a network of wetlands on campus. Filtration can be achieved with engineered systems (basic mechanical system or enhanced media filters) and landscaped based systems. The advantage of landscaped based systems is that they provide the additional functions of rainwater retention and provides biodiversity functions.

1.6.3

INFILTRATE RUNOFF FROM BUILDINGS AND IMPERVIOUS SURFACES IN THE CAMPUS CORE

This measure is based on the approach of maximizing infiltration of runoff from buildings and impervious surfaces on campus, where applicable, depending on soil conditions. It is recognized that permeability and soil conditions within the campus core are a challenge. Low impact development (LID) methods should be considered on a case by case basis to help mitigate runoff peak flow rates and volumes, and improve the quality of water that enters the wetlands, while supporting the incorporation of ecological / natural areas in the developed parts of campus.

The 2011 Rainwater Management Plan includes a section on "Green Techniques" which listed several rainwater management methods to be considered in future developments or retrofit applications, such as, rain gardens, rain barrels, bioswales, green roofs, vegetative strips, and roof storage. This list, referred to in the Plan as "green" rainwater management methods, is now commonly referred to as "Low Impact Development (LID)" rainwater management measures. In addition to these listed green methods in the 2011 Plan, permeable pavement (i.e. pervious concrete and permeable pavers) were recommended in the WSIP wherever subgrade soil conditions exist on the campus with adequate infiltration capacity to allow for this type of LID method.

LID, a sustainable rainwater practice, is an approach to land development (or re-development) that works with nature to manage rainwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage, that treats rainwater as a resource rather than a waste product. LID methods use or mimic natural processes to treat, infiltrate, evapotranspirate or reuse rainwater or runoff on the site where it is generated.

The WSIP called upon these LID methods to be considered on a building by building basis, and as specific areas on campus are developed to assist with mitigating rainwater runoff rate and volumes. UBCO is also in the process of updating its Design Guidelines to reflect LID rainwater management best practices.

1. Through the use of LID, the WSIP strives to infiltrate 100% of rainwater runoff from all buildings and impervious areas (depending on site specific soil conditions) into raingardens, drywells, infiltration galleries and landscape features within the campus core, to reduce the need for supplemental watering. The WSIP suggested soil infiltration rates greater than 0.25 inch / hour (150 mm per day) would be suitable for typical types of LID methods.

2. The WSIP sought to use permeable pavement (i.e., pervious concrete and permeable pavers) wherever subgrade soil conditions exist with adequate infiltration capacity to allow for this type of LID method. The WSIP recognized that the use of permeable pavements might be a challenge in the campus core since very densely compacted gravel-fill soils are located in this area.
3. The WSIP also sought to use green roofs on a select number of new buildings to reduce rainwater run-off volume and flow from buildings. Benefits and trade-offs associated with green roofs and evaluation criteria for installation on per project basis are identified in the Ecological Landscape and Biodiversity Section of the WSIP. With the potential installation of a water reuse system, the WSIP suggested UBCO consider using reclaimed water to irrigate green roofs to assist with maintenance during summer months. The use of green roofs will need to be considered in the context of also evaluating roofscape for renewable energy technologies, such as solar PV or solar hot water.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

1.6.4
BENEFITS AND CHALLENGES

The WSIP posed a number of qualitative benefits and challenges with the rainwater measures presented above that would need to be weighed as part of the broader decision-making process in formulating an IRMP. They were stated as follows.

RAINWATER MEASURES - BENEFITS AND CHALLENGES

MEASURE	BENEFITS	CHALLENGES
Rainwater Measure 1 - Collect and filter rainwater to enhance wetlands	• Increased biodiversity • Rainwater managed on-site • Increased capacity to respond to storm events	• Increased cost and maintenance • Potential lack of water to sustain wetlands • Low perception and dried-out landscape during summer months when water flows are low

MEASURE	BENEFITS	CHALLENGES
Rainwater Measure 2 - Infiltrate Runoff from Buildings and Impervious Surfaces in the Campus Core	• Increased biodiversity • Rainwater managed on site, near to where impervious surfaces are located • Improved envelope performance with green roofs (energy conservation) • Improved outdoor comfort (heat island reduction) • Provide opportunity for food production, learning landscapes • Creates social spaces with landscape vistas • Provides additional water quality benefit	• Potential increased cost for maintenance of some types of LID methods • Consider appropriate location + infiltration potential • Use for select number of buildings or parking areas as determined where most suitable for LID methods • Assess impact of snow removal and winter maintenance • Potential negative perception of dried out green roof (brown roof) during summer months
Rainwater Measure 3 - Implement specific rainwater improvements	• Provides a comprehensive understanding of the proposed rainwater measures and their potential implementation opportunities, making the campus planning and capital budgeting tasks more efficient and reliable	• Additional engineering analysis required to incorporate the recommended measures and reflect the 2015 Campus Plan

1.6.5

ADDITIONAL BENEFITS

The WSIP places an emphasis on expanding the permanent and seasonal wetland complexes on campus not only to assist with mitigating rainwater rate and flow, but also to enhance the ecological and biodiversity functions on campus. These features will offer the following additional benefits:

- Demonstrate UBCO's stewardship of the natural environment;
- Provide for an ecologically rich campus environment which the campus and broader community can connect with;
- Potential ability to attract new donors who are interested in funding natural landscape elements;
- Increase research opportunities to link academic research with government or non-government research based programs that are focused on for example, ecological restoration, endangered species, climate change adaptation etc.;

- Create potential for water conservation benefits associated with implementing a naturalized landscape;
- Create potential for rainwater diversion benefits associated with expanding the wetland network and infiltration strategies to manage rainwater runoff on campus; and
- Potential long-term maintenance savings associated with transitioning to a more naturalized landscape across the campus.

The resulting IRMP achieves much of what the WSIP strove to achieve, aside from explicit application of permeable pavements and green roofs.

1.7 summary of public consultation

Prior to the IRMP getting underway in spring 2016, UBCO conducted a Public Consultation process – Part 1, taking place from March 23 – April 10, 2016, with opportunities to provide input online or in person at the public open house that was held on April 7, 2016, soliciting general input from staff and students on fundamental values and approaches towards environmental protection and rainwater management. Following the completion of the IRMP Options Report, UBCO conducted a Public Consultation process – Part 2, which took place from October 31 to November 13, 2016 and again solicited input from staff and student both online and in person at the public open house that was held on November 2, 2016. A synopsis of each part is provided below, while the full reports are provided in Part 5 to this IRMP.

1.7.1 PART 1 PUBLIC CONSULTATION

The Sustainability Office notified the Okanagan campus community and project stakeholders through advertising, email, online notification and an open house. As a result of this outreach, UBCO had:

- 176 unique page views to the IRMP pages of the sustainability office
- 11 questionnaires completed
- 52 attendees to the open house
- 8 Targeted Stakeholder Interviews with UBC subject matter experts from:
    - » IK Barber School of Arts and Sciences, Biology
    - » IK Barber School of Arts and Sciences, Community, Culture, and Global Studies
    - » IK Barber School of Arts and Sciences, Earth and Environmental Sciences

» UBC Student Services, Aboriginal Programs and Services

» UBC Institute for Healthy Living and Chronic Disease Prevention and Health and Wellness

» UBC School of Engineering

» The Okanagan Institute for Biodiversity, Resilience and Ecosystem Services (BRAES)

» UBC Faculty of Management

» UBC Department of Earth, Ocean and Atmospheric Sciences

UBCO heard general support for the development of an Integrated Stormwater Management Plan for the campus. Support was expressed to manage stormwater on site rather than wasting or diverting it. UBCO learned that people viewed stormwater features, such as the campus' engineered stormwater retention pond, rain gardens and green roofs, as important to them. The retention pond in particular, was valued by participants for the relaxation and recreation amenity it provided, in addition to its stormwater functions.

UBCO heard support for the reclamation of new natural areas for stormwater management, and management of sensitive great basin spadefoot toad and water fowl habitats. Support was expressed for increased infiltration measures and constructed wetlands, when deployed with proven technologies.

Support was also expressed for utilizing stormwater for irrigation, along with planting drought resistant vegetation to reduce water use. UBCO did hear some concerns about the maintenance required for open bodies of water and the potential for increased mosquito populations.

Finally, UBCO heard strong support for the integration of education and research within the design of stormwater features. For example, support was expressed to display educational signage nearby stormwater features. These suggestions included showcasing sustainable technology and providing indigenous translations.

1.7.2

PART 2 PUBLIC CONSULTATION

The Sustainability Office notified the Okanagan campus community and project stakeholders through advertising, email, online notification and an open house. As a result of this outreach, UBCO had:

- 77 unique page views to the IRMP pages on the Sustainability Office website
- 1 public open house
- 4 questionnaires completed.
- 1 key stakeholder meeting

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

UBCO heard support for the proposed approach to managing rainwater for the campus. In particular, support was expressed for managing rainwater at the site in the Main Campus area and the exploration of strategies that take advantage of the rapid infiltration zone in in the Innovation Precinct. A suggestion was also raised to look at rainwater as a resource by managing rainwater at the building scale, including storing rainwater for future indoor and outdoor use where possible.

With regard to Low Impact Development techniques, UBCO heard the most support for swales, flow-through planters, and wet pond facilities. Although there was support for dry pond strategies, there was some concern about the how these areas might look and whether they would be useable during wet periods.

Lastly, there was a discussion on the potential for partnerships between the Academic community and the Sustainability Office, Campus Planning and Development, through the performance monitoring of existing and future rainwater infrastructure.

The IRMP is founded on a strategy to apply Low Impact Development (LID) techniques, which is in keeping with stakeholder comments on respecting natural hydrological processes, supporting campus ecology, indigenous species, protecting the existing retention pond, and the application of constructed wetlands and infiltration facilities where appropriate. In addition, the IRMP also views the opportunity for these features to serve an educational role as a living lab, also in keeping with comments provided by the stakeholders.

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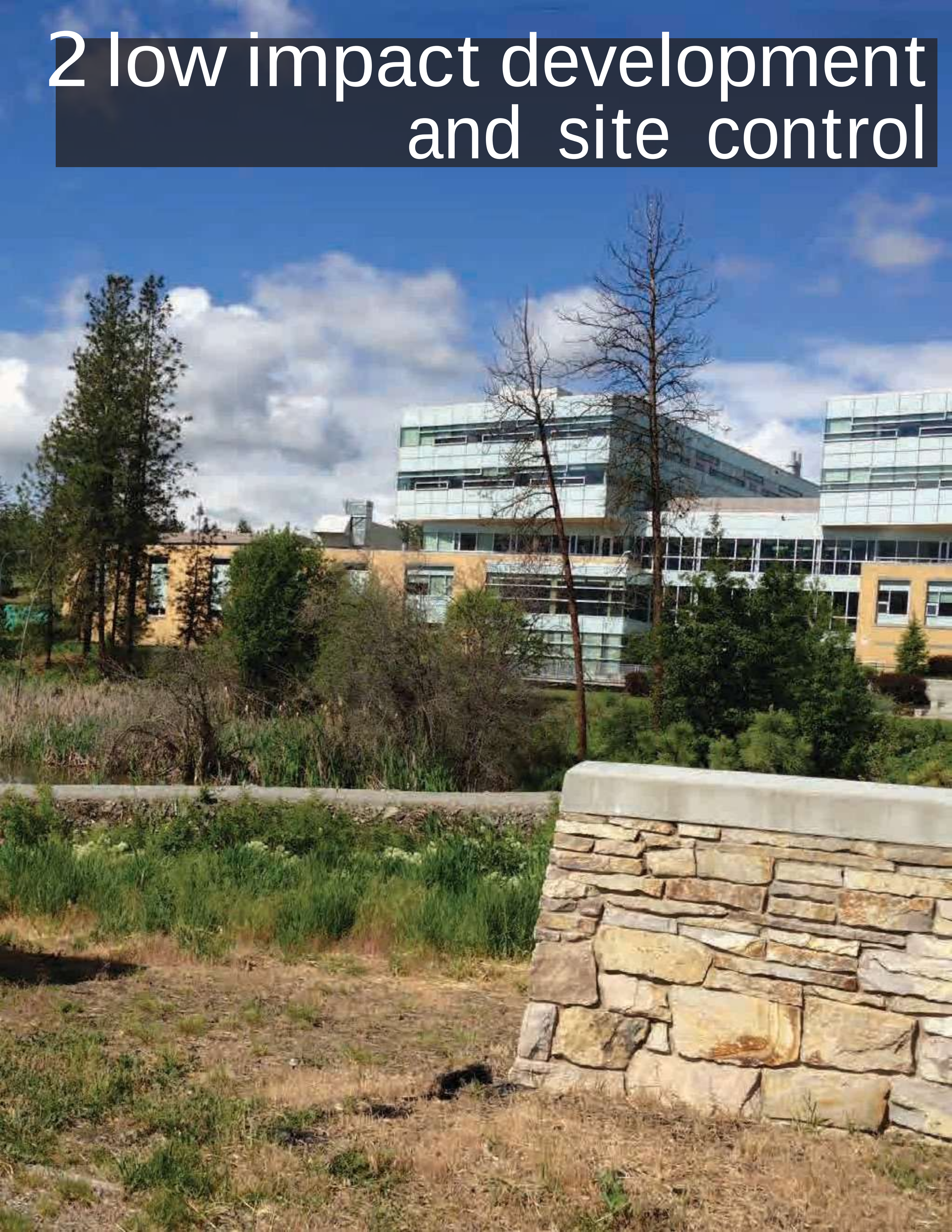
2 low impact development and site control



2.1
technical analysis and options report

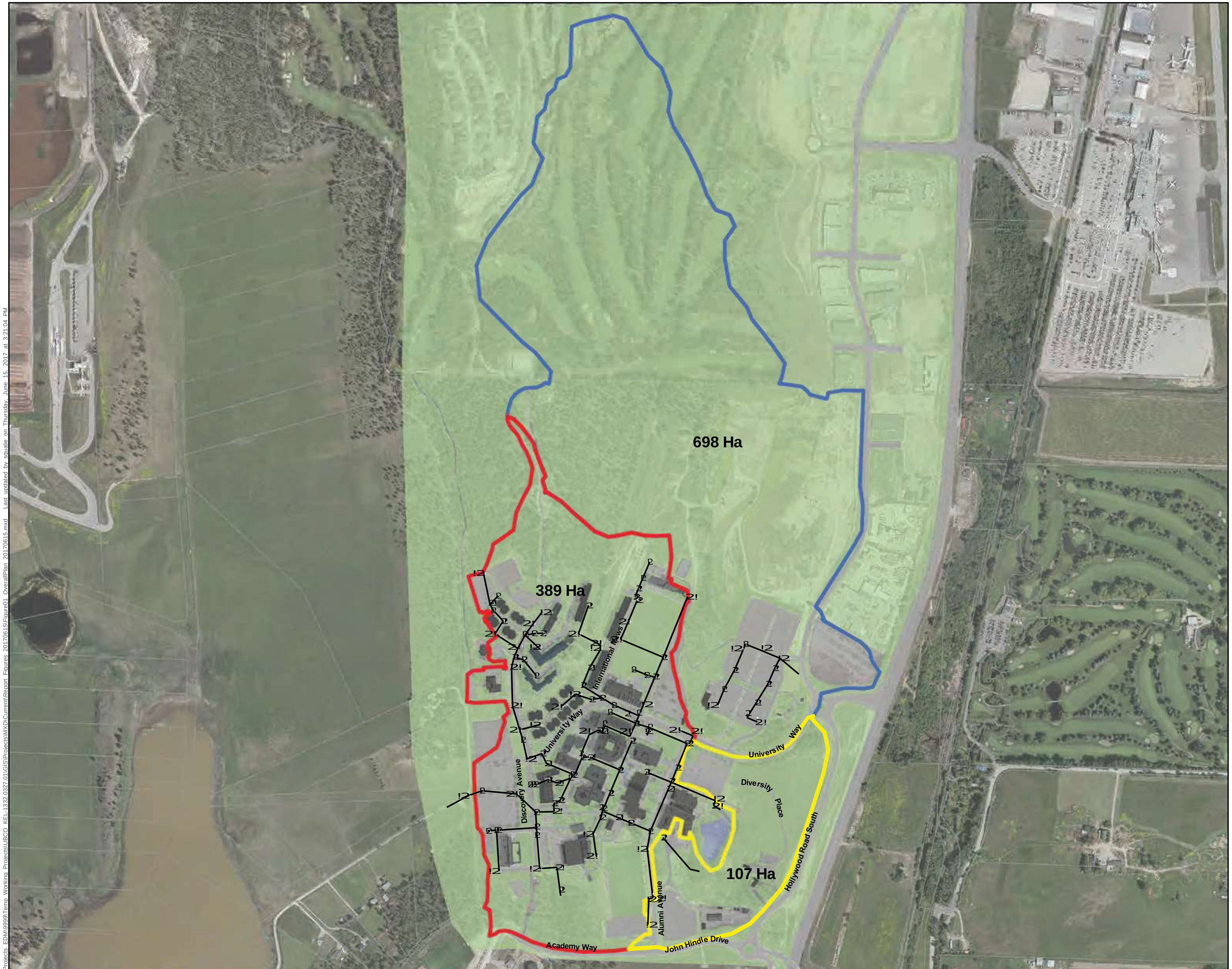
As an interim step to developing the IRMP strategy, the technical development and fundamental options were presented in the "Integrated Rainwater Management Plan, Revised Options Report" (Urban Systems, October 2016). For reference, this full document is appended as Part 3; only highlight components from that document have been extracted and inserted into this Part 1 IRMP document. Based on the decisions made by UBCO from the Options Report, the technical analysis was then further advanced. Final analytical results are presented in the sections below.

2.1.1
PRECIPITATION DESIGN EVENTS

Formulation of the precipitation design events is described in detail in the Revised Options Report contained in Part 3, however, in summary the conveyance system has been analyzed using the 1:5 year, 4 hour storm using the Modified Chicago temporal distribution. This distribution was selected since it includes the full spectrum of rainfall intensities found in the Intensity-Duration-Frequency (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. For flood loss volumes and flood routing (1:100 year event), site control retention, and rainwater disposal facility sizing, a 24 hour precipitation event has been applied.

2.2
existing conditions

There has already been much said in background documents about the study area and its contextual setting. From the perspective of drainage and hydrology, one must consider the change from existing conditions to future conditions, and the influencing factors that will have. 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. The system draining to the existing pond requires unique considerations from the Innovation Precinct areas and peripheral areas to the south east; therefore, these three unique catchments are specifically identified.



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ISMP

Existing Land Use

Legend

- Innovation Precinct Catchment
- South East Catchment
- Existing Pond Catchment

Existing Land Use

- Building
- Hardscape
- Vegetation/ Undeveloped
- Water

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

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	CH
Status:	~FINAL ~
Revision:	A
Date:	2017 / 6 / 15

URBAN systems

FIGURE 1

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1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

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 and building strategy, 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.

2.3 geotechnical conditions and soil permeability

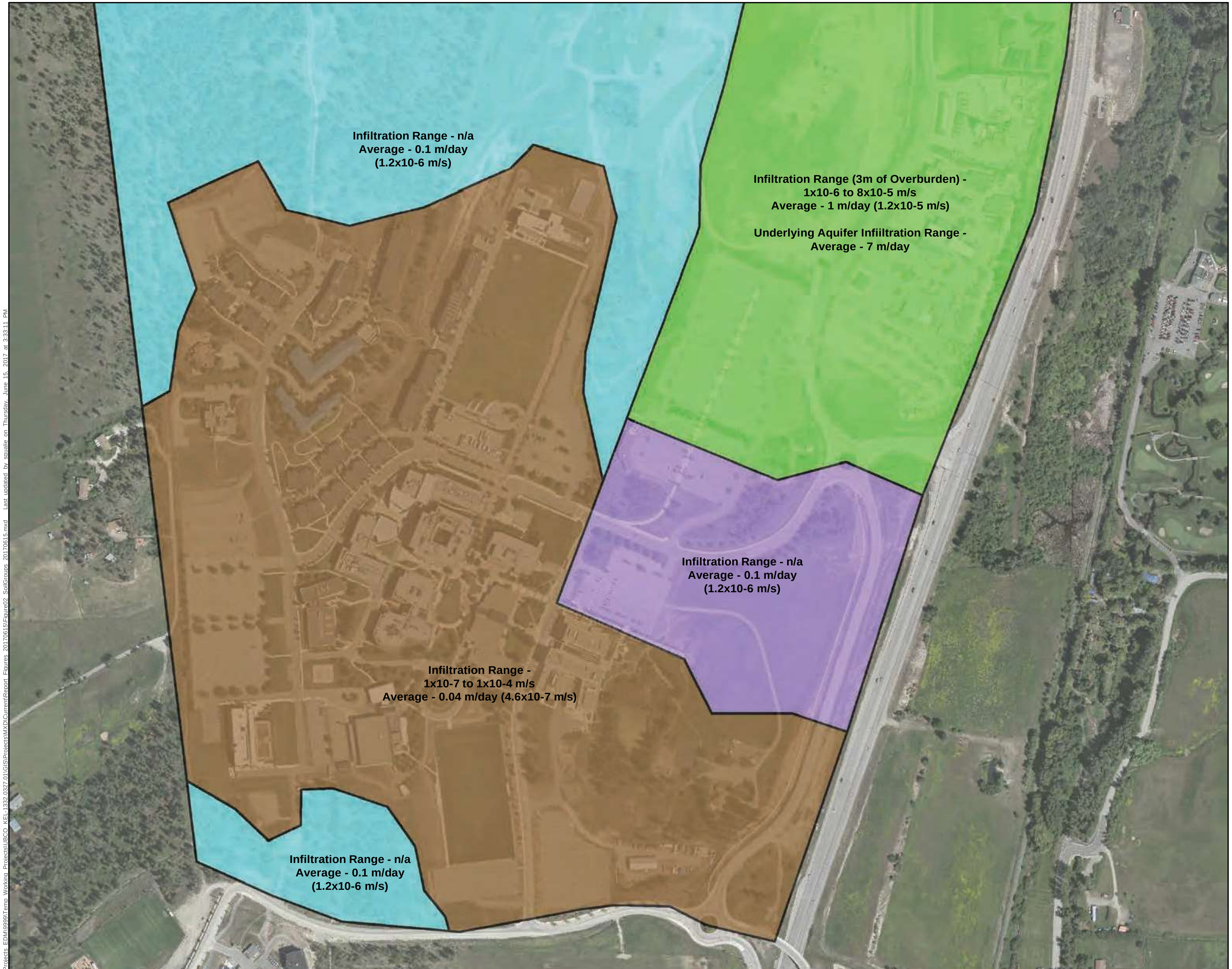
A number of field tests were undertaken to supplement information that was already understood about the property through past investigations associated with the GEID water supply system and UBCO's geothermal system. A comprehensive report of the geotechnical investigation is appended as Part 4 – Geotechnical Investigation (Piteau Associates).

In general, the soils condition and infiltration potential fall broadly into two groups. The predominant soil type capping the western half of the campus (main campus) is a fine grained unstructured soil comprised of 20 to 50% silts and clays and 20 to 50% fine sands. The second soil type is poorly sorted sand and gravel deposits that dominate the north-eastern part of the campus (Innovation Precinct). While very rapid infiltration capacity existing is the coarse underlying deposits, it is capped with a finer grained layer of deposits approximately 3 meters thick. As such, getting access to the high permeable layers requires penetrating through the top cap.

Figure 2 summarizes the recommended permeability rates for the application of LID features. These are generalized values that may vary somewhat from site to site.

Based in the findings, there are several options for disposal of rainwater to ground. The relative low permeability of the main campus is not conducive to rapid or high volume disposal, but small scale infiltration via raingardens, swales or similar features is viable. In all instances an overflow is required because not all precipitation events can be fully managed by these facilities. Overflow will occur during significant events. Also, under-drains should be considered where these facilities are near a steep slope, say within 10 meters or so, or where a series of 3 or more LID features are positioned in series and could result in the accumulation of horizontal seepage. This is something that could be monitored through the early application of LID on campus, from which decisions can be made for future facilities with respect to the need for underdrains away from slopes.

Soils in the north-east quadrant of the campus have significant recharge potential, particularly below the top 3 meter cap. With penetration through the cap, rapid disposal to ground, up to and including the 100 year event is possible.



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ISMP

Soil Group Infiltration Rates

Legend

Soil Infiltration Zone

- East Campus
- Northeast Campus
- Upper Campus
- Upper Campus Native Ground

0 25 50 100 150
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016
Piteau Associates; July 16, 2016

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Date: 2017 / 6 / 15

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FIGURE 2

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2.4
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 as Innovation Precinct. The location and boundaries of each Project is presented in Figure 3. In most cases, UBC has previously developed concept figures of each Project. Where so, they have been integrated into Figure 3 and used to estimate future impervious and pervious areas. In most cases, the concepts are preliminary and may be subject to change; however, it is the best available information at this time.

At the time of authoring this IRMP, UBC is in process of launching a land use planning process for the Innovation Precinct area. Anticipated development cell boundaries have been created and shown in Figure 3. Specific land use within each cell is not yet known; however, it is expected to have a high impervious area.

For the 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. The change in impervious surface from current conditions is the most predominant factor that will dictate the impact on catchment hydrology and infrastructure performance. Based on the Project boundaries defined in Figure 3, Table 1 below provided area statistics, with the final column estimating the anticipated relative change in impervious surface.

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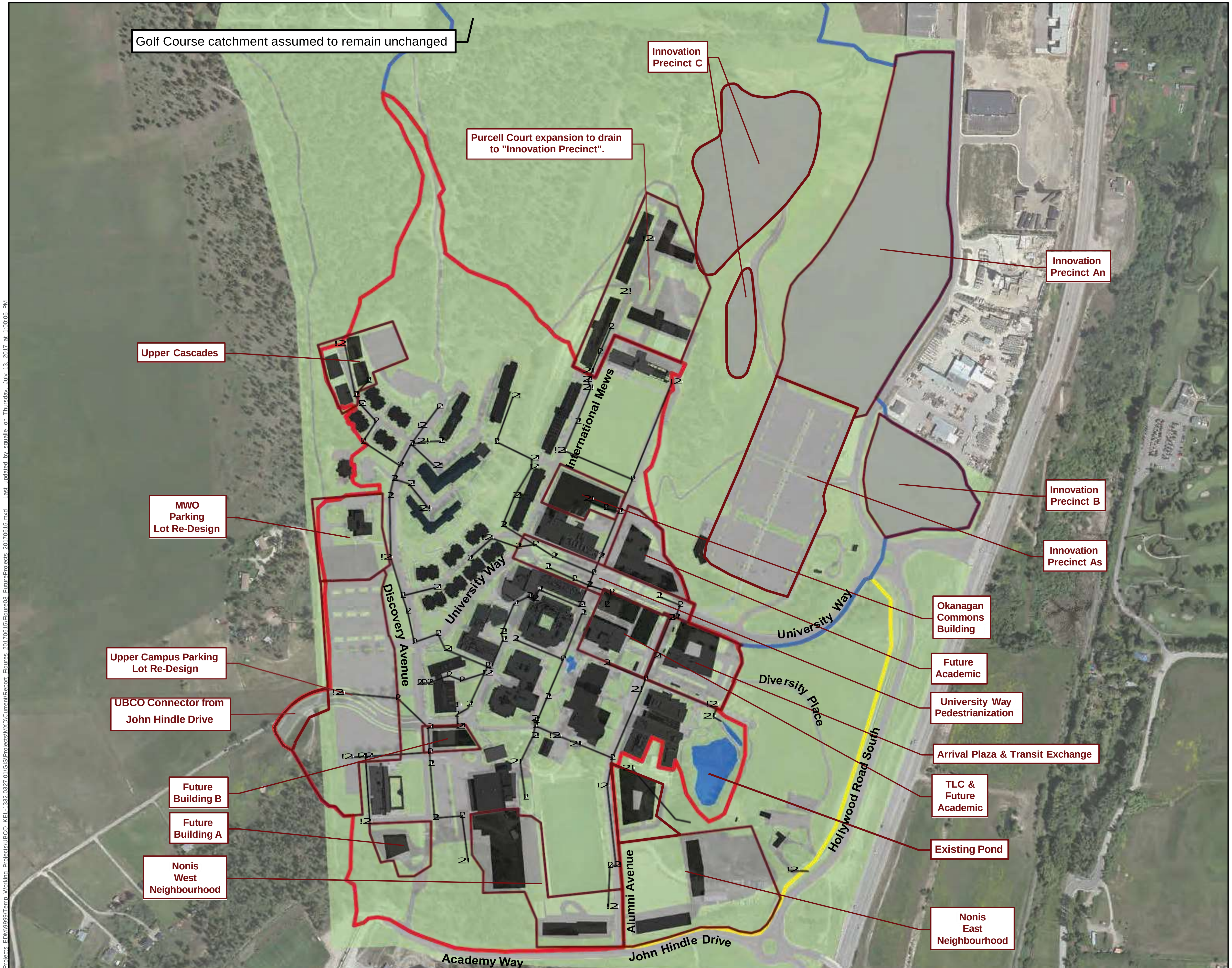

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IRMP

Future Land Use, Primary Catchments & Projects

Legend

- Future Projects
- Existing Manholes
- Existing Storm Sewers
- Catchment to Innovation Precinct
- Future Catchment Existing Pond
- South East Catchment
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

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0 25 50 100

Metres

Coordinate System:

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Data Sources:

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Project #:	1332.0327.01
Author:	JW
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URBAN systems

FIGURE 3

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1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

TABLE 1 FUTURE PROJECT AREA STATISTICS

Development Area		Existing % Impervious	Future % Impervious	Estimated Change in Impervious Area (m^2)
Future Academic	0.70	83	96	933
Future Building A	0.49	36	62	1,290
Future Building B	0.23	13	87	1,759
Mountain Weather Office (MWO) Parking Lot (see discussion below)	0.89	35	74	3,446
Nonis East	3.32	41	49	2,517
Nonis West	1.92	33	70	7,174
Okanagan Commons Buildings	0.50	8	83	3,747
TLC & Future Academic	0.88	57	87	2,651
Transit Exchange	1.04	73	82	862
University Way Pedestrianization	0.86	73	66	- 672
Upper Campus Parking Lot (see discussion below)	2.25	93	81	1,400 (accounts for increased catchment)
Upper Cascades	0.75	80	71	-716
UBCO Connector from John Hindle Drive (see discussion below)	0.21	0	80	1,644
Innovation_Precinct_An	6.51	0	90	58,553
Innovation_Precinct_C	3.22	0	90	28,658
Innovation_Precinct_B	1.92	0	90	16,643
Innovation_Precinct_As	3.37	87	87	0
Purcell Courts	2.40	4	64	15,746

Projects highlighted are increasing the catchment area to the existing storm sewer and pond system, therefore create elevated risk.

The Mountain Weather Office, Upper Campus Parking Lot, and the Connector from John Hindle Drive represent special cases because aside from their relative change in impervious surface, these Projects will increase the total catchment area draining to the existing drainage system. The catchment changes can be observed by comparing the boundary in Figure 1 with that of Figure 3. In the case of the Mountain Weather Office, portions of the expanded parking lot is new area not currently draining to the existing system. For the Upper Campus Parking Lot, despite a reduction in relative impervious surface based on the ultimate boundary shown in Figure 3, this Project will result in approximately 4,000 m^2 of new area being drained to the existing drainage system. Similarly, not only is the UBCO Connector changing to impervious surface, but the portion beyond the existing parking lot does not currently drain to the existing drainage system. These three Projects will require management over and above those Projects that are not adding new area. These needs are discussed in the section below.

2.5
site management requirements for future projects

Five fundamental decisions came from the review of the Options Report:

1. The minimum standard for Future Projects was that they would not increase risk beyond current levels, however, where opportunity presented itself strive for a higher standard.
2. The application of LID controls at the site level for Future Projects is necessary to satisfy many of the objectives and goals established in the Campus Plan and WSIP. (Presented in Table 3 below)
3. For the established main campus, it is not realistic to retain and dispose of all water at the source, and reliance on grey infrastructure (pipes) will continue.
4. Grey infrastructure upgrades would only be pursued where necessary to manage risk.
5. Infrastructure decisions will include considerations for climate change; the "full ensemble" estimations as described in the Options Report.

From the above, criteria need be established for the application of LID source controls. Table 2 below presents both the historic and the predicted future daily rainfall depth totals, for return periods from 0.5 years (6 month) to 100 years.

TABLE 2 DAILY (24 HOUR) PRECIPITATION DEPTHS

Return Period (Years)	0.5	1	2	5	10	25	50	100
Historic Precipitation 24 hour Depth (mm)	18	21	24	29	33	38	41	45
Climate Change Precipitation 24 hour Depth (mm)	19	23	27	33	38	43	47	51

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

Development of the climate change precipitation scenario is described in Section 3.1 of the Revised Options Report (Part 3 of the IRMP). The "Full Ensemble" precipitation data set has been applied to the IRMP strategy, which is based on the average of 24 GCM (global change models).

2.5.1

PERFORMANCE CRITERION

The City of Kelowna criteria stated in their Bylaw 7400 Schedule 4 – Design Standards is as follows:

- 50% of the 2 year post development flows must be routed through some form of treatment best management practice to remove solids and floatables.
- Provide storage up to the 100 year (plus 10% volumetric safety factor) event with a maximum outlet rate based upon the 5 year pre-development rate generated by the catchment area.

In this case, UBC does not generate off-site discharge to the municipal system, therefore has a zero-discharge requirement. Provided zero-discharge is met there is greater freedom in how precipitation is managed within UBC property.

Other municipal jurisdictions and other levels of government have prepared stormwater (rainwater) management guidelines since the early 2000's that are stricter than those of the City of Kelowna. While there are some variations, they are all generally similar, and those are to:

- Fully capture and retain 90% of the annual precipitation, or the 6 month 24 hour precipitation depth. 90% of the annual precipitation is approximately 50% of the 1:2 year, 24 hour volume.
- Provide water quality treatment for volumes ranging from 90% of the annual precipitation to the 1:2 year runoff volume from impervious surfaces;
- Temporarily store and release the remaining 10% of precipitation events to manage peak flow rates, and
- Ensure sufficient and safe major flow paths up to the 100 year, or in some cases the 200 year return period in large system and high risk areas.

The existing storm water conveyance system in UBCO has been sized based on 1:5 year criteria and has known surcharge and flooding challenges. It appears that insufficient attention has been paid to major overland flow paths. In light of this, risk management has higher importance. In addition UBCO has expressed itself as wanting to be a leader in rainwater management. As such, the proposed IRMP strategy for UBCO is to stretch to a high standard, while being pragmatic and recognizing the limitations and opportunities of the sites.

The following performance criterion has been developed and applied to UBCO:

1. For established drainage systems, the minimum criterion is to avoid increased flood risk over current conditions.
2. Existing storm sewers are evaluated for a 1:5 year return period event, with consideration for climate change.
3. Existing major flow routes are evaluated for a 1:100 year return period event, with consideration for climate change.
4. Future stormwater conveyances (Innovation Precinct) shall be for the 100 year peak flow, with consideration for climate change.
5. Rainwater disposal within UBCO property is required for all events up to and including the 1:100 year event, with consideration for climate change.
6. Where required, LID source controls are to retain 25 mm of runoff from impervious surfaces. 20 mm was chosen to address historic precipitation, and an additional 5 mm was added to address predicted long range climate impacts. This is approximately equivalent to the 1:2 year 24 hour precipitation volume. This is a stretch beyond typical retention criteria, but has been selected to help address current flood risk. This requirement applies to all increased impervious surfaces.
7. The on-site retention of 25 mm from impervious surfaces will also apply to new development in Innovation Precinct.
8. Where additional catchment area is being brought into the existing stormwater system of the main campus (see Section 2.4 above), retention of 50 mm is required for the additional area, not just the additional impervious surface.
9. Water quality treatment in Innovation Precinct is to be provided for the 1:2 year runoff volume generated beyond the on-site LID retention. This high standard has been selected because of rapid infiltration and added exposure to the underlying aquifer.

2.5.2

SITE CONTROL REQUIREMENTS AND OPPORTUNITIES

Based on the above, retention storage, peak discharge rates, and discharge volumes have been computed for each project as presented in Table 3 on the following page. As shown in Table 2, with the surface soils estimated to have a permeability rate of 1 meter per day, by applying adequate retention storage at the site level, theoretical modeling suggests that future development cells of Innovation Precinct should generate zero runoff during a 1:5 year event. However, development cell "As" (refer to figures) is already developed and is largely paved. It is not expected to be retrofitted with new controls. Therefore, it will generate the bulk of the runoff for events less than the 1:5 year level.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

TABLE 3 FUTURE PROJECT HYDROLOGY AND HYDRAULICS

Development Area	Total Project Area (ha)	Retention Storage for Increased Impervious Surface in m³ (Minimum Requirement)	Retention Storage if Applied to ALL Impervious Surfaces in m³ (Optional)	Total Peak Runoff Rate (m³/s)				Total Runoff Volume (m³)			
				1:5 year Historic IDF	1:100 year Historic IDF	1:5 year Climate Change IDF	1:100 year Climate Change IDF	1:5 year Historic IDF	1:100 year Historic IDF	1:5 year Climate Change IDF	1:100 year Climate Change IDF
Future Academic	0.70	23	167	0.08	0.17	0.11	0.21	110	320	160	340
Future Building A	0.49	32	76	0.00	0.07	0.05	0.09	0	150	70	160
Future Building B	0.23	44	51	0.00	0.04	0.03	0.05	0	100	50	100
MWO Parking Lot (see note 3)	0.89	167	n/a	0.00	0.10	0.07	0.14	30	320	160	340
Nonis East	3.32	63	404	0.01	0.27	0.18	0.38	140	980	430	1,120
Nonis West	1.92	196	337	0.01	0.44	0.25	0.59	90	1,500	640	1,790
Okanagan Commons Buildings	0.50	94	104	0.00	0.09	0.06	0.12	0	200	100	210
TLC & Future Academic	0.88	68	193	0.03	0.18	0.12	0.24	80	390	200	420
Transit Exchange	1.04	22	212	0.02	0.12	0.08	0.17	130	420	200	460
University Way Pedestrianization	0.86	0	141	0.06	0.25	0.16	0.33	150	590	290	650
Upper Campus Parking Lot (see note 3)	2.25	133	555	0.04	0.22	0.12	0.30	310	950	470	1,040
UBCO Connector from JH Drive (see note 3)	0.21	105	n/a	0.00	0.00	0.00	0.00	0	0	0	0
Upper Cascades	0.75	0	133	0.05	0.15	0.09	0.19	100	310	150	340
Innovation_Precinct_An	6.59	1,483	1,483	0.00	0.41	0.00	0.51	0	1,130	0	1,380
Innovation_Precinct_C	3.22	725	725	0.00	0.27	0.00	0.33	0	400	0	600
Innovation_Precinct_B	1.87	421	421	0.00	0.12	0.00	0.16	0	250	0	320
Innovation_Precinct_As	4.12	0	927	0.37	0.98	0.59	1.35	590	1,820	840	2,060
Purcell Courts	2.64	421	421	0.00	0.12	0.00	0.23	0	270	0	460

Notes:

1. The Peak Runoff Rates and Runoff Volume are reflective of applying the minimum retention requirement, which is to retain 25 mm of precipitation from all INCREASED impervious surface beyond current levels.
2. Although not required to meet the minimum criteria, a retention storage volume is also listed should 25 mm of precipitation be captured from ALL impervious surfaced. This is viewed as optional, opportunistic storage.
3. Highlighted Projects are introducing new catchment areas that do not currently generate runoff to the existing drainage system. Storage is based on 50 mm for all new catchment area plus 25 mm for all new impervious surface already within the existing catchment.
4. All values will need to be adjusted to suit the actual total development area and impervious surface area, as well as the ultimate value of retention volume provided.
5. Runoff rates and volumes noted are for the project area alone, and do not account for external areas or cumulative effects.

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1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

2.6
low impact development (lid) control options

Prescribing LID site controls is not possible within the scope of this IRMP, as that decision must be made through site planning and design processes. However, this IRMP provides some general guidance around the LID options and their applications. The WSIP suggested soil infiltration rates greater than 0.25 inch/hour (150 mm per day) would be suitable for typical types of LID methods. As noted in Figure 2, while several portions of the UBC lands have capacities in this range or higher, the existing established campus has infiltration rates in the order of 40 mm per day. However, this is still a reasonable amount and can offer significant retention provided that LID facilities provide retention storage that then permit water to infiltrate over time. As such, successful LID facilities will be those that provide depression storage. The volume of depression storage for each Future Project was presented in Table 3 above. Estimated infiltration rates in the main campus is 40 mm per day, which means that each square meter of area can dispose of 0.04 m^3 in 24 hours. If a Future Project requires to retain say 50 m^3 of water, the soil contact area required to dispose of this water within 24 hours is 1,250 m^2. It is still possible to meet the retention requirement in a smaller area however it would take more than 24 hours for the water to be disposed into the ground.

The most common, and simplest LID approach is to provide 300 mm of good quality growing medium on all landscaped surfaces. This material will generally have a void space in the order of 0.4, which translates into a storage volume of 0.12 m^3 per square meter of soil. Landscape features with a concave shape are expected to be the predominant LID technique applied. Such features are typically 200 to 300 mm deep, at minimum, which then offers an additional 0.2 to 0.3 m^3 of storage per square meter of area. For example, if a site 1 hectare in size (10,000 m^2) is 80% impervious, the sites landscaped (soft surface) area is 2,000 m^2. Assuming LID facilities are applied to half of that area (1,000 m^2), 300 mm of topsoil is applied and 200 mm of concave surface storage provided, the total storage offered on this site is 320 m^3. Therefore, with careful site planning and design, it is anticipated that most, if not all sites, will provide the opportunity to provide adequate landscape based LID features to meet the minimum storage requirements.

In order to meet the minimum retention targets for the entire campus, a preliminary estimated land base of 17,000 m^2 was noted in the Options Report. Based on refined values presented in Table 3 above, the total estimated land base is approximately 20,000 m^2, assuming average storage depth of 200 mm. 4,735 m^2 of that is for the Future Projects in the main campus catchment.

A key to meeting the control targets, however, is to maximize the redirection of hard surfaces (roof tops and paving) onto the pervious areas and into the LID features. If this is not done, the management objectives will not be met.

The companion LID Operation & Maintenance Manual which is Part 2 has been tailored for a short list of the most likely LID features to be applied at UBCO, however a more generic LID application table is presented in Table 4 on the following page to offer further guidance on other possibilities.

Site planners of Future Projects will need to consider the type and relative proximity of LID features to buildings in order to not create flood risk to the building itself. Building architecture and design may also need to be tailored to suit the landscaping and site configuration.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

TABLE 4 APPLICATION OF LID TECHNIQUES

LID Feature	Applicability			Advantages	Disadvantages
	Volume Control	WQ Control	Peak Rate Control		
Amended Soils (w/min. depth)	High (H)	High (H)	Low (L)	"Sponge effect", retains runoff volume onsite for retention / infiltration; contact with soils provides water quality treatment; easy to apply and maintain; no engineering required	Strict requirements on soil composition; local availability of soil
Green Roof	H	H	L	Volume and water quality benefits, can lower heating / cooling costs for buildings	Added construction costs and long-term maintenance of plant and soil materials; costs vary widely
Infiltration Trench	H	H	L	Mimics natural site hydrology, may result in lower infrastructure requirements (pipes, ponds) due to decreased volume of runoff reaching downstream systems	Possible groundwater contamination risks (especially in industrial or commercial applications), not useful where soils are tight (e.g., clay, silt)
Recharge Basin	H	H	H	Mimics natural site hydrology, results in lower infrastructure requirements (pipes, ponds) due to decreased volume of runoff reaching downstream systems	Possible groundwater contamination risks (especially in industrial or commercial applications), not useful where soils are tight (e.g., clay, silt)
Planter Boxes	H	H	Medium (M)	Water quality benefits (plant uptake of pollutants, lower runoff water temperature), some retention / detention capacity	Long-term maintenance of plant and soil materials
Porous Pavement	H	M	L	Reduces generation of runoff; provides water quality treatment; reduced sand & salt use in winter over standard pavement	Long-term maintenance, requiring vacuum-type street cleaning; higher cost than conventional paving, not well suited for high traffic volume areas or where fine sediment loading may clog pores
Rain Barrel (Rainwater Harvesting)	H	L	L	Onsite storage of water for irrigation, grey water reuse	More effective as a water conservation technique than rainwater management
Rain Garden	H	H	M	Provides onsite retention / infiltration of runoff, water quality benefits	Long-term maintenance of plant and soil materials
Rock / Soakaway Pit (Dry Well)	H	L	M	Mimics natural site hydrology, may result in lower infrastructure requirements (pipes, ponds) due to decreased volume of runoff reaching downstream systems	Possible groundwater contamination risks (especially in industrial or commercial applications), not useful where soils are tight (e.g., clay, silt)
Underground Infiltration System	H	H	M	Mimics natural site hydrology, may result in lower infrastructure requirements (pipes, ponds) due to decreased volume of runoff reaching downstream systems	Possible groundwater contamination risks (especially in industrial or commercial applications), not useful where soils are tight (e.g., clay, silt)
Biofiltration Swale (Bioswale)	H	H	M	Water quality benefits (plant uptake of pollutants, lower runoff water temperature)	Long-term maintenance of plant and soil materials
Constructed Wetlands	H	H	L	Water quality benefits (plant uptake of pollutants, lower runoff water temperature), some retention / detention capacity, offers environmental habitat and often viewed as a community amenity	Requires significant land area, may limit development yield
Dry Detention Pond	L	M	H	Often incorporated into community park or amenity facilities to reduce peak flows; water quality benefits (if properly designed)	Does not often address runoff volume increases; may limit development yield
Grass Swale	H	H	L	Water quality benefits, low maintenance requirements, can be enhanced with check dams to provide temporary storage	"Rural" look; less water quality treatment benefits than a bioswale; without check dams they offer little flow rate control or volume reduction
Oil / Grit Separator	L	H	L	Water quality benefits, commonly applied pre-treatment; easy to access and maintain	Can be forgotten ("out of sight, out of mind")

LID Feature	Applicability			Advantages	Disadvantages
	Volume Control	WQ Control	Peak Rate Control		
Manufactured Treatment Filter System	L	H	L	Provides advanced treatment (removal) of targeted pollutants such as TSS, metals, and nutrients; particularly suited to retrofit situations in highly urban areas	High capital and maintenance cost; can be forgotten ("out of sight, out of mind")
Perforated Storm Sewer	H	L	L	Encourages infiltration, provides effective conveyance	Possible groundwater contamination risks (especially in industrial or commercial applications), not useful where soils are tight (e.g., clay, silt); not suitable for steep slopes where piping failure may occur
Sand Filters	L	H	L	Proven water quality treatment benefits; amendments added to sand can target specific pollutants	Long-term maintenance, cost; ties up land from other uses
Rock / Soakaway Pit	H	L	M	Mimics natural site hydrology, may result in lower infrastructure requirements (pipes, ponds) due to decreased volume of runoff reaching downstream systems	Possible groundwater contamination risks (especially in industrial or commercial applications), not useful where soils are tight (e.g., clay, silt);
Underground Infiltration System	H	L	ML	Mimics natural site hydrology, may result in lower infrastructure requirements (pipes, ponds) due to decreased volume of runoff reaching downstream systems	Possible groundwater contamination risks (especially in industrial or commercial applications), not useful where soils are tight (e.g., clay, silt)
Underground Tank / Vault	L	L	H	Temporary runoff storage, useful in areas where land for a pond is not available	Long-term maintenance, cost, can be forgotten ("out of sight, out of mind")
Vegetated Filter Strips	L	M	L	Water quality benefits, especially useful along rural-section roads; low maintenance cost	Requires soil replacement and reseeding over time; performance diminishes with steeper slopes.
Wet Detention Pond	L	H	H	Detention capacity, water quality benefits (if properly designed), can service large areas; provides environmental habitat; often viewed as a community amenity	Long-term maintenance requirements, does not address runoff volume increases, land base requirements

Notes: "Natural" pond like structures have the advantage of increasing habitat and potentially increasing biodiversity; however this encourages the habitation by species at risk, which while great for the species, may decrease UBC control over that particular feature or piece of land.

3

Section 2.5.2 - Site Control Requirements and Opportunities above described both the minimum and opportunistic level of control at each Future Project. All land not identified as a Future Project are assumed to be maintained in their current condition with no site alterations. Hydrodynamic modeling was conducted to determine the cumulative effects of sub-catchments and the application of minimum site controls only. In Appendix 1 attached, model schematics present each discrete sub-catchment and how they are believed to connect to the conveyance system.

3.1 main campus

The main campus has an established drainage system. A strong motivation for applying site controls to Future Projects was to maintain or improve the hydraulic performance of this existing systems, and to enhance water quality and prevent more frequency overtopping of the existing pond. Preliminary assessment results were presented in the Options Report, but have since been refined based on advanced development of the strategy.

System performance has been re-assessed for four precipitation events:

1. 1:5 year Historic IDF Precipitation (Figure 4a)
2. 1:5 year Climate Change IDF Precipitation (Full Ensemble) (Figure 4b)
3. 1:100 year Historic IDF Precipitation (Figure 4c)
4. 1:100 year Climate Change IDF Precipitation (Full Ensemble) (Figure 4d)

In the 2011 Stormwater Master Plan, some storm sewer redirections were recommended, but have not yet been built. As part of this IRMP those previously recommended redirections were tested and were found to not offer sufficient benefit, and in fact may significantly raise risk to the pipes receiving the redirected water. Hydraulic grade lines in the receiving pipes were found to rise significantly. At this time an inventory of connecting buildings and their associated floor elevations has not been reviewed. Taking any actions that will knowingly raise the hydraulic grade line in the storm sewer system may significant increase risk to connecting building and must only be done through full exploration to understand the risks.

Piping performance results for these four precipitation events, assuming the existing piping configuration is maintained, are presented in Figure 4a, 4b, 4c, and 4d on the following pages. As noted in the legend of each figure, the color of the pipe reflects the predicted magnitude of surcharging within the pipe. Figure 4a is the best reflection of current conditions. Manholes where flooding is expected to occur appear in red, and the pattern is a strong match to observations reported by UBC staff. Section 3.2 below discusses overland flow path routing and potential flood mitigation solutions.

UBC OKANAGAN

IRMP

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

Manholes

- No Surface Flooding
- Surface Flooding

Pipe Surcharging

- None
- Minor
- Significant
- 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 25 50 100
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	JW
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 15

URBAN systems

FIGURE 4a

OKANAGAN

IRMP

1:100 Year Storm Sewer Performance Development of All Project Sites With Site Controls Current Kelowna IDF Curves

Manholes

- No Surface Flooding
- Surface Flooding

Pipe Surcharging

- None
- Minor
- Significant
- 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 25 50 100
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 15

URBAN systems

FIGURE 4b

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UBC OKANAGAN

IRMP

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

Manholes

- No Surface Flooding
- Surface Flooding

Pipe Surcharging

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

0 25 50 100
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	JW
Checked:	GS
Status:	~FINAL ~
Revision:	A
Date:	2017 / 6 / 15

URBAN systems

FIGURE 4c

UBC OKANAGAN

IRMP

1:100 Year Storm Sewer Performance Development of All Project Sites With Site Controls Full Ensemble Climate Change Prediction

Manholes

- No Surface Flooding
- Surface Flooding

Pipe Surcharging

- None
- Minor
- Significant
- 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 25 50 100
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #: 1332.0327.01
Author: JW
Checked: GS
Status: ~ FINAL ~
Revision: A
Date: 2017 / 6 / 15

URBAN systems

FIGURE 4d

U:\Projects_EDM\9999\Temp_Working_Projects\UBCO_KEL-1332.0327.01\GIS\Projects\MXD\Current\Report_Figures_20170615\Figure04D_Sewer_Performance_FE100Y_20170615.mxd   Last updated by squalie on Thursday, June 15, 2017 at 3:52:51 PM

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

Modeling indicates that the application of minimum LID site controls is successful in meeting the "no net impact" objective (not worsen the performance of the storm sewer system). The influence of future climate change demonstrates a modest increase in flood risk. Modeling has also revealed that piping performance cannot be significantly improved without extensive piping improvements. In essence, there is no "quick fix" or "easy win" to reduce system surcharging. The options and cost benefit around site controls and pipe improvements was presented in the Options Report. It remains that the application of LID controls is the most effective and cost effective approach to managing risk associate while permitting Future Projects to proceed. Future projects are encouraged to stretch beyond the minimum retention requirements, providing what is fully achievable at the site.

While Figure 4a through 4b offer insight into locations of possible flood risk, they do not in themselves fully define risk. Particularly in the absence of flow monitoring data to calibrate a model to, modeling is a theoretical indicator of performance. Historic observations should also be strongly considered in evaluating risk. On August 2, 2016 during the conduct of this IRMP study, an intense storm event lasting approximately 3 hours occurred at the campus, dropping approximately 28 mm of precipitation. According to historic precipitation statistics, this event had a return period of approximately 1:50 years. The existing storm sewer system has been designed for a 1:5 year event. During the August 2 storm, significant flooding was observed at the corner of University Way and Alumni Avenue, with flood waters travelling along the grassed swale eastbound along University Way. Despite significant flood volume loss at this location, no detrimental downstream effects were reported downstream.

Also during the August 2, 2016 event, significant flood loss volume was observed behind the Arts Building on Research Road as highlighted in Photo 1 on the right. Modeling does replicate flooding at this location.

An adjacent docking bay into the Arts and Sciences Centre served as flood storage, as shown in Photo 2 on the right. During the August 2, 2016 storm, this docking bay and surrounding area filled with water and nearly spilled to the Arts building to the east, but no spill did occur and no direct impact was suffered on this occasion.

The one observed impact on August 2, 2016 resulted from surcharge experienced into the Fipke Building, causing flood damage within the building. As part of the analysis for this IRMP, the August 2, 2016 precipitation event was modeled. While the model did replicate the flooding at the location noted above, it could not replicate flooding at the Fipke Building. As such, the observed impact remains a mystery at this time. It has been recommended to UBCO that the piping from the Fipke Building to Alumni Avenue be CCTV (video camera) inspected to see if there is a pipe blockage or pipe failure. Another potential cause is a deficient service connection or insufficient roof drainage system. Or finally, the

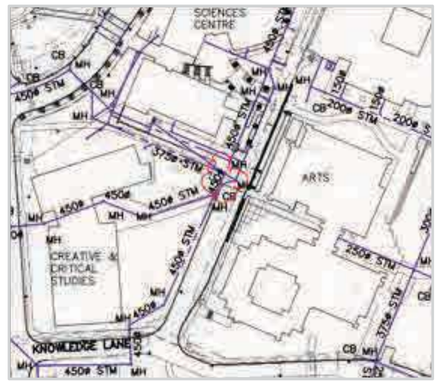


Photo 1 –Observed flooding between Arts and Creative & Critical Studies

Photo 2 - Flooding within the docking bay of the Arts and Sciences Centre (August 2, 2016) actual piping configuration is not what available mapping shows it to be. Field investigation and capacity analysis of the building systems will be required to shed more light on this occurrence.

3.2
overland flow path routing and flood mitigation assessment

Recognizing the potential risks of overland flooding, UBCO commissioned a more extensive investigation of overland flow path routing. The initial step was to understand the potential flood loss volumes and rates that may surcharge from the system at various locations under a design event. For this review, the most extreme condition was considered; that being the 1:100 year event with consideration for future climate change (Full Ensemble). Peak flood loss flow rates and volumes are listed in Figure 5.

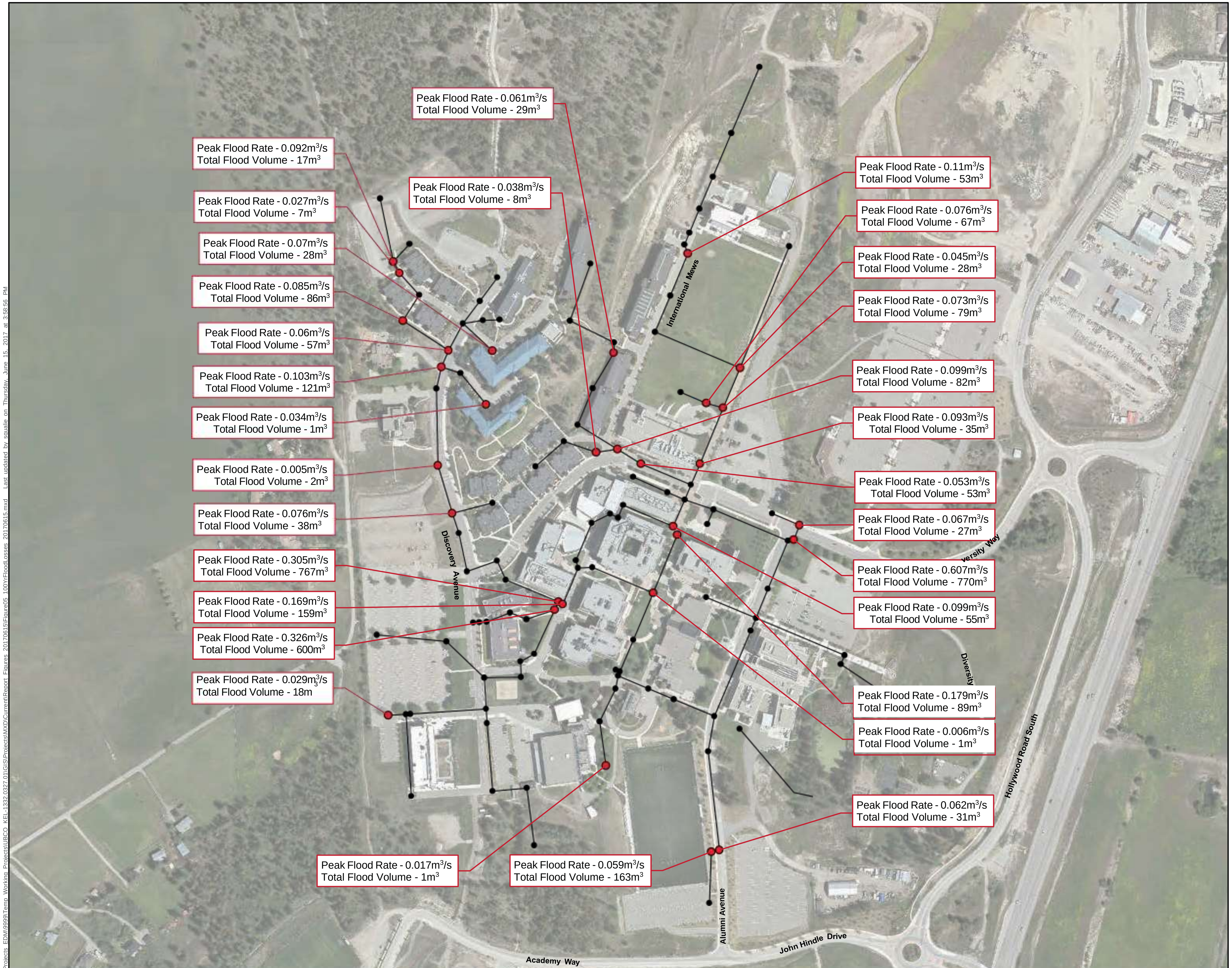
Flood path routing analysis was then undertaking based on the locations of predicted flooding. To assist with this review, a detailed topographic survey was conducted for the majority of the established campus using high resolution 3D laser scanning technology. The area scanned is encompasses by the purple boundary line shown in Figure 6. Only areas of particular concern were scanned. GIS tools are then used to trace the flow path from predicated flooding locations, results of which as depicted in Figure 6.

Also in Figure 6 is a blow up of the area behind the Arts & Sciences Centre which is a known flood location (see Photo 2 above). All other flooding locations and paths shown in Figure 6 are “predicted” or “potential” based on modeling.

The blow-up area in Figure 6 highlights the extent of the available flood storage, which has been measured to be 66 m^3. If the actual flood loss volume at this location exceeds the available storage, water will then spill and flow along the flow path shown by the solid red line, potentially impacted buildings. It is understood that during the August 2, 2016 storm event this storage area filled, but is not believed to have spilled. If this is the case, then it suggests that something in the order of 60 m^3 flooded during the August 2 event. As a comparison, a hydrodynamic model of the August 2 event suggests that 450 m^3 would have escaped from the storm sewer system at this location. This suggests that the hydrotechnical model results presented herein are generally plausible, but conservative.

3.2.1
Mitigative Options

Generally speaking, overland flow path routing does not suggest wide spread risk to buildings, however one significant flow path has the potential to impact three buildings, noted in Figure 6 as Site 1: Creative Studies, Site 2: Arts, and Site



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1:100 Year Predicted Flood Losses (Full Ensemble Climate Change Scenario)

Legend

Manholes

- Flooding
- No Flooding
- Pipes

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0 30 60 120
Metres

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 201 5

Project #: 1332.0327.01
Author: JW
Checked: GS
Status: ~ FINAL ~
Revision: A
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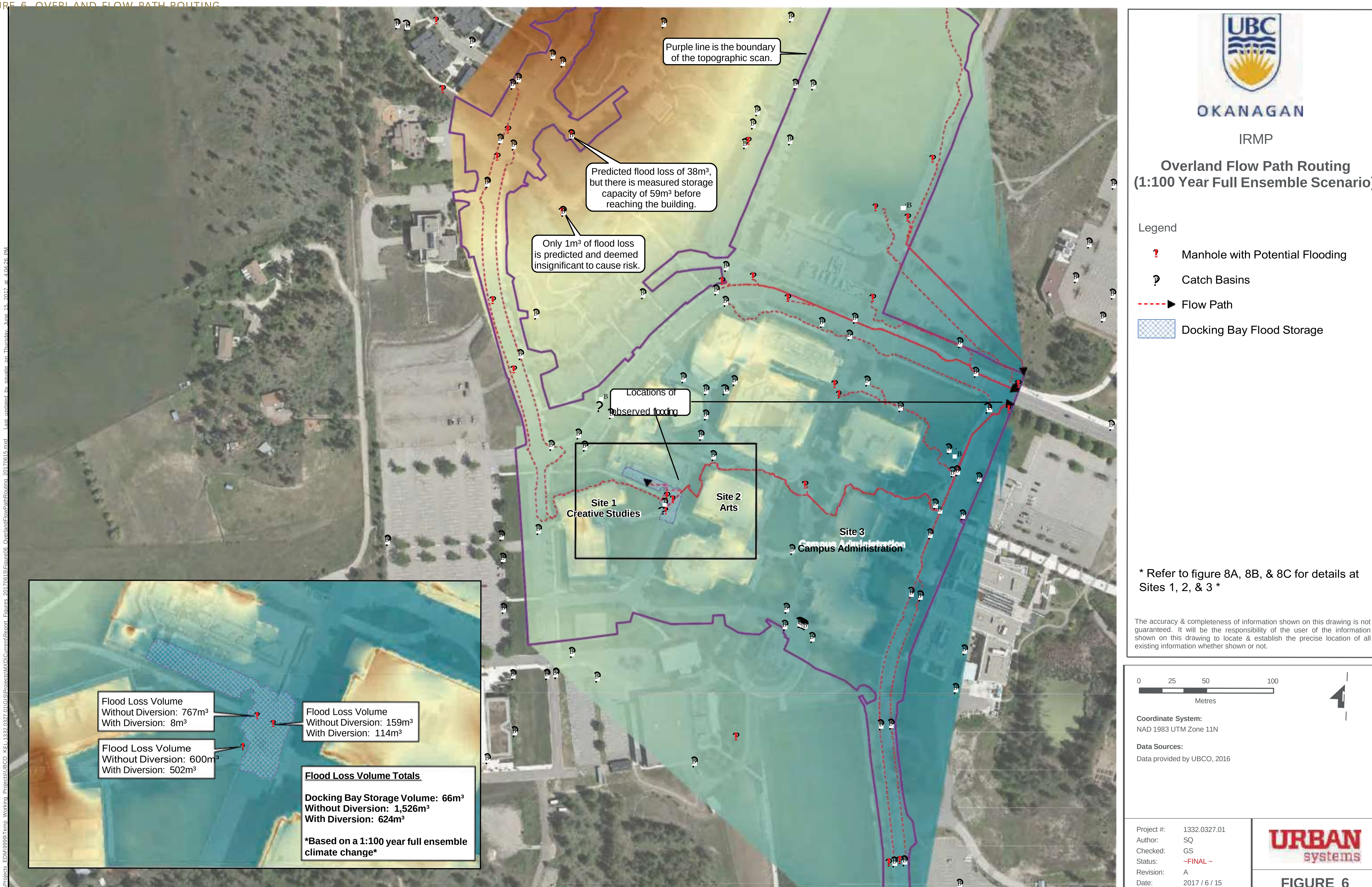
FIGURE 5



Purple line is the boundary of the topographic scan.
Predicted flood loss of 38m³, but there is measured storage capacity of 59m³ before reaching the building.
Only 1m³ of flood loss is predicted and deemed insignificant to cause risk.
Locations of observed flooding
Site 1 Creative Studies
Site 2 Arts
Site 3 Campus Administration
Flood Loss Volume Without Diversion: 767m³ With Diversion: 8m³
Flood Loss Volume Without Diversion: 600m³ With Diversion: 502m³
Flood Loss Volume Without Diversion: 159m³ With Diversion: 114m³
Flood Loss Volume Totals
Docking Bay Storage Volume: 66m³
Without Diversion: 1,526m³
With Diversion: 624m³
Based on a 1:100 year full ensemble climate change
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IRMP
Overland Flow Path Routing (1:100 Year Full Ensemble Scenario)
Legend
Manhole with Potential Flooding
Catch Basins
Flow Path
Docking Bay Flood Storage
* Refer to figure 8A, 8B, & 8C for details at Sites 1, 2, & 3 *
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0 25 50 100
Metres
Coordinate System:
NAD 1983 UTM Zone 11N
Data Sources:
Data provided by UBCO, 2016
Project #: 1332.0327.01
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FIGURE 6

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

3: Campus Administration. Before exploring actions at the location of impact, the opportunity to divert water away from the area at Discovery Avenue onto University Way was explored. Figure 7 presents a profile of the roadway at this intersection showing a significant high point in University Way east of the intersection. As such, it is not deemed realistic, without very extensive roadworks, to redirect flows on the surface. The interception and redirection of water onto University Way could only be done with high capacity inlets at the intersection in combination with a storm sewer onto University Way.

The hydrotechnical model was run to assess the relative change in system performance with the diversion in place. The predicted flood loss volumes at the docking bay location, with and without the diversion in place, are presented in the blow-up graphic in Figure 6. The model predicts a significant reduction in flood loss volume, but flood risk is not eliminated. As such, although the frequency and extent of flooding would improve with a pipe diversion, it is expected that flood protection to Site 1, 2 and 3 would still be necessary to some degree.

Figures 8a, 8b, and 8c provide additional details for each of the three risk sites. The flow path lines represent the path of flow, not the extent of flow. Determining the actual extent of flow is more detailed process that extends beyond the current scope of study. However, modeling suggests that the potential cumulative instantaneous peak flow rate at Site 1 may be in the order of 0.5 m^3/s, at Site 2 in the order of 1.0 m^3/s and at Site 3 in the order of 1.1 m^3/s. These are considered conservative values, but fair for planning purposes. Figure 8 provides profiles at numerous locations to show site grading relative to the building faces. The results suggest a high likelihood that any significant flow along these paths would likely reach the building face.

Two fundamental options have been identified to mitigate risk to these three sites.

Option 1 – Piping Solutions

As introduced in the Draft IRMP document (December 2016), resolving flooding with piping solutions will require significant investment. To eliminate overland flows from Discovery Avenue, a minimum of 170 m of storm sewer would be required on University Way. This solution will likely require a pipe size of 600 mm diameter with an estimated capital value of $204,000[5] . This minimum length assumes that the pipe ends at the University Way Pedestrianization project and discharges into its planned vegetated greenway. If it is desired that the pipe continue to Alumni Avenue, the total length increases to 375 meters. This longer solution was introduced in the Draft IRMP with an estimated capital value of $460,000. This longer pipe would also allow the interception of other flows through this corridor, however this pipe would not eliminate flood risk at Site 2 or 3 as noted in Figure 6.

[5] Based on $2.00 per mm*m including contingencies, engineering and restoration - a planning level cost. All pipe sizes notes are estimates that would be subject to change with detailed analysis and design.

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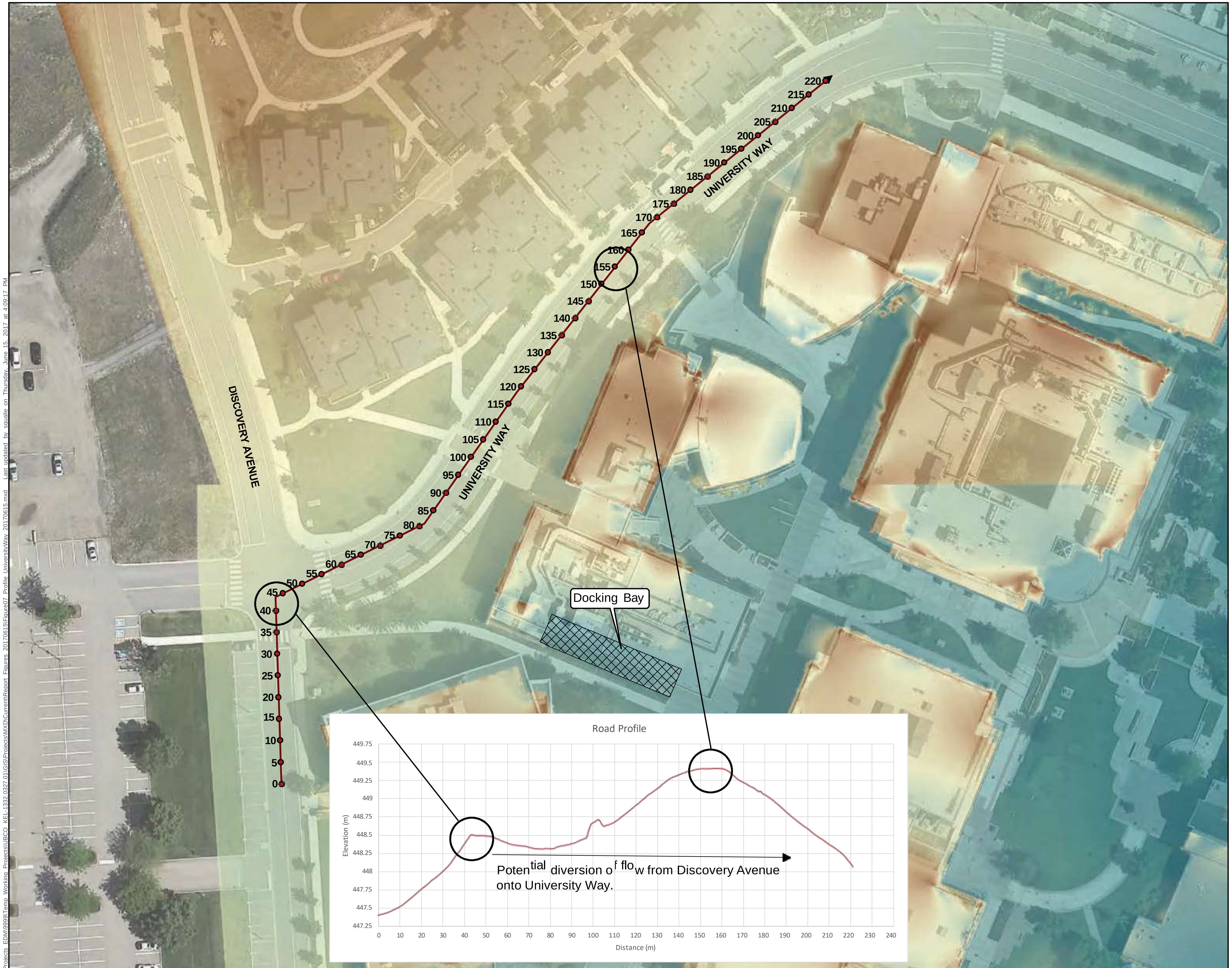

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Profile of University Way at Discovery Avenue

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0 5 10 20
Metres

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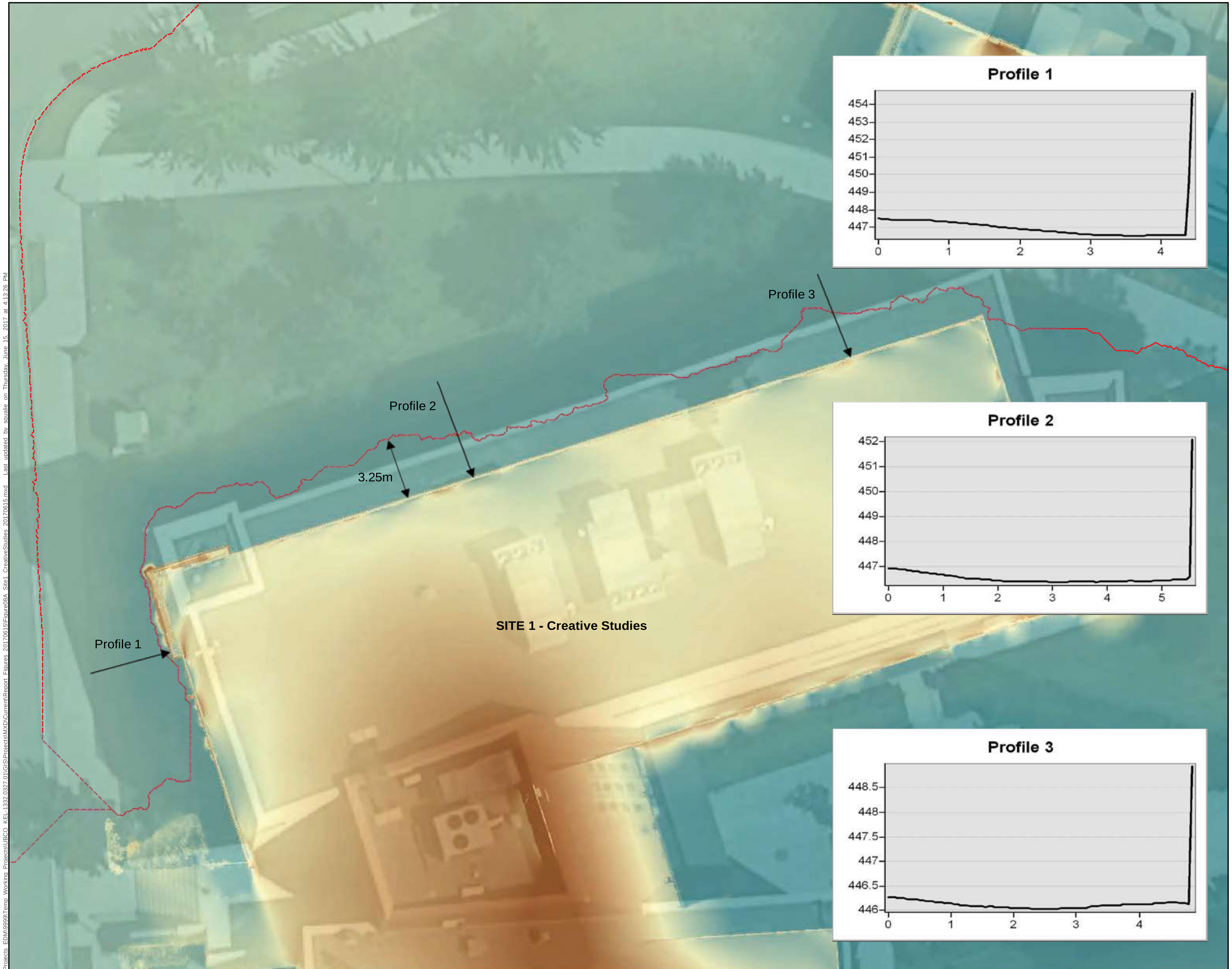
FIGURE 7



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IRMP

Overland Flow Paths in Proximity to Creative Studies Building (Site 1)

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0 2 4 8
Metres

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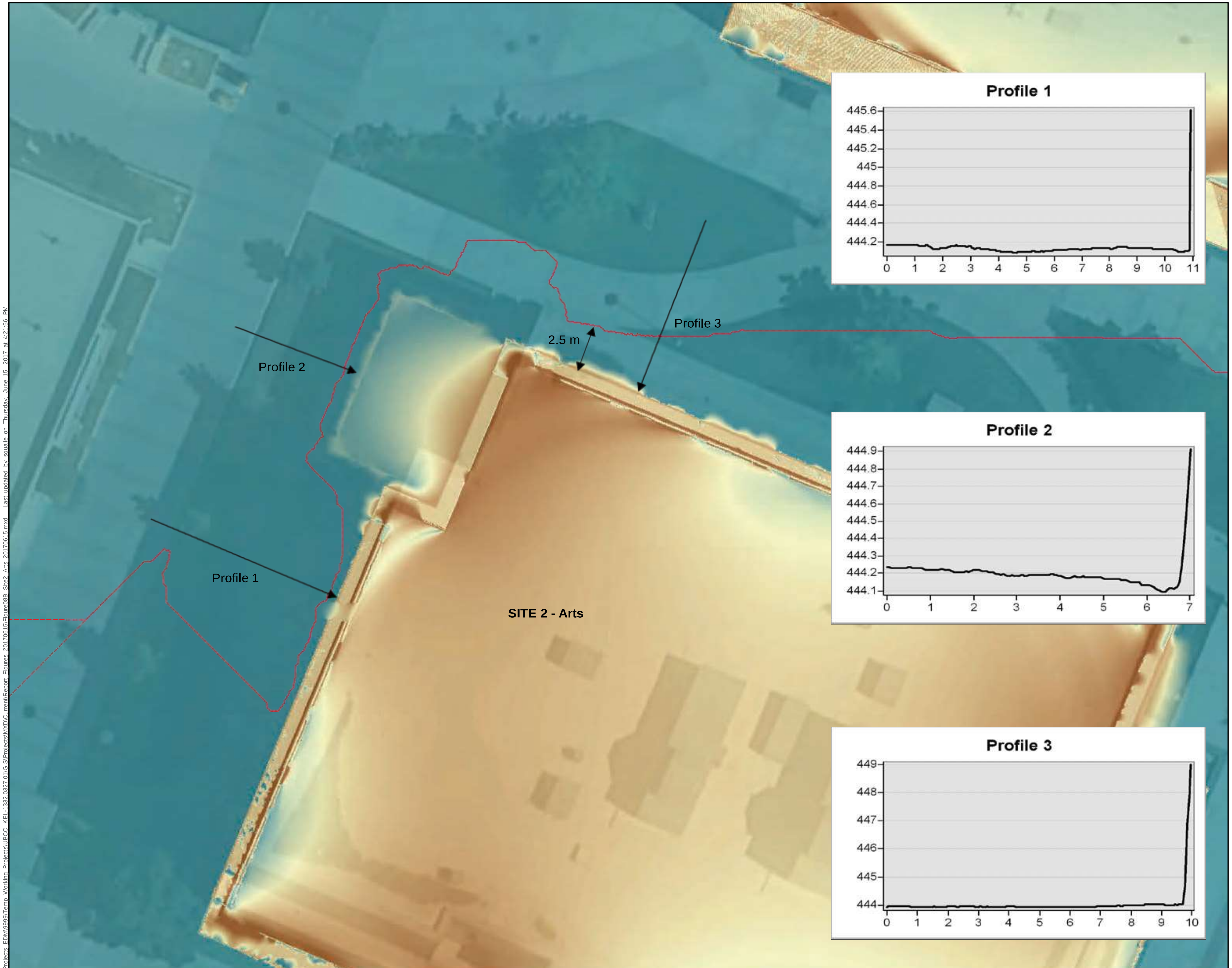
FIGURE 8A



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IRMP

Overland Flow Paths in Proximity to the Arts Building (Site 2)

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0 2 4 8
Metres

Coordinate System:
NAD 1983 UTM Zone 11N

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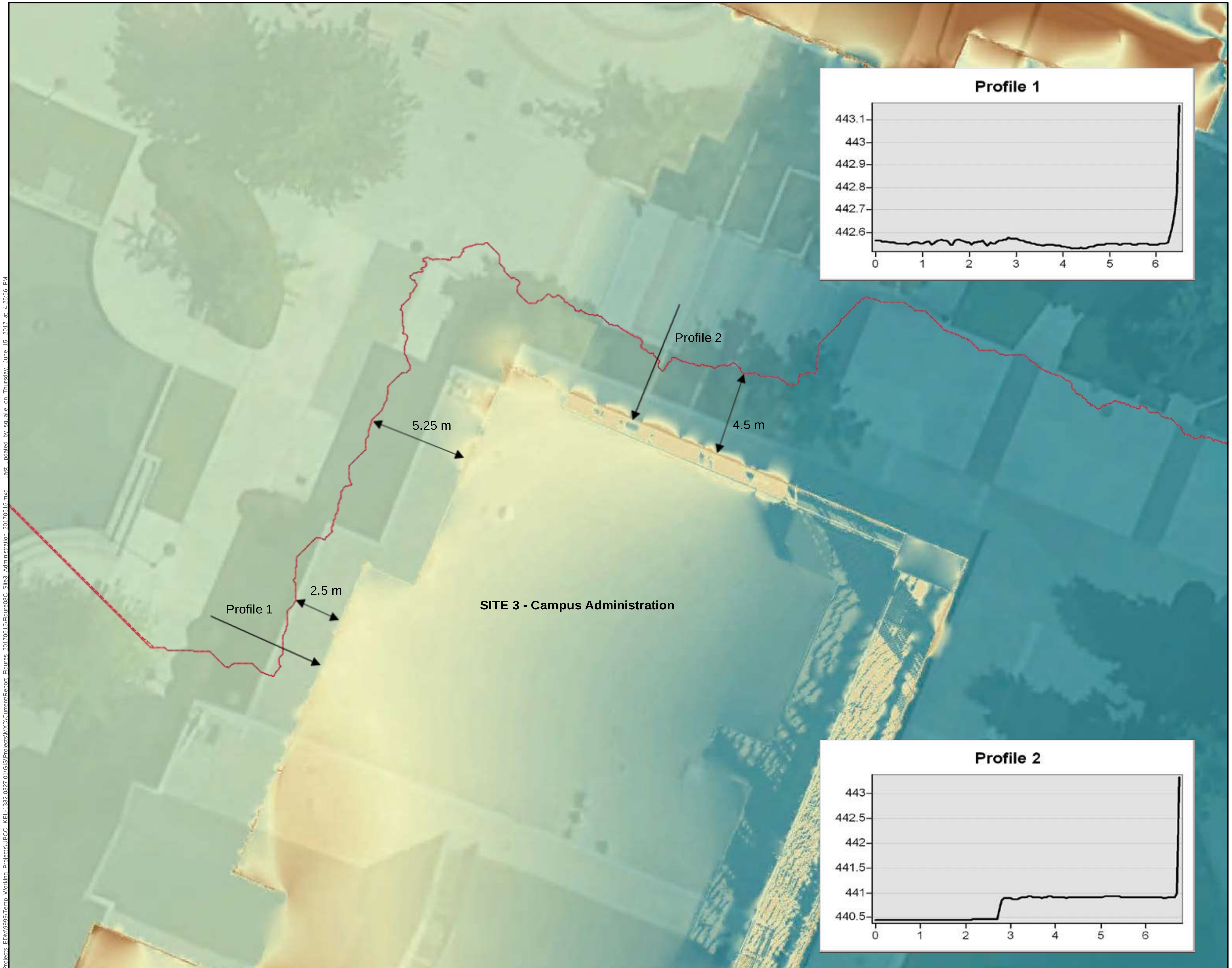
FIGURE 8B



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IRMP

Overland Flow Paths in Proximity to Campus Administration (Site 3)

0 2 4 8
Metres

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
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URBAN systems

FIGURE 8C

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

In order to eliminate flood risk to Site 2 and 3 with piping solutions, other upgrades are required. If one considers a new pipe from Site 2 through to Alumni Avenue, the minimum distance is approximately 250 meters. This pipe would be installed between buildings, largely beneath established pathways; therefore the disturbance and cost of restorations would be high. If done in combination with the University Way pipe, this pipe would need to convey about 0.6 m^3/s and likely be a 450 mm diameter pipe. If done instead of the University Way pipe, this pipe would need to convey about 1 m^3/s and likely be a 600 mm pipe (these are to eliminate all flooding and surcharging along this flow path). These solutions have an estimated capital value in the range of $225,000 to $300,000. However, in absence of the diversion on University Way, it would be desirable to extent this alternative pipe to Site 1, in which case the pipe would need to be extended an additional 100 meters, increasing the total capital cost to something in the range of $400,000. As such, fully eliminating overland flows along this corridor with piping solutions from Discovery Avenue to Alumni Avenue is likely in the range of $400,000 to $460,000, regardless of route. All potential pipe routes are depicted in Figure 9.

Option 2 – Surface / Landscaping Solutions

For this option UBC would accept the performance of the existing storm sewer system and the potential overland flow that may be generated. Surface or landscape based solutions would be applied to create a barrier to deflect water away from the buildings at risk. This may be in the form of relayed pedestrian pathways, creating a landscape berm, building an ornamental wall, or other. Detailed analysis would be required beyond the scope of this study, but it is anticipated that any "deflector" would need only be in the order of 300 mm high. A rough estimate length of deflector required to protect each building is 65 m for Site 1, 100 m for Site 2, and 60 m for Site 3, for a total length of 225 m. There is insufficient information to suggest a unit cost because they are expected to vary significantly depending on the approach selected. But to compare it to a piping solution, which is likely to cost at least $400,000, applying this capital value to 225 meters of landscape based protection equates to $1,777 per meter; a significant amount.

3.3
main campus infrastructure improvements

The primary servicing strategy for the established main (south) campus is to apply source controls through Low Impact Development Practices at all future projects. While not eliminating runoff, successful implementation as described herein will reduce annual runoff volumes and peak flow rates, allowing develop to proceed with not increase in risk at minimum, and likely reduction in risk for some locations. If successfully done, the current recommendations for infrastructure improvements are relatively few, as noted in Figure 10.

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Potential Storm Sewer Improvements

Legend

- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

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0 25 50 100
Metres

Coordinate System:
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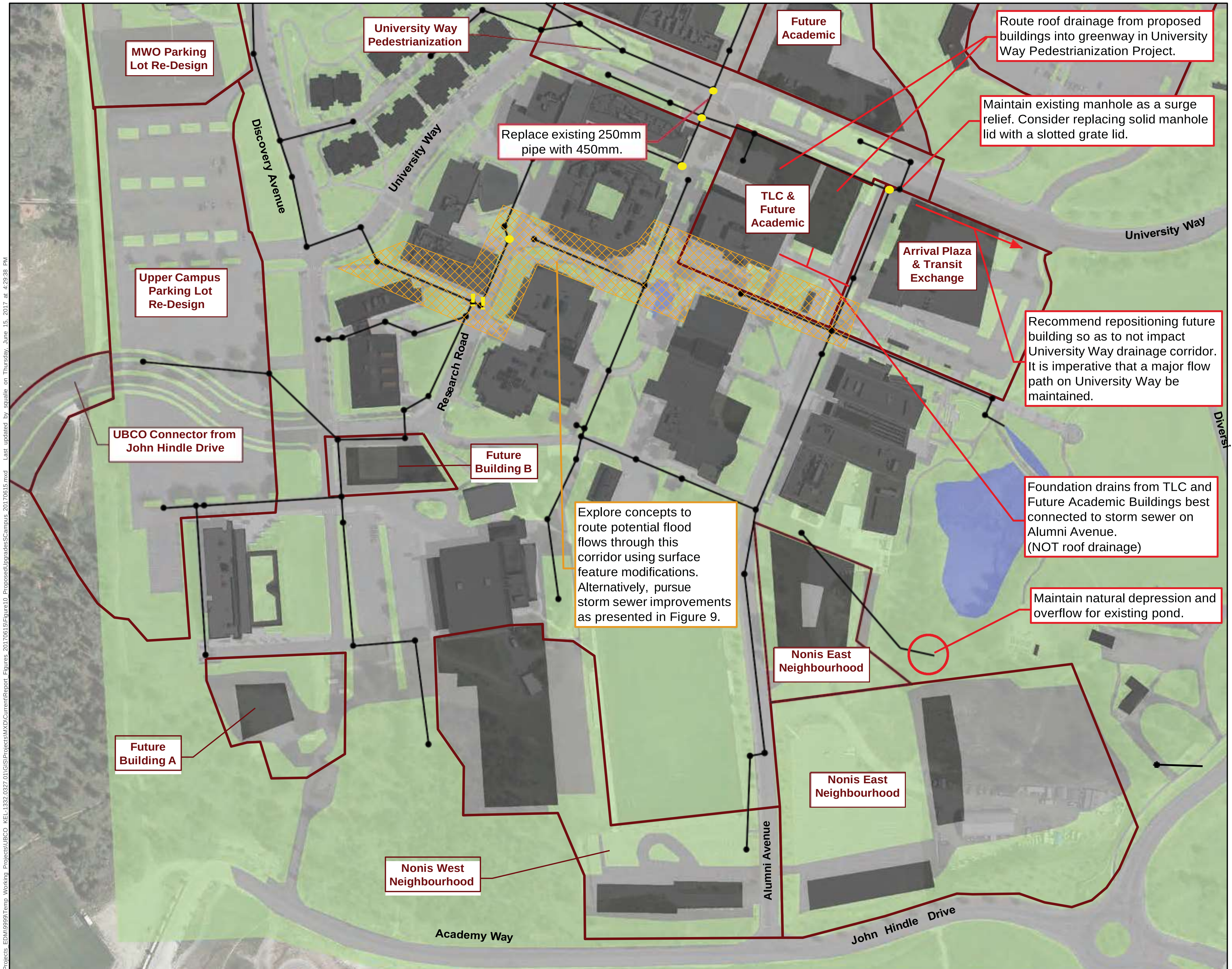
FIGURE 9



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Proposed Infrastructure South Campus

Legend

- Development Areas
- Existing Manholes
- Manholes to be Benched
- Existing Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond

Refer to text in body of report for description of controls to be applied at each Future Project.

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0 25 50 100
Metres

Coordinate System:
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FIGURE 10

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

3.4 innovation precinct (north campus)

While some existing infrastructure exists in the north campus, infrastructure needs are largely defined by future growth. Anticipated runoff rates and flows for each development cell were presented earlier in Table 3. UBCO has recently launched a land use planning and design initiative which will be necessary to refine infrastructure needs, however this IRMP lays out the fundamental requirements and presents some infrastructure concepts to be considered; these are presented in Figure 11 on the following page, along with the predicted cumulative design flows. These preliminary design flows represent the 1:100 year event with consideration for climate change. Unlike has occurred in the main campus, it is recommended that future conveyances be sized for the major flow. Following the Innovation Precinct land use planning and preliminary design process, the hydrodynamic modeling and infrastructure sizing should be checked and updated as required.

The servicing concept is described as follows:

- Site controls are to be applied at the site level in accordance with Table 3, requiring that 25 mm of retention be provided for all new impervious surface. Given the rapid infiltration capacity for this area (estimated at 1 meter per day), modeling suggest that no runoff should be created for storms equal to or less than the 1:5 year. However, this is highly dependent on the successful application of distributed LID controls. Failure to achieve distributed retention systems will have a significant impact on cumulative runoff rates and volumes. In turn, this may have significant influence on the sizing of the communal water treatment and recharge systems. It is recommended that these systems be sizes conservatively.
- It is proposed that the Purcell Courts expansion drain into Innovation Precinct for treatment and disposal given that the systems within the main campus area already overtaxed. Figure 11 shows two potential routings for this flow; one short-cutting down slope to a conveyance system expected to coincide with the anticipated access road. An alternate alignment is shown along the south limits of development cell C, merging with the GEID overflow and runoff from development cell C. It is also proposed that a cut off channel be constructed upslope of Purcell Courts to protect against any seepage or overland flow that may be generated from the slope. It may be advisable to conduct a site specific geotechnical investigation along this alignment to determine ground water levels. This may dictate the need for a subsurface French drain in addition to a surface swale.
- The GEID overflow pipe previously designed should be extended to and through development cell C. The specific routing is flexible and will be governed by topography and the layout of development.

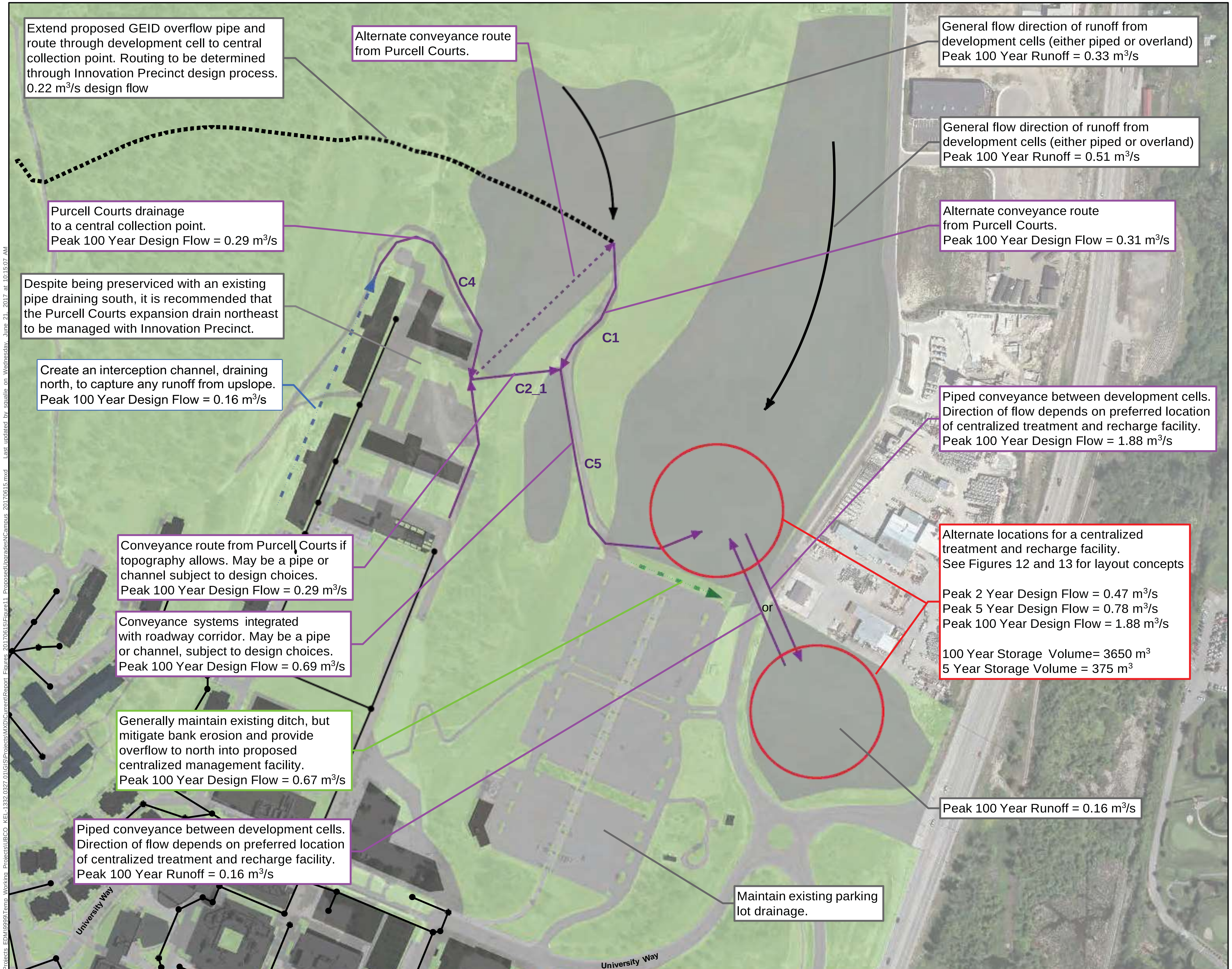
- The existing drainage ditch along the north edge of Lot H will be largely maintained, however it is recommended that minor bank erosion issues be addressed. The decision to largely maintain this ditch in its current condition is due to the presence of the Spadefoot Toad. Further discussion on environmental constraints and opportunities is presented in sections below. This ditch should be provided an overflow to a new rainwater treatment and disposal facility to prevent its current spill east over Innovation Drive.
- While the WSIP speaks to establishing a network of distributed wetlands, it is recommended that given the high permeability of the native soils, and the land base required to create an effective wetland, a single centralized constructed wetland and recharge basin be created. Two potential sites are presented in Figure 11. Unless treatment and disposal is desired on both sides of Innovation Drive, which is a possibility, a pipe will be required across Innovation Drive. The size of this pipe will depend on the location of the centralized wetland and recharge basin.
- The application of oil / grit separators immediately upstream of the constructed wetland. The number of units required likely is 1 or 2 depending on the location of the wetland and recharge basin.

A summary of conveyance design flows are provided in Table 5 below.

TABLE 5 INNOVATION PRECINCT PROPOSED INFRASTRUCTURE

Conveyance LInk	Estimated Slope (%)	Length (m)	Preliminary size assuming a pipe (mm diameter)	Design Peak Flow Rate (m^3/s)			
				1:5 year Historic IDF	1:100 year Historic IDF	1:5 year Climate Change	1:100 year Climate Change
C1	5	182	375	0.00	0.28	0.00	0.31
C4	2	75	450	0.03	0.13	0.03	0.29
C5	3	96	525	0.03	0.45	0.04	0.69
C2_1	13	71	450	0.03	0.13	0.03	0.29
Pipe crossing Innovation Drive*	0.5	150	1050	-	-	-	1.88

Pipe sizes noted are for the 1:100 year Climate Change event.
* Pipe crossing Innovation Drive assumes constructed wetland and recharge basin is on the east side of the road in Development cell B.



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Proposed Infrastructure Schematic North Campus

0 25 50 100
Metres

Coordinate System:
NUTM11

Data Sources:
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FIGURE 11

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1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

For ease of sizing and costing, all conveyances are assumed as pipes. UBCO has expressed aspirations for a pipeless Innovation Precinct, therefore open channels are appropriate and possible, however, open channels are much more difficult to size and cost in steeper terrain without adequate topographic information. It is anticipated, however, that the cost of piping will be fundamentally like open channels, given the land base and cut / fill slopes that may be required for open channels. Open channels should be designed in a way that prevents erosion and are aesthetically pleasing. An example is shown below, from the Silver Valley neighbourhood in Maple Ridge, BC (plants shown may be inappropriate for the UBCO setting).

Photo 3 –Roadside Bioswale, Silver Valley, Maple Ridge, BC

3.4.1

CENTRALIZED CONSTRUCTED WETLAND AND RECHARGE BASIN

With successful application of LID facilities for all future growth, there is expected to be little to no runoff generation for the 1:2 and 1:5 year events. This is not true for Lot H, which is reliant on the existing ditch, which does not infiltrate as intended and is inadequate to manage the parking area. As such, the wetland is largely to be sized to service Lot H, as no flow is anticipated from other growth areas for a 1:2 year event provided successful application of LID's as recommended. A constructed wetland has been selected because of the expressed aspiration of UBC. However, to perform effectively from a water quality treatment perspective, a constructed wetland requires a relatively large land base (discussed below).

The recharge basin must be sized for 100 % retention and disposal for all runoff generated up to and including the 1:100 year event, and should account for anticipated climate change. As described in Figure 2, provided the 3 meter cap of surface soils are removed, infiltration potential is estimated at 7 meter per day, which has been applied to preliminary sizing.

TABLE 6 Innovation Precinct Recharge Basin

Peak Inflow (m^3/s)					Storage Volume (m^3)				
1:5 year Historic IDF	1:100 year Historic IDF	1:2 year Climate Change	1:5 year Climate Change	1:100 year Climate Change	1:5 year Historic IDF	1:100 year Historic IDF	1:2 year Climate Change	1:5 year Climate Change	1:100 year Climate Change
0.49	1.37	0.47	0.78	1.88	137	2,213	136	375	3,652

Storage volume is that required during the precipitation event based on the difference between the incoming flow and what is discharged back to ground.

The critical design values for the constructed wetland are a predicted peak inflow rate of 0.47 m^3/s and a treatment volume of 825 m^3 (total 1:2 year, 24 hour volume entering wetland) resulting from the future condition with development and climate change. Unlike the recharge basin storage volume which represents only a portion of the incoming runoff hydrograph volume, the wetland must treat the entire incoming runoff hydrograph volume.

The critical design values for the recharge basin are 1.88 m^3/s for an inflow rate and 3,652 m^3 for a storage volume; both of which are for the 1:100 year Climate Change event. The recharge basin storage volume is only the temporary storage volume for the portion of the runoff hydrograph that exceeds the infiltration capacity of the basin. The total runoff volumes are significantly larger.

Sizing is generally consistent with the costs comparisons presented in the Options Report. In the options report it was stated that the optimal wetland and recharge basin had a discharge rate of between 10 and 21 L/s/ha depending on the precipitation event considered, and a wetland treatment volume that was 20 to 25% of the maximum temporary storage volume of the recharge basin. Sizing presented herein has an average peak disposal rate of 14 L/s/ha (per developed hectare) and a wetland marsh treatment volume equal to 23% of the recharge basin volume.

Constructed wetlands have the ability to serve as “living labs” for faculty and staff, satisfying other goals and objectives identified by UBCO. And with the right species of plants, constructed wetlands could also have a measurable impact on disposal volumes through evapotranspiration.

3.4.1.1

WATER TREATMENT

The recharge basin should be preceded by a high level of runoff treatment, to remove sediment that can limit infiltration capacity at the basin and to prevent exfiltration of potential harmful pollutants that can contaminate groundwater. Such treatment can best be achieved by providing a variety of pollutant removal processes, including settling, filtration, adsorption, chemical conversion, and biological uptake and transformation. To the extent that such a treatment facility can also provide other benefits to development at UBCO, all the better. Examples of other benefits include aesthetic character, bird and wildlife habitat, and recreational opportunities, e.g., for bird-watching.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

Several types of runoff treatment facilities can be used to meet the various objectives, generally falling within the broad category of green rainwater infrastructure. Of these, constructed rainwater wetlands, have a long history in providing runoff treatment. Real-world studies of rainwater treatment wetlands across North America shows that they score consistently high in treatment capabilities among the various green and grey structural best management practices.

TABLE 7 TREATMENT REMOVAL PERFORMANCE

Pollutant	Typical Concentration in Discharge	Typical Removal Performance*
Total Suspended Solids (TSS)	<30 mg/L	80%+
Petroleum Hydrocarbons	<10 mg/L	80%+
Fecal Coliforms	1,000 MPN/100mL	70%
Total Copper	0.005 mg/L	60%**
Total Zinc	0.030 mg/L	60%**

*Performance, or removal efficiency, is frequently a function of influent concentration, higher influent concentrations yielding greater removal percentages; values listed in table are provided to illustrate general capabilities of treatment wetlands.
**Average of removal rates for copper and zinc.

Sediments can quickly fill a wetland, limiting runoff storage volume and killing vegetation. In the past, open basins, called sediment forebays, were often used to fulfill this pre-treatment function. The constructed wetland should be preceded by "pre-treatment" to remove coarse sediments (i.e., particles larger than a medium sand, with median diameter of 0.050 mm or 50 microns). In order to reduce the footprint of the wetland as well as to simplify periodic removal and disposal of the coarse sediments, we suggest using manufactured oil/grit separators (OGS)[6], or similarly, a non-proprietary public domain design). Compared to dredging and subsequent repair of a forebay, OGS can be cleaned with standard storm drain vacuum equipment. OGS also have the advantage that they can prevent oils and greases, or other spilled materials, from entering the wetland when present in relatively low concentrations.

There are a wide variety of configurations that can be utilized to yield a constructed wetland. For illustration purposes a shallow wetland has been conceptualized. There are a number of good BMP manuals available from across North America, all with similar design guidelines for constructed wetlands. Some common features and requirements for the wetlands are:

[6] There are dozens of such OGS on the market; examples include StormCeptors, manufactured by Imbrium Industries, and CDS and Vortechs, both manufactured by Contech Engineered Solutions. Mention of these facilities does not constitute endorsement.

- Wetland cell(s) which provide a mix of shallow and deep areas.
- A serpentine primary flow path through the cell(s).
- A diverse mix of wetland plantings, including emergent vegetation along with trees and shrubs.
- Wetland hydrology is important to the design. In this case, ephemeral conditions are possible.

Subject to topography, cascading weirs may also be considered which when flowing may help entrain air into the water.

For this wetland, the following criteria yields a wetland facility area of roughly 2,200 m^2, including a 4-5 m buffer. The design closely follows the guidelines for a "shallow constructed wetland"[7].

- A water quality storm event (2-year return period event) with a total runoff volume of 825 m^3.
- A permanent ponded water volume (minimum) of 1,988 m^3 based on a design recommended 126 m^3/ha per developed contributing area.
- A maximum change in water surface elevation during the water quality storm event of 600mm (above the permanent ponded water elevation), with a maximum ponded area coverage of 1,375 m^2.
- Wetland area is allocated to achieve a mix of water depths and associated vegetation types:
  - » 20% deep water (450 – 1800mm deep)
  - » 40% low marsh (150 - 450mm deep)
  - » 35% high marsh (0-150mm deep)
  - » 5% semi-wet (normally dry areas inundated during water quality storm event)
- A "micro-pool" deep area is located at the outlet, to prevent suspension of settled solids.
- Length (of the primary flow path) to width (of the ponded area during the water quality event) ratio is about 3:1.
- Minimum average drain time for the water quality storm is 12 hours.
- Average release rate for the water quality storm is 19.1 L/s.
- In order to minimize the flooded depth at the site as well as its overall footprint, runoff exceeding the water quality storm is bypassed around the facility.

The wetland footprint has taken into account the use of manufactured oil/grit treatment facilities in lieu of an open forebay as pre-treatment.

[7] Minnesota Pollution Control Agency, The Minnesota Stormwater Manual, November 2005.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

This design is not optimized. Adjustments may be required to account for snowmelt events. Further, to ensure wetland conditions are maintained, continuous hydrologic simulation during design is strongly recommended. With successful application of LID for all future growth areas, the predominant water source will be runoff from Lot H. The bottom of the wetland will require an impermeable liner in order to retain water.

Although not satisfying many of the objectives and goals expressed by UBC, the option exists to apply an engineered proprietary water quality treatment filter in lieu of a constructed wetland. This option is being presented because of the much greater land base requirements for the constructed wetland. Comparison of shallow constructed wetland and "Imbrium JellyFish Filter" performance is:

TABLE 8 COMPARISON OF TREATMENT EFFECTIVENESS

Pollutant	Constructed Wetland	Imbrium JellyFish Filter
TSS	80%+	89%*
Total Copper	60%***	90%
Total Zinc	60%***	70%
Free Oil	80%	62%**
Trash and Floatables	100%	100%
Bacteria (fecal coliform)	70%	unknown
TN	30%	51%
TP	50%	59%

*Capable of removing most particles down to 19 microns, according to Washington Department of Ecology (WADoE); Imbrium claims removal of particles down to 2 microns. Requirement in Washington is 80% removal efficiency if influent TSS concentration is between 100 and 200 mg/L and removal to less than 20 mg/L if influent concentration is less than 100 mg/L; through its treatment technology certification process, WADoE has accepted that JellyFish can meet this requirement.
**Capable of removing 62% of oil & grease even when influent concentration is only at 1 mg/L, according to WADoE.
***Average of removal rates for copper and zinc.

Comparison of key treatment mechanisms:

- Wetland – settling, filtration, adsorption, chemical conversion, and biological uptake and transformation
- JellyFish – settling, floatation and membrane filtration (other advanced treatment facilities on the market rely on media filtration, which means the media can be adjusted or amended to target specific pollutants)

The JellyFish treatment system does not require pretreatment and may have either an internal or external bypass. Other advanced treatment facilities on the market may have other requirements.

Mention of the JellyFish treatment system does not constitute endorsement. Other advanced treatment facilities on the market may have comparable performance capabilities, certainly with respect to TSS removal and likely with respect to other pollutants.

On balance, wetlands and advanced treatment facilities such as JellyFish provide comparable levels of treatment for the most commonly targeted pollutants. The differences in removal performance noted in the table are not significant, given the high variability of pollutant concentrations in untreated runoff. Of course, other benefits, such as habitat or aesthetic value, are missing from the proprietary systems.

3.4.1.2

RECHARGE BASIN

Ultimate disposal of generated runoff, particularly to achieve 100% retention within the UBCO property, is reliant on a recharge facility. Based on the options comparison presented in the Revised Options Report (Part 3), UBCO has endorsed a recharge basin over a network of recharge wells. Again, the basin has been sized based on an estimated infiltration rate of 7 meters per day and the successful application of LID site controls, for the 1:100 year event with an allowance for climate change.

It is recommended that the recharge basin depth not exceed 1.5 meters of live storage depth, and should have a standard 0.6 meters of freeboard above the high water level, for a total basin depth of 2.1 meters. Cut slopes are suggested at 4:1, but are flexible provided they are not steeper than 3:1. Signage is required to warn of rapid water level changes, and this signage is also recommended to be added to the existing pond in the main campus.

To achieve rapid infiltration, the top 3 meters (estimated) of lower permeable material will need to be removed. Then to not exceed the recommended basin depth an estimated 0.9 meters of high permeability backfill will be required to replace the native material removed.

Sizing assumes that the infiltration rate remains constant, regardless of the water depth in the basin. A basin surface area of 2,500 m^2 is estimated [8]. Additional area for the 0.6 meter freeboard slope and an access buffer, say 3 meters wide, is required above this; resulting in a total land base requirement of 3,700 m^2. When combined with the constructed wetland, the total minimum land base is 0.59 hectares, which is smaller than the land base of the existing pond in the main campus (roughly 0.9 hectares). Sizing of the recharge basin is highly dependent on the application of LID practices and the total development area. Sizing of the recharge basin must be verified through a comprehensive engineering design process for Innovation Precinct.

[8] The average area between the basin floor and the top of the live storage zone at 1.5 meters deep.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

Except during significant storms when temporary storage is required, this basin will be normally dry and void of shallow ground water. It will not support plant life, other than perhaps desert species (succulents). Landscape architects will need to be creative to offer visual appeal to this facility, but it is critical that finishing elements and uses do not impact the infiltration capacity. The pre-treatment water quality systems and regular maintenance to remove any deposited debris is important.

With a predicted maximum storage volume of 3,652 m^3, the maximum storage depth is predicted to reach 1.46 meters. However, it is recommended that the basin offer a live storage depth of 1.5 meters, offering a total available volume of 3,750 m^3. Additional safeguard storage of 2,200 m^3 is available within the 0.6 m freeboard zone[9].

3.4.1.3

FACILITY LOCATION AND CONCEPTS

Since the Revised Options Report was completed, UBCO has advanced two conceptual layouts for Innovation Precinct as presented in Figures 12A and 12B. We understand there to be general preference for Option 1 (Figure 12A). Based on current topography, the most suitable location for a centralized facility is at the south end of IP cell An, or IP cell B, as indicated previously in Figure 11. However, alternative locations have been conceptually shown in Figures 12A and 12B to reflect the proposed development layouts and preferences expressed by UBCO. In general, Option 1 (Figure 12A) is considered to have a higher chance of success, but may still be hampered by topographic challenges, as discussed in the paragraph below. Siting the facility at a less than optimal location is expected to require additional earthworks and conveyance works. Note that Figures 12A and 12B are rough conceptualizations only and do not accurately represent the land base requirement for the facility. Making a decision on siting the facility must involve a comprehensive site planning and engineering exercise beyond the scope of this IRMP.

In Figure 12A, a long linear facility is conceptualized paralleling the roadway. This facility is conveniently located to serve all contributing areas, including the overflow from the Lot H ditch. Runoff from development will likely need to enter from several directions, therefore it is expected that at least two entry points and oil/grit separators will be required. The challenge with this configuration is that current topography rises to the north over its length, so there is likely need for either significant earthworks or consideration for cascading cells, with the lowest cell located at the south end. An architectural rendering of this option is provided in Figure 13A.

[9] Volumes assume 4:1 side slopes.

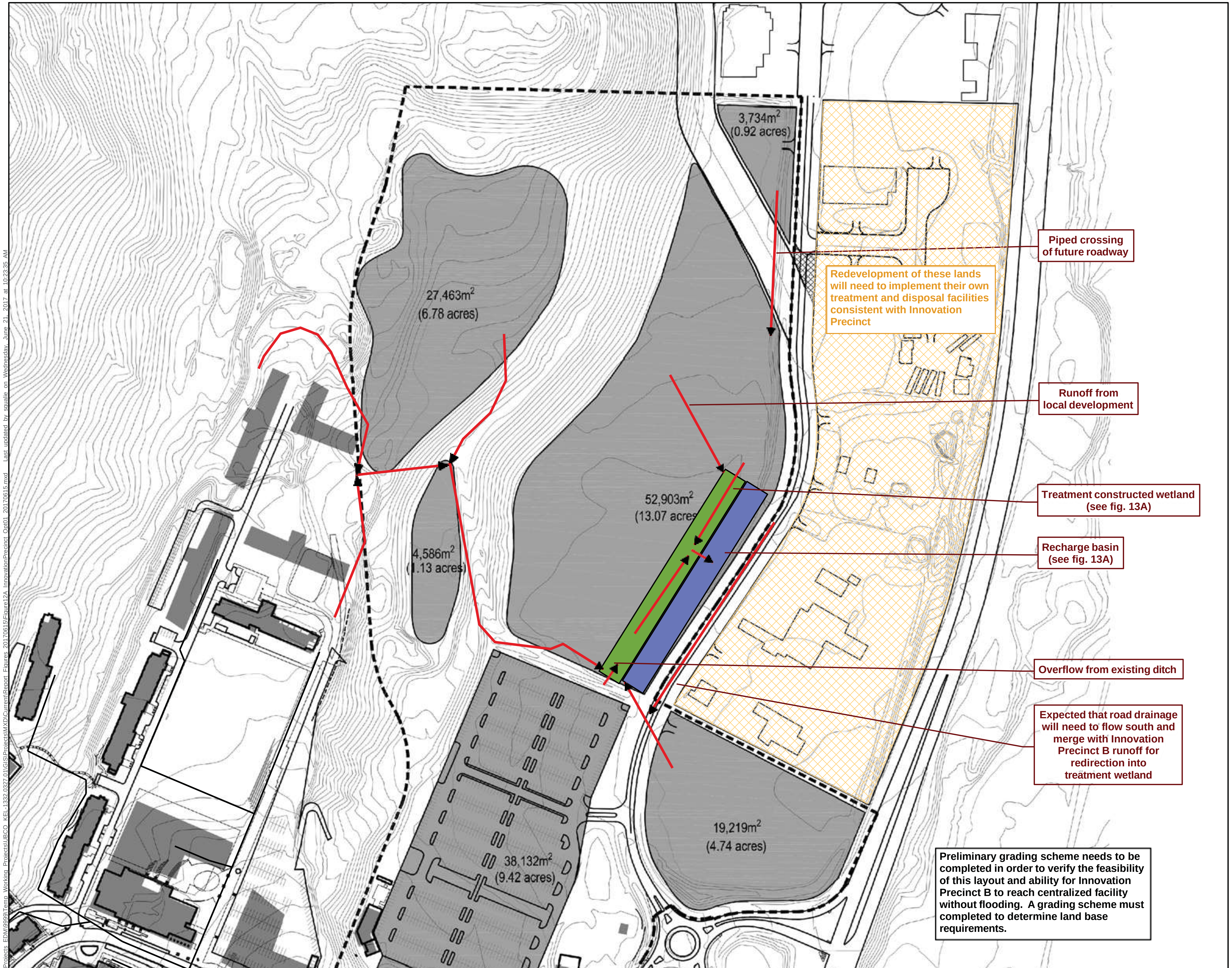
In Figure 12B the facility is conceptualized further north and in a more compact form, however this is not an optimal location from an engineering and servicing perspective. The disadvantages of this location is that it is located on what is currently higher ground, and is further away from the flow convergence point from IP cells, As, B and C. Two more optimal locations are also shown in Figure 12B, with an architectural rendering of a compact facility provided in Figure 13B.

From a geotechnical perspective, IP cell B is probably the best understood given the previous infiltration test done for disposal of spent geothermal water. It is also down-gradient or off-gradient of the GEID municipal wells and UBCO geothermal wells, limiting risk of negative interactions with those. The only concern is that IP cell B is in moderate proximity (within 280 m) of the junction of Kelowna (Mill Creek) and Scotty Creek across the highway. The two potential issues with this are: 1) it is an area that has had issues with flooding in the past, and 2) there is the question of sensitivity of aquatic habitat. These are not believed to be serious concerns. Given the source of the runoff and proposed treatment systems it is assumed that the quality of the effluent will be good to put to ground.

East of the highway, the creek appears to be underlain by a clay rich confining layer which prevents infiltration and limits interaction with the underlying aquifer (hence the historical issues with flooding). The aquifer clearly has the ability to receive a significant amount of flow west of the highway. It is expected the confining layer to limit any interaction with surface east of the highway. However, to mitigate any perceived risk, it is recommended that some observation wells be installed between the recharge area and the creek east of the highway to allow monitoring of groundwater levels and any contaminants that might find their way into the aquifer from the stormwater runoff. These can be simple 2″ PVC wells completed below the water table, through the confining layer and into the top of the aquifer.

Figures 12A and 12B also recognizes the potential development of lands east of Innovation Drive. These lands as not currently owned or controlled by UBCO. These lands in themselves represent a substantial area, nearly equal in size to Innovation Precinct. The infrastructure noted herein has not been sized to accommodate these external lands. Should these external lands develop, they too should be held to the same standard as Innovation Precinct, but will require their own dedicated management system; LID source controls, communal conveyance, treatment, and disposal.

Finally, it should be noted that the creation of a constructed wetland is likely to be inhabited by the Spadefoot Toad which currently resides in the nearby Lot H ditch, or other species. While this meets the environmental diversity objectives and goals expressed by UBC, it will also introduce impediments to Operation and Maintenance practices which are mandatory for long term function as a utility. More on environmental considerations are presented in Section 4 below.



UBC OKANAGAN

IRMP

Innovation Precinct Conceptual Layout Option 1

Legend

Flow Direction

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 Metres

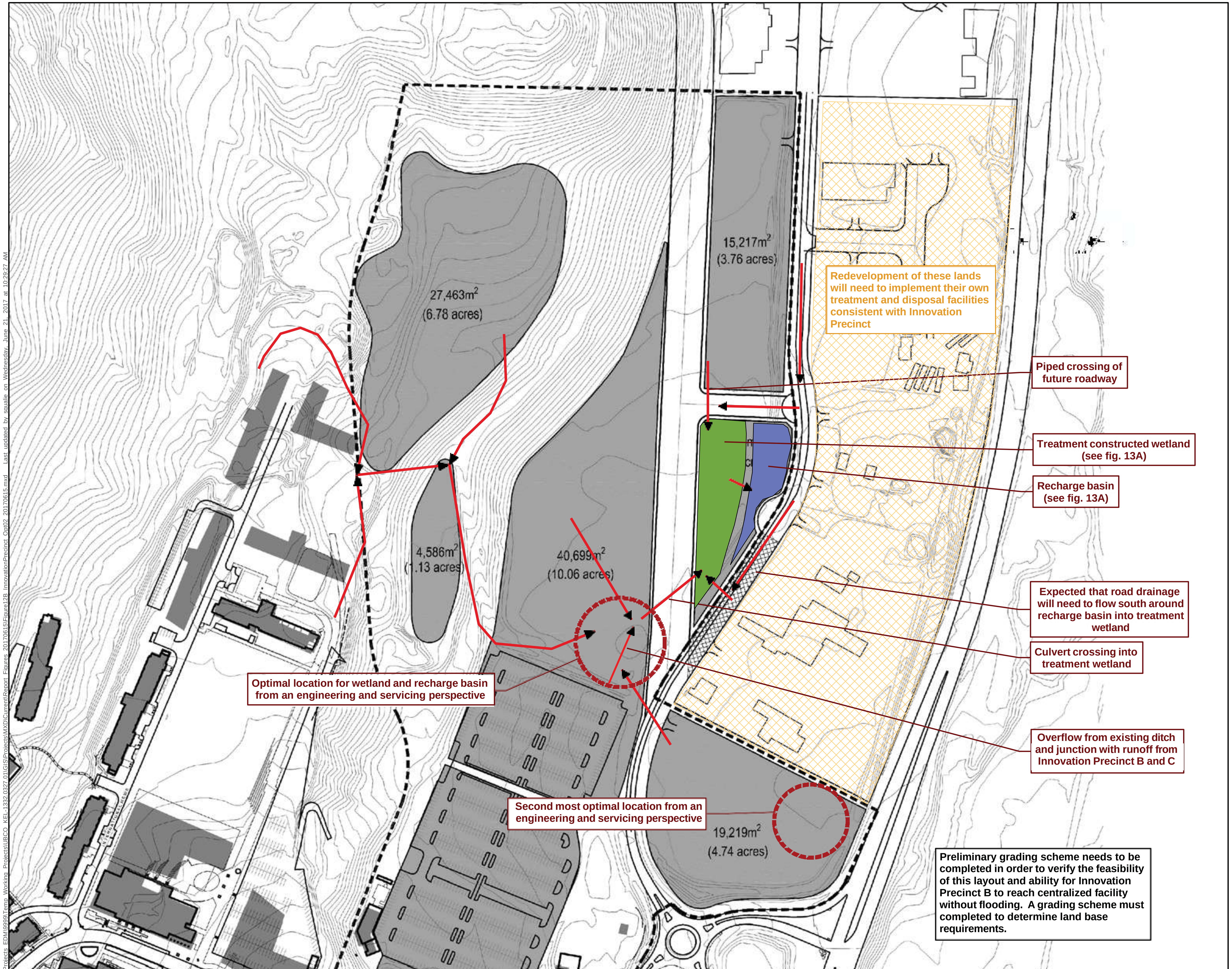
Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	JW
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 21

URBAN systems

FIGURE 12A



OKANAGAN

IRMP

Innovation Precinct Conceptual Layout Option 2

Legend

Flow Direction

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
Metres

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #: 1332.0327.01
Author: JW
Checked: GS
Status: ~ FINAL ~
Revision: A
Date: 2017 / 6 / 21

URBAN systems

FIGURE 12B

OKANAGAN

IRMP

Concept for Centralized Treatment Wetland and Recharge Basin

Linear Configuration with Bi-Directional Inputs

Legend

- Riparian Vegetation
- Wetland
- Recharge Basin
- Watercourse
- Pedestrian Path
- Road
- Trees
- Runoff Input
- Oil/Grit Separator

Not to Scale

N

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	FinalRAFT –
Revision:	A
Date:	2017 / 04 / 06

URBAN systems

FIGURE 13 a

U:\Projects_EDM\9999\Temp Working Projects\UBCO KEL-1332.0327.01\GIS\Projects\MXD\Current\December Report Figures\Figure 8 - Recharge Basin Concept.mxd Last updated by squalie on Thursday, December 8, 2016 at 12:33:13 PM

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IRMP

Concept for Centralized Treatment Wetland and Recharge Basin

Compact Configuration with Singular Input

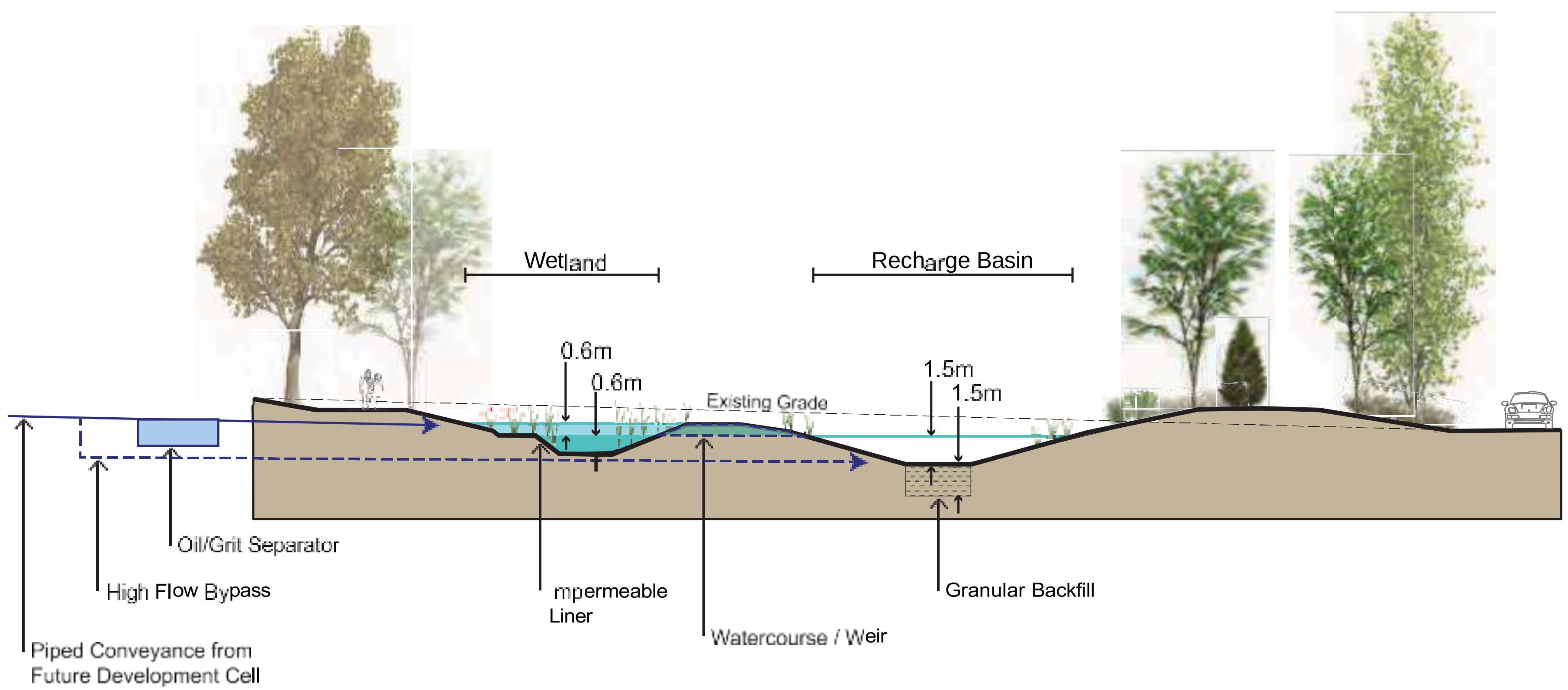
Legend

- Riparian Vegetation
- Wetland
- Recharge Basin
- Watercourse
- Pedestrian Path
- Road
- Trees
- Runoff Input
- Oil/Grit Separator

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.

Final

URBAN systems



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IRMP

Concept for Centralized Treatment Wetland and Recharge Basin

Section

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.

Not to Scale

Coordinate System:
NAD 1983 UTM Zone 11N

Data Sources:
Data provided by UBCO, 2016

Project#: 1332.0327.01
Author: SQ
Checked: GS
Status: Final
Revision: A
Date: 2017/04/06

URBAN systems

FIGURE 13c

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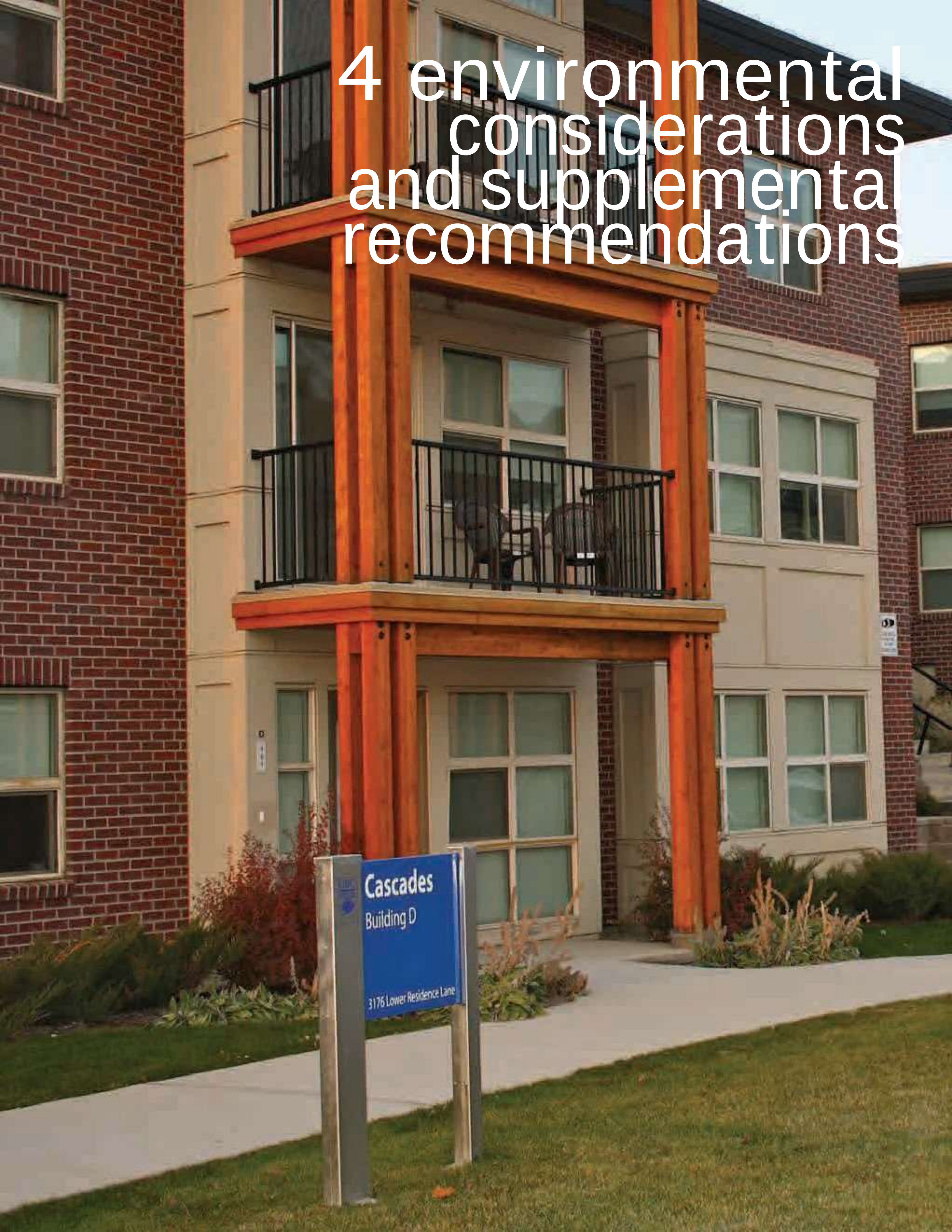
4 environmental considerations and supplemental recommendations



There are a number of environmental and habitat protection issue to be considered, summarized as follows:

4.1 existing pond in main campus

4.1.1

ENVIRONMENTAL MITIGATION RECOMMENDATIONS

- Reduce/minimize nutrient loading by addressing contributory sources (such as stopping the use of fertilizer for snow removal).
- Western Painted Turtle prefers shallow ponds with a muddy bottom and an abundance of emergent vegetation. Given that these conditions generally exist within the existing pond, it is recommended that disturbance to the substrate and vegetation be generally avoided in the main pond cell. The observed vegetation growth is not likely to significantly diminish the live storage volume of the pond. Regular maintenance should focus on the forebay.
- If disturbances or alterations (vegetation removal, dredging, bank stabilization, etc.) are required to maintain the utility of the existing pond, a qualified professional should be consulted to assess the impacts of the proposed activities and prepare and submit the necessary approval applications (i.e., Section 11 BC Water Sustainability Act application and City of Kelowna Natural Environment Development Permit application).
- A turtle survey should be undertaken prior to any maintenance activities that could result in habitat disturbance. Any detected individuals should be relocated to other suitable wetland habitats (e.g., Robert Lake or Little Robert Lake within the west campus lands).
- A qualified environmental monitor should oversee any activities that may result in disturbance to the pond and adjoining habitats.

4.1.2

CONSERVATION AND ENHANCEMENT OPPORTUNITIES

- Undertake a detailed survey of Western Painted Turtle to better understand their use of the wetland habitat. The Ecological Analysis conducted for the campus lands (Ecoscape, 2014) recommended that additional research focus on painted turtle population size, availability and location of nesting habitat, and dispersal routes. This represents one “learning” opportunity to engage students and faculty.
- Preserve or create essential habitat features, including basking rocks and logs, in shallow water areas with emergent and floating vegetation. Where possible install partially submerged logs perpendicular to the shore.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

- Maintain and or create gradual slopes on banks to provide accessibility of turtles to upland nesting areas.
- Ensure access is maintained to potential nesting sites within the upland area immediately surrounding the pond near the Engineering building. Western Painted Turtle prefer sparsely vegetated loam substrates free of roots and large stones for nesting.
- Remove invasive species and re-establish native plant species within riparian zone around the pond and the field to the east of the pond to prevent further expansion and impact on native species.
- Explore the expansion of the wetland into the area east of the pond. The Ecological Analysis conducted for the campus lands (Ecoscape, 2014) recommended that consideration be given to expanding the existing wetland complex toward Hollywood Road North to include additional open water features with cattail and bulrush components. This is not considered a need to satisfy the requirements of the IRMP.

4.2 existing ditch servicing lot h

4.2.1 ENVIRONMENTAL MITIGATION RECOMMENDATIONS

- Disturbance to the existing ditch should be avoided to minimize the potential for impacts to the Great Basin Spadefoot Toad.
- The Great Basin Spadefoot is blue-listed under the BC Conservation Data Centre and is as Threatened on Schedule 1 of the Species at Risk Act (SARA). The Province upholds the federal species and habitat requirements through various regulations and approval application processes. If disturbances or alterations (vegetation removal, bank stabilization, etc.) are required to maintain the utility of the ditch, a qualified professional should be consulted to assess the impacts of the proposed activities and prepare and submit the necessary approval applications (i.e., Section 11 BC Water Sustainability Act application and City of Kelowna Natural Environment Development Permit application).
- The ditch provides suitable breeding habitat for spadefoot toads. As such, any maintenance activities should occur during late summer (late July to early September) outside of the anticipated breeding period.
- A spadefoot toad survey should be undertaken prior to any maintenance activities that could result in habitat disturbance. Any detected spadefoot individuals should be relocated to the proposed constructed wetland or other suitable wetland habitats.
- A qualified environmental monitor should oversee any activities that may result in disturbance to the ditch and adjoining habitats.

4.2.2

CONSERVATION AND ENHANCEMENT OPPORTUNITIES

- Although not a requirement, the opportunity exists to expand the ditch and add cattails and riparian grasses along the parking lot to improve water quality and habitat.
- Deepen sections of the ditch to allow for a longer period of water retention.
- This ditch was intended to serve a utility function and may continue to do so, however UBCO could improve the stormwater quality before it enters the ditch by providing a vegetated buffer along the parking lot edge to filter runoff from the parking lot before it enters the ditch.
- Plant native trees (e.g., aspen, alder, birch, etc.) along the south side of the ditch to provide shade and reduce evaporation.
- Maintain habitat connectivity to any disturbed soils and cutbanks near the ditch. These areas provide suitable terrestrial habitats for spadefoot burrowing and estivation (summer dormancy).
- Spadefoot require access to upland terrestrial habitat for foraging. As such, it is important that habitat connectivity to the north be maintained between Innovation Precinct A and Innovation Precinct C. This will allow for the migration of adult spadefoot to the woodland habitats.
- Maintain habitat connectivity to the south along the west side of the parking lot, to allow for wildlife migration to the grassland area along Hollywood Road South and the wetland habitat comprising the existing pond.

4.3
constructed wetland and recharge basin

4.3.1

CONSERVATION AND ENHANCEMENT OPPORTUNITIES

- Provide access from the wetland to the area between Innovation Precinct A and Innovation Precinct C. This will allow for wildlife migration to upland foraging habitats.
- Incorporate suitable native aquatic and riparian species within the design of the constructed wetland. It is possible, however, that this wetland may be ephemeral and may go through periods of drought. Plants should be selected accordingly.
- Ensure the wetland has an impermeable liner to minimize infiltration.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

- Explore establishing a spadefoot population in the constructed wetland via translocation of adults from less suitable habitats (i.e., the Lot H ditch).
- Conduct any routine maintenance during least risk timing window (depending on species present, likely during late summer).
- Provide access to suitable turtle nesting sites with light soils and little vegetative cover with south exposure.
- Incorporate basking rocks and logs, in shallow water areas with emergent and floating vegetation.
- Control / prevent the establishment of invasive plant species that out-compete native species. Establish a buffer of native vegetation adjacent to the wetland.
- Add artificial snags for perching and cavity nesting.

4.4 supplemental recommendations

4.4.1 MONITORING

Monitoring of both the existing detention pond and the proposed constructed wetland and recharge basin is proposed for the following reasons:

- To provide data from which to understand system performance and make adaptive management decisions.
- To serve as a learning and engagement opportunity with faculty and staff – a living lab.

A recommended monitoring program is as follows:

1. Install a permanent water level gauge in the existing pond and the proposed constructed wetland. Ideally these will collect data in 5 minute time steps, but 1 hour would be adequate.
2. Install a permanent staff gauge with a recording float mechanism in the recharge basin that can be manually read. Given the infrequency that water is expected to store in this basin, it would seem not cost effective to install permanent gauging and telemetry. A staff gauge with a float that can record the peak water level is an economic alternative. However, this will require manual reading and recording following a storage event. The staff gauge should be read after all precipitation events that generate discharge from the treatment wetland. Alternatively, an electronic gauge can be installed, however readings are expected to be zero for the vast majority of time and for extended periods.

3. 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.
4. 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.
5. Conduct periodic water quality monitoring within the existing pond and future constructed wetland. Testing is recommended for a minimum of total suspended solids, petroleum hydrocarbons, fecal coliforms, total copper, total zinc, and nitrogen. Testing in the constructed wetland is recommended during both typical dry weather conditions and also during a precipitation event generating runoff, whereby samples of water discharging from the wetland into the recharge basin are tested. It is expected that development of the upstream catchment will take place over several years and the intent of monitoring is also to observe performance changes as the catchment conditions change. It is recommended that both dry weather and wet weather sampling be done a minimum of twice for each of the four seasons. This program would continue until the land use condition of the catchment stabilizes, at which point the sampling program may diminish. The frequency of sampling will depend on the sampling results (highly stable versus highly variable).
6. Install a 2″ PVC observation well immediately to the east of the recharge basin to sample downgradient groundwater quality. Samples should be compared against samples taken from other wells in the general area (geothermal and GEID municipal) for a chemistry comparison. Alternatively, UBCO may install a second 2″ PVC observation well up-gradient of the recharge basin to the west. It is recommended that this west observation well be located at a topographic location approximately 5 meters higher than the recharge basin. Both wells must be deep enough to sample baseline groundwater.

4.4.2

BUILDING SERVICE CONNECTIONS

The existing piping system within the main campus is known to surcharge to varying degrees. As such, connecting buildings may be vulnerable depending on their floor elevation and serviced connection relative to the hydraulic grade line in the storm sewer system. In Appendix 2 of this report, theoretical hydraulic grade line profiles are provided for several trunk routes as a performance indicator. All future buildings should consider the possibility of hydraulic grade lines reaching ground surface, and either set or protect floor slabs and foundation drains accordingly. Foundations drains should be separate from roof drains, and foundation drains should connect to the storm sewer at the lowest possible point

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

accessible. As a last resort, foundation drains may need to be protected with a backflow prevention device and sump pump. With the goal of LID retention on site, roof leaders from Future Buildings should be discharged to surface. Future buildings should be flood proofed. Ideally, new buildings will be slab on grade, or at least be planned such that all critical infrastructure and contents are above grade.

4.4.3

SITE SPECIFIC TESTING AND SITE PLANNING CONFIRMATION

The IRMP is a planning level document. Detailed design should be conducted with site specific testing of soil infiltration rates at the location of proposed LID facilities. This is most critical at locations where disposal to ground is most critical, such as dry wells and recharge basins. Further, the estimated impervious surfaces and required retention volumes are based on rough site concepts only and do not necessarily reflect final proposed conditions. Through the site development process increased impervious surface areas over current conditions should be confirmed and the retention volumes recalculated in accordance with the criteria stated herein.

4.4.4

SEDIMENT AND EROSION CONTROL STANDARDS FOR DEVELOPMENTS

If not adequately managed, sediment and erosion generated from the construction processes will likely have significant negative impact on the existing pond and any future management facilities in Innovation Precinct. It is recommended that UBCO, if not already in existence, develop rigorous sediment and erosion control guidelines for all future development and construction activity.

5

5.1 main (south) campus implementation strategy

There are few restrictions on how development of the main campus can proceed, however, the following implementation steps are suggested to support change. They are listed in order of relative priority, however none of these are fixed requirements.

1. Complete the overland flow path assessment and make decisions around flood risk management (to be completed as part of this IRMP in January).
2. Implement a permanent water level monitoring gauge in the existing pond and a flow gauge in the storm sewer outfall.
3. Continue with periodic water quality monitoring of the existing pond.
4. Conduct a painted turtle inventory assessment and consider habitat enhancements discussed herein
5. Establish rigorous Sediment and Erosion Control Criteria, if one does not currently exist
6. Review snow management programs to reduce snow storage in rainwater management facilities, and to find confident alternatives to using fertilizers and sand. Salt is less of a risk to LID features than sand, but it is preferred that a salt brine be used over rock salt. Ideally, proceed with alternatives such as beet juice.
7. Complete Design Guidelines document.

5.2 innovation precinct implementation strategy

Innovation Precinct requires a more systematic implementation process, as suggested below. Again, they are listed in order of priority.

1. Using this IRMP as a guide, conduct land use planning process to identify land base and siting of necessary controls; both LID site controls and communal treatment and disposal controls. In the process decide on this community being "pipeless" or not. This will be an important decision to design of site grading and buildings.
2. Conduct site specific infiltration testing at the precise locations of planning infrastructure.
3. Review and update, as necessary, technical analysis based on items 1 and 2 above.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

4. Consider implementing a temporary water quality forebay and recharge basin to serve the early phases of development, and then when the highest risk construction activities are complete, retrofit the facilities into their final constructed wetland and recharge basin form. This is subject to the time horizon of planned development of Innovation Precinct and UBCO's success of the Sediment and Erosion Control Criteria.

5.3 life cycle costs

Life-cycle cost analysis (LCCA) is an important tool to assist in the evaluation of feasible alternatives. LCCA assists in determining the most cost-effective option among differing alternatives to design, construct, operate, maintain and finally, dispose of/and or replace the infrastructure.

The approach applied is based on InfraGuide's best practice for Decision Making and Investment Planning. This approach is complimentary to prudent asset management decision making and helps clients to better account for the long-term financial sustainability of projects. The key steps in the analysis are listed as follows:

1. Establish assumptions, inputs and parameters (service life, study period, costs, inflation, operational assumptions)
2. Estimate costs and times of occurrences for each input
3. Discount future costs to present value
4. Compute and compare LCC for each alternative

The LCCA is calculated using the following formula:

$$LCC = Crd + Cc + Com + Cfr$$

Where:

- LCC is life cycle cost.
- Crd is research and design cost.
- Cc is capital cost.
- Com is operation and maintenance cost.
- Cfr is future replacement cost (or disposal).

The capital costs are a Class 'D' order of magnitude estimate which is typically used for cost comparison between alternative solutions. These capital unit costs are based on similar recently tendered projects in the Okanagan region, include a 35% contingency allowance, and a 10% allowance for engineering but do not include any GST.

The operation and maintenance costs have been estimated using the *City of Edmonton, "Low Impact Development Best Management Practices Design Guide, Edition 1.0", November 2011* and the *"National Water and Wastewater Benchmarking Initiative", Public Report, August 2013.* The future replacement costs have been estimated using the Asset Management BC's *Asset Management for Sustainable Service Delivery, A BC Framework and Infraguide's Decision-making and Investment Planning: Managing Infrastructure Assets* best practice documents. Table 9 below summarizes the full life cycle costs for each component identified.

This table include some provisional items, including a potential trunk storm sewer upgrades on University Way to alleviate flood risk in the main campus. Also, the table includes an Imbrium "Jellyfish" water quality treatment system which may be selected in exchange for the constructed wetland. And finally, it has been estimated that 20,000 m^2 of LID features will be required to meet the defined retention targets. This study has not prescribed what type of facility will be applied, therefore for budgetary consideration the table has assigned an assumed distribution of different LID facilities, for a total area of 20,000 m^2.

1 Vision, Goals, and Context Plans
2 Low Impact Development and Site Controls
3 Communal Infrastructure
4 Environmental Consideration and Supplemental Recommendations
5 Implementation and Life Cycle Costs

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TABLE 9 LIFE CYCLE COSTS

Item	Diameter (mm)	Units	Estimated Quantity	Unit Cost	Sub-Total	Contingency (30%)	Design and Construction Period Services (15%)	Total	Annual O&M Costs	Average Annual Renewal Contribution	Annual Life Cycle Cost	Full Life Cycle Cost	Assumed Service Life
Storm Sewer Pipe													
EXISTING Storm Sewers													
	250	lm	2,662	$343	$911,903	$273,571	$177,821	$1,363,295	$1,198	$17,041	$35,281	$2,822,440	80
	300	lm	173	$411	$71,149	$21,345	$13,874	$106,367	$78	$1,330	$2,737	$218,966	80
	375	lm	384	$514	$197,024	$59,107	$38,420	$294,550	$173	$3,682	$7,536	$602,907	80
	450	lm	802	$617	$494,207	$148,262	$96,370	$738,840	$361	$9,236	$18,832	$1,506,539	80
	500	lm	30	$685	$20,651	$6,195	$4,027	$30,873	$14	$386	$785	$62,830	80
	525	lm	296	$719	$213,161	$63,948	$41,566	$318,675	$133	$3,983	$8,100	$648,020	80
	600	lm	157	$822	$128,710	$38,613	$25,098	$192,422	$70	$2,405	$4,881	$390,481	80
	1,000	lm	21	$1,370	$28,517	$8,555	$5,561	$42,633	$9	$533	$1,075	$86,015	80
	1,200	lm	70	$1,644	$115,103	$34,531	$22,445	$172,079	$32	$2,151	$4,333	$346,679	80
NEW Storm Sewers													
South Campus University Way	450	lm	20	$473	$9,450	$2,835	$1,843	$14,128	$9	$177	$362	$28,976	80
North Campus:													
C1	375	lm	182	$514	$93,503	$28,051	$18,233	$139,786	$82	$1,747	$3,577	$286,124	80
C4	450	lm	75	$617	$46,238	$13,871	$9,016	$69,125	$34	$864	$1,762	$140,950	80
C5	525	lm	96	$719	$69,048	$20,714	$13,464	$103,227	$43	$1,290	$2,624	$209,910	80
C3	300	lm	111	$411	$45,621	$13,686	$8,896	$68,203	$50	$853	$1,755	$140,403	80
C2_1	450	lm	71	$617	$43,772	$13,131	$8,535	$65,438	$32	$818	$1,668	$133,433	80
C2_2	450	lm	141	$617	$86,927	$26,078	$16,951	$129,955	$63	$1,624	$3,312	$264,986	80
C2	600	lm	187	$822	$153,714	$46,114	$29,974	$229,802	$84	$2,873	$5,829	$466,337	80
Pipe across Innovation Drive	1,050	lm	150	$1,439	$215,775	$64,733	$42,076	$322,584	$68	$4,032	$8,132	$650,567	80
New Storm Sewer to reduce flood risk through core of existing campus (allowance)	600	lm	375	$822	$308,250	$92,475	$60,109	$460,834	$169	$5,760	$11,690	$935,168	80
Manhole Reconfiguration													
Manhole Benching	N/A	ea	7	$10,000	$70,000	$21,000	$13,650	$104,650	$175	$1,308	$2,791	$223,300	80
Drywells (Estimated Quantity in Upper Main Campus)													
Drywell	N/A	ea	12	$8,000	$96,000	$28,800	$18,720	$143,520	$300	$3,588	$7,476	$299,040	40
Landscape Based LID Feature (assumed distribution of 20,000 m^2 total requirement by type)													
Bioswale	N/A	m^2	4,750	$100	$475,000	$142,500	$92,625	$710,125	$20,188	$35,506	$91,200	$1,824,000	20
Bioswale (w. underdrain)	N/A	m^2	4,750	$110	$522,500	$156,750	$101,888	$781,138	$21,375	$39,057	$99,489	$1,989,775	20
Rain Garden	N/A	m^2	4,750	$100	$475,000	$142,500	$92,625	$710,125	$20,188	$35,506	$91,200	$1,824,000	20
Rain Garden (w. underdrain)	N/A	m^2	4,750	$110	$522,500	$156,750	$101,888	$781,138	$21,375	$39,057	$99,489	$1,989,775	20
Box Planter	N/A	m^2	500	$160	$80,000	$24,000	$15,600	$119,600	$2,125	$5,980	$14,085	$281,700	20
Box Planter (w. underdrain)	N/A	m^2	500	$180	$90,000	$27,000	$17,550	$134,550	$2,250	$6,728	$15,705	$314,100	20

Item	Diameter (mm)	Units	Estimated Quantity	Unit Cost	Sub-Total	Contingency (30%)	Design and Construction Period Services (15%)	Total	Annual O&M Costs	Average Annual Renewal Contribution	Annual Life Cycle Cost	Full Life Cycle Cost	Assumed Service Life
Swale (Sample Costs)													
Grassed Swale	N/A	m²	100	$50	$5,000	$1,500	$975	$7,475	$225	$374	$973	$19,450	20
Existing Ditch Improvements													
North Edge of Parking Lot H	N/A	LS	1	$20,000	$20,000	$6,000	$3,900	$29,900	$1,500	$1,495	$4,490	$89,800	20
Constructed Wetland													
Innovation Precinct	N/A	m²	2,200	$400	$880,000	$264,000	$171,600	$1,315,600	$44,000	$65,780	$175,560	$3,511,200	20
Recharge Basin													
Innovation Precinct	N/A	m²	3,700	$300	$1,110,000	$333,000	$216,450	$1,659,450	$37,000	$82,973	$202,945	$4,058,900	20
Stormwater Monitoring													
Existing Pond	N/A	LS	1	$30,000	$30,000	$9,000	$5,850	$44,850	$1,500	$2,243	$3,743	$74,850	20
Existing Storm Sewer	N/A	LS	1	$15,000	$15,000	$4,500	$2,925	$22,425	$2,500	$1,121	$3,621	$72,425	20
Constructed Wetland (level)	N/A	LS	1	$30,000	$30,000	$9,000	$5,850	$44,850	$1,500	$2,243	$3,743	$74,850	20
Constructed Wetland (quality)	N/A	LS	1		$0	$0	$0	$0	$2,500	$0	$2,500	$50,000	20
Recharge Basin	N/A	LS	1	$5,000	$5,000	$1,500	$975	$7,475	$1,000	$374	$1,374	$27,475	20
O/G Separators													
O/G Separators	N/A	LS	2	$50,000	$100,000	$35,000	$19,500	$149,500	$3,000	$1,869	$4,869	$389,500	80
Innovation Precinct Recharge Basin													
3 Unit Imbrium Jellyfish	N/A	LS	1	$900,000	$900,000	$270,000	$175,500	$1,345,500	$73,000	$33,638	$140,275	$5,611,000	40

appendix 1

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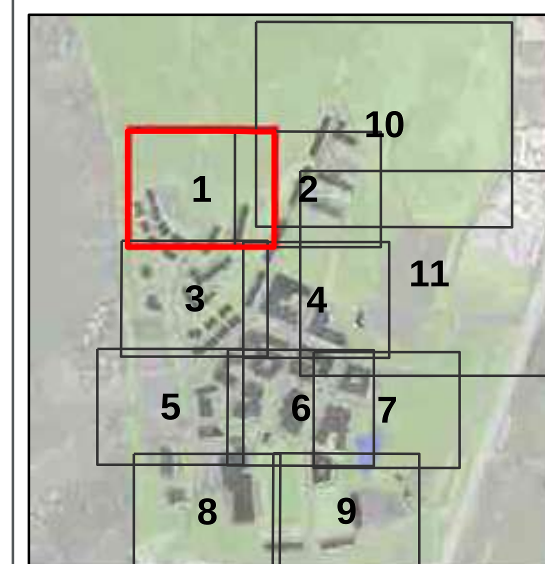
OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30

Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

APPENDIX 1.1

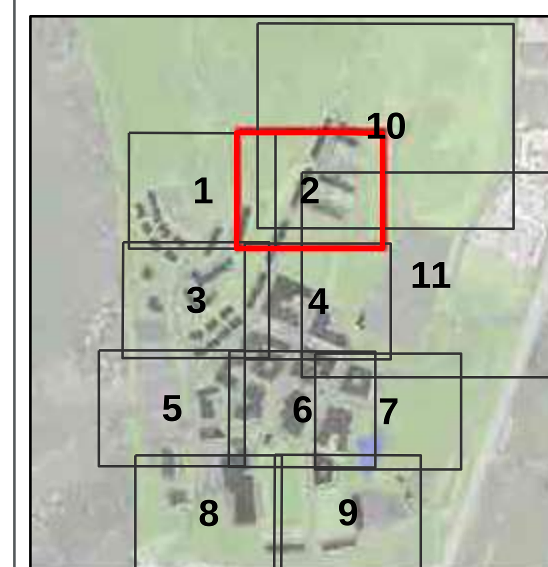
U:\Projects_EDM\9999\Temp_Working_Projects\UBCO_KEL-1332.0327.01\GIS\Projects\MXD\Current\Report_Figures_20170615\Appendix_1_-_Subcatchment_IDs_v2.mxd Last updated by squalie on Monday, June 19, 2017 at 11:18:21 AM

OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



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Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Author:	SQ
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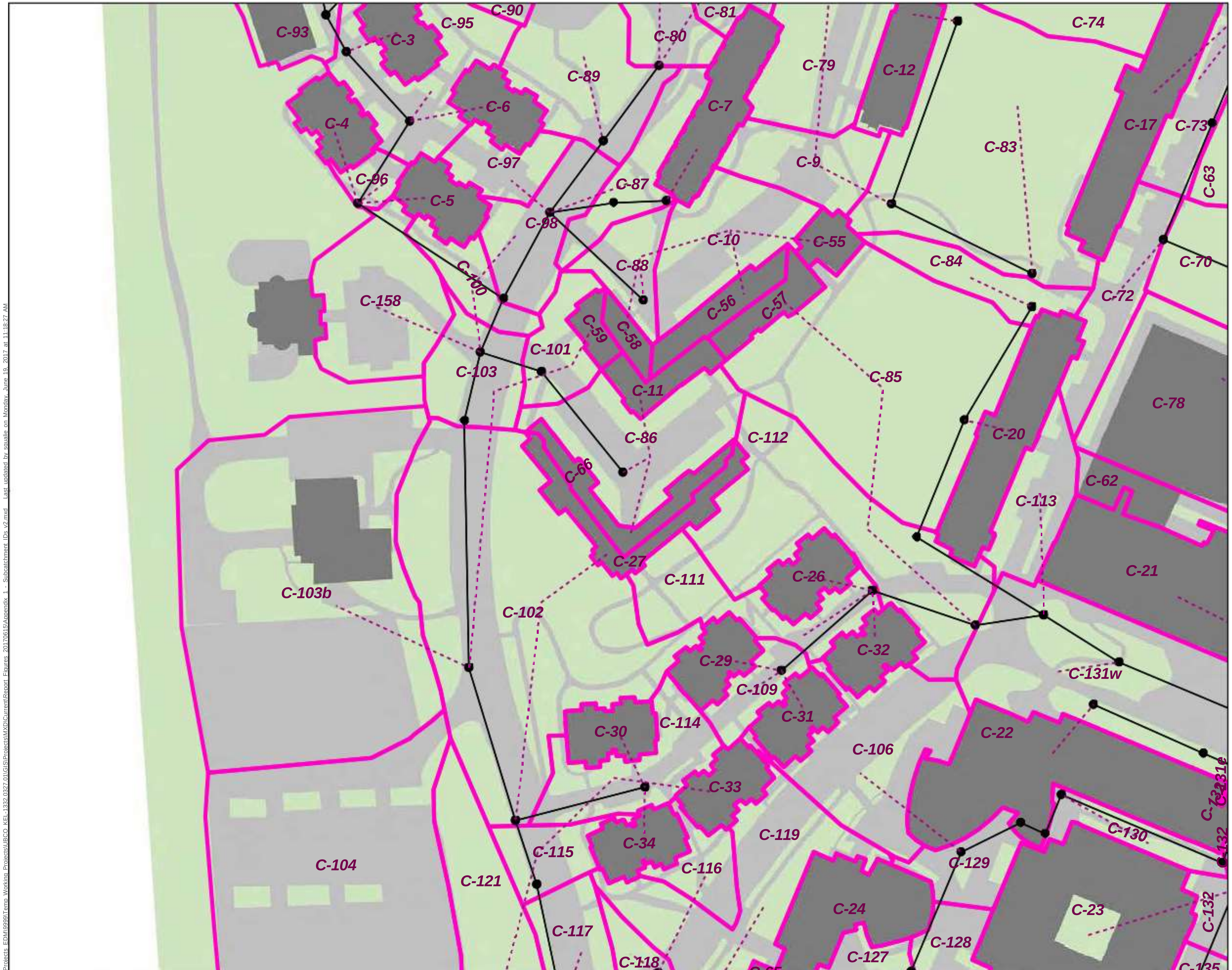
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

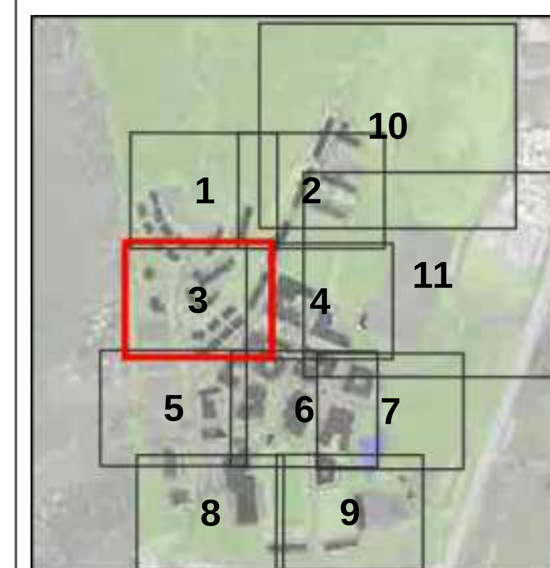
APPENDIX 1.2



IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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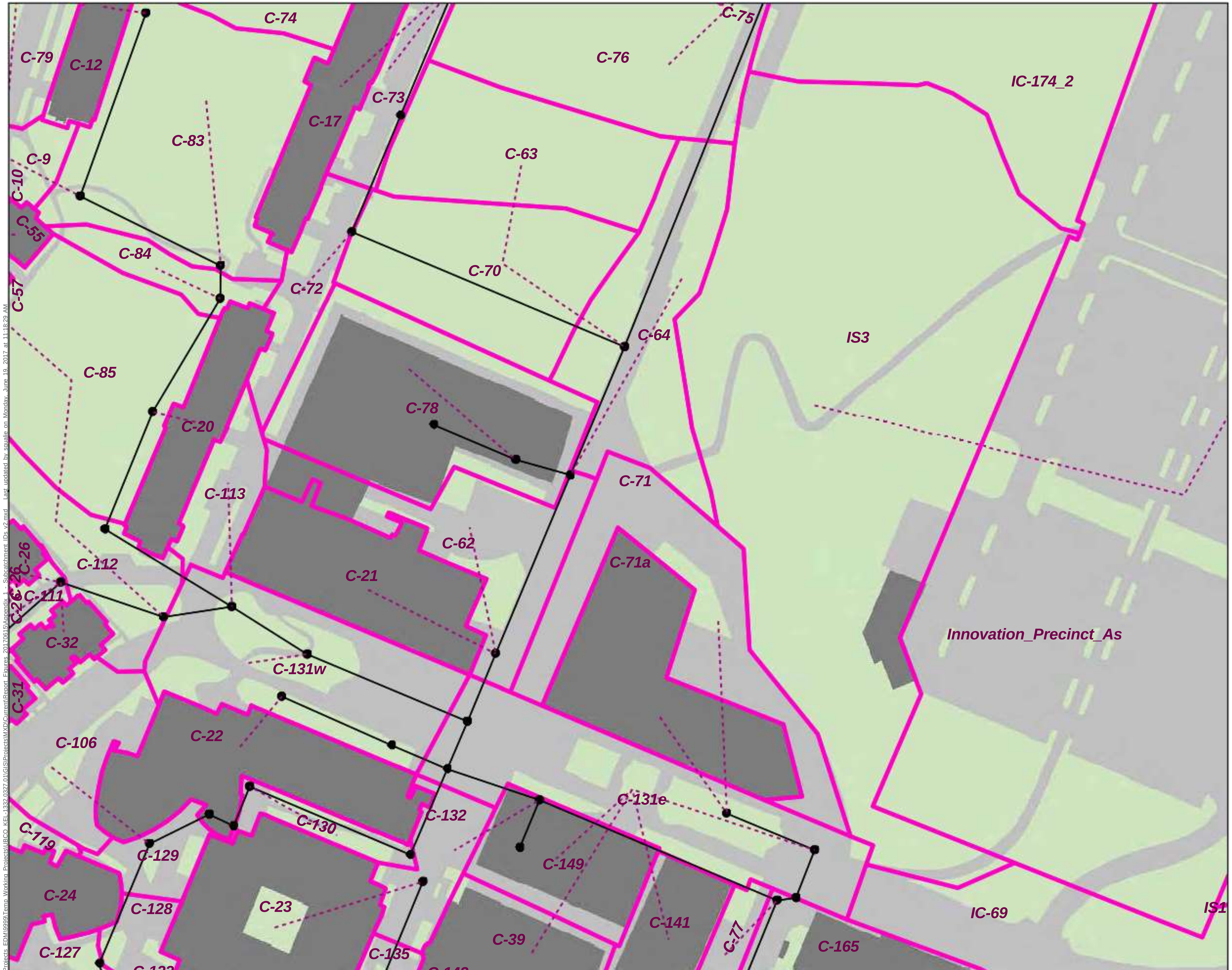
URBAN systems

APPENDIX 1.3

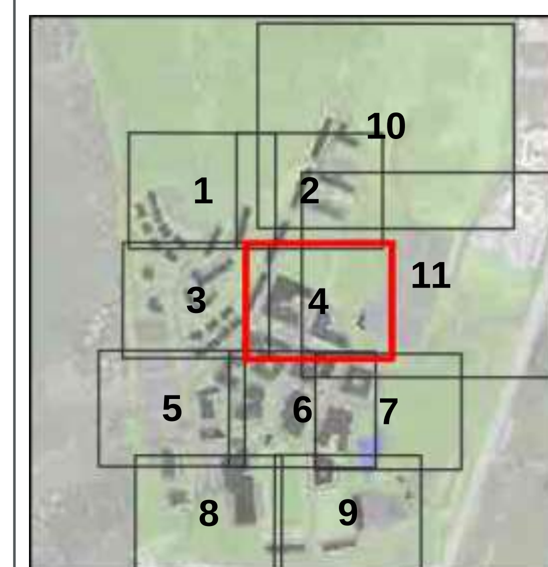


UBC OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Author:	SQ
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Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.4

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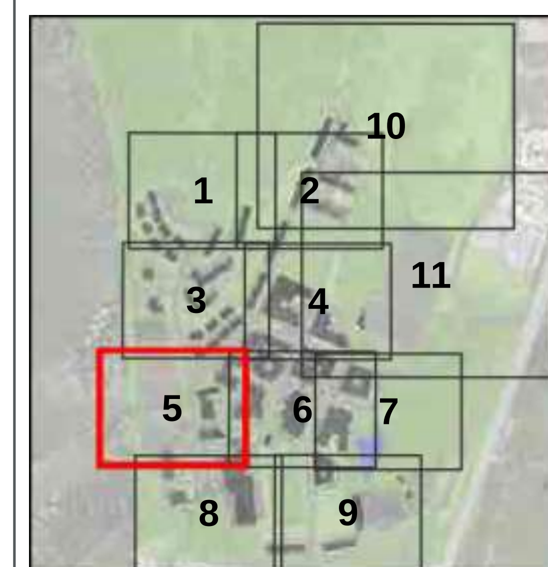
UBC OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Project #:	1332.0327.01
Author:	SQ
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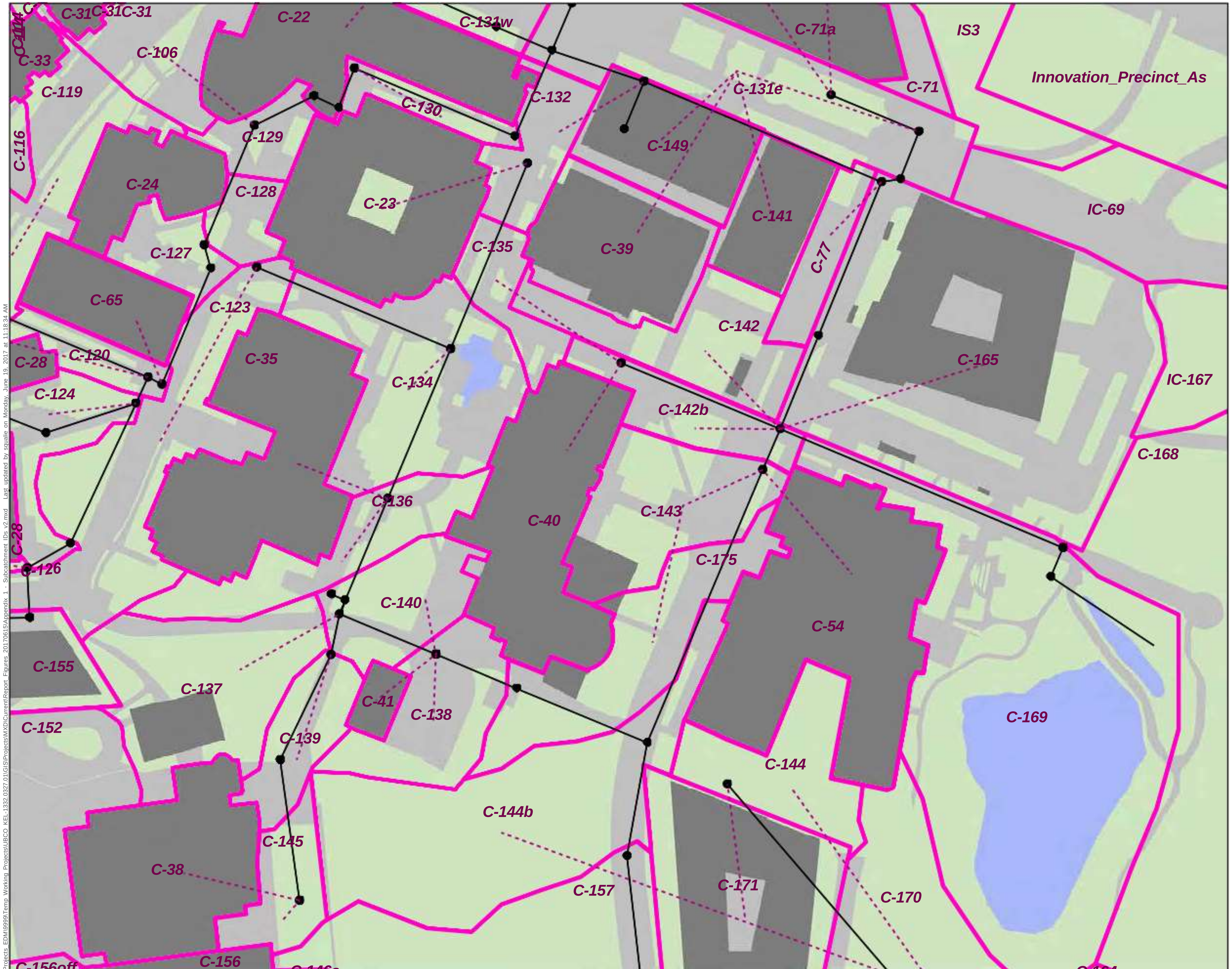
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.5

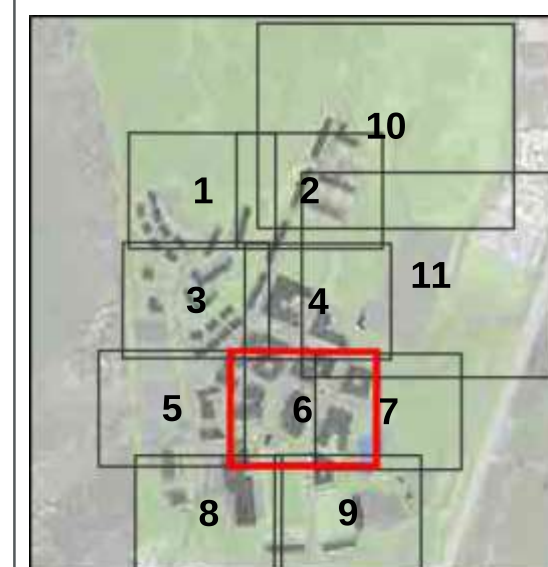


OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Author:	SQ
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Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.6

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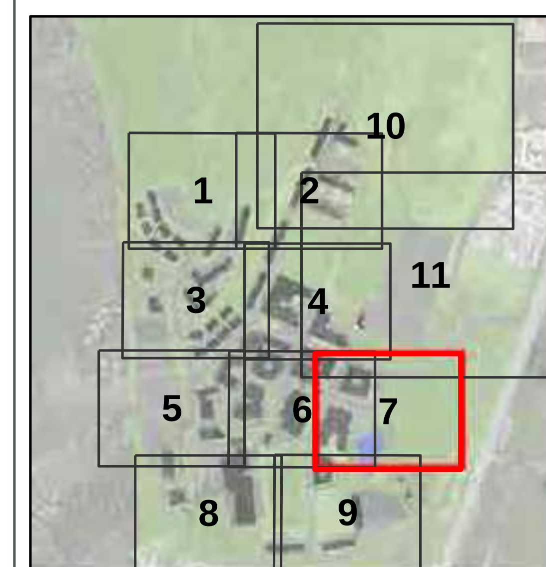
IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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.

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Author:	SQ
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URBAN systems

APPENDIX 1.7

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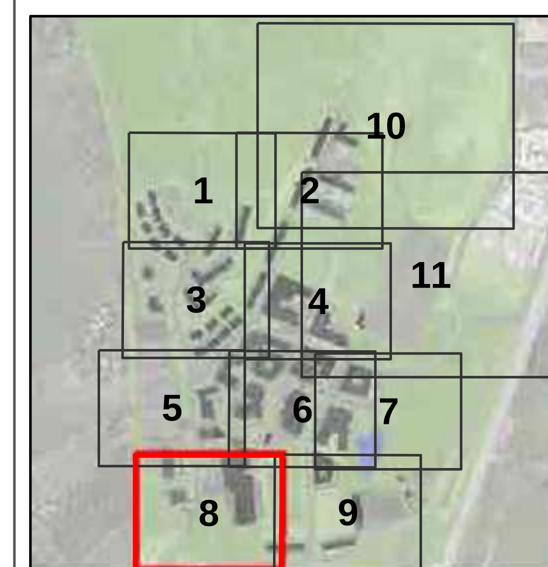
UBC OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30

Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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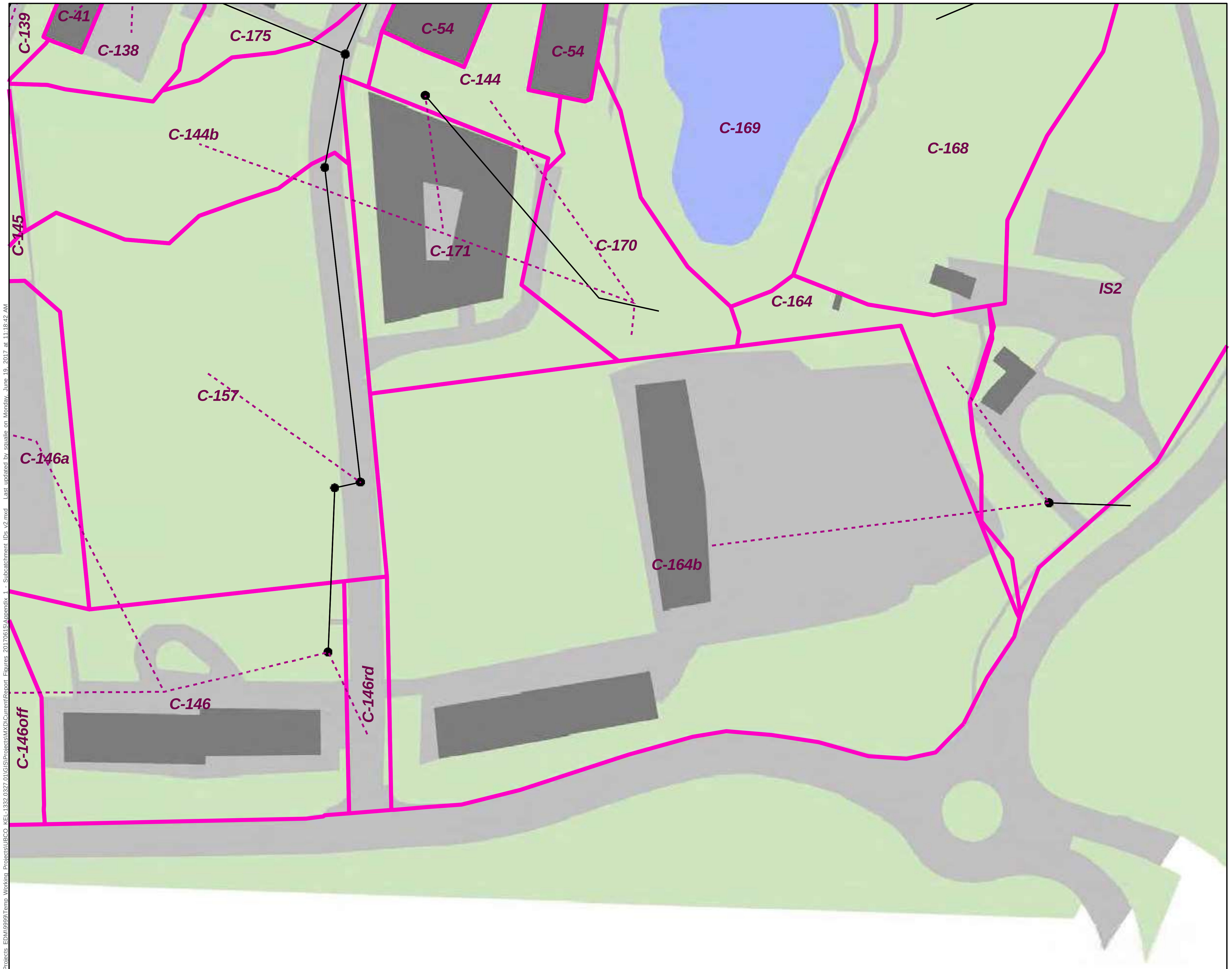
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.8

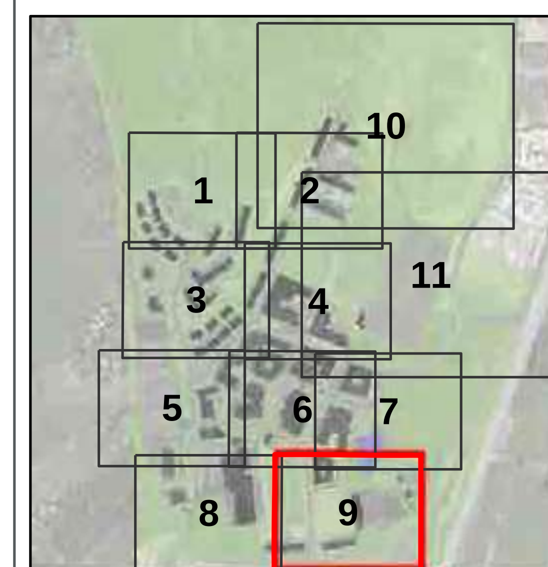


OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
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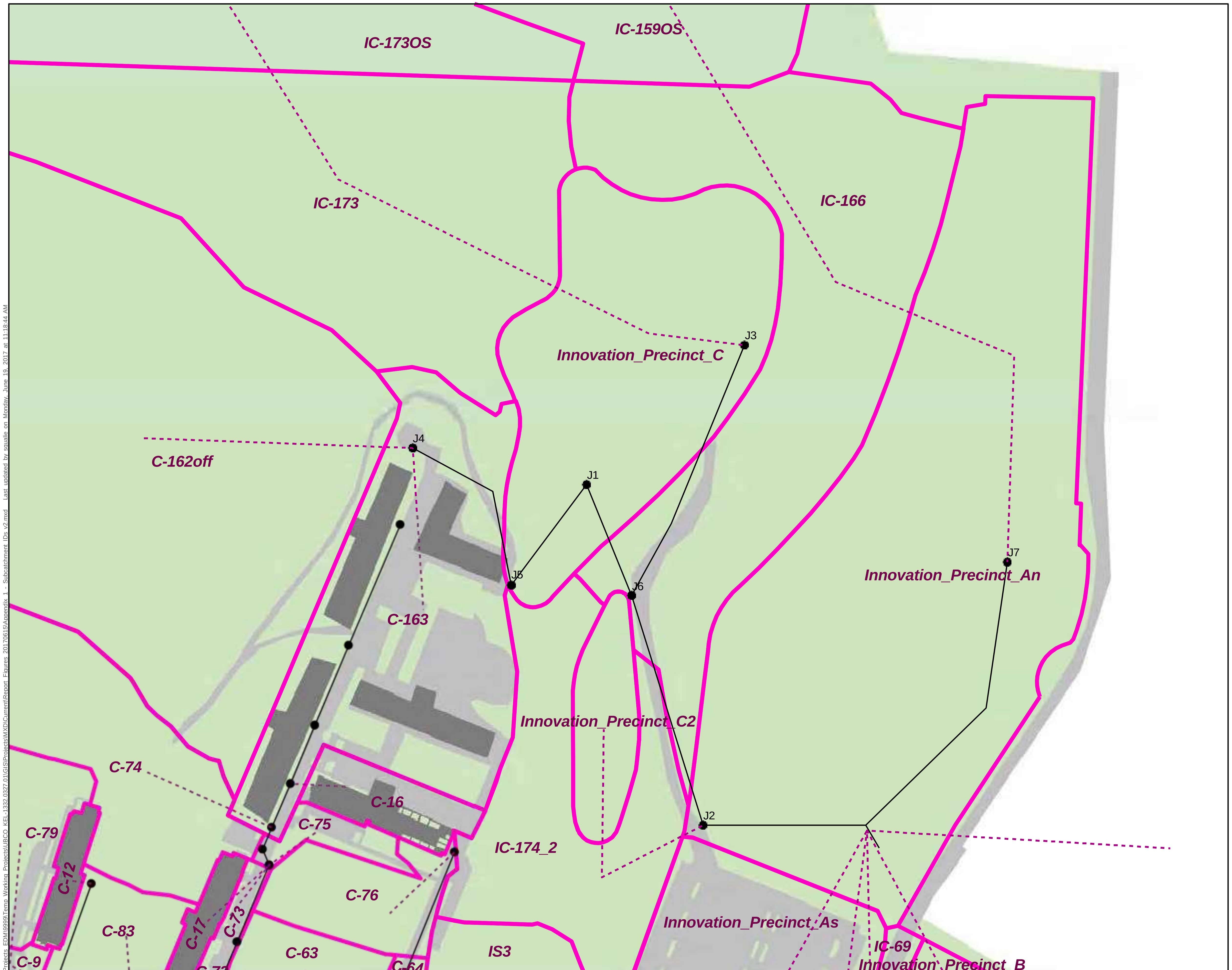
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.9

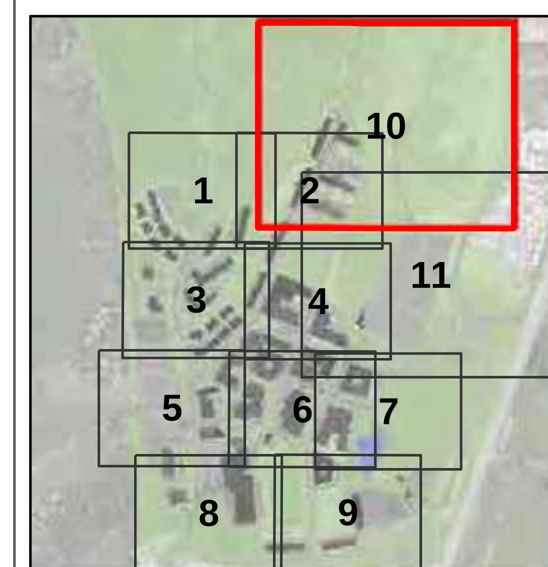


OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 12.5 25 50 75

Metres

Coordinate System:
NUTM11

Data Sources:
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Project #:	1332.0327.01
Author:	SQ
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Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.10

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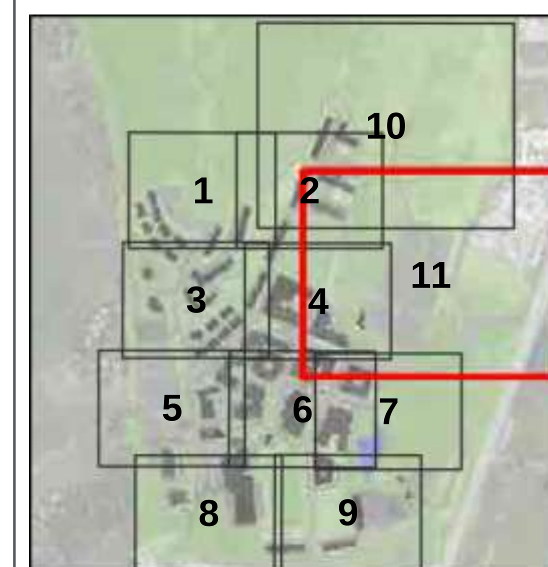
OKANAGAN

IRMP

Subcatchment IDs

- Subcatchments
- Manholes
- Pipes
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 12.5 25 50 75
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Author:	SQ
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Revision:	A
Date:	2017 / 6 / 19

URBAN systems

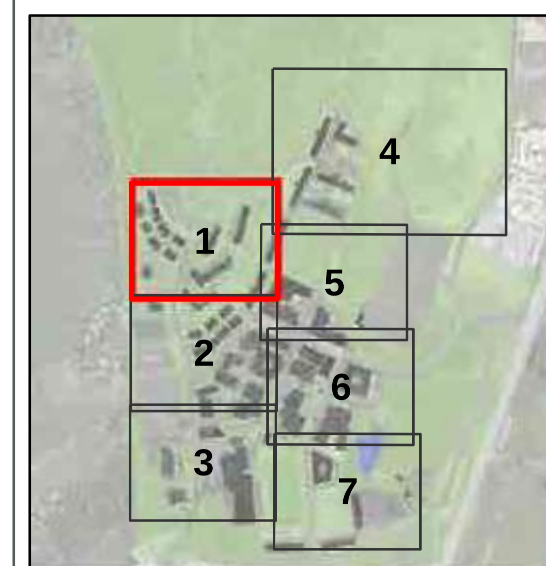
APPENDIX 1.11

OKANAGAN

IRMP

Node & Conduit IDs

Junctions
Conduits
Building
Hardscape
Vegetation / Undeveloped
Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

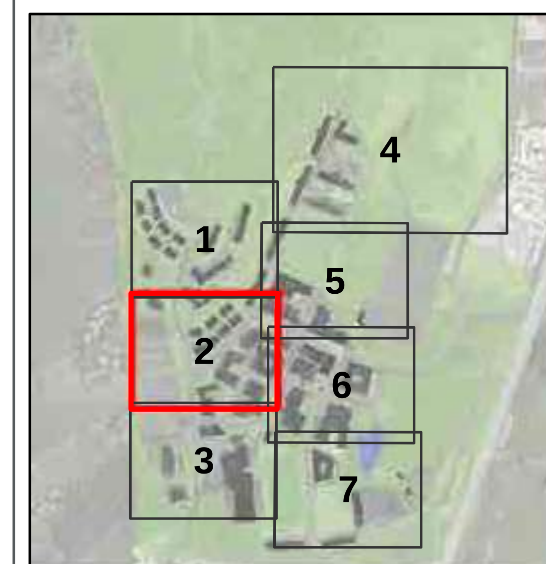
APPENDIX 1.2.1

UBC OKANAGAN

IRMP

Node & Conduit IDs

- Junctions
- Conduits
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Author:	SQ
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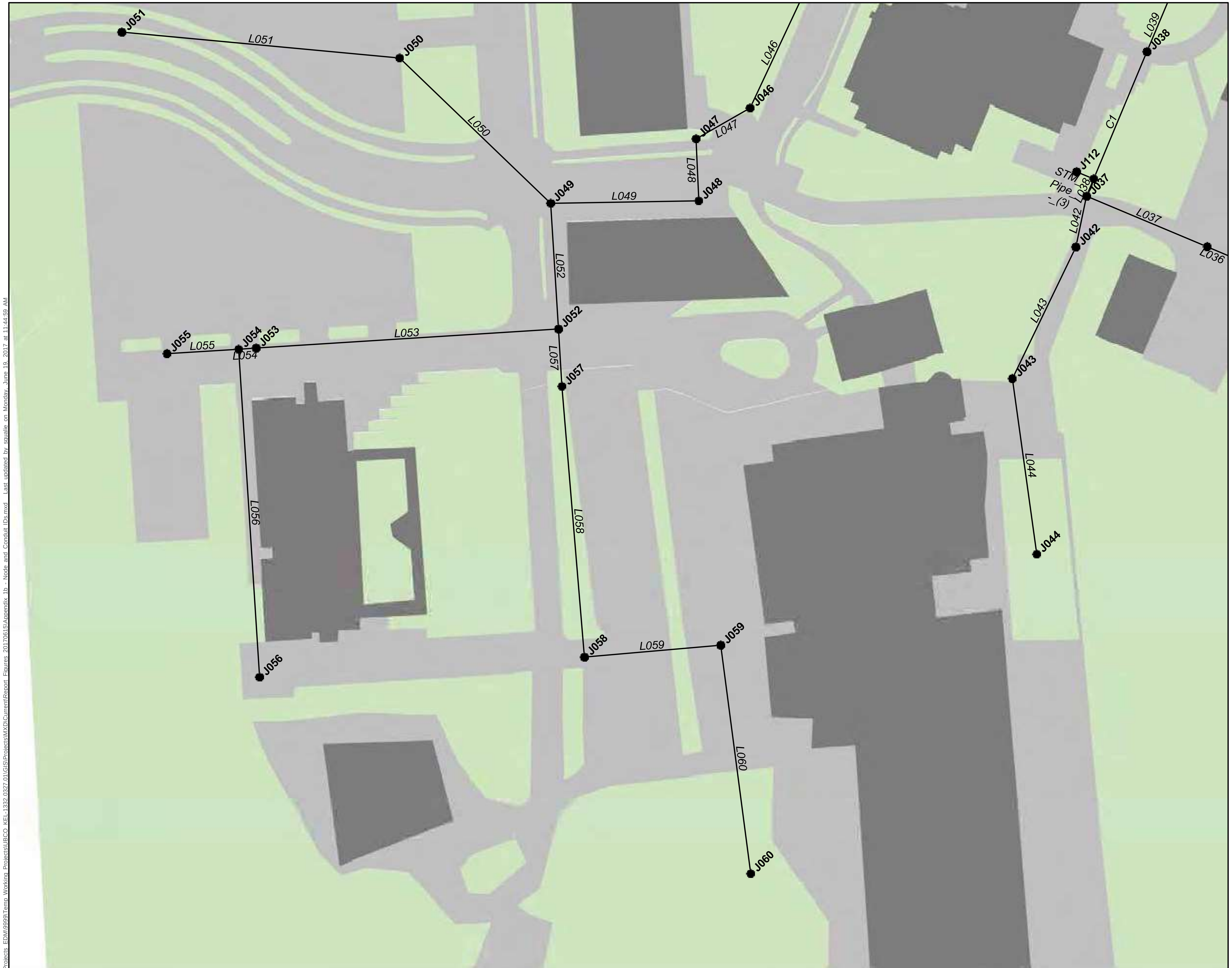
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.2.2

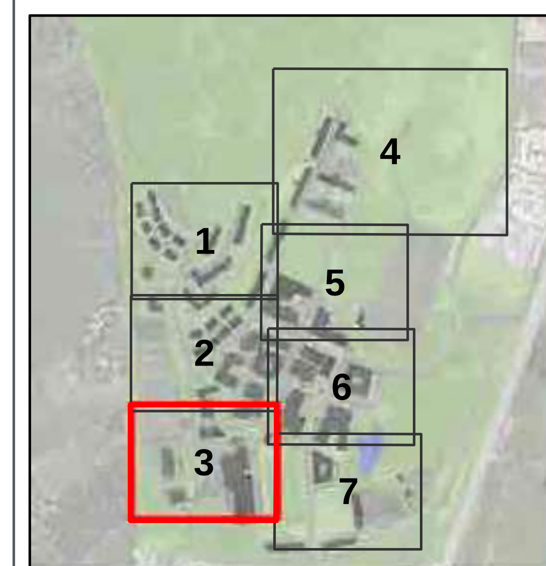


OKANAGAN

IRMP

Node & Conduit IDs

- Junctions
- Conduits
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



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URBAN systems

APPENDIX 1.2.3

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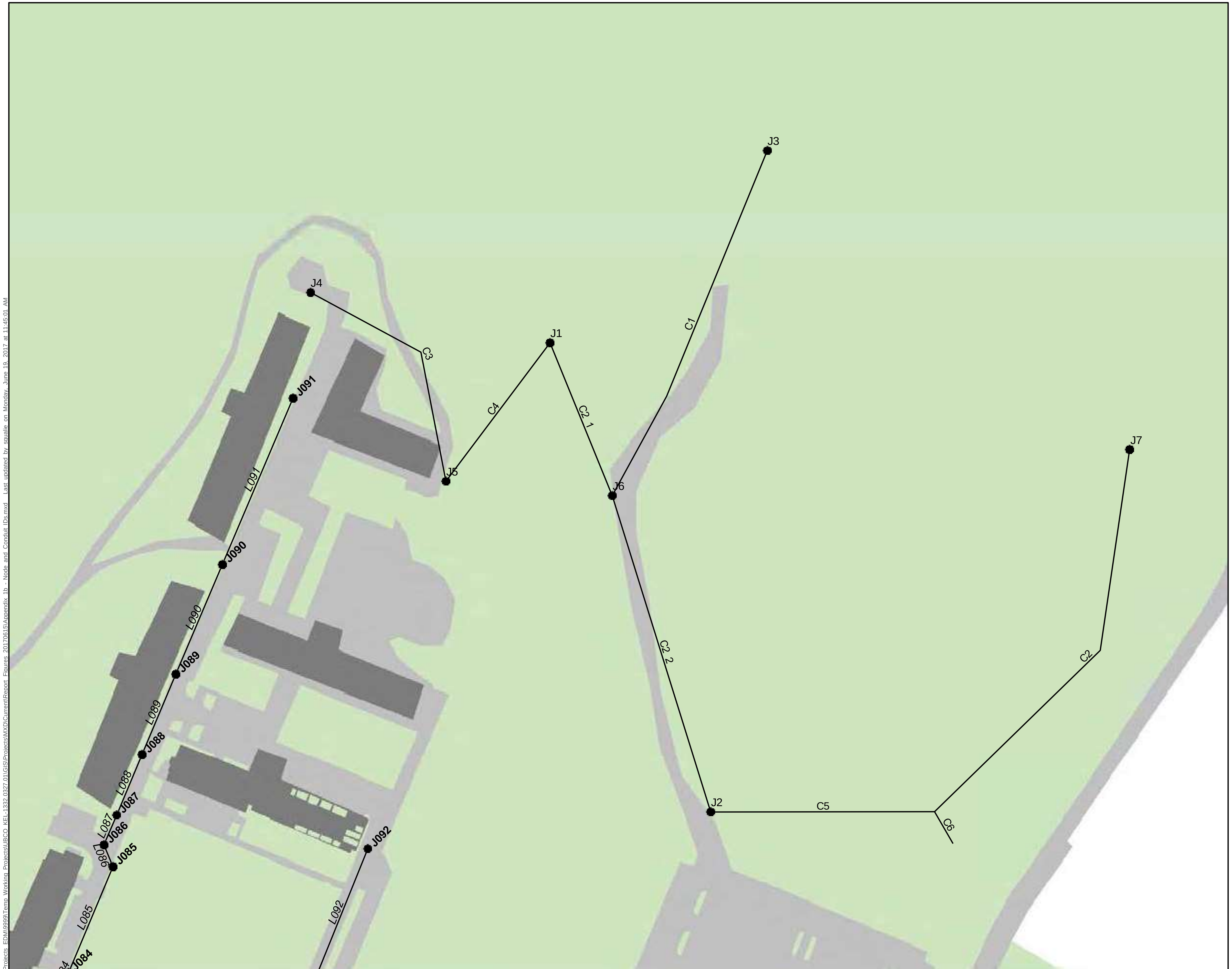
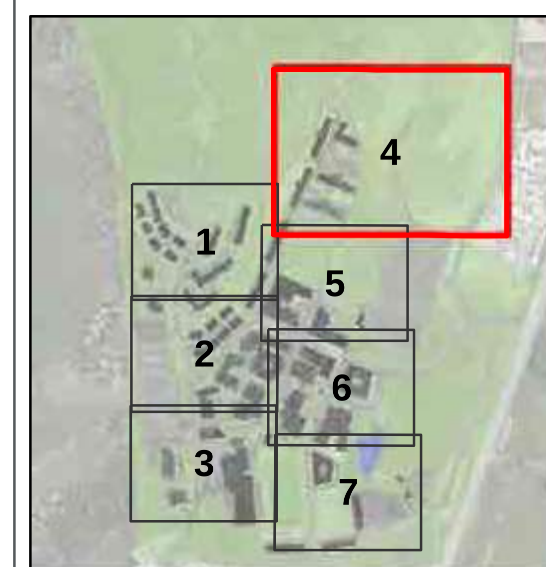


OKANAGAN

IRMP

Node & Conduit IDs

- Junctions
- Conduits
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 10 20 40 60

Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.2.4

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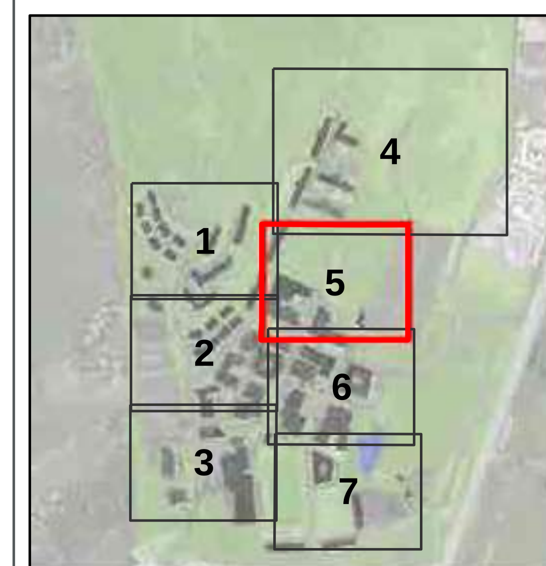
UBC OKANAGAN

IRMP

Node & Conduit IDs

- Junctions
- Conduits
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

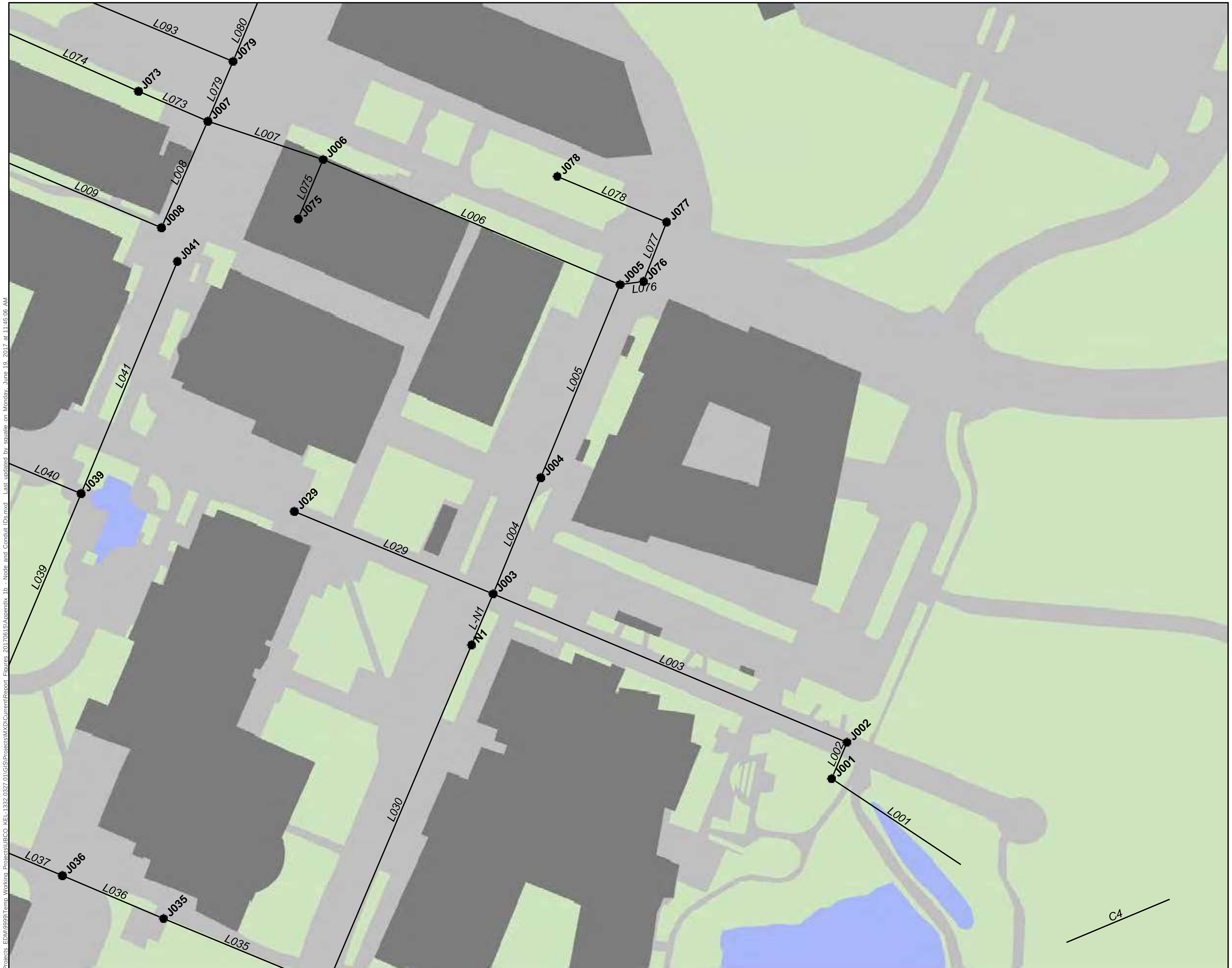
The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.2.5

U:\Projects_EDM\9999\Temp_Working_Projects\UBCO_KEL-1332.0327.01\GIS\Projects\MXD\CurrentReport_Figures_20170615\Appendix_1b - Node and Conduit IDs.mxd Last updated by squalie on Monday, June 19, 2017 at 11:45:04 AM

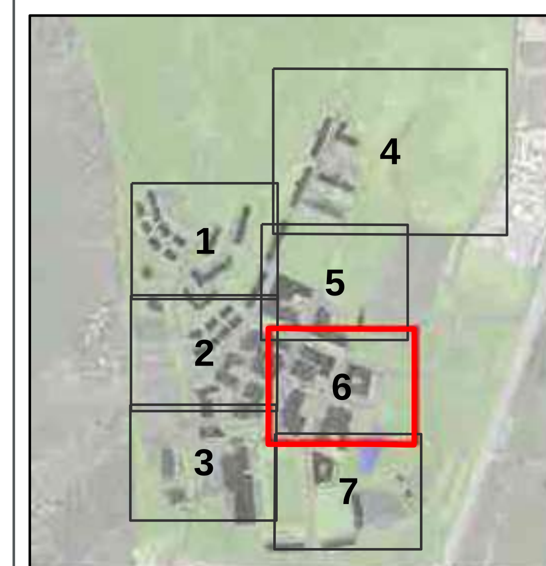


UBC
OKANAGAN

IRMP

Node & Conduit IDs

- Junctions
- Conduits
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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.

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

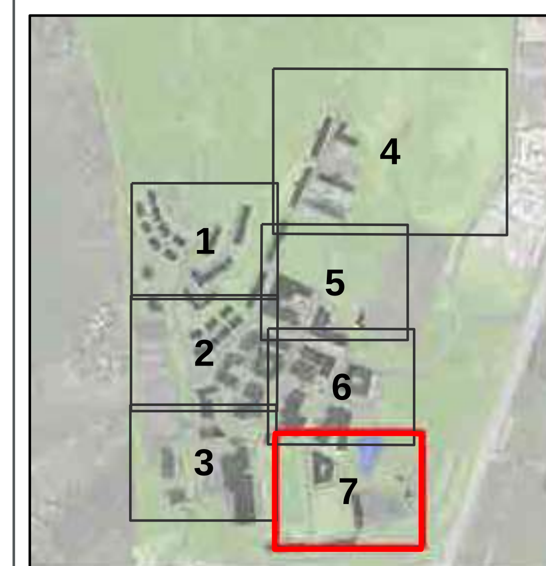
APPENDIX 1.2.6

OKANAGAN

IRMP

Node & Conduit IDs

- Junctions
- Conduits
- Building
- Hardscape
- Vegetation / Undeveloped
- Existing Pond



0 5 10 20 30
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

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.

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

APPENDIX 1.2.7

Innovation Precinct Assumed Conduit Parameters

Name	Inlet Node	Outlet Node	Length (m)	Assumed Roughness	Inlet Elev. (m)	Outlet Elev. (m)	Cross-Section	Slope (m/m)
C1	J3	J6	181.7	0.024	444.42	435.40	CIRCULAR	0.050
C4	J5	J1	74.6	0.024	445.89	444.76	CIRCULAR	0.015
C5	J2	SU2	96.5	0.024	424.14	421.41	CIRCULAR	0.028
C3	J4	J5	110.7	0.024	456.63	445.89	CIRCULAR	0.098
C2_1	J1	J6	71.1	0.024	444.76	435.40	CIRCULAR	0.133
C2_2	J6	J2	140.8	0.024	435.40	424.14	CIRCULAR	0.080
C2	J7	SU2	187.1	0.024	422.37	421.41	CIRCULAR	0.005
C6	SU2	SU1	15.8	0.01	421.41	421.21	RECT_OPEN	0.013

Innovation Precinct Assumed Conduit Junction Parameters

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J1	328291.0261	5535274.158	444.76	445.76
J2	328360.1942	5535072.078	424.14	425.14
J3	328384.6065	5535356.888	444.42	445.42
J4	328187.952	5535295.857	456.63	457.63
J5	328246.2703	5535214.483	445.89	446.89
J6	328317.8334	5535208.291	435.40	436.40
J7	328540.643	5535228.185	422.37	422.47

Innovation Precinct Sub-Catchment Parameters

Name	X-Coordinate	Y-Coordinate	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (mm)	Dstore Perv (mm)	Zero Imperv (%)	Subarea Routing	Percent Routed (%)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)	Drying Time (days)
IC-159OS	328139.782	5535919.628	IC-166	17.64	184	960	4.5	0	0.01	0.1	2	20	25	OUTLET	100	51	4.2	4	7
IC-166	328398.414	5535366.996	Innovation_Precinct_An	3.90	134	291	14	10	0.01	0.1	2	10	25	OUTLET	100	127	41.7	4	7
IC-167	328410.327	5534714.651	OF6	0.71	39	180	4.8	0	0.01	0.1	2	5	25	OUTLET	100	51	4.2	4	7
IC-173	328132.917	5535450.09	Innovation_Precinct_C	4.35	117	372	19.5	0	0.01	0.1	2	20	25	OUTLET	100	51	4.2	4	7
IC-173OS	327972.012	5535725.801	IC-173	13.65	258	530	9.7	0	0.01	0.1	2	20	25	OUTLET	100	51	4.2	4	7
IC-69	328412.041	5534807.997	SU2	1.51	40	378	3	45	0.01	0.1	2	4	25	OUTLET	100	51	4.2	4	7
IS2	328420.657	5534568.747	OF6	2.99	73	407	2.5	10	0.01	0.1	2	7	25	OUTLET	100	51	4.2	4	7
Innovation_Precinct_An	328472.373	5535191.749	J7	6.59	148	445	1.8	90	0.01	0.1	2	222	25	PERVIOUS	100	51	4.2	4	7
Innovation_Precinct_C	328316.308	5535346.319	J3	2.76	130	212	5	90	0.01	0.1	2	222	25	PERVIOUS	100	51	4.2	4	7
Innovation_Precinct_B	328546.703	5534913.159	SU2	1.87	81	231	3	90	0.01	0.1	2	233	25	PERVIOUS	100	51	4.2	4	7
Innovation_Precinct_As	328334.151	5534846.095	SU2	4.12	134	307	3.5	90	0.01	0.1	2	1	25	PERVIOUS	100	51	4.2	4	7
IS3	328238.36	5534907.847	Innovation_Precinct_As	2.02	220	92	18	10	0.01	0.1	2	5	25	OUTLET	100	51	4.2	4	7
IS1	328417.028	5534808.97	SU2	0.78	41	191	4	25	0.01	0.1	2	4	25	OUTLET	100	3	0.5	4	7
C-162off	328020.435	5535304.145	J4	6.85	169	404	12.4	3	0.01	0.1	0.05	16	25	OUTLET	100	51	4.2	4	7
C-163	328184.872	5535194.639	J4	2.64	109	242	3.5	64	0.01	0.1	0.05	41	25	PERVIOUS	100	51	4.2	4	7
IC-174_2	328281.662	5535081.075	J2	1.72	96	179	11.4	5	0.01	0.1	2	7	25	OUTLET	100	51	4.2	4	7
Innovation_Precinct_C2	328302.131	5535132.497	IC-174_2	0.46	47	98	6.3	90	0.01	0.1	2	222	25	PERVIOUS	100	127	41.7	4	7

Note: Dstore Perv values include the engineered retention storage applied through LID.

South Campus Conduit Parameters

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Inlet Elev. (m)	Outlet Elev. (m)	Entry Loss Coeff.	Exit Loss Coeff.	Cross-Section	Diameter (mm)	Slope (m/m)
L071	J071	J070	43.9	0.013	460.79	460.4	0.1	0.5	CIRCULAR	250	0.010
L082	J082	J081	47.1	0.013	442.88	442.5	0.5	0.1	CIRCULAR	250	0.008
L093	J093	J079	58.9	0.013	443.58	441.1	0.1	0.5	CIRCULAR	250	0.043
L072	J072	J021	45.2	0.013	450.82	448.6	0.1	0.5	CIRCULAR	250	0.050
L061	J061	J025	58.9	0.013	463.30	461.1	0.5	0.5	CIRCULAR	250	0.037
L083	J083	J082	100.2	0.013	445.34	442.9	0.5	0.5	CIRCULAR	250	0.024
L050	J050	J049	56.7	0.013	446.07	445.8	0.5	0.5	CIRCULAR	375	0.005
L094	J094	J093	30.1	0.013	444.98	443.6	0.5	0.1	CIRCULAR	250	0.045
L073	J073	J007	20.5	0.013	441.03	440.5	0.1	0.5	CIRCULAR	250	0.025
L084	J084	J083	42.8	0.013	445.60	445.4	0.1	0.5	CIRCULAR	250	0.005
L095	J095	J094	50.4	0.013	445.99	445.9	0.5	0.1	CIRCULAR	250	0.002
L051	J051	J050	75.6	0.013	446.44	446.1	0.1	0.5	CIRCULAR	300	0.005
L062	J062	J061	32.8	0.013	466.02	463.3	0.5	0.5	CIRCULAR	250	0.083
L040	J040	J039	71.3	0.013	438.39	437.7	0.5	0.5	CIRCULAR	250	0.010
L041	J041	J039	68.1	0.013	438.44	437.7	0.1	0.1	CIRCULAR	250	0.011
L074	J074	J073	40.7	0.013	441.51	441.1	0.1	0.1	CIRCULAR	250	0.011
L085	J085	J084	49.5	0.013	446.14	445.6	0.5	0.1	CIRCULAR	250	0.010
L096	J096	J095	42.8	0.013	446.18	446.0	0.1	0.5	CIRCULAR	250	0.004
L030	J030	N1	100.4	0.013	435.00	434.6	0.5	0.1	CIRCULAR	525	0.004
L052	J052	J049	34.2	0.013	447.56	445.5	0.5	0.5	CIRCULAR	450	0.059
L063	J063	J062	31.9	0.013	466.26	466.0	0.1	0.5	CIRCULAR	250	0.007
L064	J064	J063	14.2	0.013	467.90	466.9	0.5	0.1	CIRCULAR	250	0.070
L097	J097	J096	44.6	0.013	448.51	446.2	0.5	0.1	CIRCULAR	250	0.051
L086	J086	J085	10.1	0.013	446.87	446.7	0.5	0.5	CIRCULAR	250	0.020
L031	J031	J030	39.0	0.013	436.06	435.3	0.5	0.1	CIRCULAR	250	0.020
L042	J042	J037	14.0	0.013	443.04	443.0	0.1	0.5	CIRCULAR	250	0.005
L053	J053	J052	82.0	0.013	448.66	447.6	0.1	0.5	CIRCULAR	250	0.013
L020	J020	J019	42.5	0.013	447.38	445.9	0.1	0.5	CIRCULAR	375	0.035
L075	J075	J006	17.5	0.013	440.23	439.8	0.1	0.5	CIRCULAR	450	0.025
L021	J021	J020	22.8	0.013	447.80	447.5	0.5	0.1	CIRCULAR	375	0.015
L010	J010	J009	14.4	0.013	441.73	441.6	0.5	0.5	CIRCULAR	450	0.008
L098	J098	J097	11.2	0.013	452.18	448.5	0.5	0.5	CIRCULAR	250	0.347
L087	J087	J086	13.9	0.013	447.83	446.9	0.1	0.1	CIRCULAR	250	0.065
L032	J032	J031	107.4	0.013	438.01	436.1	0.5	0.5	CIRCULAR	250	0.018
L043	J043	J042	39.6	0.013	445.02	443.0	0.5	0.1	CIRCULAR	250	0.050
L054	J054	J053	4.7	0.013	448.80	448.7	0.5	0.1	CIRCULAR	250	0.020
L076	J076	J005	6.4	0.013	435.40	435.3	0.5	0.5	CIRCULAR	450	0.016
L022	J022	J021	54.0	0.013	448.54	447.8	0.1	0.1	CIRCULAR	375	0.015
L011	J011	J010	9.3	0.013	441.88	441.8	0.5	0.5	CIRCULAR	450	0.012
L099	J099	J098	53.1	0.013	460.67	452.2	0.5	0.5	CIRCULAR	250	0.161
L088	J088	J087	28.3	0.013	448.78	447.9	0.1	0.1	CIRCULAR	250	0.030
L044	J044	J043	48.1	0.013	445.51	445.0	0.1	0.5	CIRCULAR	250	0.010
L066	J066	J064	26.0	0.013	470.11	468.0	0.1	0.5	CIRCULAR	250	0.083
L033	J033	J032	8.9	0.013	438.08	438.0	0.5	0.5	CIRCULAR	250	0.008
L055	J055	J054	19.4	0.013	448.99	448.9	0.1	0.1	CIRCULAR	250	0.007
L077	J077	J076	17.3	0.013	435.50	435.4	0.5	0.5	CIRCULAR	450	0.006
L023	J023	J022	83.5	0.013	457.33	448.9	0.1	0.1	CIRCULAR	250	0.102
L012	J012	J011	22.4	0.013	442.17	441.9	0.5	0.5	CIRCULAR	450	0.011
L100	J100	J099	65.8	0.013	462.70	460.8	0.1	0.5	CIRCULAR	250	0.029
L089	J089	J088	37.6	0.013	451.28	448.9	0.1	0.1	CIRCULAR	250	0.064
L078	J078	J077	32.2	0.013	437.11	435.5	0.1	0.5	CIRCULAR	450	0.050
L067	J067	J026	21.8	0.013	467.61	465.4	0.1	0.5	CIRCULAR	250	0.102
L034	J034	J033	55.8	0.013	440.82	438.1	0.1	0.5	CIRCULAR	250	0.049
L045	J045	J016	9.7	0.013	442.91	442.8	0.5	0.2	CIRCULAR	450	0.013
L056	J056	J054	89.0	0.013	451.89	449.2	0.1	0.5	CIRCULAR	250	0.030
L024	J024	J023	23.9	0.013	459.74	457.3	0.5	0.1	CIRCULAR	250	0.101
L002	J002	J001	10.7	0.013	430.92	430.6	0.5	0.5	CIRCULAR	600	0.029
L013	J013	J012	43.9	0.013	442.38	442.2	0.5	0.5	CIRCULAR	450	0.005
L046	J046	J045	52.4	0.013	443.61	442.9	0.5	0.1	CIRCULAR	450	0.013
L068	J068	J067	17.9	0.013	469.42	467.6	0.1	0.1	CIRCULAR	250	0.102
L-N1	N1	J003	15.0	0.013	434.58	434.5	0.1	0.5	CIRCULAR	525	0.004
L057	J057	J052	15.6	0.013	448.48	447.6	0.1	0.1	CIRCULAR	450	0.059
L079	J079	J007	17.5	0.013	440.43	440.3	0.5	0.5	CIRCULAR	250	0.010
L101	J101	J094	23.4	0.013	446.80	445.8	0.5	0.5	CIRCULAR	250	0.042
L035	J035	J030	47.8	0.013	435.76	435.0	0.1	0.5	CIRCULAR	375	0.015
L069	J069	J026	43.4	0.013	464.40	464.0	0.1	0.5	CIRCULAR	250	0.010
L003	J003	J002	103.9	0.013	434.23	431.0	0.5	0.5	CIRCULAR	600	0.032
L014	J014	J013	8.3	0.013	442.43	442.4	0.2	0.5	CIRCULAR	450	0.006
L102	J102	J101	36.7	0.013	447.70	446.9	0.5	0.5	CIRCULAR	250	0.023
L047	J047	J046	16.9	0.013	444.96	443.6	0.5	0.5	CIRCULAR	450	0.080
L036	J036	J035	29.8	0.013	436.22	435.8	0.1	0.1	CIRCULAR	375	0.013
L025	J025	J024	19.7	0.013	461.10	459.7	0.5	0.1	CIRCULAR	250	0.069
L037	J037	J036	35.4	0.013	436.55	436.3	0.5	0.1	CIRCULAR	375	0.008
L026	J026	J025	33.1	0.013	463.93	461.1	0.5	0.1	CIRCULAR	250	0.086
L015	J015	J014	42.6	0.013	442.67	442.4	0.2	0.2	CIRCULAR	450	0.006
L103	J103	J102	41.1	0.013	449.81	449.1	0.1	0.5	CIRCULAR	250	0.018
L048	J048	J047	16.8	0.013	445.13	445.0	0.5	0.5	CIRCULAR	450	0.010
L004	J004	J003	34.1	0.013	434.64	434.3	0.1	0.5	CIRCULAR	525	0.010
L038	J111	J037	42.4	0.013	437.09	436.7	0.1	0.5	CIRCULAR	375	0.010
L016	J016	J015	5.4	0.013	442.70	442.7	0.2	0.5	CIRCULAR	450	0.006
L104	J104	J045	32.1	0.013	443.43	442.9	0.5	0.5	CIRCULAR	450	0.016
L049	J049	J048	40.1	0.013	445.53	445.1	0.5	0.5	CIRCULAR	450	0.010
L027	J027	J026	30.2	0.013	467.98	467.4	0.1	0.1	CIRCULAR	250	0.020
L005	J005	J004	56.5	0.013	435.20	434.6	0.5	0.1	CIRCULAR	525	0.010
L039	J039	J038	55.1	0.013	437.65	437.1	0.5	0.1	CIRCULAR	300	0.009
L017	J017	J016	61.6	0.013	444.50	442.8	0.5	0.2	CIRCULAR	375	0.028
L105	J105	J104	18.8	0.013	444.44	443.4	0.5	0.5	CIRCULAR	450	0.054
L028	J028	J027	31.8	0.013	470.46	469.2	0.1	0.1	CIRCULAR	250	0.040
L006	J006	J005	87.3	0.013	439.80	435.7	0.5	0.5	CIRCULAR	450	0.047
L029	J029	J003	58.3	0.013	435.39	434.5	0.1	0.5	CIRCULAR	450	0.015
L007	J007	J006	32.9	0.013	440.25	439.8	0.5	0.1	CIRCULAR	450	0.014
L106	J106	J105	27.3	0.013	445.45	444.5	0.1	0.5	CIRCULAR	450	0.035
L018	J018	J017	22.8	0.013	445.39	444.5	0.5	0.5	CIRCULAR	375	0.039
L008	J008	J007	31.5	0.013	440.97	440.6	0.5	0.5	CIRCULAR	450	0.011
L107	J107	J106	7.9	0.013	445.62	445.4	0.1	0.1	CIRCULAR	450	0.021
L019	J019	J018	34.3	0.013	445.81	445.4	0.5	0.5	CIRCULAR	450	0.012
L009	J009	J008	59.0	0.013	441.55	441.0	0.5	0.5	CIRCULAR	450	0.009
L108	J108	J107	6.6	0.013	445.70	445.6	0.1	0.1	CIRCULAR	450	0.013
L080	J080	J079	24.9	0.013	441.40	440.9	0.1	0.1	CIRCULAR	250	0.020
L070	J070	J024	21.7	0.013	460.35	460.1	0.5	0.5	CIRCULAR	250	0.010
L081	J081	J080	65.6	0.013	442.36	441.8	0.5	0.1	CIRCULAR	250	0.009
L001	J001	PrePond1	12.2	0.013	430.61	430.0	0.5	0	CIRCULAR	600	0.050
L058	J058	J057	73.5	0.013	456.00	448.5	0.5	0.1	CIRCULAR	250	0.103
L060	J060	J059	62.4	0.013	458.00	456.7	0.1	0.5	CIRCULAR	250	0.021
L065	J065	J064	70.0	0.013	471.30	468.0	0.1	0.1	CIRCULAR	250	0.048
L059	J059	J058	37.1	0.013	456.67	456.0	0.5	0.5	CIRCULAR	250	0.018
L090	J090	J089	51.4	0.013	455.07	451.3	0.1	0.1	CIRCULAR	250	0.074
L091	J091	J090	77.8	0.013	457.65	455.1	0.1	0.1	CIRCULAR	250	0.033
L092	J092	J082	141.9	0.013	445.00	442.9	0.1	0.1	CIRCULAR	250	0.015
L110	J110	J109	30.2	0.013	443.59	442.7	0.1	0.1	CIRCULAR	500	0.029
L109	J109	J081	19.2	0.013	442.70	442.5	0.1	0.1	CIRCULAR	250	0.010
STM_Pipe_-_(3)	J112	J111	5.1	0.013	441.63	441.5	0.1	0.5	CIRCULAR	375	0.020
STM_Pipe_-_(5)	J114	Pond2	57.2	0.013	431.33	430.8	0	0	CIRCULAR	525	0.010
C1	J038	J037	42.4	0.013	437.09	436.6	0.1	0.5	CIRCULAR	300	0.013
C3	Pond2	OF3	20.0	0.013	430.30	427.9	0	0	RECT_OPEN	1000	0.121
C4	Pond3	OF7	5.0	0.01	429.96	429.9	0	0	CIRCULAR	1000	0.012
C5	J1	OF1	15.0	0.01	429.90	429.8	0	0	CIRCULAR	1000	0.007

South Campus Conveyance Junction Parameters

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J028	327896.42	5535022.41	470.46	474.10
J065	327769.562	5535108.1	471.30	473.30
J068	327898.9	5534976.66	469.42	473.28
J066	327801.41	5535058.5	470.11	471.20
J027	327877.49	5534996.91	467.98	470.73
J064	327783.66	5535039.52	467.90	469.69
J063	327790.54	5535027.07	466.26	469.03
J067	327881	5534975.91	467.61	469.00
J062	327812.02	5535003.54	466.02	468.74
J026	327859.47	5534972.63	463.93	467.62
J100	327997.49	5535037.44	462.70	466.39
J069	327891.12	5534942.99	464.40	466.00
J061	327794.43	5534975.82	463.30	465.84
J025	327843.72	5534943.53	461.10	464.16
J071	327884.26	5534884.8	460.79	462.81
J099	327975.17	5534975.52	460.67	462.81
J070	327856.58	5534918.85	460.35	462.67
J024	327835.96	5534925.45	459.74	462.22
J056	327803.53	5534460.52	451.89	460.33
J060	327936.548	5534407.288	458.00	460.00
J023	327830.4	5534902.18	457.33	459.69
J091	328180.454	5535250.317	457.65	459.65
J058	327891.48	5534465.98	456.00	458.00
J059	327928.448	5534469.155	456.67	458.00
J090	328150.012	5535178.716	455.07	458.00
J089	328129.92	5535131.39	451.28	453.52
J098	328022.76	5534952.02	452.18	453.37
J072	327891.59	5534778.32	450.82	452.24
J103	327937.84	5534817.68	449.81	452.17
J022	327832.08	5534818.71	448.54	451.95
J088	328115.35	5535096.78	448.78	451.47
J053	327802.57	5534549.67	448.66	450.92
J096	327999.81	5534902.52	446.18	450.89
J054	327797.84	5534549.37	448.80	450.89
J057	327885.39	5534539.26	448.48	450.82
J021	327847.82	5534767.02	447.75	450.74
J055	327778.49	5534548.15	448.99	450.74
J087	328104.39	5535070.69	447.83	450.60
J020	327855.03	5534745.42	447.38	450.44
J086	328098.98	5535057.86	446.87	450.41
J102	327968.65	5534844.86	447.70	450.16
J084	328083.71	5535002.9	445.60	450.14
J097	328022.65	5534940.83	448.51	449.97
J085	328102.81	5535048.53	446.14	449.93
J095	327983.59	5534862.91	445.99	449.85
J052	327884.43	5534554.85	447.56	449.81
J083	328067.18	5534963.42	445.34	449.67
J019	327863.75	5534703.88	445.81	448.79
J049	327882.32	5534588.94	445.53	448.60
J050	327841.48	5534628.25	446.07	448.54
J018	327896.08	5534715.46	445.39	448.25
J051	327766.18	5534635.28	446.44	448.02
J101	328003.46	5534833.1	446.80	447.87
J108	327870.46	5534648.41	445.70	447.68
J107	327877.07	5534648.87	445.62	447.45
J048	327922.46	5534589.55	445.13	447.34
J017	327905.87	5534694.87	444.50	447.22
J106	327884.98	5534649.57	445.45	447.22
J092	328212.53	5535056.14	445.00	447.00
J044	328013.99	5534493.83	445.51	446.97
J094	328026.59	5534836.58	444.98	446.92
J047	327921.7	5534606.37	444.96	446.68
J043	328007.42	5534541.43	445.02	446.53
J105	327910.57	5534659.16	444.44	446.28
J074	328043.52	5534806.25	441.51	445.88
J046	327936.38	5534614.76	443.58	445.69
J082	328159.48	5534924.56	442.88	445.57
J093	328052.05	5534820.57	443.58	445.41
J104	327928.04	5534652.25	443.43	445.21
J042	328024.61	5534577.09	443.04	444.87
J037	328027.47	5534590.82	436.55	444.51
J012	327998.71	5534756.38	442.17	444.39
J110	328094.936	5534898.063	443.59	444.30
J013	327981.7	5534715.9	442.38	444.29
J036	328060.15	5534577.16	436.22	444.25
J081	328141.22	5534881.19	442.36	444.25
J109	328122.702	5534886.321	442.70	444.25
J014	327983.93	5534707.9	442.43	444.15
J045	327958.58	5534662.21	442.91	444.13
J040	327999.5	5534708.31	438.39	444.10
J016	327962.64	5534671.04	442.70	444.07
J038	328043.85	5534629.96	437.09	444.05
J015	327967.43	5534668.63	442.67	443.99
J011	328018.82	5534766.31	441.88	443.85
J073	328080.67	5534789.75	441.03	443.82
J009	328032.62	5534775.8	441.55	443.70
J010	328027.22	5534762.42	441.73	443.60
J080	328115.91	5534820.7	441.40	443.42
J007	328099.52	5534781.64	440.25	443.15
J079	328106.32	5534797.78	440.43	442.88
J039	328065.19	5534680.71	437.65	442.61
J035	328087.55	5534565.54	435.76	442.10
J008	328086.95	5534752.73	440.97	442.05
J075	328123.99	5534755.08	440.23	441.89
J041	328091.25	5534743.58	438.44	441.80
J034	328126.07	5534344.54	440.82	441.70
J006	328130.74	5534771.22	439.80	441.35
J029	328122.98	5534675.84	435.39	439.91
J033	328128.22	5534400.3	438.08	439.56
J032	328136.95	5534402.11	438.01	439.48
J031	328124.85	5534508.84	436.06	438.81
J030	328131.74	5534547.23	435.00	438.31
J078	328194.14	5534766.62	437.11	438.27
J004	328189.71	5534685.01	434.64	437.17
J003	328176.83	5534653.49	434.23	437.06
N1	328170.92	5534639.7	434.58	437.03
J005	328211.18	5534737.28	435.20	436.59
J077	328223.83	5534754.26	435.50	436.48
J076	328217.5	5534738.13	435.40	436.27
J002	328272.62	5534613.28	430.92	433.31
J001	328268.492	5534603.414	430.61	431.55
J111	328029.44	5534595.525	437.09	444.48
J112	328024.775	5534597.477	441.63	444.27
J114	328158.95	5534533.178	431.33	433.38
J1	328370.441	5534395.183	429.90	431.00

Established South Campus Subcatchment Parameters

Name	X-Coordinate	Y-Coordinate	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (mm)	Dstore Perv (mm)	Zero Imperv (%)	Subarea Routing	Percent Routed (%)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)	Drying Time (days)
C-3	327809.006	5535033.331	J063	0.06	52	11	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-4	327786.849	5535003.213	J061	0.06	53	11	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-5	327822.974	5534976.769	J061	0.06	51	11	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-6	327841.929	5535008.433	J062	0.06	51	11	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-7	327916.984	5535008.749	J068	0.10	52	20	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-10	327917.889	5534963.108	C-88	0.16	26	62	0.124	50.4	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-11	327896.904	5534917.282	C-86	0.04	87	5	1	99.8	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-12	327982.877	5535040.694	J100	0.14	71	20	0.01	98.2	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-16	328173.108	5535086.001	J088	0.34	39	88	0.01	87.5	0.01	0.1	0.05	1	25	OUTLET	100	25.4	1.7	4	7
C-17	328061.255	5535007.91	J085	0.17	86	20	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-20	328014.839	5534897.46	J096	0.15	75	20	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-21	328070.572	5534846.787	J080	0.28	160	18	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-22	328031.748	5534780.088	J074	0.32	322	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-23	328041.253	5534729.93	J041	0.37	338	11	0.01	92.0	0.01	0.1	0.05	1	25	OUTLET	100	25.4	1.7	4	7
C-24	327961.129	5534736.447	J013	0.14	87	16	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-26	327947.085	5534849.539	J102	0.06	58	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-27	327886.878	5534872.512	C-102	0.07	141	5	1	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-28	327903.702	5534645.634	J106	0.21	118	18	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-29	327915.493	5534821.045	J103	0.06	56	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-30	327880.158	5534796.915	J072	0.06	56	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-31	327943.428	5534802.032	J103	0.06	58	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-32	327969.11	5534824.641	J102	0.06	58	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-33	327918.707	5534778.276	C-114	0.06	57	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-34	327889.685	5534759.301	J072	0.06	57	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-35	328002.171	5534643.93	J038	0.39	197	20	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-36	327823.083	5534502.165	J053	0.25	100	25	0.01	80.7	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-38	327968.666	5534504.463	J044	0.33	220	15	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-39	328121.84	5534714.837	C-131e	0.25	120	21	0.01	97.6	0.01	0.1	0.05	128	25	PERVIOUS	100	25.4	1.7	4	7
C-40	328096.241	5534622.191	J029	0.37	183	20	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-41	328040.51	5534561.336	J036	0.03	67	5	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-54	328192.643	5534587.319	N1	0.53	531	10	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
C-70	328111.995	5534950.314	J082	0.39	56	70	0.012	1.1	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-73	328081.482	5535013.76	J085	0.11	15	79	0.011	66.6	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-74	328006.583	5535115.048	J087	1.43	63	226	0.162	3.2	0.01	0.1	0.05	15	25	OUTLET	100	25.4	1.7	4	7
C-75	328140.218	5535063.65	J085	0.18	41	44	0.073	44.6	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-76	328156.847	5535029.817	J092	0.55	53	104	0.013	9.9	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-79	327950.252	5535075.225	C-9	0.69	57	120	0.183	13.8	0.01	0.1	0.05	10	25	OUTLET	100	25.4	1.7	4	7
C-80	327891.404	5535224.07	J028	1.06	24	444	0.091	16.9	0.01	0.1	0.05	16	25	OUTLET	100	25.4	1.7	4	7
C-81	327918.505	5535063.41	J028	0.13	18	74	0.127	27.5	0.01	0.1	0.05	8	25	OUTLET	100	25.4	1.7	4	7
C-83	328011.601	5534995.37	J098	0.57	53	107	0.144	6.5	0.01	0.1	0.05	8	25	OUTLET	100	25.4	1.7	4	7
C-84	328004.751	5534950.582	J097	0.08	11	77	0.178	9.4	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-85	327973.537	5534916.778	C-112	0.54	65	84	0.167	4.4	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-86	327890.793	5534896.256	J071	0.21	41	50	0.039	52.8	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-87	327889.753	5534988.218	C-98	0.10	13	81	0.093	34.8	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-88	327886.733	5534954.768	J069	0.07	21	35	0.203	50.7	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-89	327873.577	5535039.129	J027	0.32	28	113	0.137	39.3	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-90	327853.468	5535090.968	J066	0.41	37	111	0.1	24.7	0.01	0.1	0.05	9	25	OUTLET	100	25.4	1.7	4	7
C-91	327820.955	5535104.823	J066	0.28	44	64	0.111	85.6	0.01	0.1	0.05	1	25	PERVIOUS	100	25.4	1.7	4	7
C-92	327847.585	5535196.836	J065	0.95	45	208	0.122	1.0	0.01	0.1	0.05	19	25	OUTLET	100	51	4.2	4	7
C-93	327773.726	5535072.329	J065	0.47	58	80	0.099	62.0	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-95	327814.9	5535020.106	J062	0.18	30	60	0.14	47.0	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-96	327799.276	5534983.991	J061	0.03	16	19	0.184	48.7	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-97	327843.803	5534989.275	J026	0.07	22	32	0.031	49.0	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-98	327856.608	5534967.722	C-100	0.13	21	60	0.103	83.0	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-100	327832.957	5534949.944	J024	0.07	15	43	0.054	33.4	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-101	327862.832	5534927.53	C-103	0.08	19	40	0.089	31.0	0.01	0.1	0.05	8	25	OUTLET	100	25.4	1.7	4	7
C-102	327847.607	5534837.701	J021	0.73	56	131	0.067	34.6	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-103b	327775.839	5534844.061	J022	0.89	62	145	0.058	74.1	0.01	0.1	0.05	39	25	PERVIOUS	100	25.4	1.7	4	7
C-104	327793.439	5534690.062	J050	1.63	91	179	0.013	81.7	0.01	0.1	0.05	2	25	PERVIOUS	100	25.4	1.7	4	7
C-106	327970.618	5534789.842	J012	0.23	27	83	0.083	76.6	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-109	327929.177	5534811.42	J103	0.06	15	38	0.066	48.5	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-111	327923.748	5534840.917	J102	0.15	18	85	0.137	29.3	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-112	327956.942	5534862.96	J101	0.36	28	130	0.105	23.4	0.01	0.1	0.05	7	25	OUTLET	100	25.4	1.7	4	7
C-113	328024.032	5534874.862	J094	0.11	22	50	0.022	62.5	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-114	327887.238	5534784.978	C-115	0.14	18	79	0.081	51.7	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-115	327859.137	5534755.763	C-121	0.07	21	34	0.051	47.3	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-116	327911.442	5534750.36	J018	0.06	14	46	0.089	55.2	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-117	327868.675	5534722.791	J019	0.11	23	47	0.035	66.4	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-118	327889.288	5534719.848	J018	0.05	11	42	0.065	46.2	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-119	327922.412	5534738.724	J017	0.30	16	180	0.049	46.7	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-120	327907.958	5534684.675	J016	0.19	17	112	0.037	45.4	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-121	327848.038	5534684.759	J108	0.48	25	191	0.019	29.3	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-123	327956.083	5534636.998	J040	0.46	42	109	0.023	56.9	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-124	327928.748	5534648.771	J045	0.15	19	80	0.014	53.3	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-125	327877.201	5534659.925	C-120	0.04	21	18	0.135	73.8	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-126	327884.258	5534622.445	J047	0.10	11	85	0.028	38.9	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-127	327970.612	5534713.141	J013	0.08	50	17	0.019	62.2	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-128	327995.459	5534723.779	J013	0.06	26	24	0.01	77.5	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-129	328001.762	5534752.213	J012	0.08	25	31	0.02	81.7	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-130	328055.757	5534762.743	J009	0.06	10	63	0.035	47.9	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-132	328093.792	5534749.032	J006	0.12	100	12	0.03	89.2	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-134	328053.275	5534669.438	J039	0.37	39	96	0.013	59.1	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-135	328084.547	5534698.853	J029	0.09	24	38	0.02	78.1	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-136	328022.792	5534611.857	J038	0.20	15	129	0.024	30.2	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-137	327980.877	5534566.453	J037	0.34	38	88	0.086	39.8	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-138	328059.496	5534557.086	J036	0.20	23	87	0.027	59.9	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-139	328014.476	5534549.241	J042	0.12	20	60	0.043	50.7	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-140	328047.57	5534594.71	J036	0.16	29	56	0.037	48.0	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-141	328174.19	5534725.767	C-131e	0.14	70	20	0.01	95.6	0.01	0.1	0.05	534	25	PERVIOUS	100	25.4	1.7	4	7
C-142	328146.412	5534683.808	J003	0.21	22	96	0.058	59.9	0.01	0.1	0.05	4	25	PERVIOUS	100	25.4	1.7	4	7
C-143	328136.569	5534625.68	N1	0.26	30	86	0.011	58.7	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-144b	328082.809	5534522.544	C-170	0.58	43	135	0.087	17.0	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-146	328079.578	5534326.324	J034	0.81	76	107	0.057	45.9	0.01	0.1	0.05	3	25	PERVIOUS	100	25.4	1.7	4	7
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C-168	328340.502	5534566.277	Pond3	1.59	98	162	0.043	9.7	0.01	0.1	0.05	6	25	OUTLET	100	51	4.2	4	7
C-169	328261.171	5534552.928	pond1	1.15	65	178	0.035	34.1	0.01	0.1	0.05	8	25	OUTLET	100	25.4	1.7	4	7
C-170	328223.247	5534481.688	Pond2	0.36	46	78	0.089	7.7	0.01	0.1	0.05	14	25	OUTLET	100	25.4	1.7	4	7
C-171	328166.486	5534480.734	J114	0.58	57	102	0.057	60.3	0.01	0.1	0.05	30	25	PERVIOUS	100	25.4	1.7	4	7
C-155	327909.374	5534573.478	J049	0.23	70	34	0.01	87.5	0.01	0.1	0.05	151	25	PERVIOUS	100	25.4	1.7	4	7
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C-63	328124.221	5534990.27	C-70	0.34	60	56	0.023	1.1	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-64	328168.666	5534930.636	J081	0.38	40	94	0.047	31.4	0.01	0.1	0.05	4	25	OUTLET	100	25.4	1.7	4	7
C-62	328104.989	5534858.4	J080	0.29	62	47	0.03	80.9	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7
C-65	327948.389	5534697.258	J015	0.14	85	16	0.01	100.0	0.01	0.1	0.05	0	25	OUTLET	100	25.4	1.7	4	7
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C-164b	328244.275	5534374.748	J1	2.74	122	224	0.048	46.2	0.01	0.1	0.05	6	25	PERVIOUS	100	25.4	1.7	4	7
C-165	328244.457	5534676.765	J003	1.04	86	121	0.033	81.6	0.01	0.1	0.05	13	25	PERVIOUS	100	25.4	1.7	4	7
C-71	328178.297	5534833.638	J078	0.36	44	81	0.5	92.5	0.01	0.1	0.05	37	25	PERVIOUS	100	25.4	1.7	4	7
C-149	328138.646	5534749.718	C-131e	0.20	110	18	0.01	99.0	0.01	0.1	0.05	1371	25	PERVIOUS	100	25.4	1.7	4	7
C-77	328190.722	5534711.737	J005	0.09	149	6	0.001	86.6	0.01	0.1	0.05	2	25	PERVIOUS	100	25.4	1.7	4	7
C-121s	327860.129	5534578.516	J049	0.16	30	51	0.052	46.8	0.01	0.1	0.05	3	25	OUTLET	100	25.4	1.7	4	7
C-121ss	327858.056	5534521.506	J052	0.17	25	68	0.076	20.8	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
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C-146a	328024.464	5534414.991	C-146	0.32	106	30	0.136	63.9	0.01	0.1	0.05	40	25	PERVIOUS	100	25.4	1.7	4	7
C-146off	327940.908	5534330.262	C-146	1.36	72	188	0.137	3.6	0.01	0.1	0.05	18	25	OUTLET	100	25.4	1.7	4	7
C-146rd	328139.484	5534330.009	J034	0.11	14	81	0.01	84.9	0.01	0.1	0.05	2	25	PERVIOUS	100	25.4	1.7	4	7
C-156off	327876.113	5534394.786	C-146off	1.06	173	61	0.05	23.7	0.01	0.1	0.05	22	25	OUTLET	100	25.4	1.7	4	7
C-71a	328171.643	5534811.356	J078	0.34	200	17	0.01	100.0	0.01	0.1	0.05	0	25	PERVIOUS	100	25.4	1.7	4	7
C-78	328091.213	5534903.931	J109	0.50	200	25	0.01	82.8	0.01	0.1	0.05	110	25	PERVIOUS	100	25.4	1.7	4	7
C-103	327834.11	5534918.08	J022	0.11	30	37	0.104	52.0	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-151	327810.642	5534519.153	J054	0.15	16	89	0.084	48.5	0.01	0.1	0.05	5	25	OUTLET	100	25.4	1.7	4	7
C-144	328178.375	5534540.225	C-170	0.19	47	42	0.007	1.1	0.01	0.1	0.05	6	25	OUTLET	100	25.4	1.7	4	7
C-164	328318.285	5534442.862	J1	0.19	66	29	0.103	12.5	0.01	0.1	0.05	14	25	OUTLET	100	25.4	1.7	4	7
C-142b	328145.57	5534659.64	J003	0.13	16	82	0.063	77.2	0.01	0.1	0.05	2	25	OUTLET	100	25.4	1.7	4	7

Dstore perv includes the depression storage to meet the on-lot LID requirements.

appendix 2

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OKANAGAN

IRMP

Profile Plan

- Profile 1
- Profile 2
- Profile 3
- Profile 4
- Profile 5
- Profile 6
- Profile 7
- Profile 8
- Profile 9
- Existing Manholes
- Existing Pipes
- 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 20 40 80 120
Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 15

URBAN systems

Appendix 2

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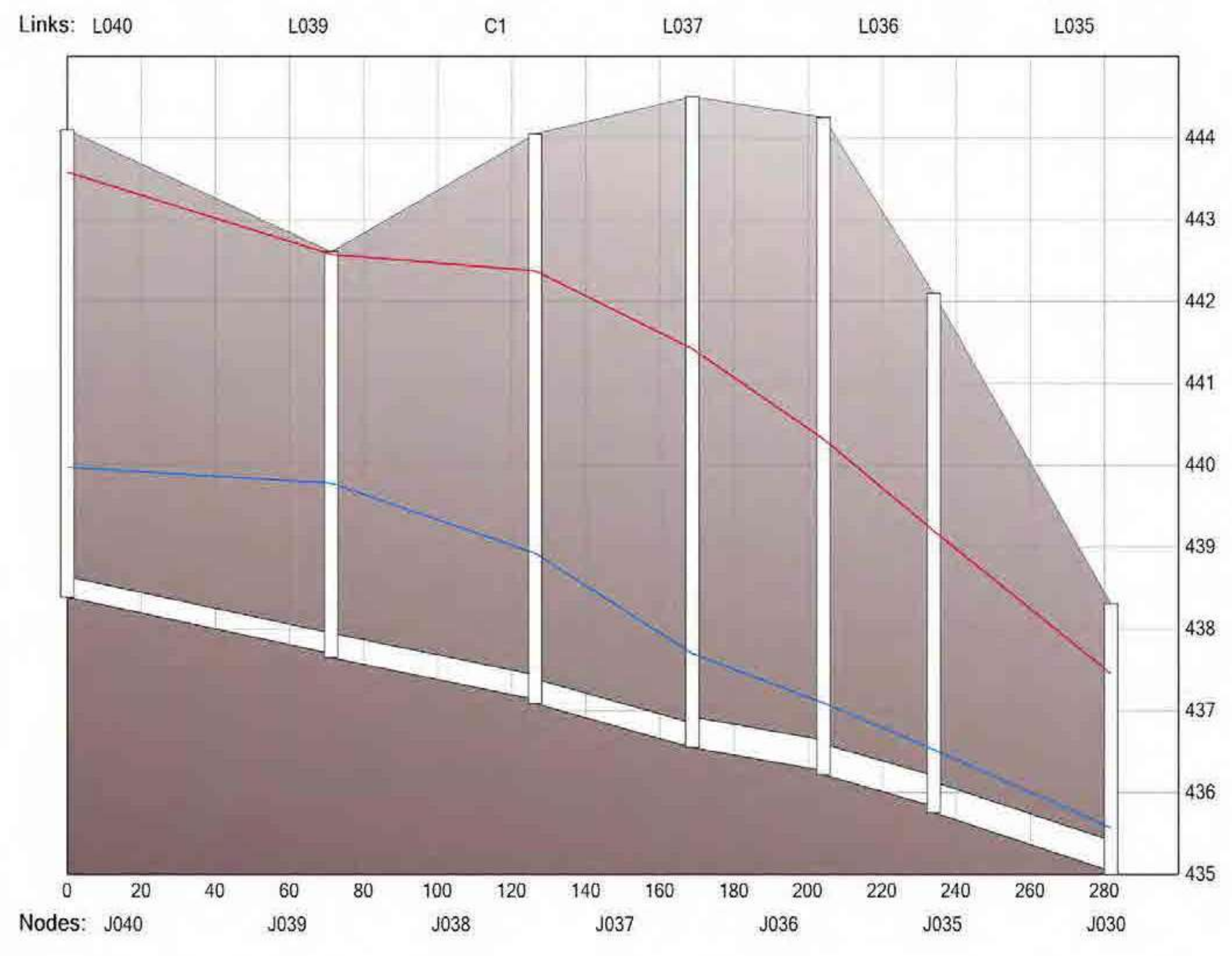


UBC OKANAGAN

IRMP

Main Campus Existing System with Future Projects Profile 1

5 Year Climate Change Event

100 Year Climate Change Event

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 40 80 160 240
Metres

N

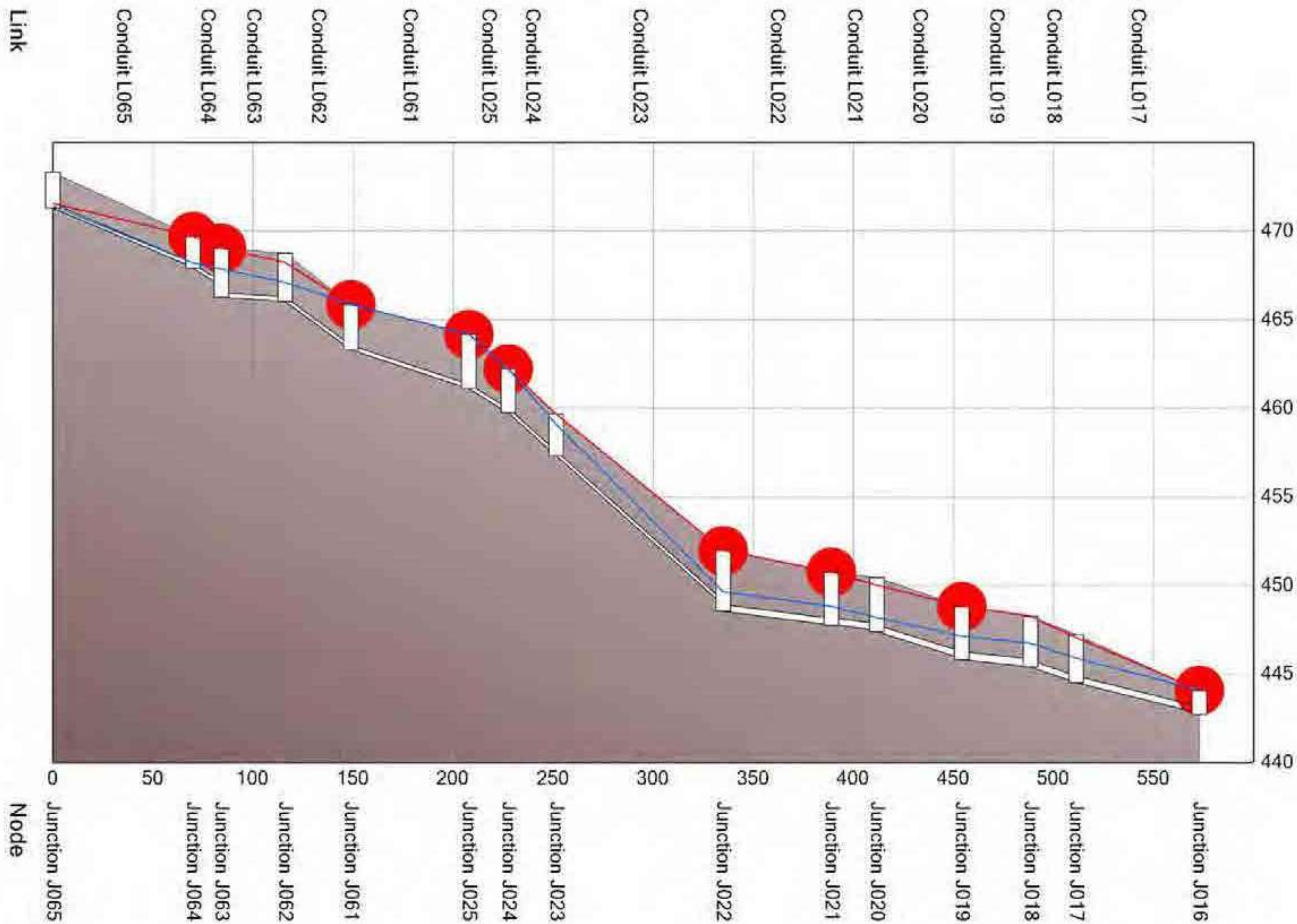
Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 15

URBAN systems

Appendix 2.1



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IRMP

Main Campus Existing System with Future Projects Profile 2

5 Year Climate Change Event

100 Year Climate Change Event

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 40 80 160 240
Metres

N

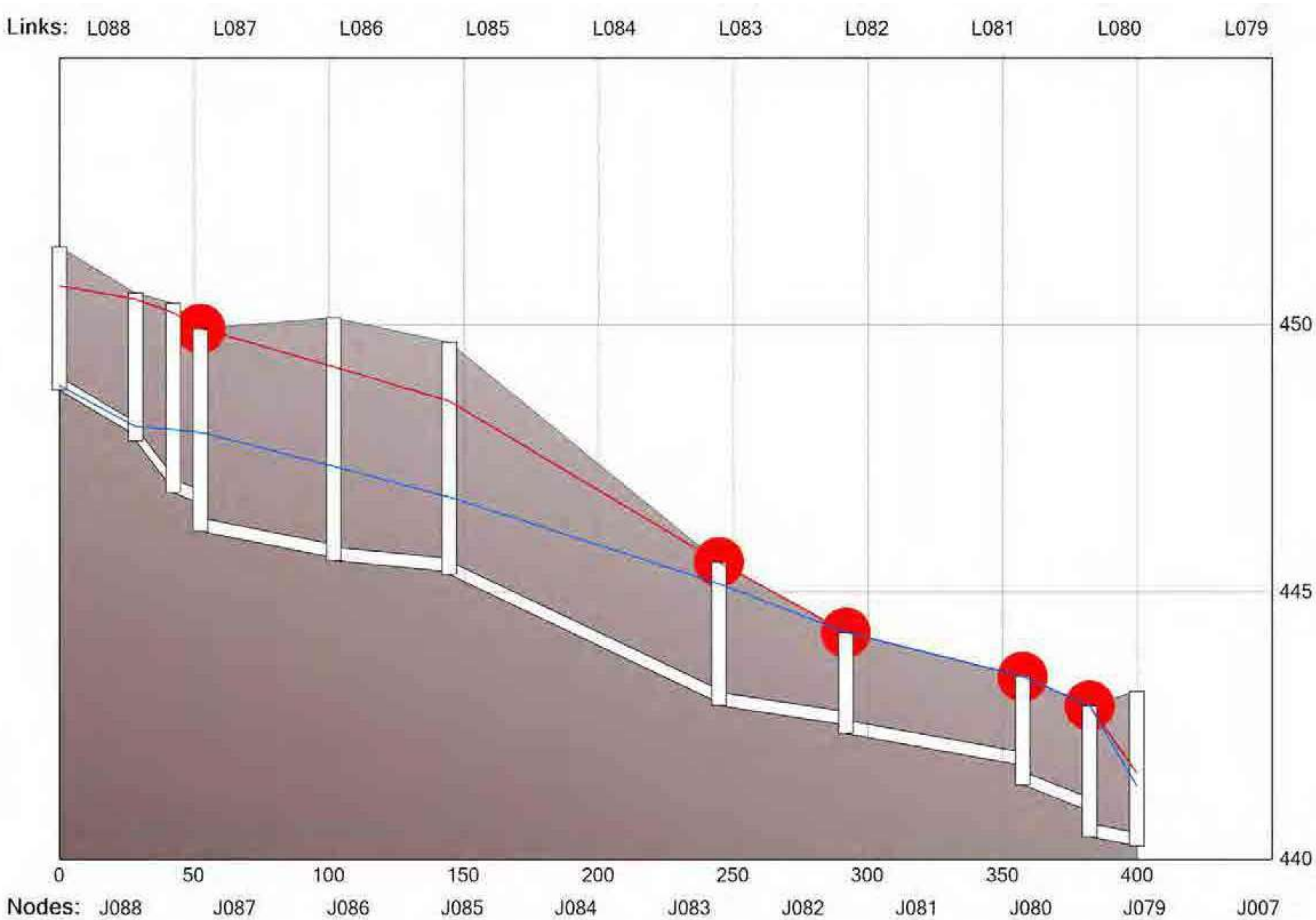
Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #: 1332.0327.01
Author: SQ
Checked: GS
Status: ~FINAL ~
Revision: A
Date: 2017 / 6 / 19

URBAN systems

Appendix 2.2



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IRMP

Main Campus Existing System with Future Projects Profile 3

5 Year Climate Change Event

100 Year Climate Change Event

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 40 80 160 240

Metres

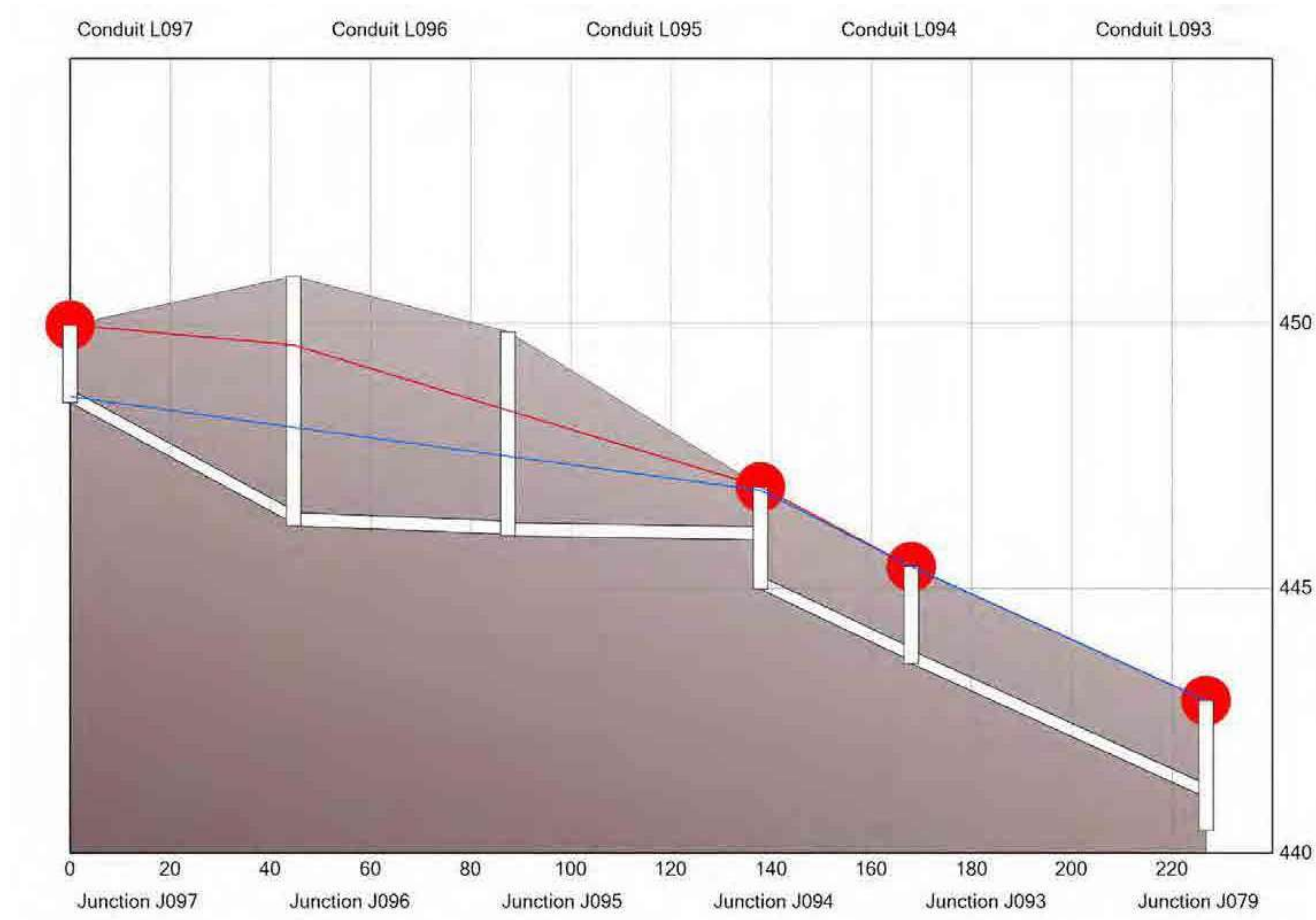
Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #: 1332.0327.01
Author: SQ
Checked: GS
Status: ~ FINAL ~
Revision: A
Date: 2017 / 6 / 19

URBAN systems

Appendix 2.3



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IRMP

Main Campus Existing System with Future Projects Profile 4

5 Year Climate Change Event

100 Year Climate Change Event

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 40 80 160 240
Metres

N

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
Author:	SQ
Checked:	GS
Status:	~ FINAL ~
Revision:	A
Date:	2017 / 6 / 19

URBAN systems

Appendix 2.4

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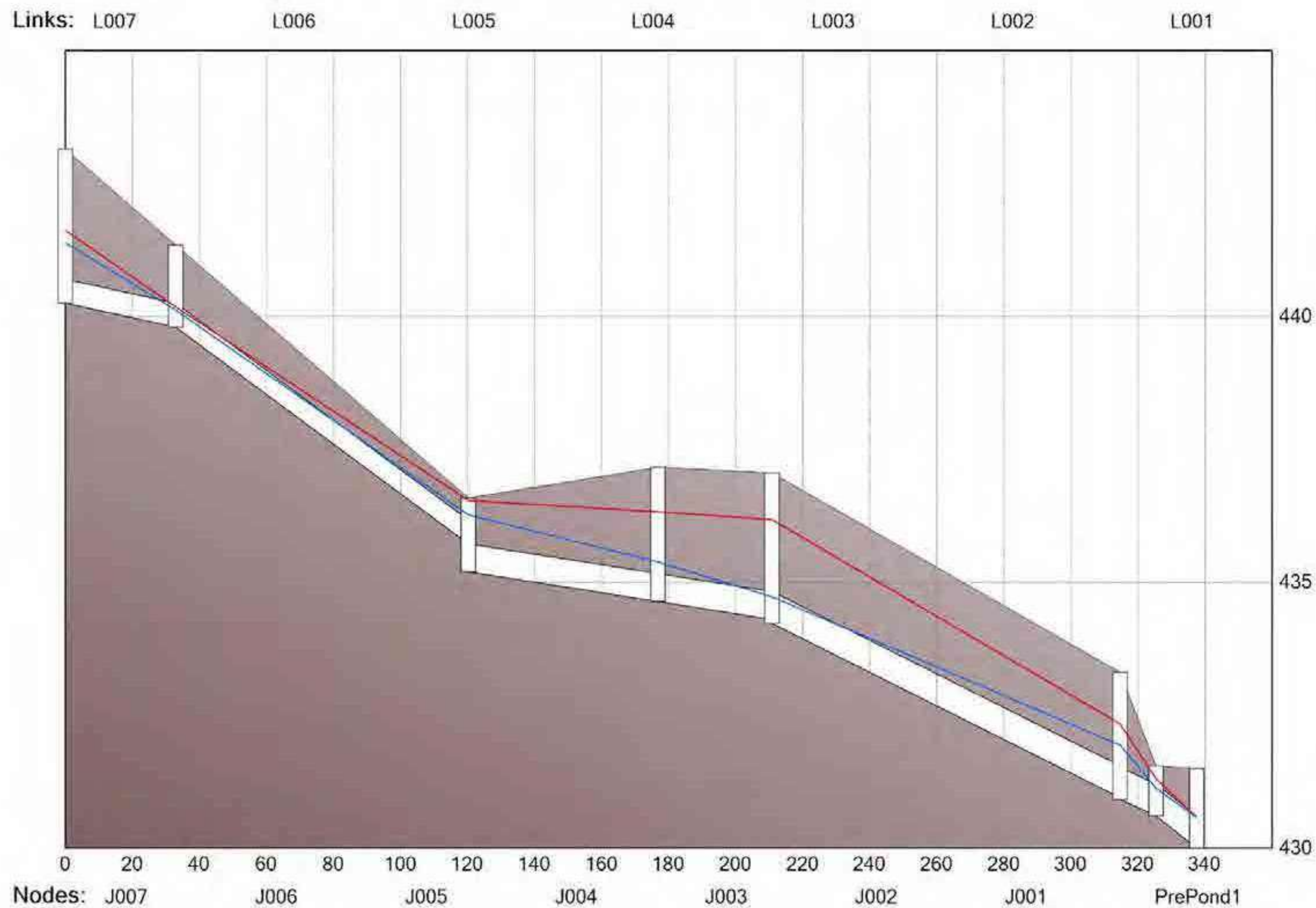

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IRMP

Main Campus Existing System with Future Projects Profile 5

5 Year Climate Change Event

100 Year Climate Change Event

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0 40 80 160 240

Metres

Coordinate System:
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Data Sources:
Data provided by UBCO, 2016

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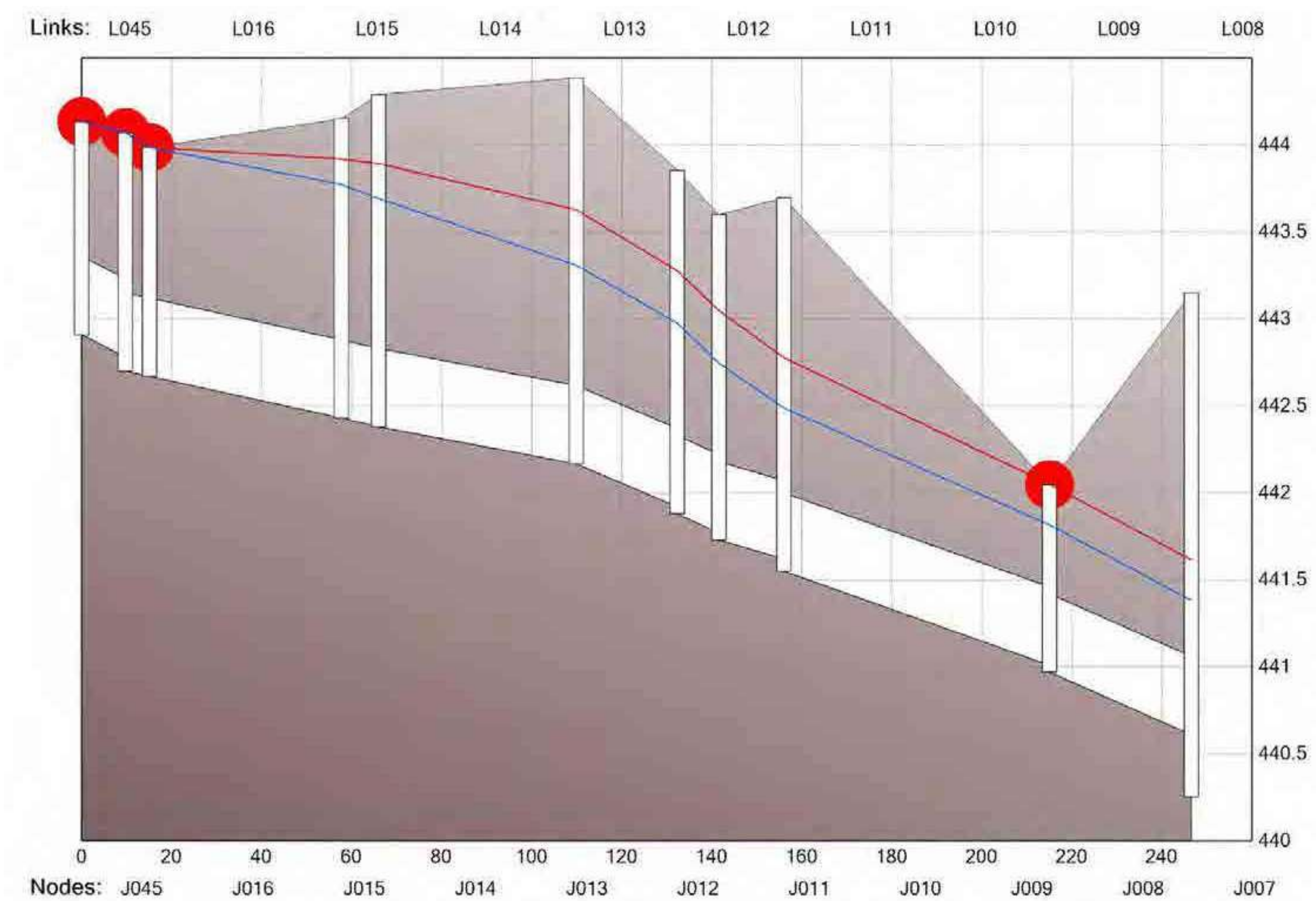
Author: SQ
Checked: GS
Status: ~ FINAL ~
Revision: A
Date: 2017 / 6 / 19

URBAN systems

Appendix 2.5



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IRMP

Main Campus Existing System with Future Projects Profile 6

5 Year Climate Change Event

100 Year Climate Change Event

0 40 80 160 240

Metres

N

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #: 1332.0327.01
Author: SQ
Checked: GS
Status: ~ FINAL ~
Revision: A
Date: 2017 / 6 / 19

URBAN systems

Appendix 2.6

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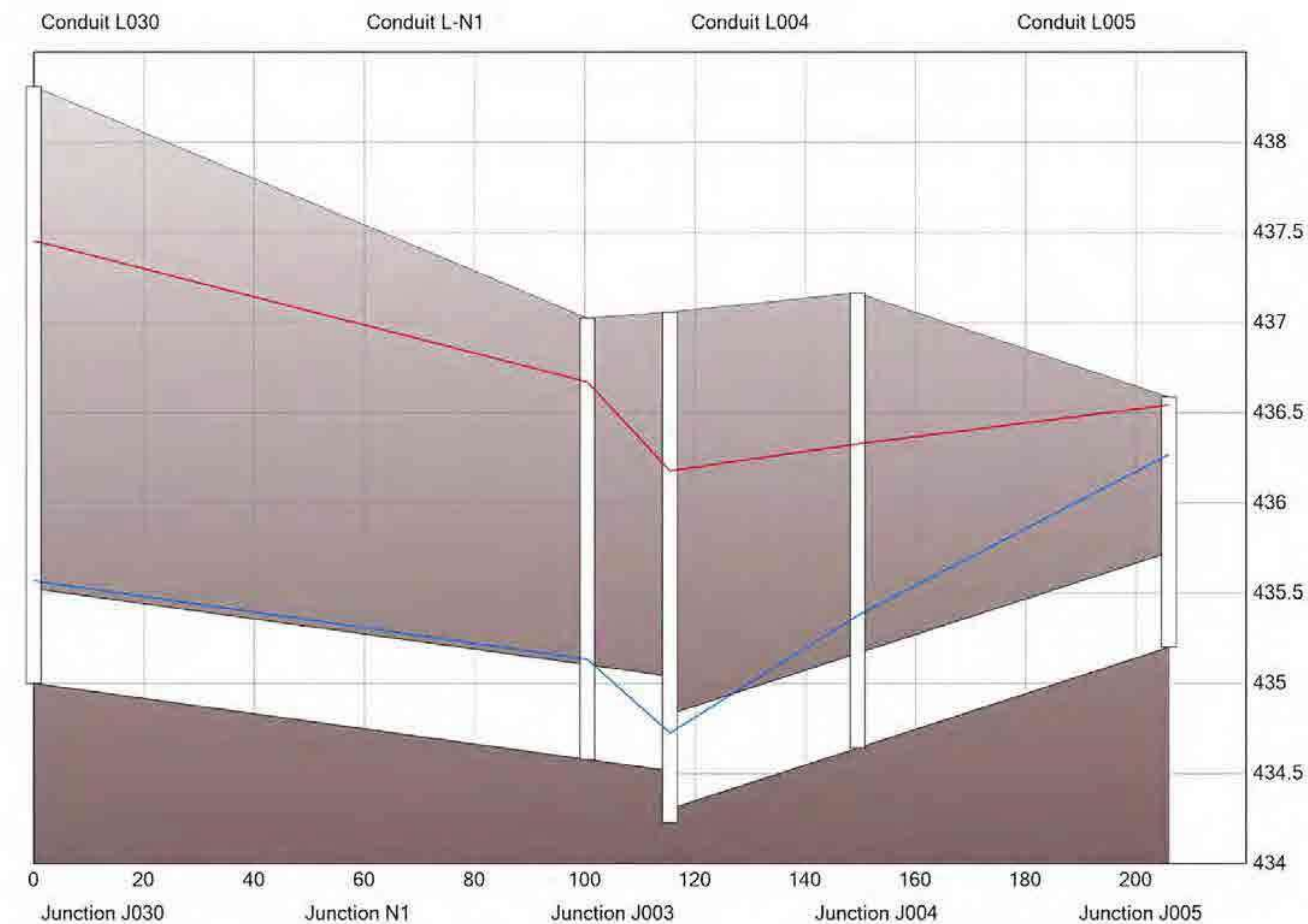

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IRMP

Main Campus Existing System with Future Projects Profile 7

5 Year Climate Change Event

100 Year Climate Change Event

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 40 80 160 240

Metres

Coordinate System:
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Data Sources:
Data provided by UBCO, 2016

Project #:	1332.0327.01
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Revision:	A
Date:	2017 / 6 / 19

URBAN systems

Appendix 2.7

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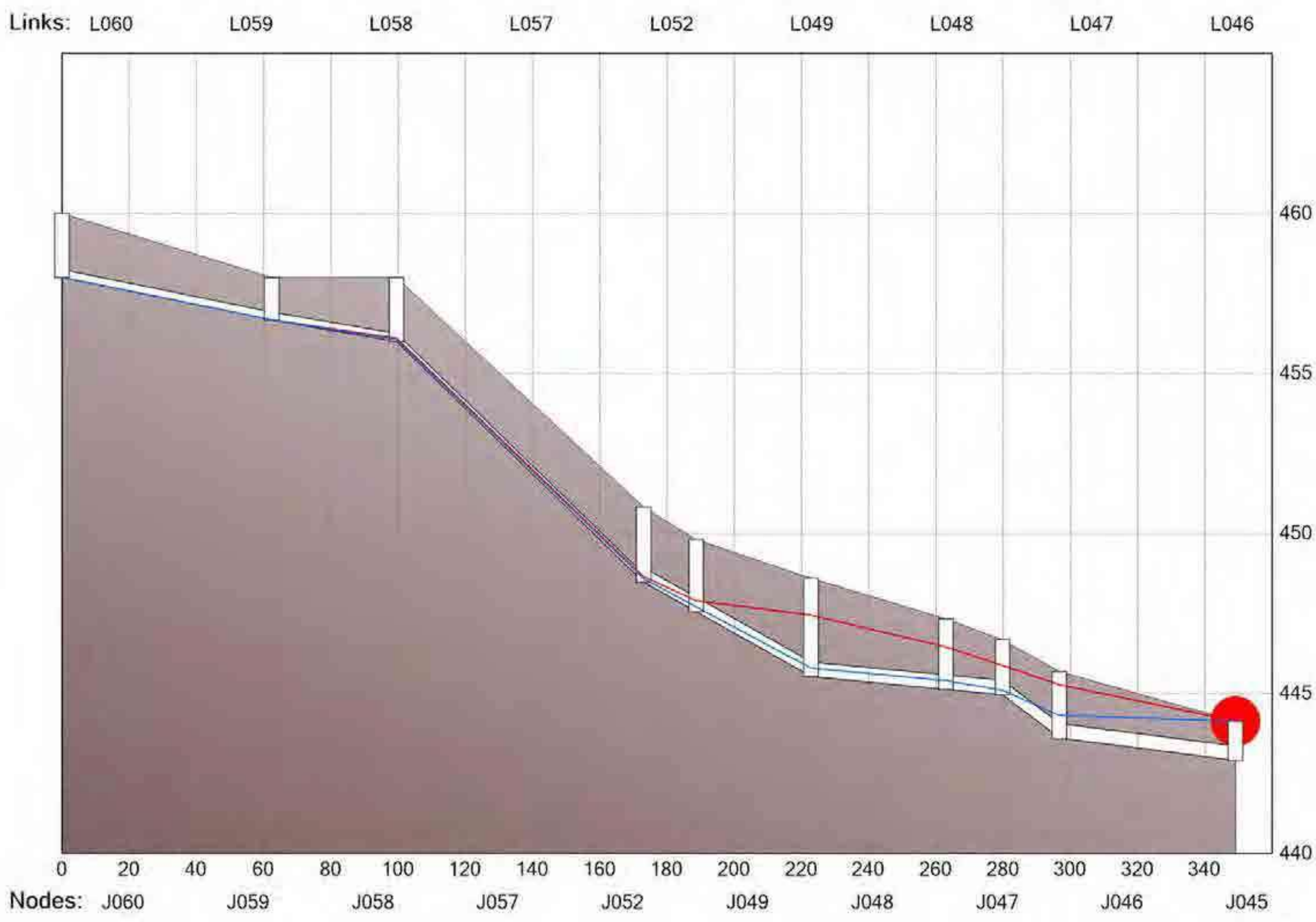

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IRMP

Main Campus Existing System with Future Projects Profile 8

5 Year Climate Change Event

100 Year Climate Change Event

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 40 80 160 240

Metres

N

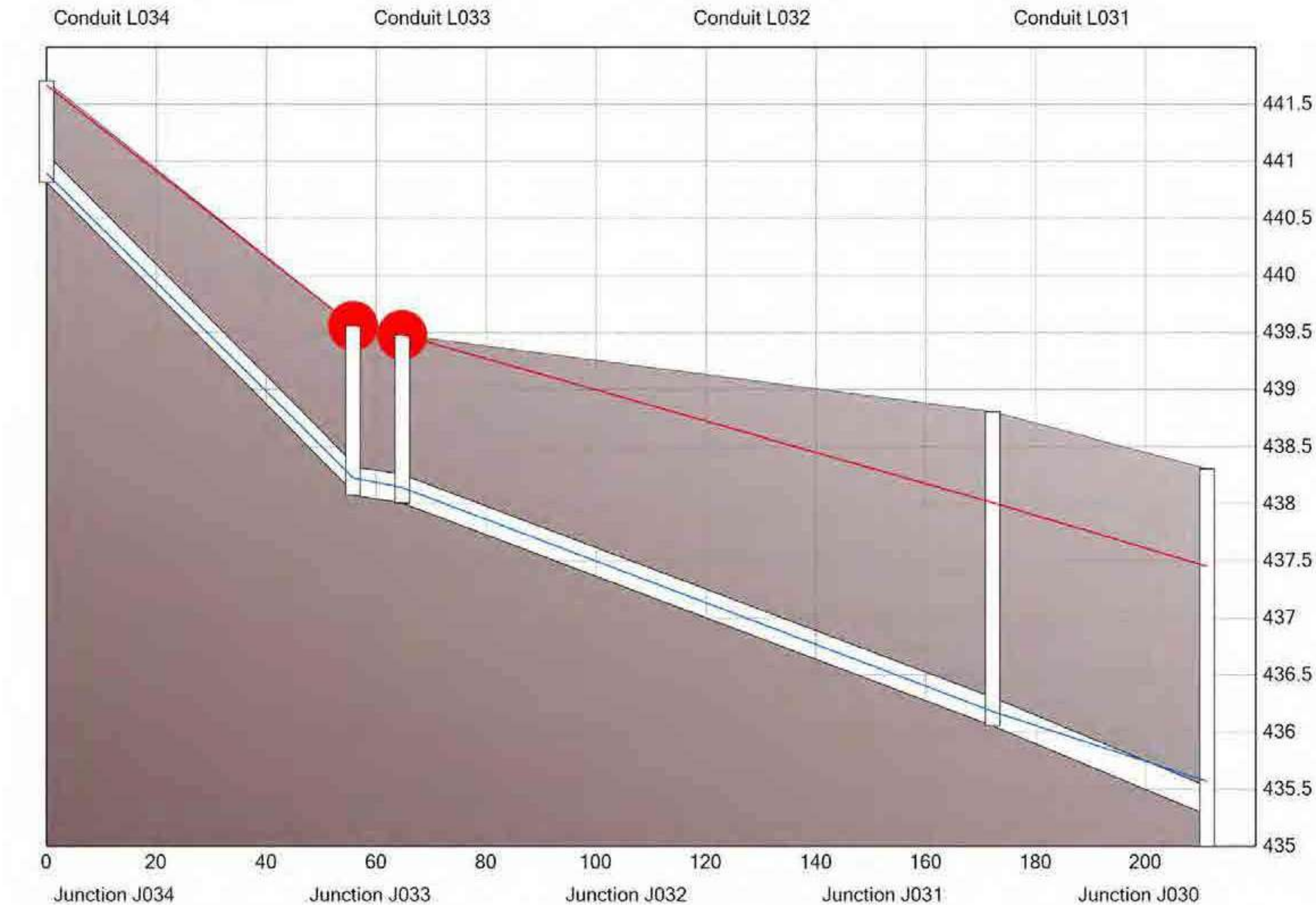
Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #: 1332.0327.01
Author: SQ
Checked: GS
Status: ~ FINAL ~
Revision: A
Date: 2017 / 6 / 19

URBAN systems

Appendix 2.8



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IRMP

Main Campus Existing System with Future Projects Profile 9

5 Year Climate Change Event

100 Year Climate Change Event

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 40 80 160 240

Metres

Coordinate System:
NUTM11

Data Sources:
Data provided by UBCO, 2016

Project #: 1332.0327.01
Author: SQ
Checked: GS
Status: ~ FINAL ~
Revision: A
Date: 2017 / 6 / 19

URBAN systems

Appendix 2.9

CREDITS

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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