# NORTH EAST COMOX NEIGHBOURHOOD STORMWATER MANAGEMENT PLAN - PHASE 1 OF 3

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January 14, 2013

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# SECTION A BACKGROUND & STUDY OBJECTIVES

## 1.0 INTRODUCTION

This study was commissioned by a consortium of North East Comox land owners and developers, intended to address the potential impacts of storm drainage emanating from these lands. The scope of work herein is based on the Terms of Reference document dated August 8, 2012, a copy of which is attached as Appendix A.

A number of overarching study objectives were jointly established by the development community and Town of Comox. These objectives include developing a Stormwater Management Plan that:

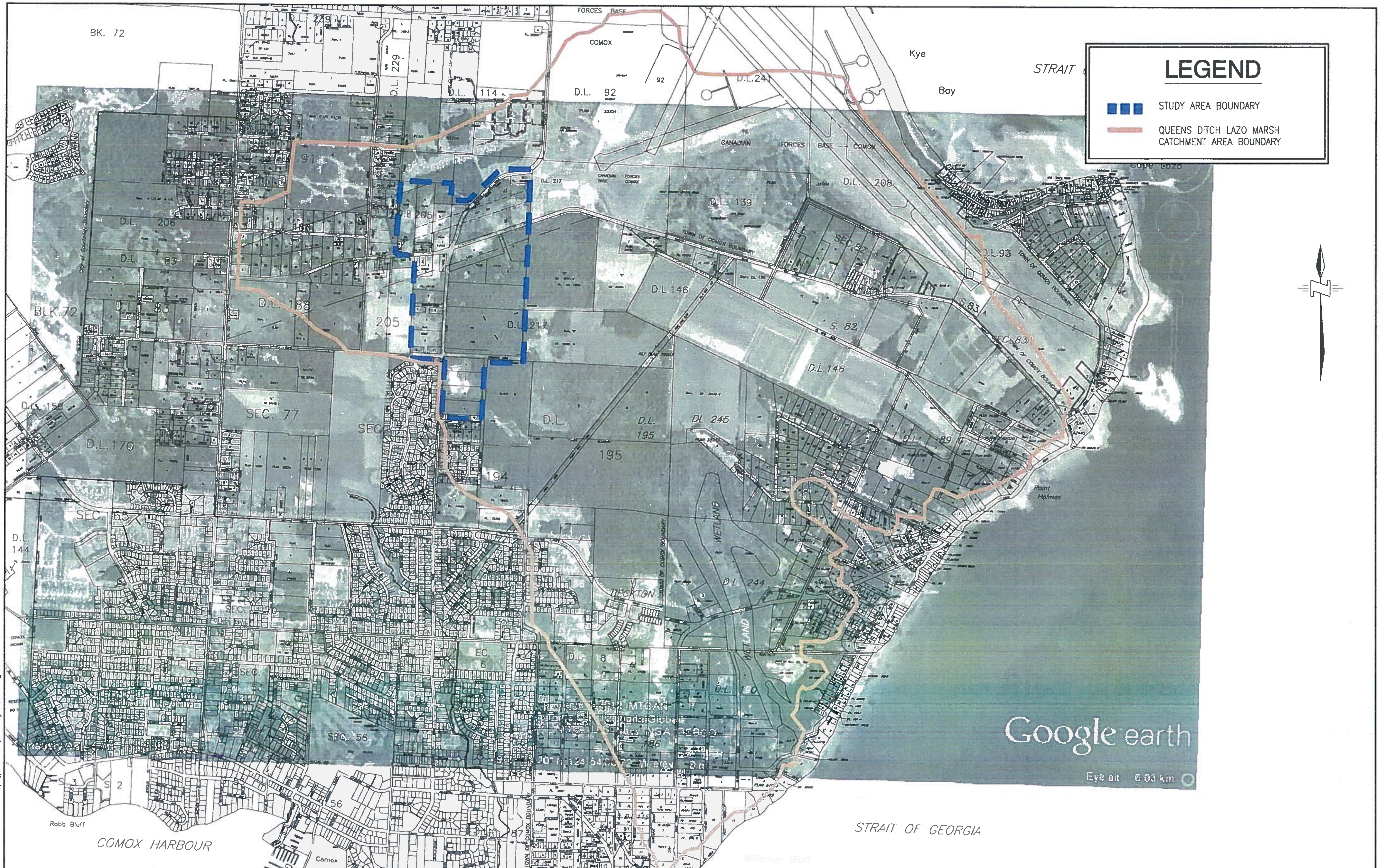
- Establishes how the Town, development community, regulatory agencies and citizens will grow and live within the NE Comox watershed, which includes the Queen's Ditch and Lazo Marsh.
- Provides the Town, regulators, the public, and developers with the information required to balance development, growth and the environment. Specifically, the SWMP identifies potential negative impacts and mitigation strategies required to offset the impacts.
- Provides enhancement opportunities for aquatic life and habitat.
- Will enable orderly and cost effective development and re-development opportunities.

Drawing A-1, overleaf, indicates the extents of the Queen's Ditch/Lazo Marsh catchment boundary, as well as the limits of the current study. Note the watershed catchment boundary indicated on Drawing A-1 varies slightly from that shown in the Terms of Reference document. This minor amendment is based on ground truthing of the catchment, undertaken following the completion of the Terms of Reference.

### EVOLUTION OF STORMWATER BEST MANAGEMENT PRACTICES

The fundamentals of community stormwater management have evolved considerably in recent times, toward mitigating the effects of land development on the hydrologic cycle, as well as better recognizing and accounting for environmental resources within community watersheds. The move has led communities away from a capture, pipe and convey mentality, to a more holistic philosophy that considers the overall health of the watershed. Research through the 1990s and early 2000s culminated in BC publishing the "Stormwater Planning Guidebook" in 2002, which formalized the objectives and guiding principles for an "Integrated Stormwater Management Plan (SWMP)". The purpose of an SWMP is to provide guidance in the application of land use planning tools, thereby protecting property and aquatic habitat, while at the same time accommodating land development and population growth.

Since the Guidebook's release in 2002, two additional publications have been produced. They are:

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NORTH EAST COMOX NEIGHBORHOOD INTEGRATED STORMWATER MANAGEMENT PLAN

EXTENTS OF QUEEN'S DITCH/LAZO MARSH CATCHMENT BOUNDARY
COMOX, B.C.

Project No. 2211-46500-2
Drawing No.
A-1
Sheet 1 of 4
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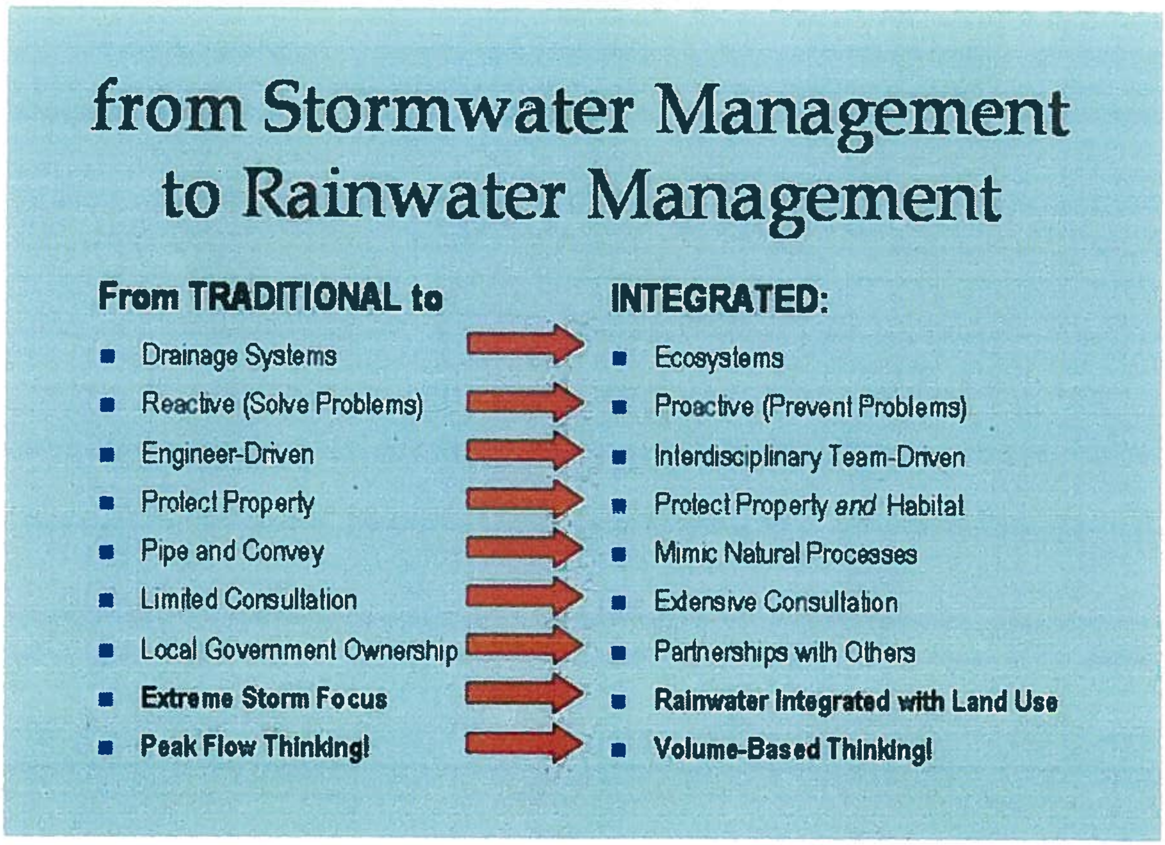
- Beyond the Guidebook: Context for Rainwater Management and Green Infrastructure in British Columbia, June 2007.
- Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia, June 2010.

Henceforth, any references to the "Guidebook" shall be considered collectively as references to the 2002, 2007 and 2010 documents, unless explicitly noted otherwise.

The 2007 and 2010 publications introduce the migration away from "stormwater management" to "rainwater management", claiming that "stormwater suggests there is a problem, whereas rainwater is a resource". The evolution of the integrated approach over the past decades is summarized in Figure 1 below.

**Figure 1: Evolution of Integrated Rainwater Management Planning**



## 2.0 GOALS AND OBJECTIVES

The Northeast Neighbourhood of Comox is currently utilized as large lot residential (estate lots), with some vacant commercial/industrial land adjacent to the airport. The development community and Town of Comox have partnered to develop a strategy for managing stormwater, while allowing for community growth; development that fits both within current Zoning and the Town's Official Community Plan (OCP).

The overall goals for the NE Comox SWMP are as follows:

- Management of the stormwater system in the study area will be consistent with the Town of Comox OCP [including DPA 7 (Riparian Areas), DPA 11 (Wildlife Corridors), and DPA 16 (Energy and Water Conservation and Reduction of Greenhouse Gas Emissions), and zoning for land use.
- The SWMP will be consistent with, and meet the requirements of, the Town's subdivision servicing Bylaw 1261, as certified by a Professional Engineer, licenced to practice in the Province of British Columbia. Further, it will confirm the suitability of the study area for the use intended, as certified by a Professional Engineer, licenced to practice in the Province of British Columbia.
- The SWMP will establish pre-development hydrological and hydrogeological conditions within the study area. Development controls and stormwater management features will be recommended to maintain existing groundwater flows and water quality into Hilton Springs and the Lazo Marsh. Note: the aquifer that feeds Hilton Springs and Lazo Marsh extends well beyond the study area. As such, the above certification is to be based on rainfall infiltration rates being statistically maintained, as derived from analysis of historical data. This study cannot predict changes to the Springs as a result of external developments or factors beyond the author's control. Further, pre-development conditions will be based on drainage patterns as of December 01, 2011, and 100% forest cover.
- Estimated post-development discharges from the study area will mimic estimated pre-development discharges so that statistically there is no significant increase in discharge, both in terms of flood frequency and flow duration. Professional Engineering certification will include an assessment of historic flows based on statistical analysis, and a regional regression analysis to verify modeling against measured discharges in adjacent basins. Certification will be limited to the assumption that historic data and parameters (rainfall and run-off) remain consistent into the future, and are only applicable to the study area. MCSL's liability will extend to designs undertaken by MCSL, being intended to control run-off from the study area to pre-development flows and duration, over the agreed range of the storm events. MCSL cannot be held liable for other changes in the "Queens Ditch / Lazo Marsh Catchment Area", which are beyond its control or are outside the study area identified in drawing A-1.
- Prevent adverse impacts on downstream or adjacent lands as a result of stormwater from the study area. Professional Agrologist confirmation of no adverse impact to arable lands and farm operations and crop production to be provided.

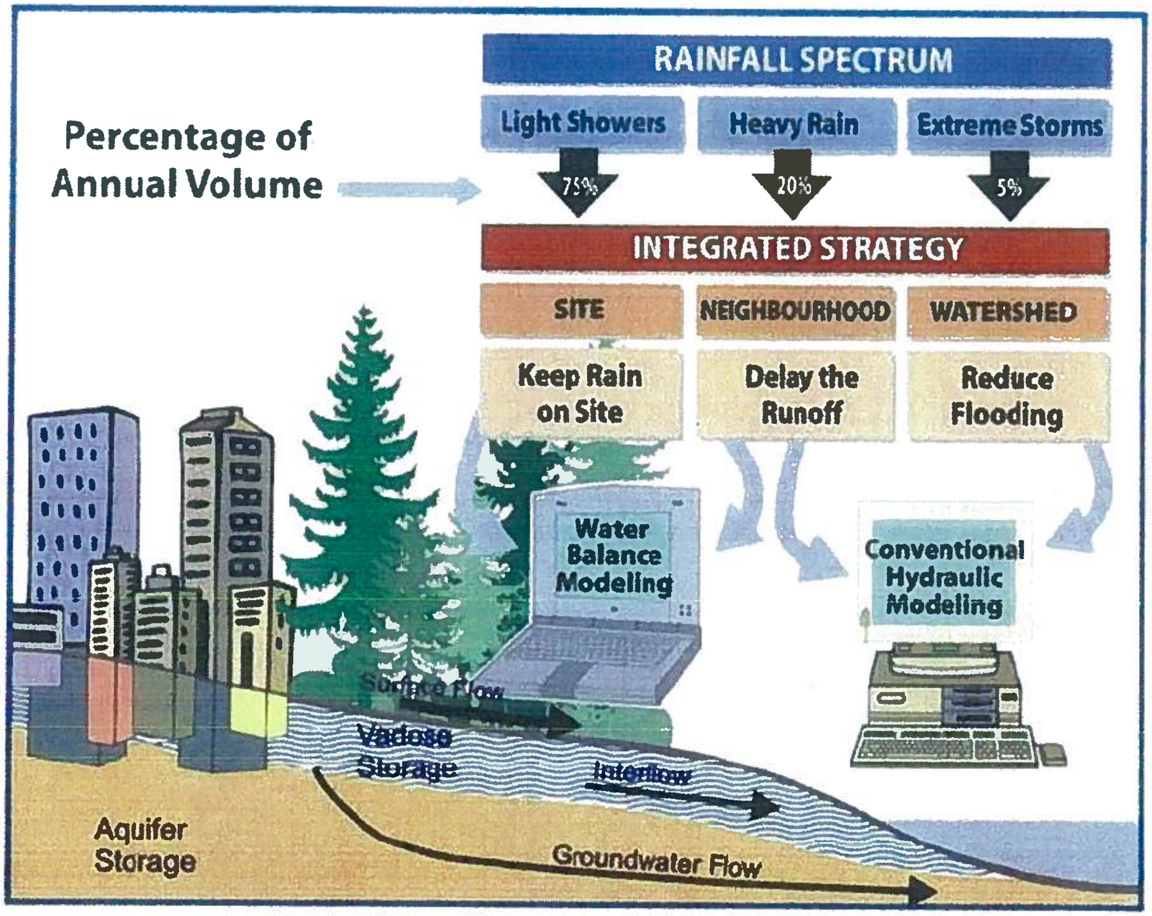
- Develop mitigating strategies which demonstrate no increase in the frequency or duration of flooding on adjacent/down gradient agricultural properties, nor in the "Queen's Ditch".
- Stormwater management facilities will be designed to remove 80% of the estimated total suspended solids (TSS) of the annual average loading in accordance with the Stormwater Management Guidebook.
- Post-development run-off will be utilized to maintain or enhance base flow stream discharges, including through the promotion of groundwater re-charge facilities where suitable.
- Not adversely affect downstream fish habitat and the Lazo Marsh, as certified by a Registered Professional Biologist.
- Utilize 'source controls' and Best Management Practices to manage smaller, frequent precipitation events, and employ stormwater detention facilities to manage larger, infrequent events.
- Establish run-off water quality targets. The SWMP will establish specific goals and objectives that apply to the entire study area, and that will be adhered to during each phase of development.
- Undertake this study in a collaborative manner that provides opportunities for input by the Town throughout the process. It is intended the Town has an active role in establishing any specific methodologies and objectives.
- Provide performance criteria and design details for inclusion in the Town's Development Servicing Bylaw 1261.

## 3.0 BACKGROUND

### 3.1 HISTORICAL BACKGROUND

In 2002, the Guidebook introduced a science-based methodology, allowing setting of performance targets for managing rainwater run-off volumes and run-off rates. The guidebook linked the use of performance targets to the Integrated Strategy (Figure 2), and defined the rainfall spectrum in terms of three tiers, with each tier corresponding to a component of the Integrated Strategy, namely: *Rainfall Capture, Run-off Control* and *Flood Mitigation*, as indicated below.

**Figure 2 – Integrated Strategy for Managing the Rainfall Spectrum**




**Source:** *Stormwater Planning: A Guidebook for British Columbia*, 2002

The mean annual rainfall (MAR) is defined as the rainfall event that occurs once per year, on average. The distribution of rainfall events relative to the MAR is fairly constant throughout British Columbia. The following rainfall tiers are the building blocks of an integrated strategy for managing the complete spectrum of rainfall events:

→ **Tier A Events*** – The small rainfall events that are less than half the size of a MAR, and account for approximately 90% of all rainfall events. The suggested target for Tier A events is to capture the first 30mm (1/2MAR) of rainfall per day at the source, and restoration of natural hydrologic pathways.

→ **Tier B Events*** – The large rainfall events that are greater than half the size of a MAR, but smaller than a MAR, accounting for about 10% of all rainfall events. The target for Tier B events is detention of the balance of the MAR, and release to storm sewers or stream channels at a rate that approximates a natural forested watershed.

→ **Tier C Events*** – The extreme rainfall events exceeding a MAR. An extreme event may or may not occur in any given year. The target is to ensure the stormwater system is capable of safely conveying an extreme flood event from rainfall greater than 60mm (e.g. the 100-Year Flood, $Q_{100}$).

* For the purpose of setting performance targets, a rainfall event is defined as total daily rainfall (i.e. depth of rainfall accumulated over 24 hours).

The rainwater management targets established in the 2002 guidebook were primarily directed toward small land area controls, with the assumption that the overall watershed benefited from the strategies employed at each site. Later research indicated that watershed health was not necessarily improving with implementation of localized source controls alone. In 2007, "Beyond the Guidebook" methodology was released to allow practitioners to assess both site-level rainwater management measures AND flood relief projects, creating a "watershed approach" that addresses stream protection and/or restoration.

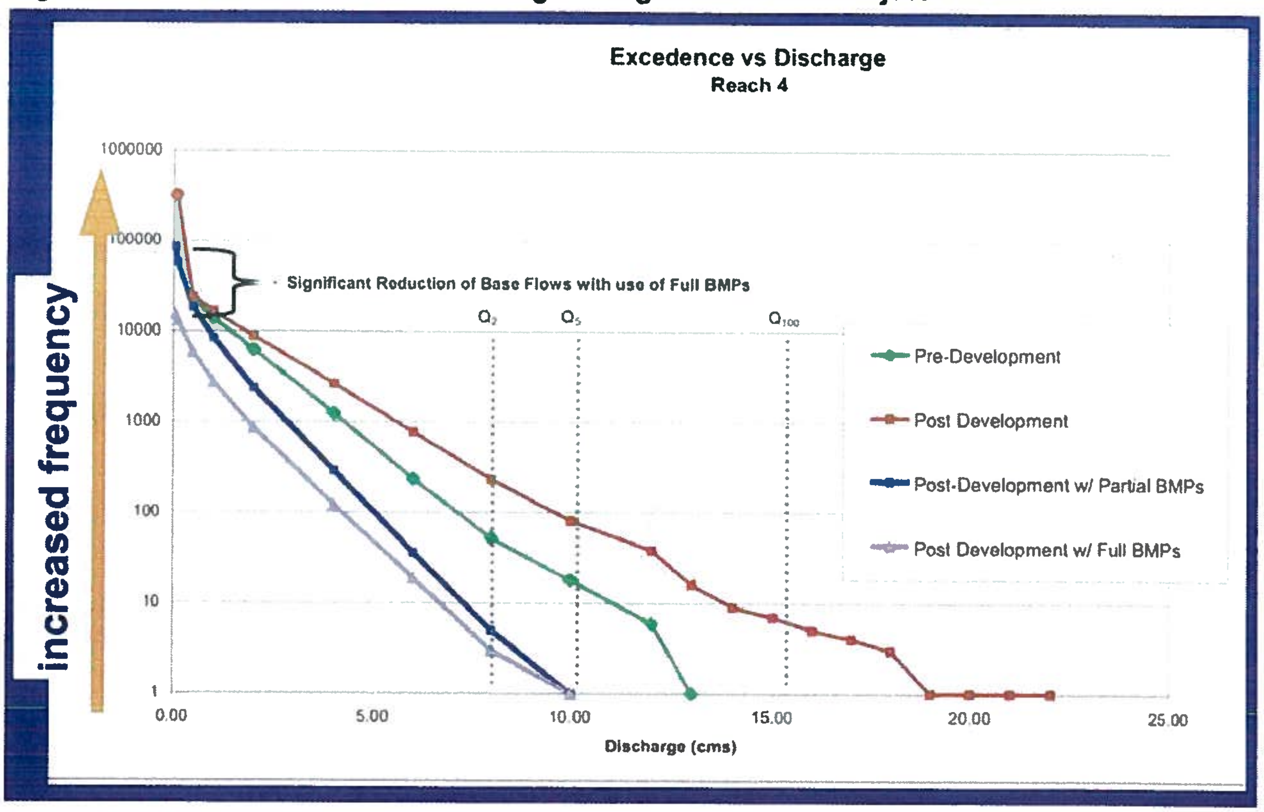
To properly plan at the watershed level, the Water Balance Model planning tool (powered by QualHYMO) was introduced by the Partnership for Water Sustainability in British Columbia. This tool integrates the Water Balance Model and QualHYMO to provide engineers and planners with a run-off based approach for source control evaluation and stream health assessment. This approach was piloted by the City of Surrey, Fergus Creek Integrated Stormwater Management Plan, where the run-off based approach was simulated using QualHYMO, illustrating four scenarios for the Watershed, namely:

1. Pre-Development Case: representing the watershed in accordance with the Design Criteria Manual of the City of Surrey. This watershed is essentially in its current state with a mixture of urban and rural development. This watershed condition provides the baseline upon which all other scenarios can be compared[1].
2. Post-Development condition without mitigation: provides a view of the potential impacts due to development, if mitigation were not included in future planning and development. This case represents the extreme, to provide a comparison for both the pre-development condition and the mitigated development condition of the watershed.
3. The "Guidebook" scenario: represents a developed watershed where one half of the mean annual storm must be retained on site. For storms that exceed this volume, the discharges are detained in a series of ponds to prevent increases in downstream flooding. (One unintended consequence to implementing the full Guidebook requirement was to significantly reduce the baseflows in the stream.)
4. An alternative mitigation case has been developed to eliminate the unintended reduction in base flows and to provide a more balanced approach.

[1] Note the current study defines pre-development site conditions as fully forested with existing roads, whereas the Fergus Creek study utilized present day site cover and land use as its pre-development scenario.

The results of the above cases are presented below in Figure 3, which indicates the statistical exceedance of all rainfall events in relation to stream discharge. By balancing the pre and post-development exceedance curves with appropriate stormwater controls throughout the watershed, the overall stream health of Fergus Creek was predicted not only to be maintained, but potentially enhanced. It is this methodology that has now been widely accepted in BC, and is proposed for the NE Comox Neighbourhood Integrated Stormwater Management Plan Study.

**Figure 3: Exceedence vs. Stream Discharge – Fergus Creek Pilot Project**




### 3.2 NE COMOX NEIGHBOURHOOD SWMP APPROACH

Working with the Town and its consultant - Morrison Hershfield - the QualHYMO tool will be utilized to assess the potential impacts of development within the NE Comox study area.

Morrison Hershfield (MH) indicated in its May 05, 2011 letter, "*The approach we believe would be adequate to address only the sub-watershed [i.e. the study area] and their potential impacts. If the changes within the sub-watershed can be managed in a way that will maintain the existing flow duration relationships there would be no changes to the downstream system which includes both the Queen's Ditch and its floodplain. The approach provides a simpler approach to protect the downstream areas from increased flood risks.*"

On this basis, the following approach has been agreed upon for the NE Comox study area, in accordance with the attached Terms of Reference:

*"Utilizing an appropriate suite of "Low Impact Design" (LID) techniques, post-development hydrology will approximate the existing (pre-development) stormwater flow-duration relationship over the spectrum of historic data. Extreme run-off/flood events will be mitigated/managed through the use of appropriately designed stormwater detention and retention facilities.*

*Soils within the study area have a finite capacity to capture and infiltrate run-off, without impacting existing hydrogeological regimes, or breaking out down slope in a manner inconsistent with pre-development conditions. The site specific locations and magnitude of groundwater recharge at each proposed location will need to be modeled and documented, for purposes of informing the detailed design.*

*We propose to utilize the performance criteria founded on the 2007 "Beyond the Guidebook" document, and the existing Town of Comox Subdivision Servicing Standards.*

## 3.3 SPECIFIC DESIGN/STUDY CRITERIA

- *A focus on flow duration, i.e., provide an analysis of the discharge rates that could adversely affect downstream properties, if flow durations were increased. The opportunity may exist to extend the flow duration of smaller events, thus providing a net environmental benefit, whilst decreasing flood potential.*
- *Large, infrequent events (eg: 25, 50 and 100 year run-off events), are to have peak run-off rates attenuated [not to exceed pre-development peak], through the use of ground recharge, community based detention and other BMPs.*
- *Flood routing is to be estimated, up to and including the Q100 event, using statistical methods.*
- *Changes in expected flow-duration and overall drainage basin average annual volume will not cause erosive forces in excess of pre-development conditions, nor result in downstream aquatic habitat degradation. This will be inferred based on the sub watershed analysis."*

# SECTION B EXISTING PHYSICAL CONDITIONS

## 4.0 QUEEN'S DITCH CATCHMENT OVERVIEW

The Queen's Ditch/Lazo Marsh Watershed encompasses approximately 1000 hectares of land, most of which drains to the Queen's Ditch. Topography within the catchment varies from flat to gently rolling, with elevations ranging from sea level to approximately 55m. Present day land use within the catchment consists of a mixture of urban residential, rural residential, light industrial, institutional, agricultural, and airfield (CFB Comox). Existing vegetation within the 80 hectare study area is predominantly second growth forest, with some grass lands and gravel extraction operations.

Present day drainage infrastructure within public roadways consists mainly of roadside ditching along Pritchard and Knight Roads with some underground piping along Brighton Road and the south west end of Pritchard. Underground piping has also been constructed to drain the intersection roundabout at Knight and Pritchard Roads. This hard pipe system discharges into the roadside ditching on the south side of Knight Road.

Lands upstream of the study area are generally comprised of large lot, semi-forested rural residential properties, although a number of agricultural operations also exist. Constructed storm drainage systems up-gradient of the study area are predominantly roadside ditches and culverts. A stormwater detention pond exists in the Forest Grove subdivision on Hudson Road. Run-off from this area passes through the study area, unmitigated, discharging into the Queen's Ditch.

### 4.1 HISTORY OF FLOODING IN THE AREA

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.

**Figure 4 Headquarters of the Queen's Ditch**

Discussions with Chris Williams, land owner and farmer of lands which lie at the headwaters of the Queens 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.

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.

**Figure 5 Seasonal flooding of agricultural lands adjacent to the Queen's Ditch**

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 a statutory right of way in favour of the Department of National Defence.

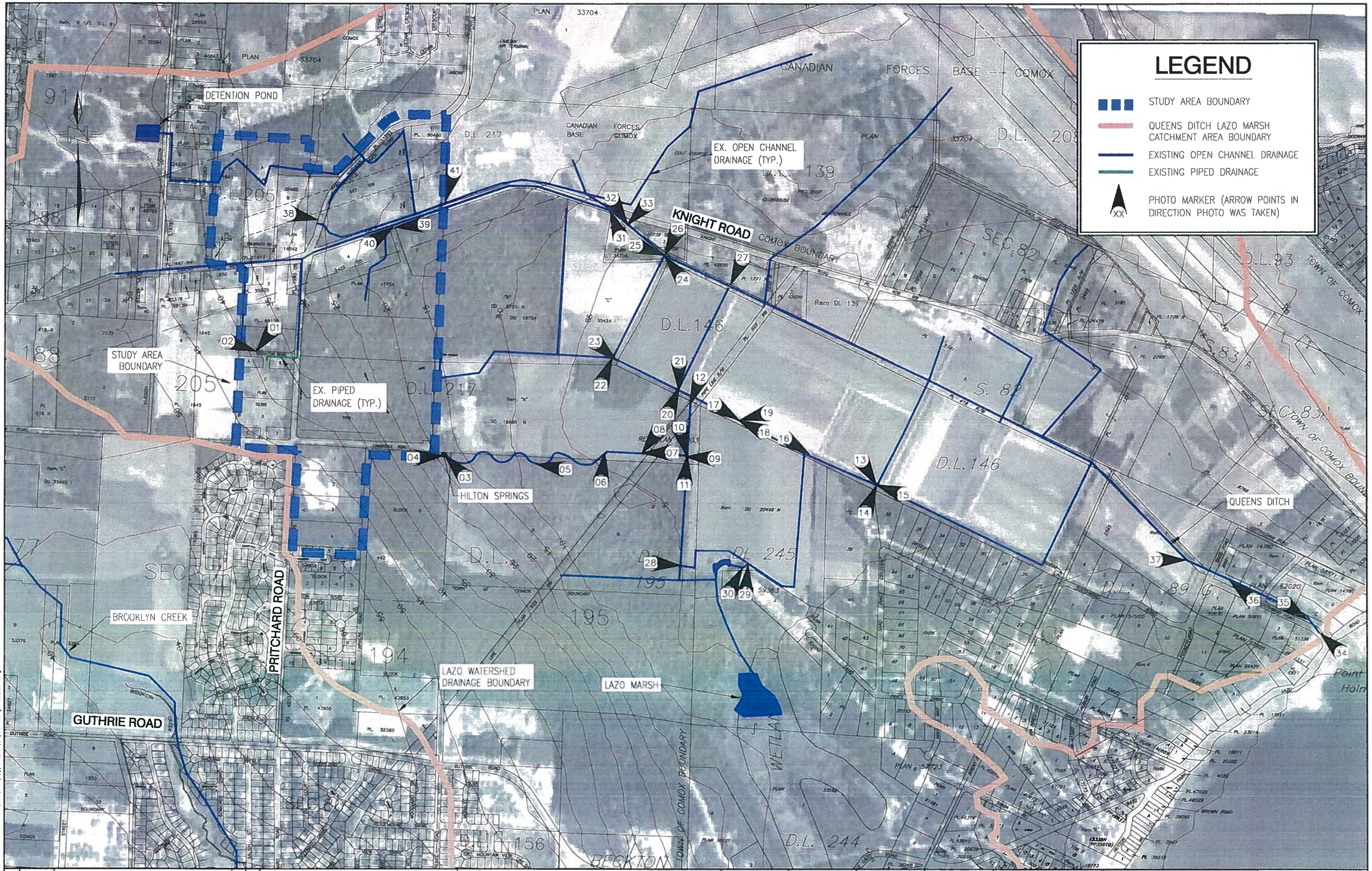
## 5.0 FIELD RECONNAISSANCE AND PHOTO LOG

MCSL has undertaken a series of site investigations allowing verification of existing drainage patterns, ground cover, land usage, etc., as required to establish Queen's Ditch catchment baseline conditions. These inspections, carried out on May 7th, May 10th and June 6th of 2012, have been documented in the photo log attached as Appendix B. Drawing A-2, overleaf, indicates the location and direction of each photo.

### 5.1 GENERAL FINDINGS OF SURFICIAL INVESTIGATION – DRAINAGE MAPPING

Major <u>constructed</u> drainage features within the study area include:

- Roadside ditching along Knight Road (photo #39), along the northern portion of Pritchard Road from Foxxwood Drive to Knight Road, and at several locations along Military Row.
- Open ditching extends across multiple properties lying north of Knight Road, conveying run-off from further upcatchment to the Queen's Ditch.
- A piped drainage system is utilized at the roundabout at Knight and Pritchard Roads.
- A piped drainage system was installed along Brighton Road, discharging to the drainage ditch on the west side of Prichard Road.
- Constructed ditching/fisheries enhancement works completed on Lot 1, Plan 15375 (the "Gage" property).

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NORTH EAST COMOX NEIGHBORHOOD
INTEGRATED STORMWATER MANAGEMENT PLAN

LOCATION AND DIRECTION OF PHOTOS

COMOX, B.C.

Project No. 2211-46500-2
Drawing No.
A-2
Sheet 2 of 4
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Drawing A-3, overleaf, indicates all inventoried drainage features within, and adjacent to, the study area.

Artesian groundwater conditions were observed at Hilton Springs (photo #3) and at the western terminus of Brighton Road (photo #1). Flow emanating from Hilton Springs is sufficient to create a defined drainage path (photo #5). This open channel flows east from the Springs to a series of formalized farm ditches near the CFB Comox fuel pipeline right-of-way (photo #8). The farm ditching downstream of Hilton Springs is also directly connected to Lazo Marsh, as well as a number of smaller lateral drainage ditches. A number of these lateral ditches appear to be capable of reversing flow direction, depending on the amount of run-off and the configuration of downstream outlet controls. The presence of natural springs and the use of outlet controls allow for year round flow in the agricultural ditching network.

Drainage ditches located within the agricultural land area (adjacent to the Queen's Ditch) have been excavated to a grade sufficient to force the dewatering of arable lands. Detrimental effects of intentional dewatering are documented in the 2002 Marsh Study[2]. An extensive series of informal outlet control structures are utilized by farmers to manipulate ground and surface water conditions throughout the year. The outlet control in photo #37 is located near the mouth of the Queen's Ditch, and affects a large portion of the catchment area upstream. This control is used by the farmers to flood fields during winter months, and provide water for irrigation during the dry months.

## 5.2 QUEEN'S DITCH

The Queen's Ditch was constructed initially as an outfall for sanitary sewerage generated within CFB Comox. It is believed this watercourse was a formalization of Lazo Creek, modified over time to accommodate the bulk of the stormwater drainage originating from the air base. The Queen's Ditch begins at a point approximately 100m east of the CVAC terminal, on the south side of Knight Road. The ditch drains to the south east, eventually discharging to the Strait of Georgia, at Point Holmes.

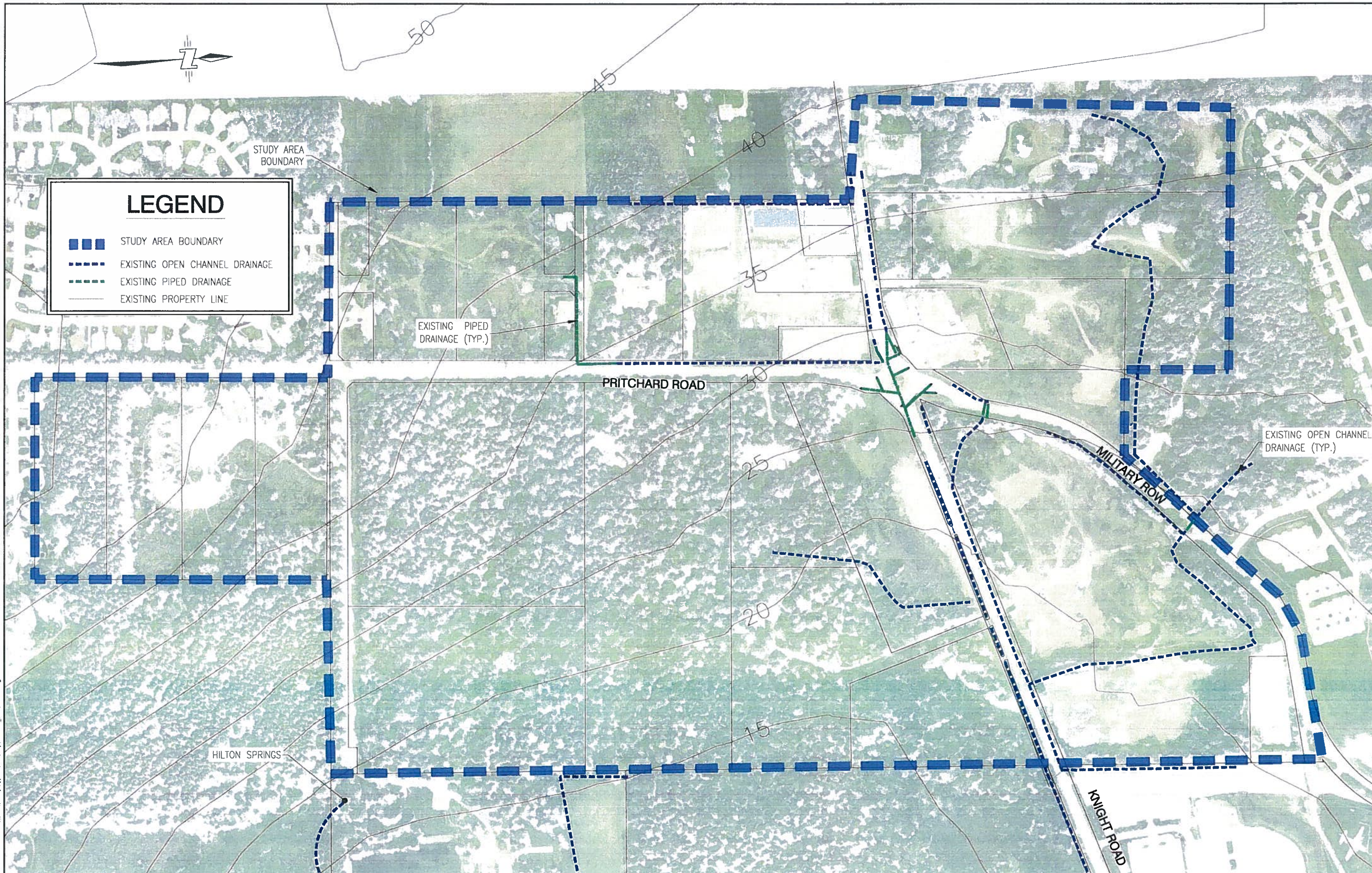
Channel geometry is relatively consistent, both in terms of cross section and gradient. The capacity of the ditch continues to decrease over time, as accumulated sediment and vegetation reduce channel cross section and conveyance efficiency. We understand from a past 19 Wing maintenance contractor that essentially no maintenance of this ditch has occurred over the past (approximately) 10 years. Photo #32 was taken at the headwaters of the Queen's Ditch, and clearly indicates the excessive vegetation within the ditch. Note the (approximately) 20cm diameter tree growing in the middle of the ditch, indicative of the infrequent maintenance the ditch receives.

Past studies of the Queen's Ditch suggest channel capacity is insufficient to meet the demands of existing land uses. The Queen's Ditch capacity is also influenced by tidal action and storm surges. It is not uncommon for the ditch to experience backwater effects nearly all the way to Knight Road during extended periods of rainfall concurrent with high tides/storm surges.

## 5.3 GENERAL CONDITION OF DRAINAGE INFRASTRUCTURE

Existing culverts within and downstream of the study area range in size from 450mm to several meters in diameter, at the outlet of the Queen's Ditch (photo #34). A number of existing culverts

[2] "Toward a Management Plan for the Lazo Watershed & Queen's Ditch", 2002, William Marsh

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NORTH EAST COMOX NEIGHBORHOOD INTEGRATED STORMWATER MANAGEMENT PLAN

INVENTORIED DRAINAGE FEATURES WITHIN THE STUDY AREA
COMOX, B.C.

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were observed to be undersized (photo #28), and/or at the end of their service life (photo #30). Overall, it would appear that most culverts are functional, although a large number are nearing, or have reached the end of their effective service lives.

Ditching within the study area, with the exception of the Queen's Ditch, appears to be adequately maintained.

The limited pipe network, having been installed relatively recently within the study area, appears to be in excellent condition.

## 6.0 SUBSURFACE INVESTIGATIONS

A number of geological/hydrogeological studies have been undertaken within the NE Comox area in the past. This information has been supplemented with a series of studies completed as part of the current SWMP process. Key studies referred to in this SWMP include:

- *Toward a Management Plan for the Lazo Watershed and Queen's Ditch*, 2002, William Marsh
  - *Documented land use changes within the catchment over time, assessed hydraulic constraints within the watershed, and began to develop a management framework for the watershed.*
- *Environmentally Sensitive Areas Study – N.E. Sector Development Plan*, 1993, Chislett, Lattey Manson.
  - *Develops recommendations for development within North East Comox, based on environmental constraints within the catchment.*
- *Hydrogeological Assessment for Storm Water Infiltration, Knight Road*, 2007, Koers and Associates Engineering.
  - *Assessed the geology/hydrogeology within the catchment, makes recommendations for future stormwater management.*
- 2010 Simpson Geotechnical Stormwater Detention Pond Feasibility Assessment, Lot 1, VIP 15375, Comox District (attached as Appendix C).
  - *Assessed the feasibility of constructing storm water management features on the above noted property.*
- 2010 Simpson/GW Preliminary Hydrogeological Assessment Report (attached as Appendix C).
  - *Preliminary assessment of the hydrogeological regime within select areas of the catchment.*
- 2010 GW Solutions Pritchard Road Detailed Hydrogeological Assessment Report (attached as Appendix C).
  - *Final assessment of hydrogeological regime within select areas of the catchment, makes recommendations for maintaining the existing groundwater regime.*
- 2012 MCSL Infiltration Potential Analysis (ongoing).

- *Determination of infiltration potential within specific portions of the study area, for fine calibration of hydraulic models.*

The complex nature of the hydrogeology within NE Comox is well documented. GW Solutions has described the geomorphology of the area as "a series of nearly flat benches, trending north west to south east, with intervening gentle slopes", with surficial lithology alternating between "loose, dry, silty sand, dense, damp, gravely silt, and firm, wet, silt and clay".

Based on available provincial aquifer mapping, the study area is underlain by aquifer No. 408. This confined aquifer covers approximately 148 $km^2$, reaching from the Comox Harbour to within 10km of Merville. The confined nature of the aquifer has led to a "low vulnerability" rating from the province.

Analysis undertaken by GW Solutions has determined that artesian flow conditions exist within portions of the study area. Generally, these conditions exist below a geodetic elevation of 25m, although seasonal variations in piezometric head of up to 2m were noted during the course of study.

A series of shallower aquifers and aquatards also exists in the Knight and Pritchard Roads area. This complex, irregular system of permeable sand and gravel lenses, separated by dense glacial morain caps, extends throughout the study area. A number of permeable strata discharge to the ground surface. The Hilton Springs is one such example.

Based on the geological and hydrogeological conditions encountered, a number of fundamental design parameters are indicated:

- Avoid penetration of artesian strata during servicing/grading of the site.
- Avoid modification of the surface of the land, or subsurface, that would result in lowering the various water tables within the site.
- Introduce groundwater into areas of shallow recharge, in order to effectively mimic pre-development conditions.
- Monitor groundwater conditions for a period of time, to ensure that ongoing hydrogeological processes are consistent with the findings of past reports, etc.

In order to assess the recharge capacity of shallow aquifers within the study area, a series of infiltration tests are being performed during winter 2013. Test locations have been selected based on the relative location of detailed soils information already in hand, and recommendations made by the project's geotechnical team. The results of this analysis will be used to inform the design of mitigating features, detailed in Phases 2 and 3 of this report.

## 7.0 STUDY SUBCATCHMENTS

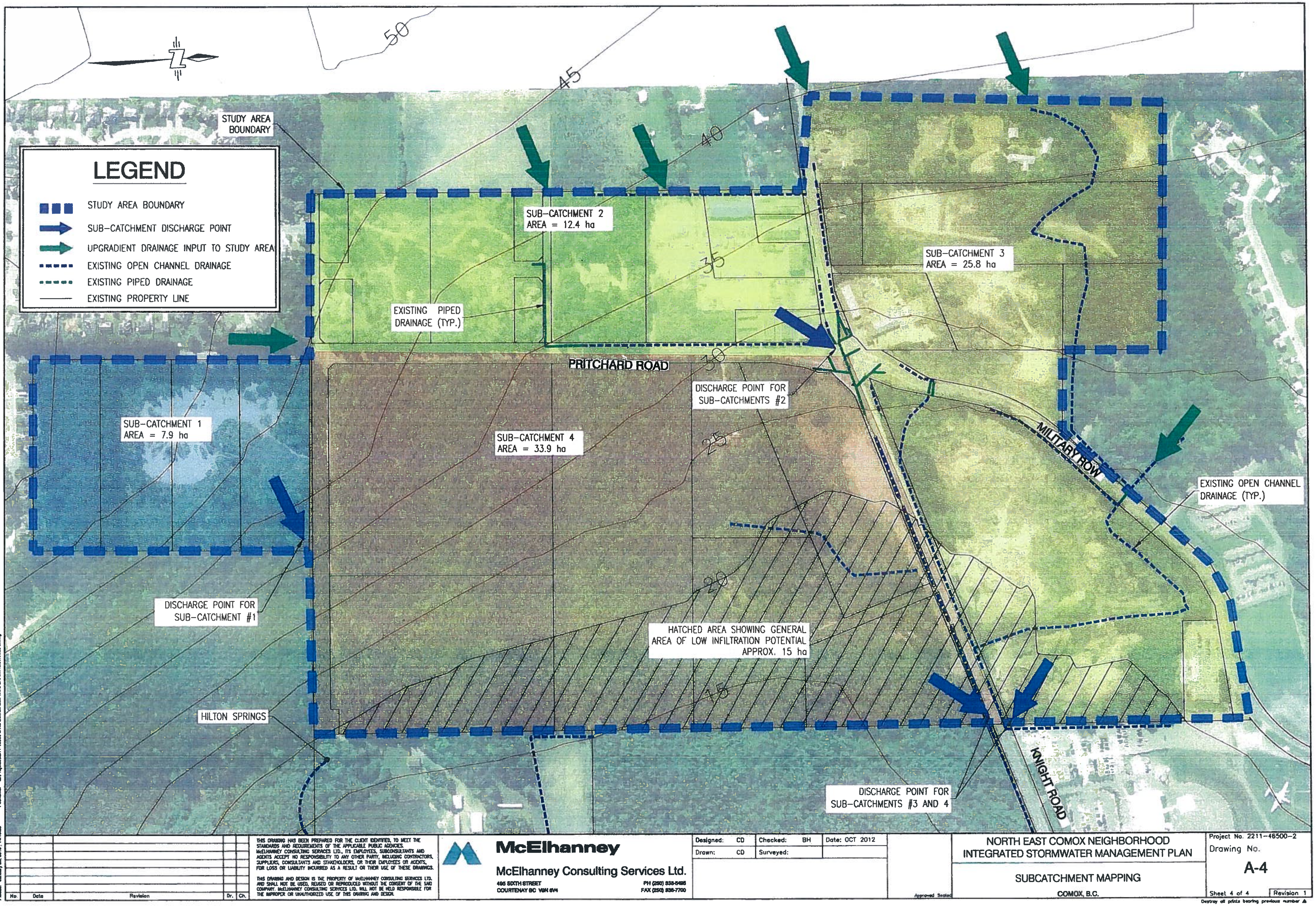
For the purpose of developing a detailed and differentiated hydraulic model, the study area has been segmented into four distinct subcatchment areas. These areas were selected based on a number of criteria, including:

- Existing property boundaries.
- Existing drainage patterns; points of concentration.
- Ground cover.

- Soils conditions expected.
- Present day land use.

The study area consists of approximately 80 hectares, in varying states of improvement. The relative locations of each subcatchment are identified on Drawing A-4, overleaf.

- **Subcatchment 1** is approximately 8 hectares and lies east of Pritchard Road and south of Cambridge. This area represents the highest point of land within the study area, with elevations ranging from 35 to 55m. The land is largely forested at present, with the exception of the gravel pits located on Lots 1-3, Block A, D.L. 194, Comox District, Plan 442. Additionally:
    - Lands within Subcatchment 1 generally slope to the north east, at an average gradient of approximately 5%.
    - There are no known man-made drainage systems within the subcatchment.
    - In general, the groundwater table ranged from 0.5 to 2.4m in depth where test holes detected measurable groundwater. In some cases boreholes were not extended past 2.4m depth or met with refusal conditions, with no groundwater noted or detected. Refer to the 2010 GW Solutions hydrogeological report attached as Appendix C for further details.
    - The Town of Comox Official Community Plan (OCP) has designated this area as Residential: Low Rise Apartments, Townhouses & Ground Oriented Infill, and Residential: Ground Oriented Infill.
    - A catchment discharge point was selected in the lower north east corner of the catchment (Hilton Springs).
- **Subcatchment 2** lies west of Pritchard Road, and south of Knight Road. Present day ground cover consists of grasslands, second growth forest, and cleared light industrial land. A large portion of the catchment is currently vacant, though residential, institutional and light industrial uses also exist.
    - The 12 hectare parcel ranges in elevation from 25 to 45m and gently slopes north east with an average grade of 3.5%.
    - Shallow groundwater tables range from 1.5m below existing grade along the south subcatchment border, to artesian conditions along the western edge of the boundary.
    - A spring was observed at the west end of Brighton Road. This run-off follows the roadside gutter and is collected by a catchbasin.
    - Existing drainage is limited to a small amount of hard piping along Brighton Road, which discharges into the drainage ditching on the west side of Pritchard Road, thence along Pritchard Road and into the Knight Road open ditch system. An urban style (catchbasin/hard pipe) drainage system was installed at the Knight Road roundabout.



LEGEND
STUDY AREA BOUNDARY
SUB-CATCHMENT DISCHARGE POINT
UPGRADIENT DRAINAGE INPUT TO STUDY AREA
EXISTING OPEN CHANNEL DRAINAGE
EXISTING PIPED DRAINAGE
EXISTING PROPERTY LINE
STUDY AREA BOUNDARY
SUB-CATCHMENT 2 AREA = 12.4 ha
SUB-CATCHMENT 3 AREA = 25.8 ha
SUB-CATCHMENT 1 AREA = 7.9 ha
SUB-CATCHMENT 4 AREA = 33.9 ha
EXISTING PIPED DRAINAGE (TYP.)
PRITCHARD ROAD
DISCHARGE POINT FOR SUB-CATCHMENTS #2
MILITARY ROW
EXISTING OPEN CHANNEL DRAINAGE (TYP.)
DISCHARGE POINT FOR SUB-CATCHMENT #1
HATCHED AREA SHOWING GENERAL AREA OF LOW INFILTRATION POTENTIAL APPROX. 15 ha
HILTON SPRINGS
KNIGHT ROAD
DISCHARGE POINT FOR SUB-CATCHMENTS #3 AND 4
50
45
40
35
30
25
20
15
No. Date Revision Dr. Ch.
McElhanney
McElhanney Consulting Services Ltd.
Designed: CD Checked: BH Date: OCT 2012
Drawn: CD Surveyed:
NORTH EAST COMOX NEIGHBORHOOD INTEGRATED STORMWATER MANAGEMENT PLAN
SUBCATCHMENT MAPPING
COMOX, B.C.
Project No. 2211-46500-2
Drawing No.
A-4
Sheet 4 of 4 Revision 1

- A catchment discharge point was selected at the lower (north eastern) corner of the subcatchment (corner of Knight and Pritchard Roads).

- **Subcatchment 3** is bounded to the south by Knight Road, and to the north, east and west by the study area boundary. The catchment is 28 hectares in size and is at present utilized primarily as commercial/light industrial.
  - Shallow groundwater tables range from 0.5 to 2.0m deep while ground elevations range from 20 to 35m.
  - The area gently slopes south east at approximately 2.5%.
  - An open channel meanders across the subcatchment and connects to the roadside ditching at the east end of Knight Road as shown in Drawing A-2. The open channel conveys run-off from lands upstream of the study area. Roadside ditching along Military Row and Knight Road drain directly to the Queen's Ditch.
  - A subcatchment discharge point run-off from the subcatchment discharges at the east study area boundary in the roadside ditching along Knight Road.

- **Subcatchment 4** covers 34 hectares, and is bound by Pritchard Road to the west, Knight Road to the north, Cambridge Road to the south and the study boundary to the east.
  - The area is largely covered in second growth tree cover, with the exception of modest openings around existing residences and a small cleared area along the south side of Knight Road.
  - Current zoning within the subcatchment is residential and light industrial. The area is largely undeveloped, save for four existing houses.
  - Elevations in the subcatchment range from 15 to 40m, and the area generally slopes north east with an average grade of 3.5%.
  - Shallow groundwater tables range from 0.5 to 2.0m in depth. Areas showing potentiometric surfaces above ground elevations were observed just south of the subcatchment.
  - Constructed drainage within the subcatchment is minimal, consisting of roadside ditching along the south side of Knight Road.

The study area subcatchments presented above are defined for the purposes of the post-development case, each parcel being developed separately and with varying land use. For the pre-development scenario, the study area is viewed as homogenous, and therefore the baseline condition is formulated based on the whole rather than the individual parts.

# SECTION C HYDRAULIC MODELING

## 8.0 COMPUTER MODEL

Prior to evaluating the potential impacts of any land use change, hydrologic modeling of the study area in its 'pre-development' condition is to be undertaken. This modeling will be utilized as the basis for all assessments of the efficacy of stormwater management facilities proposed in this study. In this case it is assumed pre-development conditions include:

- All privately held lands (to be developed) are generally undeveloped with mature vegetation throughout.
- Existing roads and drainage infrastructure are to be considered in historic (pre-development) condition.

The intent of Phase 1 of the NE Comox SWMP is to "establish baseline flow/duration relationships for the study area utilizing QUALHYMO software, and verification using a regional analysis". On this basis, the model has been set up and verified as described below.

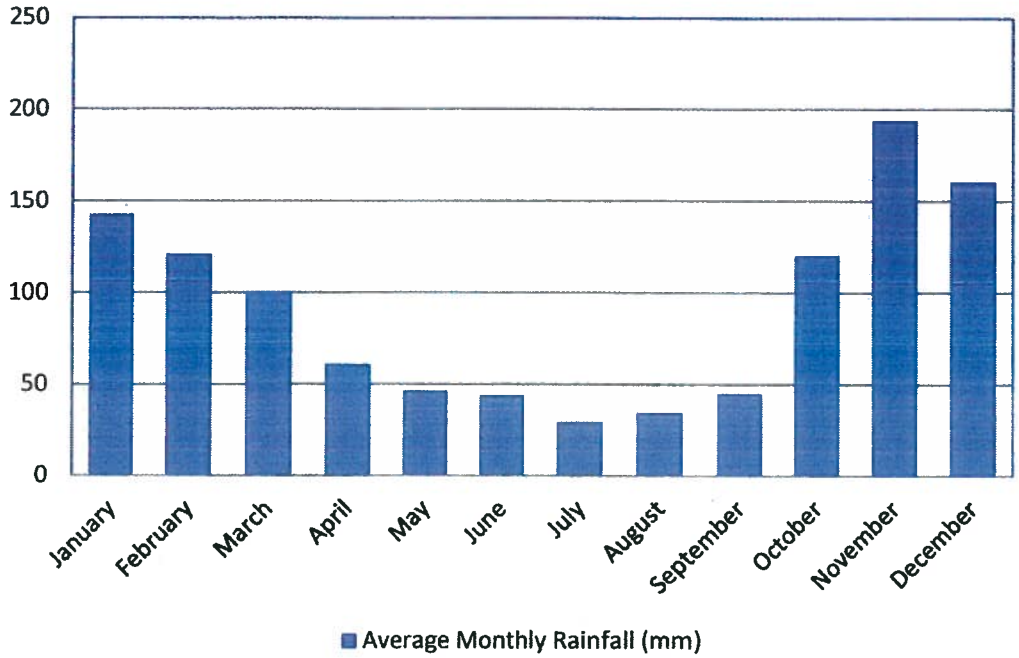
The Hydrologic modeling analysis for this study utilized the latest update of the QUALHYMO computer model as implemented within the updated Water Balance Model. QUALHYMO accounts for various hydrologic processes that produce run-off from urban areas which include:

- Time-varying rainfall.
- Evaporation of standing water.
- Snow accumulation and melting.
- Rainfall interception from depression storage.
- Infiltration of rainfall into unsaturated soil layers.
- Percolation of infiltrated water into groundwater layers.
- Interflow between groundwater and surface water.

### 8.1 RAINFALL

For purposes of modeling the NE Comox Neighbourhood Study Area, the Environment Canada rain gauge at the Comox Airport has been used. The Environment Canada website displays "Canadian Climate Normals or Averages" for all its stations. Figure 6 overleaf shows the long-term average monthly rainfall at the Comox Airport. The graph provides a key observation of the seasonal distribution of rainfall: The summers are relatively dry, and most of the rainfall occurs between October and March each year.

**Figure 6: Monthly Average Rainfall* (1971-2000)**




* Obtained from Environment Canada – Canadian Climate Normals

Climatic data, obtained from weather station ID: 1021830 (Comox Airport) for the three key parameters used in the model, is provided below:

1. Rainfall depths in tenths of millimetres measured in hourly increments from May 1962 to September 2005[3].
2. Temperature measured in tenths of Degrees Celsius in hourly increments from May 1962 to Dec 2007.
3. Monthly Pan Evaporation coefficients from 1962 to 1999.

Data for the three parameters noted above was not available for all years of record. Thus, rainfall temperature data was truncated from 1963 to 2004, and the evaporation data file extended to the end of 2004 by using the statistical monthly averages for this period of time.

Rainfall statistics for the study are as follows[3]:

- 40% of all days have some amount of rainfall falling primarily in November, December and January as shown on Figure 6.
- The Mean Annual Rainfall (MAR) based on daily amounts of rainfall is calculated to be 44 mm/day, with only 0.8% of rainfall days exceeding this amount.
- The largest single day of rainfall measured to-date is 113mm, which occurred on December 22, 1957. However, this is outside the available record for the study, which shows a maximum daily rainfall accumulation of 102.6.
- The longest single-event storm for the period of record is 36 hours with a total accumulation of rainfall of 119.6mm (12/20/1986 to 12/21/1986).

[3] Rainfall data can be found on the attached CD Rom.

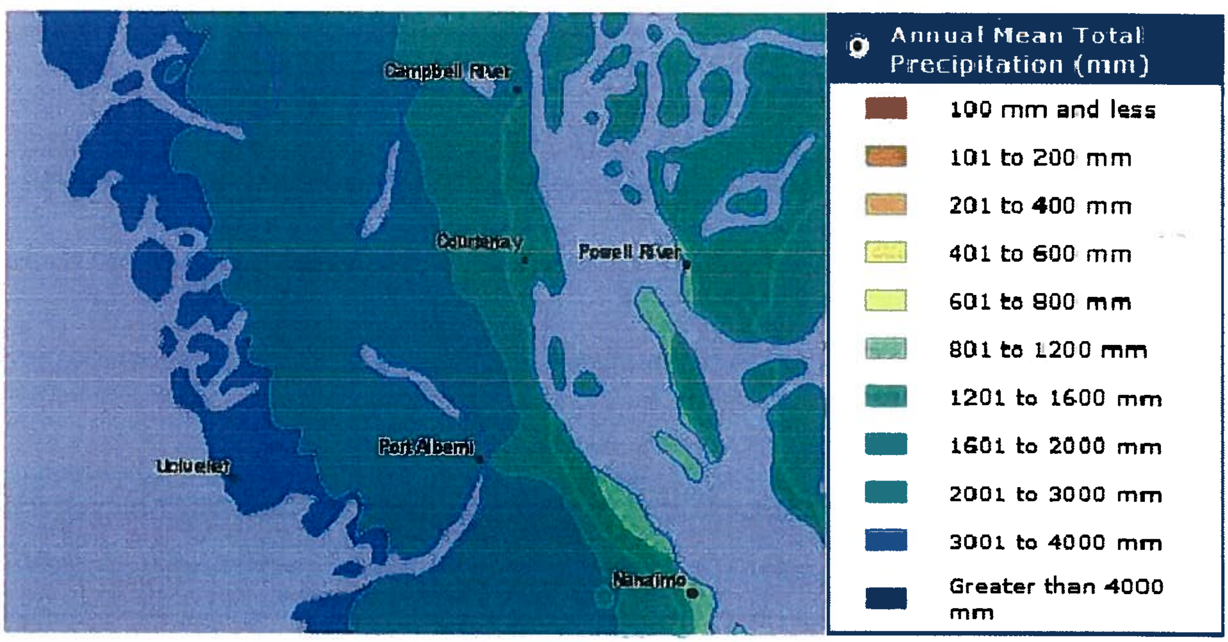
## 8.2 REGIONAL HYDROLOGY - MODEL CALIBRATION & VERIFICATION

In order to ascertain the accuracy of a hydraulic model, verification is ideally required against known rainfall and run-off values within the study area. Where such data is not available, comparison in the form of a regional analysis can serve as a suitable alternative. In the present context, the latter option is required, as essentially no run-off or stream flow data is available within the Queen's Ditch/Lazo Marsh watershed.

The intent of the regional analysis is to compare model results with similar watersheds within the same geographic area. Peak discharge rates and run-off volumes are typically used. The regional analysis method is most accurate when utilizing long term flow measurements. Thus, proxy streams selected for comparative analysis were selected, in part, based on the duration of reliable flow data available.

To select an appropriate proxy stream, the nearby gauge needs to be within a region of similar climate and geography, including land use and soil characteristics. Figure 7 indicates the regional Annual Mean Total Precipitation for the mid-Vancouver Island and Discovery Islands region.

**Figure 7: Regional Mean Annual Precipitation Atlas**




Source: Annual Mean Total Precipitation (Atlas of Canada)

http://atlas.nrcan.gc.ca/site/english/maps/environment/climate/precipitation/precip?layers=pcp_annual&scale=42051275.911682&mapxy=-1694825.2083336664%201868243.25&mapsize=1150%201350&urlappend=

The map suggests the region around Courtenay/Comox receives an annual average of 801 to 1200mm of precipitation (Comox Airport weather station reports a mean annual precipitation value of 1179 mm (1971-2000)). Areas banding Courtenay/Comox, including Campbell River, are in the 1201 to 1600mm average annual precipitation zone (Campbell River airport weather station reports 1451 mm of total annual precipitation on average). Seasonal variations at available Island weather stations were compared and found to be consistent with Figure 7 throughout the region.

Based on regional mean annual precipitation, streams initially considered for use in a regional analysis are shown on Figure 8 (overleaf), and listed within Table 1, below. Streams with catchments of up to 250 square kilometres were selected. Continuous gauges were favoured over seasonal or intermittent, however, the Little River Station was ultimately deemed most favourable based on its proximity, state of development and drainage area size. Monthly average data from this stream was used to verify the model parameters when considering the volume of run-off. Of the seven streams listed in Table 1, six were deemed suitable for use in the verification process. The Little Oyster River was excluded from this analysis, largely because it is a seasonal gauge only monitoring flows between the months of June and October.

All other stations were deemed suitable based on their geographic characteristics, as well as their relative state of catchment development and similar soil characteristics. Notably:

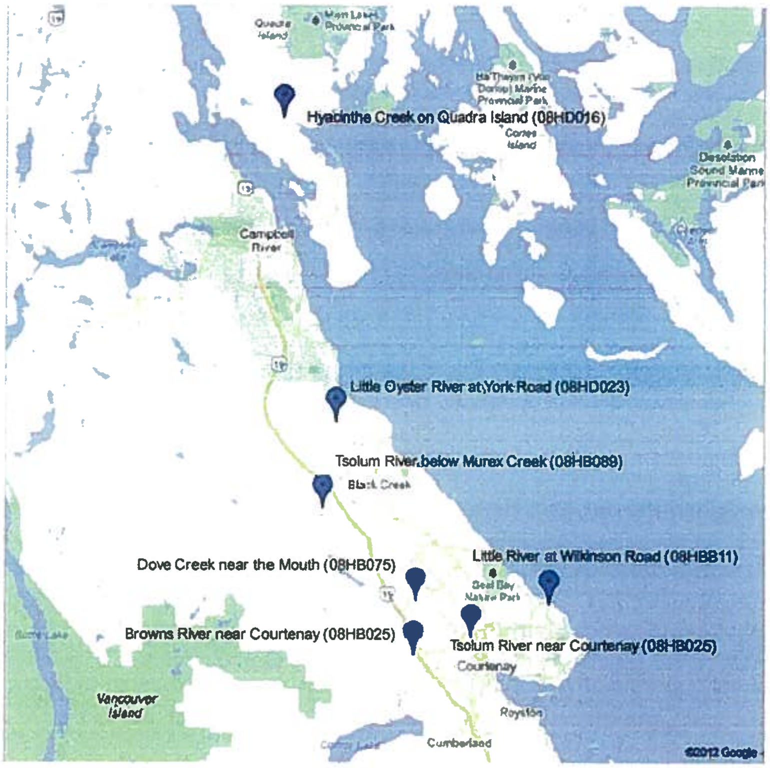
- Hyacinthe Creek and the Browns River were found suitable based on their relatively undeveloped catchments. This is significant, as the terms of reference require pre-development site conditions similar to existing within these catchments.
- Dove Creek and the Tsolum River were deemed suitable based on their lack of development. These watersheds were also favourable based on their long record of flow data and similar geographic and soil characteristics.

**Table 1: Regional Stream Characteristics**

| ID | Name | Area ($km^2$) | Years of Record | Continuous |
|---|---|---|---|---|
| 08HD016 | Hyacinthe Creek on Quadra Island | 7.68 | 1990-1999 | Yes |
| O8HB011 | Tsolum River near Courtenay | 251 | 1964-2010 | Yes |
| 08HD023 | Little Oyster River at Yorke Rd | 38 | 1994-2008 | Seasonal |
| 08HB089 | Tsolum River below Murex Creek | 86.7 | 1997-2008 | Yes |
| 08HB075 | Dove Creek Near the Mouth | 41.1 | 1985-2008 | Yes |
| 08HBB11* | Little River at Wilkinson Rd | 19.3 | 1987-92 | Intermittent |
| 08HB025 | Browns River near Courtenay | 86 | 1960-2008 | Yes |

* Provincial Station – Only Monthly Average Flow Data available from Comox/Black Creek Water Allocation Plan (MC MoE, 1997)

**Figure 8: Hydrometric Station Locations**




Model verification follows a two-step process: adjustment of base flow parameters for calibration of total run-off volumes, followed by adjustment of unit hydrograph parameters for calibration of peak discharge rates. Given the limited data available for the area, the above stations were all utilized for the calibration of run-off volumes and peak flows.

### 8.3 VERIFICATION – RUN-OFF VOLUMES

The Little River Provincial Station provided monthly flow rates for four years (from 1988 to 1991). However, peak flow rates were not available at this station. As this gauge is located in close proximity to the project site, it was best suited for adjustment of model base flow parameters used for calibration of total run-off volumes. The recorded data is provided in the table overleaf.

**Table 2: Recorded Monthly Average Discharges at Little River**

Station Name: **LITTLE RIVER AT WILKINSON ROAD**
Station Number: **08HBBII**
Natural Flow:
Drainage Area (sq.km.): 19.3
Flow in m³/sec

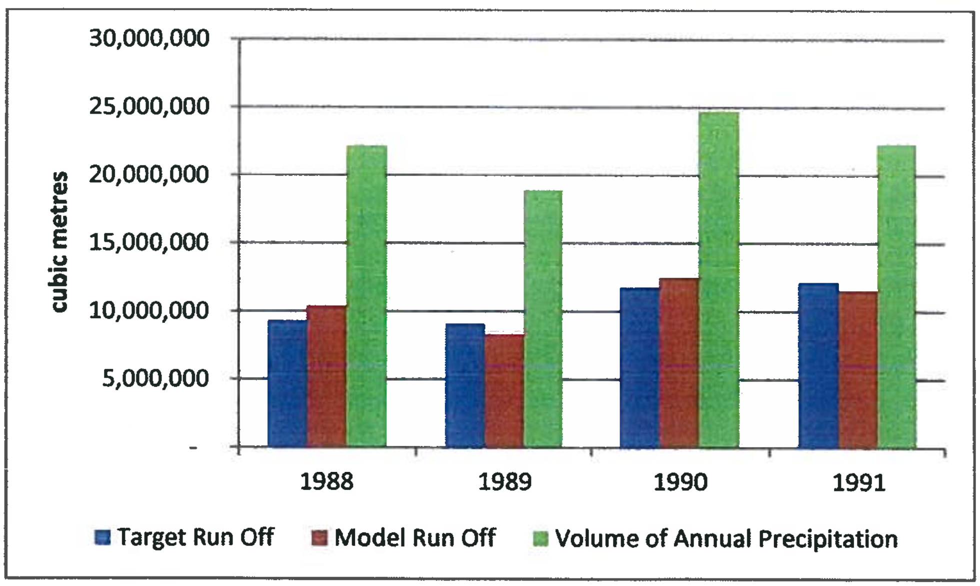
| | Degrees | Minutes | Seconds |
|---|---|---|---|
| Latitude | | | |
| Longitude | | | |

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | MAD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | | | | | | | | | | | | 0.582 | |
| 1988 | | 0.249 | 0.322 | 0.301 | | 0.064 | 0.024 | 0.028 | 0.135 | 0.085 | 0.881 | 0.561 | 0.219 |
| 1989 | 0.484 | 0.683 | 0.532 | 0.308 | 0.083 | 0.041 | 0.045 | 0.049 | 0.051 | 0.219 | 0.380 | 0.618 | 0.289 |
| 1990 | 0.825 | 0.789 | 0.487 | 0.251 | 0.153 | 0.245 | 0.046 | 0.004 | 0.026 | 0.222 | 0.739 | 0.721 | 0.373 |
| 1991 | 1.054 | 1.046 | 0.511 | 0.276 | 0.088 | 0.073 | 0.060 | | 0.124 | 0.112 | | | 0.321 |
| 1992 | | | 0.295 | 0.400 | | | | | | | 0.562 | | |
| MEAN | 0.788 | 0.692 | 0.429 | 0.307 | 0.108 | 0.106 | 0.044 | 0.027 | 0.084 | 0.159 | 0.640 | 0.621 | 0.332 |

The minimum mean monthly discharge of 27 l/s (0.027 $m^3/s$ for August) for the Little River Station, reported in the Comox/Black Creek Water Allocation Plan report, was used as the minimum base flow parameter in the model. This value can be scaled for development of the site specific continuous model.

The Little River Basin (drainage area = 1930ha) was modelled in an effort to produce similar run-off volumes reported by the Provincial Hydrometric Station records for the years 1988 to 1991. Target (actual recorded measurements) and Model discharge rates were compared, and base flow input parameters adjusted until Model and Target run-off values closely matched. Figure 9 indicates the correlation between model and target values. There appears to be reasonable agreement between the two data sets; the bar chart emphasizes the modest relative variation of model estimates vs. actual recorded volumes.

**Figure 9: Comparison of Yearly Run-off Volumes**



For comparison, the annual total rainfall volume for the Little River drainage area is given for the four years. This generally indicates that stream flow volumes follow the patterns of rainfall within each catchment, and that the total stream flow volume averages about 50% of total annual precipitation. The stream flow volume is a combination of surface run-off and shallow interflow that returns to the stream. The remaining 50% of the total rainfall volume is either abstracted by vegetation, returned directly to the atmosphere through evaporation losses, or transferred to deeper ground water aquifers(s).

The process of establishing rainwater management targets has evolved from the Guidebook's reliance upon storms and volumes to the Beyond the Guidebook approach which includes volume, flow duration and peak flood management. The targets derived during this study combine these concepts to allow the development to mimic the natural hydrology of water capture and consumption by vegetation, shallow interflow return to the stream, deep groundwater losses and controlled surface run-off rates. These methods will result in stream flows that are natural in terms of rate and duration.

## 8.4 VERIFICATION – PEAK FLOWS

Peak flow data is not available at the Little River Provincial station, thus, peak flow data from the other five gauges in the region was gathered and utilized to adjust unit hydrograph parameters for calibration of peak discharge rates within the study area.

The continuous rainfall, evaporation and temperature data available for modeling of the study area extended from 1963 to 2004. Only the years that were common to the modeling and hydrometric data were used for calibration purposes.

Flood frequency analysis was undertaken for each of the five stations in the region to determine peak discharges rates for the 2-year up to the 100-year frequency return period. All predictions were then normalized to a unit area discharge, and then scaled to the subject study area (80 hectares). To arrive at a target discharge rate for the study area, the model was adjusted until the return period discharge from the model matched the established average target discharge rates, as shown on Figure 10.

The resultant model parameters from the exercise above will be used for modelling the drainage in the study area, to estimate the volume of run-off and peak discharges for the "Pre-Development" condition.

Drawing A-4 also indicates upland drainage patterns and their paths through the study area. These flows have not been considered in the modeling as they do not influence the amount of run-off generated within the study area lands, nor the study area lands' influence on the receiving environment downstream. Later detailed design of municipal storm drainage infrastructure will account for the conveyance of unattenuated upgradient run-off, as quantified by rational method calculation. It is expected that traditional hard pipe/open ditch drainage systems will be used to convey upgradient runoff through the study area.

**Figure 10: Peak Discharge Calibration**

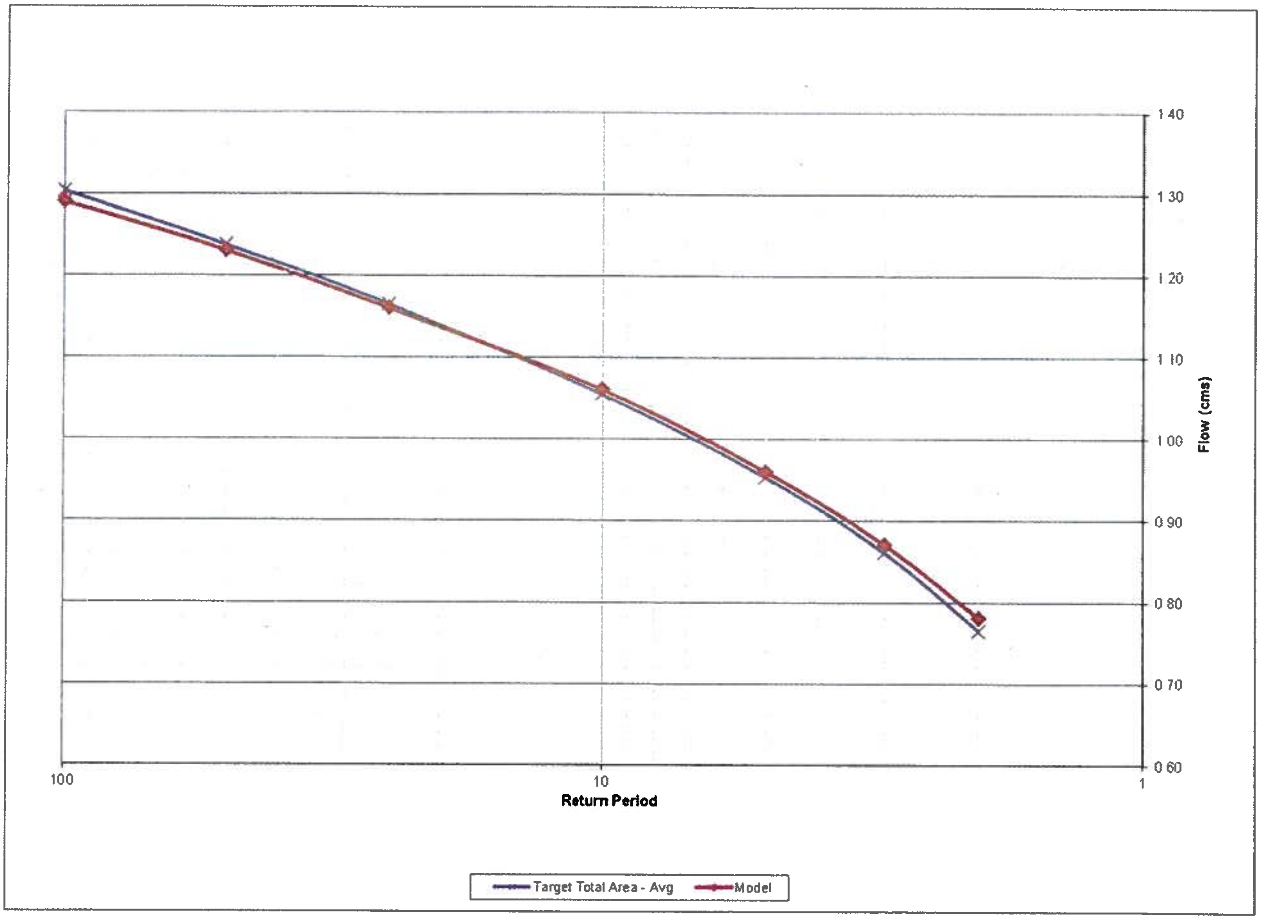



**Table 3: Pre-Development Model Parameters**

| | | Time To Peak | | Initial Abstraction | | Soil Storage | | | Base Flow |
|---|---|---|---|---|---|---|---|---|---|
| Area (Ha) | Impervious % | Impervious (hrs) | Pervious (hrs) | Impervious (mm) | Pervious (mm) | Min (mm) | Max (mm) | Decay $mm^{-1}$ | (cms) |
| 80 | 5 | 3 | 15 | 2.5 | 12 | 20 | 250 | 0.04 | 0.00112 |

The parameters listed in Table 3 are consistent with the observations of the physical characteristics of the study area, namely:

- There is little impervious area.
- Soil Storage is significant due to the nature of the granular overburden layer.
- Initial Abstraction of 12mm is as expected, given the significant vegetation and undulating terrain within the study area.

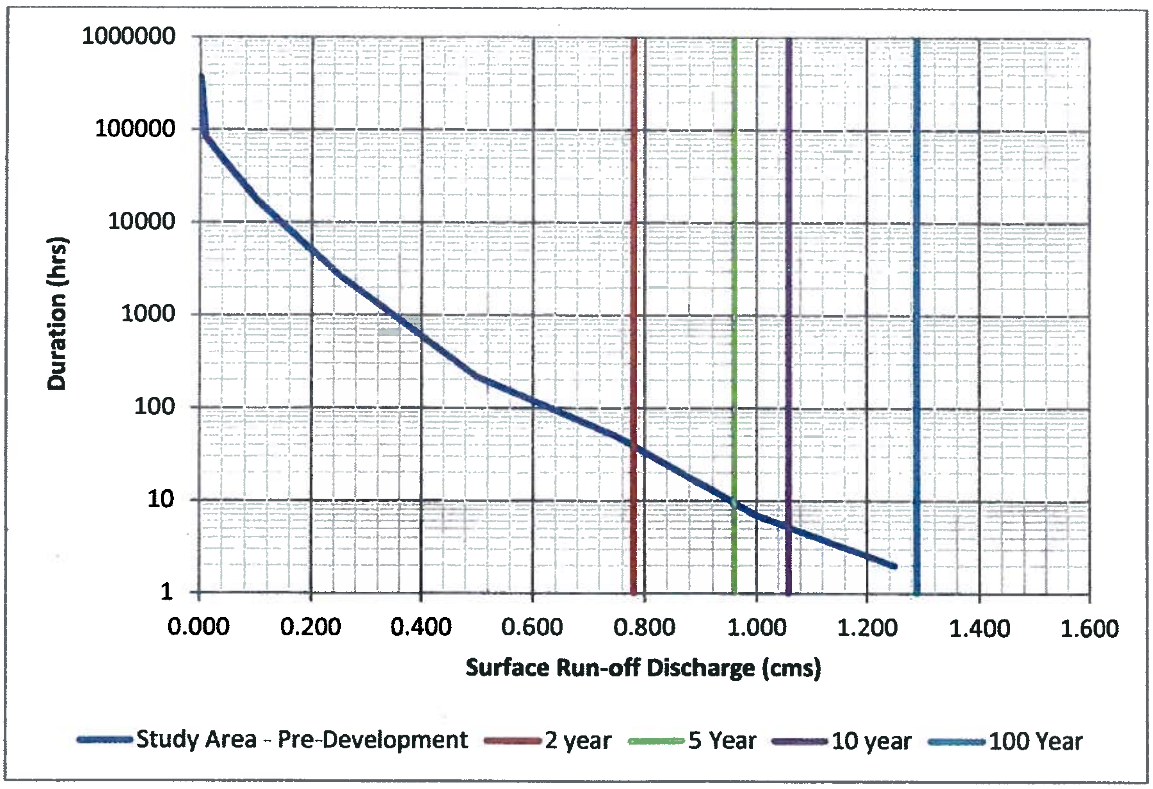
The verified flow-duration relationship for the study area is shown on Figure 11. This figure includes the calculated 2, 5, 10 and 100 year return period discharges. This relationship will form the basis of the targets for pre-development flows in the Study Area, and the metric against which post-development modelling will be compared to, up to the 1:100 year return periods.

The hydrologic mass balance for the study area over the period of analysis (41 years) was calculated by the QualHymo model, as follows.

| | |
|---|---|
| Total Rainfall | 51180 mm |
| Total Surface Run-off | 16355 mm |
| Total Abstractions[4] | 8195 mm |
| Total Volume Infiltrated | 26630 mm |
| Total Volume transferred to deep groundwater | 18380 mm |

Based on QualHymo results, approximately 28% of the total rainfall volume over the period of record has translated into direct surface run-off. The amount of water flowing through the vadose soil layer (interflow) is calculated by subtracting the Total Volume Infiltrated by the amount transferred to deep groundwater. This amount is 8250mm over the duration of the model (1963-2004). Adding the interflow volume to the run-off volume for the total amount of water discharged downstream results in an average of about 50% of all rainfall, which correlates well with the previous comparison of annual run-off volumes (see Figure 9).

**Figure 11: Flow-Duration Relationship for the Study Area**




[4] Abstractions include (surface ponding, interception, and evapotranspiration)

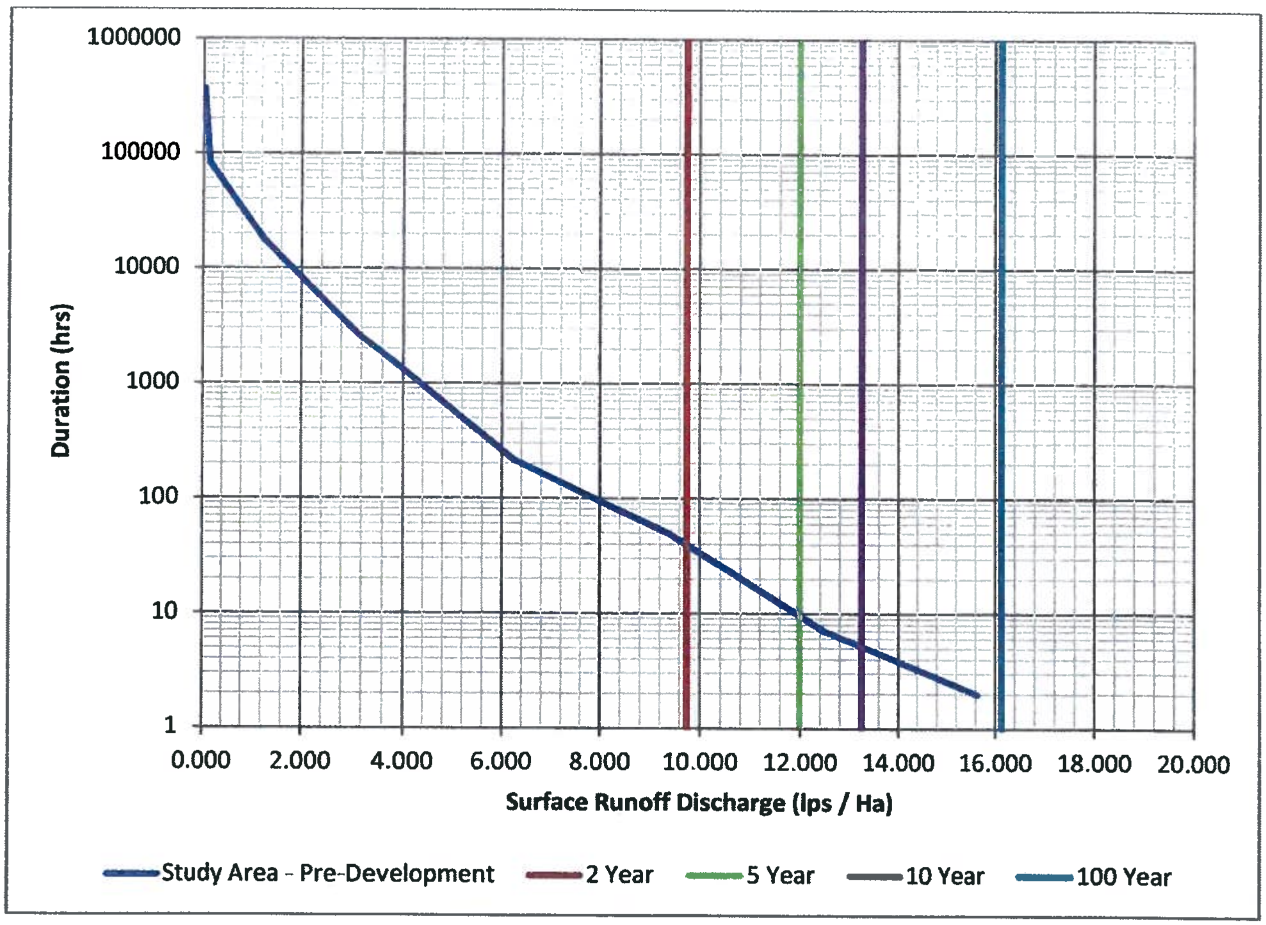
## 8.5 PRE-DEVELOPMENT STORMWATER TARGETS

As the study area is relatively small, it is assumed that the hydrologic response is fairly uniform over the entire catchment. That is, the same pre-development input parameters are to be used for further analysis, regardless of subcatchment size. On this basis, the post-development stormwater targets are to reflect the above stated pre-development condition. The following list summarizes the key volumetric targets on a per unit area basis, allowing each subcatchment to achieve a normalized target as product of its total area.

- The following rates form the discharge targets for the study area:
  - 16.1 l/s/ha for the 1 in 100 year event
  - 13.3 l/s/ha for the 1 in 10 year event
  - 12.0 l/s/ha for the 1 in 5 year event
  - 9.8 l/s/ha for the 1 in 2 year event
- Average total run-off should not exceed 400 mm/year.
- Infiltrated volumes should meet an average of 650 mm/year, with about 200 mm/year allowed to infiltrate through the shallow ground water system (the Vadose Layer) and thence return to the surface.

In general, development at the "lot level" should match the normalized discharge-duration results of Figure 11 above, as shown on Figure 12.

**Figure 12: Flow-Duration Target Relationship for the Study Area**



## 8.6 STORMWATER QUALITY TARGETS

The current Town of Comox design guidelines do not specifically address issues of water quality. Accordingly, this study will establish targets based on 'acceptable or expected' annual average loadings for the pre-development state of the land (mature natural forested area with a minimal amount of developed roads). On this basis, it will be necessary to quantify the probable sediment yield for the study area, and provide mitigation measures to meet the stated pre-development objective. This will ensure that the downstream environment is not deprived of "normal" sediment loads.

Run-off contaminated through contact with street litter, eroded swales, deicing chemicals, animal droppings, traffic residues, fertilizers, biocides, atmospheric dust fall and other substances, will eventually enter the receiving environment. It is now well accepted that Total Suspended Solids (TSS) is a key indicator of overall water quality, as other pollutants tend to adhere to the suspended particles in the run-off. In addition, land under construction can have erosion rates from 50 to 500 times the rate of undeveloped land. In contrast, a stable post-development watershed generates much less sediment due to erosion. The Stormwater Management Guidebook recommends an objective of 80% removal of the estimated TSS. This target is appropriate for the transition period of construction and the time to reach a fully mature post-development watershed.

Mitigation measures often include sediment removal facilities (ponds, infiltration basins, grass swales and vegetation buffers, etc.). Sediment loadings will affect the operation of, and the maintenance costs for, the sedimentation facilities, i.e., loadings will determine the clean-out timing and size of the facilities. The loading of sedimentation facilities will vary greatly depending on the state of surface soil exposure within the catchment, the development staging and the sediment control practices implemented within the catchment. Sediment yields for different land use conditions are shown in Table 4, (Ports, 1975) (MMM, 1985).

**Table 4: Sediment Yield as a function of Land Use**

| Land Use | Sediment Yield (tonnes/ha/yr) |
|---|---|
| Natural Forest | 0.66 |
| Agricultural | 0.11 to 2.2 |
| Urban Construction | 1.8 to 73.5 |
| Stable Watershed | 0.039 to 0.367 |
| Urban Areas | 0.10 to 0.61 |

The above table will form the basis of the targets for the NE Comox SWMP: i.e., a watershed undergoing land use change from an assumed forested condition to urbanization. On this basis, the long-term annual average sediment loading should strive to achieve:

- 0.66 tonnes/ha/year, based on land use predominantly natural forest.

This measure of sediment loading needs to be tested in terms of current loading, and monitored over time to ensure conformance to study objectives. Sampling will be undertaken for TSS and other contaminants at the study area discharge point. Continued monitoring should be considered by the Town to ensure the efficacy of mitigation strategies, whether it is a community pond or individual "lot level" controls maintained over time. At this stage, the above target provides a reasonable estimate of annual loadings for purposes of testing the efficacy of different mitigation strategies using the modeling software. Once testing is complete, the modeling and/or planned mitigation strategies can be adapted to meet specific (or known) targets, through the adaptive management plan.

# SECTION D CONSULTATION TO DATE

## 9.0 PUBLIC MEETING NUMBER ONE SUMMARY

Comment Sheets received at Neighbourhood Meeting #1

Two comment sheets were provided; copies of both are attached as Appendix D.

Note, per the comment received:

- Climate change impacts are being considered with the study. The agreed Terms of Reference have been modified to include this. (Page 6 of 11, Phase 2, section 2.viii)
- The Ministry of Agriculture has been contacted, and will be asked to meet with the project team to discuss their concerns.

Feedback received via NE Comox SWMP Website

None. Website for comments set up April, 2012. Email address: necismp@mcelhanney.com.

Written Comments provided directly to the Town

None.

## 10.0 STAKEHOLDER CONSULTATION

A Stakeholder information release letter was distributed to the Department of National Defence, the Agricultural Land Commission, K'omox First Nation, the Comox Valley Regional District, the Ministry of Environment, the Ministry of Agriculture, the Ministry of Transportation and Infrastructure, and Department of Fisheries and Oceans, on August 8, 2012.

Written feedback was received from the K'omox First Nation (Appendix E). An invitation has been extended to the K'omox First Nation and all other stakeholders to a stakeholder information meeting on January 15, 2013 to review the Phase 1 report, in accordance with the Terms of Reference.

A summary of key points from the DND meeting held September 13, 2012, is as follows:

- DND has indicated they will not review, or endorse the SWMP, but would like to be informed of progress, outcome, etc.
- DND indicated it is clearly their preference that the Town take over ownership of the Queen's Ditch, though this is not the forum to negotiate such a transaction.
- Town advised that there is no desire on their part to take over the QD.
- DND expects that provincial and municipal legislative requirements for stormwater management will be seen as minimum targets, to be exceeded wherever possible.

- Agreed that a DND representative should attend the stakeholder information sessions, even if DND does not actively participate.
- Agreed that MCSL would continue to forward information to DND as it becomes available, but DND would not respond unless there are specific amendments required, noting that all correspondence to the Town/MCSL would be public.

# Appendix A

## Terms of Reference

McElhanney

August 8, 2012

Our File: 2211-46500-0

Town of Comox
1810 Beaufort Ave
Comox, BC V9M 1R9

**Attention: Marvin Kamenz, Town Planner**

Dear Sir,

**NORTH EAST COMOX STORMWATER MANAGEMENT [SWMP] PLANNING
PROPOSED SWMP TERMS OF REFERENCE (REVISED)**

**INTRODUCTION**

This document is further to a draft dated 27 July, 2011, and to subsequent discussions with both Town staff and the Town's hydrologic engineering consultant regarding the above.

Provided herein is the scope of study as agreed to with the Town's engineering expert, complete with explanation of underlying fundamental SWMP approach, specific objectives, methodology, and deliverables[1]. Drawing SK-1, Rev.0, appended to this document, indicates the limits of the lands to which these terms of reference and subsequent study apply. Hereafter, the lands identified as "2011 NE Comox SWMP Study Area" on drawing K-1, Rev. 0 will be referred to as the "study area".

The Town of Comox requires site specific stormwater management guidelines for the study area that will meet the following goals and objectives:

- The management of the stormwater system in the study area will be consistent with the Town of Comox OCP [including DPA 7 (Riparian Areas), DPA 11 (Wildlife Corridors), and DPA 16 (Energy and Water Conservation and Reduction of Greenhouse Gas Emissions), and Zoning for land use.
- Be consistent with and meet the requirements of the Town's subdivision servicing Bylaw 1261, as certified by a Professional Engineer, licenced to practice in the province of British Columbia. Will confirm the suitability of the study area for the use intended, as certified by a Professional Engineer, licenced to practice in the province of British Columbia.
- The SWMP will establish predevelopment hydrological and hydrogeological conditions within the study area. Development controls and stormwater management features will be recommended to maintain existing ground water flows and water quality to Hilton Springs and the Lazo Marsh. Note: the aquifer

[1] Unless specifically noted otherwise, the term "stormwater" refers to surface and ground water quantity and quality.



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that feeds Hilton Springs and Lazo Marsh extends well beyond the study area. As such, certification is to be based on rainfall infiltration rates being statistically maintained, as derived from analysis of historical data. MCSL cannot be held responsible for changes to the spring as a result of external developments or factors beyond its control. Further, predevelopment conditions will be based on drainage patterns as of December 01, 2011, and 100% forest cover.

- Estimated post-development discharges from the study area will mimic estimated pre-development discharges so that statistically there is no significant increase in discharge, both in terms of flood frequency and flow duration. Professional Engineering certification will include an assessment of historic flows based on statistical analysis, and a regional regression analysis to verify modeling against measured discharges in adjacent basins. Certification will be limited to the assumption that historic data and parameters (rainfall and runoff) remain consistent into the future, and are only applicable to the study area. MCSL's liability will extend to those designs meant to control runoff from the study area to pre-development flows and duration over the range of the historically statistical flows. MCSL cannot be held liable for other changes in the "Queens Ditch / Lazo Marsh Catchment Area", which are beyond its control or outside of the study area identified in drawing SK-1.
- Prevent adverse impacts on downstream or adjacent lands as a result of stormwater from the study area. Professional Agrologist confirmation of no adverse impact to arable lands and farm operations and crop production to be provided.
- Develop mitigating strategies to demonstrate no increase in the frequency or duration of flooding on adjacent/down gradient agricultural properties, nor in the "Queen's Ditch".
- Stormwater management facilities will be designed to remove 80% of the estimated total suspended solids (TSS) of the annual average loading in accordance with the Stormwater Management Guidebook.
- Estimated post-development discharges will seek to maintain or enhance base flow stream discharges, including through the promotion of groundwater re-charge facilities.
- Not adversely affect downstream fish habitat and the Lazo Marsh, as certified by a Registered Professional Biologist.
- Utilize 'source controls' and Best Management Practices to manage smaller, frequent precipitation events, and employ stormwater detention facilities to manage larger, infrequent events.
- Establish runoff water quality targets. The SWMP will establish specific goals and objectives that apply to the entire study area, and that will be adhered to during each phase of development.
- Undertake this study in a collaborative manner that provides opportunities for input by the Town throughout the process. It is intended the Town has an active role in establishing any specific methodologies and objectives.

- Provide performance criteria and design details for inclusion in the Town's Development Servicing Bylaw 1261.

## BACKGROUND

Morrison Hershfield (MH) indicated in its May 05 letter, "*The approach we believe would be adequate to address only the sub-watershed [i.e. the study area] and their potential impacts. If the changes within the sub-watershed can be managed in a way that will maintain the existing flow duration relationships there would be no changes to the downstream system which includes both the Queen's Ditch and its floodplain. The approach provides a simpler approach to protect the downstream areas from increased flood risks.*"

We agree this to be the simplest means of providing the needed environmental stewardship and protection from flooding of lands down gradient. Through recent discussions with the Town and its consulting engineer, we agree these results can be achieved through continuous simulation modeling and the application of site specific source controls and BMPs.

Specific mitigation targets are to be established which are consistent with the practices of others elsewhere in BC. Remi Dube, P.Eng., City of Surrey Development Services, indicated recently that the City of Surrey has adopted a strategy intended to manage runoff in lowland areas of the municipality. Source level controls are utilized to the extent in-situ conditions allow; further attenuation of peak runoff rates is provided through large, community based detention facilities. Mitigation in NE Comox will follow a similar philosophy, with specific attention to rates and duration of stored water release, as a function of historical [known] variations in rainfall rates during and after 'typical' storm events. Continuous simulation modeling is required to achieve this outcome.

## MANAGEMENT APPROACH

Utilizing an appropriate suite of "Low Impact Design" (LID) techniques, post-development hydrology will approximate the existing (pre-development) stormwater flow-duration relationship over the spectrum of historic data. Extreme runoff/flood events will be mitigated/managed through the use of appropriately designed stormwater detention and retention facilities.

Soils within the study area have a finite capacity to capture and infiltrate runoff without impacting existing hydrogeological regimes, or breaking out down slope in a manner inconsistent with pre-development conditions. The site specific locations and magnitude of groundwater recharge at each proposed location will need to be modeled and documented, for purposes of informing the detailed design.

We propose to utilize the performance criteria founded on the 2007 "Beyond the Guidebook" document, and the existing Town of Comox Subdivision Servicing Standards.

Specifically:

- A focus on flow duration, i.e., provide an analysis of the discharge rates that could adversely affect downstream properties, if flow durations were increased. The opportunity may exist to extend the flow duration of smaller events, thus providing a net environmental benefit, whilst decreasing flood potential.
- Large, infrequent events (eg: 25, 50 and 100 year runoff events), are to have peak runoff rates attenuated [not to exceed pre-development peak], through the use of ground recharge, community based detention and other BMPs.
- Flood routing is to be estimated, up to and including the Q100 event, using statistical methods.
- Changes in expected flow-duration and overall drainage basin average annual volume will not cause erosive forces in excess of pre-development conditions, nor result in downstream aquatic habitat degradation. This will be inferred based on the sub watershed analysis.

## METHODOLOGY

Given the importance placed on the forthcoming SWMP and the desire of the Ownership Group to advance studies in a timely manner, it is understood regular review and feedback will be required during execution of this planning study. To this end, the schedule of meetings and presentations noted in the following sections is as provided by Town staff. Note there is to be a minimum of one meeting per month with Town staff.

### <u>Phase 1 – Establish Pre-Development Site Conditions, Hydrology, Hydrogeology</u>

1) Public consultation strategy to be developed by the consultant and presented to Council in conjunction with the Terms of Reference, for receipt by resolution.

2) Stakeholder information release by email. The followings stakeholders will receive correspondence indicating the scope of study, objectives, timing, and invite feedback/input.

   i) Town of Comox

   ii) Department of National Defence

   iii) Agricultural Land Commission

   iv) Ministry of Agriculture

   v) Komox First Nations

   vi) Ministry of Transportation and Infrastructure

   vii) Comox Valley Regional District

   viii) Department of Fisheries and Oceans

   ix) Ministry of Environment

3) Neighbourhood meeting number 1 - to introduce the NE Comox Stormwater Management Plan process. The following will apply to all neighbourhood meetings:

    i) All neighbourhood meetings to be "open house" format; no formal presentations.

    ii) Sign in sheets to be provided to establish email lists for project updates and feedback.

    iii) Comment sheets to be provided; will be accepted at the consultant office, or Town Hall for one week following meeting.

    iv) The consultant will establish an email address for project information and inquiries. All inquiries to be logged and responses provided.

    v) Meetings will be advertised in the Comox Valley Record, two consecutive advertisements, the last not less than three, or more than 10, days before the meeting. Meetings will also be advertised on the Town's website, and notice emailed to those who have provided an email address on a sign in/contact sheet.

    vi) Feedback received will be addressed and incorporated into the study (in consultation with Town staff and its consultant). Information will be presented to attendees regarding the next stages of study. Comments will be received for a maximum of 10 business days following the meeting.

4) Determine quantitative stormwater runoff targets for the study area, such that the environmental integrity of the Queens Ditch / Lazo Marsh Catchment Area is preserved.

5) Establish the physical limits of the study area; compile mapping of same.

6) Review of past studies and available data regarding physical characteristics (state of vegetation/ground cover, and groundwater regime of the study area; review of past studies pertaining to the Queens Ditch / Lazo Marsh Catchment Area.

7) Conduct a site visit with key project personnel and Town staff to review study area site conditions, existing points of discharge, topography, etc.

8) Establish baseline flow/duration relationships for the study area utilizing QualHYMO software, and verification using a regional analysis.

9) Town Review Meeting 1. Results obtained to date will be presented to the Town. Feedback provided by the Town will be incorporated.

10) Report to be presented to Council by staff for receipt by resolution. Once received, an email notice will be sent out to those who have signed the contact list, advising the document is posted on the Town's website.

11) Stakeholder Meeting Number 1. Invitees to include all parties noted in Task 2, to be contacted via email.

12) Neighbourhood Meeting Number 2, including presentation of tasks to be undertaken in phase 2, and allowance for feedback. To follow Stakeholder Meeting 1. See Task 3 for contact/format details. Feedback from attendees to be incorporated into the working document, in consultation with the Town of Comox and its consultant.

**Phase 2 – Determine Post-Development, Unmitigated Flow Rates, Volumes**

1) Develop a post-development model scenario (QualHYMO) without utilizing LID techniques or other stormwater controls. This scenario will serve as the base/control scenario against which the efficacy of mitigation is compared.

2) Introduce LID techniques via QualHYMO to determine the optimal configuration/arrangement. LID strategies to be evaluated include, but are not limited to:

   i) Limiting impervious surface, alternative road cross section, encourage the use of pervious pavers for driveways, private walks, etc.

   ii) Retention of existing vegetation where possible, inclusion of greenways where practical (may include moving proposed greenways to portions of the site where ground water recharge is feasible, etc.).

   iii) Introduction of amended top soils, use of engineered fill areas for stormwater infiltration, etc.

   iv) Controls at the individual "lot level" such as "soakaway pits", rock gardens, etc.

   v) Street level controls including rain gardens and subsurface exfiltration galleries.

   vi) Additional street level controls such as strategic plantings to promote interception and evapotranspiration.

   vii) Neighbourhood level controls such as ponds or other detention facilities, to be the final control, likely required for only the larger more infrequent events.

   viii) Allowance for climate change adaption using the capabilities ofQualHYMO and climate change projections from the Pacific Institute for Climate Solutions.

3) QualHYMO will be used to establish the design infiltration rates, volumes, etc. as applicable for each LID control. That is, the area/volume of exfiltration galleries required, the depth and extent (area) of amended soils. Each LID will be considered in relation to the lot layout and preferred areas where exfiltration will be most effective. As a result, the current layout may be amended.

4) Utilizing the LID design target/levels developed in the preceding task, preliminary design of LID features will be undertaken using QualHYMO/SWMM to size exfiltration galleries, mimic the effects of amended soils, size detention facilities, etc.

5) Town Review Meeting 2. Results obtained to date will be presented to the Town. Feedback provided by the Town will be incorporated.

6) Report to be presented to Council by staff for receipt by resolution.

7) Stakeholder Meeting 2. Invitees (via email) to include all parties noted in Task 2; draft reporting to be presented.

8) Neighbourhood Meeting 3. To follow Stakeholder Meeting 2; draft reporting to be presented. See task 3 for meeting format details. Feedback from attendees to be incorporated into working document, in consultation with Town staff.

**Phase 3 – Develop Design Standards**

1) Standard details will be produced for the LID measures to be utilized within the study area, as well as a graphic indicating the specific areas suitable for each type of LID measure, required implementation rates, etc.

2) Develop an "Adaptive Management Plan" to allow for continued refinement of the LID "tools" utilized, ensuring pre/post-development runoff continuity. Adaptive management plan to include design safeguards for onsite stormwater systems (e.g. retention, detention, ground water recharge) such that failure of the onsite system (e.g. reduced capacity due to siltation) does not increase the flow duration of storm water entering the Town system and provides onsite indication of failures prior to impacting properties. Also to be identified as when a system requires geotechnical analysis to ensure slope stability is not compromised. Expected maintenance requirements are to be outlined, and, where feasible, indicators of decreased capacity/efficacy are to be built into LID "tools".

3) Professional Agrologist review of SWMP findings, certification of no net impact to arable lands and farm operations and farm productivity. Development of ALR buffer specifications, specific to the local context, in consultation with the Professional Agrologist.

4) Registered Professional Biologist review of findings, certification of no net impact to downstream fish habitat.

5) Town Review Meeting 3. Results obtained to date will be presented to the Town feedback provided by the town will be incorporated.

6) Report to Council for receipt by resolution.

7) Stakeholder Meeting 3. Invitees to include all parties noted in Task 2; draft reporting to be presented.

8) Neighbourhood Meeting 4. To follow Stakeholder Meeting 3; draft reporting to be presented. See Task 3 for contact information and meeting format.

9) Town Review Meeting 4. Results obtained to date will be presented to the Town. Feedback provided by the Town will be incorporated.

10) Draft final report preparation, amendments based on the outcome of Tasks 7, 8 and 9.

11) Draft Final SWMP to be presented to Council by staff for receipt by resolution. Once received, an email notice will be sent out to those who have signed the contact list, advising the document is posted on the Town's website.

12) Issuance of final report. Note final reports must contain the Town of Comox's Professional Certification Statements, as detailed in Appendix A.

13) Email notification to be sent out to those who have signed the contact list, advising the document is posted on the Town's website.

## DELIVERABLES

The following deliverables/review materials will be provided to Town staff:

1. Public Consultation Strategy.
2. Initial Design Brief – Summary of design criteria, rainfall events to be mitigated.
3. Phase 1 Design Memo/Phased Report – Summary of Phase 1 effort, including public input summary and submission copies.
4. Phase 2 Design Memo/Phased Report – Summary of Phase 2 effort, including public input summary and submission copies.
5. Phase 3 Design Standards Report. Adaptive Management Plan and Professional Certifications.
6. Draft final SWMP Report – Summary of Phase 3 effort, including public input summary and submission copies.
7. Final SWMP.

Note all reports, meeting notices, and other relevant materials provided by the consultant are to be posted on the Town's website.

## SCHEDULE/MILESTONE DATES

The following is a preliminary estimate of the schedule which will be updated regularly throughout the process:

| | | |
|---|---|---|
| 1. | Public Consultation Strategy | April 2012 |
| 2. | Initial Design Brief | May 2012 |
| 3. | Phase 1 Design Memo/Phased Report | July 2012 |

4. Phase 2 Design Memo/Phased Report — September 2012
5. Phase 3 Design Standards Report — October 2012
6. Draft final SWMP Report — November 2012
7. Final SWMP — November 2012

**CLOSURE**

It is intended it be explicitly understood by all parties that the findings and recommendations made in the final North East Comox/Pritchard Road Stormwater Management Plan (SWMP), once completed to the satisfaction of the Town, will provide the technical direction and specific design parameters required to advance PLR conditions, design approvals, construction and registration of lands within the study area.

As such, we look forward to your confirmation as to acceptability of the above document, or your suggestion as to any edits, deletions or additions the Town believes would be warranted.

Yours truly,

McELHANNEY CONSULTING SERVICES LTD.

Bob Hudson, P. Eng.
Project Manager

Reviewed by:

Ian Whitehead, P.Eng.
Regional Manager

cc: Richard Kanigan, Town of Comox
Glenn Westendorp, AScT, Town of Comox
Jack Hornstein
Brian McLean
Chris Gage
Marty Petersen
Jim Dumont, P.Eng
Mark DeGagne, P.Eng

## APPENDIX A - TOWN OF COMOX PROFESSIONAL CERTIFICATION STATEMENTS

1. The SWMP

The purpose of this Storm Water Management Plan (the "SWMP") is to ensure that when and if all those lands within the Town of Comox identified in the SWMP (the "Water Management Area") are ultimately improved and developed as contemplated by the SWMP and either current zoning or the current Official Community Plan, the impact of surface and ground water flows originating from the Water Management Area on downstream and down-slope flood frequency and flood duration for up to and including the 100 year runoff event will be the same or less as of the date of this SWMP and ground water flows and quality originating from the Water Management Area will be substantially the same as of the date of this SWMP including ground water flows and quality to Hilton Springs, Lazo Marsh and down-slope lands. This statement is made on the basis that historic rainfall patterns remain consistent into the future, the lands in the Water Management Area are developed in accordance with either the current zoning or the current Official Community Plan of the Town of Comox; that the Town adopts as recommended in this SWMP such drainage regulations and requirements as are recommended in the SWMP; and that the SWMP is fully implemented by the Town of Comox in respect of the future development of the lands in the Water Management Area.

This SWMP is consistent with and meets the requirements of Town of Comox Subdivision and Development Servicing Bylaw, 1261.

<closing>

Submitted by,
<engineers name or Engineering Company's name>
I certify this to be report prepared by
<Engineers Signature>
<Engineer's Name Typed>, P.Eng.

I, ____________, Professional Agrologist have reviewed the <SWMP official title> as prepared by <Name of Engineer> and dated XXXXX, hereafter referred to as the SWMP. The SWMP will not adversely impact the existing agricultural potential of down-slope lands within the Agricultural Land Reserve.

Submitted by,
<Professional Agrologist's name or Company's name>
I certify this to be report prepared by
< Professional Agrologist's Signature>
< Professional Agrologist's Name Typed>, Professional Agrologist

I, ____________, Registered Professional Biologist have reviewed the <SWMP official title> as prepared by <Name of Engineer> and dated XXXXX, hereafter referred to as the SWMP. The SWMP will not adversely impact the existing downstream fish habitat or the environmental integrity of Lazo Marsh.

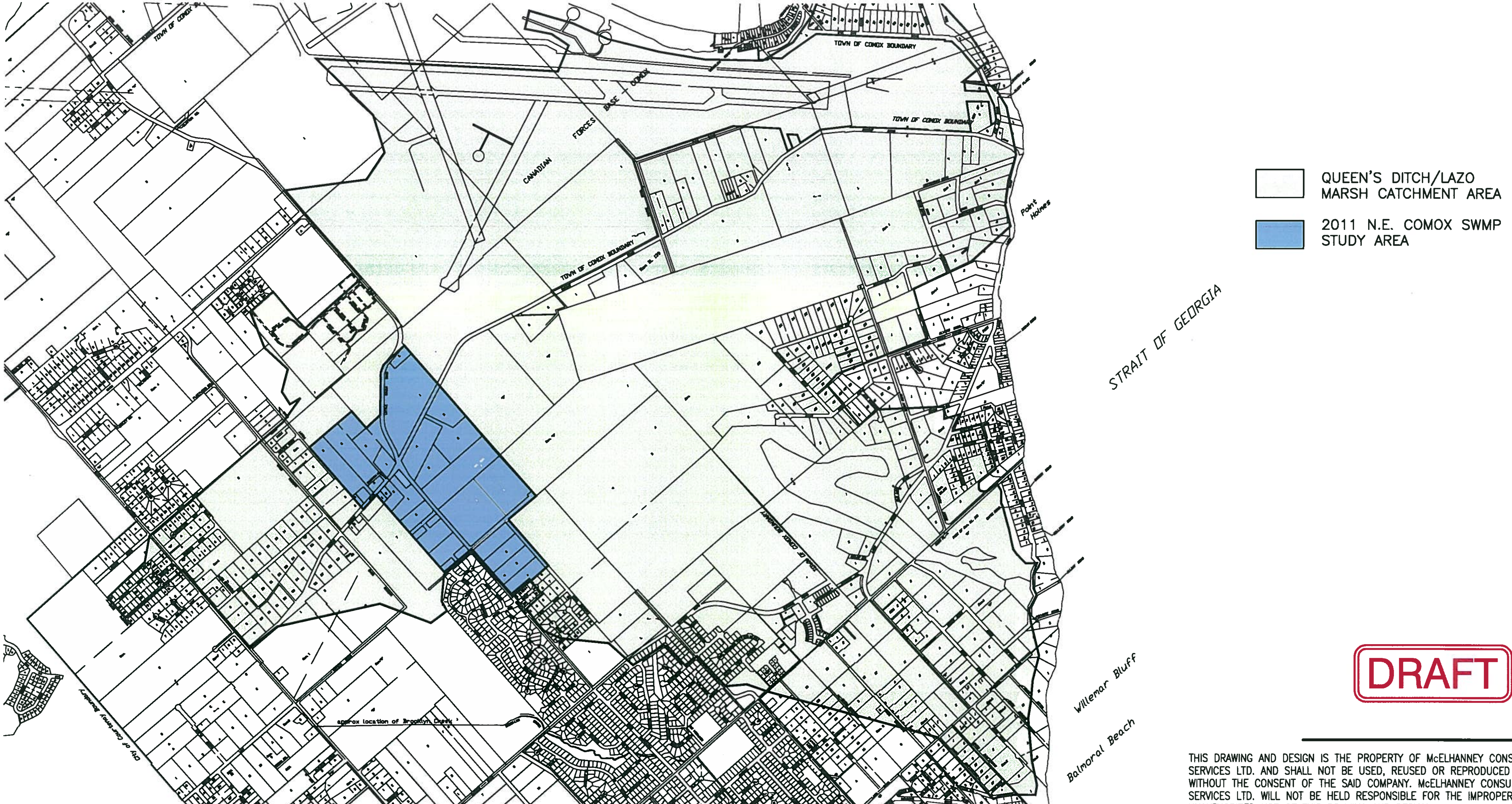
Submitted by,
<RPBio's name or Company's name>
I certify this to be report prepared by
<RPBio's Signature>
<RPBio's Name Typed>, Registered Professional Biologist

2. Site Plans on a Site by Site Basis

I _________________, P. Eng hereby certify that I have reviewed all plans attached hereto (the "Plans") relevant to the development of **[legal]** (the "Lands"), and hereby certify that if the Plans and drainage facilities and systems shown on the Plans are provided, built and operated to the specifications and standards provided in the Plans, that the development of the Lands will be in accordance with the Town's Storm Water Management Plan adopted by Council on ____________ 2012, and Town of Comox Subdivision and Development Servicing Bylaw, 1261, and the impact of surface and ground water flows originating from the Water Management Area on downstream and down-slope flood frequency and flood duration will be the same or less as of the date of this certification; existing ground water flows and quality originating from the Water Management Area will be substantially the same as of the date of this certification including ground water flows and quality to Hilton Springs, Lazo Marsh and down-slope lands.

3. The Facilities as Constructed and Completed On a Specific Site

I ________________, P. Eng certify that drainage facilities on ____________ the Lands, conform to the Plans certified by me on ____________ and on ____________, approved by the Town, and I also certify that the specifications, size, capacity and performance of the drainage facilities conform to the said Plans, and that the installation of the drainage facilities has been completed in accordance with sound engineering practice.






Plotted: February 29, 2012, 10:41:53

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| Designed: | CE |
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| Date: | DEC 06,2011 |
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**McElhanney**
McElhanney Consulting Services Ltd.
495-6th STREET
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# TOWN OF COMOX

## NORTH EAST COMOX STORM WATER MANAGEMENT PLAN STUDY AREA

| | |
|---|---|
| Client Project No | — |
| Client Drawing No | – |
| MCSL Project No. | 2211–46500–0 |
| Drawing No. | SK-1 |
| Sheet 1 of 1 | Revision 0 |

Destroy all prints bearing previous number ▲

# Appendix B

Photo Log

**Photo #1 – Spring at Brighton Road**

**Photo #2 – Spring at Brighton Road**


Photo #3 – Head of Hilton Springs

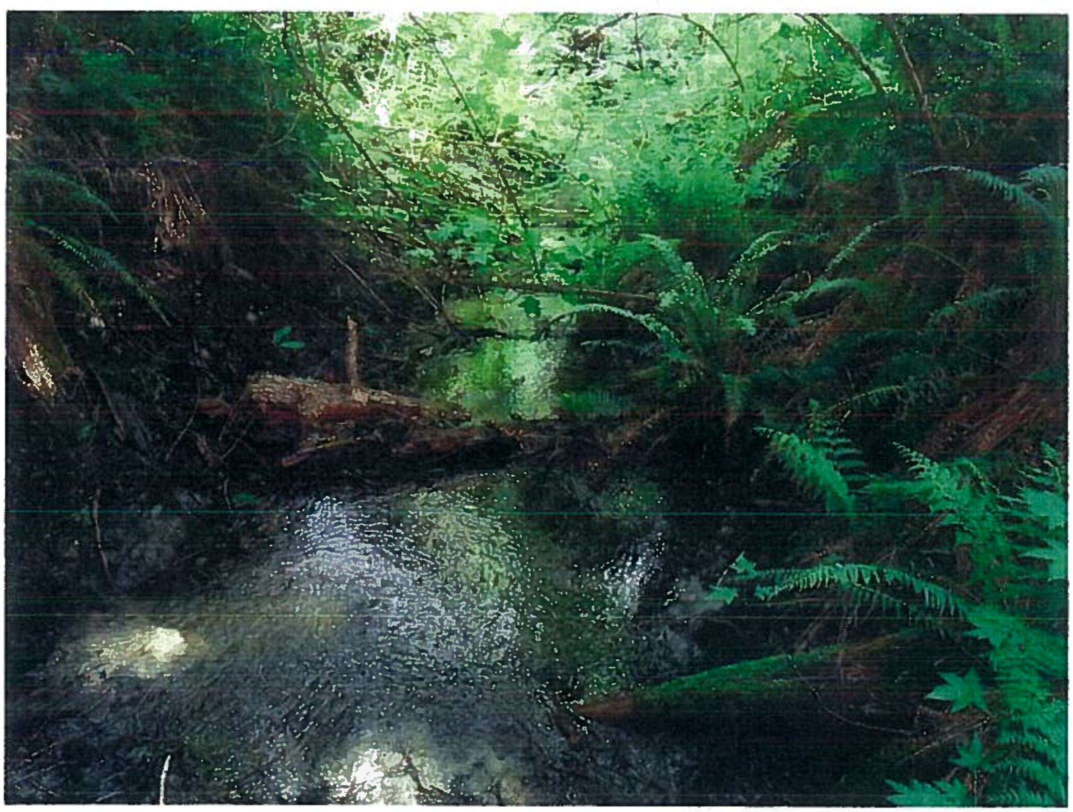
Photo #4 – Head of Hilton Springs (looking down stream)

Photo #5 – Hilton Springs Channel (looking up stream)

Photo #6 – Hilton Springs Channel (looking down stream just before entering ditch)

**Photo #7 – Hilton Springs Ditch at Pipeline ROW**

**Photo #8 – Hilton Springs Ditch at Pipeline ROW**

Photo #9 – Outlet Ditch from Hilton Springs

Photo #10 – Outlet Ditch from Hilton Springs

Photo #11 – Farm Ditch at Outlet from Hilton Springs (looking north)

Photo #12 – Farm Ditch (looking south)

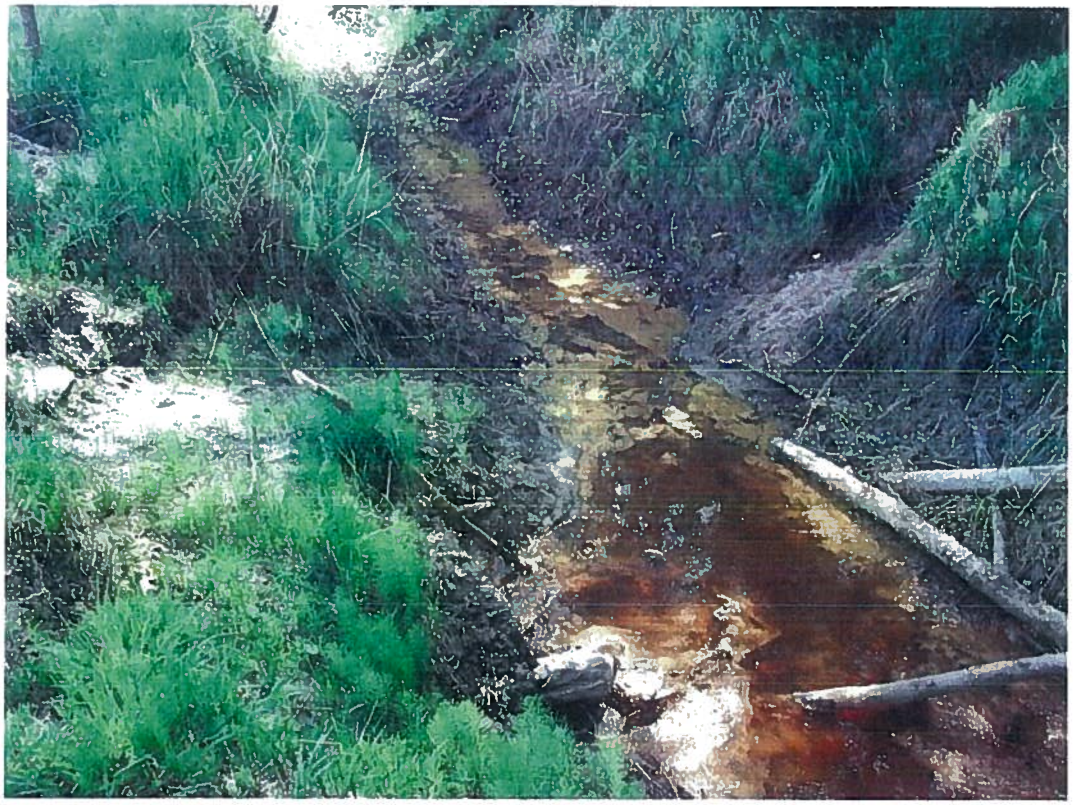

Photo #13 – Farm Ditch (upstream culvert)

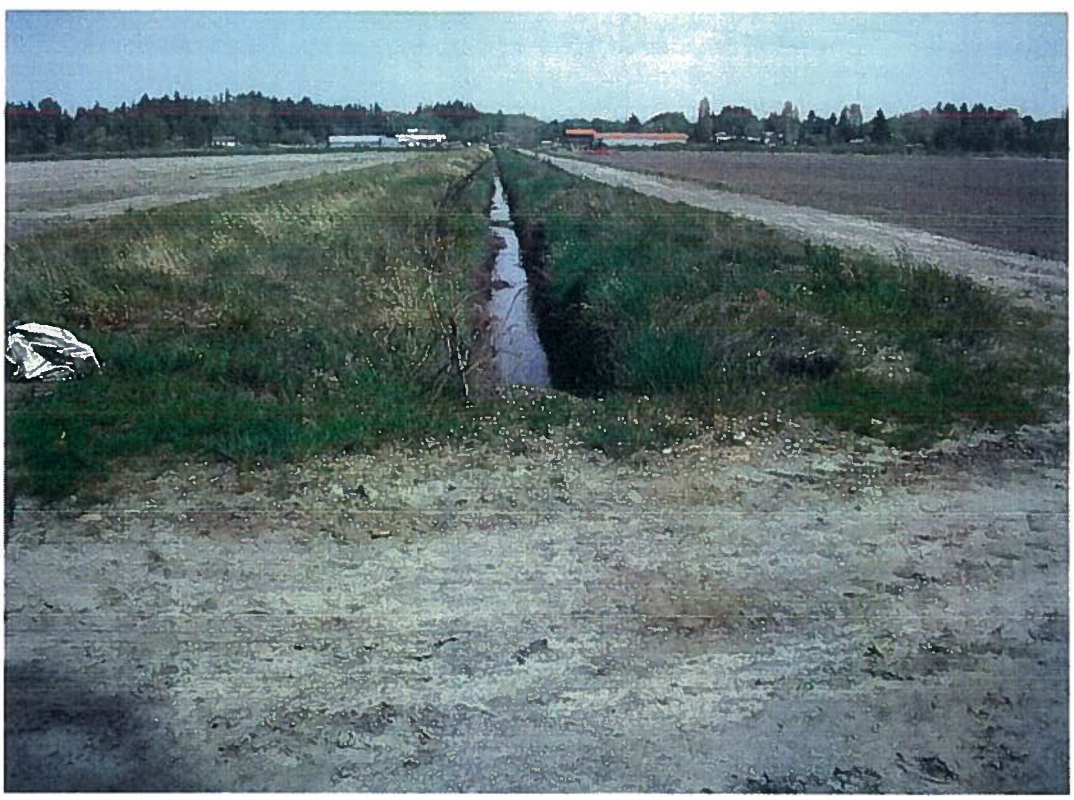

Photo #14 – Farm Ditch

Photo #15 – Farm Ditch (looking west)

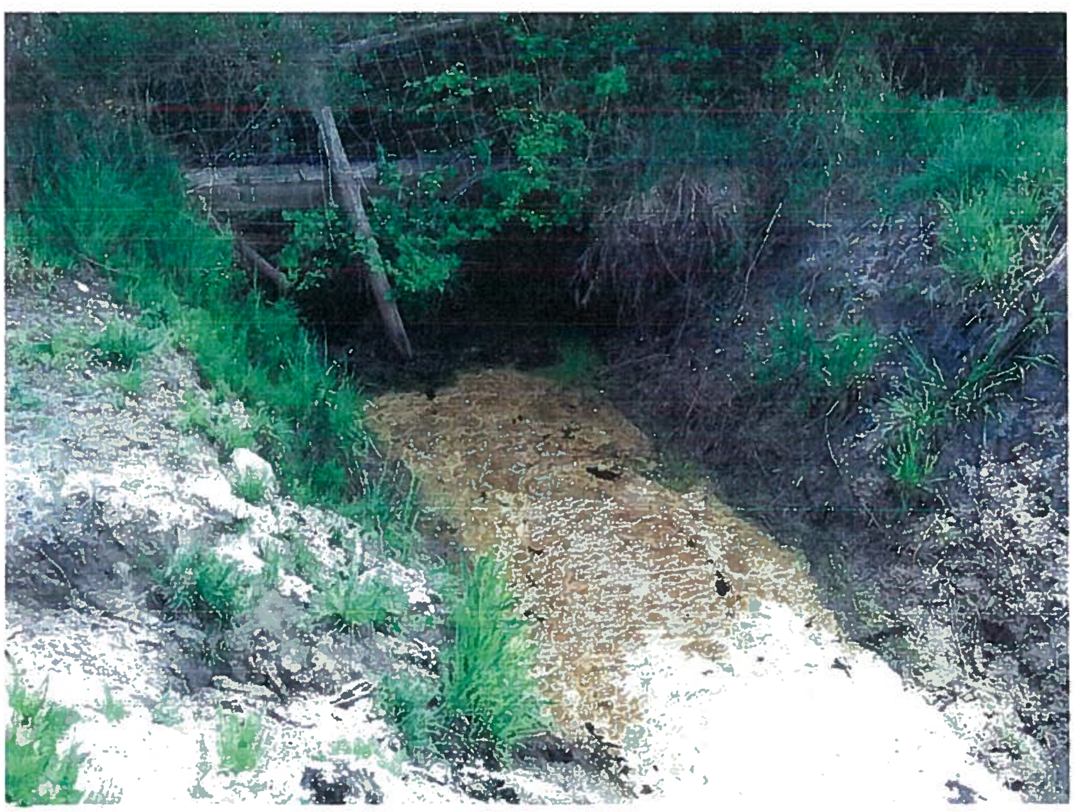

Photo #16 – Farm Ditch

Photo #17 – Farm Ditch

Photo #18 – Farm Ditch

Photo #19 – Farm Ditch culvert (looking at culvert outlet)

Photo #20 – Farm Ditch


Photo #21 – Farm Ditch (culvert inlet)


Photo #22 – Farm Ditch

Photo #23 – Beaver dam blocking Farm Ditch

Photo #24 – Queen's Ditch

Photo #25 – Queen's Ditch

Photo #26 – Farm Ditch culvert emptying into Queen's Ditch

**Photo #27 – Farm Ditch culvert emptying into Queen's Ditch**

**Photo #28 – Farm Ditch (culvert inlet)**

Photo #29 – Farm Ditch (culvert inlet)

Photo #30 – Farm Ditch culvert outlet with abandoned outlet control

Photo #31 – Head of Queen's Ditch

Photo #32 – Head of Queen's Ditch showing excessive vegetation

Photo #33 – Head of Queen's Ditch showing erosion

Photo #34 – Outlet of Queen's Ditch

Photo #35 – Outlet of Queen's Ditch

Photo #36 – Queen's Ditch near outlet

Photo #37 – Rudimentary control structure near outlet of Queen's Ditch

Photo #38 – Culvert Headwall (crossing Military Row)

Photo #39 – Culvert Outlet (South side of Knight Road)

Photo #40 – Roadside Ditch (South side of Knight Road)

Photo #41 – Culvert Headwall (crossing Knight Road west of Airport)

# Appendix C

2010 Simpson Geotechnical Stormwater Detention Pond Feasibility Assessment, Lot 1, VIP 15375, Comox District

2010 Simpson/GW Preliminary Hydrogeological Assessment Report

2010 GW Solutions Pritchard Road Detailed Hydrogeological Assessment Report

SIMPSON GEOTECHNICAL LTD

January 8, 2010
File: SGL09-039

434438 BC Ltd. and RS & D Contracting Ltd.
P.O. Box 1336
Comox, BC
V9N 7Z8

Attention: Mr. Chris Gage

**Re: Geotechnical Assessment for Proposed Stormwater Detention Ponds**
**Lot 1, D.L. 217, Comox District, Plan 15375, Comox, BC**

## INTRODUCTION

As requested, Simpson Geotechnical Ltd. (SGL) has reviewed the geotechnical considerations related to onsite groundwater recharge for the proposed detention ponds shown as Pond 1 and Pond 2 on Figures 1. We understand that this assessment is required as a part of the Development Permit application for the two ponds in accordance with the Town of Comox Official Community Plan (OCP) Section 7.6.4.3(g). That section states that:

> *No significant disruption of the ground surface must be permitted below the 30-metre elevation contour unless a geotechnical-engineered design is used to maintain the integrity of the ground water discharge area;*

We have previously provided geotechnical comment for Pond 1[1]. Geotechnical comment for Pond 2 has previously been provided in a report by Levelton Consultants Ltd. [2] (Levelton). That report also addressed proposed parking and refueling facilities that are not a part of the current Development Permit application. We understand that the Town of Comox requires that the OCP Section 7.6.4.3(g) considerations for the two ponds be combined into a single report, focused on only the current Development Permit application. This report is provided to address that requirement.

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[1] Geotechnical Assessment for Proposed Stormwater Detention Pond and Ditch Relocation, Lot 1, VIP 15375, Comox District (Northeast Corner of Knight Road and Military Row) Comox, BC, Simpson Geotechnical Ltd. File SGL09-020, July 15, 2009 Revised August 27, 2009.

[2] Follow-up Letter for Hydrogeological Impact from New Refueling Station, Comox Valley Airport, Levelton Consultants Ltd. File VI09-0818-00, 26 June 2009.

377 Milton Street, Nanaimo, BC V9R 2K8
phone 250 753 7424 • fax 250 714 0265 • simpsongeotech@gmail.com

## PROPOSED DEVELOPMENT

The proposed detention ponds would be located in the north and south central areas of the subject property as shown on Figure 1. The proposed base of Pond 1 would be located approximately 1m below the existing ground surface. The base of Pond 2 would be located approximately 2 to 2.2m below the existing site grade. We understand that the existing ground surface elevation at the two ponds is approximately 19m and 22m respectively, .

We also understand that the current Development Permit application is for construction of the two detention ponds only at this time. Consequently no facilities for collection of stormwater surface runoff and no inlet to the pond for collected storm water runoff is proposed at this time.

## BACKGROUND

A surficial geology map of the site area published by the Gelogical Survey of Canada as map 32-1960 was obtained. That map indicates the subject property to be located in an area that is underlain by varied stony, gravelly and sandy marine veneer generally less than 1.5m thick, overlying ground moraine glacial till.

The Regional District of Comox-Strathcona Aquifer Classification Project Report indicates that the subject site is located over the Comox-Merville Aquifer (BC Aquifer 408). That report indicated the aquifer to be within the Quadra Sand material that underlies the till. The report concluded that the aquifer is confined in the Quadra Sand by the overlying till and marine clay throughout most of its area.

## SITE ASSESSMENT

Our site assessment was conducted on June 26, 2009 and included observations of the site and general vicinity and the logging of four test pits located around the proposed Pond 1.

The site was noted to be relatively flat and level, with a gentle slope down to the southeast. The property was partially cleared with a gravel ground surface and partially vegetated, primarily with brush and small trees. There were several soil stockpiles noted on the site. The eastern portion of the property was being used for storage of landscape materials such as topsoil, bark mulch and compost.

There was a ditch located around the northern and southern boundaries of the site with a flow split located near the central area of the Military Row side of the property. A ditch also bisected the property north to south and the proposed detention ponds would be located on opposite sides of that ditch. The ditches drained to the southeastern corner of the property from both the north and west where they discharged to the roadside ditch on the northern side of Knight Road.

The four test pits encountered relatively consistent subsurface conditions that comprised sand with variable cobble, gravel and silt content to the maximum excavated depth of 1.8m. Topsoil was encountered overlying the sand in Test Pits 3 and 4. Heavy groundwater seepage was encountered in all test pits at 0.8 to 1.1m below the ground surface. Heavy sloughing of the test pit walls below the seepage depth was noted.

We have not conducted subsurface assessment for Pond 2. However, the referenced Levelton report indicated that they have encountered subsurface conditions in the area that comprised sand and gravel, overlying marine clayey silt, overlying glacial till, overlying Quadra Sand. They note that the soil layers are roughly planar and the fine grained marine clay and and till extend to depths of at least 6m below the ground surface.

The Levelton report further noted that the fine grained marine clay and till serve as a confining layer over the Quadra Sand. An artesian peizometric surface at 22m elevation, confined by the till layer, was reported at the airport site located eastward of the subject property. Potential for a perched water table on the till surface was also noted.

## DISCUSSION AND RECOMMENDATIONS

Based on the proposed development and subsurface conditions described above, it is our opinion that development of the proposed detention ponds described above will not have significant impact on the onsite groundwater recharge provided the recommendations provided herein are followed.

Excavation for the ponds should be planned and monitored to avoid breaking through the confining layer of marine clay and/or glacial till.

## CLOSURE

This report was prepared by Simpson Geotechnical Ltd. for the exclusive use of 434438BC Ltd., RS & D Contracting Ltd. and their appointed agents for the proposed detention ponds described herein. Any use or reliance made on this report by an unauthorized third party is the responsibility of that third party. The Town of Comox Council is considered an authorized third party and may rely on this report in consideration of the development permit application for the detention ponds.

This report has been prepared in accordance with standard geotechnical engineering practice. No other warranty is provided, either expressed or implied.

We trust this report meets your immediate requirements. Please contact the undersigned if you require further information.

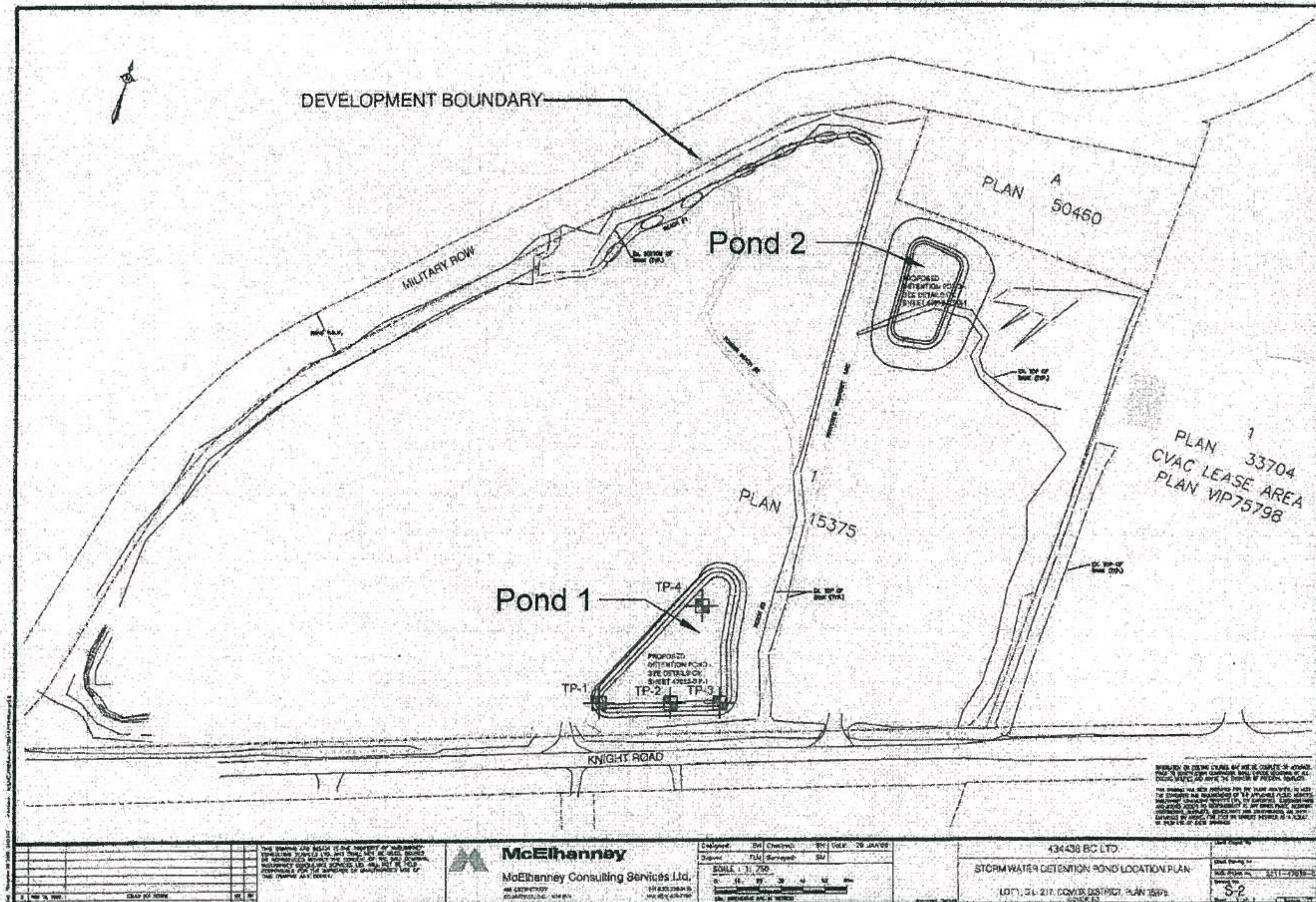
**Simpson Geotechnical Ltd.**

Per:
Richard Simpson, P.Eng.

PROFESSIONAL
PROVINCE OF
R.R. SIMPSON
BRITISH COLUMBIA
ENGINEER

8, 2010

Attachments: Figure 1 - Site Plan
Test Pit Logs (2 pages)




| | | | |
|---|---|---|---|
| **Project:** Proposed Detention Ponds | | SIMPSON Geotechnical Ltd | |
| **Title:** Geotechnical Site Plan | | | |
| **Client:** 0434438BC Ltd and RS & D Contracting Ltd. | | | |
| **File:** SGL09-039 | **Drawn by:** RRS | **Scale:** NTS | **Date:** January 2009 |
| **Dwg. No.:** Figure 1 | | | |

# Test Hole Logs

Proposed Detention Pond
Lot 1, VIP 15375, Comox District
Comox, BC

Excavated June 26, 2009

| Test Hole No. | Depth (m) | Description |
|---|---|---|
| TH-1 | 0 – 1.5 | Medium to coarse grained sand and gravel, trace to some cobbles to 150mm diameter, clean to a trace of silt, well graded, damp becoming saturated at 1m depth, brown<br>- end of test pit at 1.5m depth in sand and gravel<br>- free water at 1m depth<br>- heavy sloughing of test hole walls below free water |
| TH-2 | 0 – 0.5 | Sand and silt, organic, trace of rootlets, dark brown, damp |
| | 0.5 – 1.5 | Medium to coarse grained sand and gravel, decreasing gravel content with depth, trace to some cobbles to 150mm diameter, clean to a trace of silt, well graded, damp becoming saturated at 1m depth, brown<br>- end of test pit at 1.5m depth in sand and gravel<br>- free water at 1m depth<br>- heavy sloughing of test hole walls below free water |
| TH-3 | 0 – 0.3 | Silty sand and gravel, trace of rootlets, damp, brown |
| | 0.3 – 0.5 | Sandy silt, organic, roots, damp, dark brown (topsoil) |
| | 0.5 – 1.4 | Medium to coarse grained sand and gravel, trace to some cobbles to 150mm diameter, clean to a trace of silt, well graded, damp becoming saturated at 0.8m depth, brown |
| | 1.4 – 1.5 | Sand, fine to medium grained, saturated, golden brown<br>- end of test pit at 1.5m in sand<br>- free water at 0.8m depth<br>- sloughing of test hole walls below free water |

Soil classification based on Canadian Foundation Engineering Manual, 4th Edition
P.P. = unconfined compressive strength by pocket penetrometer
M = Natural moisture content as percent of dry weight

# Test Hole Logs

Proposed Detention Pond
Lot 1, VIP 15375, Comox District
Comox, BC

Excavated June 26, 2009

| Test Hole No. | Depth (m) | Description |
|---|---|---|
| TH-4 | 0 – 0.2 | Organic sand and silt, trace of rootlets, damp, dark brown (topsoil) |
| | 0.2 – 0.5 | Sand and gravel, some silt, damp, red-brown |
| | 0.5 – 1.8 | Medium to coarse grained sand, some gravel, trace to some cobbles to 150mm diameter, clean to a trace of silt, well graded, damp becoming saturated at 1.1m depth, grey-brown |

- end of test pit at 1.8m depth in sand, some gravel
- free water at 1.1m depth
- heavy sloughing of test hole walls below free water

Soil classification based on Canadian Foundation Engineering Manual, 4th Edition
P.P. = unconfined compressive strength by pocket penetrometer
M = Natural moisture content as percent of dry weight

SIMPSON GEOTECHNICAL LTD

July 27, 2010
File: SGL10-024

Pritchard/Cambridge Road Owners

Attention: Rob Leighton, Leo Richards and Brian McLean

**Re: Preliminary Hydrogeological Assessment**
**Proposed Residential Subdivisions**
**Lot 3 and 4, D.L. 217, Comox District, Plan 33750 and Lot C and D, Plan 50385**

We are pleased to provide the enclosed preliminary hydrogeological assessment report that was prepared in collaboration with GW Solutions Inc. The intent of that work was to assist in the advancement of site development strategies that would minimize post-development impacts on the existing groundwater regime as is required by the Town of Comox Official Community Plan.

As detailed in the enclosed report, the subject site has relatively complex hydrogeology with multiple aquifers that appear to provide water to several sensitive receptors. The report presents a model of the site subsurface and hydrogeology that was interpolated from available information from the site and vicinity that should be verified through boreholes and the installation and monitoring of groundwater monitoring wells on the site.

Once the hydrogeologic model is verified or adjusted as may be necessary based on the results of the recommended boreholes and groundwater monitoring, we can provide recommendations for the site development and rainwater management that would minimize impact on the existing groundwater regime.

We trust this report meets your immediate needs. Please do not hesitate to contact us to discuss the report.

Yours truly,
**Simpson Geotechnical Ltd.**

Per:
Richard Simpson, P.Eng.

PROFESSIONAL ENGINEER – PROVINCE OF BRITISH COLUMBIA – R.R. SIMPSON

encls.: Pritchard Road, Comox – Preliminary Hydrogeology, GW Solutions Inc., July 23, 2010

377 Milton Street, Nanaimo, BC V9R 2K8
phone 250 753 7424 • fax 250 714 0265 • simpsongeotech@gmail.com

July 23, 2010
10-16

Simpson Geotechnical Ltd
377 Milton Street
Nanaimo BC V9R 2K8

Attention: Richard Simpson, P.Eng.

Re: **Pritchard Road, Comox – Preliminary Hydrogeology**

Dear Richard,

This letter provides a summary of the preliminary hydrogeological assessment completed at the location of a proposed residential development along Pritchard Road in Comox, BC. This report has been produced in collaboration with Simpson Geotechnical Ltd to provide information about the existing surface water and groundwater regime at and near the site. We understand that this assessment is required in accordance with the Town of Comox Official Community Plan (OCP) Section 7.6.4.3(g). That section states that:

*No significant disruption of the ground surface must be permitted below the 30-metre elevation contour unless a geotechnical-engineered design is used to maintain the integrity of the ground water discharge area.*

GW Solutions is providing a conceptual model of the movement of water at surface and in the subsurface so that the site development can be designed to minimize any water related environmental impact.

## 1. Regional Hydrology and Hydrogeology

The site is in the Lazo Watershed[1]. There is no reported surface water feature and perennial stream on the site. Figure 1 shows aquifers reported in the BC Water Atlas. According to this regional characterization of the hydrogeology, the site is located over a confined sand and gravel aquifer (Aquifer 408), classified as being moderately productive, highly used, and having a low vulnerability to surface contamination.

The site is located northwest of Aquifer 407, classified as being moderately productive, not used very much, and being highly vulnerable to surface contamination.

[1] Toward a Management Plan for the Lazo Watershed and Queen's Ditch, by William Marsh, 2002

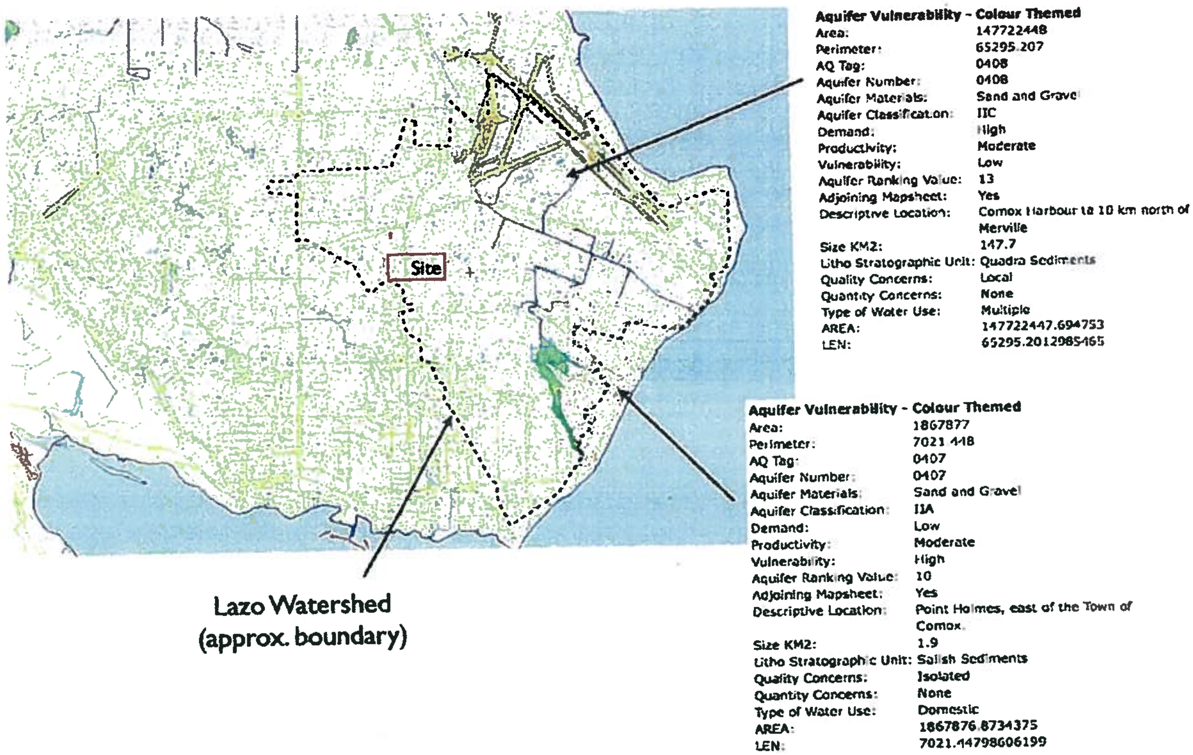



Figure 1 : Aquifers at and near the site according to BC Water Atlas

## 2. Local Hydrogeology

The aquifer characterization and delineation available from the BC Water Atlas provides a regional context. GW Solutions used the following information to detail the lithology of the subsurface and to identify both aquifers and aquitards. Aquifers typically consist of unconsolidated sand and/or gravel and aquitards consist of consolidated silt, sand and gravel (glacial till), or silt and clay:

- Logs of water wells available on the BC Water Atlas;
- Logs of the test pits dug on site by Simpson geotechnical; and
- Information provided in a recent Master Thesis Report[2] (2009).

---

[2] Hydrogeological Investigation of Quaternary and Late Cretaceous Bedrock Aquifers, Comox Coalfield, Vancouver Island, British Columbia, Canada, by Gypsy C. Fisher, University of Victoria

### *2.1 Master Thesis*

In her research, Gypsy Fisher used detailed information collected along two escarpments (the Willemar and Lazo bluffs) and available drilling logs to build a conceptual model of the overburden deposits. The results are illustrated with cross sections and fence diagrams. It shows that soil deposits in the studied area consist of a sequence of low and high permeability material, a few meters to tens of meters thick. Figure 2 shows a cross section located south of our site, and Figure 3 shows a fence diagram covering an area southeast of our site.

Unfortunately, our site is located outside of the area subject to Gypsy's research.

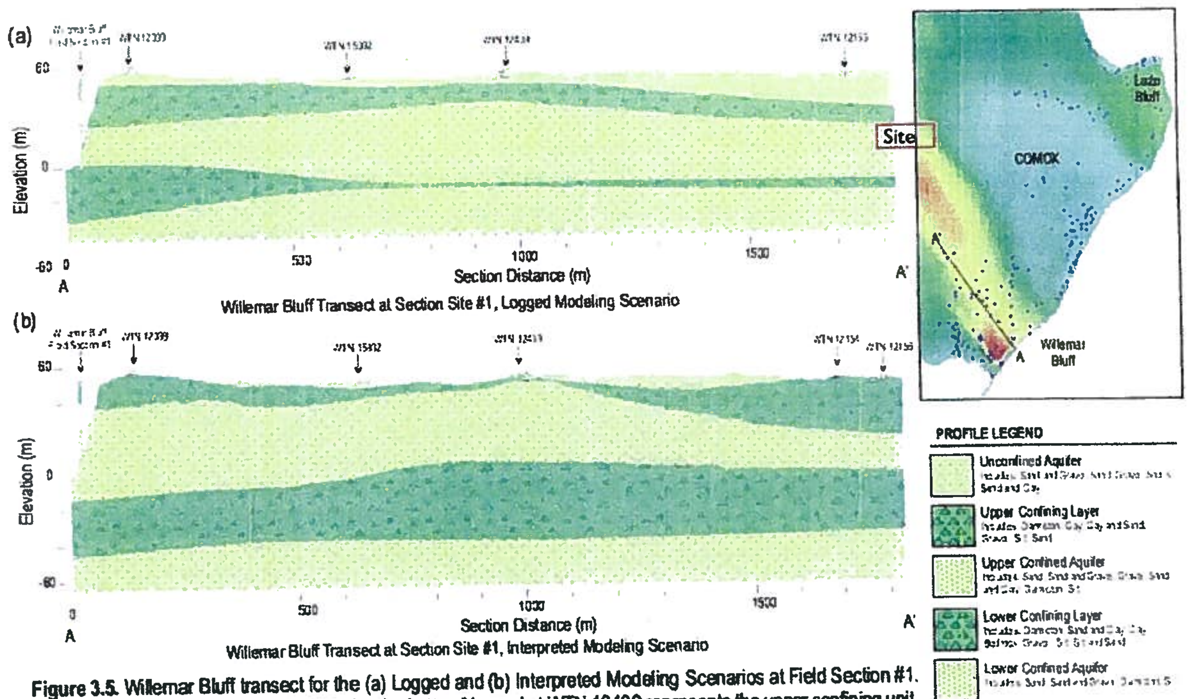



Figure 3.5. Willemar Bluff transect for the (a) Logged and (b) Interpreted Modeling Scenarios at Field Section #1. Recognizing that the "hardpan with gravel at the bottom" logged at WTN 12439 represents the upper confining unit, the top of the well was chosen to represent the lower contact of the overlying unconfined sand and gravel aquifer. Illustrated by the two profiles above, by adding the interpreted contact at WTN 12439 the model produces hydrostratigraphic surfaces that more closely matched the well log dataset.

Figure 2: Cross section south of the site (Gypsy Fisher – 2009)

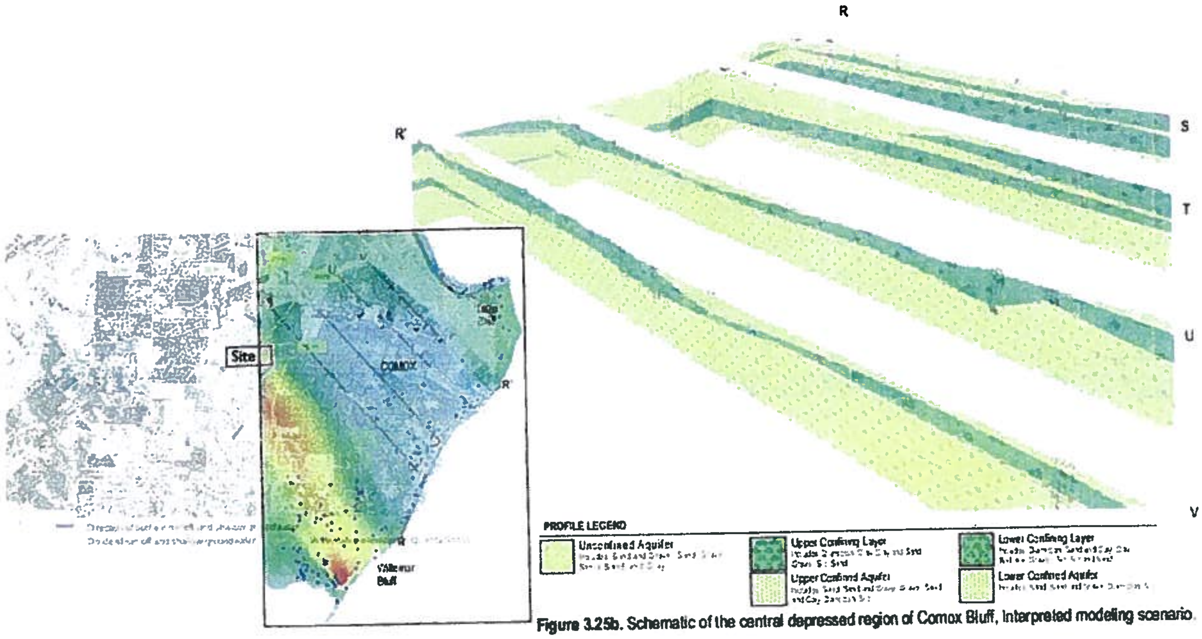



Figure 3: Fence diagram describing soil deposits (Gypsy Fisher – 2009)

### *2.2 Estimated Stratigraphic Units*

GW Solutions has interpreted the lithology along three cross sections, using the soil description provided by the well logs available from the BC Water Atlas, and by Simpson Geotechnical for the test pits dug on site. The test pits located on the west side of Pritchard Road are referred to as W (e.g. W 3 for TP 3) and E for the test pits located on the east side of Pritchard Road. The elevation of the test pits was surveyed and the elevation of the ground at the location of the water wells was estimated using Google Earth. The locations of the cross sections are shown in Figure 4 and the cross sections are presented in Figures 5 through 7. Light blue is used to represent layers made of permeable soils and brown to represent soils with low permeability. The potential location of water tables is shown with blue dash lines.

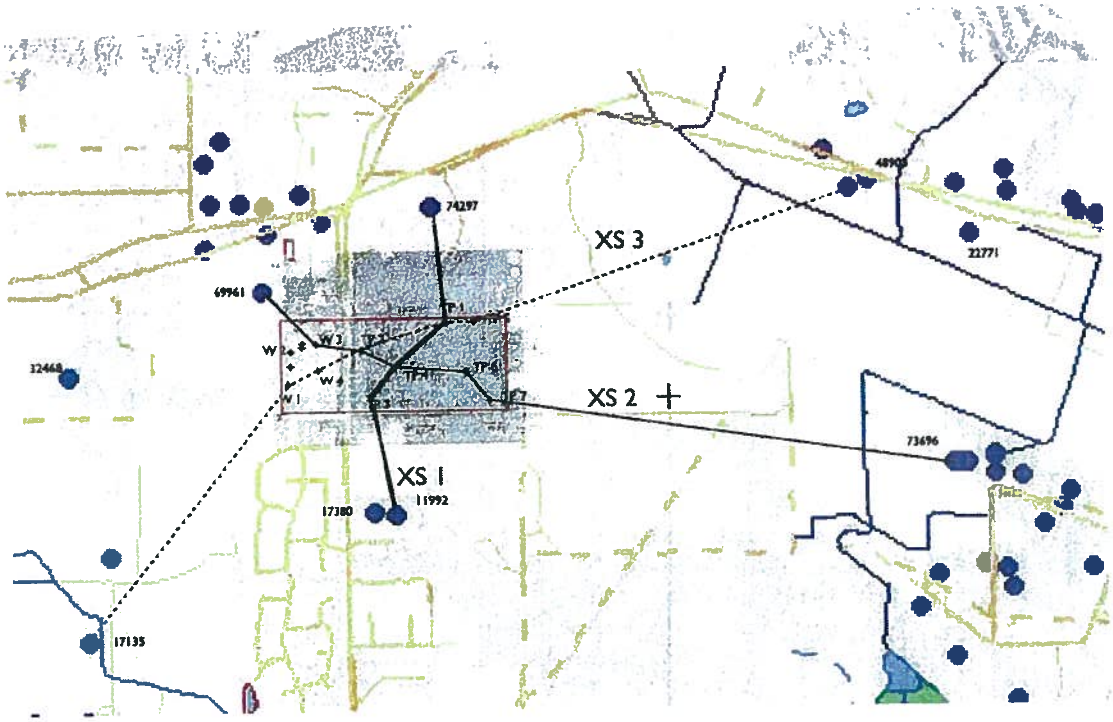



Figure 4: Location of the cross sections

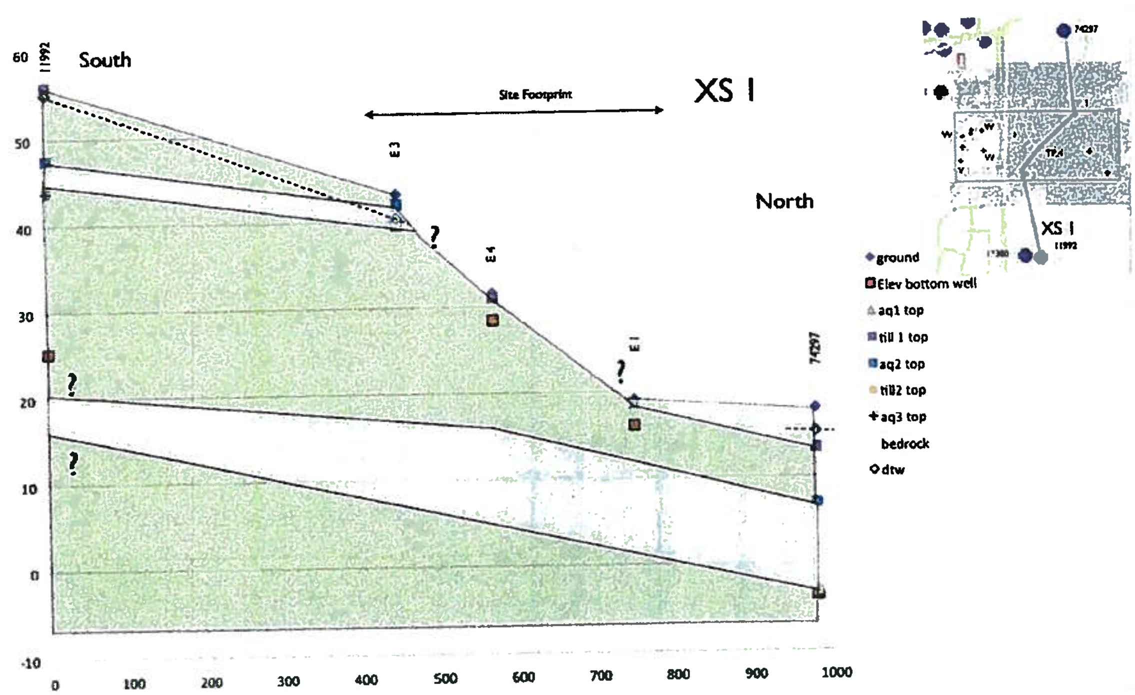



Figure 5: Cross section XS 1

Cross section XS 1 (Figure 5) indicates that the ground slopes between approximately 55 m and less than 20 m elevation. A permeable sandy layer, approximately 3 m thick, is present at shallow depth (less than 10 m) and possibly daylights in the south central part of the site. Seepage was observed in E3, possibly related to a shallow aquifer in this soil horizon. A deep aquifer was encountered in Well 74297, approximately 10 m to 20 m below ground. This aquifer possibly extends below the site.

Permeable material was encountered in E1, at the northeast corner of the site. It is possibly connected to the shallow aquifer encountered in Well 74297, which most likely corresponds to the headwaters of the Queen's Ditch shallow aquifer.

These permeable and aquifer bearing layers are separated by low permeability till units.

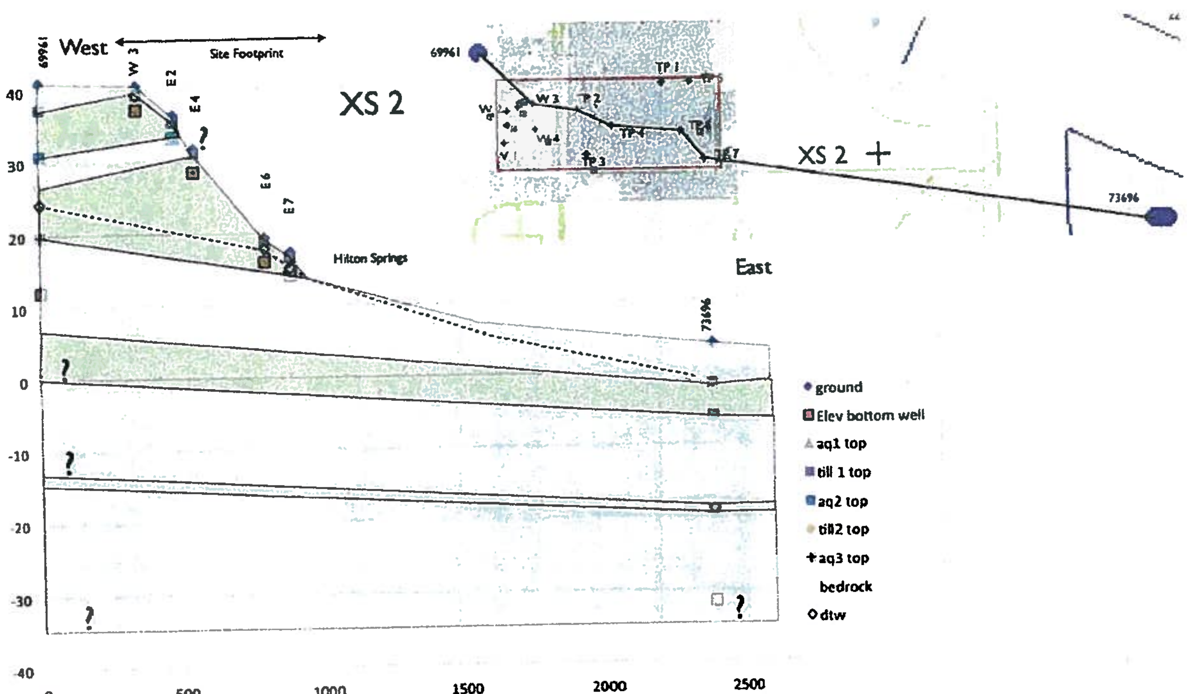



Figure 6: Cross section XS 2

Cross section XS 2 (Figure 6) also shows the sequence of permeable and low permeability units. It indicates the presence of a veneer of permeable material at surface in the western part of the site. A 3 m to 5 m thick confined aquifer is encountered at an elevation of approximately 30 m and possibly daylights east of E 2. A thicker aquifer is present at an elevation between 0 m and 20 m. It is confined on its eastern section and the Hilton Springs correspond to the location where this aquifer becomes unconfined.

A sequence of thick aquifers is likely present deeper.

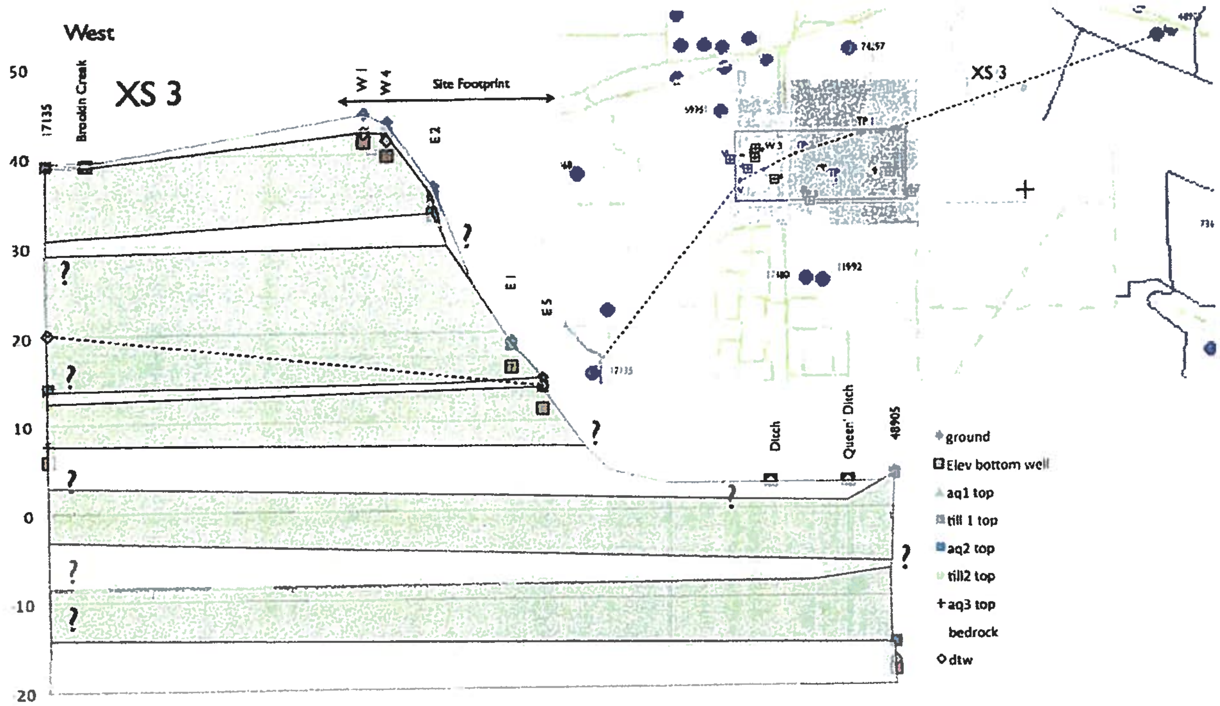



Figure 7: Cross section XS 2

Cross section XS 3 (Figure 7) indicates the presence of a veneer of permeable material at surface in the southwestern part of the site. The 3 m to 5 m thick confined aquifer encountered at an elevation of approximately 30 m identified on XS 2 is also revealed through the interpretation of the lithology along XS 3. A relatively thin permeable lens may be present around elevation 15 m and possibly daylights near the eastern boundary of the site. The thicker aquifer present at an elevation between 0 m and 8 m is likely the aquifer linked to the Hilton Springs and to the Queen's Ditch water system.

# 3. Issues to Consider

### *3.1 Sensitive receptors*

The site is located on a hump above and west of sensitive ecosystems (Figure 8). The Lazo watershed which includes Lazo Marsh and Queen's Ditch has been under stress in the last 80 years due to the change in land use within its boundary. As the site is within the Lazo watershed, any modification of the drainage on our site due to land development should be done to minimize detrimental effects to the heath and dynamic of the Lazo Watershed, taking into account the recommendations of Marsh 2002 report.

The eastern side of the site likely drains toward Brooklyn Creek. Therefore a portion of the drainage post development should be directed towards Brooklyn Creek to create a water balance for the site post development mimicking the conditions pre-development.

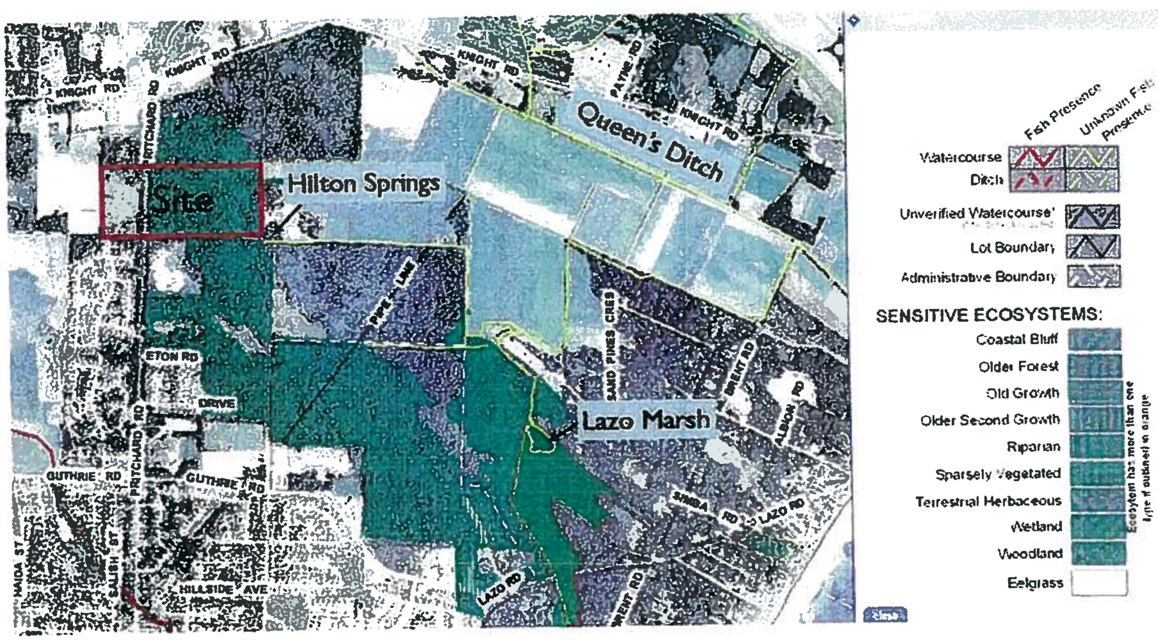



Figure 8: Sensitive ecosystems in Lazo Watershed

# 4. Additional Information Required

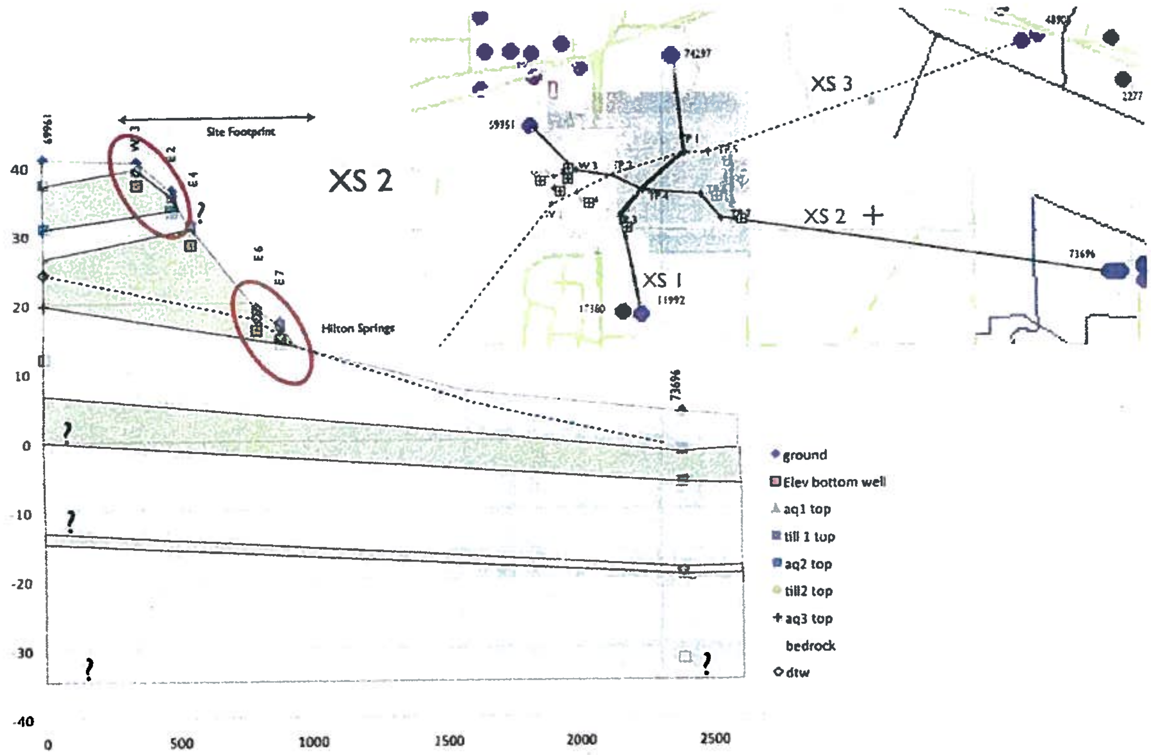



Figure 9: Assumptions to be confirmed along XS 2

All the cross sections presented in this report have been drawn based on limited information. Some assumptions have been relied upon and need to be confirmed. For example, Figure 9 shows the potential role played by the veneer of permeable material at surface and the possibility of a relatively thin aquifer daylighting halfway through the site. It indicates also that the eastern boundary of the site possibly corresponds to an area where the deep confined aquifer feeding the Hilton Springs becomes unconfined.

Similar areas are circled in Figure 10 and show where some of the assumptions used to draw the cross sections need to be confirmed or refuted.

The surface water and groundwater regimes at these locations need to be adequately defined in order to not disturb both the infiltration that recharges the aquifers and to not change the water flow to sensitive receptors.

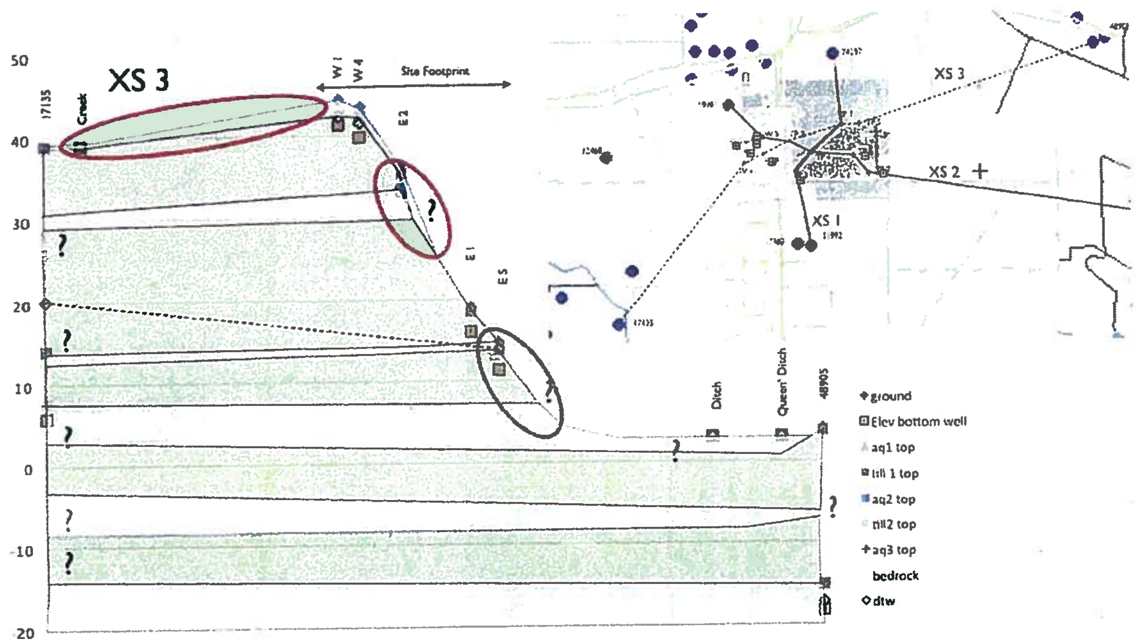



Figure 10: Assumptions to be confirmed along XS 3

## 5. Proposed Investigation

Simpson Geotechnical Ltd and GW Solutions propose to complete an additional subsurface investigation to further define the surface and groundwater regime. Figure 11 shows the locations where complementary information is required.

A series of shallow boreholes will be completed with monitoring wells to further define the soil units at shallow depth and to estimate the elevation of the water table. The proposed locations of these shallow monitoring wells are shown with the green stars.

Two deeper holes (10 m and 25 m deep) completed with monitoring wells are also proposed to confirm the presence and thickness or the confined aquifers. The boreholes are proposed to be drilled using a Sonic drilling rig because this drilling method provides non disturbed core samples. This will allow a good identification of the relatively thin soil units expected to be encountered on site and therefore clearly differentiate the aquifers (permeable soils) from the aquitards (low permeability materials).

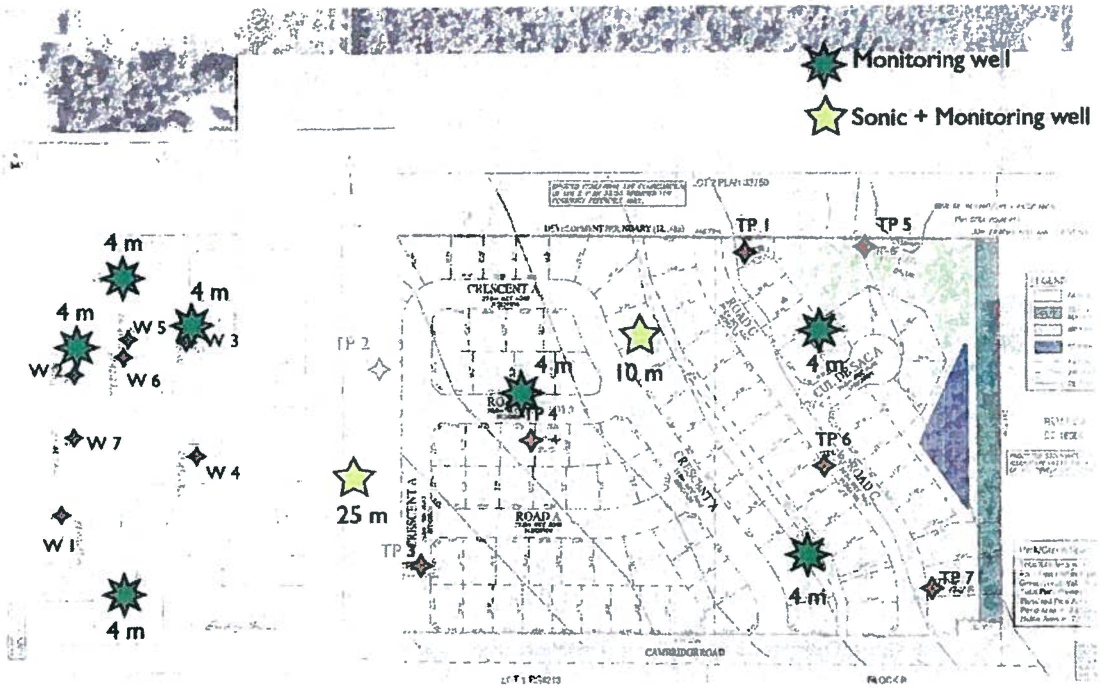



Figure 11: proposed investigation

## 6. Closure

Conclusions and recommendations presented herein are based on information provided in part by others. This preliminary study has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgment has been applied in developing the recommendations in this report.

This report was prepared by personnel with professional experience in hydrogeology. Reference should be made to the 'GW Solutions Inc. General Conditions and Limitations', attached in Appendix 1 that forms a part of this report. GW Solutions is pleased to produce this document. If you have any questions, please do not hesitate to contact me.

Yours truly,

**GW Solutions Inc.**

Gilles Wendling, Ph.D., P.Eng., President

Appendix

Appendix 1 – GW Solutions General Conditions and Limitations

# Appendix 1

# GW Solutions Inc. Reports – General Conditions

This report incorporates and is subject to these "General Conditions".

**1.0 USE OF REPORT**

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

**2.0 LIMITATIONS OF REPORT**

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS's investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

**2.1 Information Provided to GW SOLUTIONS by Others**

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

**3.0 LIMITATION OF LIABILITY**

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:
(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;
(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

**4.0 JOB SITE SAFETY**

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

**5.0 DISCLOSURE OF INFORMATION BY CLIENT**

The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

**6.0 STANDARD OF CARE**

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

**7.0 EMERGENCY PROCEDURES**

The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

**8.0 NOTIFICATION OF AUTHORITIES**

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

**9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE**

The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

**10.0 ALTERNATE REPORT FORMAT**

Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

December 20, 2010
10-16

Simpson Geotechnical Ltd
377 Milton Street
Nanaimo BC V9R 2K8

Attention: Richard Simpson, P.Eng.

Re: **Pritchard Road, Comox – Detailed Hydrogeology**

Dear Richard,

This letter provides a summary of the detailed hydrogeological assessment completed by GW Solutions Inc. (GW Solutions) at the location of a proposed residential development along Pritchard Road in Comox, BC (the Site). This report has been produced in collaboration with Simpson Geotechnical Ltd (Simpson) to provide information about the existing surface water and groundwater regime at and near the site.

# 1. Background

We understand that this assessment is required in accordance with the Town of Comox Official Community Plan (OCP) Section 7.6.4.3(g), which states that:

> *No significant disruption of the ground surface must be permitted below the 30-metre elevation contour unless a geotechnical-engineered design is used to maintain the integrity of the ground water discharge area.*

A number of environmentally sensitive hydrologic features have been documented downhill from the Site. GW Solutions was asked to provide guidance on estimating the surface and subsurface water flow patterns to allow Site development to be designed so as to minimize any water related environmental impact.

In a report dated July 23, 2010, GW Solutions presented results of a desktop review of available data to provide a conceptual model of the movement of water at surface and in the subsurface across the Site. The report also identified portions of the Site in which available data were insufficient to confidently estimate surface water and groundwater flow regimes, and recommended the construction of a series of monitoring wells to fill this data gap.

Between September 1 and December 20, 2010, GW Solutions performed a site investigation consisting of the following components:

- a site reconnaissance by Mr. Arnd Burgert, P.Geo., a GW Solutions hydrogeologist;
- drilling nine boreholes using a sonic drill rig to obtain continuous core of the sedimentary column;
- logging the drill core;
- installing monitoring wells in the boreholes;

- developing and purging all new wells and checking response; and
- measuring water levels (September 22/23 and December 17, 2010).

The location of the test pits, shallow and deep monitoring wells is shown in Figure 1.


**Figure 1: Location of test pits and monitoring wells**

The test pits dug by Simpson and located on the west side of Pritchard Road are prefixed with W (e.g. W 3 for TP 3) while those on the east side are prefixed with E. Monitoring wells are prefixed with S for shallow and D for deep. The elevations of the test pits and monitoring wells were surveyed and the elevations of the ground at the locations of the water wells were estimated using Google Earth.

The new lithological information and water level data were collated, revised cross sections were drawn, and the conceptual water flow model was refined. The results are presented in the remainder of this report, with monitoring well logs included as Appendix 2.

## 2. Site Topography, Geomorphology, and Vegetation

A topographic map of the Site and surrounding area is presented as Figure 2. The Site is located on a topographic upland that marks the drainage divide between the Brooklyn Creek drainage to the west and the Lazo Watershed to the east. Topography across the Site is subdued, with a gentle slope from southwest to northeast. Elevation drops from about 44 m (geodetic) in the southwest corner of the Site to about 17 m at its northeast corner.

Geomorphology of the Site is described by a series of nearly flat benches trending approximately northwest-southeast, with intervening gentle slopes. Surficial lithology consists alternately of loose, dry, silty sand, dense, damp gravelly silt, and firm, wet, silt and clay.

No incised drainage channels were observed. Surficial sediments covering most of the Site were dry or slightly damp, with the exception of the eastern end of the Site where standing water was noted, and the access trail there was very muddy.

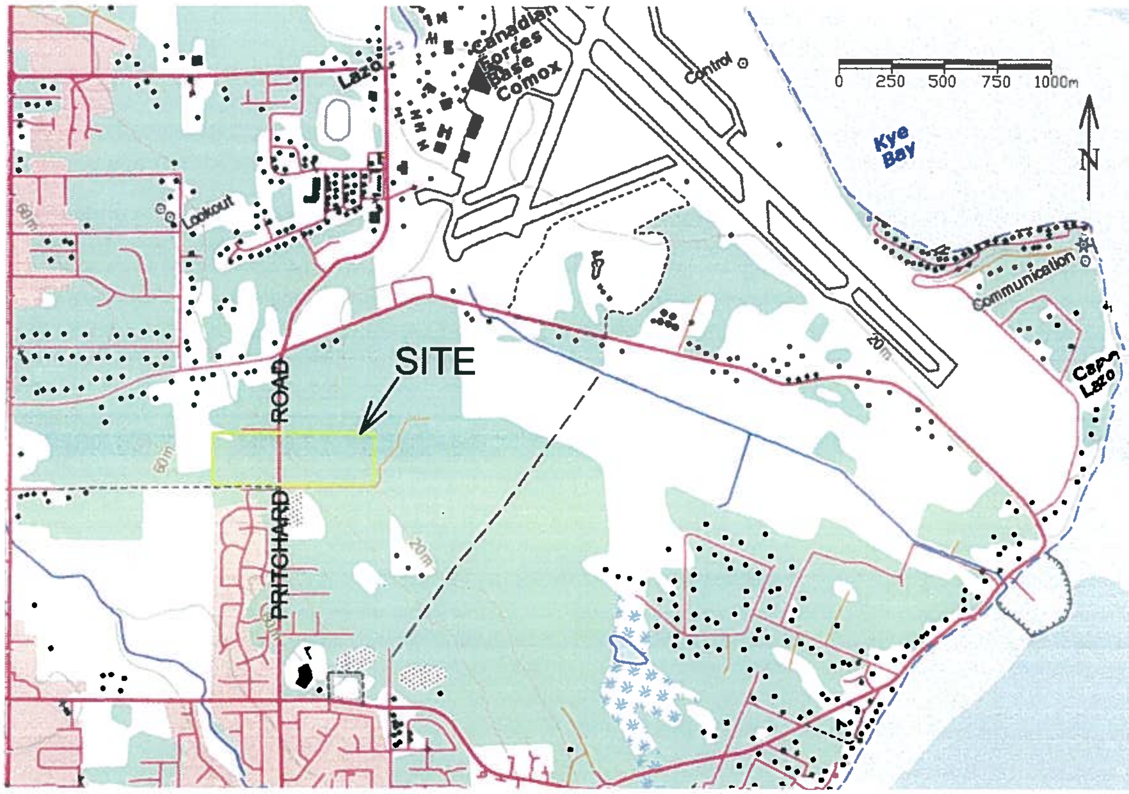



**Figure 2: Topography of the Site and surrounding area**

The portion of the Site lying west of Pritchard road has been cleared, and is covered by grass, weeds, and patches of juvenile Red Alder. The portion of the Site lying east of Pritchard Road is covered by a mature stand of second growth timber consisting mainly of Douglas Fir with a minor component of Western Red Cedar. The understory is sparse, with occasional patches of shrubby salal.

## 3. Sensitive Receptor Environments

The Site is located just east of the drainage divide between the Brooklyn Creek drainage to the west and Lazo Watershed to the east. Several sensitive ecosystems have been documented within Lazo watershed, including Hilton Springs, Queen's Ditch, and Lazo Marsh (Figure 3).

The Lazo watershed has been under stress in the last 80 years due to the change in land use within its boundary. As most of the Site lies within the Lazo watershed, any modification of the drainage on the Site due to land development should be done in a manner that minimizes detrimental effects on the health and dynamic of the Lazo Watershed, taking into account the recommendations of the Marsh (2002) report. In particular, the design of the development's drainage system should attempt to maintain opportunities for water to infiltrate into the ground. The development should avoid causing significant changes either to winter peak flows discharged to streams or ditches, or summer base flows from springs and seeps. Recommendations in support of these goals are included in this report.

The easternmost end of the site likely drains toward Brooklyn Creek. Therefore a portion of the drainage post development should be directed towards Brooklyn Creek to create a water balance for the Site post development mimicking the pre-development conditions.

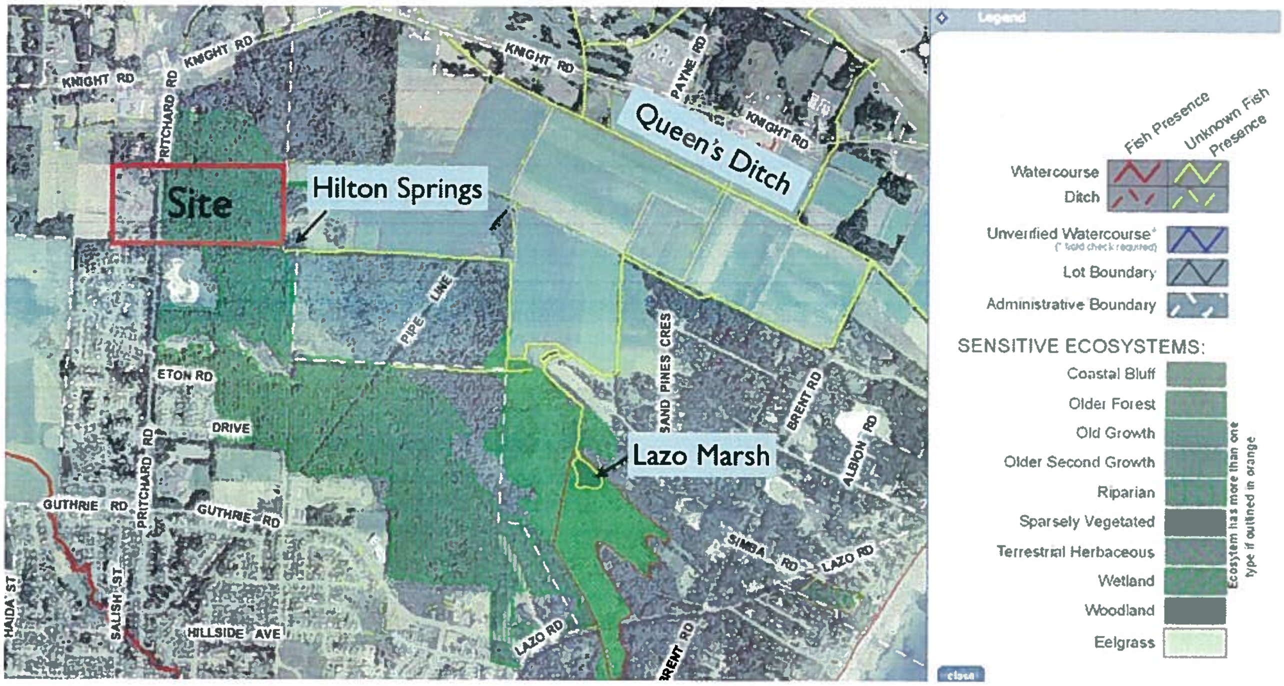



**Figure 3: Sensitive ecosystems in Lazo Watershed**

## 3. Regional Hydrology and Hydrogeology

The site is situated in the Lazo Watershed, which is well described in the document "Toward a Management Plan for the Lazo Watershed and Queen's Ditch", by William Marsh, 2002. Figure 4 shows aquifers reported in the BC Water Atlas. There is no mapped surface water feature or perennial stream on the Site. According to this regional characterization of the hydrogeology, the Site is located over a confined sand and gravel aquifer (Aquifer 408), classified as being moderately productive, highly used as a water source, and having a low vulnerability to surface contamination.

The Site is located northwest of Aquifer 407, classified as being moderately productive, not used as a water source very much, and being highly vulnerable to surface contamination.

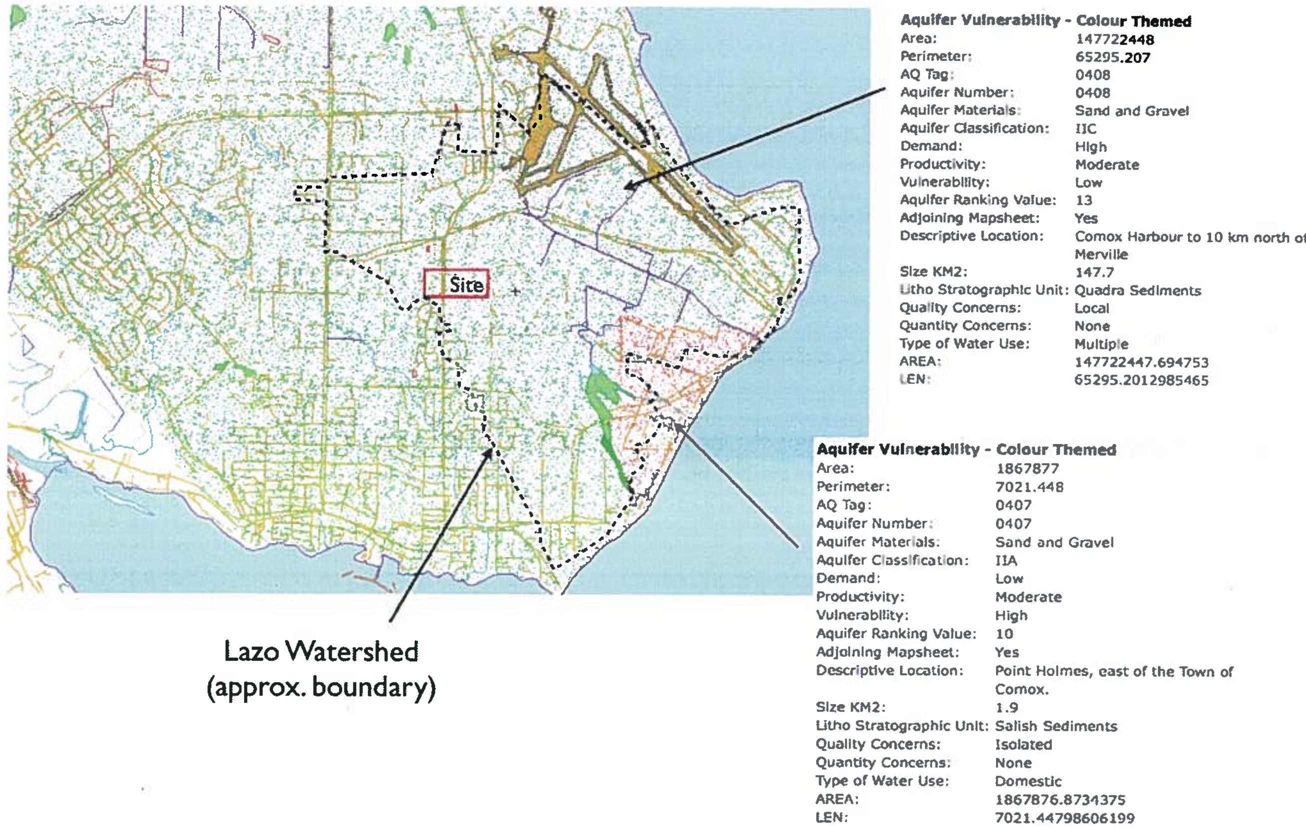



**Figure 4: Aquifers at and near the Site, as mapped by the BC Water Atlas**

The sedimentary column hosts a series of layered sediments of varying permeabilities. The sediments are part of a regionally mapped surficial lithological unit called the Quadra Sands which at one time occupied much of the Strait of Georgia. The Quadra Sands were deposited by preglacial outwash during the advance of the Fraser glaciation, either in glacio-fluvial or possibly shallow marine or deltaic environment. A layer of dense glacial moraine (till) caps the sedimentary sequence in many places.

Most of the mass of the Quadra Sands formation was subsequently eroded by later meltwaters, with remnant occurrences of Quadra Sands sediments distributed along the coast of the Strait of Georgia from southern Vancouver Island to Quadra Island near Campbell River.

Groundwater seepage through the Quadra Sands unit is often intricately controlled by the multiple sedimentary layers of varying grain size and permeability. Downward seepage through the upper unsaturated strata is interrupted by aquitard layers of lower permeability. Seepage then pools on top of the aquitard layer forming an upper aquifer, and diverts laterally toward "holes" in the aquitard, or possibly toward their daylight extent where the water emanates from the ground as springs or seeps. Since summer base flows in coastal streams are predominantly groundwater fed, the Quadra Sands unit plays an important role as a natural water reservoir supplying water year-round to streams and rivers.

# 4. Local Hydrogeology

The aquifer characterization and delineation available from the BC Water Atlas provides a regional context. To provide an understanding of Site hydrogeology at a level of detail suitable for pre-design purposes, GW Solutions has prepared a site-specific conceptual model of the lithology of the subsurface identifying both aquifers and aquitards. Aquifers typically consist of unconsolidated sand and/or gravel having relatively high permeability, while aquitards consist of low-permeability consolidated silt, sand and gravel (glacial till), or silt and clay. Information was obtained from the following sources:

- Information provided in a recent Master Thesis Report[1] (2009);
- Logs of water wells available on the BC Water Atlas;
- Logs of the test pits dug on site by Simpson geotechnical;
- Logs of monitoring wells drilled by GW Solutions; and
- Monitoring well water levels measured by GW Solutions.

## *4.1 Master Thesis*

In her research, Gypsy Fisher used detailed information collected along two escarpments (the Willemar and Lazo bluffs) and available drilling logs to build a conceptual model of the overburden deposits. The results are illustrated with cross sections and fence diagrams.
It shows that soil deposits in her study area consist of a sequence of low and high permeability materials, a few meters to tens of meters thick. Figure 5 shows a cross section located south of the Site, and Figure 6 shows a fence diagram covering an area southeast of the Site. Unfortunately, the Site is located outside of the area subject to Gypsy's research.

[1] Hydrogeological Investigation of Quaternary and Late Cretaceous Bedrock Aquifers, Comox Coalfield, Vancouver Island, British Columbia, Canada, by Gypsy C. Fisher, University of Victoria

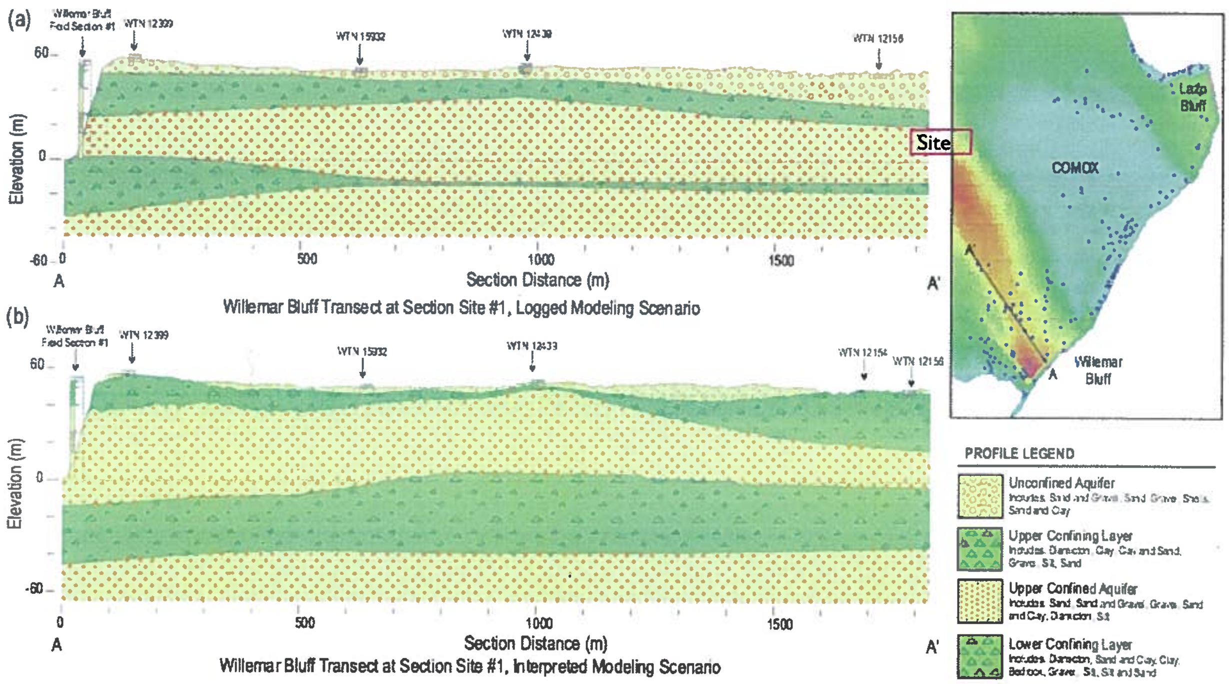



**Figure 3.5.** Willemar Bluff transect for the (a) Logged and (b) Interpreted Modeling Scenarios at Field Section #1. Recognizing that the "hardpan with gravel at the bottom" logged at WTN 12439 represents the upper confining unit, the top of the well was chosen to represent the lower contact of the overlying unconfined sand and gravel aquifer. Illustrated by the two profiles above, by adding the interpreted contact at WTN 12439 the model produces hydrostratigraphic surfaces that more closely matched the well log dataset.

**Figure 5: Cross section south of the Site (Gypsy Fisher - 2009)**

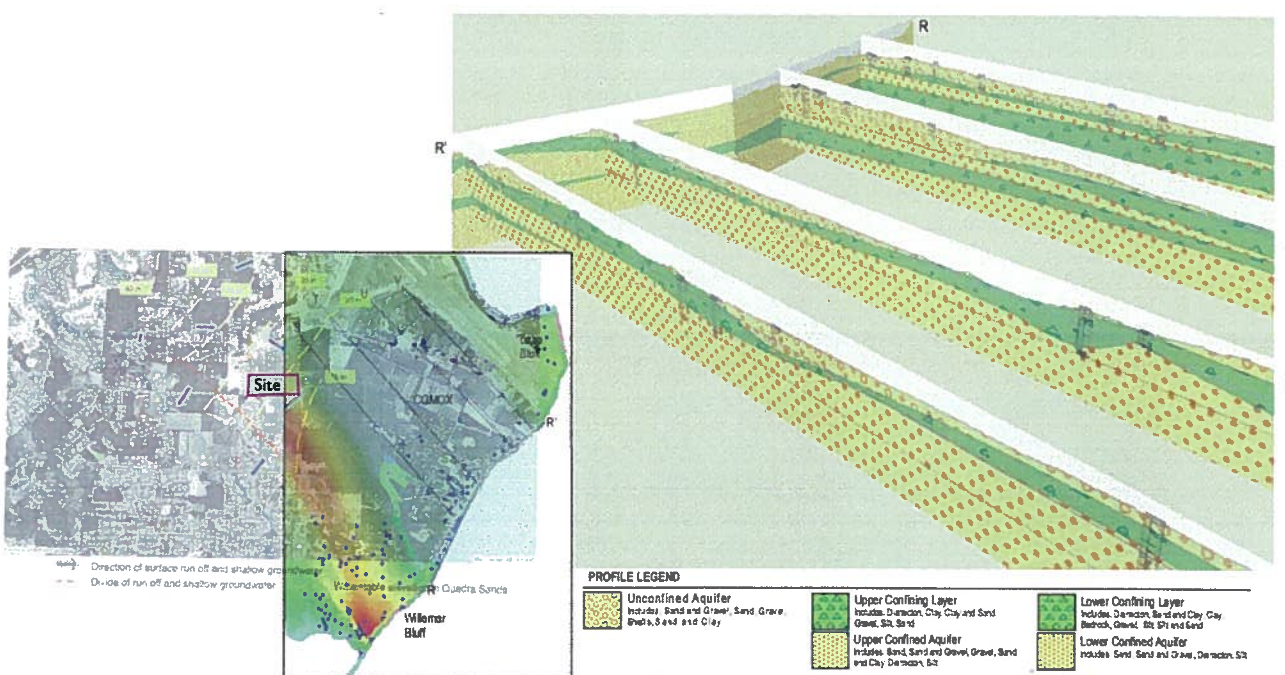



**Figure 3.25b.** Schematic of the central depressed region of Comox Bluff, Interpreted modeling scenario.

**Figure 6: Fence diagram describing soil deposits (Gypsy Fisher – 2009)**

### *4.2 Estimated Stratigraphic Units*

GW Solutions has interpreted the lithology of the Site along three cross sections, using the sediment descriptions provided by the well logs available from the BC Water Atlas, logs of test pits excavated by Simpson Geotechnical, and logs of boreholes drilled by GW Solutions during September, 2010. The locations of the cross sections are depicted in Figure 7 by green lines labeled XS1, XS2, and XS3. The cross sections are presented in Figure 8 through Figure 10. On the sections, light blue is used to represent layers made of permeable sediments and brown to represent sediments with low permeability. The estimated location of the highest monitored groundwater levels is shown with blue dashed lines.

Water level measurements indicate that numerous water-bearing zones are present, each perched above the next by an intervening low-permeability zone (aquitard). Such a distribution is typical of sediments in the Quadra Sands. The aquitards do not cut off the downward seepage of groundwater, but rather slow the seepage rate down by several orders of magnitude with respect to the aquifer layers. The result is a dynamic system of groundwater recharge, temporal storage, transfer between layers, and eventual discharge. Water levels in some of the aquifer zones are higher than the top of the aquifer sediments, indicating that recharge at elevation is producing pressure in the formation (artesian head).


**Figure 7: Location of the cross sections**

Cross section XS 1 (Figure 8) indicates that the ground slopes between approximately 55 m and less than 20 m elevation from south to north. A permeable sandy layer, approximately 3 m thick, is present at shallow depth (less than 10 m) and possibly daylights in the south central part of the site. The source of seepage observed in E3 is likely the same shallow permeable layer. Loose, well-drained, sandy sediments occur at surface along a topographic bench near E4.

Permeable material was also encountered in E1, at the northeast corner of the site. The permeable sediments at this location may be connected to the shallow aquifer encountered in Well 74297, which most likely corresponds to the headwaters of the Queen's Ditch shallow aquifer.

A deep aquifer was encountered in Well 74297, approximately 10 m to 20 m below ground. This aquifer may extend below the Site, and possibly correlates with a sandy aquifer encountered in monitoring well D2. At D2, the piezometric level is slightly higher than the top of the aquifer sediments, indicating confining conditions.

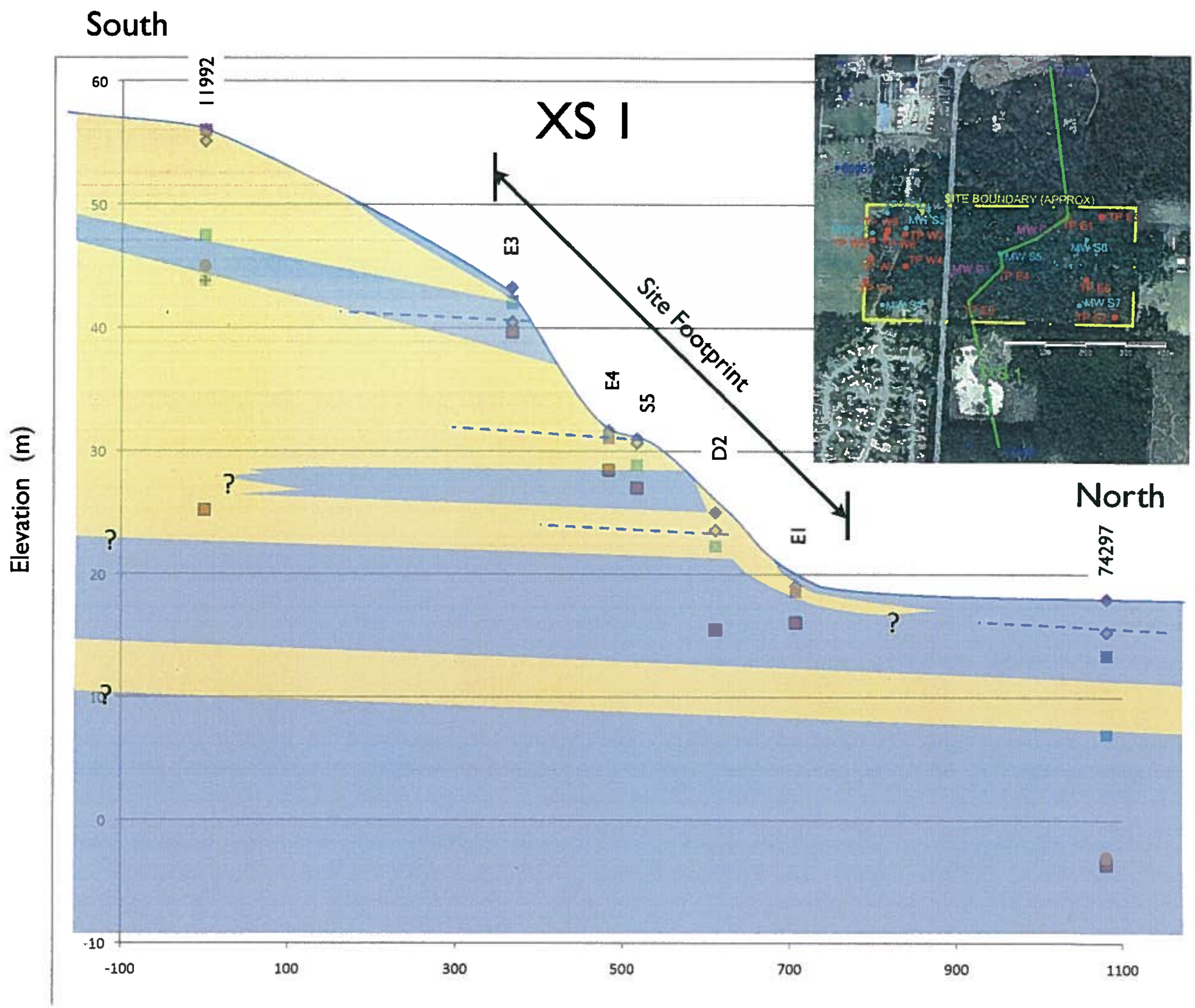



**Figure 8: Cross section XS 1**

Cross section XS 2 (Figure 9) also shows the sequence of permeable and low permeability units. It indicates the presence of a veneer of permeable material at surface in the western part of the site. A 3 m to 5 m thick confined aquifer is encountered at an elevation of approximately 30 m, and it appears to continue as far as S3, where the aquifer appears to daylight.

A thicker aquifer is present between elevations of 0 m and 20 m. Its western section is confined, and Hilton Spring corresponds to the location where this aquifer becomes unconfined and daylights.

A sequence of thick, confined aquifers is likely present deeper.

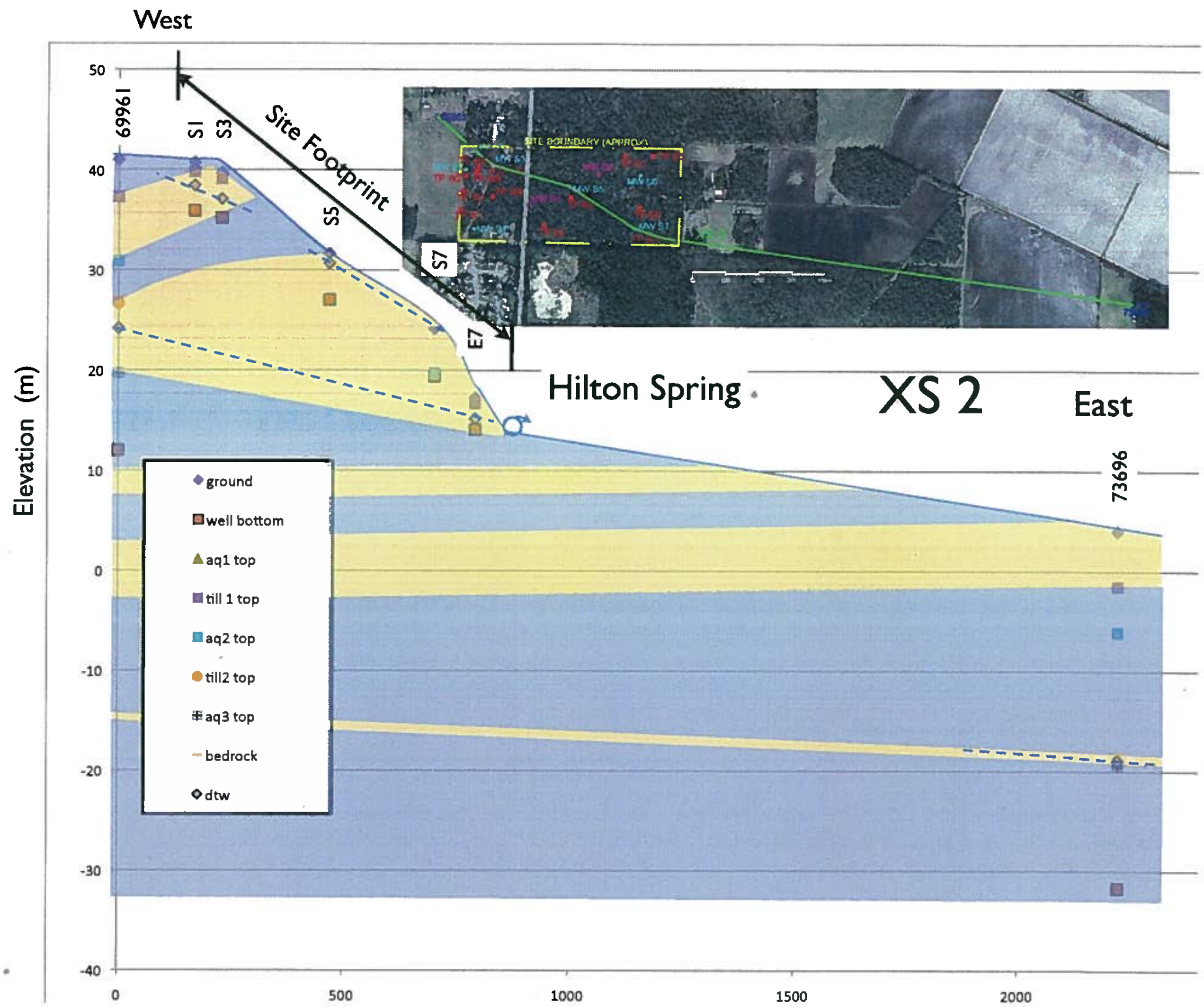



**Figure 9: Cross section XS 2**

Cross section XS 3 (Figure 10) indicates the presence of a veneer of permeable material at surface in the southwestern upland part of the site. A layer, at least 5 m thick, of loose silty sand was encountered in S4 at a depth of 4.3 m.

The 3 m to 5 m thick confined aquifer encountered at an elevation of approximately 30 m identified on XS 2 is also revealed through the interpretation of the lithology along XS 3. A relatively thin permeable lens is present around elevation 25 m and possibly daylights in the northern portion of the Site, possibly correlating with sandy sediments at surface near D2. A thicker aquifer present between elevations of 10 m and15 m is likely the aquifer linked to the Hilton Springs and to the Queen's Ditch water system.

Seepage was also noted in September, 2010 at ground surface at E1 (northeast quadrant of the site), indicating that flowing artesian conditions are present in the shallow (< 5 m) subsurface in that area. The existence of flowing artesian conditions in the northeast portion of the Site was confirmed by the construction of monitoring well S6, in which a permeable sandy unit is overlain by a confining layer of silty clay. On December 17, 2010, the water level in S6 was 2.5 m *above* ground level.

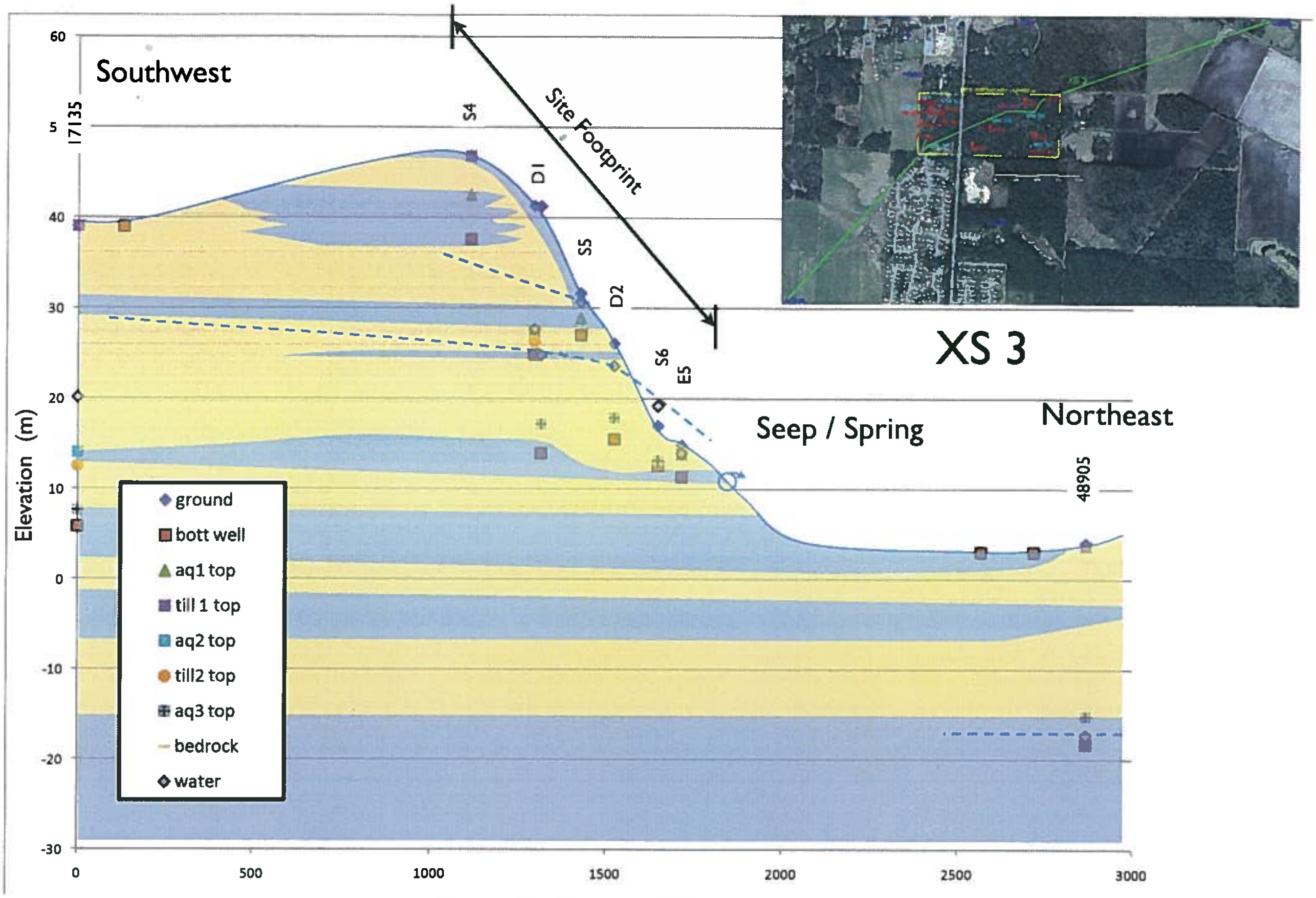



**Figure 10: Cross section XS 3**

# 5. Discussion

Precipitation, surface flows, and groundwater are interconnected. Undeveloped land such as that at the Site offers the opportunity for precipitation (rain, snow) to infiltrate into the ground to replenish water reserves in the underlying aquifers. In particular, a lithology such as the unconsolidated sediments present at the Site allows most of the water input (annual precipitation) to infiltrate into and to move through the ground, hence the lack of a developed drainage pattern at surface at the Site.

The water infiltrating into the ground during the wet season seeps slowly through the network of interconnected permeable units, taking months or years to daylight again as a spring or seep, or possibly be intercepted by a water well. Springs and seeps are an important source of cool water that sustains base flows in streams during the dry season, and groundwater is critical to the health of aquatic habitats.

Past methods of rainwater management (formerly referred to as stormwater management) involved designs meant to rid an area of storm water as quickly as possible, with little thought given to the effect on receptors. As the permeable interface of natural soils are replaced by hard surfaces such as roads, driveways, and roofs, the opportunity for water to infiltrate into the ground is decreased. At the same time, rainwater that used to take months or years seeping through the earth before daylighting at a stream may rush through a constructed rainwater drain system to be discharged to a stream in a matter of minutes. The resulting unnatural peak flow resulting from the storm water surge can be detrimental to stream channels and banks.

New methods of rainwater management system tend to minimize the disruption of the water flow through the ground, following precipitation events of a wide range of intensities.

Upland areas in which water infiltrates downward to replenish aquifers are termed recharge areas, while lowland areas where groundwater seeps out of the ground are called discharge areas. The Pritchard Road Site spans an upland area and a series of benches where recharge occurs, as well as a low-lying discharge area where groundwater comes to surface year-round. The intervening sedimentary column consists of an intricate sequence of discontinuous strata of greatly varying permeability, and the actual seepage paths of water are likely complex. Numerous water-bearing zones are present, separated by aquitard layers. The aquitards do not cut off the downward seepage of groundwater, but rather slow the vertical seepage rate down while diverting seepage laterally toward either a window in the aquitard or a seep or spring at the ground surface. The result is a dynamic system of groundwater recharge, temporal storage, transfer between layers, and eventual discharge.

A traditional approach to rainwater management at the Site is certain to upset the intricate groundwater balance at play. Unfavorable changes to the flow regime (increased peak flows and reduced base flows) downgradient of the Site are likely to occur unless the proposed development is designed with mitigative measures in mind.

Fortunately, the Site offers ample opportunity to incorporate surface rainwater management features to encourage infiltration and reduce peak flows. Provided that appropriate features are incorporated in the development's design, it is likely that post-development groundwater levels and surface flows can be maintained near pre-development conditions. Rainwater management features for improving infiltration and reducing peak flows that may be applicable to the Site are discussed in the following section.

## 6. Rainwater Management Features to Consider

Generalized suggestions relating to potential areas for rainwater infiltration at the Site are made in this section. It should be noted that mapping of surficial geology at the Site is beyond the scope of the current study, and suggestions made here are not for design purposes. Unsaturated sandy sediments such as those encountered at the Site are good targets for surface rainwater infiltration, and where practicable storm water mains could be directed toward or through such areas. The best success will be achieved when infiltration features are spread about a site rather than concentrated in one area.

Unsuitable areas for infiltration exist in the discharge area at the eastern end of the Site where artesian heads were encountered in a shallow aquifer.

It should be understood that rainwater management features suitable for the recharge area in the western upland portion of the Site will not be suitable for the discharge area in the eastern portion. A feature designed to infiltrate water into unsaturated sediments could act as a groundwater drain if installed in a discharge area, drawing water out of the ground.

### 6.1 Vegetated swales and soakaways

Where space permits, a simple yet effective feature for infiltrating rainwater is a roadside swale. As opposed to a conventional ditch with a constant grade, the long axis of the swale should be terraced, with horizontal runs of appropriate lengths which then drop down to a continuation below. This configuration allows water to pond temporally during precipitation events. Soakaways can range in size and can be located within lots.

### 6.2 Leaky storm drains

Replacing conventional solid storm drain pipes with perforated pipes or infiltrator galleries will give collected water a chance to exfiltrate into the ground. Leaky storm drain pipes must be installed over permeable sediments. Rather than being installed at a constant grade, they should be installed in a terraced sequence to allow water to temporally pond during a precipitation event rather than rush along the pipe.

### 6.3 Lot grading

Where practicable, roof leaders (downspouts) should be disconnected from storm drains and instead diverted into the yard for infiltration. Lot grading becomes critical to ensure water does not flood footings or basements. Over much of the Site, permeable sediments occurring at surface are suitable for infiltration, but permeable fill could be placed as appropriate to provide temporal in-ground storage for water. Within lots and across the development site, retentive grading (constructed hummocky/swaled topography) should be applied rather than constant grades.

### 6.4 Porous pavement and paving blocks

Porous pavement allows water to infiltrate through, reducing the load that is diverted to a storm drain catch basin. Paving blocks are suitable for light traffic areas, walkways, and sidewalks.

### 6.5 Rain gardens

Rain gardens within lots and in community areas are designed to detain storm water.

### 6.6 Check dams in utility trenches

Permanent check dams made of bentonite should be installed about every 20 m along utility trenches to prevent granular fill in trenches from becoming pathways for rapid water seepage. The height of the check dams should correspond to half the depth of the utility trenches.

### 6.7 Infiltration wells or trenches

If excess infiltration capacity is required, consideration could be given to installing one or more infiltration wells or trenches. Before being infiltrated into an aquifer, storm water must pass through a passive filter.

# 7. Discharge Area Design Criteria

Figure 11 and 12 present the estimated piezometric isocontours (elevation of the water table) for the hydrogeological conditions encountered in the shallow and deep aquifers in September and December 2010. It shows a general movement of the shallow groundwater northeastward. Groundwater in the deep aquifer moves eastward, with a lower hydraulic gradient. Both shallow and deep groundwater daylight at surface on the east side of the property, in the area shaded blue in the figures.


**Figure 11: Piezometric conditions – September 2010**


**Figure 12: Piezometric conditions – December 2010**

The piezometric levels were monitored up to 2.7 m higher in December than in September.

The presence of the discharge area in the eastern lowland portion of the Site necessitates special design considerations, since a shallow aquifer there exhibits artesian conditions. Flowing conditions have been observed, and a head of 2.5 m above ground level was measured in monitoring well S6 (see monitoring well log in Appendix 2). An artesian head in a shallow aquifer was also noted in monitoring well S7, where the groundwater level rose 1 m above ground level.

Figure 13 shows the estimated thickness of soil above the first water table encountered. The values range between greater than 9 m and less than 0 m. The shape of the isocontours is approximate due to the limited number of locations where data is available. However, it shows a reduction of the thickness of non-saturated soil as we move north and east across the Site. Non-saturated thickness of less than 2.5 m may create limitations to the types of residence that could be built (e.g. no basement allowed). This parameter will also have to be taken into account when designing trenches for utility corridors.


**Figure 13 Soil thickness above water table (December 2010)**

At the site of S6, the shallow gravelly sand aquifer is confined by a 2 m thick layer of glacial till overlying 1 m of silt. At S7, the confining layer is about 4 m thick. Wherever this confining till layer is encountered in the lowland area (approximately the eastern third of the Site), it should be preserved. Excavations into the till in the lowland area should not take place.

During construction, excavation contractors should be advised of the requirement to protect the confining layer, and consideration should be given to storing a supply of powdered or granular bentonite on site. If the confining till/silt layer were to be accidentally breached, the bentonite could be thoroughly mixed in equal proportion with native soil and backfilled to create a seal.

GW Solutions understands that the placement of up to 7 m thick of fill material is proposed on the eastern quarter of the property so that the final grade will be well above the estimated high piezometric levels (Figure 14). The soil to be placed will be inorganic soils excavated when reshaping the topography of the property. The type and volume of soil that will be excavated is presently unknown, but its hydraulic characteristics should be taken into account when placing it as fill, so that infiltration of rainwater is promoted.

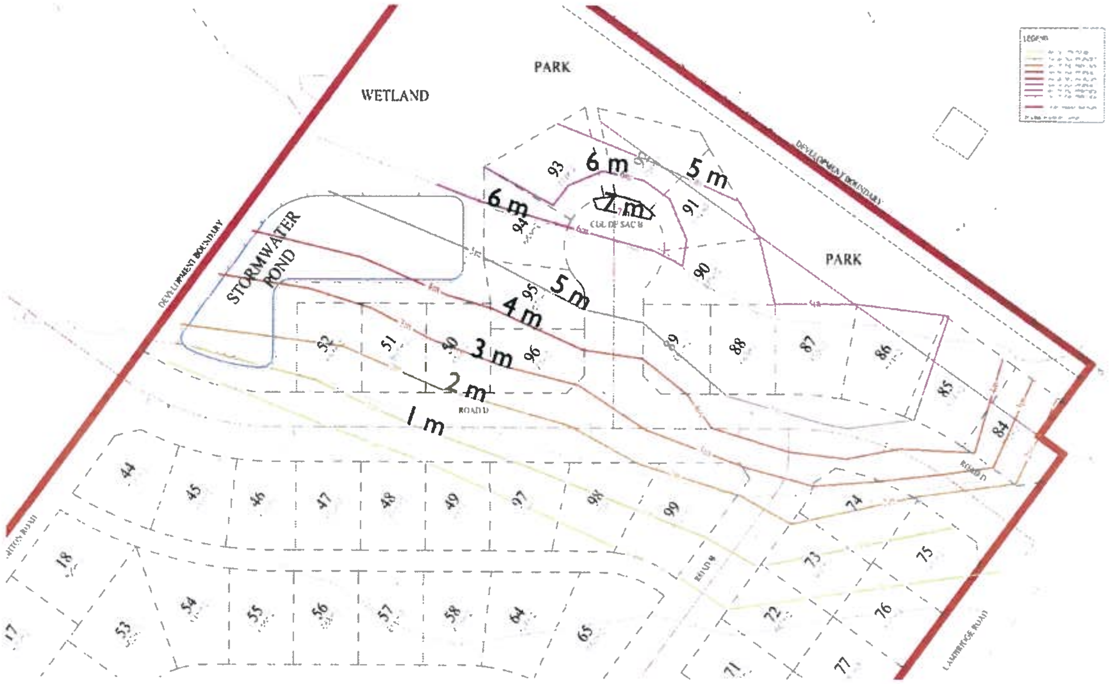



**Figure 14: Proposed placement of fill material (To be updated to reflect December 2010 conditions)**

In a case where construction happens to occur at or near a seep or spring, the seep or spring can be offset slightly so as to allow construction to proceed, but its flow should be preserved, and directed away from structures. Concentration of flows from such seeps/springs by directing the flows into ditches or storm drains should be avoided. The natural flows should be mimicked as much as possible.

## 8. Recommendations

GW Solutions makes the following recommendations, based on the work completed to date and the available information on the hydrogeological conditions at the Site at the time the work was completed:

- The land development should not include modification of the surface of the land or the subsurface that would result in the lowering of the water table of the various aquifers encountered below the footprint of the Site. This is particularly the case in portions of the Site where the depth to the water table is shallow or where artesian conditions are encountered.
- The design of the land development and building schemes has to be discussed and reviewed by a senior hydrogeologist so that situations that could be detrimental to the proposed constructions (e.g., water ingress in buildings, flooding of the land) or to the aquifers and to the environment are avoided.
- The aquifers have presently been monitored in the early fall when the groundwater levels are typically at their lowest and in December when water levels are more representative of high water level conditions. Winter monitoring should be conducted again in January or February 2011 to confirm that the high groundwater levels potentially reached during the year are adequately estimated.
- The hydraulic conductivity of the fill material should be tested prior to final design and placement of the fill. Layers of conductive soils (sand) may have to be incorporated in the fill, either as "sandwiched" layers or as "trenches" to promote infiltration of rain water.
- A monitoring program could be designed and implemented to assess the flow of Hilton Spring and to collect data prior and post development. It could consist of installing a flume or weir, or alternatively installing a shallow monitoring well at the location of the spring, and equipping it with an electronic data logger. Such a work could be associated with environmental stewardship and could become an asset in the future, should the need to prove that the land development had no negative impact on Hilton Spring and the Lazo watershed become relevant.
- The monitoring wells constructed during this study will be valuable for future water level monitoring, and at least some should be preserved. The monitoring well casings could be cut short and completed beneath steel access covers.
- Monitoring wells that will not be preserved are subject to formal closure pursuant to Section 9 of the Groundwater Protection Regulation (Water Act). For wells over 4.57 m in depth, the closure must be supervised by a registered well driller, hydrogeologist, or geotechnical engineer.

## 9. Closure

Conclusions and recommendations presented herein are based on information provided in part by others. This preliminary study has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgment has been applied in developing the recommendations in this report.

This report was prepared by personnel with professional experience in hydrogeology. Reference should be made to the 'GW Solutions Inc. General Conditions and Limitations', attached in Appendix 1 that forms a part of this report. GW Solutions is pleased to produce this document. If you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

GW Solutions Inc.

PROFESSIONAL PROVINCE OF G. R. WENDLING BRITISH COLUMBIA ENGINEER

Gilles Wendling, Ph.D., P.Eng.,
President

Appendices

Appendix 1 – GW Solutions General Conditions and Limitations
Appendix 2 – Monitoring Well Logs
Appendix 3 - Photos

**Appendix 1**

GW Solutions Inc. Reports – General Conditions

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS's investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 Information Provided to GW SOLUTIONS by Others

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:
(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;
(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT

The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES

The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

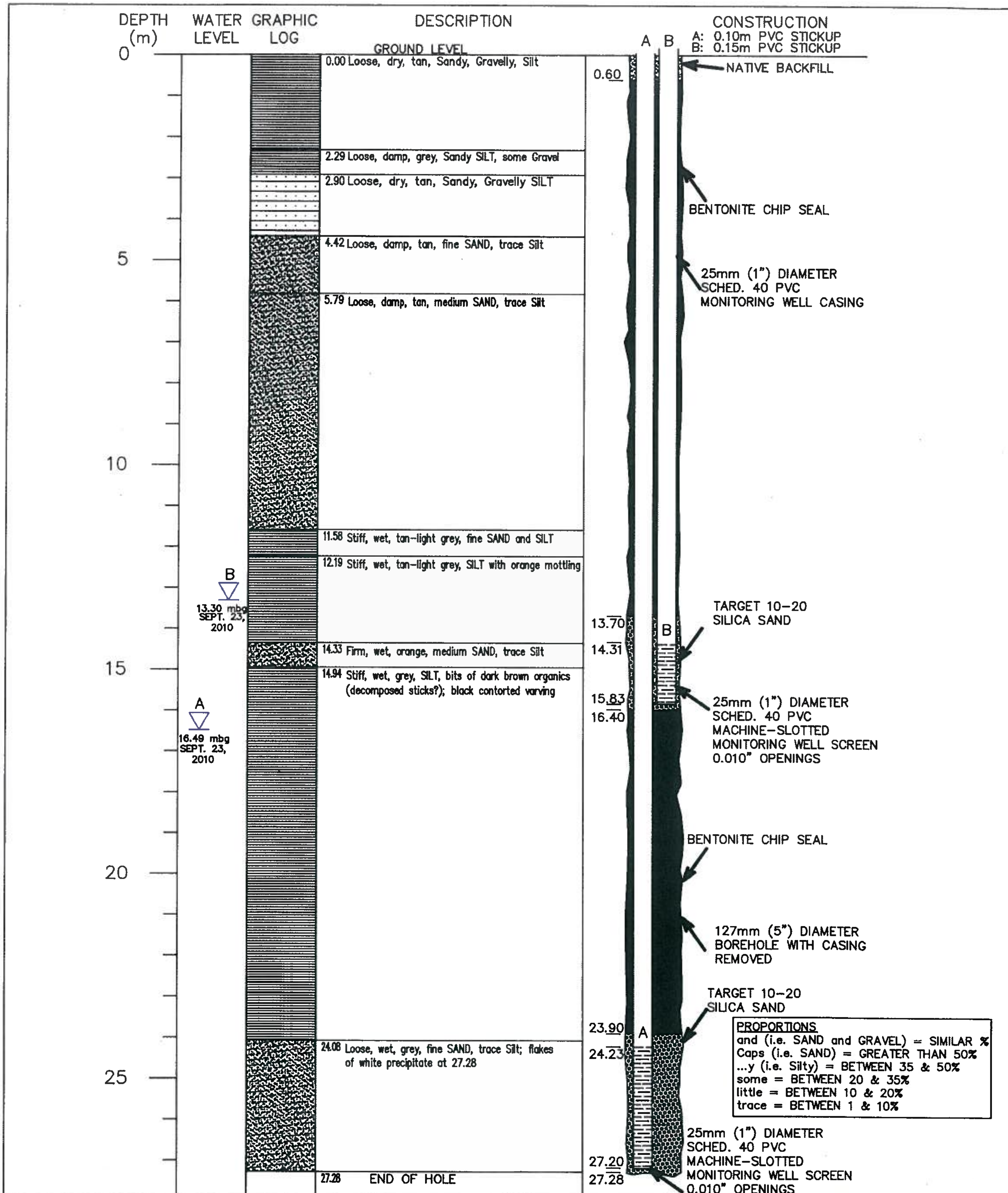
9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE

The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT

Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

# Appendix 2




**MW D-1**

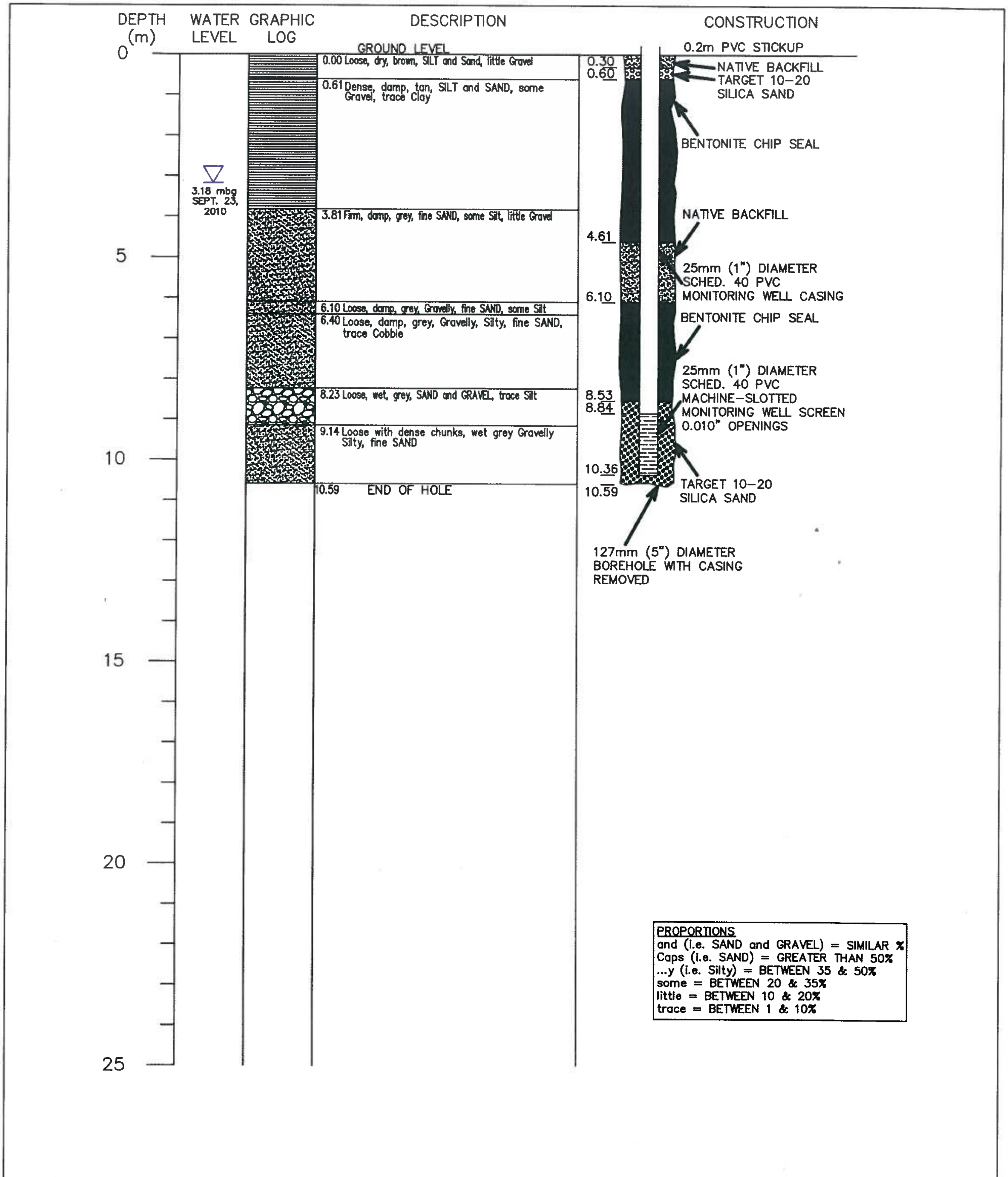
DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 20-SEP-2010
COMPLETION DATE: 20-SEP-2010

SIMPSON GEOTECHNICAL, LTD.

MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C.

MONITORING WELL LOG AND CONSTRUCTION DETAILS MW D-1

DRAWN BY: AB
DATE: SEP 2010
SCALE: 1:125




**MW D-2**

DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 1-SEP-2010
COMPLETION DATE: 1-SEP-2010

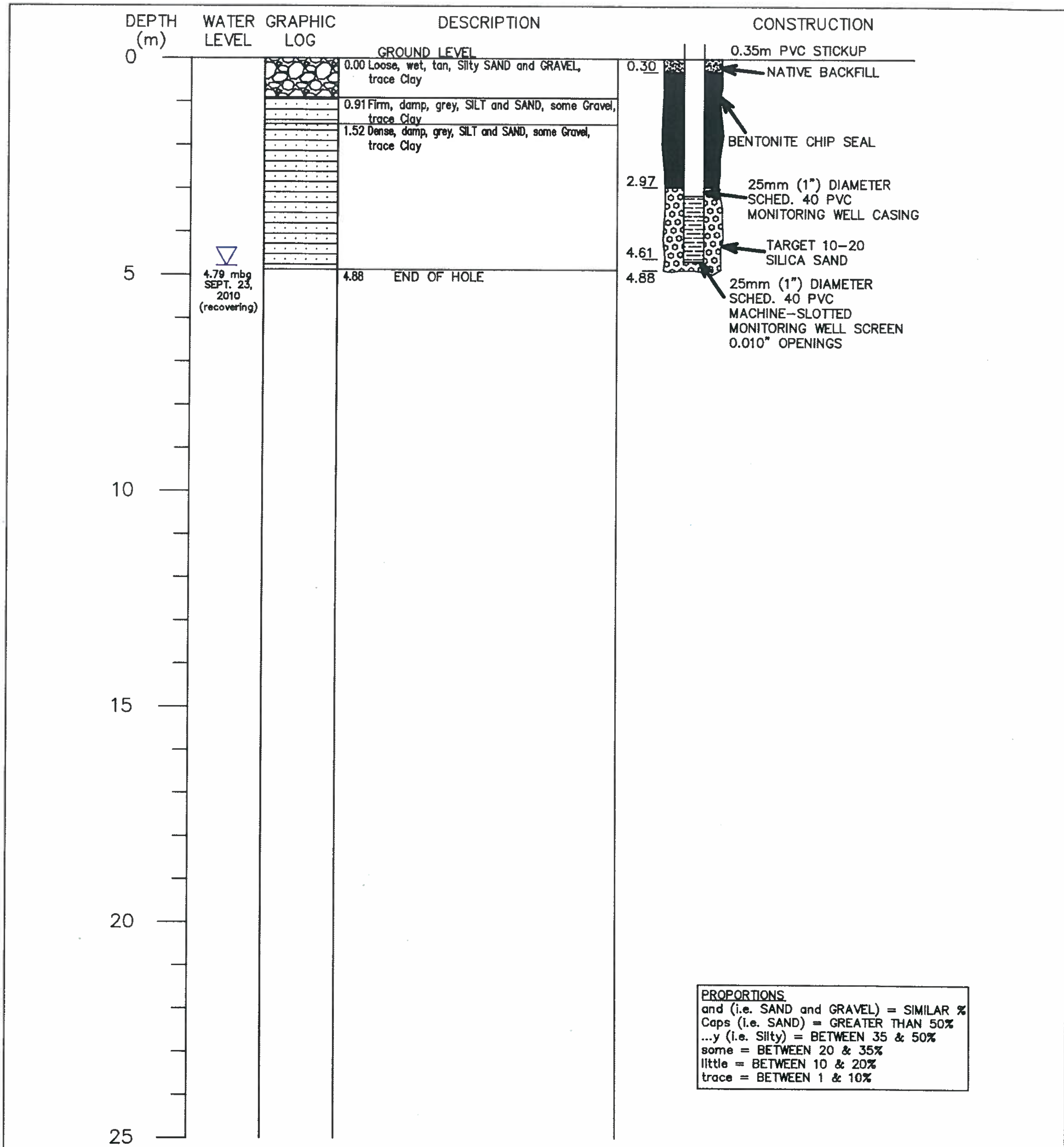
SIMPSON GEOTECHNICAL, LTD.

GW Solutions

DRAWN BY: AB
DATE: SEP 2010
SCALE: 1:125

MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C.

MONITORING WELL LOG AND CONSTRUCTION DETAILS MW D-2




**MW S-1**

DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 22-SEP-2010
COMPLETION DATE: 22-SEP-2010

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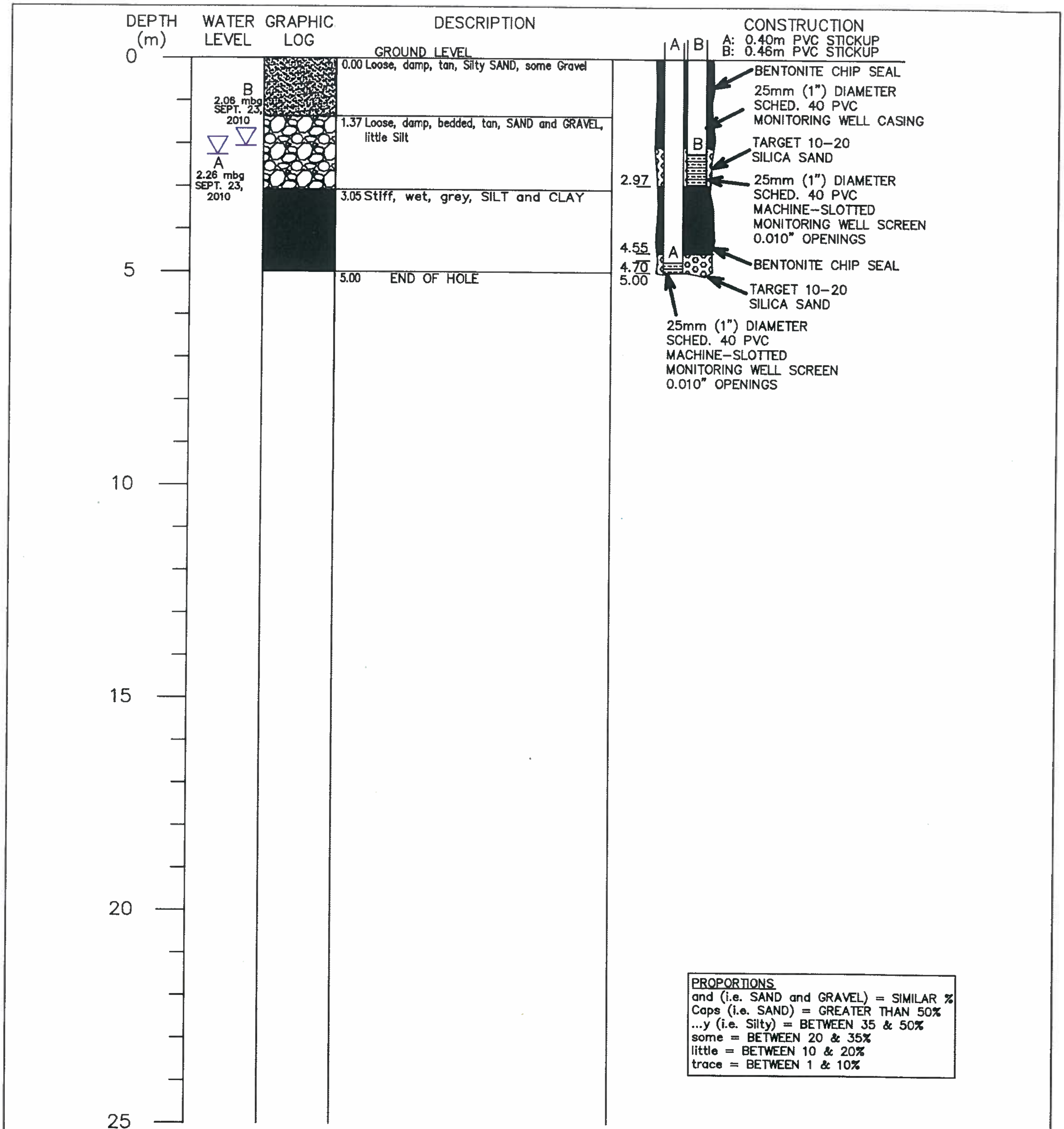
|---|---|---|
| SIMPSON GEOTECHNICAL, LTD. | GW Solutions | DRAWN BY AB<br>DATE SEP 2010 |
| MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C. | MONITORING WELL LOG AND CONSTRUCTION DETAILS MW S-1 | SCALE 1:125 |




**MW S-2**

DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 22–SEP–2010
COMPLETION DATE: 22–SEP–2010

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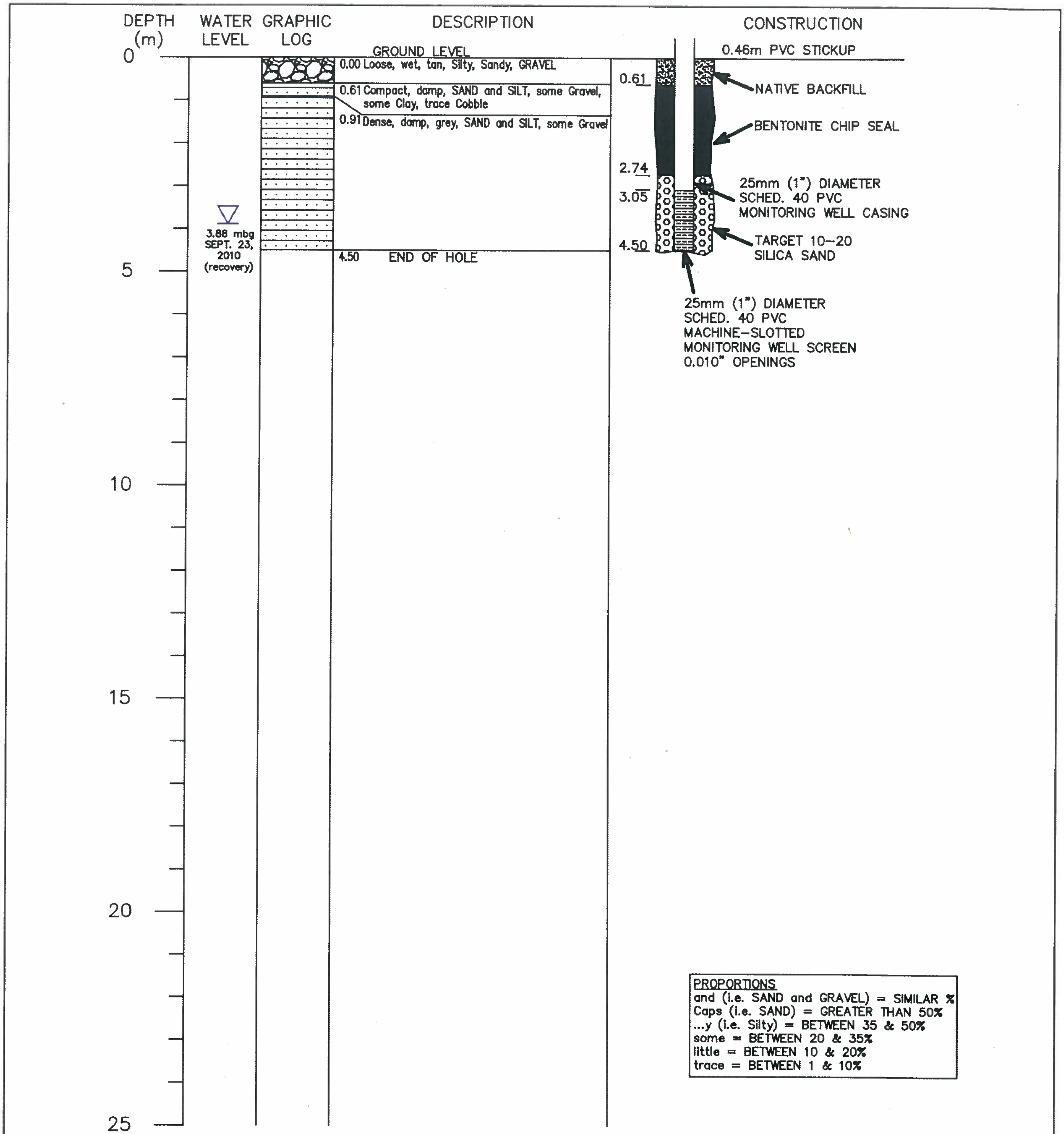
|---|---|---|---|
| SIMPSON GEOTECHNICAL, LTD. | GW Solutions | DRAWN BY AB | |
| MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C. | MONITORING WELL LOG AND CONSTRUCTION DETAILS MW S-2 | DATE SEP 2010 | SCALE 1:125 |




**MW S-3**

DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 22–SEP–2010
COMPLETION DATE: 22–SEP–2010

**SIMPSON GEOTECHNICAL, LTD.**

**MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C.**

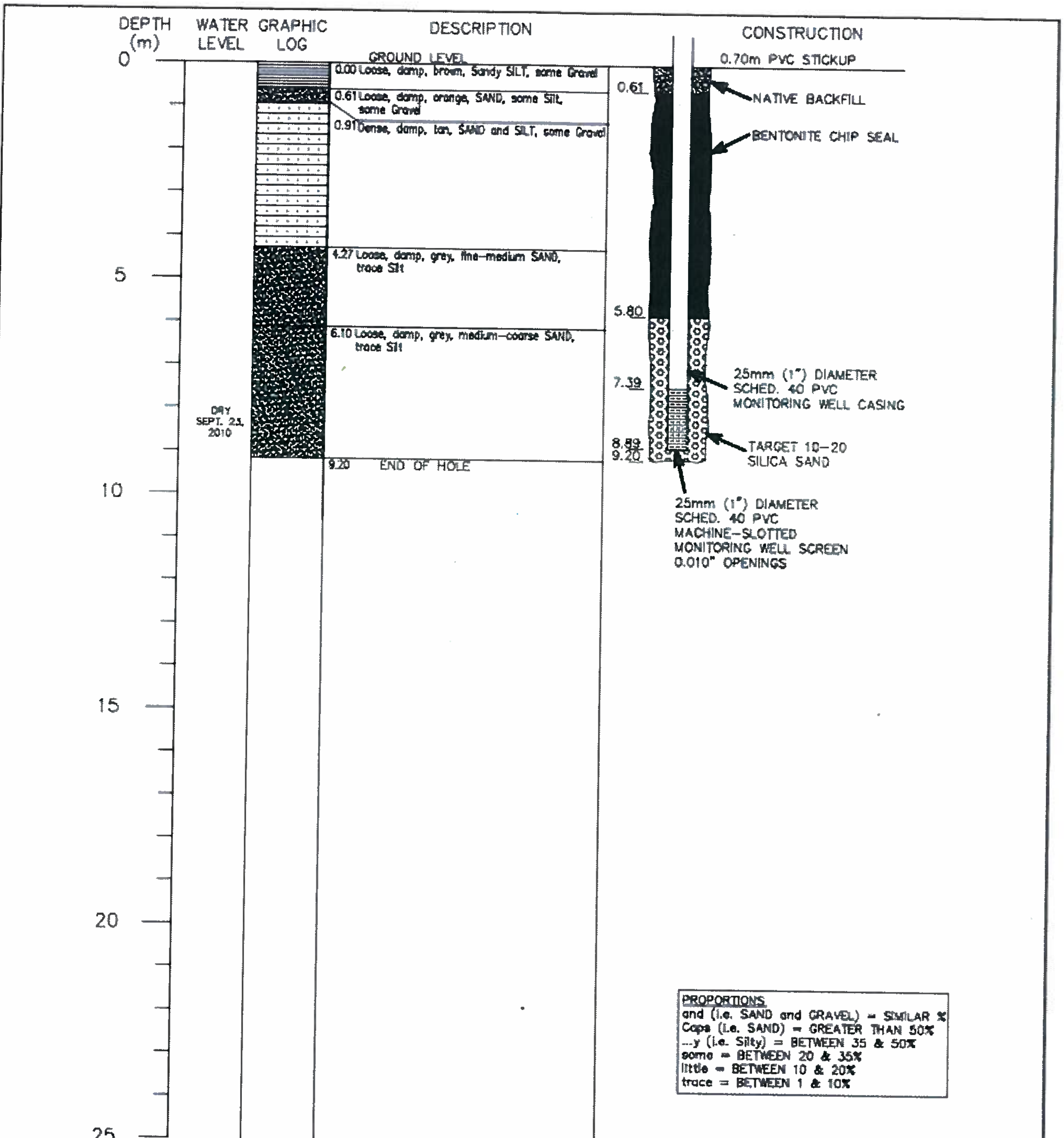
GW Solutions

**MONITORING WELL LOG AND CONSTRUCTION DETAILS MW S-3**

DRAWN BY: AB

DATE: SEP 2010

SCALE: 1:125




**MW S-4**

DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 22-SEP-2010
COMPLETION DATE: 22-SEP-2010

**SIMPSON GEOTECHNICAL, LTD.**

**MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C.**

GW Solutions

**MONITORING WELL LOG AND CONSTRUCTION DETAILS MW S-4**

DRAWN BY: AB
DATE: SEP 2010
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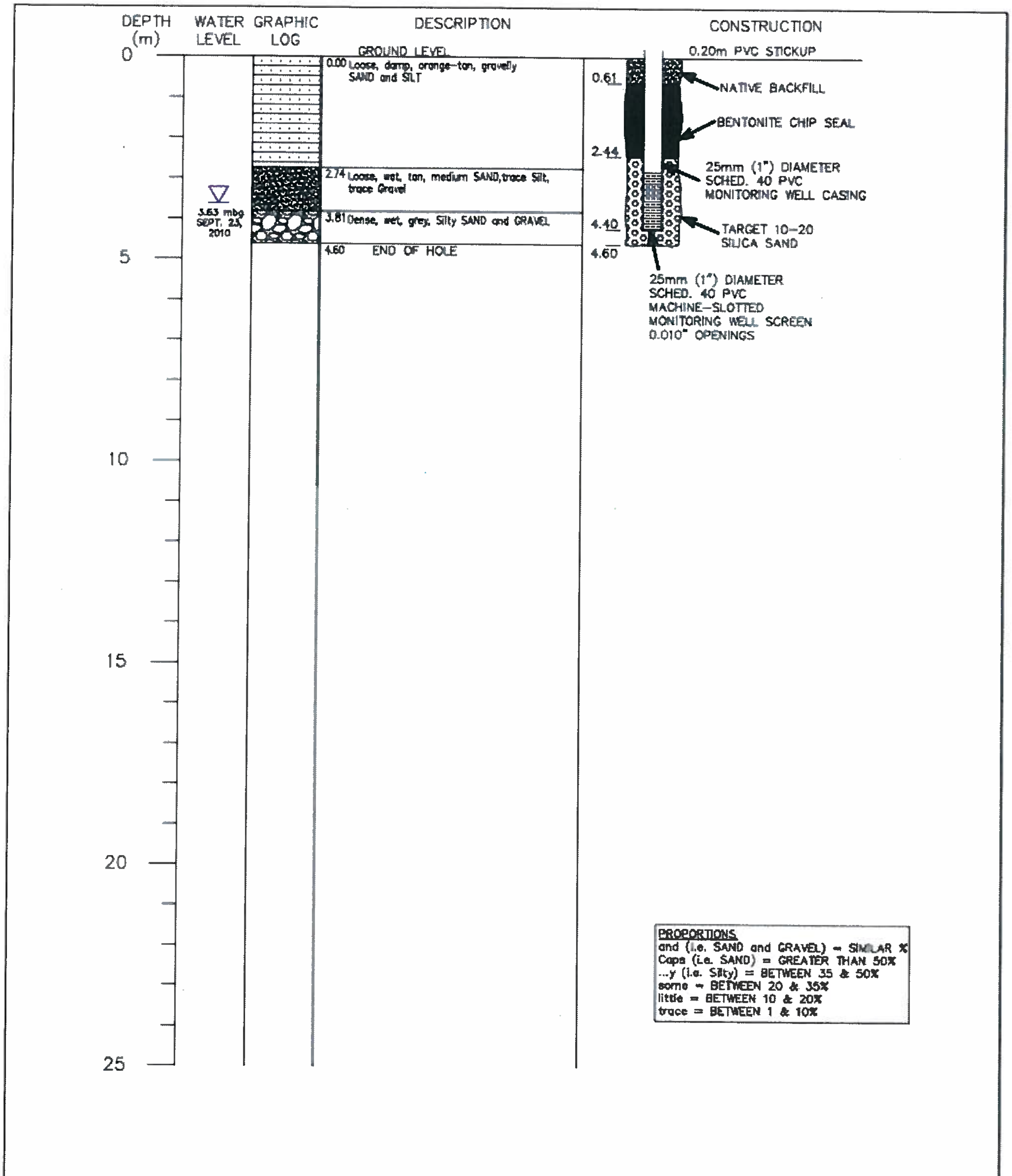



**MW S-5**

DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 20–SEP–2010
COMPLETION DATE: 20–SEP–2010

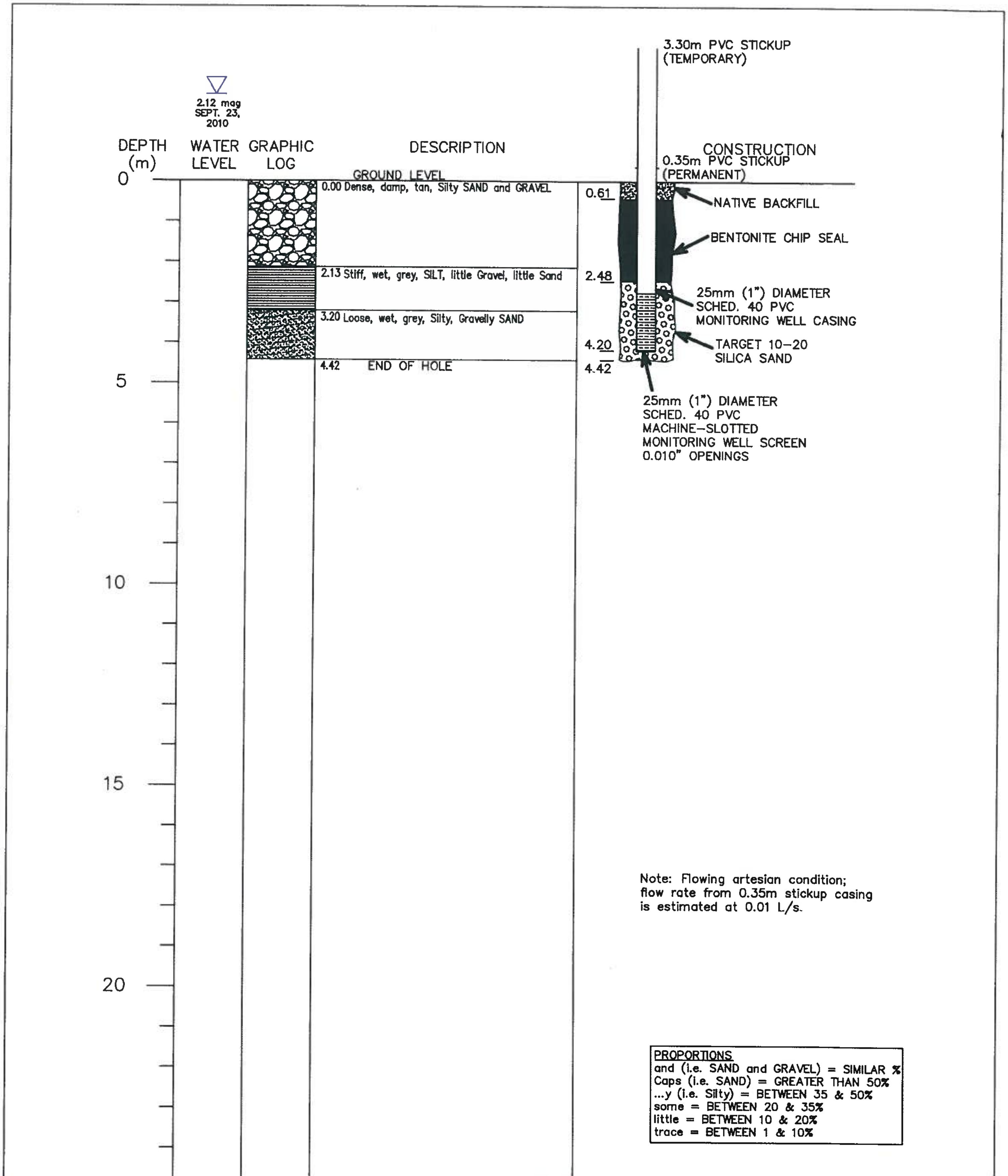
**SIMPSON GEOTECHNICAL, LTD.**

**MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C.**

GW Solutions

**MONITORING WELL LOG AND CONSTRUCTION DETAILS MW S-5**

**DRAWN BY** AB
**DATE** SEP 2010
**SCALE** 1:125




**MW S-6**

DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 20–SEP–2010
COMPLETION DATE: 20–SEP–2010

**SIMPSON GEOTECHNICAL, LTD.**

GW Solutions

**MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C.**

**MONITORING WELL LOG AND CONSTRUCTION DETAILS MW S-6**

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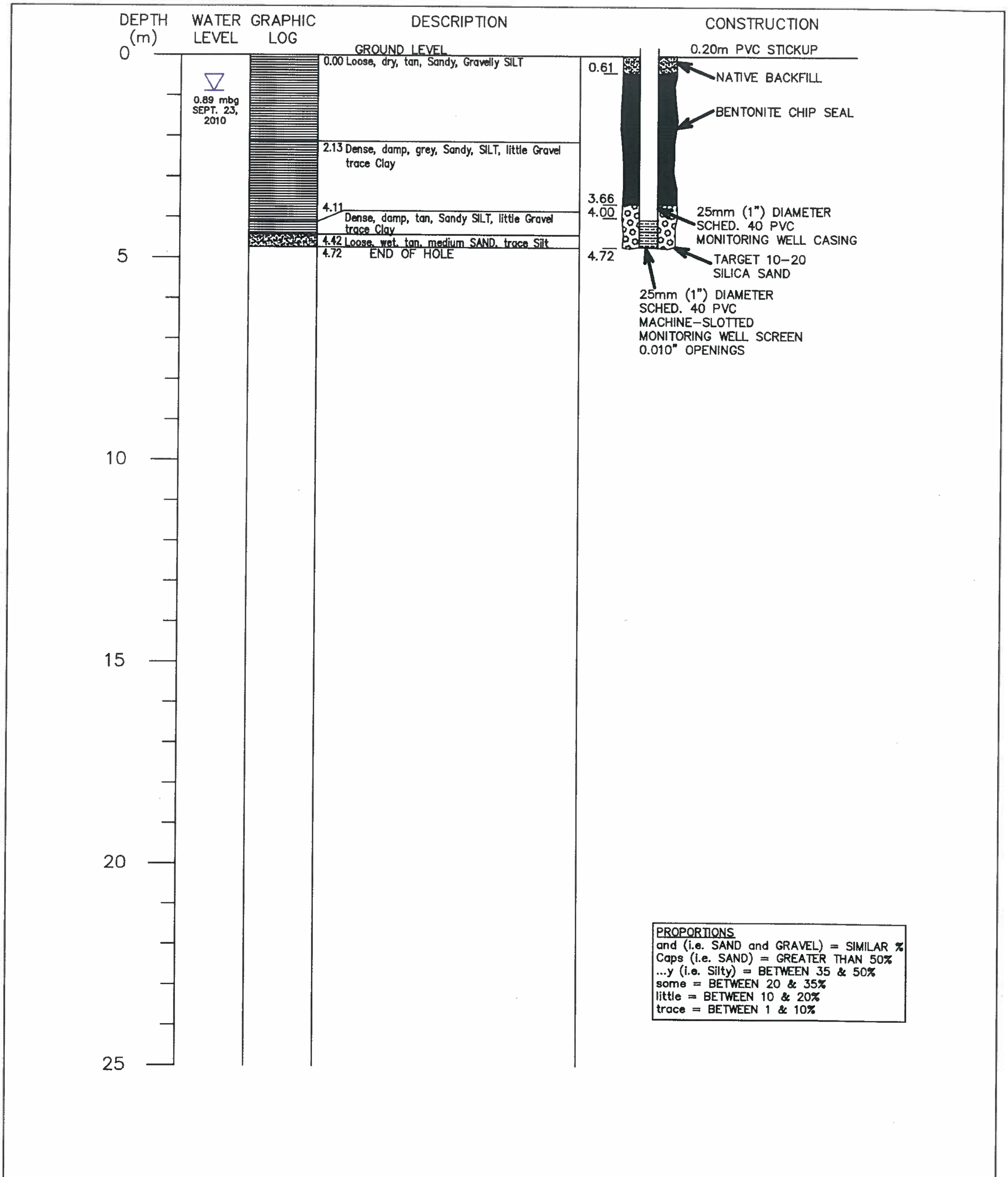
| DRAWN BY | AB |
| DATE | SEP 2010 |
| SCALE | 1:125 |




**MW S-7**

DRILL CONTRACTOR: MUD BAY DRILLING CO. LTD.
RIG: BOART LONGYEAR DB320 MINI SONIC DRILL
DRILLER: IAN TAYLOR
LOGGED BY: ARND BURGERT
START DATE: 20–SEP–2010
COMPLETION DATE: 20–SEP–2010

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| SIMPSON GEOTECHNICAL, LTD. | GW Solutions | DRAWN BY: AB<br>DATE: SEP 2010 |
| MONITORING WELL CONSTRUCTION, PRITCHARD ROAD LAZO, B.C. | MONITORING WELL LOG AND CONSTRUCTION DETAILS MW S-7 | SCALE: 1:125 |

# APPENDIX 3

# PHOTOS

Photo 1: Boart Longyear Mini-Sonic drill drilling a borehole at the Site


Photo 2: Clean sand of the Quadra Sands formation encountered in borehole S4 was deposited by glacio-fluvial meltwater. These sediments represent a great opportunity for infiltration of rain water.


Photo 3: Measuring the water level in S6, in the northeast portion of the Site. Artesian conditions exist, with a water level 2.1 m above ground measured on September 23, 2010.


Photo 4: Year-round standing water in the lower (eastern) portion of the Site. Groundwater seeping to surface causes wet conditions.

# Appendix D

## Comment Sheets

## COMMENT SHEET

## NE COMOX INTEGRATED STORMWATER MANAGEMENT PLAN
## NEIGHBOURHOOD MEETING

**Name & Address** Tammi Whelan.

1416 Cambridge Rd. Comox BC

Comments Welcome:

Will the available data on global warming be utilized in developing the mitigation plan? I would like to see this included.

Thanks!

Comments can also be submitted by email to:

neciswmp@mcelhanney.com

McElhanney

TOWN OF COMOX

June 7, 2012

## COMMENT SHEET

## NE COMOX INTEGRATED STORMWATER MANAGEMENT PLAN
## NEIGHBOURHOOD MEETING

**Name & Address**

CRIG M. WILLIAMS

1271 KNIGHT Rd COMOX V9M3T2

Comments Welcome:

The plan proposed 7 June 2012 will definitely impact the ALR. LAND OFF PRITCHARD & KNIGHT Rd.

WATER SHOULD BE DEALT WITH AS DECIDED IN THE 70's / 80's. USE THE GRAVEL PIT OWNED BY THE CROWN AS A RETENTION POND & THE EXCESS PUMPED OVER THE HILL & DOWN INTO COMOX HARBOUR.

GO & VISIT THE ACESS CENTRE - JILL HATFIELD DISTRICT AGRICULTURIST.

Comments can also be submitted by email to:

neciswmp@mcelhanney.com

McElhanney

TOWN OF COMOX

June 7, 2012

# Appendix E

K'omoks First Nation letter
dated August 22, 2012

K'ómoks First Nation
3320 Comox Road, Courtenay BC V9N 3P8 Tel: (250) 339-4545 Fax: (250) 339-7053

August 22, 2012

Mr. Bob Hudson, P Eng
McElhanney Consulting Services
495 Sixth Street
Courtenay, BC V9N 6V4

Dear Mr. Hudson,

**Re: North East Comox Integrated Stormwater Management Plan**

Thank you for your recent referral of the above noted document, initiated by the Town of Comox and members of the land development community.

We anticipate that there will be direct and profound concerns for K'ómoks First Nations resulting from this Plan. K'ómoks First Nation is already negatively impacted by stormwater flows that originate away from K'ómoks First Nation lands and additional development could have similar negative consequences for both lands currently under our jurisdiction and on parcels that may be transferred to our government as part of the Treaty Settlement Process that is currently underway.

We request a meeting with the Town of Comox and key representatives as soon as possible to enable a full explanation of the consequences specifically for K'ómoks First Nation. In the interim, we would request that the Town of Comox amend the draft to include specific text in this document on the cultural and historic value of lands within our Traditional Territory. Every area, parcel, or right of way, even those that have been heavily compromised by development, may have critical values. Therefore, an adequate assessment of these values must be part of each and every proposal that impacts the lands. We request that the Town of Comox specifically address this issue in the stormwater management plan and look forward to discussing this with you at the upcoming meeting.

Our membership has recently signed the Agreement in Principle with federal and provincial agencies, and as such K'ómoks First Nation has moved to a higher level and spectrum of consultation and accommodation with regards to matters relating to lands and waters in our Traditional Territory. We retain the right to continue with activities that are critical to the social/cultural heritage and economic livelihood of K'ómoks First Nation. Our interests cannot be in any way hampered or limited by any development approvals under consideration by the Town or its agents.

The Supreme Court of Canada made it clear that both the provincial and federal governments owe a fiduciary duty of utmost good faith to consult with the First Nations with respect to our lands and resources. This consultation must at minimum be in good faith with the intention of substantially addressing the concerns of the First Nation whose lands are at issue. The courts have also confirmed that government is obliged to make an initial assessment of our rights and must not only engage in meaningful consultation but also must seek an accommodation of our interests which include cultural and economic ones.

Again, thank you for this referral, and we look forward to our upcoming meeting.

Sincerely,

Ernie Hardy
Chief