Staff report

DATE: November 16, 2017

FILE: 5330-20

TO: Chair and Directors
Electoral Areas Services Committee

FROM: Russell Dyson
Chief Administrative Officer

Supported by Russell Dyson,
Chief Administrative Officer

R. DYSON

RE: **Lazo Creek Watershed - Drainage Improvements Options Analysis**

Purpose

To update the Electoral Areas Services Committee (EASC) on the results of the Queen's Ditch options analysis and recommend a path forward.

Recommendation from the Chief Administrative Officer

THAT further study work be completed to assess the effectiveness and viability of managed retreat/wetland restoration in improving drainage in the lower Lazo Creek Watershed;

AND FURTHER THAT $27,000 from Service 152, Electoral Area B Feasibility Studies, be allocated to a flow monitoring program for the Lazo Creek Watershed;

AND FINALLY THAT the McElhanney report titled "Comox Valley Regional District Queen's Ditch Lowland Area Drainage Improvements Options Analysis" and dated September 14, 2017 be referred to the Committee of the Whole for information.

Executive Summary

- Queen's Ditch flood mitigation is a corporate strategic priority of the Comox Valley Regional District (CVRD) Board.
- The lowland areas of the Lazo Creek Watershed lie just above sea level with a drainage gradient of about 0.05 per cent, or nearly flat, and have longstanding issues with flooding that have and continue to affect local residents.
- Prior to the construction of the Queen's Ditch, much of the lower Lazo Creek Watershed was marshland.
- These lowland areas provide drainage for upland areas within the watershed, including lands within Lazo North (Area B), the Town of Comox (Comox), and Canadian Forces Base (CFB) Comox.
- In response to residents' concerns of flooding in the lowland areas, the CVRD committed to undertake a feasibility study to evaluate the viability of a local service area (LSA) to manage drainage in the lower Lazo Creek Watershed.
- A Lazo Creek Watershed Technical Advisory Committee (TAC) and Public Advisory Committee (PAC) were established to inform development of this work. Membership includes select stakeholder agencies and organizations with an interest or jurisdictions in the watershed area along with local area residents and affected community stakeholders.
- As part this work, McElhanney Consulting Service Ltd. (MCSL) was retained to evaluate options for improving the Queen's Ditch drainage system. Hydraulic modeling was undertaken to analyze system response to five drainage improvement options.

- Of these five options, managed retreat or wetland restoration, appears to offer reductions in flooding with modest ongoing maintenance requirements. Additional benefits include the restoration of lost wetland habitat and the potential for partnership opportunities with select stewardship organizations.
- Staff are seeking approval from the EASC to undertake further study work to better understand the effectiveness and viability of managed retreat/wetland restoration in reducing flooding frequency and duration within the lowland areas of the Lazo Creek Watershed.
- Staff are also seeking approval to implement a flow monitoring program to assist in verifying surface water flows at key locations within the Lazo Creek Watershed.
- The situation is complex with multiple competing interests and values. Continued consultation with all stakeholders will be key to identifying and implementing a sustainable solution.

Prepared by:	Concurrence:
	M. Rutten
Darry Monteith Engineering Analyst	Marc Rutten, P.Eng General Manager of Engineering Services

Stakeholder Distribution (Upon Agenda Publication)

Lazo Creek Watershed PAC	✔
Lazo Creek Watershed TAC	✔

Background/Current Situation

The Queen's Ditch is a constructed drainage channel, partially built within Lazo Creek. The Queen's Ditch catchment area, known as the Lazo Creek Watershed, is approximately 1300 hectares in size.

The lowland areas of the Lazo Creek Watershed lie just above sea level with a drainage gradient of about 0.05 per cent, or nearly flat, and have longstanding issues with flooding that have and continue to affect local residents. These lowland areas provide drainage for upland areas within the watershed, including lands within Area B, Comox, and CFB Comox.

Historic Land-Use Changes

Prior to the construction of the Queen's Ditch, much of the lower Lazo Creek Watershed was marshland. Outflows from the area were slow, with few open channels and very low gradients.

In 1946 the Department of National Defence (DND) constructed the Queen's Ditch to carry sewage and stormwater from CFB Comox to the Strait of Georgia. While this enhanced outflow from the area, the ditch's hydraulic gradient limited its ability to carry large flows efficiently.

Beginning around the 1950's, wetland areas started to be converted to agricultural lands through construction of drainage ditches along roads and farm fields, increasing the volume of surface and subsurface flows into the Queen's Ditch. This was coupled with residential development in the upper watershed and continued development of CFB Comox lands, adding large areas of impervious land cover and further increasing flows into the ditch.

Over time, expansion and intensification of the drainage network, along with further land clearing, wetland conversion, and development of impervious surfaces have continued to increase stormwater loading and delivery rates into the Queen's Ditch. Added to this, sea level and gravity continue to be significant constraints to the hydraulic efficiency of the system.

Historic land-use changes within the Lazo Creek Watershed are documented in the 2002 report *"Toward a Management Plan for the Lazo Watershed and Queen's Ditch"* by William M. Marsh. Illustrative mapping developed as part of this work can be found in Appendix B.

Project History

In 1997, a large portion of the agricultural land adjacent to the Queen's Ditch was flooded for an extended period of time, resulting in the loss of an entire potato crop. The farmer subsequently filed a lawsuit naming the Attorney General of Canada, Province of BC, and the Comox-Strathcona Regional District (CSRD) as defendants. In 1999, the farmer discontinued the lawsuit against the CSRD in exchange for a waiver of legal costs, and a commitment by the CSRD to undertake a management plan for the Lazo Creek Watershed.

The William M. Marsh report was completed in 2002, with funding contributed by the CSRD, the provincial government, DND, and Comox. The report was well regarded and contained numerous recommendations for better rainwater management in the upper and lower reaches of the Lazo Creek Watershed.

Flooding has continued to affect many local residents in the lower Lazo Creek Watershed. Affected property owners feel there has been an increase in the frequency and severity of flooding over the past number of years. Property owners report that flood waters are entering basements and damaging structures, crops and equipment and they are worried about the effect that such regular flooding is having on their property values, and upset at the reduced access to their lands.

Consultation for the north-east Comox stormwater management plan in 2014, with the spectre of additional development in the upper reaches of the watershed, was the catalyst for formation of the Lazo Watershed Property Owner's Committee (LWPOC) in December 2014.

In 2015, the LWPOC presented their concerns to both the EASC and the Committee of the Whole (COW). During subsequent meetings with the Area B Director, senior CVRD staff, and DND representatives, the LWPOC communicated support for a feasibility study to explore the viability of a LSA to manage drainage in the lower Lazo Creek Watershed. In August 2015, in response to a letter from Area B Director Rod Nichol, the COW passed a motion to proceed with the feasibility study. A following staff report presented to the EASC in November 2015, provided further recommendations for completing this work.

In early 2016, the CVRD established two committees to advise on matters relating to improved drainage in the area including the possible creation of a LSA.

- A PAC was created to provide guidance and support on matters of public interest. Members include: LWPOC, Little River Enhancement Society and Nature Trust BC.
- A TAC was created to provide guidance and support on technical and jurisdictional matters. Members include: Comox, DND, Ministry of Transportation and Infrastructure (MoTI), Ministry of Agriculture and Fisheries and Oceans Canada.

In 2017 staff retained two consultant to evaluate the feasibility of establishing a LSA to manage drainage in the Lazo Creek Watershed. From this work the following two report were received:

1. *"Queen's Ditch Lowland Area Drainage Improvements Options Analysis"* completed by MCSL and dated September 14, 2017 (Appendix A).
2. *"Queen's Ditch Drainage Service Governance Study"* completed by Stewart McDannold Stuart (SMS) and dated July 14, 2017.

Both reports were presented and discussed with both the TAC and the PAC in fall 2017. The SMS report will be presented to the EASC in a separate staff report.

MCSL Options Analysis

MCSL was retained to investigate options for improving the Queen's Ditch drainage system with the intent of providing a level of service consistent with the following parameters:

- Residential properties should ideally not flood during a rainfall equivalent to a 1:10 year return, 24-hour rainfall event. This level of service is typical of many municipally operated storm drainage functions.
- Agricultural lands should be subject to the provincial Agricultural and Rural Development Subsidiary Agreement (ARDSA) requirements for drainage.

Hydraulic modeling was undertaken using PCSWMM software to analyze system response to five drainage improvement options.

1. Cleaning and deepening of the Queen's Ditch, including both a lined channel and unlined channel option.
2. The addition of overflow channeling, including both a Lazo Marsh bypass option and a DND bypass option.
3. Diking and pumping of the low areas.
4. Managed retreat/wetland restoration, modeled as a +/- 40m wide water surface along the Queen's Ditch and the abandoning of several low areas within adjacent agricultural lands that cannot be consistently drained.
5. Construction of detention ponds, or off-channel storage.

The PCSWMM software used for modeling only identified nodal flooding, or a loss of water at defined nodes within the system. Flood extents were not modeled.

To inform the hydraulic modeling, MCSL first completed a topographic survey and mapping of the drainage system to assist in determining major flow pathways. This mapping was not exhaustive but worked to identify those network components with the greatest degree of influence on flooding.

In the absence of flow monitoring data to accurately predict runoff at various point within the catchment, a land-use assessment of the entire Queen's Ditch catchment area was completed utilizing percent impervious as a proxy for surface water runoff. This methodology did not account for flow attenuation work completed as part of the land development process. Long term Official Community Plan build out conditions were used for modeling future scenarios.

Two modeled scenarios were completed for each of the five options, one under current conditions and a second under future sea level rise and climatic conditions. Sea level rise conditions were modeled as a rise of 1.0m above present day maximums by the year 2100, or 3.34m geodetic. Rainfall data was adjusted to anticipated climatic conditions as a result of climate change.

In 2017 DND completed construction of three large stormwater detention ponds intended to help mitigate peak flows from a portion of CFB Comox lands. Based on hydraulic modeling completed by DND, these ponds provide for a slight reduction in flooding of the lowland areas. The modeling undertaken as part of the MCSL study assumes the DND ponds are constructed and functioning as intended.

While the MCSL report does not offer specific recommendations on a preferred option, the following observations can be made:

- Diking and pumping provides the best opportunity to lower water table levels and decrease flooding and has the flexibility to adapt to changing hydrologic conditions. This option however, requires large infrastructure investments with high long-term operations and maintenance costs.
- Managed retreat provides the second greatest improvement in overall drainage however, flooding is still observed at points of lateral connection under sea level rise conditions.
- Operations and maintenance costs are lowest with the DND bypass option, followed by managed retreat. However, based on hydraulic modeling, managed retreat provides far greater flood mitigation with similar costs.
- All improvement options will require new statutory rights of way or the purchase of land.
- Improvement options that require works to existing channels, particularly the Queen's Ditch, will require extensive environmental approvals. Those options with less impact on existing channels are expected to have significantly less onerous permitting requirements.

Managed Retreat/Wetland Restoration

Managed retreat, or wetland restoration, offers added benefit over some of the other options analysed in the MCSL report.

Managed retreat benefits:

- Reductions in flooding
- Restores lost wetland habitat, increases biodiversity, and provides opportunities for enhanced salmonid returns
- Properly designed and constructed, will function naturally and require modest ongoing maintenance
- Provides for partnership opportunities with select stewardship organizations

Some challenges do exist with this option and more work will need to be completed to better understand its implications.

Detractors of managed retreat:

- Requires a significant amount of land to construct and will need approvals from numerous land owners. This process may be simplified given that a number of properties along the Queen's Ditch are held by the same owner. In total there are 14 distinct property ID's within the regional district fronting the Queen's Ditch, with a total of 11 individual property owners. The map in Appendix C shows those parcels fronting the Queen's Ditch.
- Improvements will result in a net loss of agricultural lands which will need to be addressed with the Agricultural Land Commission. This loss of land base may be partially offset by improvements to the surrounding agricultural lands due to decreased flooding and control of groundwater elevations.
- Requires significant environmental approvals. Further discussion with federal and provincial agency staff is required to better understand environmental requirements.
- Capital construction costs are high, however partnership opportunities may exist not only with DND through the Vote 10 funding program, but also with stewardship organizations interested in habitat and wetland restoration.

Next Steps

Staff are recommending that further work be completed to better understand the effectiveness and viability of the managed retreat option.

Next steps:

- Undertake a flow monitoring program to allow further calibration of hydraulic models, assist in conveyance system sizing and estimate relative runoff rates from each jurisdiction.
- Undertake more detailed hydraulic modeling work to understand flood water extents and confirm effectiveness in achieving the desired level of service.
- Undertake preliminary conceptual design work, confirm required environmental/regulatory approvals, costs, timing, and other considerations.
- Engage with interested stewardship organization to explore potential partnership opportunities.
- Continued engagement with the PAC and the TAC.

A flow monitoring program will be implemented as soon as possible so that 2017/2018 winter flows can be measured. A detailed budget and work plan for the proposed modeling and conceptual design work will be included for approval in the 2018-2022 financial plan for Service 152, Electoral Area B Feasibility Studies. It is expected that this study work will take place in 2018.

During consultation with both the PAC and the TAC it was noted that the MCSL study focused on improving the hydraulic efficiency of the lower drainage network and did not address strategies aimed at reducing the volume and rate of runoff from development within the watershed. It is understood that improved rainwater management within the Lazo Creek Watershed continues to be an important part of any solution. CVRD staff will work together with MoTI and Comox staff towards improved development standards for rainwater management within the watershed.

Policy Analysis

Queen's Ditch flood mitigation is a corporate strategic priority of the CVRD Board.

At their August 11, 2015 meeting the COW passed the following motion:

> *THAT a feasibility study be conducted to develop a rainwater drainage service that addresses capital upgrades and ongoing maintenance in and around the Queen's Ditch area of the Lazo Marsh.*

At their November 9, 2015 meeting the EASC passed the following motions:

> *THAT a feasibility study be conducted in two-phases to assess the viability of establishing a local service area to rehabilitate and manage the lower Lazo watershed drainage system;*
>
> *AND FURTHER THAT the Electoral Area 'B' feasibility studies service 152 2016 - 2020 financial plan include $5,000 for possible service establishment costs, and that the 2016 - 2020 financial plan also commit $30,000 of community works funds for capacity building and supporting planning work;*
>
> *AND FURTHER THAT a staff report on findings of the first phase of a feasibility study be presented to the electoral area services committee by July 2016;*
>
> *AND FINALLY THAT the Comox Valley Regional District provide a letter of interest to the Department of National Defence expressing interest to enter into negotiations for a contribution agreement with the Department of National Defence for the design and installation of infrastructure supporting the management of the lower Lazo watershed drainage system.*

Options

1. EASC members direct staff to undertake further work to evaluate the effectiveness and viability of managed retreat/wetland restoration in improving drainage in the lower Lazo Creek Watershed.
2. EASC members direct staff to undertake further work to evaluate the effectiveness and viability of an alternative option(s).

Staff recommend option one as it offers reductions in flooding with additional opportunities for habitat restoration and strategic partnerships.

It is recommended that any option for further analysis also include a flow monitoring program to verify rainwater runoff at various points within the catchment. Approving this work now will ensure 2017/2018 winter flows are captured in this program.

Financial Factors
The potential exists for the CVRD to assume responsibility of the Queen's Ditch in return for a capital investment through the DND Vote 10 funding program. This process was initiated in March 2016 through a letter of interest sent to DND Vote 10 program staff. More recent discussions with Vote 10 program staff indicate there may also be a possibility of sharing in the cost of future project development work. CVRD staff will continue to work with Vote 10 program staff on cost sharing opportunities for the project.

Flow monitoring data is required to accurately predict rainwater runoff at various points within the catchment. In order ensure 2017/2018 winter flows are captured, it is recommended that $27,000 in unallocated funds for Service 152, Electoral Area B Feasibility Studies, be allocated to a flow monitoring program for the Lazo Creek Watershed.

If further project development work is supported, a detailed budget and work plan will be included in the 2018-2022 financial plan for Service 152, Electoral Area B Feasibility Studies.

Legal Factors
Governance options for the creation of a LSA along with an overview of the legal regulatory regime and common law legal liability risks associated with the provision of a drainage service are considered in a separate report to be presented to the EASC.

Regional Growth Strategy Implications
Project work will be developed to align with the goals and objectives of the Comox Valley Regional Growth Strategy to "provide affordable, effective and efficient services and infrastructure that conserves land, water and energy resources."

Intergovernmental Factors
Approximately 45 per cent of the Lazo Creek Watershed falls within CVRD Area B, 28 per cent within Comox, and 27 per cent within CFB Comox. Any viable solution to flooding in the lower Lazo Creek Watershed will require the collaboration of all jurisdictions within the watershed.

DND has indicated a desire to hand over responsibility for the Queen's Ditch to the CVRD and has also expressed willingness to participate in a possible future LSA set up to manage the Queen's Ditch and associated drainage network.

The Comox boundary wraps almost entirely around the Lazo Creek Watershed, with the last several hundred meters of the Queen's Ditch and outfall falling within town boundaries. PAC members feel strongly that Comox should be part of any drainage solution for the area and continue to voice concerns about development in the upper watershed.

The situation is complex with multiple competing interests and values. The CVRD will continue to work with DND, Comox and other members of the TAC and PAC towards identifying and implementing a sustainable solution.

Interdepartmental Involvement
The Engineering Services Branch has taken the lead in preparing this report.

Citizen/Public Relations
Staff will continue to work closely with the PAC through the next phase of this work. Consultation with all stakeholders will be key to identifying and implementing a sustainable solution.

Attachments: Appendix A – "McElhanney Consulting Serviced Ltd., *Queen's Ditch Lowland Area Drainage Improvements Options Analysis,* September 14, 2017"
Appendix B – "Map of Historic Land-Use Changes"
Appendix C – "Map of Property Boundaries along Queen's Ditch"

September 14, 2017

Appendix A

Comox Valley Regional District – Queen's Ditch Lowland Area Drainage Improvements

Options Analysis

McElhanney Consulting Services Ltd.
495 Sixth Street
Courtenay, BC
V9N 6V4

Contact: Bob Hudson, P.Eng.
Phone [250-338-5495
Email: b.hudson@mcelhanney.com

MCSL File: 2211-47468-00

Executive Summary

Flooding of the Queen's Ditch and adjacent agricultural lands has occurred for many years. It is believed that this flooding has increased in duration and extents over time, likely corresponding to the infilling of the historic Lazo wetland that occupied the (present day) Queen's Ditch lowland areas, and the development of lands within the Queen's Ditch/Lazo catchment. This hypothesis appears to be corroborated by first hand accounts from land owners within the area.

In an effort to provide some relief, the Comox Valley Regional District (CVRD) has agreed to investigate the feasibility of creating a Local Service Area (LSA), to finance the initial construction of drainage network improvements, and to fund the ongoing operation and maintenance of this service.

McElhanney Consulting Services Ltd. (MCSL), has investigated the feasibility of implementing several different drainage system improvements, with the intent of providing a level of service for residential properties that is consistent with that provided by neighboring jurisdictions. It was also agreed that drainage improvements should ensure that arable lands meet Agricultural and Rural Development Subsidiary Agreement (ARDSA) requirements.

Five drainage improvement options were considered, each evaluating a based degree of effectiveness in reducing flooding, technical feasibility (including anticipated higher-level government approvals), estimated capital construction cost, and relative operation and maintenance costs.

1. **Diking and pumping of lowland areas** appears likely to provide the best opportunity to lower water table levels, and decrease flooding under current, and long term (climate change and sea level rise) conditions.
2. **Managed Retreat/Wetland Reinstatement**, is modeled as a +/- 40m wide (water surface) along the Queen's Ditch, and the abandoning of several low areas that cannot be consistently drained within the agricultural lands adjacent to the Queen's Ditch, provides significant improvement in overall drainage, under current sea level and climatic conditions. Longer term projected sea level rise will decrease the effectiveness of this option.
3. **Cleaning and deepening of the Queen's Ditch**, as described in Option 1-2, provides the next greatest reduction in hydraulic grade within the Queen's Ditch, provided that a lined channel section is constructed. Modest flooding of lateral connections persists, even with improvements. Significant flooding is modeled without lining the improved ditch section. Under climate change conditions, Significant flooding is modeled, regardless of lining
4. **The Lazo and DND Bypass** options provide varying levels of flood reduction. Under present-day conditions, the Lazo Bypass is modeled as being minimally effective in reducing the hydraulic grade within the Queen's Ditch. Performance of the DND bypass is approximately equivalent to cleaning and deepening the Queen's Ditch without channel lining improvements. When consideration is given to the impacts of climate change (sea level rise), neither bypass option is effective at reducing flooding under design rainfall conditions.

5. **Off-Channel Storage** is not considered practical, given the flat gradient of the lowland areas, and volume of storage that must be provided to mitigate flooding.

Contents

Figures

Tables

1. Introduction

The Comox Valley Regional District (CVRD) has retained McElhanney Consulting Services Ltd. (MCSL), to provide assistance and technical support, for the evaluation of options to improve drainage within portions of the Queen's Ditch drainage catchment.

This assignment includes the following components, and has been prioritized, as follows:

Phase 1 - Drainage Catchment Mapping - including assembly of existing mapping, survey data and information, survey of existing drainage features and topography to augment information already in hand, preparation of drainage mapping, and ground truthing of same.

Phase 2 – Land Use Assessment – preparation of mapping and tabulated land uses within the various jurisdictions that drain to the Queen's Ditch and Lazo Marsh. Land use is mapped by subcatchment, and point of connection to the Queen's Ditch System, and includes information on current land use/percent impervious, and longer term Official Community Plan land uses.

Phase 3 – Verification of Surface Water Flows in Select Lowland Waterways/Ditches – flow monitoring in select, representative locations to allow for the calibration of hydraulic models, conveyance system (infrastructure) sizing, and estimating of relative runoff rates from each contributing jurisdiction. Note Phase 3 has not proceeded at this time, due to budget constraints.

Phase 4 – Lowland Area Conveyance Improvements Options Analysis – evaluation of five specific options to decrease the extents, depth, and frequency of flooding. Options to be considered include:

- Cleaning and deepening of existing ditching, upsizing culverts as required.
- The addition of "overflow channeling" to redirect runoff around the Queen's Ditch, directly to the ocean.
- Diking and pumping of low areas.
- Managed retreat, or wetland restoration.
- Construction of detention ponds or off-channel storage (within the lowland areas).

Phase 5 – Implementation of Preferred Option and Development of a Management Plan – not completed at this time. (TBD).

2. Background Information

2.1. Site Description

The Queen's Ditch/Lazo Marsh Watershed consists of approximately 1000 hectares of land within the jurisdiction of the Comox Valley Regional District (Electoral Area B) and the Town of Comox. Topography within the Queen's Ditch watershed ranges from sea level, to approximately 55m, geodetic. The area of interest in this study is limited to the defined "lowland areas", surrounding the Queen's Ditch. Land use within the "lowland areas" is generally agricultural, but the study area does interface with rural, residential properties as well.

MCSL drawing SK-1, overleaf, indicates the extents of the watershed, as well as jurisdictional boundaries.

Lands upstream of the study area are generally comprised of large lot, semi-forested rural residential and agricultural properties within the CVRD. Within those portions of the Town of Comox that drain to the Queen's Ditch and Lazo Marsh, land use ranges from commercial, to varying densities of residential development, to undeveloped, forested land. Additional detailing of existing land use/development can be found in later sections.

2.2. History of Flooding in the Area

The following excerpt is provided from the 2013 North East Comox Neighborhood Stormwater Management Plan, prepared by MCSL:

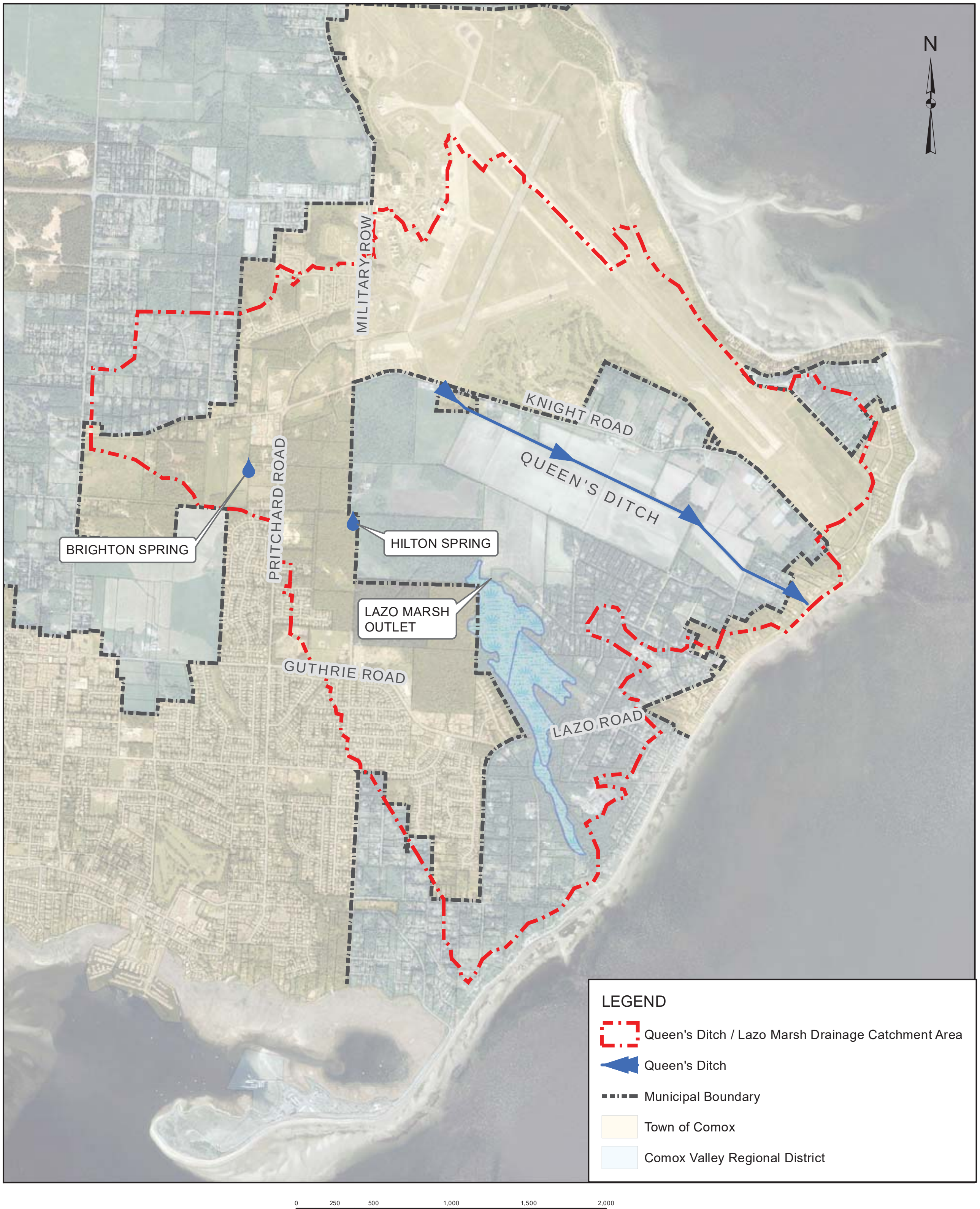
Lowland areas adjacent to the Queen's Ditch have a long history of flooding, this having been the subject of ongoing dialogue between land owners, the Ministry of Transportation and Infrastructure, the Department of National Defence, Town of Comox, and Comox Valley Regional District.

The Queen's Ditch was initially constructed in 1946 as a sewage outfall, disposing of wastewater from CFB Comox. The ditch has, over time, transitioned from a sewage outfall to a storm drainage conduit for the airbase. As development of upland areas proceeded, a formalized drainage network was gradually constructed. Nearly all of these (primarily) open ditches led directly to the Queen's Ditch. Over time, agricultural operations were established on lands adjacent to the ditch, as these lands were drained and converted to arable fields. By approximately 1960, most of the low-lying marsh area adjacent to the ditch had been dewatered and converted to agricultural use.

Discussions with Chris Williams, land owner and farmer of lands which lie at the headwaters of the Queen's Ditch, suggest flooding has occurred regularly from the 1970s to the present. Mr. Williams was not aware of any flooding prior to his occupation of 1271 Knight Road.

Figure 1 Headwaters of the Queen's Ditch

In 1997, flooding of "Woodrow Farms" led to a suit being filed against the Crown, alleging that land development within upland areas of the catchment had caused flooding which, in turn, led to the loss of crops. Fault was eventually attributed equally to the plaintiff and defendant, based on the lack of maintenance of the Ditch, and alteration of natural drainage on private lands.



Queen's Ditch / Lazo Marsh Drainage Improvements

Study Area

SK-1

Rev 0

McElhanney

Visual inspection of lands adjacent to the Queen's Ditch during extended periods of precipitation, indicates surficial flooding remains a frequent occurrence.

Lands down gradient of the study area are largely low-lying agricultural properties. Storm drainage and groundwater table management within the farm lands is manipulated by an extensive series of excavated ditches, culverts, and a number of privately operated flow-regulating structures. The Queen's Ditch travels through these agricultural lands, within an easement in favour of the Department of National Defence.

Figure 2 Seasonal flooding of agricultural lands adjacent to the Queen's Ditch

2.3. Ongoing Stormwater Management Improvement by the Department of National Defence

In 2015 the Department of National Defence (DND) commissioned a study to provide options to mitigate stormwater runoff from southern portions of CFB Comox, that directly or indirectly discharge into the Queen's Ditch. This study included the preparation of on-base drainage system mapping, and hydraulic models of the DND stormwater collection system, and the Queen's Ditch. This information was used to assess the feasibility, and efficacy, of a number of mitigating "tools" that could be utilized by DND. Three general types of improvements were considered, including:

- The construction of new stormwater detention ponds, and/or the expansion of existing ponds. This option was, through consultation with DND, determined to provide the greatest cost/benefit of the options analyzed, when consideration was given to maintaining ongoing base operations with minimal disruption, physical (site) constraints, and operation and maintenance requirements.
- Re-direction of outfalls away from the Queen's Ditch. Prior to development of the CFB Comox site, some of the lands that now drain to the Queen's Ditch were believed to have drained north to the Little River catchment, or directly over the Kye Bay Bluffs. This redirection of runoff has increased the land area tributary to the Queen's Ditch, to a degree, and exacerbates the high (peak) runoff rates that enter the Queen's Ditch.

  Although technically feasible to redirect several of the larger outlets from the base to the north, senior DND staff were not in favour of disrupting the airfields to construct the very large, and very deep storm drains required under this option.

- Conveyance Management. Options including constructing a parallel piped drainage, intercepting flows up to a 1:100 year return rainfall event, and conveying directly to the ocean, upgrading (widening and deepening) the existing Queen's Ditch, and managed retreat were investigated. It was ultimately decided that any off-base improvements would be deferred, as presently available funding was mandated to be spent on Federal lands.

DND has undertaken hydraulic modeling to determine peak runoff rates and flood water extents around the Queen's Ditch, with its preferred mitigating measures implemented (construction of three new detention ponds and the expansion of a fourth pond). The following observations of system performance have been made:

- Outflows from those portions of the CFB Comox site that were redirected to detention ponds were mitigated to 1:10 year, predevelopment levels. Although actual attenuated runoff rates are less than the 1:100 predevelopment levels initially targeted, significant reductions in peak runoff were achieved within those subcatchments that could be directed to new detention ponds.
- A slight reduction in flooding of the lowland areas was achieved by constructing the proposed detention ponds. This modest reduction in flood extents was only noted during rainfall events less intense than the Mean Annual Rainfall (MAR) (approximately 2mm/hr, for 24 hours).

Construction of three of the four proposed DND detention ponds will be complete in 2017. The fourth proposed pond is expected to be constructed in the near future, pending budget and regulatory approvals.

Modeling undertaken as part of this study assumes that DND's proposed detention ponds have been constructed, and are functioning as intended.

3. Drainage System and Catchment Mapping

MCSL has prepared overall drainage system mapping of the lowland study area utilizing data acquired via several sources, including:

- Data provided by the Department of National Defence.
- Topographic survey completed by MCSL in 2017.
- Visual inspections, and site reconnaissance.
- Input from CVRD Parks Staff.
- Input from existing land owners within, or adjacent to, the study area.
- Topographic survey and Lidar data, already in hand.

The mapping produced herein is intended to assist in the determination of major flow pathways/conduits within the drainage system, to allow for system modeling and evaluation of drainage improvement options. The drainage system mapping is not intended to be exhaustive, but rather to identify those network components having the greatest degree of impact/influence on flooding within the lowland areas.

In order to determine the hydraulic capacity of major drainage system components, culverts, pipes, ditches and other features were physically measured by field personnel at representative points within the system.

MCSL drawing SK-2, overleaf, contains an overview of drainage system routing within the study area.

4. Land Use Assessment

It was agreed amongst the project team that, in the absence of flow monitoring data of sufficient quality and duration to accurately predict rainwater runoff at various points within the catchment, percent impervious would be a reasonable proxy for surface runoff. This method of runoff estimation is not as accurate as flow monitoring utilizing continuous data logging, collected at multiple points within the drainage area. However, it does provide a reasonable starting point for analysis.

4.1. Land Use Mapping and Percent Impervious Calculation

Orthophoto imagery was utilized to create overall land use mapping throughout developed portions of the Queen's Ditch/Lazo Marsh drainage. Based on existing Official Community Plan (OCP), zoning designations, and observations of current development conditions, this mapping was delineated into drainage subcatchments, and further segregated into similar usage (and therefore percent impervious).

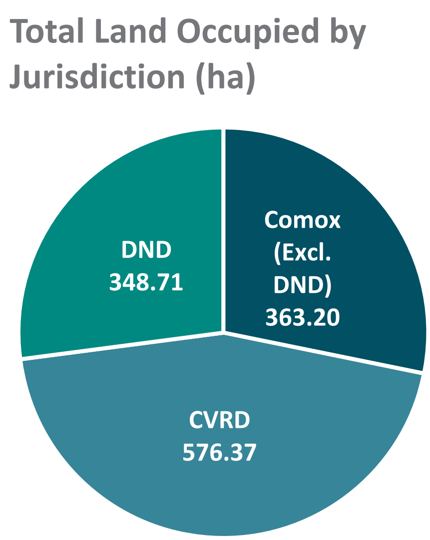


Figure 3

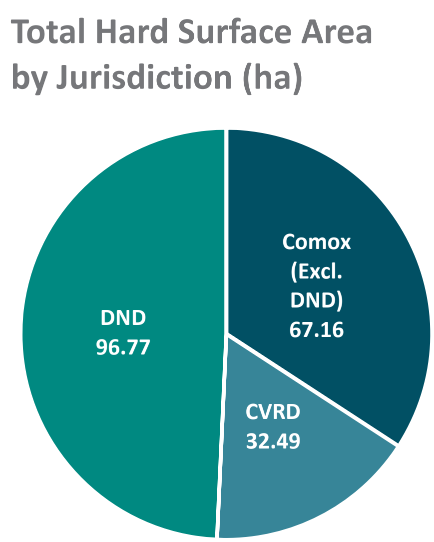
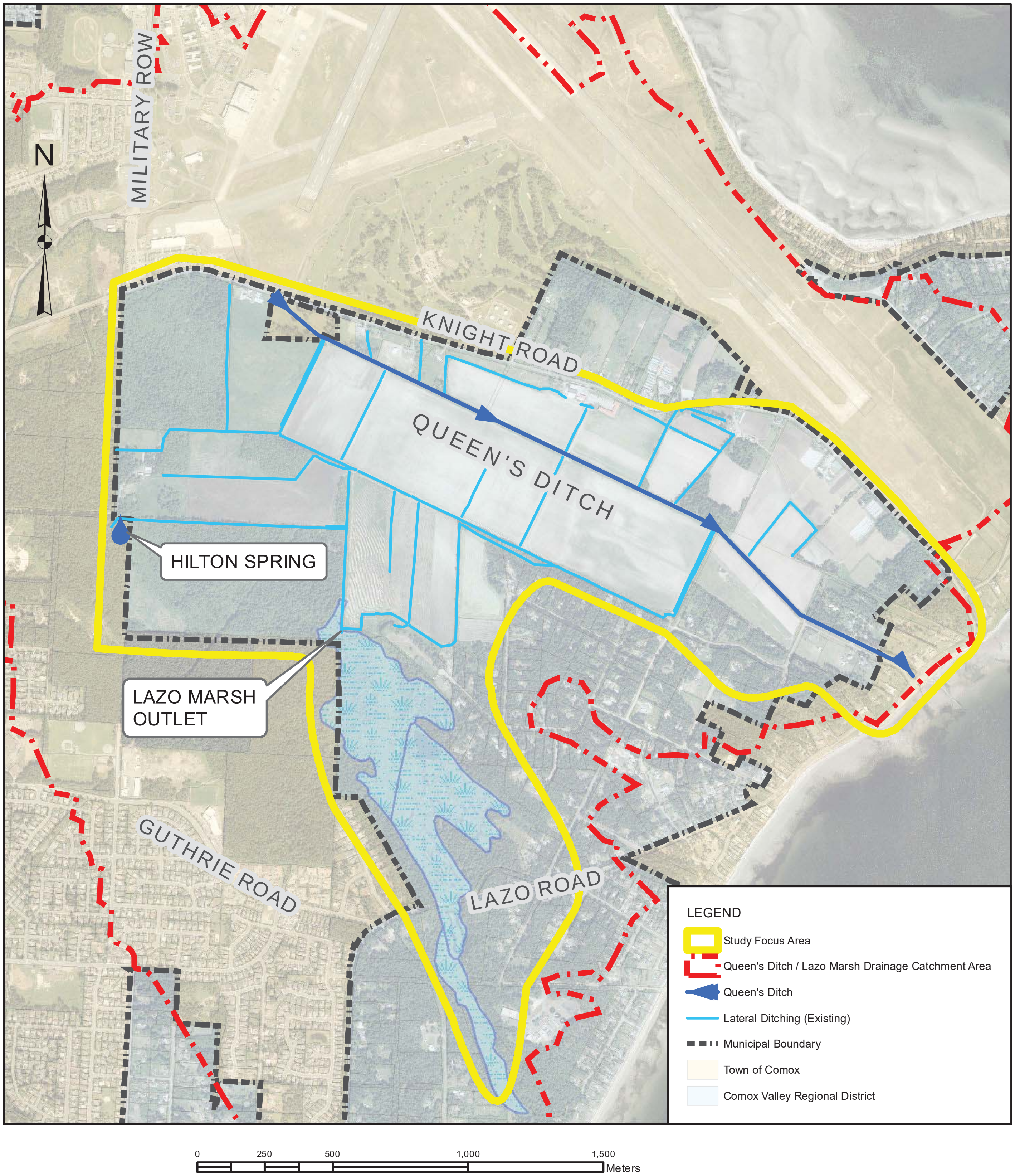


Figure 4

Representative land uses/neighbourhoods were sampled to determined their respective percent impervious. The process utilized in this exercise was similar to that used in the NE Comox Neighborhood Stormwater Management Plan.

Appendix A contains a number of figures that were used throughout the catchment to manually measure hard surfaced areas, i.e., rooftop, asphalt, concrete and other improvements, in order to



Queen's Ditch / Lazo Marsh Drainage Improvements

Study Focus Area and Drainage Network Overview

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SK-2

Rev 0

provide a representative numeric value for each specific land use observed. This information will, in addition to providing an initial basis for flow apportionment between jurisdictions, inform the hydraulic model developed to evaluate drainage system improvement options. More specifically, land use data (hard surfaced areas) has been used to determine initial abstractions (the volume of rainwater that is lost to depression storage and evapotranspiration), CN numbers, drying time, zero impervious routing, catchment width (overland flow length and specific pathways within subcatchments), Manning's "n" value for overland conveyance, etc.

Drawing SK-3, overleaf, contains subcatchment boundary mapping, present-day land use, and points of connection to the Queen's Ditch System.

4.2. Percent Impervious Calculation

Present-Day, and longer term (Official Community Plan) land use/development conditions within the Queen's Ditch catchment, have been reviewed, and summarized in the following **Figures 5 to 10**:

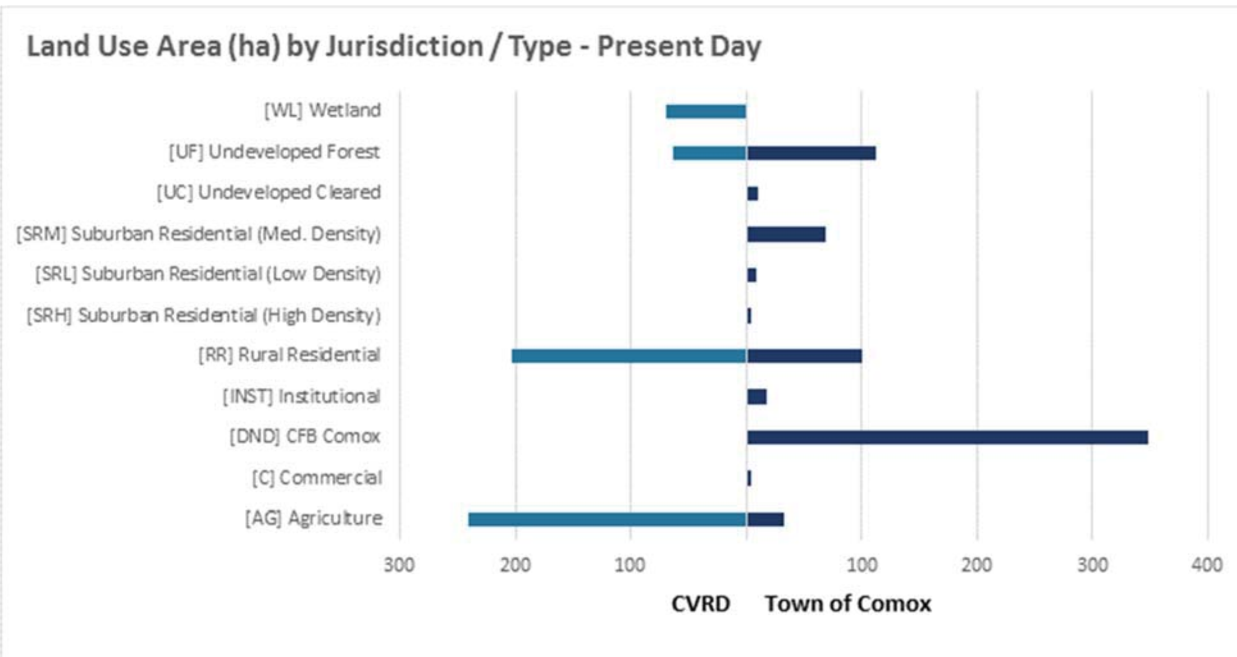
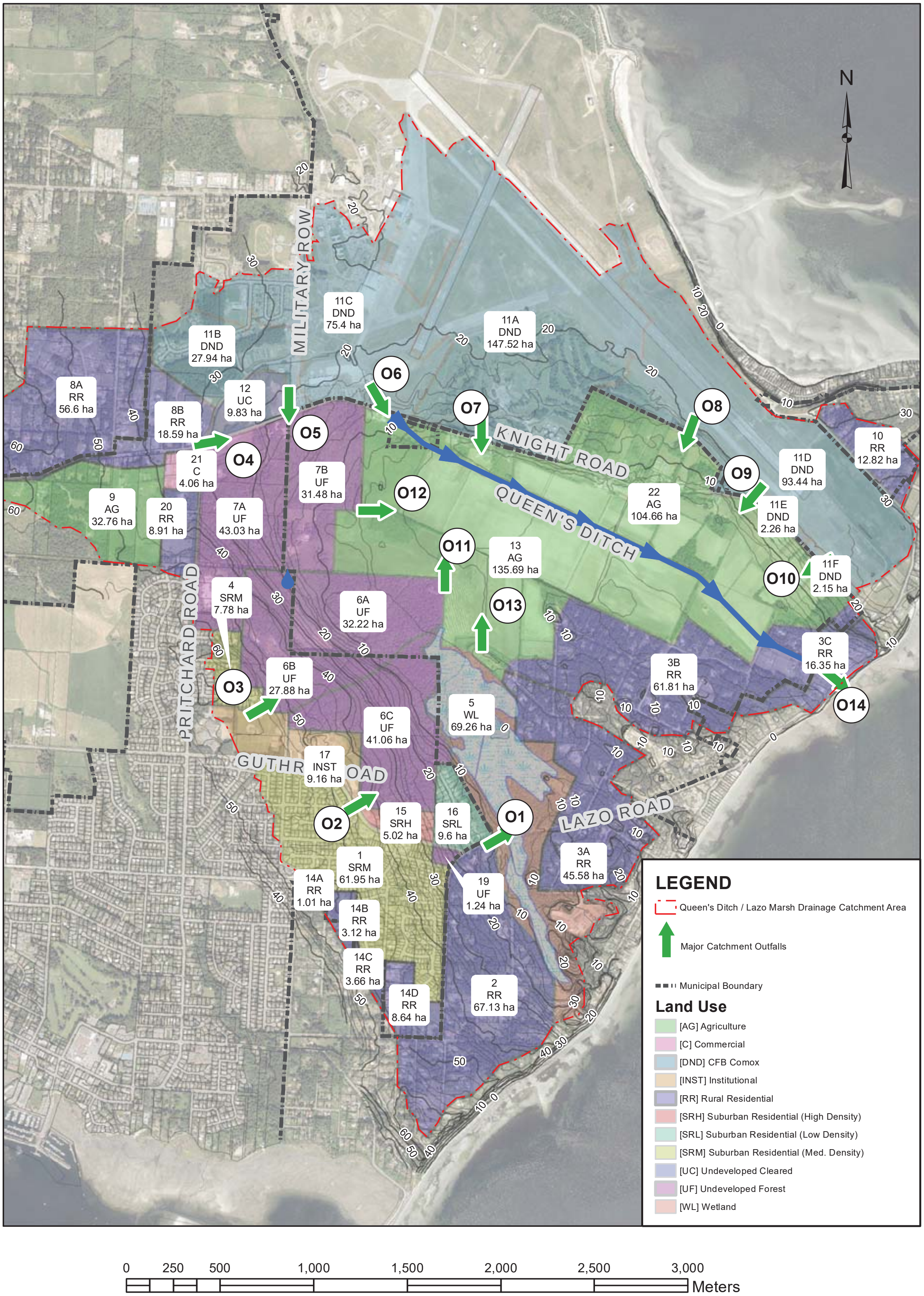


Figure 5



Queen's Ditch / Lazo Marsh Drainage Improvements

Land Use & Subcatchments

McElhanney

SK-3

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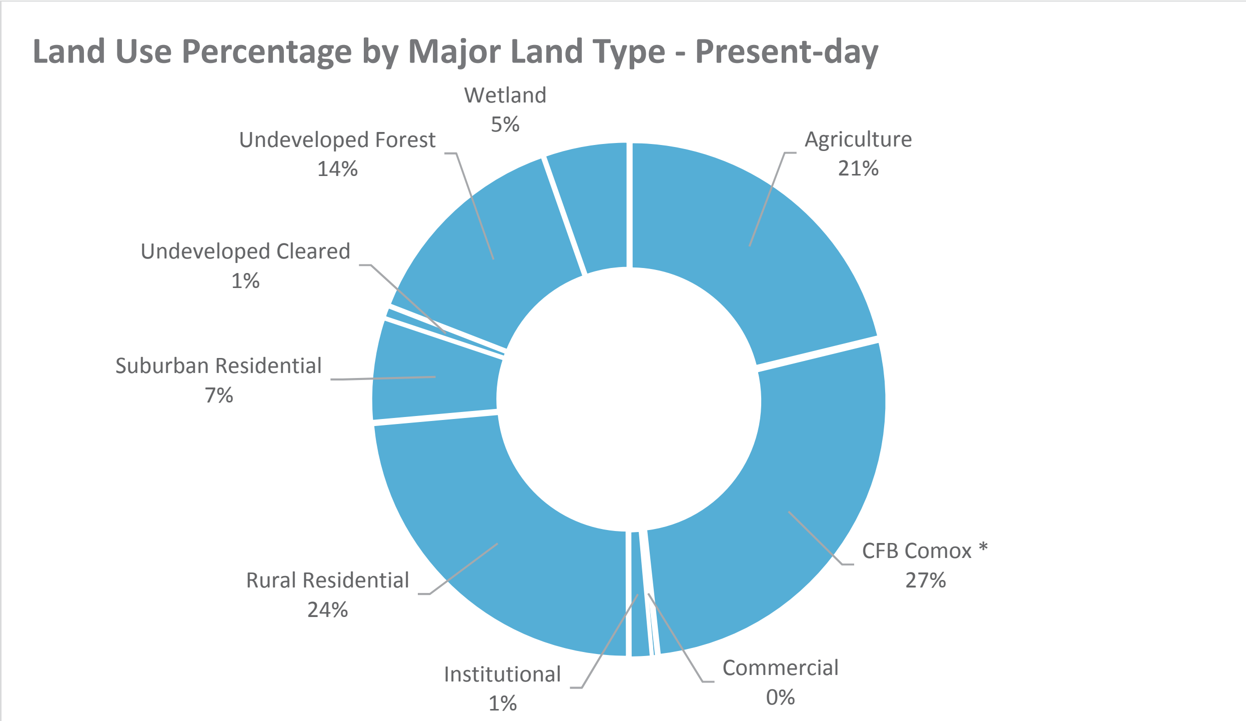
Land Use Percentage by Major Land Type - Present-day
Wetland
5%
Agriculture
21%
Undeveloped Forest
14%
Undeveloped Cleared
1%
Suburban Residential
7%
CFB Comox *
27%
Rural Residential
24%
Institutional
1%
Commercial
0%

Figure 6

Subcatchment Hard Surface / Impervious Values - Present-day

Subcatchment ID	Jurisdiction	Land Use Type	Subcatchment Area [ha]	Hard Surface Area [ha]	Hard Surface [%]
1	Comox	Suburban Residential (Med. Density)	61.95	33.45	54
2	CVRD	Rural Residential	67.13	10.74	16
3A	Comox	Rural Residential	45.58	7.29	16
3B	CVRD	Rural Residential	61.81	9.89	16
3C	Comox	Rural Residential	16.35	2.62	16
4	Comox	Suburban Residential (Med. Density)	7.78	4.20	54
5	CVRD	Wetland	69.26	0.00	0
6A	CVRD	Undeveloped Forest	32.22	0.00	0
6B	Comox	Undeveloped Forest	27.88	0.00	0
6C	Comox	Undeveloped Forest	41.06	0.00	0
7A	Comox	Undeveloped Forest	43.03	0.00	0
7B	CVRD	Undeveloped Forest	31.48	0.00	0
8A	CVRD	Rural Residential	56.60	9.06	16
8B	Comox	Rural Residential	18.59	2.97	16
9	Comox	Agriculture	32.76	0.00	0
10	CVRD	Rural Residential	12.82	2.05	16
11A	Comox	CFB Comox *	147.52	39.68	27
11B	Comox	CFB Comox *	27.94	7.33	26
11C	Comox	CFB Comox *	75.40	34.83	46
11D	Comox	CFB Comox *	93.44	14.93	16
11E	Comox	CFB Comox *	2.26	0.00	0
11F	Comox	CFB Comox *	2.15	0.00	0
12	Comox	Undeveloped Cleared	9.83	0.00	0
13	CVRD	Agriculture	135.69	0.00	0
14A	CVRD	Rural Residential	1.01	0.16	16
14B	Comox	Rural Residential	3.12	0.50	16
14C	CVRD	Rural Residential	3.66	0.59	16
14D	Comox	Rural Residential	8.64	1.38	16
15	Comox	Suburban Residential (High Density)	5.02	3.06	61
16	Comox	Suburban Residential (Low Density)	9.60	2.69	28
17	Comox	Institutional	9.16	2.93	32
18	Comox	Institutional	8.66	2.77	32
19	Comox	Undeveloped Forest	1.24	0.00	0
20	Comox	Rural Residential	8.91	1.43	16
21	Comox	Commercial	4.06	1.87	46
22	CVRD	Agriculture	104.66	0.00	0
			1288.27	196.42	

** DND supplied data*

Hard surface defined as asphalt, concrete, and packed gravel surfaces

Figure 7

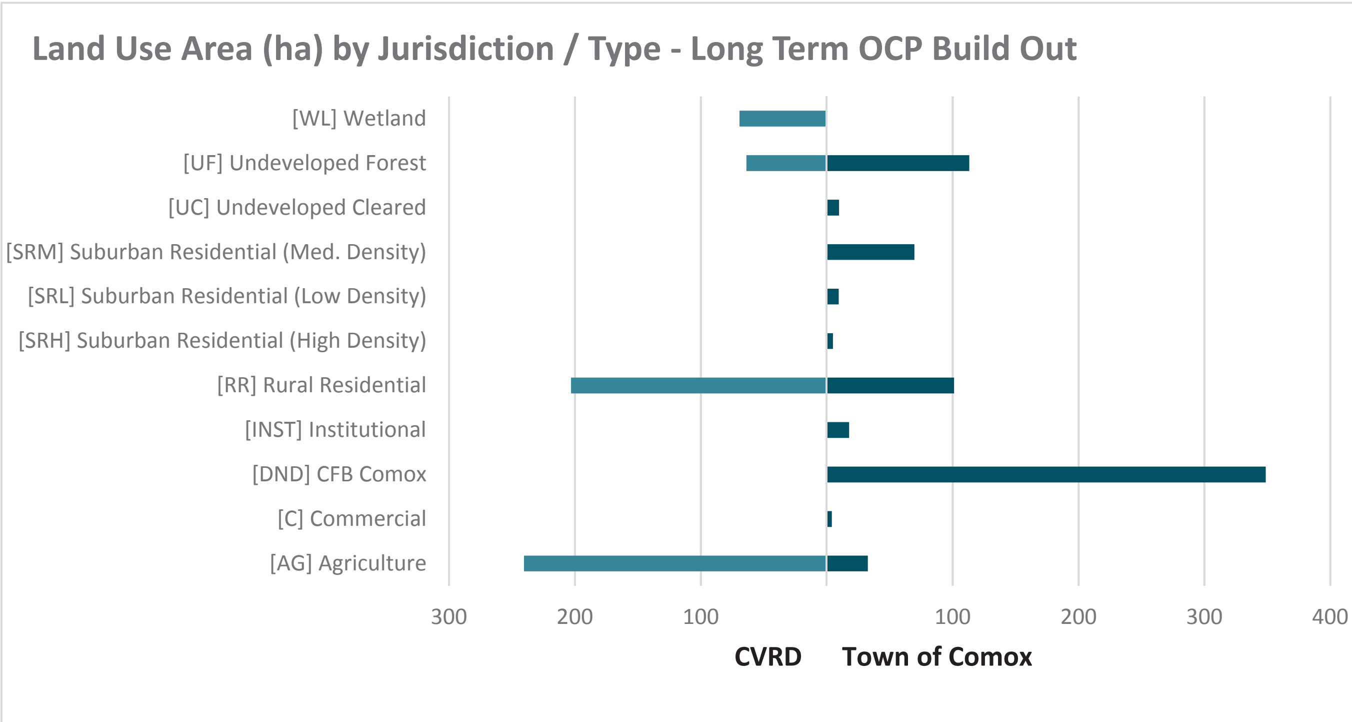

Figure 8

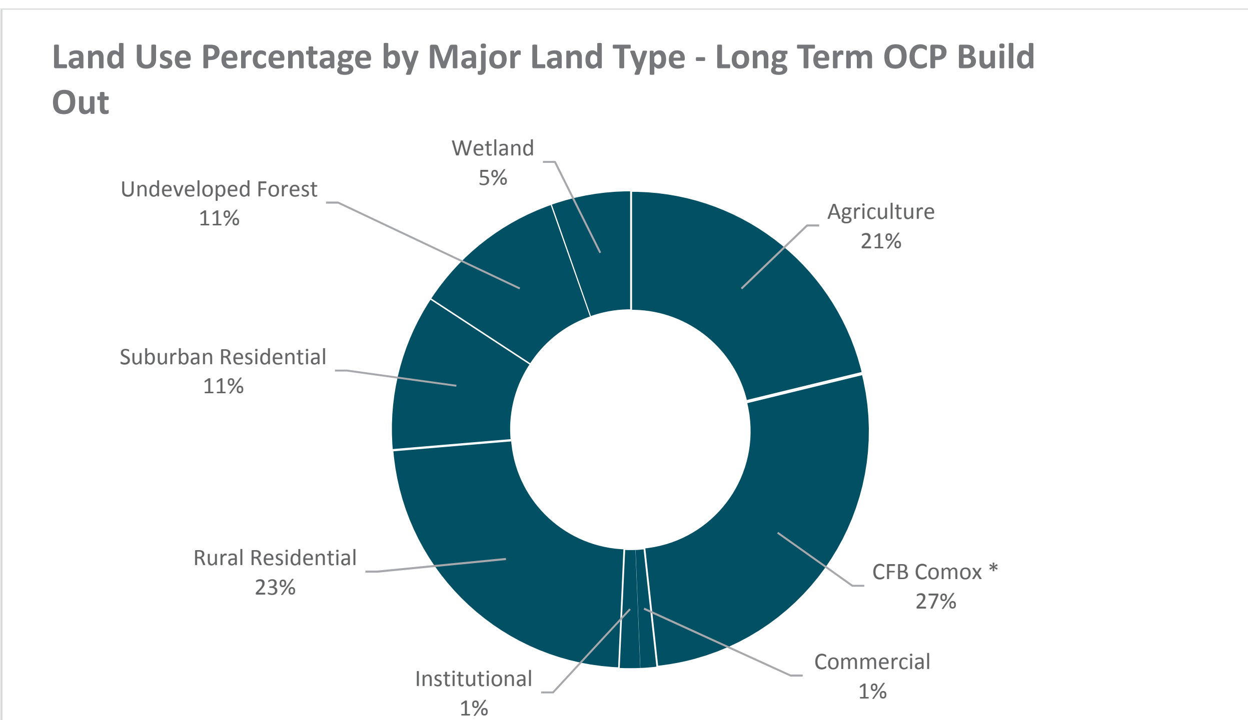

Figure 9

Subcatchment Hard Surface / Impervious Values - Long Term OCP Build Out (Assumed 20 Year Horizon)

Subcatchment ID	Jurisdiction	Land Use Type	Subcatchment Area [ha]	Hard Surface Area [ha]	Hard Surface [%]
1	Comox	Suburban Residential (Med. Density)	61.95	33.45	54
2	CVRD	Rural Residential	67.13	10.74	16
3A	Comox	Rural Residential	45.58	7.29	16
3B	CVRD	Rural Residential	61.81	9.89	16
3C	Comox	Rural Residential	16.35	2.62	16
4	Comox	Suburban Residential (Med. Density)	7.78	4.20	54
5	CVRD	Wetland	69.26	0.00	0
6A	CVRD	Undeveloped Forest	32.22	0.00	0
6B	Comox	Undeveloped Forest	27.88	0.00	0
6C	Comox	Undeveloped Forest	41.06	0.00	0
7A	Comox	Suburban Residential (High Density)	43.03	23.24	54
7B	CVRD	Undeveloped Forest	31.48	0.00	0
8A	CVRD	Rural Residential	56.60	9.06	16
8B	Comox	Rural Residential	18.59	2.97	16
9	Comox	Agriculture	32.76	0.00	0
10	CVRD	Rural Residential	12.82	2.05	16
11A	DND	CFB Comox *	147.52	39.68	27
11B	DND	CFB Comox *	27.94	7.33	26
11C	DND	CFB Comox *	75.40	34.83	46
11D	DND	CFB Comox *	93.44	14.93	16
11E	DND	CFB Comox *	2.26	0.00	0
11F	DND	CFB Comox *	2.15	0.00	0
12	Comox	Commercial	9.83	4.52	46
13	CVRD	Agriculture	135.69	0.00	0
14A	CVRD	Rural Residential	1.01	0.16	16
14B	Comox	Rural Residential	3.12	0.50	16
14C	CVRD	Rural Residential	3.66	0.59	16
14D	Comox	Rural Residential	8.64	1.38	16
15	Comox	Suburban Residential (High Density)	5.02	3.06	61
16	Comox	Suburban Residential (Low Density)	9.60	2.69	28
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18	Comox	Institutional	8.66	2.77	32
19	Comox	Undeveloped Forest	1.24	0.00	0
20	Comox	Suburban Residential (Med. Density)	8.91	1.43	16
21	Comox	Commercial	4.06	1.87	46
22	CVRD	Agriculture	104.66	0.00	0
			1288.27	224.18	

** DND supplied data*

Hard surface defined as asphalt, concrete, and packed gravel surfaces

(yellow box) - Area Changed based on OCP Land Use

Figure 10

5. Desired Level of Service to be Achieved

Through discussions with the Comox Valley Regional District and the Public Advisory Committee (PAC), expectations for the desired level of service provided by the Queen's Ditch and lowland area drainage system were established. It was agreed that initial modeling and analysis would be carried out based on the following parameters:

- Residential properties should ideally not flood during rainfall equivalent to a 1:10 year return, 24-hour rainfall event. Nuisance flooding, or ponding may be acceptable within landscaped areas, yards, etc., but residences should not be inundated with flood waters during rainfall events with a recurrence interval of less than 1:10 years. This level of service is typical of that provided by many modern, municipally operated storm drainage functions. This implies that all conveyance system components, including piping, ditching, culverts and bridges, should be capable of conveying runoff from a 1:10 year design rainfall event.
- Agricultural lands, including fields, and improvements necessary to carry out agricultural activities (barns, sheds, outbuildings, etc.) should be subject to the Agricultural and Rural Development Subsidiary Agreement (ARDSA) requirements, also known as the "Agricultural Drainage Criteria". Briefly, these requirements note that agricultural drainage systems should:
    i. Be capable of removing runoff from the 10-year, 5-day storm, within 5 days during the dormant period (November 1 to February 28).
    ii. Be capable of removing runoff from the 10-year, 2-day storm, within 2 days during the March 1 to October 31 growing period.
    iii. Be capable, between storm events, and in periods where drainage is required, of maintaining base flows in channels at a minimum of 1.2m below field elevation.
    iv. Be sized to convey both base flows, and design storm events.

6. Hydraulic Model Development and System Response Modeling

Hydraulic Modeling Software and Approach

A rainfall runoff and conveyance system model was developed utilizing PCSWMM software. PCSWMM, developed by Computational Hydraulics International (CHI), uses the computational engine from the US Environmental Protection Agency's Stormwater Management Model, widely held as an industry standard hydrologic and hydraulic simulation platform. PCSWMM enhances the base software with additional features and flexibility for a more efficient user interface. The software's primary purpose is simulating stormwater runoff and conveyance, but also allows the user to calculate backwater effect, and flooding via a "2-Dimensional" software add-in module.

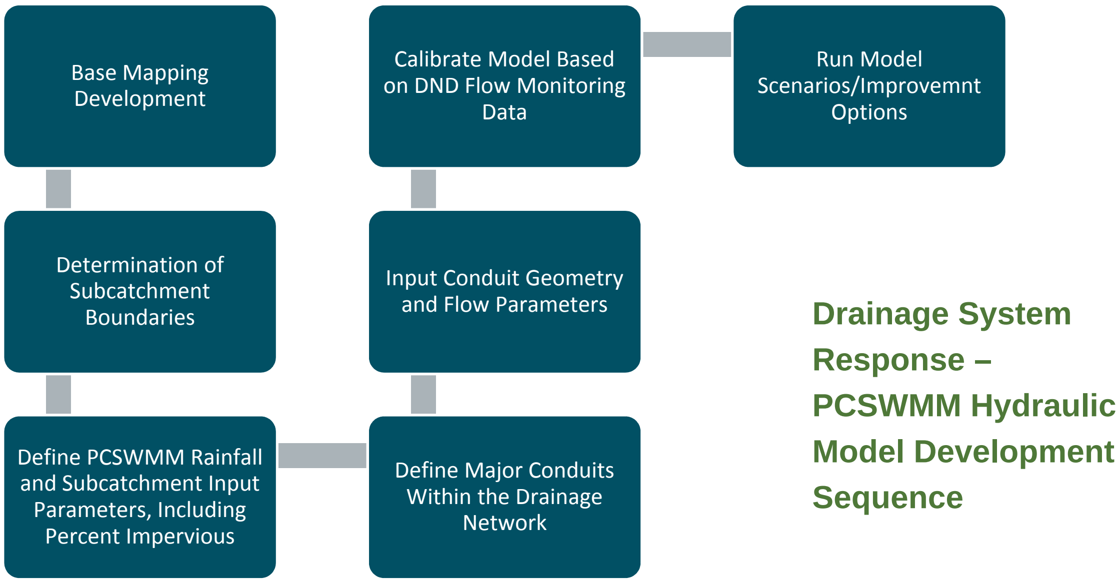


Figure 11

In order to estimate the existing performance of the Queen's Ditch drainage network, it is necessary to understand with some degree of certainty the peak surface and groundwater flows that are intercepted and conveyed by the Queen's Ditch System. To this end, data from a number of sources was compiled and reviewed, including:

- Flow monitoring data in hand from the Department of National Defence, including data recorded at major DND outfalls/points of connection to the Queen's Ditch System, and at the Queen's Ditch outlet at Point Holmes.
- Visual observations of typical wet weather flow conditions at key points within the system.
- Flow data collected by MCSL during past drainage studies in the catchment.
- Assessment of hydraulic constraints within conduits discharging into the system. I.e., a pipe of given diameter and slope has a maximum capacity that can be used as an upper bound flow "check".
- Measured percent impervious of the various subcatchments within the Queen's Ditch Catchment, as discussed in Section 4.

Sea Level, Storm Surge, Rainfall and Climate Change Modeling Parameters

Tera Tech, in its June 2014 report entitled "Functional Plan for Queen's Ditch", prepared on behalf of the Department of National Defence, has determined that the 200-year astronomical high tide at the Queen's Ditch outfall should be set at 2.34m geodetic, inclusive of allowance for storm surge. Past studies and modeling of the Queen's Ditch have utilized this value. For consistency, MCSL recommends that this value be held for modeling of present-day conditions in the current study.

The 2014 Tetra Tech report has also recommended that further analysis within the Queen's Ditch area account for anticipated rise in sea level, predicted at this time to reach 1.0m above present-day maximums by year 2100. Although similar modeling recently undertaken by the Department of National Defence has excluded sea level rise, the CVRD has requested that sea level rise be considered in hydraulic modeling utilized to test drainage network improvement options. Present-day plus sea level rise model scenarios have therefore utilized a 200-year astronomical high tide plus storm surge elevation of 3.34m geodetic.

The design (modeled) rainfall event utilized in this analysis is a 10-year return, SCS Type 1A rainfall distribution, with Climatic data obtained from CFB Comox. The SCS Type 1A design storm is a synthetic design rainfall event commonly utilized in Pacific Coastal regions for the design of new stormwater infrastructure. The rainfall used in the modeling exercise was derived from the latest intensity duration frequency (IDF) curve for the Comox airport weather station. The 1:10 year SCS Type 1A storm is characterized by a daily rainfall of approximately 80mm and a peak intensity of 12.8mm/hr. The US Soil Conservation Service SCS Type 1A design storm is based on historic rainfall data recorded on the west coast of Washington and Oregon States. As a result, the SCS Type 1A is a good approximation of coastal British Columbia rainfall.

In order to more accurately model system response to a discrete rainfall event, the model was "primed" by running a 24-hour rainfall event, followed by 9 hours of "drying time", before the onset of the design rainfall event. This process allows modeled soil to become saturated, and more realistically simulate real world initial abstractions (depression storage and evapotranspiration), and infiltration.

Table 1 indicates modeled (Q_{10}) peak flow rates at the outfall locations identified on **Sketch SK-3** (noted as 01 through 014).

Q10 Modeled Peak Runoff Rates	
Outlet Number	Peak Runoff Rates (L/s)
O1	412
O2	1391
O3	288
O4	801
O5	409
O6	2114
O7	1570
O8	1700
O9	61
O10	67
O11*	614
O12*	200
O13*	866
O14*	5580

*Peak flow rates are governed by flooding in QD

Options Analysis – Model Results

Five specific drainage network improvement options have been considered to decrease flooding frequency and duration within the lowland areas. These options were selected as they provide a broad cross section of the potential options available to the CVRD. Capital construction costs for each option, as well as the anticipated performance and relative benefits and detractors of each option, have been discussed. Provided below is a summary of modeled scenarios:

Model Scenario 1-1, Present-day/Existing Conditions– System Performance

Present-day drainage system function has been modeled to determine existing system performance, and to set a base line to allow for evaluation of improvement option efficacy. **Drawing Plan 1-1**, located in **Appendix B**, contains a PCSWMM generated (plan view) representation of conduit (ditch or channel) capacity. PCSWMM identifies "flooding", that is loss of rainwater from the defined conduit system, as a blue coloured node. Those conduits not experiencing flooding, i.e., operating within their modeled capacity, are shown in green.

The Queen's Ditch and many of its lateral connections are shown to flood under present-day conditions. These model results corroborate first hand accounts provided by land owners in the area.

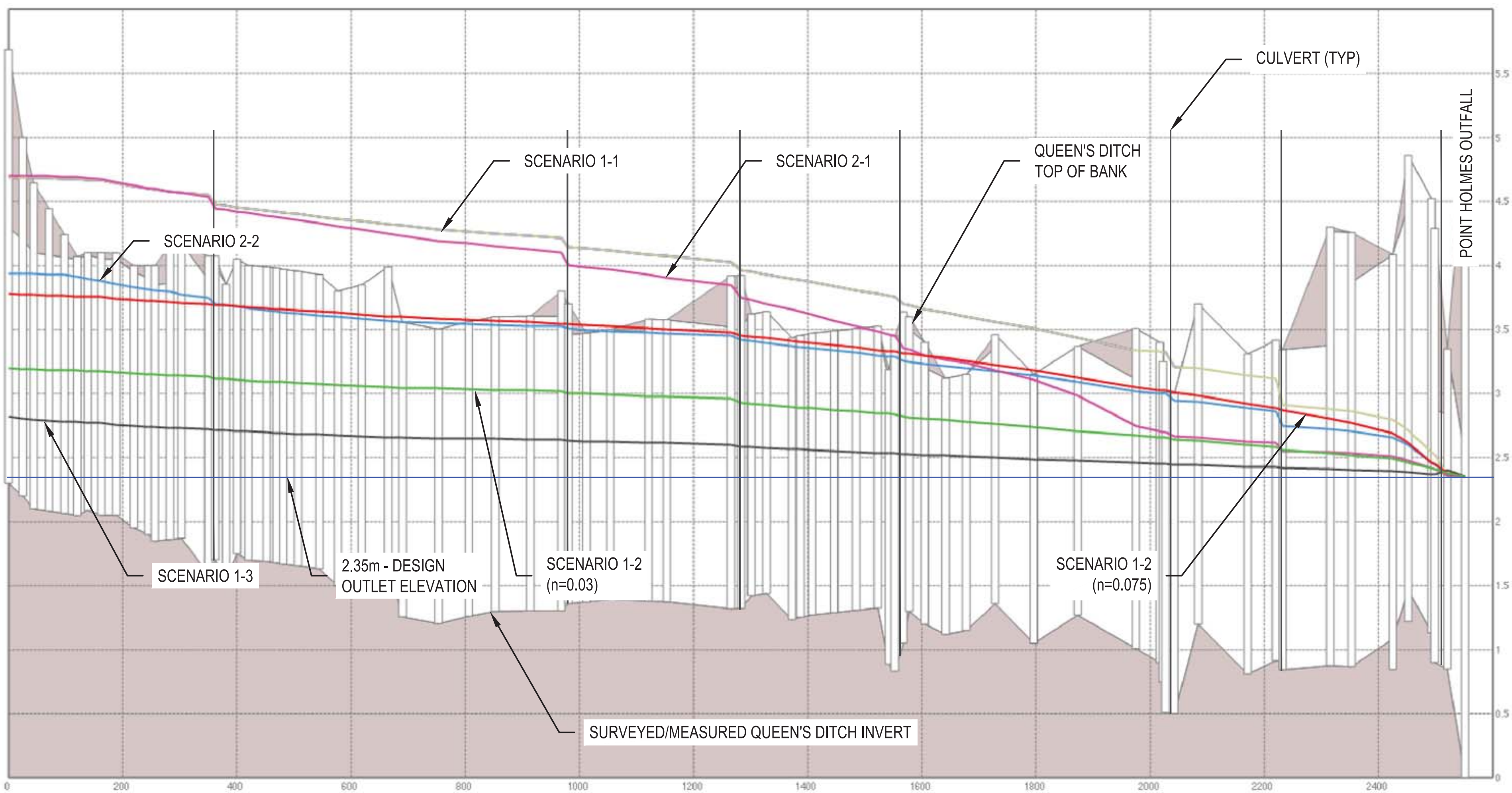
Drawing Profile-1 and Profile -2, overleaf, are PCSWMM generated hydraulic profiles of the Queen's Ditch. These profiles include a number of model scenarios, including present-day (Scenario 1.1). Key observations of present-day model results include:

- The hydraulic grade of the Queen's Ditch as modeled exceeds the top-of-bank over most of the alignment, during a 1:10 year return rainfall event.
- Flooding begins at a point approximately 550m upstream of the Pt. Holmes outfall.
- A number of flow restrictions exist within the Queen's Ditch; these generally correspond to undersized culverts.
- The modeled top-of-bank was based on survey data collected in early 2017. It was determined during the collection of this data that much of the land surrounding the Queen's Ditch was lower in elevation than the ditch, i.e., the Queen's Ditch is diked.

Improvement Option 1 - Cleaning and Deepening of the Queen's Ditch (Model Scenario 1-2) – System Performance

Model Scenario 1-2 assumed that the Queen's Ditch alignment would be maintained horizontally, but a number of physical improvements would be made to improve hydraulic capacity. Specifically, it was assumed that:

- The base of the Queen's Ditch would be widened to 6m. **Drawing SK-4**, overleaf, indicates the assumed limits of cleaning and deepening.
- Side slopes of the Ditch would be graded at 1 horizontal to 1 vertical.
- All culverts would be removed (it was assumed that existing culverts would be replaced with new culverts of sufficient capacity to ensure no hydraulic restriction occurred).
- Two different channel roughness conditions were modeled; one assumed similar conditions to present-day (no channel lining), the other assumed that a lined section would be utilized (carefully placed and appropriately graded rock or synthetic liner).



Option 1 - Cleaning/Deeping of Existing Ditching Geomerty

Scenario Number	Scenario Decription	Queen's Ditch Geometry	Channel Lineing/Roughness	Queen's Ditch Culverts
1-1	Existing	Existing	Existing (n = 0.075)	Existing Sizes
1-2	Medium	Single X-Section 6m Wide 1:1 Side Slopes	Existing (n = 0.075) Lined (n = 0.03)	Removed Entirely
1-3	Large	Single X-Section 10m Wide 4:1 Side Slopes	Lined (n = 0.03)	Removed Entirely

Option 2 - Interceptor Pipes

Scenario Number	Scenario Decription	Queen's Ditch Geometry	Mannings n in Ditch	Queen's Ditch Culverts	Outlet Configuration
2-1	Lazo Interceptor	Existing	Existing (n = 0.075)	Existing Sizes	Independent of Queen's Ditch
2-2	DND Interceptor	Existing	Existing (n = 0.075)	Existing Sizes	Independent of Queen's Ditch

McElhanney
McElhanney Consulting Services Ltd.
1307 SHOPPERS ROW
CAMPBELL RIVER, B.C. V9W 2C9
PH (250) 287-7799
FAX (250) 287-7662

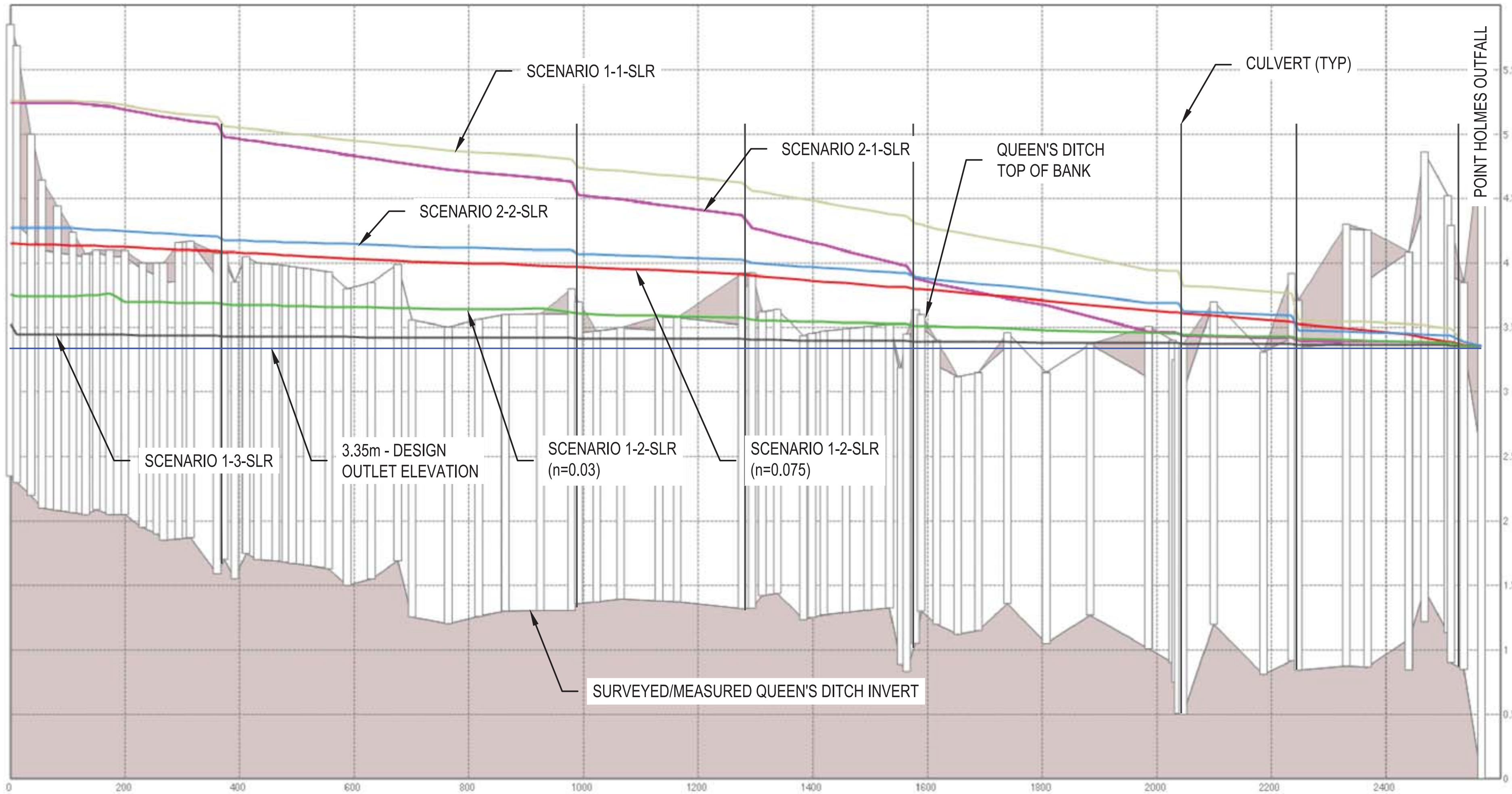
QUEEN'S DITCH HYDRAULIC GRADE
10 YEAR SCS TYPE 1A DESIGN STORM

CVRD LAZO/QD

Drawing No.
PROFILE - 1

DATE : 2017/08/10

Sheet 1 of 2 Revision 1



Option 1 - Cleaning/Deeping of Existing Ditching Geomerty

Scenario Number	Scenario Decription	Queen's Ditch Geometry	Channel Lineing/Roughness	Queen's Ditch Culverts
1-1	Existing	Existing	Existing (n = 0.075)	Existing Sizes
1-2	Medium	Single X-Section 6m Wide 1:1 Side Slopes	Existing (n = 0.075) Lined (n = 0.03)	Removed Entirely
1-3	Large	Single X-Section 10m Wide 4:1 Side Slopes	Lined (n = 0.03)	Removed Entirely

Option 2 - Interceptor Pipes

Scenario Number	Scenario Decription	Queen's Ditch Geometry	Mannings n in Ditch	Queen's Ditch Culverts	Outlet Configuration
2-1	Lazo Interceptor	Existing	Existing (n = 0.075)	Existing Sizes	Independent of Queen's Ditch
2-2	DND Interceptor	Existing	Existing (n = 0.075)	Existing Sizes	Independent of Queen's Ditch

McElhanney

McElhanney Consulting Services Ltd.

1307 SHOPPERS ROW
CAMPBELL RIVER, B.C. V9W 2C9

PH (250) 287-7799
FAX (250) 287-7662

QUEEN'S DITCH HYDRAULIC GRADE

10 YEAR SCS TYPE 1A DESIGN STORM
WITH SEA LEVEL RISE & CLIMATE CHANGE

CVRD LAZO/QD

Drawing No.

PROFILE - 2

DATE : 2017/08/10

Sheet 2 of 2 Revision 1

- Model scenarios were run to replicate (a) present-day high tide plus storm surge, and (b) present-day high tide, plus storm surge, plus sea level rise.
- **Drawing Plan 1-2 (Appendix B**), indicates present-day nodal flooding under scenario 1-2. **Drawing Plan 1-2 SLR** shows modeled nodal flooding under sea level rise conditions.

System Performance Under Improvement Option 1

- Present-day sea level - flooding was observed at several points along the Queen's Ditch with no channel lining. Improvement of the channel by lining resulted in no modeled flooding of the Queen's Ditch.
- Flooding was observed under both channel options (lining or no lining) in the lateral connections to the Queen's Ditch. Many of these lateral connections are believed to have lower top-of-bank elevation than that of the Queen's Ditch. Field elevations adjacent to both the Queen's Ditch and lateral ditching is, in many places, lower than the Queen's Ditch top-of-bank.
- Maintaining groundwater elevations a minimum of 1.2m below surface grade is problematic. With high tide elevations of 2.35m, a minimum ground elevation of 3.55, plus allowance for hydraulic grade would be required throughout agricultural lands. This implies raising of large tracts of farmland would be required.
- The time required to drain agricultural areas of flood waters has not been modeled at this time.
- Sea level rise – extreme flooding was observed under both channel lining options.

Benefits of Improvement Option 1

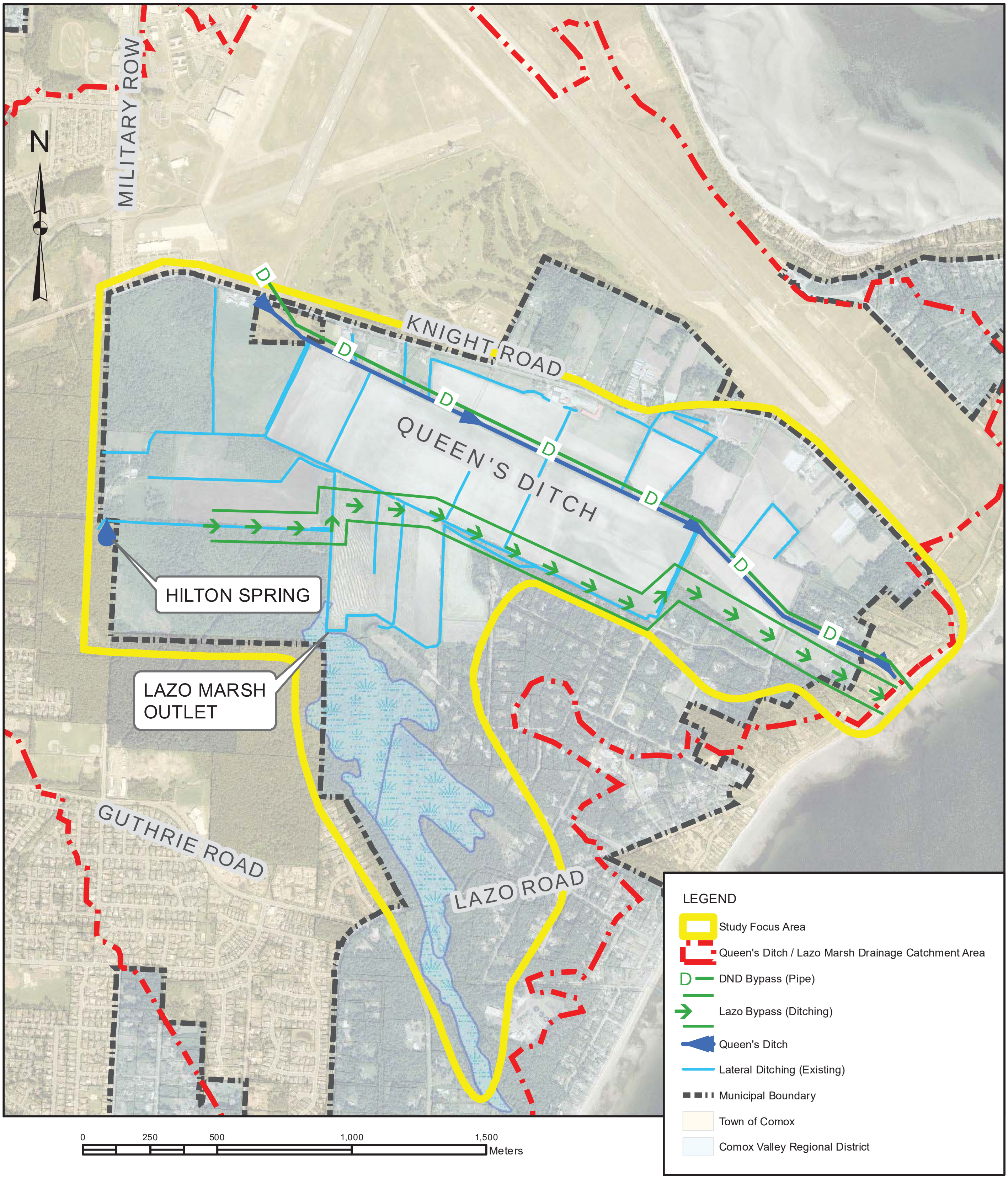
- Simplicity of construction, when channel lining is not required. However, constructing a lined channel section will be moderately difficult, and costly.
- This scenario would not require acquisition of additional lands, easements, or Rights-of-Way.

Detractors of Improvement Option 1

- Environmental approvals (Ministry of Environment, Fisheries and Oceans Canada) could be difficult to obtain. Restoration of habitat will likely be required.
- Regular maintenance of the new channel section will be required to ensure that performance is maintained.
- Does not resolve flooding issues under present-day conditions, without channel lining improvements.
- Neither channel lining option prevents flooding under sea level rise conditions.

Improvement Option 2 - Overflow Channeling/Redirection of Flows (Model Scenario 2-1 & 2-2) – System Performance

Two scenarios were considered that would redirect runoff that would otherwise be tributary to the Queen's Ditch away from the system. These options have been referred to as the "Lazo Marsh bypass" (Model Scenario 2-1), and the "DND bypass" (Model Scenario 2-2). **Drawing SK-5**, overleaf, indicates the general arrangement at the two bypasses.



Queen's Ditch / Lazo Marsh Drainage Improvements

"DND" & "Lazo" Bypass Options

SK-5

Rev 0

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The Lazo Marsh bypass was modeled as an overflow that would not allow the marsh's water level to exceed 4.3m geodetic. A number of routing options exist for the bypass, including:

- Through the lowland agricultural areas, across numerous private properties, to Point Holmes.
- Along Lazo Road, outletting near Point Holmes.
- Directly to the south of the marsh, crossing Curtis Road.

Each of the above route options has specific benefits and challenges. At this stage of investigation, routing feasibility has not been fully confirmed. Should the CVRD wish to pursue redirection of Lazo flows, further analysis will be required.

The "DND bypass" assumes that all flow tributary to the Queen's Ditch originating on CFB Comox would be intercepted and conveyed to Point Holmes, prior to entering the Queen's Ditch. Given the topography, and constraints with land tenure, if this option were to be pursued, it would likely require that a pipe interceptor be constructed. Preliminary modeling indicates that sufficient elevation head exists to convey stormwater from DND under modeled climate change, and present-day tidal/sea level rise conditions.

Drawing Plan 2-1 and **Plan 2-2 (Appendix B)** indicate flooding extents under present-day sea level conditions; **Drawings Plan 2-1 SLR** and **Plan 2-2 SLR** show flooding under sea level rise conditions.

System Performance Under Improvement Option 2 – Lazo Bypass

- Model results indicate that the Lazo Marsh bypass option moderately decreases the hydraulic grade of the Queen's Ditch, but does not alleviate flooding, under present-day conditions.
- Flooding resulting from sea level rise is significantly more extensive than present-day sea levels. **Drawings Plan 2-1**, and **Plan 2-1 SLR** indicate modeled (conveyance system) flooding extents under present-day and long-term sea level conditions.

System Performance Under Improvement Option 2 – DND Bypass

- Model results indicate a significant reduction in hydraulic grade within the Queen's Ditch resulting from the construction of the DND bypass. Flooding is still present, although it is generally limited to lateral connections to the Queen's Ditch.
- Construction of the DND bypass does not alleviate flooding when sea level rise is accounted for. Refer to **Drawings Plan 2-2** and Plan **2-2 SLR**.

Benefits of Improvement Option 2

- The DND bypass could provide a significant reduction in flooding of the lowland areas adjacent to the Queen's Ditch.
- It may be possible to utilize the existing Queen's Ditch easement, for DND bypass construction. Long-term upgrade requirements for the Queen's Ditch should be confirmed, to ensure that ample easement width exists for open channel improvements.
- Initial modeling indicates that conveyance within the DND bypass would not be adversely affected by sea level rise (assuming a pressure pipe conduit is utilized).
- Simplistic infrastructure, operation and maintenance requirements are not onerous.

- It may be possible to leverage funding from the Federal Government for design and construction of the DND Bypass.

Detractors of Improvement Option 2

- Some ROW or land acquisition would likely be required for either bypass option.
- The Lazo bypass is minimally effective in reducing flooding.
- Each Lazo bypass routing option has challenges to be resolved:
    - Across the lowland farm lands – the alignment would need to cross many properties with no existing ROW; the drainage would need to avoid existing open channels/ditching, minimal grade is available, etc.
    - Along Lazo Road – this 1.9 km alignment has minimal grade, and would require very large conduit; to reduce energy loss in the pipe, inlet structures would need to be large, to allow for escape of water from the marsh, without increasing the standing water level.
    - South under Curtis Road – this alignment is relatively short, but would need to cross a height of land that is approximately 20m higher than the marsh.
- The costs of constructing the DND bypass are high, and would require coordination with the federal government.
- Both bypass options would require significant environmental consideration and approvals.

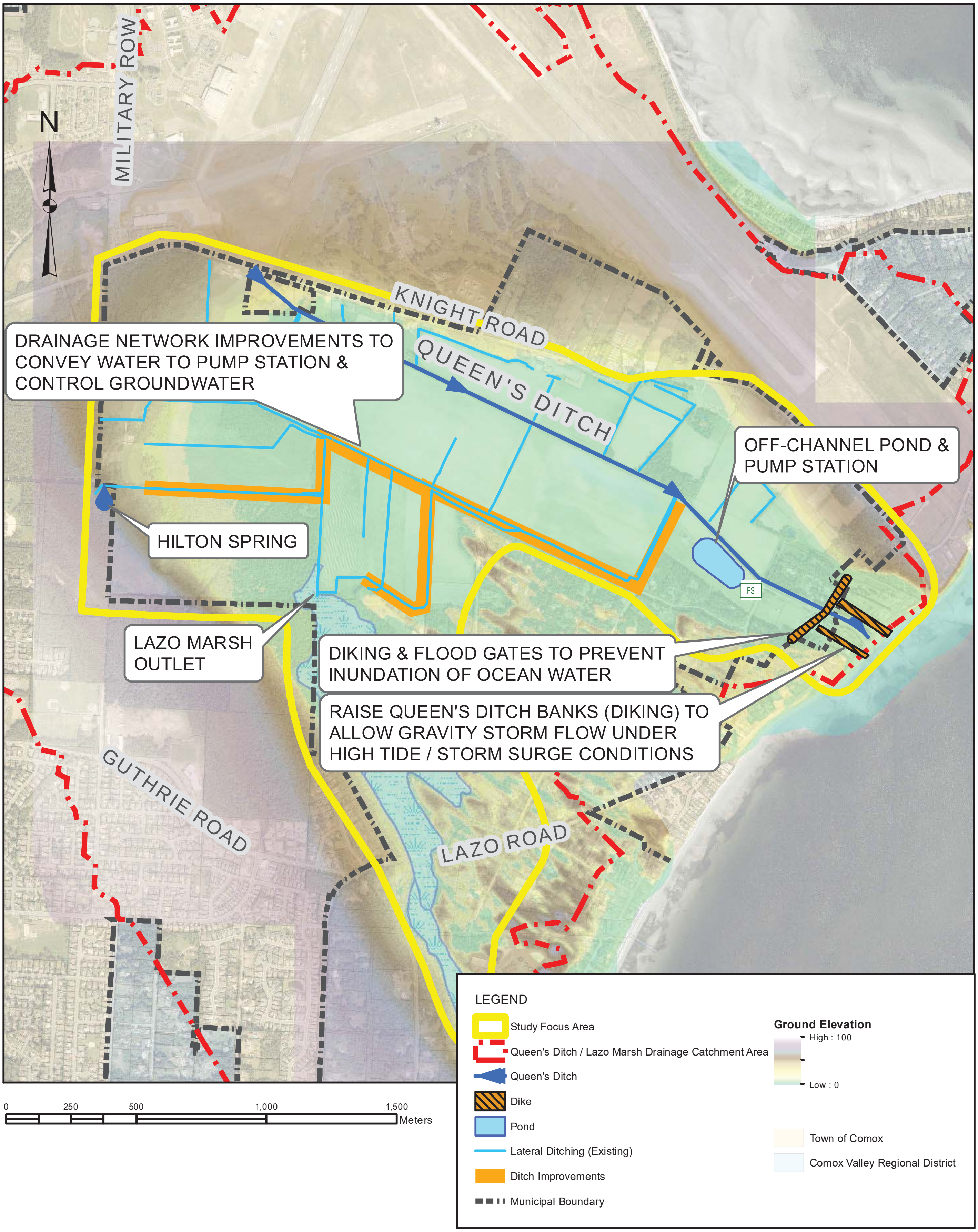
Improvement Option 3 - Diking and Pumping of Lowland Areas – System Performance

Consideration has also been given to the installation of flood protection diking and mechanical pump systems to alleviate flooding in lowland areas surrounding the Queen's Ditch. It would be desirable to utilize gravity drainage within the catchment to the extent possible, only calling upon mechanical pumps when tidal conditions and/or rainfall intensity overwhelm the drainage system. **Drawing SK-6,** overleaf, schematically indicates the potential arrangement of this improvement option. Conceptually, a dike and pump drainage system to service the Queen's Ditch area would require the following:

- Diking of any points of intrusion of seawater (likely limited to the discharge at Point Holmes, but to be confirmed).
- Installation of flood gates at the Point Holmes outfall.
- Construction of an "off-channel" storage facility that could be utilized to lower groundwater, and provide a reservoir from which to pump.
- Construction of a stormwater pump station sized appropriately to lift a (present-day modeled) 10-year/ 24-hour flow of approximately 6m^3/s.
- Drainage network improvements upstream of the proposed pumpstation, to ensure that runoff is allowed to drain freely to the storage facility/ pumpstation.

System Performance

Model scenarios were not run specifically to analyze the effectiveness of dike and pump improvements, at this time. The current PCSWMM model is not capable of modeling flood extents,



Queen's Ditch / Lazo Marsh Drainage Improvements

Dike & Pump Schematic Overview

SK-6

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and would provide minimal information beyond what could reasonably be inferred based on information already in hand. More specifically, the existing model, if used to estimate dike and pump performance, would essentially remove any backwater effect from the model. This would simulate the removal of any effect that the ocean, including sea level rise and storm surge, would have on system conveyance capacity, upstream of the pump location.

A more sophisticated model, which simulates the time dependent relationship between flooding of the lowland areas and tidal levels, would assist in the optimization of pump system requirements, including pump sizing, estimated (annual) pump hours/runtime, and specific drainage network improvements required to ensure that runoff is conveyed within the existing drainage network, to the pump location. Notwithstanding model status, the following observations can be made.

- Given appropriate design, including provision for restriction of upward groundwater intrusion into the pump "well", and adequate depth and storage volume within the well to allow for drainage network ditching to flow freely, i.e., without flooding, or backwatering, groundwater depths could conceivably be lowered to meet Ministry of Agriculture guidelines.
- Gravity flow under typical operating (tidal, storm surge and rainfall) conditions is possible, assuming appropriate upstream drainage improvements are undertaken, and regular maintenance completed.

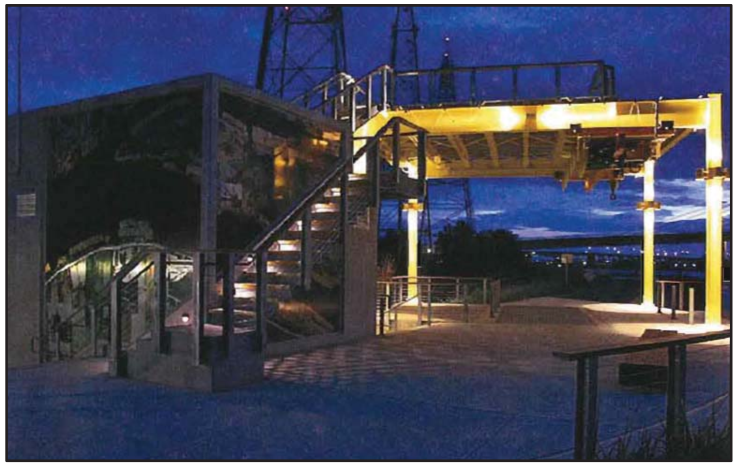
Benefits of Diking and Pumping

- Level of service can be controlled and modified over time. That is to say, the rate, duration, and frequency of pumping, and therefore flood control, can be manipulated based on sump design, pump logic, etc.
- Properly designed, a pump system could be utilized relatively infrequently, becoming activated only when tidal, storm surge, and rainfall conditions necessitate.
- A dike and pump arrangement could be established that allows for, and accommodates sea level rise and climate change. For example, the pumpstation could be designed with provision for additional pumps, or replacement with larger pumps to accommodate increasing flows, or increased pump head requirements.

Detractors of Diking and Pumping

- Stormwater pumps of this size are not uncommon in low-lying foreshore areas, but may be considered too large and costly for this application. As a point of reference, the City of Richmond's No. 4 Road Pumpstation is similarly sized (peak discharge of 6.0 m3/s), contains 4 -127 hp pumps, and was constructed in 2012 at a cost of $4.6 million, inclusive of adjacent diking improvements. In order for a pump system to alleviate flooding within the lowland areas, significant upgrades will also be required to collection and conveyance ditching, at additional cost.

- The Queen's Ditch is known to contain several fish species. The use of "fish friendly" pumps will likely be a requirement of Ministry of Environment and/or Fisheries and Oceans Canada permitting for works within fish habitat. This requirement will limit the types of pumps used to Archimedean screw pumps, or an axial flow pump.



City of Richmond - No. 4 Road Pumpstation

- Significant upgrades will likely be required in sections of the Queen's Ditch downstream of the pumpstation. The channel section along Southwind Road will need to be enlarged, and possibly diked, and the existing Lazo Road culvert replaced with a much larger pipe, or bridge to make full use of the utility provided by a pumpstation.

Improvement Option 4 - Managed Retreat, or Wetland Restoration – System Performance

The Queen's Ditch lowland area, historically, consisted of large extents of wetland habitat, spanning from Point Holmes to the Lazo Marsh. This wetland area was, over time, filled in and/or drained to allow for agricultural use. These modifications to the Queen's Ditch lowlands were documented in the 2002 document "Towards a Management Plan for the Lazo Watershed and Queen's Ditch", prepared by William Marsh, on behalf of the (then) Comox-Strathcona Regional District. To illustrate the significant loss of wetland in the area, Mr. Marsh compared available aerial photography from 1931 to 1996. The figures below, (from the 2002 Marsh report), illustrate the change in wetland area.

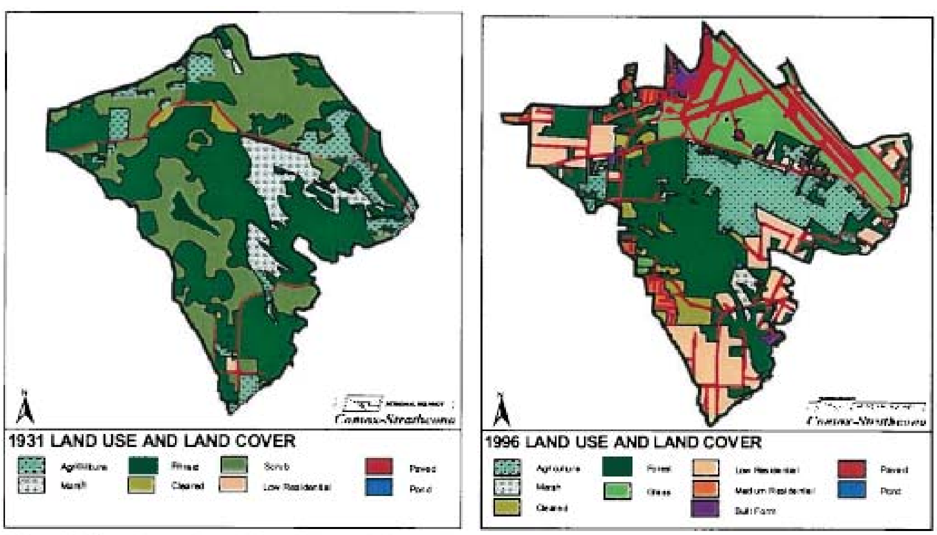


Figure 12

The vast capacity of the (historic) wetland to attenuate runoff has greatly diminished, while stormwater runoff from within the catchment has increased as a result of hard surfacing/development.

Managed Retreat is the term used to reference removal of flood protection works, to allow for controlled flooding of low-lying areas, particularly in coastal regions. Given the anticipated rise in sea level over the next 100 years, and the very high cost of protecting coastlines and low-lying (often agricultural) lands immediately inland, many jurisdictions are considering Managed Retreat as not only viable, but preferable to extensive flood protection works.

Flood protection works in the Queen's Ditch catchment are, presently, limited to drainage improvements (ditching, culverting, etc.), to convey upland runoff and lower groundwater. Removal of these improvements, given the adjacent residential development and ongoing agricultural land uses is not considered feasible. However, it may be possible to "reinstate" some, or all, of the wetland that historically occupied the QD lowland areas. We would envision this "reinstatement" to generally consist of extensive widening, dredging, and revegetation of the existing Queen's Ditch Channel, and potentially some of the lateral connections, in areas with the lowest average ground elevations.

To simulate the creation of a wetland area, Queen's Ditch model Scenario 1-3 was developed with the following cross-sectional elements, as illustrated on **Drawing SK-7**, overleaf.

- A base ditch width of 10m.
- 4H:1V side slopes, which will create a surface water area approximately 40m wide.
- Channel lining to increase hydraulic efficiency (additional depth/width of wetland could be used as an alternate to lining).
- All culverts and crossings removed entirely.

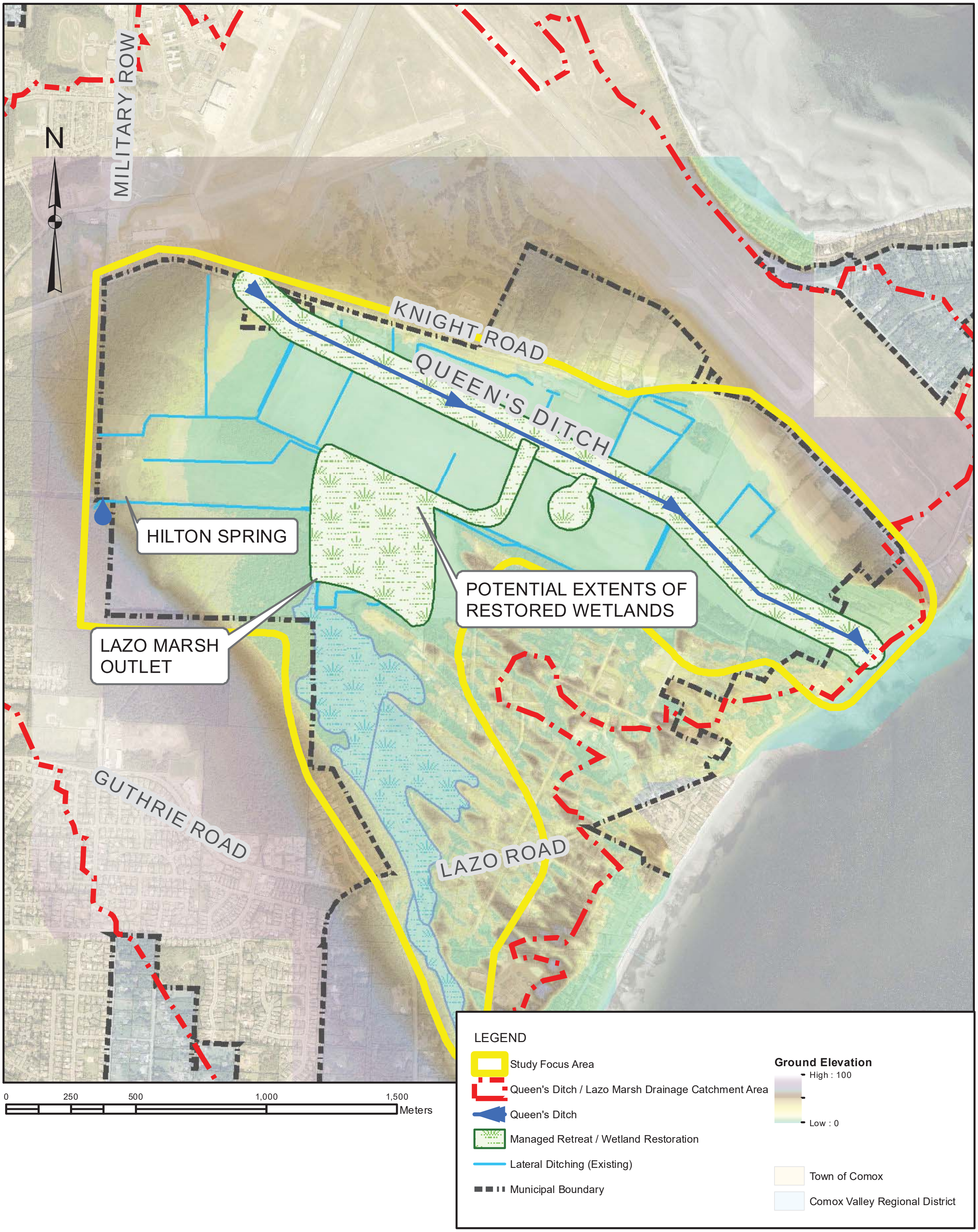
Refer to **Drawings Plan 1-3** and **Plan 1-3 SLR** for flooding extents.

System Performance

- Hydraulic grade in the Queen's Ditch is modeled below existing ground elevations, based on the design rainfall event and current sea levels.
- Minor flooding of lateral ditching was observed under present-day sea level conditions. Additional modeling would verify if this flooding could be alleviated by lateral ditch maintenance or enhancements.
- Flooding presents during sea level model scenarios. The Queen's Ditch (top-of-bank) elevation is lower in several locations than the expected maximum sea level. Raising the top-of-bank, or diking of channel, will not allow for drainage of field areas or existing lateral drainage connections.

Benefits of Managed Retreat/Wetland Restoration

- Restores lost wetland habitat, increases biodiversity in the region, and provides opportunities to enhance salmonid returns.
- Properly designed and constructed, the system will function naturally, and require modest ongoing maintenance.
- Excavated material from the wetland can potentially be used to regrade/raise lower areas adjacent to the existing Queen's Ditch.
- Opportunities to partner with organizations like Ducks Unlimited can be explored. Ducks Unlimited has completed many similar projects, are familiar with provincial and federal



Queen's Ditch / Lazo Marsh Drainage Improvements

Managed Retreat / Wetland Restoration

SK-7

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approval requirements, and has experience in accommodating ongoing, adjacent, agricultural uses. Ducks Unlimited is often able to contribute financially to wetland restorations projects.

Detractors of Managed Retreat/Wetland Restoration

- Requires substantial amounts of land to construct. In the case of the Queen's Ditch, there are numerous land parcels (and therefore land owners), that will need to consent to the improvements.
- Improvements will result in a net loss of agricultural land. This issue will need to be addressed at the time of Agricultural Land Commission (ALC) approvals. It is important that, in making a case for ALC approvals, it be demonstrated that loss of land base would be potentially offset, to a degree, by increased productivity within agricultural lands surrounding the Queen's Ditch, due to decreased flooding and control of groundwater elevations. Longer term, sea level rise will lead to much greater loss of agricultural land.
- Will not control flooding, longer term, if sea level rise as modeled is realized. However, this option could potentially be augmented with diking and pumping.
- Capital construction costs are high.

Improvement Option 5 - Stormwater Detention / Off-Channel Storage

Consideration was given to the potential benefits of constructing stormwater detention ponds, or providing "off-channel storage", for high flows within the Queen's Ditch. This option was not modeled, explicitly. In order to simulate controlled flooding, or off-channel storage, a more complex 2D hydraulic model would be required. However, based on present-day condition model results, the following observations have been made:

- The total volume of rainfall to be conveyed by the Queen's Ditch during a 10-year return, 24-hour rainfall event, is approximately 600,000,000 litres, or 600,000 cubic metres. This volume is exclusive of groundwater inflow, and any residual ponded/flood waters from preceding rainfall events that are able to re-enter the drainage system.
- Given the very low (existing) ground elevations of the "lowland" areas, and present-day flooding (as modeled in scenario 1-1), it would be difficult to create sufficient "live" storage within the lowland areas to mitigate flooding. For example, if we were to assume that one quarter of the total runoff was to be "stored" for a period of 6 hours (between low tides), at a depth of 0.4m, an area of 50 hectares would be required (exclusive of any allowance for freeboard, etc.).
- Significant improvements would be required to the conveyance system downstream of the detention facility, to ensure that it could fully drain between tide cycles.
- Stormwater detention, as a best management practice for mitigating peak runoff rates into the Queen's Ditch, would be far more effective if located (hydraulically) above the lowland areas. By mitigating runoff at, or near the source, peak runoff entering the Queen's Ditch system would be significantly decreased.
- The efficacy of detention storage adjacent to the Queen's Ditch is questionable under current sea level land climatic conditions. Further, more sophisticated modeling is required to

determine feasibility. Longer term, under sea level rise conditions, off-channel storage will not function.

Comparison of Improvement Options – Hydraulic Performance

Provided below is a relative ranking of the hydraulic performance of the five conveyance system improvement options analyzed. Consideration has been given only to the selected improvement options' ability to reduce hydraulic grade within the Queen's Ditch, and modeled nodal flooding under the specific rainfall and tidal scenarios considered in this study.

1. Diking and pumping of lowland areas appears likely to provide the best opportunity to consistently lower water table levels, and decrease flooding. This option could continue to function under changing/increasing rainfall volumes and intensities, as is likely to occur due to climate change, sea level rise, and storm surge conditions. Flexibility to adapt to changing hydrologic conditions can be achieved with the diking and pumping option through the addition of more, or larger, pumps.

2. Managed Retreat, modeled as a +/- 40m wide (water surface) along the Queen's Ditch, and the abandoning of several low areas that cannot be consistently drained within the agricultural lands adjacent to the Queen's Ditch, provides significant improvement in overall drainage. Under present-day sea level and storm surge conditions, Managed Retreat is modeled without flooding of the Queen's Ditch. When sea level rise and storm surge are added, modest flooding is observed, primarily at points of lateral connection to the Queen's Ditch.

3. Cleaning and deepening of the Queen's Ditch, as described in Option 1-2, provides the next greatest reduction in hydraulic grade within the Queen's Ditch, provided that a lined channel section is constructed. Modest flooding of lateral connections persists, even with improvements. Significant flooding is modeled without lining the improved ditch section.

   Under climate change conditions, Significant flooding is modeled, regardless of lining. However, some of the flooding of the Queen's Ditch appears to be caused by localized depressions in the top-of-bank.

4. The Lazo and DND Bypass options provide varying levels of flood reduction. Under present-day conditions, the Lazo Bypass is modeled as being minimally effective in reducing HGL within the Queen's Ditch. Performance of the DND bypass is approximately equivalent to cleaning and deepening the Queen's Ditch without channel lining improvements.

   When consideration is given to the impacts of climate change (sea level rise), neither bypass option is effective at reducing flooding under design rainfall conditions.

5. Off-Channel Storage is not considered practical, given the flat gradient of the lowland areas, and volume of storage that must be provided to mitigate flooding.

7. Estimates of Cost

7.1. Capital Construction Costs of Improvement Options Considered

“Class D” capital construction cost estimates have been prepared for four of the five improvement options considered. Costing is not included at this time for the provision of off-channel storage/detention, as additional modeling is required to fully determine the extents of the improvements required. Detailed estimates can be found in **Appendix C**. Note that the costs of local improvement area wide ditch, culvert and pipe improvements that are common to all improvement options, are not included in the estimates below. It is important to note that Class D cost estimates are prepared in the absence of detailed engineering design, and contain large contingencies. These Class D estimates are intended to provide order of magnitude costing, and a relative cost ranking for those options considered.

Option 1 – Cleaning and Deepening of the Queen’s Ditch (includes channel lining)

Estimated Construction Cost = $5.1 million

Engineering (10% of Estimated Cost) = $0.5 million

Contingency (30% of Estimated Cost) = $1.5 million

Total Estimated Cost = $7.1 million

Option 2 – DND/Lazo Bypass

Estimated Construction Cost = $6.4 million / $4.7 million

Engineering (10% of Estimated Cost) = $0.6 million / $0.4 million

Contingency (30% of Estimated Cost) = $1.9 million / $1.2 million

Total Estimated Cost = $9 million / $5.7 million

Option 3 – Diking and Pumping

Estimated Construction Cost = $6.3 million

Engineering (10% of Estimated Cost) = $0.6 million

Contingency (30% of Estimated Cost) = $1.9 million

Total Estimated Cost = $8.8 million

Option 4 – Managed Retreat/Wetland Restoration

Estimated Construction Cost = $11.1 million

Engineering (10% of Estimated Cost) = $1.1 million

Contingency (30% of Estimated Cost) = $3.3 million

Total Estimated Cost = $15.6 million

Option 5 – Off-Channel Storage/Detention

Not provided at this time.

7.2. Estimated Operation and Maintenance Costs of Improvement Options Considered

Given the very conceptual nature of this study, the determination of ongoing operation and maintenance costs for infrastructure improvements is challenging. Until such time as more detailed investigations (engineering design development, environmental approvals requirements, etc.) are undertaken, operation and maintenance budgets have been estimated utilizing data provided from a number of sources, including CVRD operations staff. Operation and maintenance costing noted herein should, at this preliminary stage, be used for comparative purposes only. Annual operation and Maintenance cost estimates can be found in **Appendix D**, and are summarized below.

Option 1 – Cleaning and Deepening of Existing Queen's Ditch	$202,000
Option 2 – DND Bypass	$27,000
Option 2 – Lazo Bypass	$184,000
Option 3 – Diking and Pumping	$136,000
Option 4 – Managed Retreat/Wetland Restoration	$80,000
Option 5 – Off-channel Storage/Detention	Not costed

8. Comparison of Improvement Options Considered

A brief comparison of improvement options was undertaken based on a number of broadly ranging criteria. The relative ranking of each option, is, admittedly, somewhat subjective. Notwithstanding, a number of relative observations can be made.

- Diking and pumping is likely to be the most impactful option, in terms of flood control and groundwater management. This option provides the additional benefit of flexibility to adapt to changing sea level and climatic conditions, the impacts and timing of which are difficult to estimate.
- All improvement options, with the exception of cleaning and deepening the Queen's Ditch, require acquisition of ROW or purchase of land.
- Improvement options that require works to existing channels (particularly the Queen's Ditch) will require extensive environmental approvals (Ministry of Environment, Fisheries and Oceans Canada). Those options with less impact on existing channels are expected to have significantly less onerous permitting requirements.

- Operation and maintenance costs are lowest with the DND Bypass Option, followed by Managed Retreat/Wetland Restoration. However, based on hydraulic modeling, the latter option provides far greater levels of flood mitigation than the DND Bypass, with similar construction costs.

Table 2

Evaluation Criteria, or Consideration	Cleaning and Deepening (with channel lining)	DND/Lazo Bypass	Diking and Pumping	Managed Retreat/ Wetland Restoration	Off-Channel Storage
Effectiveness in reducing flooding within the lowland areas under current sea level and climatic conditions.	4	2/2	5	5	1
Effectiveness in reducing flooding within the lowland areas under sea level rise and climatic change conditions.	1	2/2	5	3	1
Effectiveness in reducing depth to groundwater, per Agricultural Standards.	2	1/1	5	4	1
Makes use of existing Rights of Ways of Easements.	5	1/1	1	1	1
Minimizes land dedication required to construct (loss of agricultural land).	5	3/3	3	1	1
Limits environmental impacts, including potential loss or disruption of aquatic habitat.	1	4/2	2	3	4
Difficulty anticipated in obtaining environmental approvals.	2	4/2	1	4	3
Expected capital construction costs.	3	3/2	2	1	3
Anticipated ongoing operation and maintenance costs, including electricity. (not costed at this time)	3	5/3	4	5	3
Potential funding partnerships (DND, Ducks Unlimited, etc.)	1	3/1	1	3	1

*Numeric rating represents increasing relative benefit, from 1 to 5

9. Next Steps

A number of additional tasks related to the work carried out herein should be undertaken, prior to marking the final determination of local service area feasibility, including:

- Engage neighboring jurisdictions and stakeholders (Town of Comox, DND), to establish a preliminary commitment to a Local Service Area. The ability to finance works that benefit multiple jurisdictions may not exist, without the participation of said jurisdictions.
- Undertake conceptual designs of the preferred option, and potentially an alternate, to confirm feasibility, (constructability, required higher level government approvals, costing, etc.). This

information will likely be required prior to seeking final stakeholder approval for the creation of a Local Service Area.

- Seek feedback from the PAC regarding desire to explore development of a Local Service Area, based on the expected magnitude of construction and operation and maintenance costs.
- Undertake a flow monitoring programme to allow for further calibration of hydraulic models, assist in conveyance system sizing, and to estimate the relative runoff rates from each jurisdiction. Consideration should be given to involving representatives from the Town of Comox, CVRD, and DND, to ensure that all jurisdictions are in agreement as to monitoring locations, and methodology.
- Apportion capital construction and operation and maintenance costs for the preferred option, based on the expected local service area boundaries, to allow stakeholders to evaluate the efficacy infrastructure being considered, versus relative cost for service.

10. Closure

We trust the information provided herein is sufficient to allow the Comox Valley Regional District to proceed with approval of the Options Analysis. Please do not hesitate to contact the undersigned at your convenience, if you have any questions or wish to discuss further.

MCELHANNEY CONSULTING SERVICES LTD

PROFESSIONAL PROVINCE OF R. J. HUDSON # 34898 BRITISH COLUMBIA ENGINEER

Reviewed by:

PROFESSIONAL PROVINCE OF R.A. WATSON BRITISH COLUMBIA ENGINEER

Bob Hudson, P.Eng..
Branch Manager

Randy Watson, P.Eng.

BH/njg

REVISION HISTORY

Date	Status	Revision	Author
September 14, 2017	Final	Rev.0	BH
August 14, 2017	Draft2	Rev. 2	BH
July 14, 2017	Draft1	Rev. 1	BH
July 7, 2017	Draft0	Rev. 0	BH

LIMITATION

This report has been prepared for the exclusive use of the Comox Valley Regional District. The material in it reflects the best judgement of the Consultant in light of the information available to the Consultant at the time of preparation. As such, McElhanney, it employees, sub-consultants and agents will not be liable for any losses or other consequences resulting from the use or reliance on the report by any third party.

Appendix A

FIGURES MEASURING PERCENT IMPERVIOUS THROUGHOUT CATCHMENT

LOCATION PLAN

SITE PLAN

McElhanney
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495 Sixth Street
Courtenay BC
Canada V9N 6V4
Tel 250 338 5495

CATCHMENT 1
SAMPLE AREA - MORALEE DRIVE

47468 - QUEENS DITCH DRAINAGE LAND USE ASSESSMENT
SUBCATCHMENT 1 - MORALEE DRIVE SAMPLE AREA
LAND USE: SRM-1
SAMPLE AREA PERCENT IMPERVIOUS = 49%

DATE: 2017-04-13, 16:53 FILE: G:\2211 Engineering\47000 - 47999\47468 CVRD QD Flow&Lazo\4.0 Engineering (in-house)\Civil 3D Files\Base Map\47468 - Location and Site Plans - Imperv Calcs.dwg

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495 Sixth Street
Courtenay BC
Canada V9N 6V4
Tel 250 338 5495

CATCHMENT 1
SAMPLE AREA - FORESTER AVENUE

47468 - QUEENS DITCH DRAINAGE LAND USE ASSESSMENT
SUBCATCHMENT 1 - FORESTER AVENUE SAMPLE AREA
LAND USE: SRM-1
SAMPLE AREA PERCENT IMPERVIOUS = 56%

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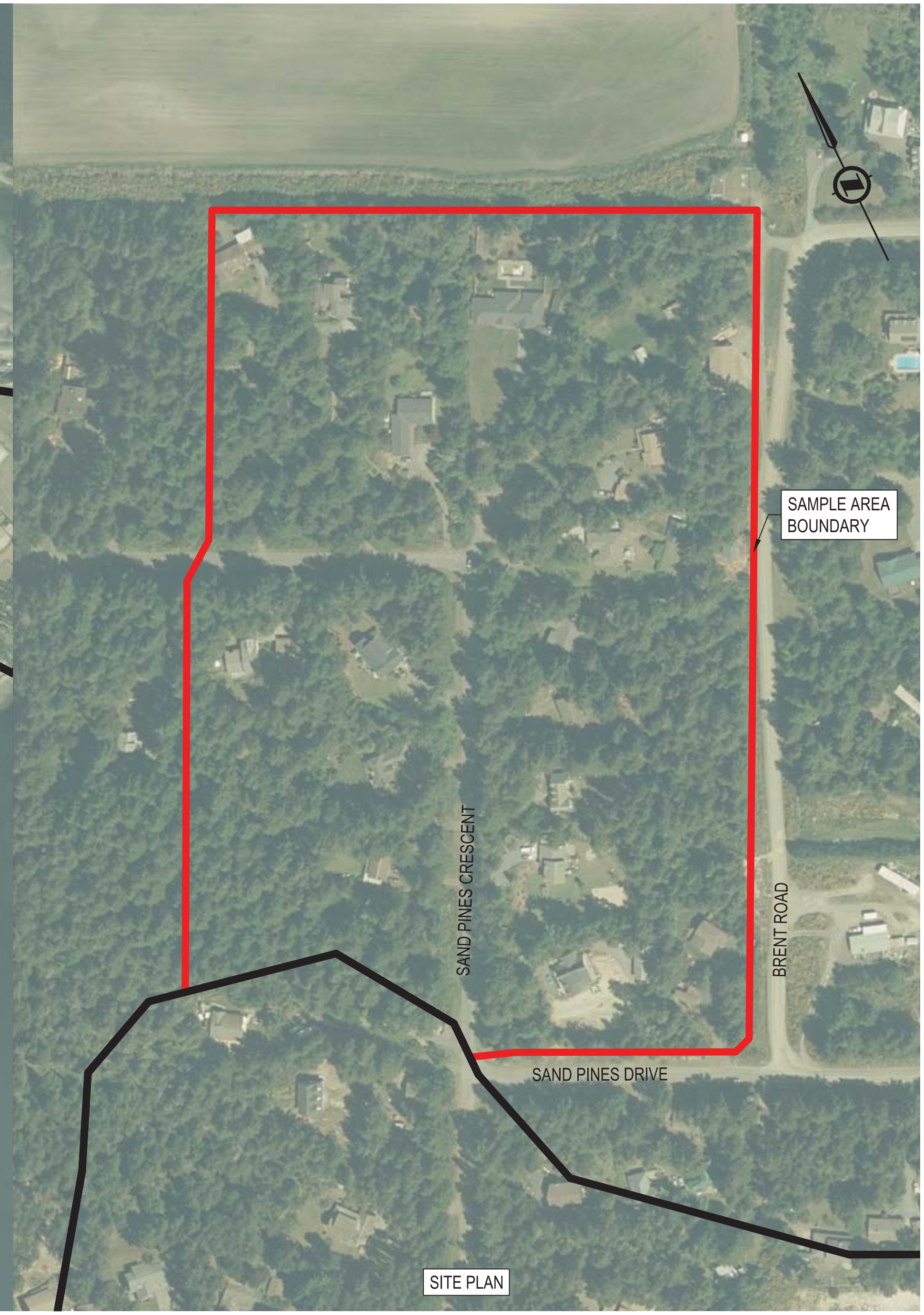
LOCATION PLAN



SITE PLAN

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CATCHMENT 3B
SAMPLE AREA - SAND PINES CRESCENT

47468 - QUEENS DITCH DRAINAGE LAND USE ASSESSMENT
SUBCATCHMENT 3B - SAND PINES CRESCENT SAMPLE AREA
LAND USE: RR
SAMPLE AREA PERCENT IMPERVIOUS = 16%

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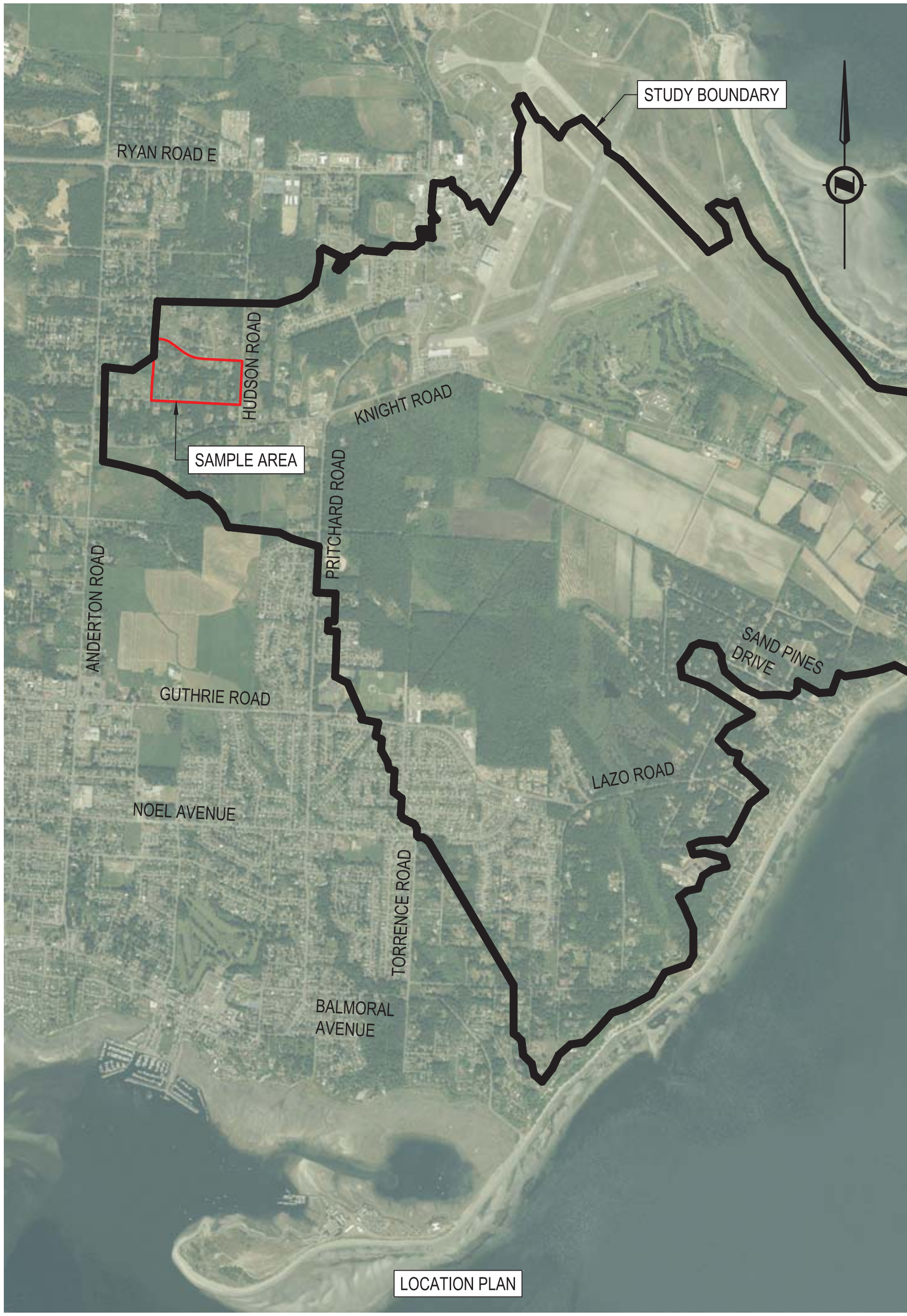

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McElhanney Consulting Services Ltd.
495 Sixth Street
Courtenay BC
Canada V9N 6V4
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CATCHMENT 8A
SAMPLE AREA - THURBER ROAD

47468 - QUEENS DITCH DRAINAGE LAND USE ASSESSMENT
SUBCATCHMENT 8A - THURBER ROAD SAMPLE AREA
LAND USE: RR
SAMPLE AREA PERCENT IMPERVIOUS = 15%

DATE: 2017-04-13, 16:53 FILE: G:\2211 Engineering\47000 - 47999\47468 CVRD QD Flow&Lazo\4.0 Engineering (in-house)\Civil 3D Files\Base Map\47468 - Location and Site Plans - Imperv Calcs.dwg

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Tel 250 338 5495

CATCHMENT 15
SAMPLE AREA - EAST GUTHRIE ROAD

47468 - QUEENS DITCH DRAINAGE LAND USE ASSESSMENT
SUBCATCHMENT 15 - EAST GUTHRIE ROAD SAMPLE AREA
LAND USE: SRH
SAMPLE AREA PERCENT IMPERVIOUS = 61%

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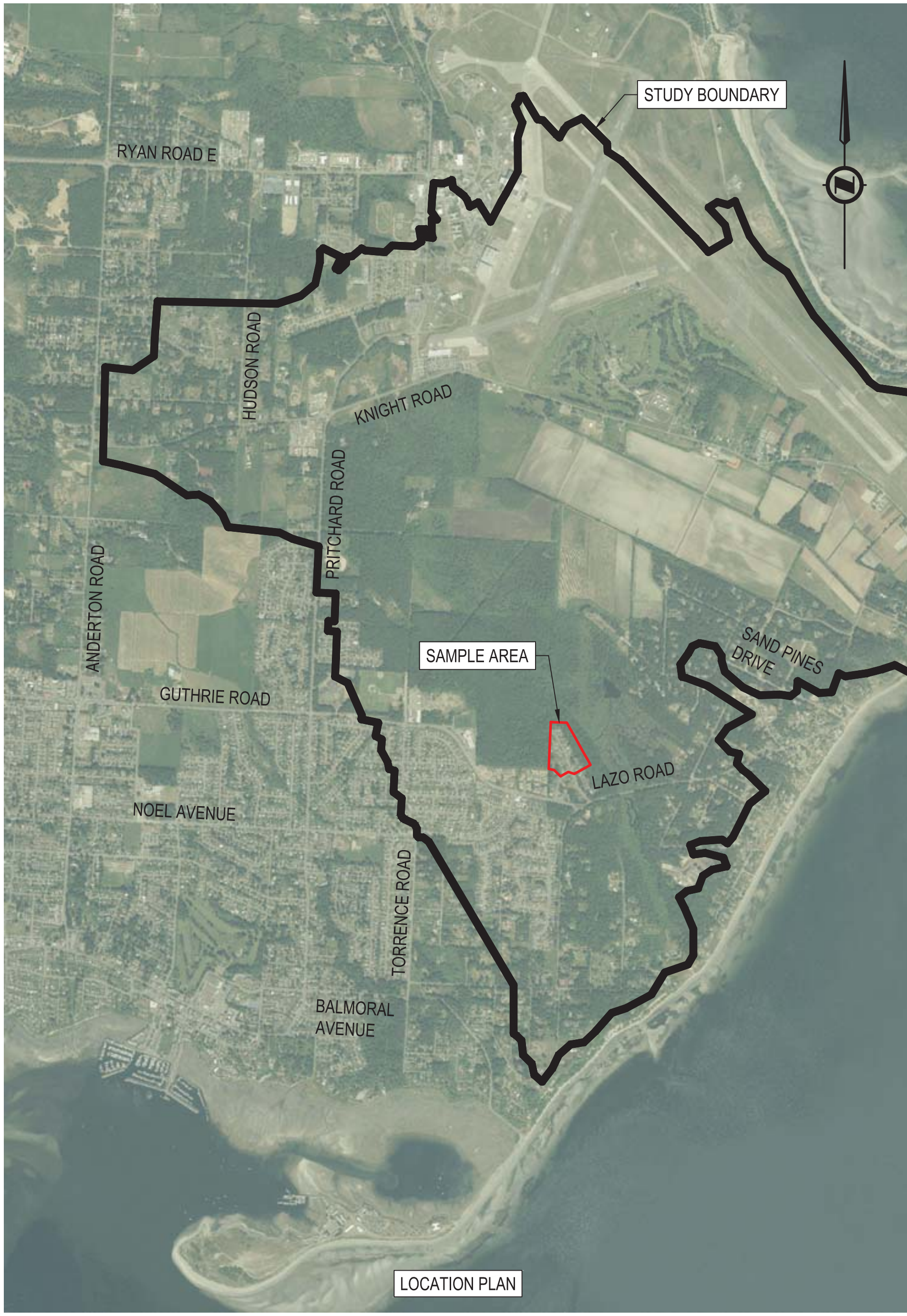

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Courtenay BC
Canada V9N 6V4
Tel 250 338 5495

CATCHMENT 16
SAMPLE AREA - COLBY ROAD

47468 - QUEENS DITCH DRAINAGE LAND USE ASSESSMENT
SUBCATCHMENT 16 - COLBY ROAD SAMPLE AREA
LAND USE: SRL
SAMPLE AREA PERCENT IMPERVIOUS = 28%

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CATCHMENT 17
SAMPLE AREA - BROOKLYN ELEMENTARY

47468 - QUEENS DITCH DRAINAGE LAND USE ASSESSMENT
SUBCATCHMENT 17 - BROOKLYN ELEMENTARY SAMPLE AREA
LAND USE: INST
SAMPLE AREA PERCENT IMPERVIOUS = 32%

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Canada V9N 6V4
Tel 250 338 5495

CATCHMENT 21
SAMPLE AREA - KNIGHT ROAD

47468 - QUEENS DITCH DRAINAGE LAND USE ASSESSMENT
SUBCATCHMENT 21 - KNIGHT ROAD SAMPLE AREA
LAND USE: C
SAMPLE AREA PERCENT IMPERVIOUS = 46%

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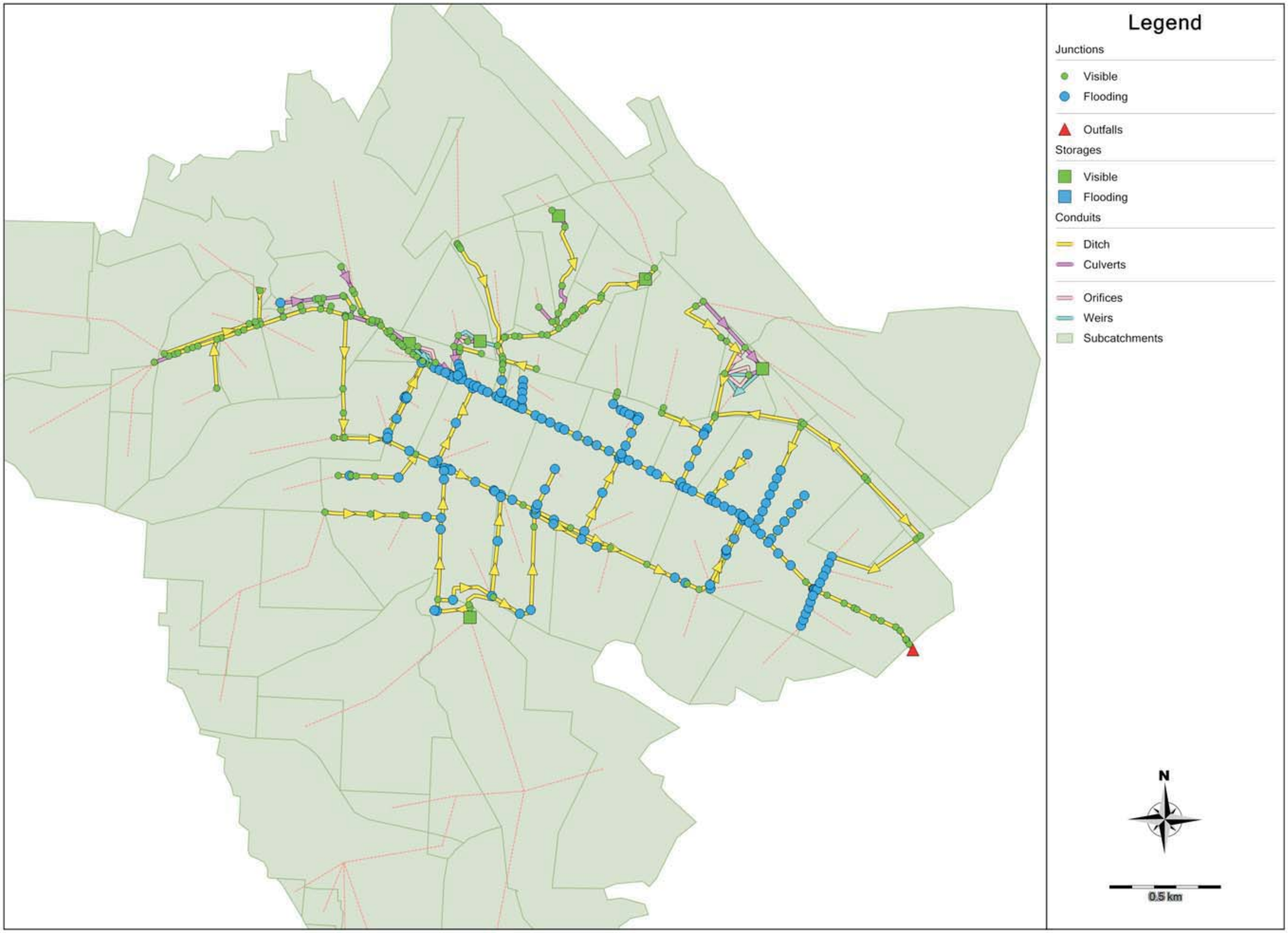
Appendix B

DRAWING PLAN FIGURES

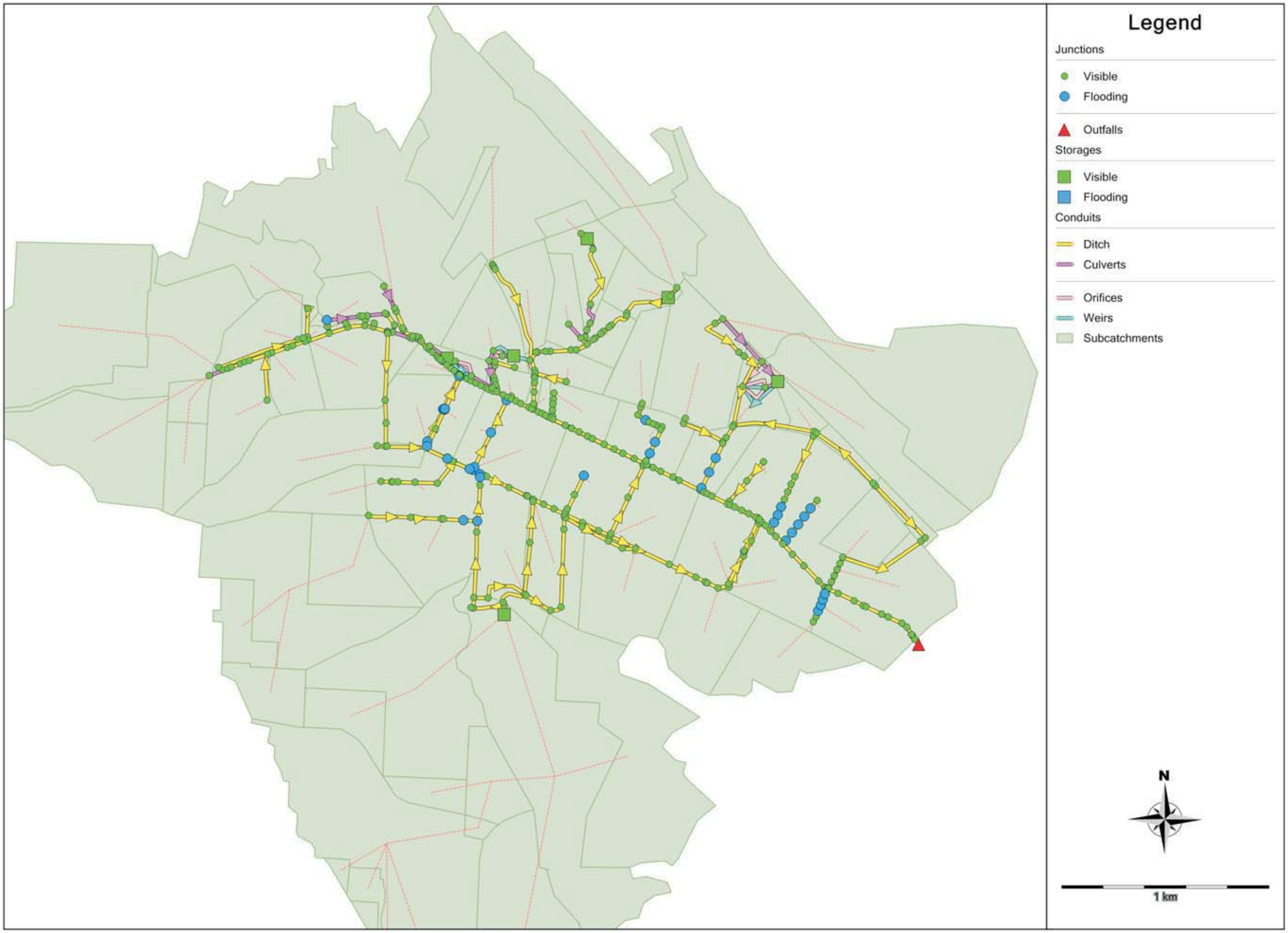


McElhanney
McElhanney Consulting Services Ltd.
1307 SHOPPERS ROW
CAMPBELL RIVER, B.C. V9W 2C9
PH (250) 287-7799
FAX (250) 287-7662

QUEEN'S DITCH FLOODING AREA

CVRD LAZO/QD

Drawing No.	PLAN 1-1
DATE:	2017/06/1
Sheet 1 of 1	Revision PB



*LINED CHANNEL (n = 0.03)

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1307 SHOPPERS ROW
CAMPBELL RIVER, B.C. V9W 2C9

PH (250) 287-7799
FAX (250) 287-7662

QUEEN'S DITCH FLOODING AREA

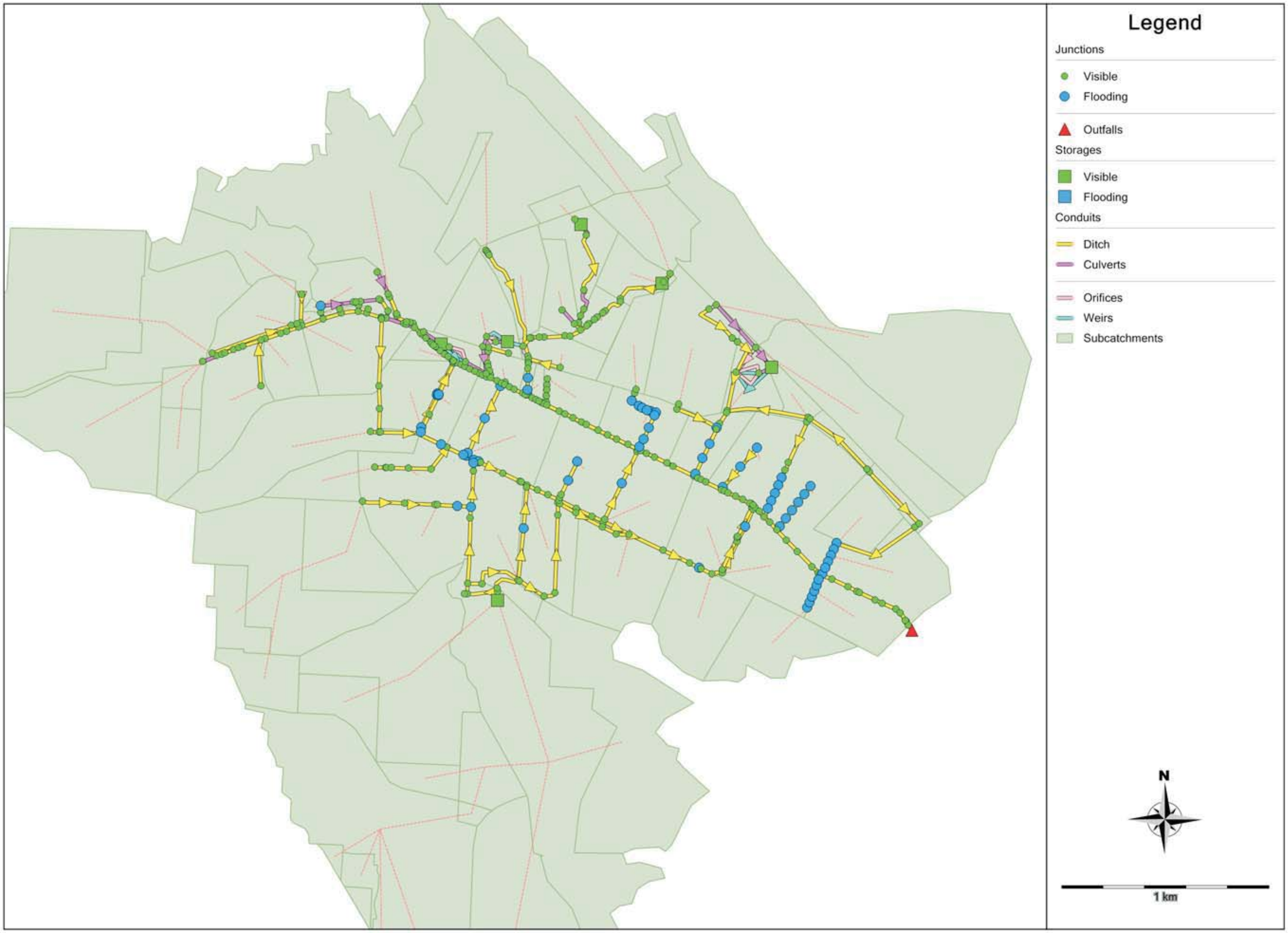
CVRD LAZO/QD

Drawing No.

PLAN 1-2

DATE: 2017/06/1

Sheet 1 of 1 Revision PB



*EXISTING CHANNEL (n = 0.03)

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McElhanney Consulting Services Ltd.
1307 SHOPPERS ROW
CAMPBELL RIVER, B.C. V9W 2C9
PH (250) 287-7799
FAX (250) 287-7662

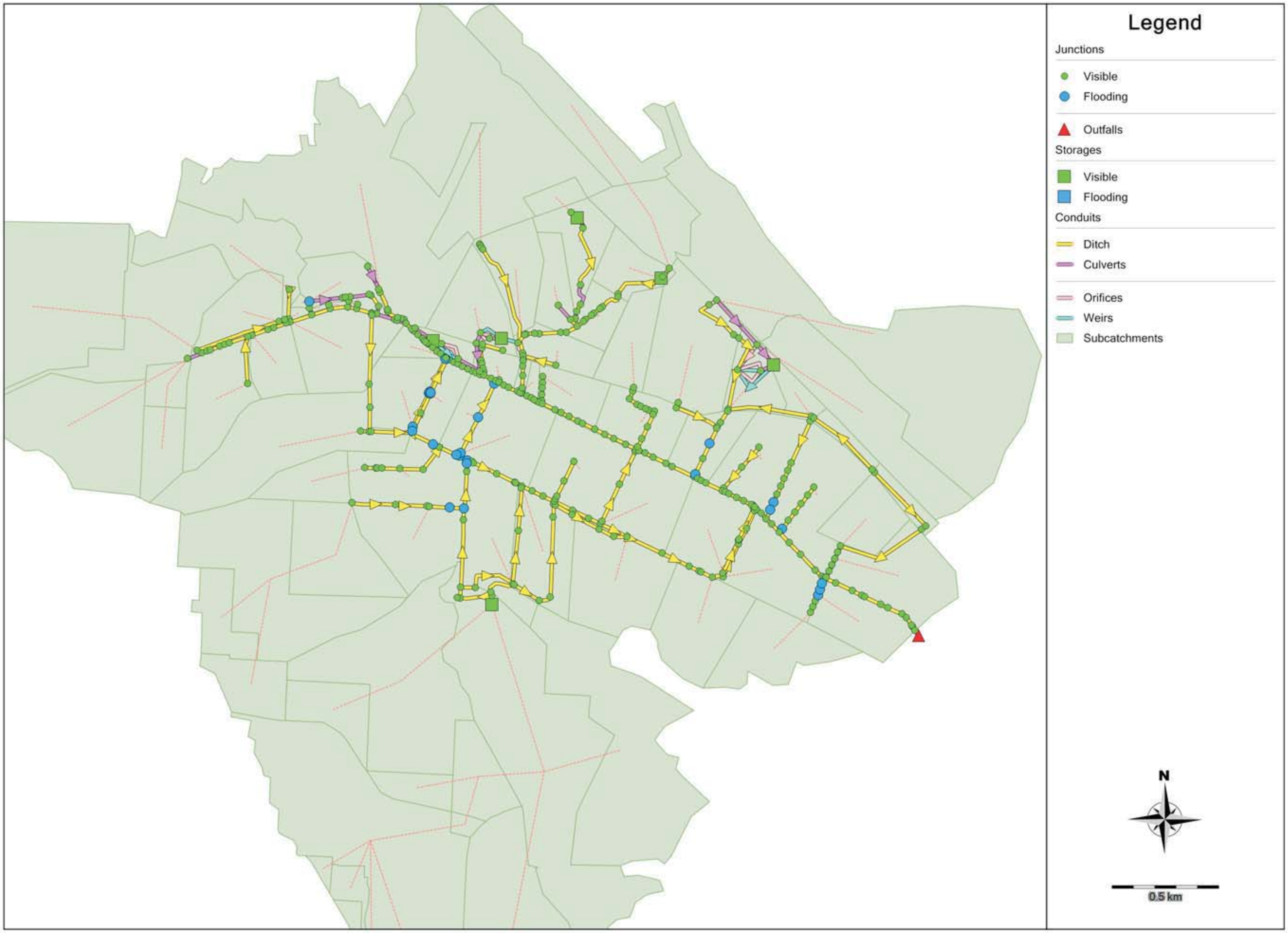
QUEEN'S DITCH FLOODING AREA

CVRD LAZO/QD

Drawing No. PLAN 1-2

DATE: 2017/06/1

Sheet 1 of 1 Revision PB



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McElhanney Consulting Services Ltd.

1307 SHOPPERS ROW
CAMPBELL RIVER, B.C. V9W 2C9

PH (250) 287-7799
FAX (250) 287-7662

QUEEN'S DITCH FLOODING AREA

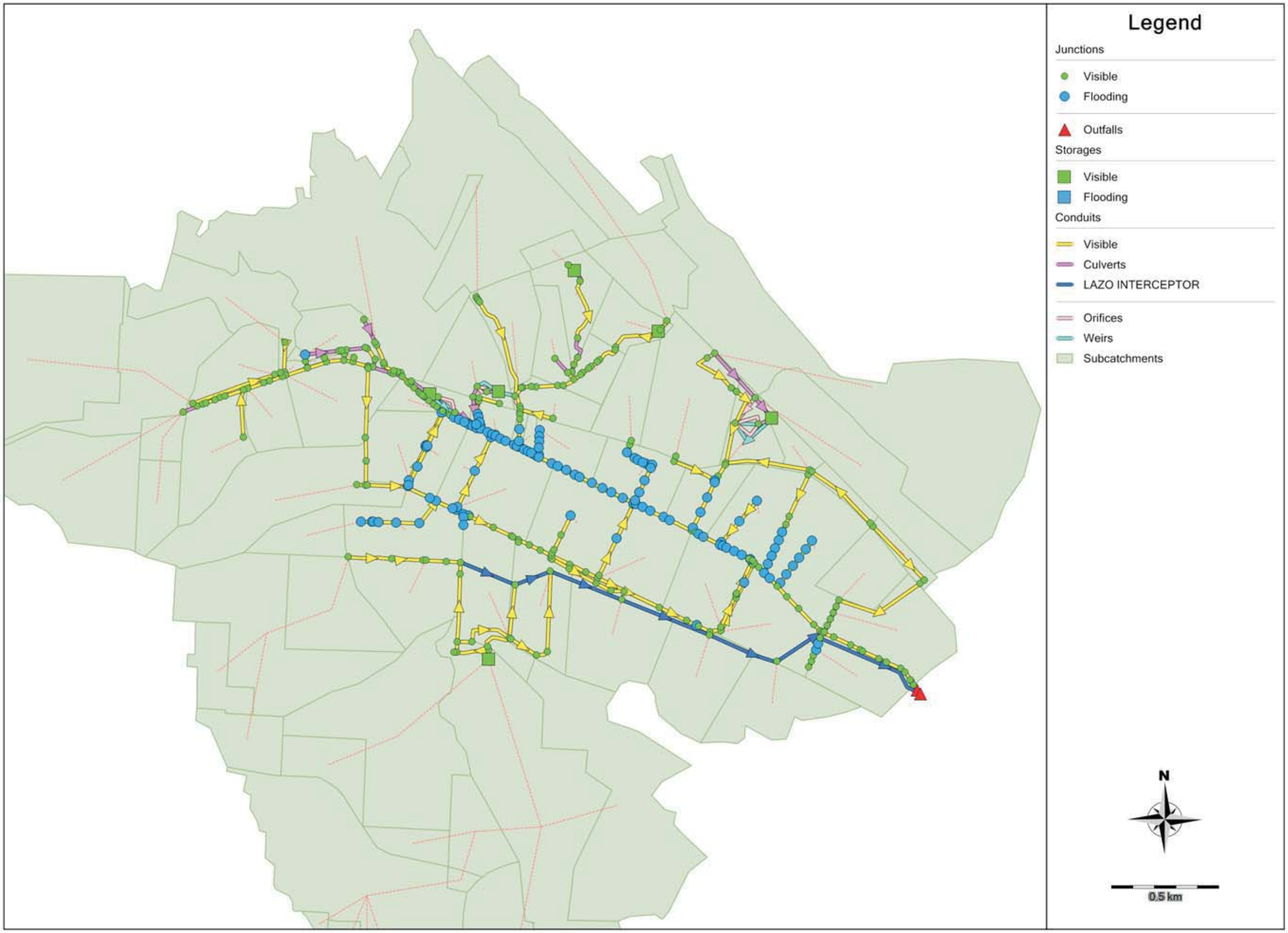
CVRD LAZO/QD

Drawing No.

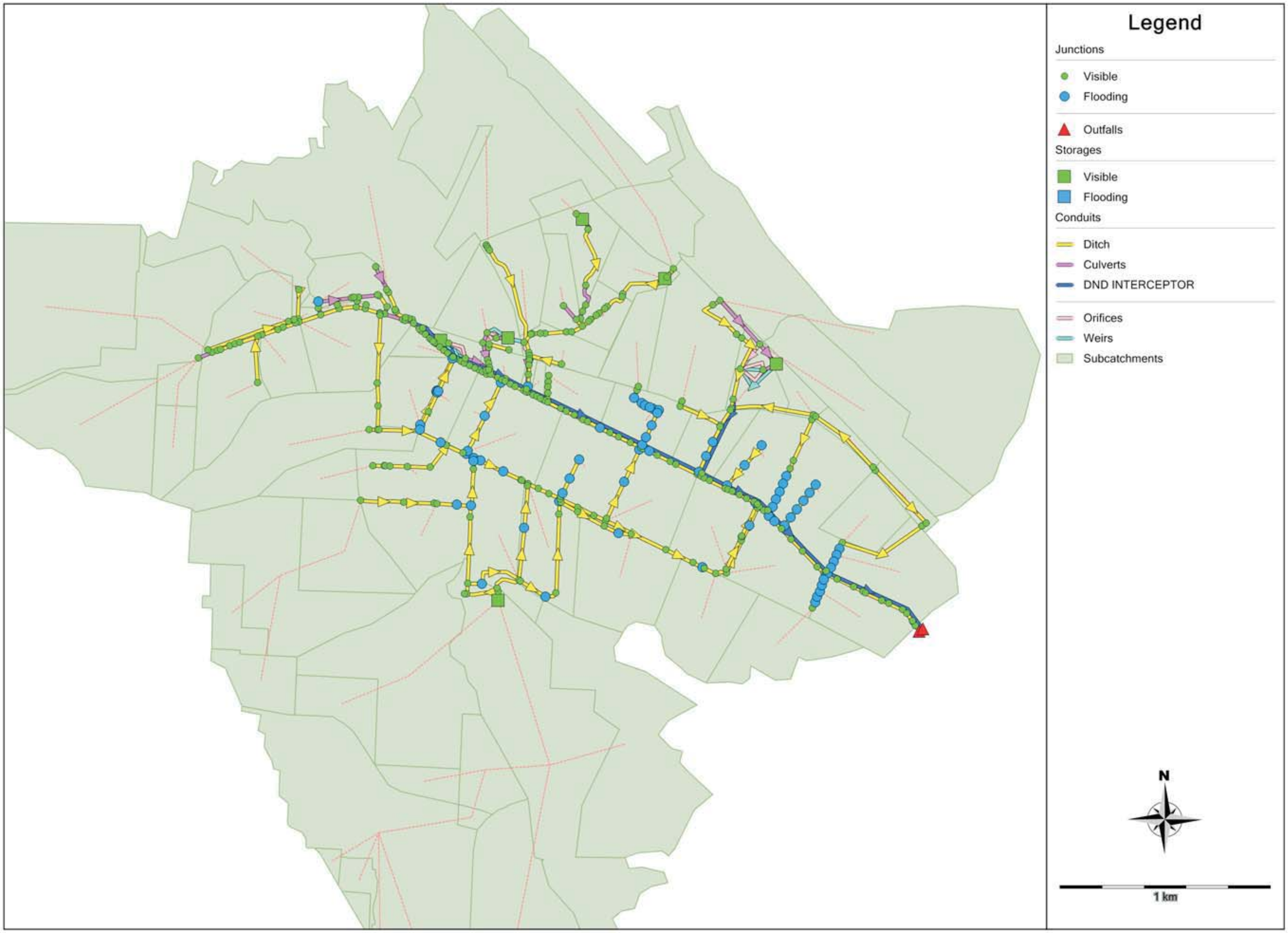
PLAN 1-3

DATE: 2017/06/1

Sheet 1 of 1 Revision PB



McElhanney McElhanney Consulting Services Ltd. 1307 SHOPPERS ROW CAMPBELL RIVER, B.C. V9W 2C9 PH (250) 287-7799 FAX (250) 287-7662	QUEEN'S DITCH FLOODING AREA CVRD LAZO/QD	Drawing No. PLAN 2-1 DATE : 2017/06/1 Sheet 1 of 1 Revision PB



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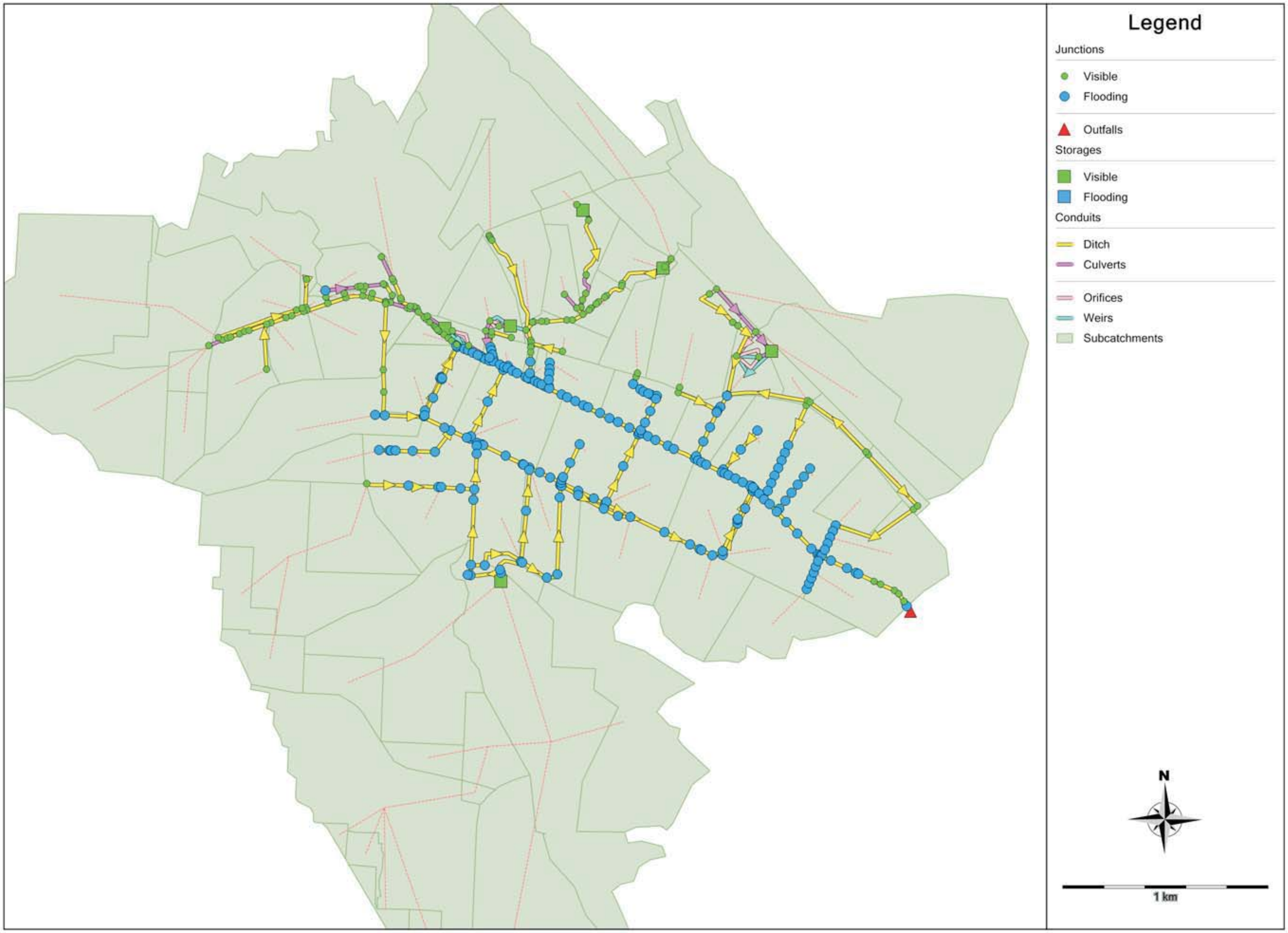
QUEEN'S DITCH FLOODING AREA

CVRD LAZO/QD

Drawing No. PLAN 2-2

DATE: 2017/06/1

Sheet 1 of 1 Revision PB



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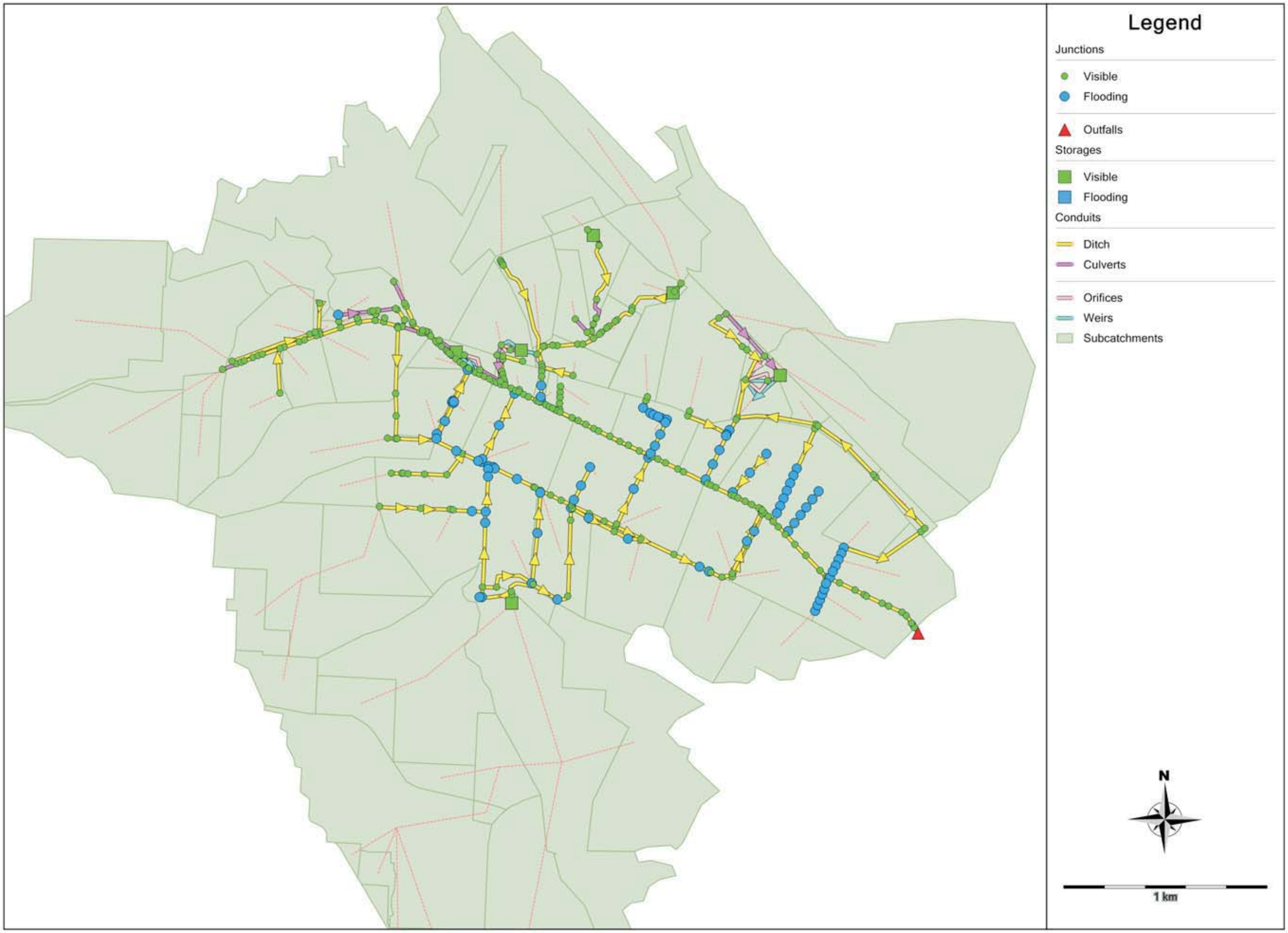
QUEEN'S DITCH FLOODING AREA

CVRD LAZO/QD

Drawing No.
PLAN 1-1.SLR

DATE: 2017/06/1

Sheet 1 of 1 Revision PB



*LINED CHANNEL (n = 0.03)

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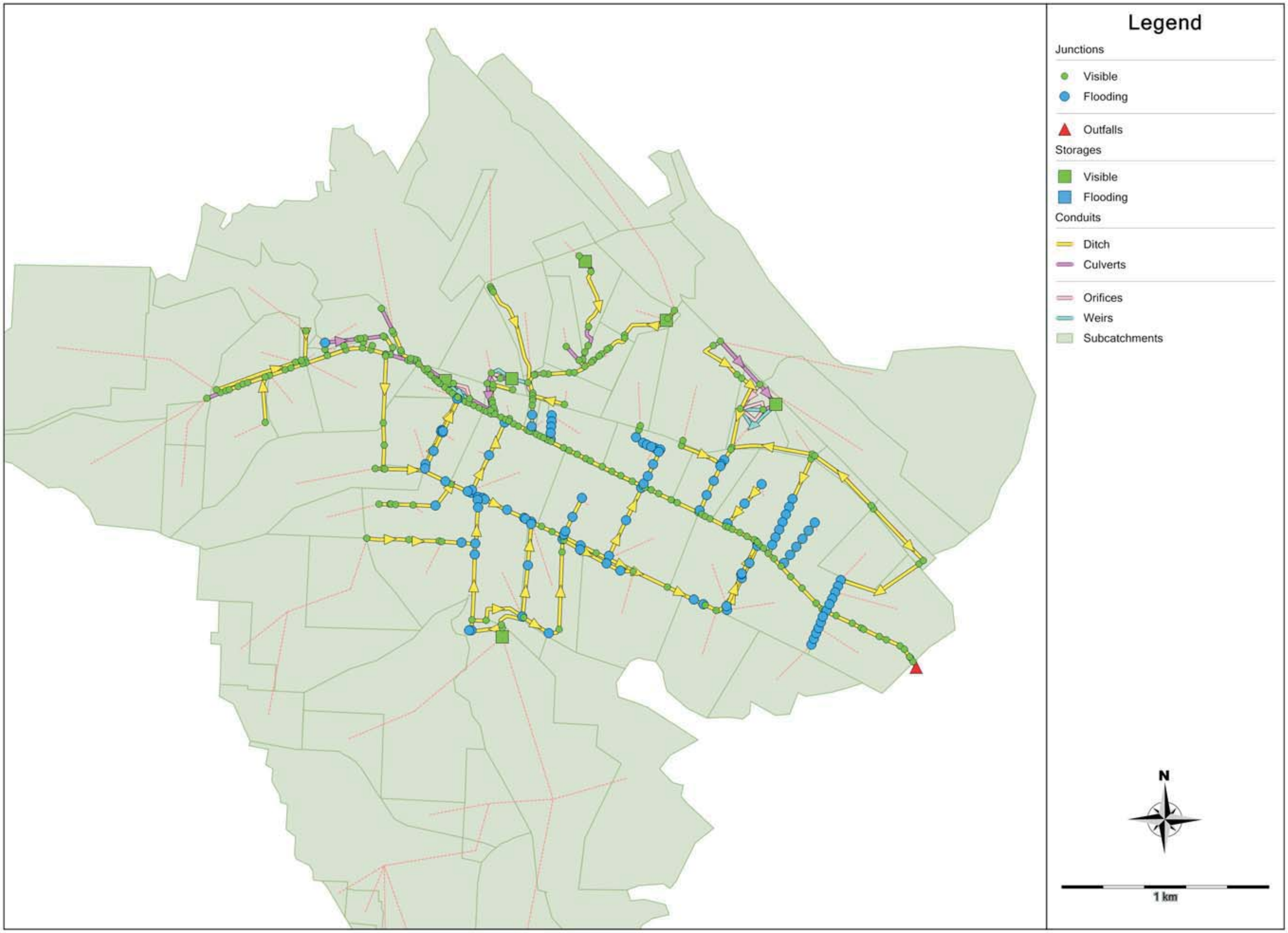

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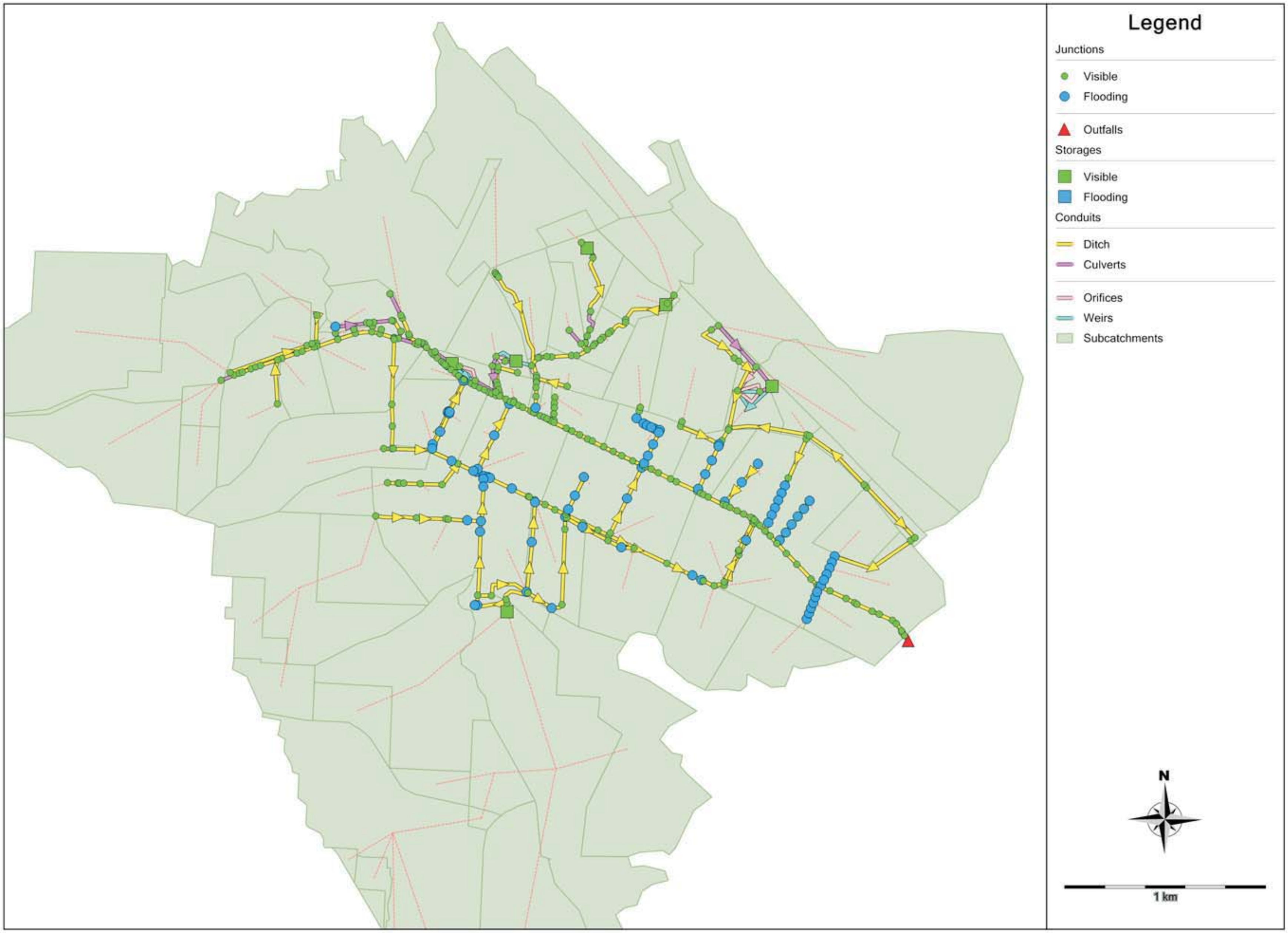
QUEEN'S DITCH FLOODING AREA

CVRD LAZO/QD

Drawing No.	PLAN 1-2.SLR
DATE:	2017/06/1
Sheet 1 of 1	Revision PB



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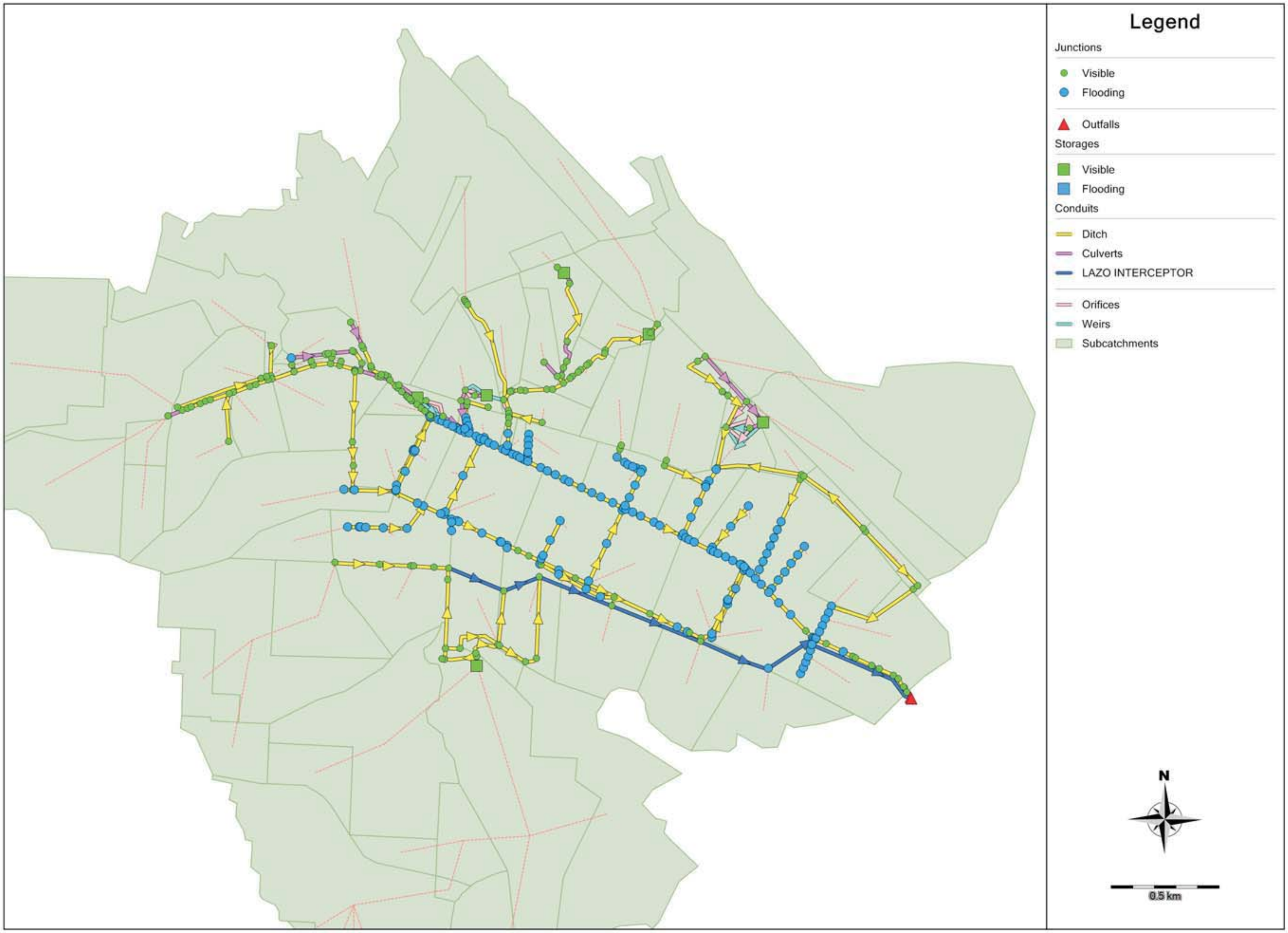
QUEEN'S DITCH FLOODING AREA

CVRD LAZO/QD

Drawing No.	PLAN 1-3.SLR
DATE:	2017/06/1
Sheet 1 of 1	Revision PB



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CAMPBELL RIVER, B.C. V9W 2C9

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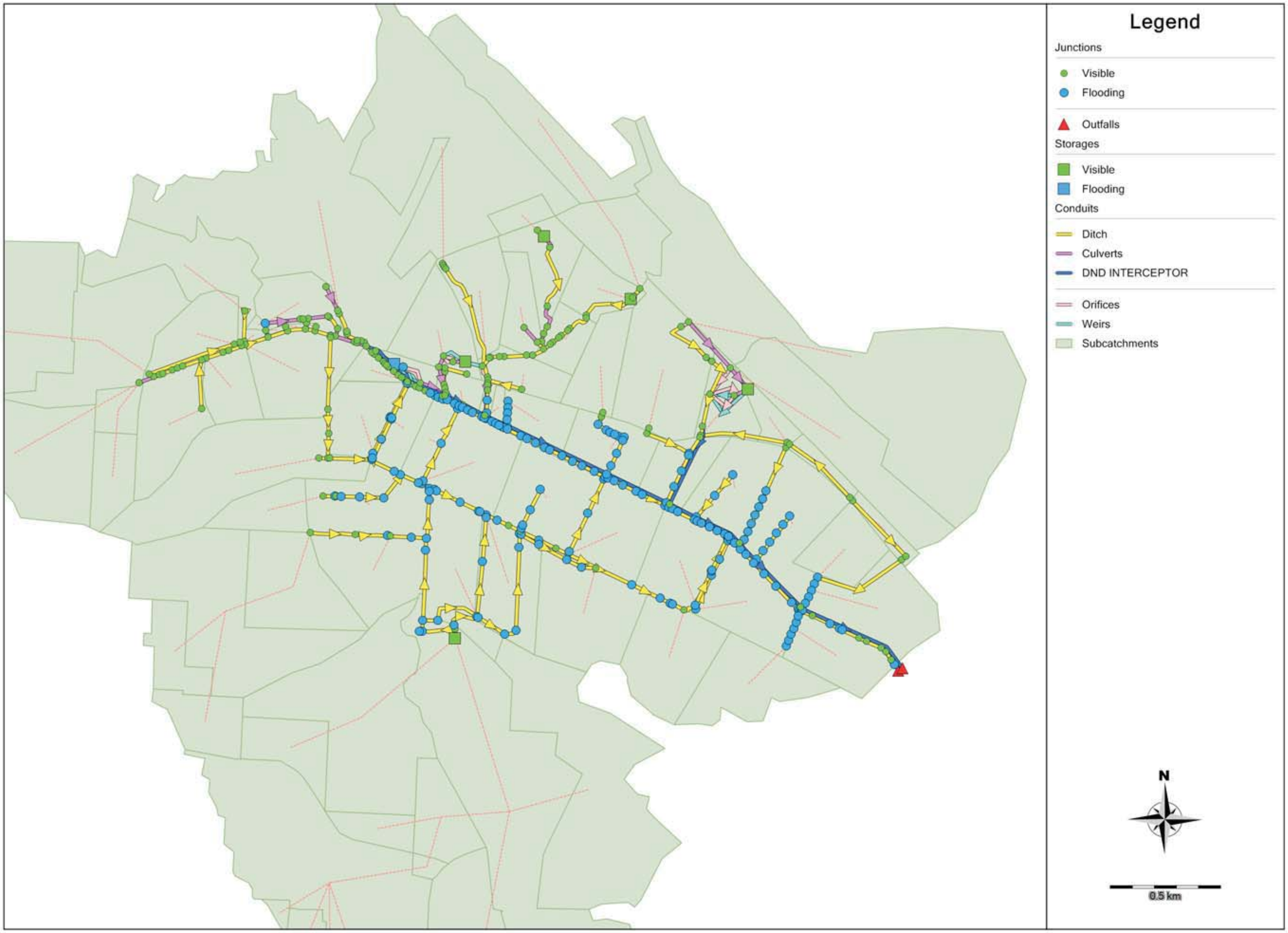
QUEEN'S DITCH FLOODING AREA

CVRD LAZO/QD

Drawing No.	PLAN 2-1.SLR
DATE:	2017/06/1
Sheet 1 of 1	Revision PB



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QUEEN'S DITCH FLOODING AREA

CVRD LAZO/QD

Drawing No.

PLAN 2-2.SLR

DATE: 2017/06/1

Sheet 1 of 1 Revision PB

Appendix C

"CLASS D" CAPITAL CONSTRUCTION COST ESTIMATES

COMOX VALLEY REGIONAL DISTRICT July 5, 2017
MCSL 2211-47468-00 - Queens Ditch Drainage System Upgrade Options Analysis Rev 0
Construction Cost Estimate By: CDE
Chk: BH

Class D - Issued for Options Analysis Reporting

Item	Description	Unit	Quantity	Unit Price	Sub total	Total
	Option #1 - Cleaning and Deepening of Existing Channel					
	Earthworks					
1.1	Soil Stripping, stockpiling and reuse	m^2	12,750	$ 7	$ 89,250	
1.2	Channel excavation	m^3	70,750	$ 17	$ 1,202,750	
1.3	Class 25 riprap channel liner supply and placement c/w geotextile underlay	lm	2,550	$ 1,420	$ 3,621,000	
					Subtotal	$ 4,913,000
	STORMWORKS					
2.1	Existing culvert removal and offsite disposal	ea.	15	$ 1,250	$ 18,750	
					Subtotal	$ 18,750
	MISCELLANEOUS					
3.1	Fish salvage	ls	1	33,000	$ 33,000	
3.2	Environmental monitoring	ls	1	50,000	$ 50,000	
3.3	Bypass pumping (100m-150m sections)	ls	1	40,000	$ 40,000	
3.4	Native species replanting & hydroseeding	ls	1	65,000	$ 65,000	
3.5	Land Acquisition (SRW)	ha	-	20,000	$ -	
					Subtotal	$ 188,000
					Construction Total (Rounded)	$ 5,120,000
				Engineering and Construction Services (10%)	$512,000	
				Contingency (30%)	$1,536,000	
					Total (Rounded)	**$7,168,000.00**

Class D - Issued for Options Analysis Reporting

Item	Description	Unit	Quantity	Unit Price	Sub total	Total
	Option #2 - Overflow Channeling and/or Piping					
	LAZO BYPASS					
1.1	Soil Stripping, stockpiling and reuse	m^2	35,250	$ 7	$ 246,750	
1.2	Channel excavation	m^3	49,680	$ 17	$ 844,560	
1.3	Class 25 riprap channel liner supply and placement c/w geotextile underlay	lm	2,760	$ 1,000	$ 2,760,000	
					Subtotal	$ 3,851,310
	LAZO BYPASS MISCELLANEOUS					
2.1	Fish salvage	ls	1	11,500	$ 11,500	
2.2	Environmental monitoring	ls	1	40,000	$ 40,000	
2.3	Bypass pumping (100m-150m sections)	ls	1	25,000	$ 25,000	
2.4	Native species replanting & hydroseeding	ls	1	35,000	$ 35,000	
2.5	Land Acquisition	ha	6	20,000	$ 110,400	
					Subtotal	$ 221,900
					Part A Construction Total (Rounded)	$ 4,073,000
				Engineering and Construction Services (10%)	$407,300	
				Contingency (30%)	$1,221,900	
					Part A Total (Rounded)	**$5,702,000.00**
	DND BYPASS					
3.1	Existing culvert removal and offsite disposal	ea.	6	$ 1,250	$ 7,500	
3.2	Twin 1.375m HDPE storm pipe	lm	2,550	$ 1,700	$ 4,335,000	
3.3	Pipe berm	m^3	48,500	$ 30	$ 1,455,000	
3.4	Box culvert manhole	ea.	8	$ 22,000	$ 176,000	
3.5	Storm system inlets / overflow structures	ea.	7	$ 35,000	$ 245,000	
3.6	Lazo Road crossings	ea.	2	$ 25,000	$ 50,000	
3.7	Outlet structures	ea.	2	$ 40,000	$ 80,000	
					Subtotal	$ 6,348,500
	DND BYPASS MISCELLANEOUS					
4.1	Environmental monitoring	ls	1	10,000	$ 10,000	
4.2	Bypass pumping (minor)	ls	1	5,000	$ 5,000	
4.3	Native species replanting & hydroseeding	ls	1	5,000	$ 5,000	
4.4	Land Acquisition (SRW)	ha	5.10	20,000	$ 102,000	
					Subtotal	$ 122,000
					Part B Construction Total (Rounded)	$ 6,471,000
				Engineering and Construction Services (10%)	$647,100	
				Contingency (30%)	$1,941,300	
					Part B Total (Rounded)	**$9,059,000.00**

COMOX VALLEY REGIONAL DISTRICT — *July 5, 2017*
MCSL 2211-47468-00 - Queens Ditch Drainage System Upgrade Options Analysi — *Rev 0*
Construction Cost Estimate — *By:* *CDE*
Chk: *BH*

Class D - Issued for Options Analysis Reporting

Item	Description	Unit	Quantity	Unit Price	Sub total	Total
	Option #3 - DIKING AND PUMPINC					
	Earthworks					
1.1	Clearing and grubbing	m^2	4,000	$ 5	$ 20,000	
1.2	Soil Stripping, stockpiling and reuse	m^2	11,900	$ 7	$ 83,300	
1.3	Pond excavation	m^3	6,150	$ 17	$ 104,550	
1.4	Berm construction	m^3	9,000	$ 30	$ 270,000	
1.5	Pump flume constructior	m^3	8,000	$ 30	$ 240,000	
1.6	Class 25 riprap channel liner supply and placement c/w geotextile underlay	lm	500	$ 1,420	$ 710,000	
1.7	Ditch cleaning / widening	lm	5,000	$ 12	$ 60,000	
					Subtotal	$ 1,487,850
	STORMWORKS					
2.1	Diversion structure (to pond)	ls	1	$ 50,000	$ 50,000	
2.2	Flood gates, piping and structure at dike	ls	1	$ 80,000	$ 80,000	
2.3	Pumphouse (at pond)	ls	1	$ 4,500,000	$ 4,500,000	
2.4	Lazo Road crossings	ea.	1	$ 25,000	$ 25,000	
2.5	Outlet structures	ea.	1	$ 40,000	$ 40,000	
					Subtotal	$ 4,695,000
	MISCELLANEOUS					
3.1	Fish salvage	ls	1	9,500	$ 9,500	
3.2	Environmental monitoring	ls	1	50,000	$ 50,000	
3.3	Bypass pumping (100m-150m sections)	ls	1	25,000	$ 25,000	
3.4	Native species replanting & hydroseeding	ls	1	50,000	$ 50,000	
3.5	Land Acquisition (SRW)	ha	3	20,000	$ 60,000	
					Subtotal	$ 134,500
					Construction Total (Rounded)	$ 6,317,000
				Engineering and Construction Services (10%)	$631,700	
				Contingency (30%)	$1,895,100	
					Total (Rounded)	**$8,844,000.00**

Class D - Issued for Options Analysis Reporting

Item	Description	Unit	Quantity	Unit Price	Sub total	Total
	Option #4 - MANAGED RETREAT					
	Earthworks					
1.1	Clearing and grubbing	m^2	15,000	$ 5	$ 75,000	
1.2	Soil Stripping, stockpiling and reuse	m^2	25,500	$ 7	$ 178,500	
1.3	Channel excavation and local placement of surplu	m^3	255,000	$ 15	$ 3,825,000	
1.4	Class 25 riprap channel liner supply and placement c/w geotextile underlay	lm	2,550	$ 2,600	$ 6,630,000	
					Subtotal	$ 10,708,500
	MISCELLANEOUS					
2.1	Fish salvage	ls	1	66,000	$ 66,000	
2.2	Environmental monitoring	ls	1	100,000	$ 100,000	
2.3	Bypass pumping (100m-150m sections)	ls	1	60,000	$ 60,000	
2.4	Native species replanting & hydroseeding	ls	1	175,000	$ 175,000	
2.5	Land Acquisition (SRW)	ha	30	20,000	$ 590,000	
					Subtotal	$ 401,000
					Construction Total (Rounded)	$ 11,110,000
				Engineering and Construction Services (10%)	$1,111,000	
				Contingency (30%)	$3,333,000	
					Total (Rounded)	**$15,554,000.00**

Appendix D

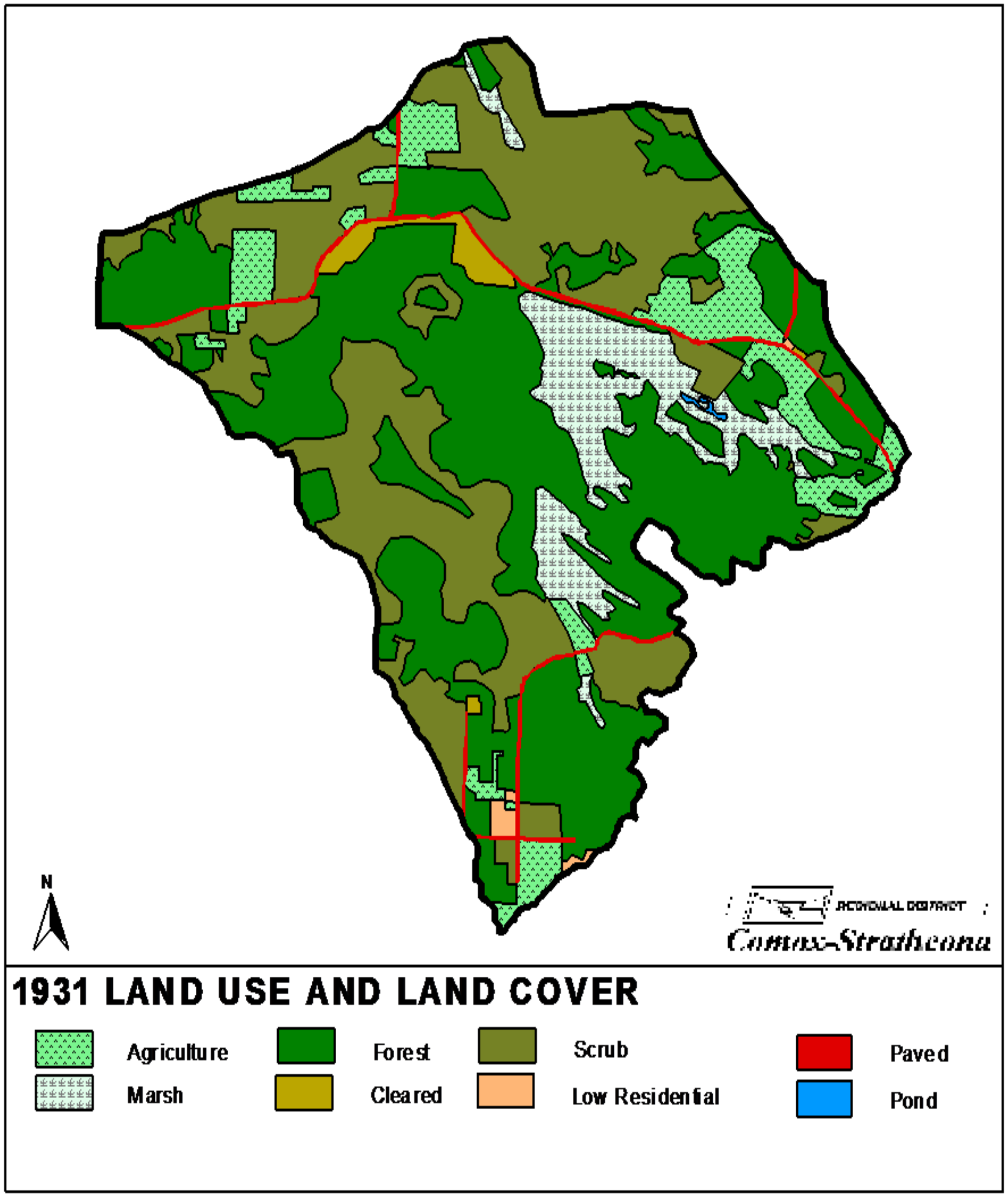
ANNUAL OPERATION AND MAINTENANCE COST ESTIMATES

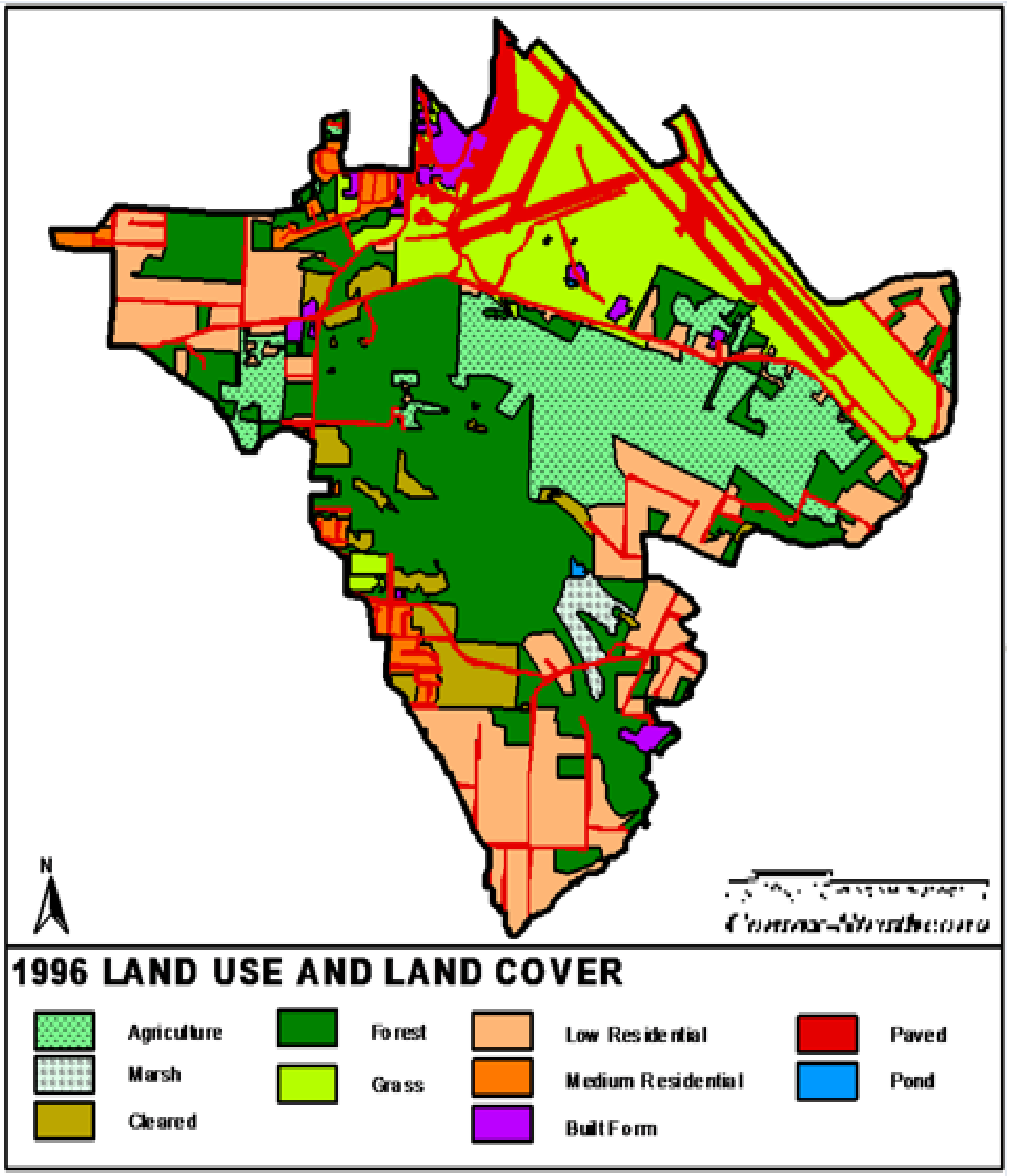
Class D - Issued for Options Analysis Reporting

Item	*Description*	*Hours*	*Hourly Rate*	*Lump Sum*	*Sub Total*	*Total*
	Option 1 - Cleaning and Deepening					
1.1	Weekly "drive by" inspection by CVRD Staff	78	$ 48		$ 3,752	
1.2	Budget for minor repairs by CVRD Staff (back sloughing, removing large woody debris, etc.)			$ 10,000	$ 10,000	
1.3	Ditch cleaning by subcontract (assumed required every 5 years, budget 20% of total per year)	510	$ 336		$ 171,360	
1.4	Annual culvert inspections by CVRD Staff	24	$ 48		$ 1,154	
1.5	Access road maintenance by subcontractor	2550	$ 2		$ 5,738	
1.6	Misc Expenses budget (insurance, administration, etc.)			$ 10,000	$ 10,000	
						$ 202,000
	Option 2 - DND Bypass					
2.1.1	Weekly "drive by" inspections	91	$ 48		$ 4,377	
2.1.2	Annual flushing of pipes (no allowance for video inspection, mobilization charges included)	2550	$ 3		$ 7,013	
2.1.3	Annual access road maintenance	2550	$ 2		$ 5,738	
2.1.4	Misc Expenses budget (insurance, administration, etc.)			$ 10,000	$ 10,000	
						$ 27,000
	Option 2 - Lazo Bypass					
2.2.1	Weekly "drive by" inspection by CVRD Staff	91	$ 48		$ 4,377	
2.2.2	Budget for minor repairs by CVRD Staff (back sloughing, removing large woody debris, etc.)			$ 10,000	$ 10,000	
2.2.3	Ditch cleaning by subcontract (assumed required every 5 years, budget 20% of total per year)	552	$ 275		$ 151,800	
2.2.4	Annual culvert inspections by CVRD Staff	24	$ 48		$ 1,154	
2.2.5	Access road maintenance by subcontractor	2760	$ 2		$ 6,210	
2.2.6	Misc Expenses budget (insurance, administration, etc.)			$ 10,000	$ 10,000	
						$ 184,000
	Option 3 - Diking and Pumping					
3.1	Daily inspection (1.5 man hours)	78	$ 48		$ 3,744	
3.2	Weekly maintenance of station internals (3 man hours per week, plus annual disposables budget of $5000)	156	$ 48	$ 5,000	$ 12,488	
3.3	Annual minor component replacement (budget allowance, does not include major component replacement)			$ 15,000	$ 15,000	
3.4	Annual major component replacement fund (highly dependent on system design)			$ 60,000	$ 60,000	
3.5	Dike Maintenance Act Inspection and reporting			$ 5,000	$ 5,000	
3.6	Dike Maintenance			$ 10,000	$ 10,000	
3.7	Estimate electrical consumption (highly variable)			$ 20,000	$ 20,000	
3.8	Misc Expenses budget (insurance, administration, etc.)			$ 10,000	$ 10,000	
						$ 136,000
	Option 4 - Managed Retreat					
4.1	Weekly "drive by" inspections	91	$ 48		$ 4,377	
4.2	Access road maintenance by subcontractor	3500	$ 2		$ 7,875	
4.3	Annual culvert inspections	24	$ 48		$ 1,154	
4.4	Vegetation/organics removals (assumed required every 10 years, 10% of cost carried per year)	13000	$ 5		$ 65,000	
4.5	Misc Expenses budget (insurance, administration, etc.)			$ 10,000	$ 10,000	
						$ 80,000
					Total Estimated Operations & Maintenance (Rounded)	***$ 629,000***

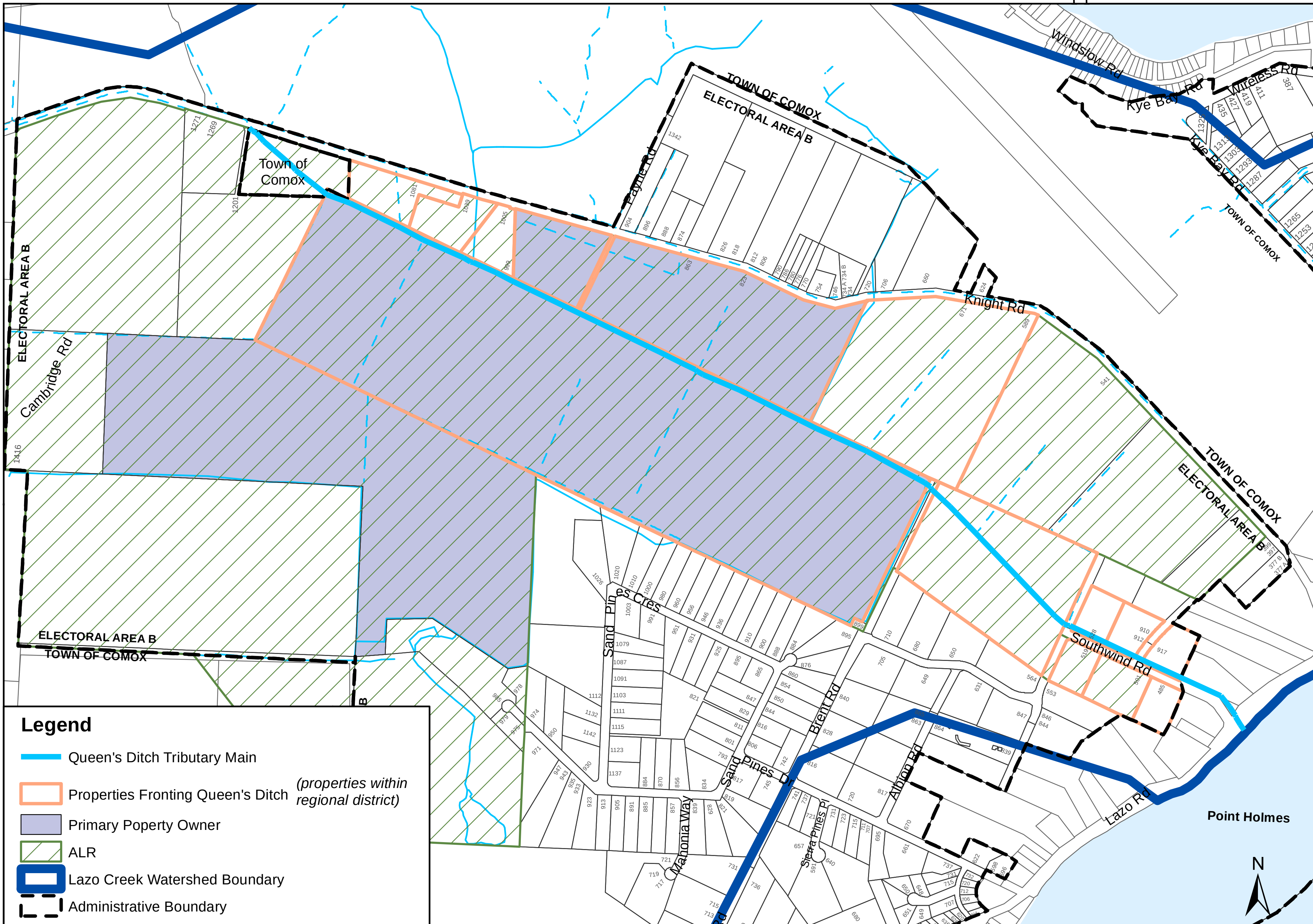
Land Use 1931 vs 1996

‘Towards a Management Plan for the Lazo Watershed & Queen’s Ditch’, prepared by William Marsh





Appendix C



Properties Fronting Queen's Ditch

Comox Valley REGIONAL DISTRICT

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