MVIHES
MID VANCOUVER ISLAND HABITAT ENHANCEMENT SOCIETY

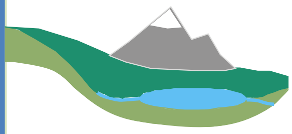
Shelly Creek Water Balance
and
Sediment Reduction Plan

Phase 1 – Physical and Environmental Investigations

Mid Vancouver Island Habitat Enhancement Society

Presented to:

Mid Vancouver Island Habitat Enhancement Society
P.O. Box 935,
Parksville BC V9P 2G9



June 23, 2017

J.M.K. (Jim) Dumont, P.Eng. P.Ag. | 201 Scott Point Drive, Salt Spring Island, BC V8K 2R1, Canada | Tel 250 221 1470 | jimdumont@shaw.ca

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

LIST OF TABLES

APPENDICES

Appendix A Land Use Zoning

Acknowledgements

The Shelly Creek Water Balance and Sediment Reduction Plan has been completed with the assistance of the following funders:

This report is dedicated to Faye Smith, who was the backbone of stream stewardship in the Oceanside area for the past 30 years. She will be greatly missed.

1. INTRODUCTION

Mr. Jim Dumont has been retained by the Mid Vancouver Island Habitat Enhancement Society (MVIHES) to assist in the assessment of the Shelly Creek watershed. The objectives of the project were:

1) to determine the causes of stream channel erosion in the Shelly Creek watershed, and
2) to determine the water balance for Shelly Creek, and provide a rainwater strategy to restore stream health.

The study is presented in four separate volumes that consist of:

1. **Summary**: is a very brief description of the issues and mitigation strategies;
2. **Technical Summary**; is a document that contains a brief description of the background information and mitigation strategies;
3. **Phase 1**; The detailed collection of information describing the Shelly Creek watershed and the human impacts that have occurred; and
4. **Phase 2**: The detailed description of the stream, the analysis undertaken, and the development of the recommended mitigation strategies.

1.1 Study Area

The Shelly Creek Watershed lies within the Regional District of Nanaimo (RDN) and the City of Parksville as illustrated on **Figure 1-1**. The focus of the Phase 1 component of the study is to examine the physical characteristics of the watershed and the processes of change in causing the observed adverse impacts. The final portion of the study will examine the stream and develop a number of mitigation strategies to mitigate human induced impacts.

This study has addressed two question that included:

1. What is causing the stream channel to fill with sediment?
2. How can we restore the stream's health?

1.2 Scope of Work

Reported within this document is an analysis of the biophysical conditions of the Shelly Creek Watershed. The Phase 1 report includes the following specific tasks:

1. Review background information including climate, streamflow, surface soils, surficial geology, surficial hydrogeology, land use planning, OCP, biological information, historical air photos.

   This task has collected available physical data and information about the watershed describing the existing conditions plus the historical conditions and provide a comparison that may lead to an indication of the alterations of the watershed that have affected the stream. This will provide insight into the processes and possible mitigation strategies.

▬ Shelly Creek Watershed

Shelly Creek Watershed
Figure 1-1

Collection and compilation of biological information has been completed to document the changes in the productivity of the stream and identify deficiencies in aquatic habitat that may be limiting the fishery resource.

2. Undertake a field reconnaissance to determine physical dimensions of the stream at selected locations and of the mineral soil components of the bed and bank of the stream.

   This task provides a specific physical description of the stream channel and its condition relating to stability, the potential for water induced erosion, and hydraulic capacity.

3. Develop a description of the natural Water Balance using recorded climate and stream flow data,

   This task utilized an analysis of the available data and a regional analysis to assist in describing the conditions in the stream. The regional analysis is needed because actual flow records and not available and information is required to proceed to Phase 2.

The Phase 2 report will build upon this information by examining Shelly Creek and will complete the following tasks:

4. Prepare and calibrate models for watersheds using the Water Balance Methodology,

   This model building would allow the creation of a watershed model that would replicate the flood discharges and flow durations to provide input into an assessment of available stream habitat.

5. Undertake analysis and develop mitigation strategies for watersheds based upon land use zoning and typical development patterns. The mitigation strategies would fall into two categories:
   a. Physical stream modifications, and
   b. Standards for future development within the watershed.

   This task would assess methodologies and mitigation techniques required to restore the watershed function and stream stability.

6. Provide an overview of the development design and approval processes that identifies the roles and responsibilities of the regulators. Provide comment on the standards and guidelines to provide a description of the processes and how they could be used to implement the mitigation strategies developed as part of this study.

7. A focussed field trip to identify potential stream modification strategies and projects.

1.3 Background Documents

Background information was derived from a number of diverse sources that included:

- RDN Mapping;

- RDN and Parksville bylaws and Official Community Plans (OCP's);
- Stormwater Guidebook for British Columbia, 2002;
- Beyond the Guidebook 2007;
- Stormwater Source Control Design Guidelines, 2012, MetroVancouver;
- Options for a Region-Wide Baseline for On-Site Rainwater Management, 2015, MetroVancouver
- Fergus Creek ISMP, 2004, McElhanney Consulting Services Ltd.;
- Primer on Water Balance Methodology for Protecting Watershed Health, 2014, Partnership for Water Sustainability in BC;
- Western Washington Hydrologic Model (WWHM) , 2001, Washington Department of Ecology;
- Western Washington Hydrologic Model (WWHM) , 2012, Washington Department of Ecology;
- National Pollutant Discharge Elimination System (NPDES), General Permit For Waste Discharge Requirements (WDRs) for Storm Water Discharges From Small Municipal Separate Storm Sewer Systems (MS4s), Order No. 2013-0001-DWQ, NPDES NO. CAS000004, 2015, California State Water Resources Board;
- Watershed Determinants in Ecosystem Functioning", Horner, et, al, 1996;
- Experience from Morphological Research on Canadian Streams MacRae, ASCE, 1997;
- Vulnerability of Natural Watercourses to Erosion Due to Different Flow Rates", Lorent, Ministry of Natural Resources of Ontario, 1982;
- HYDAT Database, National Water Data Archive, Environment Canada;
- Climate Normals 1981 – 2010, Environment Canada;
- Intensity Duration Frequency (IDF), 2014, Environment Canada;
- Climate Data Archive, environment Canada;
- Geological Survey of Canada Open File 7796; 2015;
- Water Budget Project: RDN Phase One (Vancouver Island), Waterline Resources Inc. June 17, 2013;
- Low-Impact Development Hydrologic Analysis, Prince George's County, Maryland July 1999; and
- Soils of Southern Vancouver Island, MOE Technical Report 17, J.R. Jungen, P.Ag., B.C. Ministry of Environment, August 1985.
- The Canadian System of Soil Classification, Research Branch Agriculture and Agri-Food Canada, Publication 1646, Third Edition 1998
- City of Parksville Storm Drainage Master Plan – Final Report, Koers & Associates Engineering Ltd. March 11. 2016.

As additional information becomes available the Watershed Plan can be updated. There should be no immediate need to add a level of detail to the Plan until specific needs are identified by projects that can obtain the necessary physical data which can then be included in the existing analysis methodology and models. We anticipate little additional cost in data acquisition from future development or municipal infrastructure design and only modest cost to update the watershed analysis as data becomes available.

1.4 Advances in Rainwater Management

The science of rainwater management is advancing and sharing of information is key in successfully implementing a strategy that will not be quickly outdated. The information presented below includes a summary of several the documents during which it became apparent that there were differences in assumptions and approaches that changed over time as a result of the advance of scientific knowledge and the need to change standards has become apparent. The advancement of our knowledge base should be seen to be an ongoing process which can be combined with a description of how the standards within each of the document have been established. The timeline of milestones in our understanding of watershed processes is discussed below with linkages to the above noted guidance documents.

In **2002** the Province published the **Stormwater Planning a Guidebook for British Columbia** in which the principles retain, detain, and convey were introduced. This is that rainwater was to be retained on site, any that couldn't would be detained to provide flood protection and very large storms a safe conveyance system was required. The details of the concept for retention included the volume of rainfall representing one half (½) of a Mean Annual Storm (MAS) with infiltration of this volume over a period of twenty-four (24) hours. The basis for these recommendations was a qualitative assessment linking stream health to the volume of runoff as a proportion of total precipitation. No quantitative analyses of streams or watersheds were undertaken to support the assumption linking retention volumes and stream health.

In **2012** MetroVancouver published the **Stormwater Source Control Design Guidelines** which built upon the assumptions of the Guidebook. The Guideline recommended increasing the retention volume to 0.72 MAS up from the ½ MAS of the Guidebook however no quantitative analyses of stream discharge or conditions were provided. Included within the Guideline document were a series of charts (beginning with Figure B-4 within that document) that indicate where subsurface conditions include soils with infiltration rates less than 5 millimetres per hour (mm/hr) there may be difficulty in achieving the disposal requirements and that a baseflow discharge with a rate of 0.25 L/s/ha would be required to drain the constructed infiltration systems within the required 24 hour period. This was due to the lack of infiltration capacity that would require an infiltration area larger than the project site as water does not infiltrate that quickly in these soils. With hindsight it is obvious that the infiltration capacity is a function of the watershed and that physical constraints must be balanced with requirement to retain rainwater on site. An extension of that observation is that the rainwater management targets should be based upon the conditions within the watershed and not directly tied to a prescriptive approach to retaining a fixed quantity of precipitation.

In **2015** MetroVancouver published the **Options for a Region-Wide Baseline for On-Site Rainwater Management** which was intended to provide guidance for areas that were not included in the Integrated Stormwater Management Plans (ISMP's) within the region. This Baseline document expanded upon the work completed in the Guideline and through analysis of rainwater retention revised the requirement to 0.5 MAS and increased the retention volume drain time to 48 hours. The baseflow release was formalized for all areas and set at a rate of 0.25 L/s/ha. Again no quantitative analyses of streams or watersheds were undertaken to support the assumption linking retention volumes and stream health.

In a separate process the **City of Surrey** undertook the **Fergus Creek ISMP** and in **2004** the analytic methods of assessing the watershed using stream flow duration to provide a measure of stream erosion, habitat degradation, and sediment transport was initiated. This was an extension of the designs of the initial phases of development in the **East Clayton Neighbourhood** in **2001** where it was found that the retention of a prescriptive quantity of rainfall would not provide a benefit to the receiving stream. The Fergus Creek ISMP provided a quantitative link between retention volumes, stream habitat, erosion potential, water quality, and flood prevention which resulted in establishing the size and operating parameters for stormwater retention systems within the watershed. The leap in understanding the analyses needed to define the hydrologic functions of a watershed ultimately led to the **Water Balance Methodology**.

The Water Balance Methodology was showcased in **2014** in the Partnership for Water Sustainability in BC publication **Primer on Water Balance Methodology for Protecting Watershed Health** provided details on the analytical methods which were established to demonstrate the impacts of urban development upon a stream and to demonstrate the effectiveness of alternative mitigation methods. The Methodology includes a stream flow duration which directly links to aquatic habitat, potential stream erosion and sediment transport. Key components of the Water Balance Methodology include precipitation, infiltration, interflow and aquifer flows combined with the duration of flow in a stream to manage aquatic habitat, stream erosion, reduction of flood risks and improvement of water quality. The calibrated continuous models can assess the imposition of urban development and establish the size of mitigation methods to provide the most cost effective tools to manage stream and watershed health. The results of applying the Water Balance Methodology has led us to conclude that the impacts to a stream increase with imperviousness in a watershed and that the sizing of mitigation works should also increase with imperviousness. We agree that development greatly impairs the function of the subsurface interflow system and that directing extra water to the aquifers can lead to unintended consequences. This has led to establishing a set of three watershed targets that will allow streamflow to be maintained while not increasing flood risks. These watershed targets include a **volume** to be retained and detained, a **baseflow** release rate to augment streamflow without increasing flood risks, and an **area** of infiltration so as to maintain the natural rate of aquifer recharge.

In an interesting parallel process the **Washington Department of Ecology** introduced the Western Washington Hydrologic Model (WWHM) in **2001**. This model was applicable to the detailed analysis of watersheds and streams using the development and watershed flow duration as a measure in defining the works necessary to mitigate the impacts of urban development. In **2012** the Western Washington Stormwater Manual was released which mandates the use of the WWHM for new developments as a requirement of meeting the commitments under the National Pollutant Discharge Elimination System (NPDES) permitting process. The specific requirement is stated as "*Stormwater discharges shall match developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 8% of the 2-year peak flow to 50% of the 2-year peak flow*." In Washington the developer and their engineer use the WWHM to establish the required mitigation works and how they would be utilized within the development.

The **California State Water Resources Board** has initiated in **2015**, a program to halt stream degradation. They have made the following statement "*Changes in flow and sediment loads to streams and other watercourses can result in significant and long-standing impacts to beneficial uses of our waters. These changes are collectively referred to as "hydromodification." The Water Boards have teamed with some of the nation's top scientists to devise ground breaking ways to effectively and efficiently measure and control the impacts associated with hydromodification.*" To mitigate the effects of hydromodification they now mandate a flow duration analysis and require developments to meet stringent standards to demonstrate no adverse changes occur as a result of development. The state has created a computer model that will be applied by developers and their engineers to design the required mitigation works and how they would be utilized within the development. The use of flow duration is fundamental to the analyses and in measuring the success of the proposed on-site mitigation works within each development.

A product of the Partnership for Water Sustainability in BC has been the **Water Balance Model** which incorporates the principles of the Water Balance Methodology. Comments from users of this planning tool has resulted in creation of the Water Balance Express for Homeowners. This simplified tool relies upon established watershed planning to seed the **WBMExpress** with watershed targets that are applied on a lot by lot basis as part of the building permit and construction process. This study will result in the development of the watershed target values that can be used within a version of the WBMExpress for the Shelly Creek, or for the larger RDN.

2. BACKGROUND INFORMATION

A minimum amount of information is required to undertake the watershed assessment and to formulate a mitigation plan. A summary of the scientific and recorded information is provided herein.

2.1 Rainwater Management

The multiple risks resulting from development include:

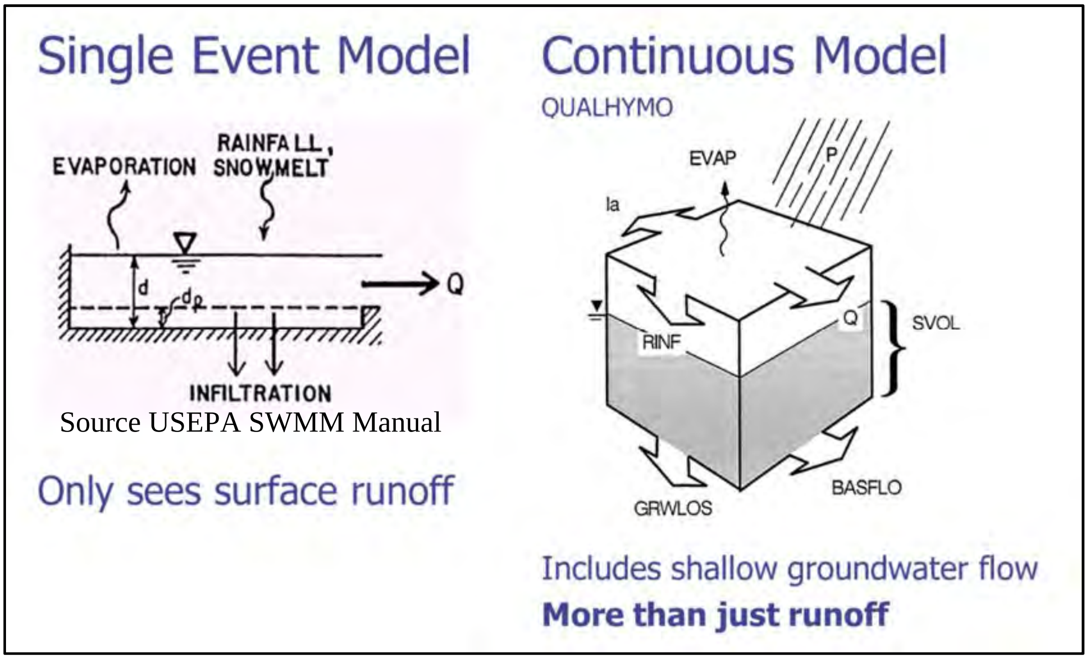
1. **Increased flood risks** in downstream reaches;
2. **Aquatic habitat damage** and the loss of fisheries resources.
3. **Increased erosion** and property damage; and
4. **Costs** associated with flood damage and repairs to eroded streams.

Rainwater management in a mixed rural and urban area must include the goal of mitigating adverse impacts which would result from drainage improvements and urban development. Achieving this goal involves application of **standard engineering analysis and methodologies** combined with **typical design techniques** in an **innovative manner**. Therefore all the assessments, analyses, and recommendations are a result of well documented standards of engineering practice.

The innovation is in the application of these methodologies in the field of municipal engineering where other practices have been widely adopted. The practice of municipal engineering and the specific applications in drainage design places a special emphasis upon on creating infrastructure with the sole purpose of reducing surface flooding and inconvenience during infrequent large storm events such as a 1 in 5 year return period event.

Many currently available hydrologic models have their roots in drainage design where the emphasis is with very large and infrequent rains. In contrast, rainwater management and stream health problems are mostly associated with common and relatively small rains such as would occur on an average daily basis with a return period of much less than a 1 in 1 year event. Hence the efforts must be placed in providing quantifiable analyses that demonstrate the impacts upon the stream and the effectiveness of any proposed mitigation works.

The assumptions and simplifications that are legitimately used with drainage design models are not appropriate for models assessing stream impacts and rainwater management systems. The simplification associated with drainage system modelling as compared to rainwater modelling for watersheds and urban impact mitigation can be seen in **Figure 2-1**. The graphic on the left was extracted from the United States Environmental Protection Agency Storm Water Management Model (US EPA SWMM) User Manual and provides a visual representation of the processes that are analyzed with standard calculations. As can be seen the primary information derived is the surface runoff resulting from precipitation by subtracting evaporation, surface storage and infiltration. The path the infiltration takes is not assessed, rather the rainwater infiltrated into the ground is considered to be merely a loss used to calculate the surface runoff. While SWMM is capable of continuous simulation the subsurface, or groundwater, routines need to be turned on to be included in the calculations.



Source USEPA SWMM Manual

Figure 2-1 Single Event versus Continuous Model

The calculation approach applied in the QUALity HYdrologic MOdel (QUALHYMO) computer model which was used in the analyses and assessments undertaken in this study are shown on the right in **Figure 2-1**. As can be seen the surface soils and Interflow System are an integral part of the analysis. Thus the results of this study are much more appropriate in assessing watershed hydrologic responses to climate and in assessing mitigation of urban impacts.

The assessment and analyses undertaken and documented in this report utilize standard scientific and engineering principles which are not typically used in standard engineering design of municipal infrastructure.

2.1.1 Increased Downstream Flooding

As rural land is undergoing development drainage works are created which direct any surface runoff more quickly to the receiving stream. Additionally there is an increase in impervious areas such as roads, buildings, driveways, sidewalks, etc., and in the number of directly connected methods of drainage, such as ditches, sewers and roadways which results in an increase in greater runoff. These factors combine to yield higher volumes of surface runoff volumes and flow rates as compared to predevelopment conditions.

In a conventional drainage system either the downstream system to receive the flow is enlarged, or new outlets for the stormwater runoff are constructed to accommodate development. While these detention ponds are not common in the City of Parksville or this part of the RDN they are very common in other jurisdictions. As an alternative, storage, in the form of stormwater detention facilities, are frequently utilized to control the stormwater runoff so that the peak flows discharging from the development do not exceed acceptable predevelopment flow rates in the downstream receiving drainage system for a given return period event.

If the post development discharge rates are not restricted then there is a real increase in the risk of flooding and its associated damages to properties in a downstream direction from the development. This increased risk is attributable to both property and life of people in the affected areas. It is critical that the predevelopment rates of discharge be maintained to prevent adverse impacts. The generally accepted flood protection is the 1 in 200 year return period event (Q_{200}) along natural flood plains or a Q_{100} in urban areas of British Columbia. However the standard design practice in municipal infrastructure design in British Columbia utilizes a somewhat different standard for drainage system design with a primary intent to prevent post development discharges from exceeding predevelopment rates over a wider range of return periods from a 2 to 100 year return period events (Q_2 to Q_{100}).

2.1.2 Aquatic Habitat Damage

"*Watershed Determinants in Ecosystem Functioning*", Horner, et, al, 1996 documented the impacts of development upon the aquatic environment with some very interesting findings. They reported that the impacts from development fell into four different categories with the effects from highest to lowest being:

1. Changes in hydrology
2. Disturbance to riparian corridor
3. Degradation of in-stream habitat
4. Deterioration of water quality

The importance of the total imperviousness of a watershed was identified as shown on **Figure 2-2** which indicates an impact with as little as 10% impervious area. The impact increased significantly beyond that value with an identified critical value of 30% being the upper limit to support a population of cold water fish species.

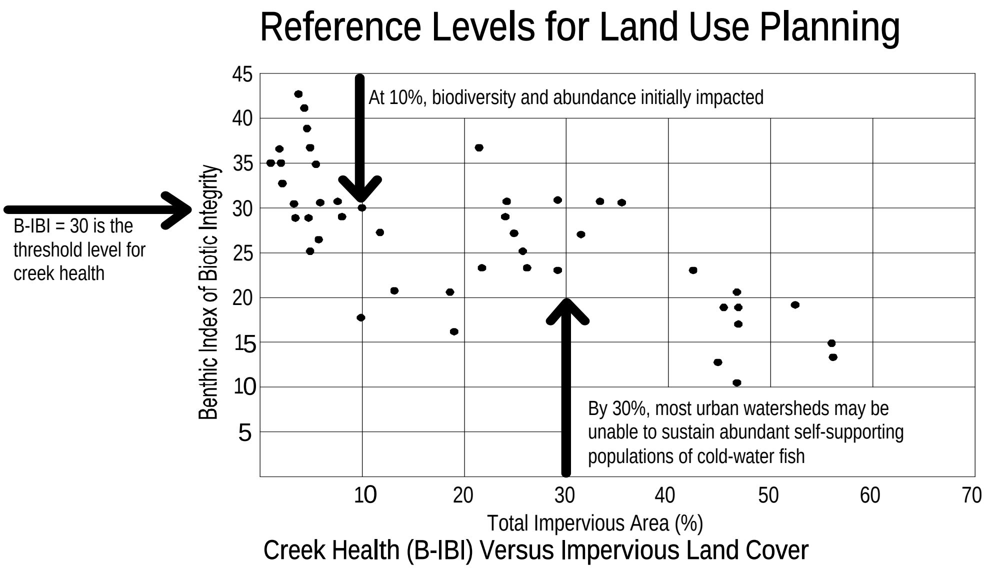


Figure 2-2 Stream Health versus Impervious Cover

The next findings that were presented included the impacts upon water quality that derive from urban development as shown on **Figure 2-3**. The acute and chronic toxicity levels of pollutants in the stream becomes a factor for cold water fish species only after an imperviousness of 60% is reached. Therefore water quality would only be an issue long after the other effects of development had eliminated the cold water fish species from the stream.

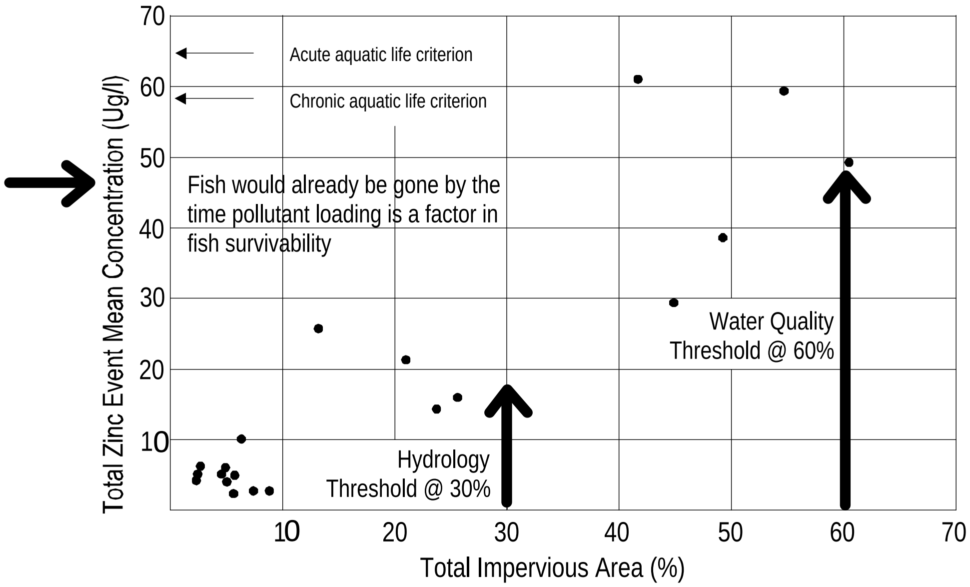


Figure 2-3 Water Quality versus Impervious Cover

The conclusion of this information is that the impacts of development must be mitigated in order to allow healthy populations of cold water fish species which include all species of salmonids.

2.1.3 Increased Erosion

The increased erosion in the streams is an impact of development that relates to the changes in hydrology which include greater rates and volumes of discharge in the stream. A traditional engineering approach to prevent increased stream erosion has been to limit post development discharge rates to those occurring from predevelopment conditions. That approach also generally assumes that a 2 or 5 year return period event (Q_2 or a Q_5) rate of discharge would not result in stream erosion. Both of these assumptions can be shown to be incorrect. Both the discharge rates and the flow durations when combined are the critical factors in stream erosion. Two excellent references include:

- "*Experience from Morphological Research on Canadian Streams*" MacRae, ASCE, 1997"
- "*Vulnerability of Natural Watercourses to Erosion Due to Different Flow Rates*", Lorent, Ministry of Natural Resources of Ontario, 1982

The erosion in streams has been found to be a related to the duration of discharge above critical threshold values rather than simply the discharge rate. Further the threshold discharges are less than commonly accepted a Q_2 or a Q_5 events. Therefore an increase in erosion can be avoided if both the duration and flow and the rates of discharge are maintained following urban development.

2.1.4 Increased Costs

Increased costs associated with stream erosion induced by urban development have long been documented. A very recent example can be found in the Town of Comox where Brooklyn Creek has experienced increased erosion due to urban development. The eroded material accumulated in the lower reaches of the stream with the result being a reduced stream capacity and increases in flood levels. An extensive and very expensive rehabilitation program has been undertaken to protect properties from eroding stream banks and increased flood damages. The costs of the stream rehabilitation were unexpected and costly.

2.2 Statistical Analysis

A statistical analysis of stream discharge and retention volumes is required for this assessment. The annual maximum discharge rates and retention volumes calculated during the period of simulation were further assessed using statistical methods to estimate the probability of occurrence and the volumes associated with various return periods.

One method used to estimate the frequency of discharge and the size stormwater retention facilities with small discharge rates is one of continuous simulation. This approach allows a probabilistic analysis of runoff in the study area. The probabilities attached to various events, or put another way, their return periods, are correctly determined so as to properly carry out any associated risk analysis. The probabilities are determined by frequency analyses of the simulation results, in exactly the same way as if there were recorded data available.

Statistical analysis of both watershed discharge and retention volumes is a part of the analysis completed as part of this study. This approach is complimentary to the continuous hydrologic and hydraulic simulation process as the calculations produce results that are suited to this type of analysis.

The standard method of determining the return period of frequency associated with any given discharge or retention volume begins with acquiring the annual maximum value for each series of events to be analyzed. From the continuous simulation record the greatest discharge and/or retention volume which occurs in every year is extracted from the results of the simulation.

The assumptions inherent in the statistical analysis are that the values represent a series of independent events. The values are ranked from highest to lowest and are plotted against probability. A curve is extended through the points of the plot to establish a relationship of magnitude with probability, or return period of the event.

The standard Weibull plotting position defines:

Probability = (1 / Return Period)
Return Period = (N+1)/R; where
N = Number of Events
R = Rank (largest event to smallest)

A specific distribution curve is then fitted to the plotted data. The Log Pearson Type III curve fitting methodology has been used in this analysis because it has been almost universally accepted as the standard for statistical analysis of stream flood discharge.

This methodology provides an analytically rigorous estimate of the size and operation of stormwater facilities.

2.3 Stream Flow Records

The first step in understanding the hydrologic operation of a watershed is to evaluate recorded stream flow data. Where recorded data is not available for a given watershed the standard of engineering practice is to use a Regional Analysis of Streams with flow records to establish a reasonable estimate of the values to be found for a given watershed. To select a potential list of stream for consideration a selection criteria has been established which includes the following:

- Located on southern Vancouver Island;

- Minimum of 10 years of continuous records which include annual maximum of both mean daily and peak daily discharges;
- Unregulated discharges; and
- Watersheds did not contain large lakes which could attenuate peak discharges.

A total of eighteen (18) streams were found which met these criteria and a comparison of their recorded stream flow records was undertaken to identify watersheds which are similar to Shelley Creek. The location of the watersheds for which a suitable duration of stream flow records with both daily and instantaneous discharge measurements and that had a recording period which overlapped the climate data were available are shown on **Figure 2-4**.

The watersheds shown on **Figure 2-4** are color coded to correspond the listing in shown in **Table 2.1**. The listing of the watersheds are listed in order of the magnitude of the flood discharge as measures in Liters per second per hectare of watershed area (L/s/ha) from smallest to largest. The information presented in the table can be visually correlated to the watershed locations shown on **Figure 2-4**.

Table 2.1 – Flood Discharges (L/s/ha)

Stream Gauging Station		Return Period Years								Area (km^2)
		200	100	50	25	10	5	3	2	
08HB032	Millstone River	9.5	8.8	8.0	7.2	6.0	5.0	4.2	3.4	86
08HD011	Oyster River	12.1	11.9	11.5	11.1	10.2	9.2	8.2	7.0	302
08HB075	Dove Creek	16.7	16.5	16.3	15.9	15.0	14.0	12.7	11.2	41
08HA016	Bings Creek	17.1	16.3	15.4	14.3	12.4	10.7	9.0	7.4	16
08HA003	Koksilah River	18.0	17.7	17.1	16.5	15.2	13.7	12.1	10.4	209
08HB089	Tsolum River	19.5	18.6	17.6	16.5	14.7	13.0	11.5	9.9	87
08HA001	Chemainus River	22.3	21.0	19.5	17.9	15.5	13.4	11.5	9.6	355
08HB074	Cruickshank River	22.4	22.0	21.5	20.8	19.2	17.4	15.3	13.0	213
08HA010	San Juan River	23.2	22.5	21.6	20.6	19.0	17.3	15.8	14.2	578
08HB002	Englishman River	23.3	22.0	20.5	18.8	16.3	13.9	11.8	9.8	319
08HB025	Browns River	41.1	36.7	32.5	28.5	23.2	19.2	16.1	13.4	88
08HB024	Tsable River	51.3	47.5	43.9	39.2	32.9	27.5	23.0	18.8	113
08HB014	Sarita River	63.7	57.5	51.4	45.5	37.8	31.9	27.3	23.3	162
08HA072	Cottonwood Creek	69.1	65.5	61.5	57.2	50.6	44.6	39.4	34.2	4
08HA068	Garbage Creek	82.4	69.0	60.1	54.5	51.0	50.5	50.2	48.4	3
08HB048	Carnation Creek	90.6	79.2	68.6	58.7	46.4	37.6	31.1	25.7	10
08HA070	Harris Creek	123.3	110.7	98.3	85.8	69.2	56.2	46.0	37.1	28
08HA069	Renfrew Creek	203.6	179.7	158.0	138.3	114.7	98.2	86.4	76.8	8

Vancouver Island Watersheds

Figure 2 - 4

The watersheds can be loosely divided into three groupings based upon the magnitude of the flood discharges. The smallest flood discharge rates correspond to the largest number of watersheds with a range of 100 year return period (Q_{100}) discharges of from approximately 10 to 50 L/s/ha. The second group has a Q_{100} discharge in the range of from 60 to 120 L/s/ha. One watershed has a much higher Q_{100} discharge of over 175 L/s/ha.

The variation of discharge is related to the location of the watershed those with a western exposure and/or higher elevations have a greater magnitude of flood discharge. The watersheds which would be most representative of the developed portions along the eastern shore of Vancouver Island would include Dove Creek near Courtenay, Millstone River near Nanaimo, Bings Creek near Duncan, and possibly the Oyster River neat Saratoga Beach. These watersheds have similar stream connectivity, aspect, and elevation. These watersheds have a Q_{200} of 9.5, 16.7, and 17.1 L/s/ha respectively. The Oyster River near Saratoga Beach has a similar Q_{200} of 12.1 L/s/ha.

The watersheds that would provide the best correlation to the watershed characteristics and hydrologic response of the Shelly Creek watershed would be Bings Creek located in the Cowichan Valley. The flood discharge values are comparable to the Oyster River and Dove Creek. Each of these streams have greater flood discharges than the Millstone River in Nanaimo where a lake attenuates the flood discharges.

At this time there are no other sources of reliable long term stream flow records. In future this lack of data can be overcome if a monitoring program is undertaken. A long term stream monitoring program in a watershed should extend for a continuous period of more than ten (10) years. This duration of monitoring would be the minimum required to supplement the data used in this study.

2.4 Climate Records

Simulation of stream flow and watershed discharges is required for this study. Climate data is an essential part of the information that is required for continuous simulation. As with stream flow there is a lack of specific local climate data that can be used directly. This results in the need to utilize a representative data set from a nearby climate recording station. A short list of acceptable climate stations was established using this following selection criteria:

- Located on the eastern side of southern Vancouver Island,
- included in the Environment Canada Climate Normals summaries,
- published Environment Canada Intensity Duration Frequency (IDF) data
- minimum of 20 years of Environment Canada archived hourly records for rainfall and temperature and daily precipitation used to derive snowfall contribution

Four Environment Canada climate stations were found which met the selection criteria, these being:

- Campbell River Airport;
- Comox Airport,
- Nanaimo Airport, and
- Victoria, International Airport

The location of the Climate Stations is shown on **Figure 2-5**. The Comox Airport is located to the north and the Campbell River Airport station is located further to the north. The Nanaimo Airport Station is to the south and the Victoria Airport station is farther south in Saanich.

A comparison of the annual normal precipitation and the 24 hour rainfall volumes for a range of return periods is provided in **Table 2.2**.

Table 2.2 – Precipitation Data

Climate Station	24 Hour Rainfall Volume (mm) Return Period (Years)						Average Annual Precipitation (mm)
	2	5	10	25	50	100	
Campbell River	58.3	70.0	77.7	87.5	94.7	101.9	1,451.5
Comox	58.8	74.4	84.8	97.9	107.6	117.2	1,179.0
Nanaimo	57.9	72.7	82.5	94.8	104.0	113.0	1,162.7
Victoria	53.2	71.2	83.0	98.0	109.1	120.2	883.3

As can be seen the all of the climate stations have similar 24 hour rainfall volumes for the respective return periods. The Comox and the Nanaimo climate stations have very similar annual precipitation volumes. While Campbell River sees greater annual volumes and Victoria has less annual precipitation. The variability in the IDF Curve amounts of rainfall is small, however the annual total precipitation for Victoria significantly less. The annual rainfall volume recorded at either the Comox or Nanaimo climate stations would be representative for the Shelly Creek watershed.

MVIHES
Mid Vancouver Island Habitat Enhancement Society

Shelly Creek Watershed Plan

Climate Stations

Figure 2 - 5

2.5 Geology of the Region

A description of the geology of the region would begin at the base of bedrock geology, overlain by the surficial sediments of various types. The very upper veneer of the surficial deposits have been modified by climate and biochemical processes to form the top soils over the period since the retreat of the last glaciers. We will examine the geology from the base and progress upward to the most important surficial soils with interact directly with the climate of the region.

The Shelly Creek watershed lies within the Nanaimo Lowland lies below 600 metres elevation and extends along the east coast of Vancouver Island from Sayward to Jordan River. It is largely underlain by sedimentary rocks of Upper Cretaceous age. The Lowland consists of undulating topography and sharp ridge-like crests separated by narrow valleys.

2.5.1 Bedrock Geology

Bedrock in the study area consists of dark green Devonian to Jurassic-aged volcanic and metamorphic rocks of the Wrangellia terrain (basement) that are overlain by Upper Cretaceous-aged Nanaimo Group sedimentary rocks as shown on **Figure 2.6** extracted from the Geological Survey Of Canada Open File 7796.

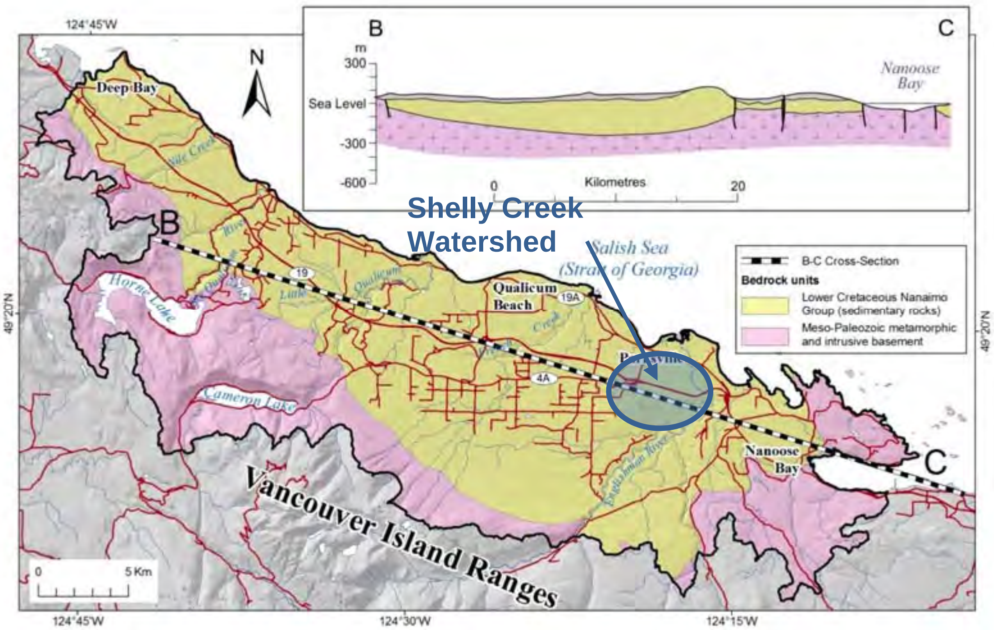


Figure 2-6 **Bedrock Geology**

2.5.2 Surficial Geology

The landscape of southern Vancouver Island has been considerably modified by glaciation during the Pleistocene epoch. The Fraser glaciation, the most recent, has resulted in the most extensive surficial deposits. This event began with the advance of glacial ice from the mainland Coast Mountains down the Strait of Georgia. Approximately 18,000 to 19,000 years ago, this ice sheet crossed the southeastern part of Vancouver Island.

With glacial retreat, uplift of the land occurred rapidly and a sea level near to that of the present was reached about 12,000 years ago. Another brief submergence occurred along eastern Vancouver Island, climaxing about 11,500 years ago, again followed by rapid emergence. As a result marine deposits accumulated along the coastal region up to an elevation of approximately 100 metres.

The surficial deposits found within the area are predominantly the result of glaciation. Deposits resulting from the natural processes of colluviation (by gravity) are also widespread while environmentally Induced deposits (Ie. organic) are locally important. Collectively these deposits form the parent materials of all the soils which have formed. The separation of these surficial materials (landforms) was the third level of differentiation in mapping the soils.

The following information in this section of this report has been derived from the Geological Survey of Canada Open File 7796, 2015. The unconsolidated sediment in the study area is comprised of marine, fluvial and glacial materials. They generally form an extensive cover and can exceed 100 m in thickness but bedrock outcrops are not uncommon, reflecting the highly variable nature of the sediment thickness. The Nanaimo Lowland is covered by a succession of two groups of glacial deposits (Vashon and Dashwood) separated by non-glacial deposits (Cowichan Head formation) and proglacial outwash deposits

Six major types of surficial deposits were identified in the Shelly Creek watershed. These were comprised of a bedrock outcrop known as Little Mountain and the remaining being comprised of the Capilano Sediment and Vashon Drift.

Capilano Sediments generally overly the Vashon Drift and are up to 25 m thick. Thick glaciomarine and marine sediments were deposited depressed coastal areas and are considered to be postglacial, but still affected by glacial meltwater during early deglaciation. Relative sea level fell from elevations of approximately 150 to 50 masl in the first thousand years following deglaciation, eventually reaching a minimum 15 m below present sea level. Subsequent and continued uplift led to entrenching and terracing of late glacial and older deposits and vegetated slopes reduced the level of aggradation. Fluvial terraces formed in valleys and deltas formed seaward where sediment supply was adequate. Deltaic and alluvial sediment grading to modern sea level and are commonly classified as Salish sediments.

Vashon Drift has a thicknesses generally up to 30 m, except at observed locations where depressions were filled by approximately 60 m of drift. The specific surficial deposits found within the Shelly Creek watershed are shown on **Figure 2-7** and include:

- Till Blanket,
- Marine Veneer,
- Alluvium Terraces,
- Coarse Glaciomarine Blanket, and
- Undifferentiated Glaciofluvial Deposits.

2.6 Hydrogeology of the Shelly Creek Watershed

The surface hydrology of the Shelly Creek Watershed is affected by the flow of water beneath the ground surface and the ability of the soil profile to accept surface water. The hydrogeology of the region has been described in the report Water Budget Project: RDN Phase One (Vancouver Island), Waterline Resources Inc. June 17, 2013.

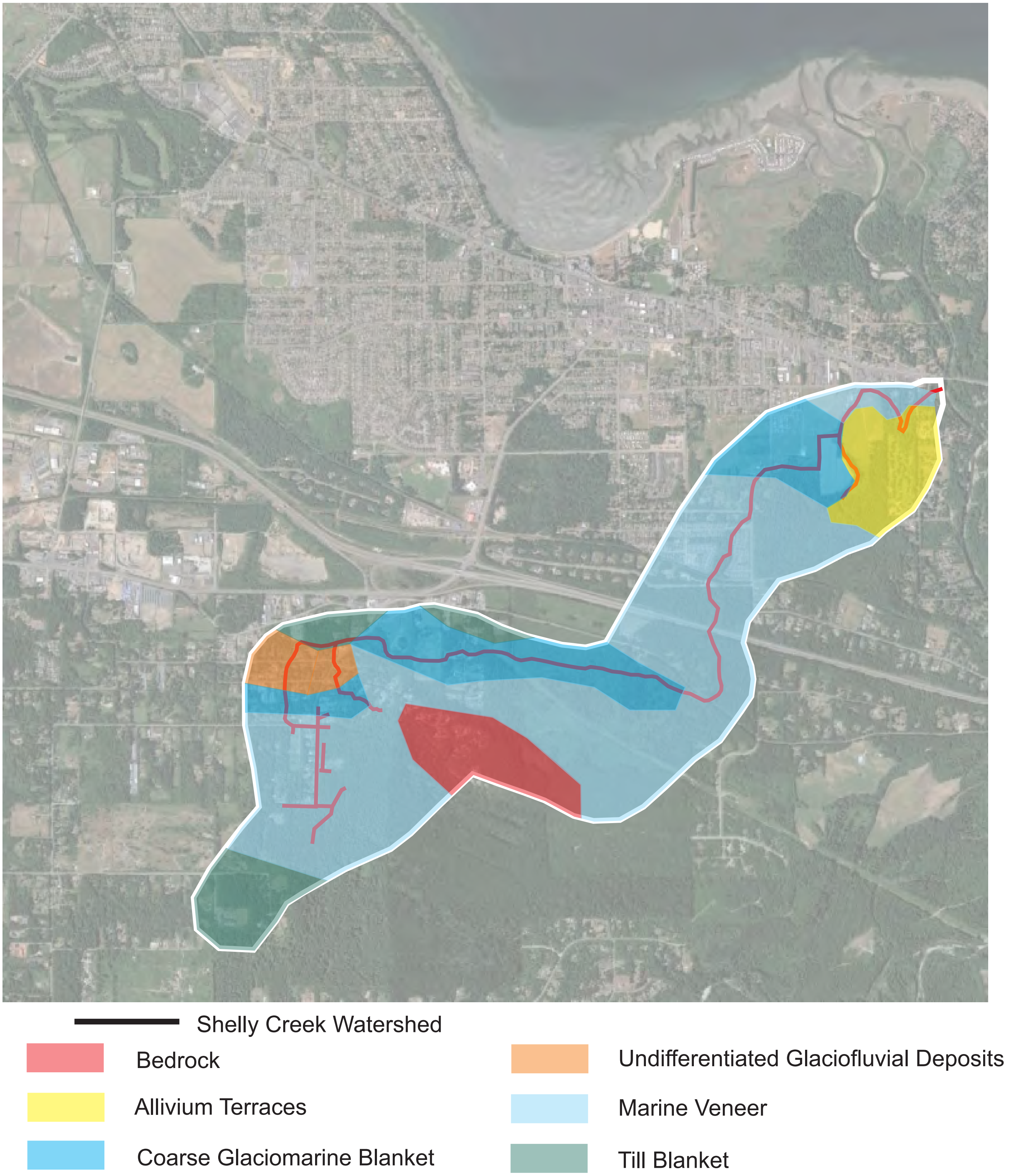
An observation can be made by reviewing the location of the top of the saturated aquifer in relation to the ground surface. A ground profile which crosses the Shelly Creek Watershed can be seen on **Figure 2-8**.

It is clear that the aquifer water surface is a considerable distance below the surface and lies within the Quadra Sand deposit located below the Vashon and Capilano deposits.

A second observation is the direction of flow of the water contained within the auifer. Generally the flow direction is downward toward the Englishman River, and to Shelly Creek where it crosses the piezometric surface (groundwater table). Where the creek crosses the water table springs will occur that allow water to enter the stream and flow within the channel.

The groundwater flowing into the streams is replenished by infiltration and downward movement of precipitation. Information regarding the quantity of annual recharge is described in report Water Budget Project: RDN Phase One (Vancouver Island), Waterline Resources Inc. June 17, 2013. Two zones of recharge is shown on **Figure 2-9**. Two zones have been identified within the Shelly Creek Watershed; an upper and lower zone that annually recharges the aquifer with from 75 to 130 mm. A central zone provides a smaller range of annual recharge of from 25 to 75 mm.

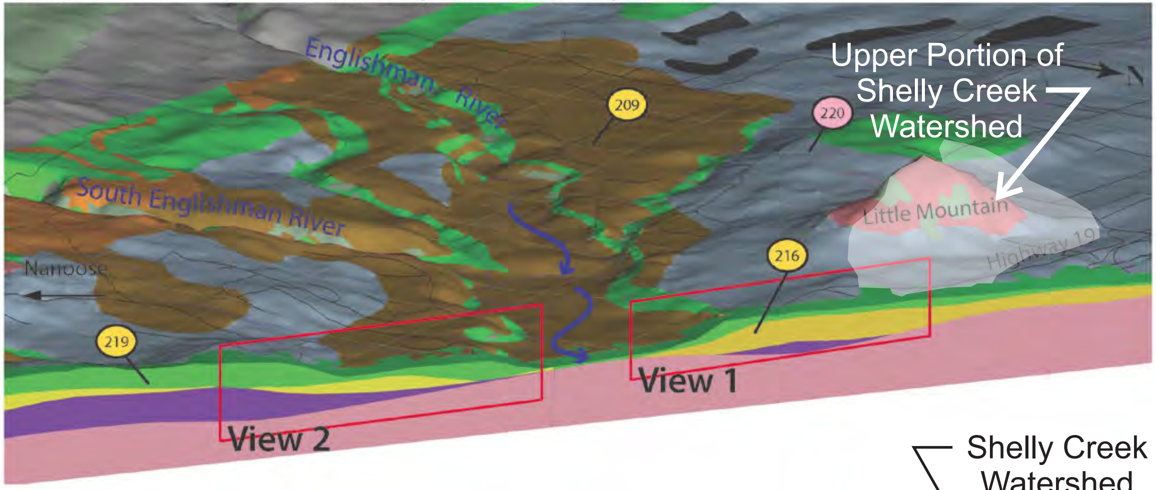
From **Table 2** we can see that the average annaul depth of precipitation within the Shelly Creek Watershed is expected to be approximately 1170 mm. From this we can conlude that from 2% to 6% and from 6% to 11% of the precipitation reaches the aquifer from these two recharge zones.



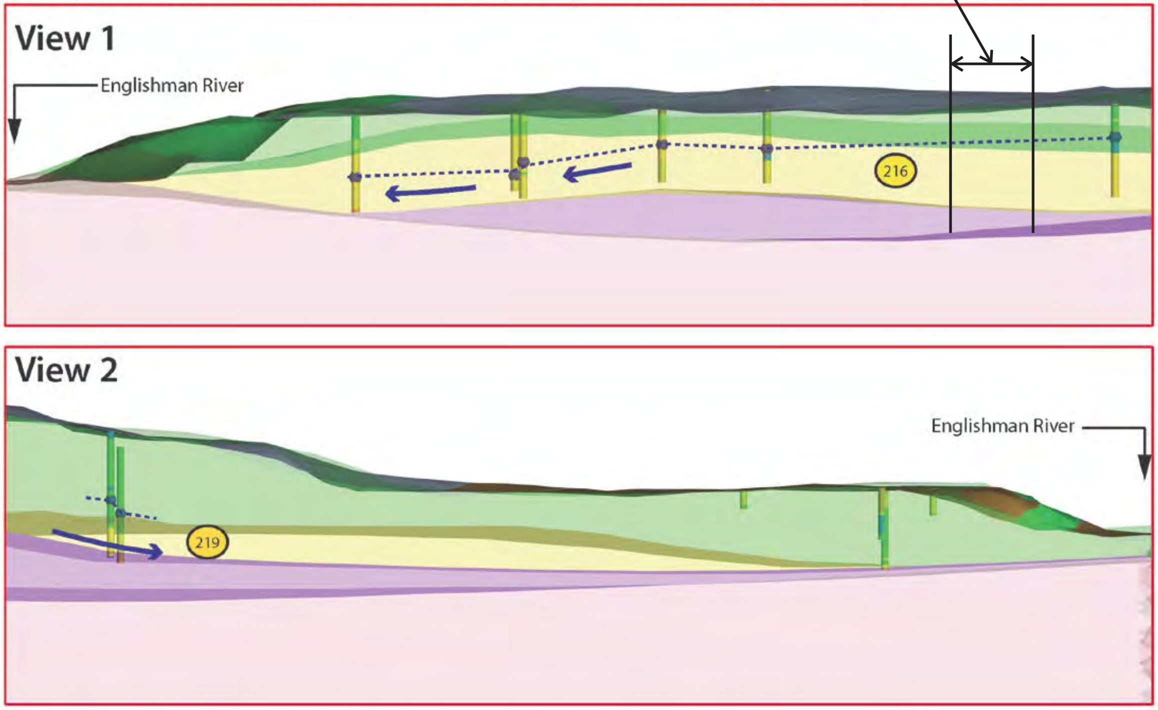
Source: Geological Survey of Canada Open File 7966, 2015,
Natural Resources Canada

Watershed
Figure 2 - 7

3D Geomodel section from Nanoose to lower Englishman River (looking southwest).



Close-up view of 3D model showing borehole materials and transparent Geovolumes (approximately 200m-thick slice)



LEGEND

1. Hydrostratigraphy - Surface and Subsurface

- Capilano/Salish (*undifferentiated*)
- Capilano Marine (*not identified in subsurface*)
- Vashon (*Glacial Fluvial*)
- Vashon/Capilano (*undifferentiated*)
- Quadra Sand
- Pre-Quadra
- Bedrock/Colluvium

2. Borehole Material

- Gravel/Boulder
- Glacial Till
- Sand
- Water Level
- Silt/Clay
- Glacial Till
- Bedrock

3. Hydrogeology

- 216 Mapped Aquifer Number
- 220 (*Colour relates to Hydrostratigraphic Unit*)
- Flow Direction
- Piezometric Line

Source: Water Budget Project: RDN Phase One (Vancouver Island),
Waterline Resources Inc. June 17, 2013

Shelly Creek Watershed Plan

Hydrogeology

Figure 2 - 8

▬ Shelly Creek Watershed

Total Groundwater Annual Recharge

🟨 25 - 75 mm/year

🟧 75 - 130 mm/year

Source: Water Budget Project: RDN Phase One (Vancouver Island), Waterline Resources Inc. June 17, 2013

Aquifer Recharge

Figure 2 - 9

As discussed in **Section 2.3** the watershed that would provide the best correlation to the watershed characteristics and hydrologic response of the Shelly Creek watershed would be Bings Creek located in the Cowichan Valley.

One critical factor for stream health is the quantity of water that enters the stream and is discharged through it. As the only source of water in the watershed is precipitation the ratio of the precipitation to the total stream discharge is an important measure of the hydrology of the stream.

Due to the limited availability of recorded data the following assessment must be limited to those years where data is available. Comparison of the recorded precipitation to the total stream discharge is shown in **Table 2.3**.

Table 2.3 – Bings Creek Precipitation and Stream Discharge

Year	Total Precipitation (m^3)	Bings Creek Total Stream Discharge (m^3)	Discharge Coefficient (Discharge / Precipitation)
1985	13,407,500	7,253,280	0.54
1986	19,827,600	14,916,528	0.75
1987	14,291,000	11,573,712	0.81
1988	15,128,000	9,965,376	0.66
1989	13,080,450	10,091,520	0.77
1990	20,376,300	16,051,824	0.79
1991	18,646,500	14,569,632	0.78
1992	16,222,300	14,601,168	0.90
1993	14,019,750	10,186,128	0.73
1994	16,595,850	14,506,560	0.87
1995	22,227,000	17,754,768	0.80
1996	20,683,200	15,137,280	0.73
1997	20,715,750	19,836,144	0.96
1998	20,311,200	20,939,904	1.03
1999	23,494,900	21,255,264	0.90
2000	15,097,000	8,293,968	0.55
2001	15,241,150	10,879,920	0.71
2002	15,921,600	N/A	N/A
2003	17,586,300	17,912,448	1.02
2004	17,505,700	12,362,112	0.71
2005	18,108,650	14,065,056	0.78
Average	17,547,033	14,107,630	0.80

Note: Red values indicate incomplete annual records.

A graphical view of the discharge when compared to precipitation is shown on **Figure 2-10**.

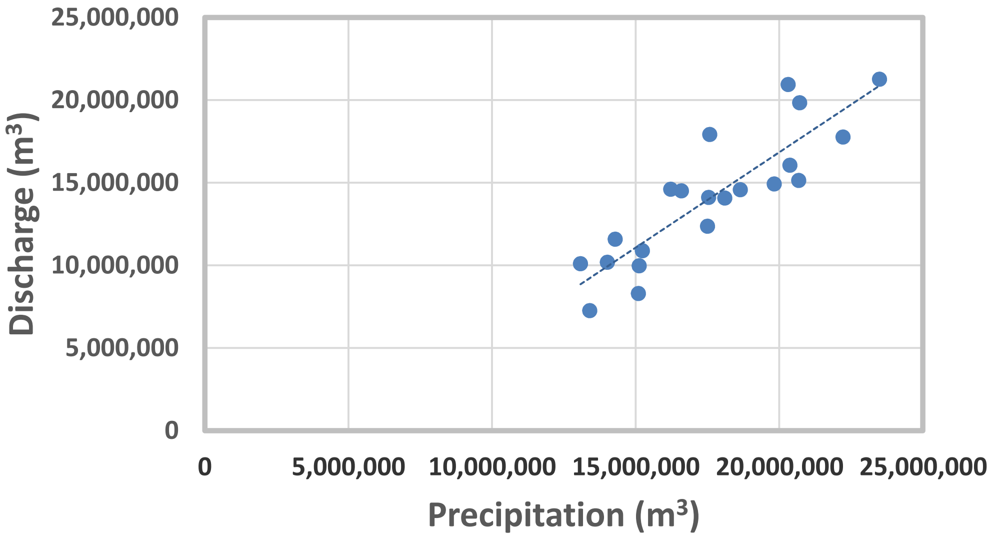


Figure 2-10 **Volume of Annual Precipitation versus Stream Discharge**

The graphical representation shows that for years with smaller precipitation the corresponding rates of discharge are increasingly small. Extension of the trend line beyond the limits of the data may lead to incorrect conclusions that no stream discharge would occur unless a preciptation threshold of approximately 6,000,000 m^3 were acheived.

A second view of the information is presented on **Figure 2-11**which shows the discharge coefficient in relation to the precipitation total.

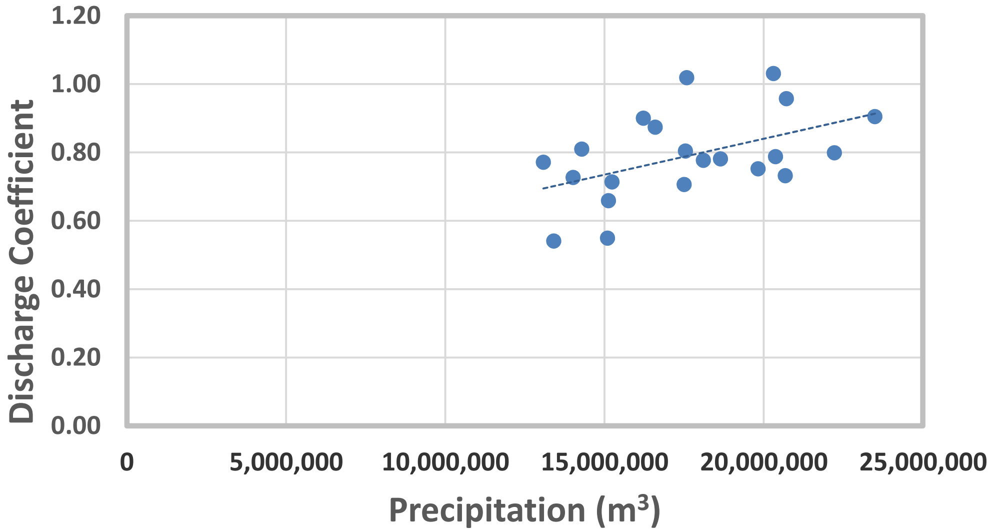


Figure 2-11 **Discharge Coefficient versus Precipitation**

The information contained on this chart indicates that in some years there is more actual stream discharge than precipitation. This is an indication of the storage and release from groundwater over a time period that is greater than a single year. That for this watershed the groundwater reservoir is an important source of water for the streams.

2.6.1 Rainwater in Watersheds

An average of nearly 80% of the total precipitation that falls within the watershed enters the stream. However only between 2% and 11% would come from aquifer discharge. This indicates that the hydrogeology is much more complex than one might initially believe.

The key conclusions reached by examining the geologic profile, along with the climate and streamflow records are that shallow surface water can move in a lateral direction, and that soil water must flow through unsaturated conditions to reach the saturated aquifers.

The hydrologic cycle describes the path of water as is circulates through the environment is a good place to begin examining the complexity of hydrogeology and water movement through the soil layers.

As rainwater falls from the sky it follows a number of possible paths as shown on the diagram showing the hydrologic cycle on **Figure 2-12**.

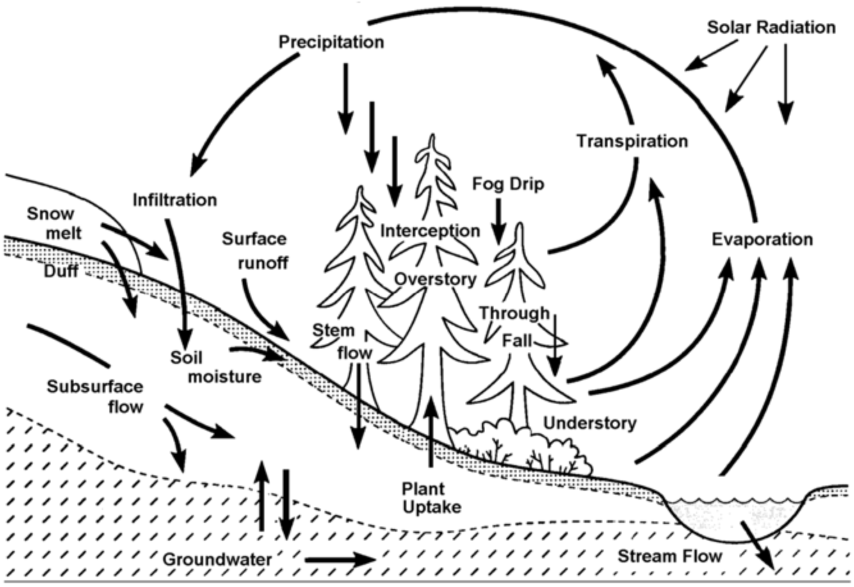


Figure 2-12 Hydrologic Cycle

The first observation is that in order to have transpiration the rainwater must first infiltrate into the soil where it is absorbed by the plants. This separates and clearly differentiates the processes of evaporation and transpiration.

As can be seen all of the infiltrated rainwater does not flow to the aquifer and then to the stream. The subsurface flow path can be both vertical and horizontal in the layers above groundwater. This important physical process has been called interflow as it does not involve flow through a saturated soil. The Water Balance Methodology examines the flow path of water in the watershed, and the flow in the stream.

2.6.2 Watershed Water Balance

The water balance of a watershed encompasses the mass balance and the flow paths of water. The mass balance involves processes that add or subtract water from the watershed and include precipitation in the form of rain and snow, evaporation, transpiration, and stream flow. The flow path is critical to understanding the hydrologic operation of a watershed and these flow paths can be from the atmosphere, return to the atmosphere, flow into the ground, flow through the ground in both saturated and unsaturated conditions, and flows in a stream.

The three flow paths of rainwater exist in a watershed from the point of rainfall until it enters the stream as shown on **Figure 2-13**. The flow paths include:

1. **Surface runoff** where the amount of time water spends on this path is typically in the order of minutes to hours. Where lakes and ponds are a part of the flow path the time could be extended to days.
2. **Interflow** is the system that seasonal with water entering shallow unsaturated soils and typically flowing to the stream within a year.
3. **Deep groundwater** is the flow entering the saturated aquifers where flow duration can be from years to decades depending upon the flow path and porosity of the aquifer.

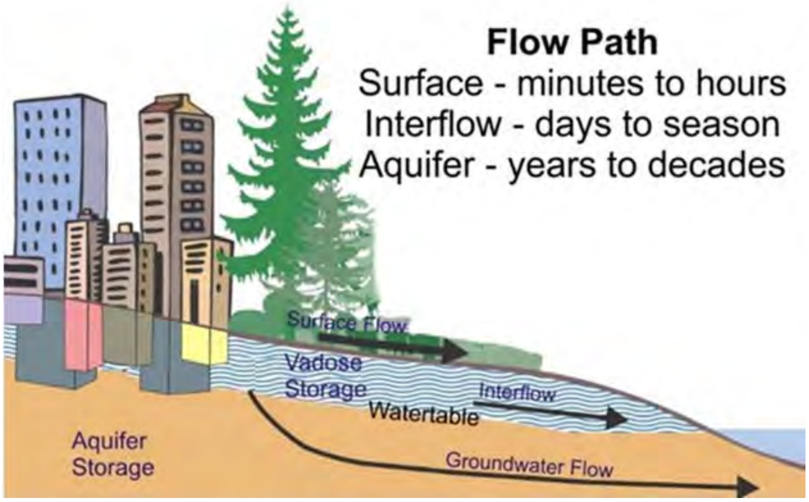


Figure 2-13 Watershed Flow Paths

The concept of differential flow paths and the proportions of rainfall following these pathways which was first published in a document entitled Low-Impact Development Hydrologic Analysis, Prince George's County, Maryland July 1999 is shown in **Figure 2.14**.

The information presented suggests that under natural conditions in Maryland the water balance as a proportion of total precipitation is composed of:

1.	Surface runoff	10%
2.	Evapotranspiration	40%
3.	Aquifer recharge	25%, and
4.	Interflow	25%.

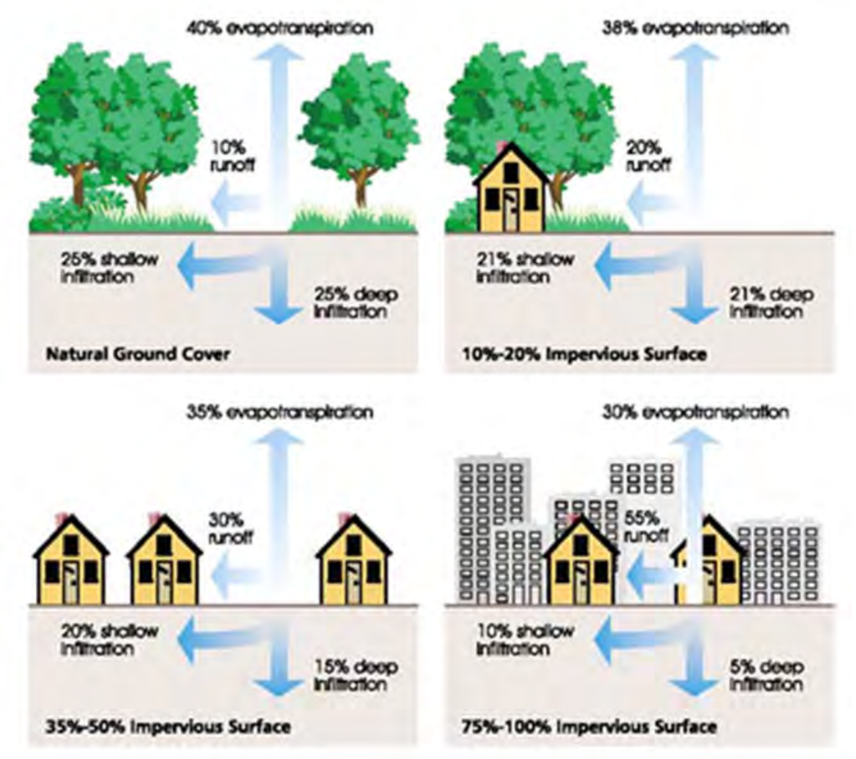


Figure 2-14 Water Flow Paths

This goes on to suggest that in Maryland under a dense development the water balance as a proportion of total precipitation is altered to be:

1.	Surface runoff	55%
2.	Evapotranspiration	30%
3.	Aquifer recharge	5%, and
4.	Interflow	10%.

Additional discussion of subsurface water flow and its division between interflow and aquifer flow will be discussed in **Section 2.9** following the discussion of soil formation in the Shelly Creek Watershed in **Section 2.10**.

2.7 Vegetation Zonation

Information in this section of this report has been derived from the *Soils of Southern Vancouver Island*, MOE Technical Report 17, J.R. Jungen, P.Ag., B.C. Ministry of Environment, August 1985. The Shelly Creek watershed lies within the area examined in that report. I have extracted and summarized the following technical information directly from that report.

Two major characteristics of the Pacific coast climate, interacting with the topography of Vancouver Island results in two vegetation regions. One is dominated by westerly air flow lifting over west-facing mountain slopes (Outer Coastal Region) and the other is dominated by the rain shadow effect of descending air on the leeward side of both the Vancouver Island Ranges and Olympic Mountains (Inner Coastal Region). Each of the vegetation regions has a particular vertical sequence of climax vegetation communities.

The Shelly Creek watershed lies within the Inner Coastal Region and the vegetation zonation can be described as containing four vegetation zones, with five subzones. These zones reflect different macroclimatic conditions resulting from decrease in precipitation and changes in elevation. This vegetation region occurs on the south and eastern areas of Vancouver Island.

Coastal Grand Fir - Western Red Cedar Zone occurs from sea level to about 300 m elevation and is restricted to a narrow strip along the southeast and east coast of Vancouver Island. It is characterized by a climatic climax forest of grand fir and western red cedar on deep, well drained sites. In response to frequent disturbance, coast Douglas-fir is the predominant seral species found on most sites. Broad-leaved tree species such as Pacific madronne, Garry oak, and bigleaf maple are also common on some sites. Climatic moisture deficits are prevalent in this zone.

Coastal Western Hemlock Zone occurs from sea level to 900 m from Nanaimo to Kelsey Bay, and above the Coastal grand fir - western red cedar zone to the south. The major macroclimatic feature influencing the zone is the rain shadow, with descending Pacific air masses drying with movement eastward. The zone is characterized by a climatic forest of western hemlock on deep, well drained sites. The long-lived coast Douglas-fir is the dominant seral species on most disturbed sites. Two subzones have been differentiated to reflect changes in western hemlock dominance in the succession and stronger podzolic soil forming processes due to increased moisture.

The coast Douglas-fir subzone (sea level to 500 m has been intensively disturbed and mature western hemlock is uncommon. Forest understories are dominated by salal, Oregon-grape, and mosses. Pacific madronne may become common on drier sites.

The western hemlock subzone (sea level to 900 m}, with higher growing season precipitation, is characterized by faster invasion of western hemlock regeneration and increasing accumulation of forest floor organic materials, resulting in improved forest capabilities. Red alder and coast Douglas-fir are common seral species, the former especially prevalent on disturbed floodplains and road margins.

Coastal Western Hemlock - Pacific Silver Fir Zone and specifically the yellow cedar subzone of this zone occurs above the Coastal western hemlock zone, ranging in elevation from 700 to 1100 m. Precipitation is high, with snow common, and negligible moisture deficits in the growing season. Coast Douglas-fir may be a dominant seral species on drier sites; otherwise, this subzone is similar to that In the Outer Coastal Region.

Subalpine Mountain Hemlock - Pacific Sliver Fir Zone is found in an elevation range of about 1000 to 1800 m. The upper limits of the zone are either the height of land, exposed bedrock with soils too shallow to support trees, or isolated patches of alpine tundra. Vegetation is similar to that described for the Outer Coastal Region.

2.8 Surface Soils in the Shelley Creek Watershed

The shallow surface soils are a mixture of organic material and mineral soil particles. Following the last glaciation and the retreat of the glaciers from the study area there was little or no organic material in the top soil. The mineral components which now make up the nonorganic portion of the top soils began to change as a result of rainfall, the introduction of plants and invertebrate animals and climate. A description of the nonorganic surficial materials and the study area sets the background for understanding the evolution and hydrologic responses of the shallow top soils that are now found within the Shelly Creek watershed.

<u>Examination of surficial soils is critical to understanding the hydrology of an area because it is the top soil that interacts with the climate and precipitation.</u> The shallow (less than 1 m in depth) soils are most affected, and altered, by the interaction of both rainwater and biological activity are commonly referred to as “top soil”. The surficial soils are modified over time by these factors and their physical and chemical characteristics will be altered from those of the original geological materials.

Information in this section of this report has been derived from the *Soils of Southern• Vancouver Island*, MOE Technical Report 17, J.R. Jungen, P.Ag., B.C. Ministry of Environment, August 1985. The Shelly Creek watershed lies with the area examined in that report. I have extracted and summarized the following technical information directly from that report.

The surficial soils develop as a result of combined physical characteristics of the geological materials, topography, biological activity and climate. Our past experience leads us to believe that these processes and the resulting soil properties are not well understood by many practitioners in the area of water resources. Understanding the nature of the shallow soils allows us to view how they interact with rainwater and determine how they alter the flow path to the stream. A brief description of the soil formation processes and the soil types that are present within the Shelly Creek watershed are included below. This is included so as to provide a basic understanding of the soil formation processes and can be considered a primer on soil formation.

Surface soils are the product of the environmental factors under which they have developed and are developing. These factors include the mineral parent materials plus topographic, climatic and biological influences. The climatic and biological factors are the normal forces of change acting in soil development. One very important aspect in understanding the hydrology within the Shelly Creek watershed lies in the descriptions of the shallow surficial soils and their formation. The shallow surface soils form the Interflow media and directly interact with any rainfall. The physical properties of these shallow soils determines hydrologic response of the watersheds; specifically how the rainfall interacts with the landscape, where the rainwater goes and how the rainwater gets there.

Soils and their classification is based on the nature of the soil profile which reflects the influence of the various factors of soil formation. The delineation of the kinds of soils and recognizing their properties and Interpretive potential is in essence the purpose of soil surveys.

A surface soil (top soil) is the naturally occurring unconsolidated mineral or organic material at the earth's surface which is able to support plant growth. The type of soil at a given location is the result of climate, organisms and topography acting on the parent material over time. Solis display a continuum of properties, reflecting the variation of these soil forming factors.

The colours of the soils beneath the layer of forest litter range from reddish brown to yellowish brown. The reddish brown colour, probably due to unhydrated iron oxide (hematite) is most distinct when exposed during cultivation or excavation. The entire weathered layer soils seldom extends beyond a depth of 600 mm or 750 mm (two or two and one half feet).

Since the onset of urban development there has been a pattern of removal of large contiguous portions of the organic soil horizon combined with the replacement of the native vegetation with species more desirable in an urban setting. The long term soil genesis under these conditions will ultimately result in soil types that are far different than those found in the mid-19th Century.

The mountainous physiography of Vancouver Island, the climate, vegetation, and landforms, many of which have been influenced, moulded or formed by glaciation are the physical and environmental setting for the soils of the area. The soil parent materials are of glacial origin or have been subsequently modified by natural processes of colluviation, fluvial activity, and marine inundation. The soils found represent a broad spectrum with respect to their nature and characteristics. Taxonomically the soils have been classified into five soil orders.

Soli classifications seek to group similar soils in order to organize our knowledge of soils and enable prediction of their behavior. In The System of

Soil Classification for Canada, soil groupings are based on properties' that indicate a similar mode of origin. The soil order is the highest level of generalization in this system. Of the nine orders, three occur in the area:

1. Solis of the humid forested regions containing significant amounts of amorphous aluminum, iron, and/or organic matter (**Podzolic** order};
2. Soils with weakly developed horizons (**Brunisolic** order);
3. Soils which are Influenced by periodic or long-term water saturation (**Gleysolic** order); and,

For a vast majority of the area the soils have developed under the influence of a coniferous forest. The effect, of a coniferous forest on the soil is normally toward the development of the Podzolic Soil Order. A major factor in soil genesis is the midsummer drought in July and August, which brings about dehydration and chemical precipitation processes, an upward movement of water and a slight decrease in the acidity of the soil. Chemical precipitation centres in the formation of numerous iron concretions, which have the appearance of small rusty gravel, in the first 300 mm or more of the soil horizon. The pellets of iron oxide thus formed absorb and hold substantial amounts of other minerals. The location and distribution of the Soil Orders can be seen on **Figure 2-15**.

2.8.1 Podzolic Order

In general, Podzollc soils occur along the western edge of the area at higher elevations. In practice, Podzollc soils are difficult to distinguish in the field from Brunisolic soils for both have similar colour.

Podzolic soils are by far the most widespread in the area due mainly to the maritime climate which is characterized by high precipitation, low moisture deficits and cool to moderately cold soil temperature regimes. The soil moisture regimes are humid to perhumid. These factors act on the soil parent material to form bright, reddish-coloured, deeply weathered soils which are strongly leached, have low base saturations and are very acid.

2.8.2 Brunisolic Order

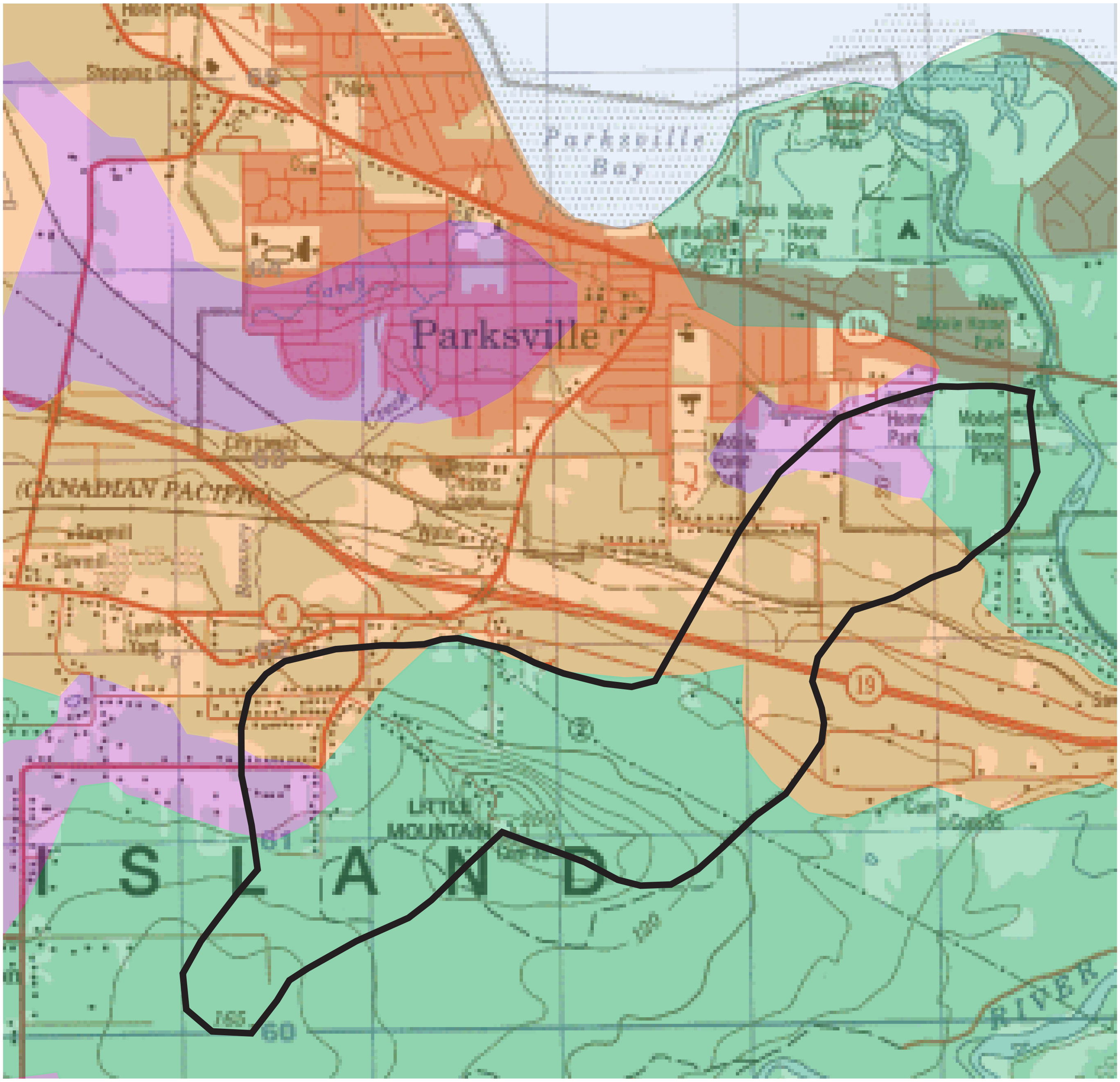
Brunisolic soils occur along the southeastern coastal lowland and on the Gulf Islands. They also occur on relatively young fluvial and fine textured marine sol I parent materials.

Brunisolic soils occur where the climate is characterized by warm, dry summers with high moisture deficits and relatively low total precipitation. The soil moisture regime is Semiarid while the soil temperature regime is Mild Mesic. Compared to the Podzols, the Brunisolic soils are less acid and leached, have much lighter colors and higher base saturations.

2.8.3 Gleysolic Order

Poorly drained Gleysolic soils are found on level to very gently sloping terrain, usually on marine and fluvial deposits where moisture accumulation and/or seepage exert a significant role. Soil profiles are strongly gleyed and mottled, and saturated for long periods. Typical vegetation in gleysolic areas include red alder, cottonwood, willow, skunk cabbage and sedges.

Gleysolic soils develop In the presence of excessive moisture that results in permanent or periodic reducing conditions. As a result, the gleyed subsoil is bluish-gray to greenish-gray and reddish-brown mottles usually occur in the profile. These soils occur where the water table is high because of proximity to bodies of water (e.g. floodplains) or in depressional sites, or on materials with low hydraulic conductivity.



Soil Great Group

🟧 Podzol

🟩 Brunisol

🟪 Gleysol

Shelly Creek Watershed Plan

Surface Soils

Figure 2 - 15

2.9 Demonstrating Interflow

The occurrence of Interflow has long been ignored as it is difficult to observe. We can conclude that water flows through the soils in a manner that is not initially obvious and to demonstrate the process it is necessary to examine several characteristics of soils and aquifers. The soil characteristic to be considered include soil formation, geologic profiles, and visual observations.

Several key observations can be made that include:

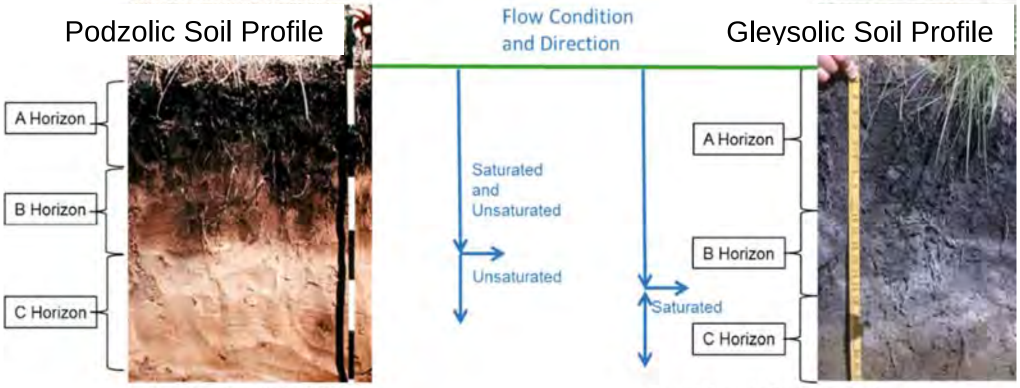
1. Vertical flow of rainwater saturated soil will only occur to a very shallow depth and that a different mechanism of groundwater recharge must involve flow through unsaturated soil.
2. Shallow subsurface water can move in a lateral direction, and that water must flow through unsaturated conditions to reach the aquifers.
3. The shallow interflow is easily and a different flow path will be result. This indicates that disruption of the interflow system is a simple process and an unintended consequence of construction.
4. The water is not infiltrating into the compacted gravels indicating that compacted gravels are impervious.

The information that leads to these conclusions is discussed below.

2.9.1 Soil Formation

The first observation can be made by examining and understanding the formation of soils. Two examples of the Great Order soils found within the study area are shown on **Figure 2-16**. The soils shown are found within the study area with the Podzols being the most prevalent and the Gleysols occur over a scattered and much smaller areas.

The shallow surface soils are a mixture of organic material and mineral soil particles. The surficial soils develop as a result of the combination of physical characteristics of the geological materials, topography, climate, and biological activity. Following the last glaciation and the retreat of the glaciers from the study area there was little or no organic material in the top soil. The mineral components which now make up the nonorganic portion of the top soils began to change as a result of rainfall, the introduction of plants and invertebrate animals and climate.



- Iron leached into B Horizon
- C Horizon typically dry

Grey (gleyed) B and C Horizons typically saturated for extended periods

Figure 2-16 Soil Profile and Water Movement

The Pozolic Soil on the left formed under a forest cover with biological activity adding organic matter and is the most prevalent soil within the study area. Water has a great influence in leaching the oxidized iron from the upper or A Horizon into next lower layer or the B Horizon. The red colour of the B Horizon is indicative of the iron oxides deposited as within this soil layer. The lower C Horizon is largely unchanged from its original condition because water and biologic processes seldom penetrate into this soil layer. We can conclude that water does not readily move downward in a vertical direction. The combined thickness of the A and B Horizons is typically not more than 60 cm and can often be observed to be as shallow as 30 cm.

The Gleysolic Soil shown on the right was formed in conditions which include extended durations of saturation interspersed by dryer periods. These periods are typically seasonal and these soils are often found in topographic lows or where subsurface drainage is restricted. The wetting and drying cycles result in periods when the soil chemical processes are dominated by oxidation, during dryer periods, and reduction during anoxic wet periods. The grey colouration is indicative of an accumulation of the chemical compounds that result over time in these soils as a result of chemical oxidation and reduction.

The direction of flow of the water is generally in a vertical direction with rising and falling groundwater levels indicating a saturated condition below the water table.

The key conclusion reached when considering the shallow soil information is that concentrated flows of rainwater flowing vertically through unsaturated soil and will not flow vertically to any great depth. A different mechanism of groundwater recharge must be occurring which includes both vertical flow and lateral flow through unsaturated soils.

2.9.2 Visual Observation

Simple observations of the items on **Figure 2-17** combined with some thought can lead to additional conclusions.

Figure 2-17 Interflow Blockage

The compacted gravel pathway is located in a forested park where the ground slopes downward from right to left with a surface slope of approximately 4%, or 4 metres of drop over a 100 metre distance.

The rain has stopped several hours prior to the time when the photo was taken yet there is water ponded on the gravels pathway. Water can be observed flowing up out of the ground and onto the pathway filling the shallow depressions.

These observations lead to two key conclusions:

1. The shallow interflow is being disrupted by the pathway and a different flow path has been established. This indicates that disruption of the interflow system is a simple process and an unintended consequence of the pathway construction.
2. The water is not infiltrating into the compacted gravels of the pathway indicating that compacted gravels are impervious.

2.10 Soil Properties

An understanding of the physical characteristics of the shallow surficial soils will aid in developing an understanding of the existing watershed hydrology and how we can mitigate for any alterations to the surface that would occur through a development process. The soil is composed of two different components; organic matter and the mineral soil which is made up of a mixture of nonorganic particles.

The nonorganic particles have a varying proportion of clay, silt, and sand determines the textural classification of the soil. The Textural Soil Triangle as shown in **Figure 2-18** provides a graphical presentation of the soil textural classification system used in Canada.

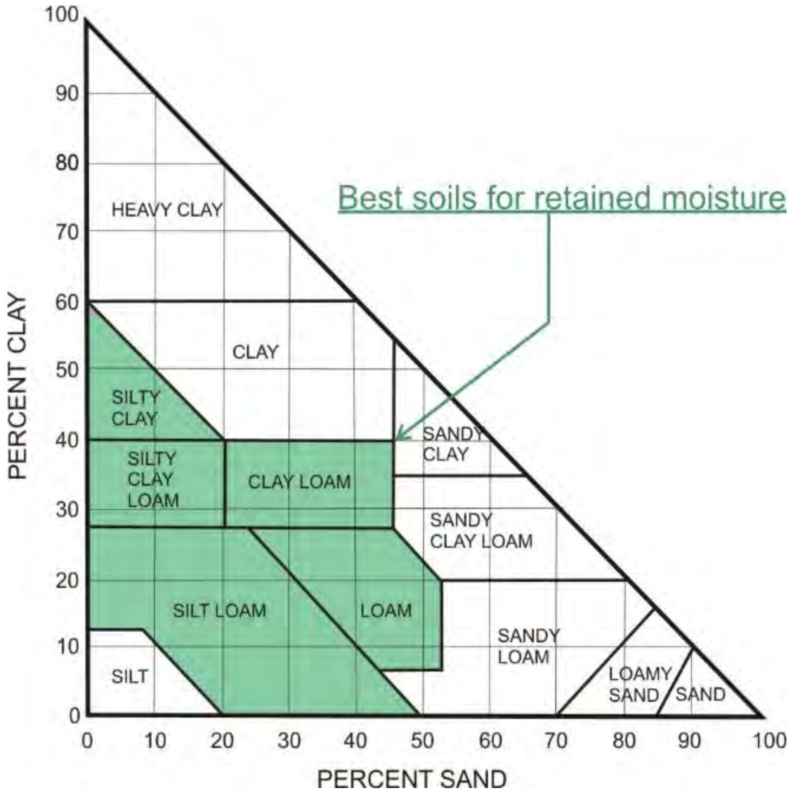


Figure 2-18 Soil Texture Triangle

The Soil Texture Triangle provides the relative proportion of the soil content of the mixture of clay, silt, and sand. This classification is critical in determining the interaction of soil and water.

Three significant physical conditions of soil and water occur at three different water contents. The physical state is shown on **Figure 2-19** and the terms can be defined as:

- **<u>Saturated</u>** is when every possible free space within the soil is filled with either water or the mineral soil. Saturated soils drain quickly to the Field Capacity.
- **<u>Field Capacity</u>** is the moisture content when air displaces some of the water volume as it drains away. At this moisture content the water is adhering to soil particle and will not freely flow away. Continued water losses are limited to evaporation, plant uptake and a small amount of gravity flow.
- **<u>Wilting Point</u>** is the moisture content when plans can no longer access the water in the soil and even evaporation of soil moisture ceases.

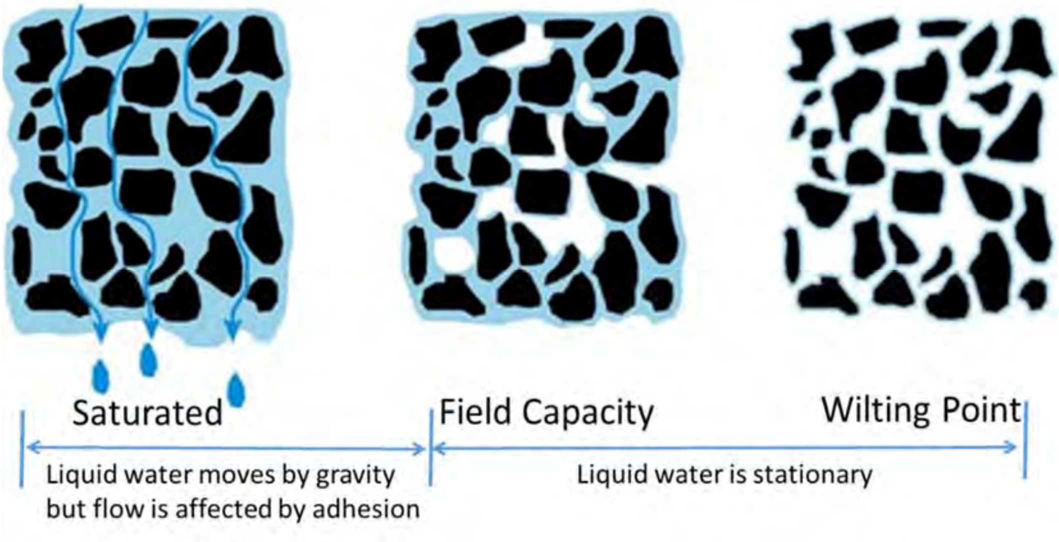


Figure 2-19 Soil Moisture Conditions

A soil will only retain the water where the content is at or less than Field Capacity. The greater the field capacity the greater the retained moisture. This view must be tempered with the knowledge that moisture less than the wilting point is not available to plants. The best soil for retaining plant useable moisture has the greatest difference between the Field Capacity and the Wilting Point. The water retaining capacity of a soil relates to its and the difference between the Wilting Point and Saturation and is shown on **Figure 2-20**.

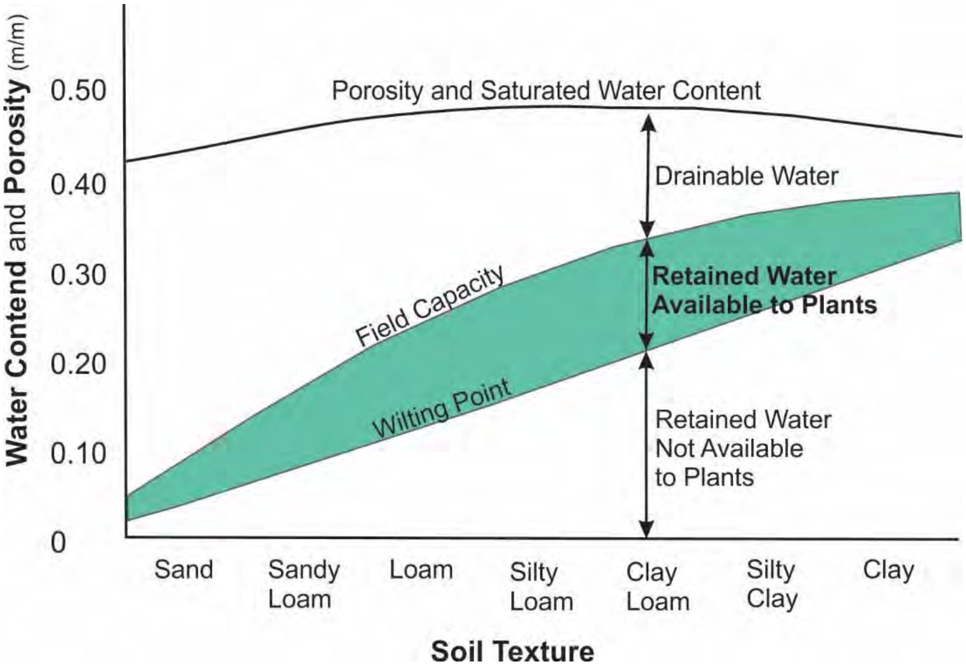


Figure 2-20 Soil Moisture Retention Capability

The water retention capacity of the soil is dependent upon the quantities of sand, silt and clay. A soil composed entirely of sand has a large drainable moisture content yet will not retain much moisture for plants. A clay soil will retain a large amount of water but it will not be available to plants. The best soil for retaining plant available water is one that contains a mixture of sand, silt, and clay in roughly equal amounts. The best soils are identified on **Figure 2-20** and their texture (content of sand, silt, and clay) can be seen on **Figure 2-19**.

This information confirms the common knowledge that sandy soils retain very little water and that they dry out quickly following a storm. Also confirmed are the best soil types for retaining soil moisture for use by plants are soils with a mixture of silts, clays, and sand. The soils which retain the most plant available moisture are within the textural classifications of Loam, Silty Loam, Clay Loam, and Silty Clay. These soils retain moisture for plant use while allowing the excess to drain quickly thus avoiding excessive durations where the root zone is saturated and plant damage can occur.

2.11 Soil and Water Transmission

Important hydrological differences relate to how rapidly water flows through the soil and how much water can be retained by the soils which is a function of the soil texture (the blend of sand silt and clay). This information is important in establishing the hydrology of the area and ultimately in sizing mitigation measures to manage environmental impacts of urban development. The range of the rate of flow water through the soils have been provided in the *Soils of Southeast• Vancouver Island Duncan-Nanaimo Area*, MOE Technical Report 15, J.R. Jungen, P.Ag., P. Sanborn, P.J. Christie, P.Ag., B.C. Ministry of Environment, June 1985. The Shelly Creek Watershed lies within that study area and it is reasonable to assume that the soils within the watershed share similar water transmissivity. The following definition of the rates were used in the noted report:

- **Very Slow** - The soil has very little if any water transmission. Generally fine textured soils dominate. Water transmission through the soil is less than 0.125 cm/hr.
- **Slow** - The soil has very little water transmission. Generally moderately fine textured soils such as clay loams and silty clay loams dominate. Water transmission through the soil is 0.125 cm/hr. to 2.5 cm/hr.
- **Moderate** - There is good water transmission. Generally medium-textured soils such as loams and silt loams dominate. Water transmission through the soil Is 2.5 cm/hr to 12.5 cm/hr.
- **Rapid** - The soil water transmission is too great for optimum growth. Generally moderately coarse-textured soils such as sandy loams and gravelly loams dominate. Water transmission through the soil is 12.5 cm/hr to 25 cm/hr.
- **Very Rapid** - Excessive water transmission throughout the soil. Porous, coarse-textured soils such as sands and gravels

dominate. Water transmission through the soil is greater than 25 cm/hr.

The water transmission rates identified in the noted report range from slow to rapid within the study area while for a majority of the soils within the Podzolic and Brunisolic Orders a slow rating is applicable. The rate of infiltration would be from 0.125 cm/hr. to 2.5 cm/hr. For this study we have used and average of the slow rate of 1.3 cm/hr or 13 mm per hour.

2.12 Water Transmission versus Permeability

It is important to identify the difference between the rate of infiltration and permeability. These terms are often mistakenly and incorrectly used.

Infiltration is a measure of downward rate of water movement through the air-soil interface with the soil seldom being saturated.

Permeability is a measure of the conductibility of a saturated soil and is defined by Darcy's Law where

$V = K (\Delta h / L)$, *velocity (m/s), where*
K = *hydraulic permeability, (m/s)*
L = *flow path length, (m)*
Δh = *change in hydraulic head* ($h_{in} - h_{out}$) *over the distance L, (m)*

and $Q = VA$, *discharge rate of a measured volume over a time* (m^3/s)
A = *flow area perpendicular to flow path L,* (m^2)

Permeability can be determined through laboratory testing as shown in **Figure 2-21** where flow rate and distances are measured.

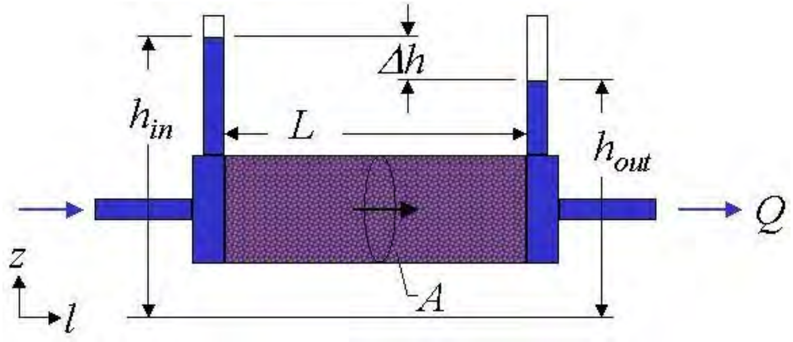


Figure 2-21 Permeability Test

It is clear that permeability cannot be a measure of infiltration in spite of the similar units of measure used to describe its properties.

2.13 Water Balance Of Shelly Creek Watershed

The previous compilation of watershed information included climate, water gauging, geology, hydrogeology, surficial soils, soil physics, and pedology provides an encompassing base of knowledge that allows us to develop the water balance within the watershed. That means delineating the flow paths to describe how and where precipitation falling from the sky will pass through the watershed. As the primary concern is flow in the stream we can divide the flow paths into major and minor flow paths defined by similar process.

If we assign precipitation as being 100% then we saw that stream flow was approximately 80%, and evaporation and transpiration would account for approximately 20% of the total.

Of the water that reaches the stream; surface runoff to the stream was approximately 10% of the total. The amount of precipitation reaching the aquifer was approximately 10% and if we assume all of it reaches the stream rather than passing beyond the bounds of the watershed.

The identified flow paths and relative volumes do not add up and the amount that has yet to be assigned must represent the discharge through the shallow interflow system that is located immediately below the ground surface. This then represents approximately 60% of the total precipitation which flows to Shelly Creek.

A summary of the approximate annual water balance in the Shelly Creek Watershed is shown in **Table 2.4**.

Table 2.4 – Annual Water Balance of Shelly Creek Watershed

Flow Path	Total (mm)	Total (%)
Precipitation	**1,170**	**100**
Evaporation and Transpiration	**235**	**20**
Stream Flow	**935**	**80**
Surface Runoff	115	10
Aquifer Recharge / Discharge	120	10
Interflow	700	60

The interflow system has been identified as a critical flow path within the watershed yet it is not well understood. This can be seen as a case of out of sight and out of mind where there is an assumption that any water that infiltrates into the ground will eventually end up in the stream. However if we consider the soil physics of water flowing through soil and the evidence of the pedology (soil formation process) then it is obvious that the interflow system is very fragile and subject to unintended damage.

The interflow system is very shallow, typically less than 1 m from the ground surface. Flow within the interflow system can readily be intercepted by simply building a road and ditch to improve the drainage of a land parcel. The ditch will allow the interflow to be intercepted and will thus allow the water to be collected and diverted to the stream much quicker than would naturally occur, within a few days rather than over the course of a season. While this does not increase the peak discharge to the stream it does reduce the discharge in Shelly Creek within a few days of dry weather and far sooner in a dry period such as occurs each summer.

2.14 Recommendation

We recommend that the Water Balance Methodology be used within this watershed and others within the RDN to establish the watershed targets and estimates of predevelopment flood discharges that will be used within the Regional District. This process will assure a standardized approach and eliminate the repeated costs to home owners, house builders, and developers for undertaking the necessary analysis while completing projects within the RDN.

3. CHANGES IN THE WATERSHED

Alteration of the watershed condition can be viewed as those that have occurred in the past and those that are anticipated to occur in the future.

3.1 Historical Alterations of the Watershed

A series of changes have been occurring during the recent past, approximately the past fifty (50) years.

A view of the watershed in 1968 can be seen on **Figure 3-1** where the alterations in the watershed include:

- Forest harvesting and regeneration of various ages,
- Clearing and farming in the lower reach where some channelization is evident,
- The road, rail, and hydro R-O-W's and associated construction, and
- Urban development in the Errington area south of the Alberni Highway plus the associated roads and ditches.

A second view of the watershed is the condition in 1992 can be seen on **Figure 3-2** where the alterations include:

- Construction of the Island Highway,
- Additional development in the Errington area, and
- Additional logging activities.

A third view of the watershed condition in 2015 is shown on **Figure 3-3** where further changes include:

- Urbanization of the agricultural lands in the lower watershed,
- Urban development of the forested area in the lower watershed,
- Additional rural development in the Errington area and to the north of the Island Highway. The rural developments include roads and ditches that divert the flow of water in addition to the increase in impervious surface area.

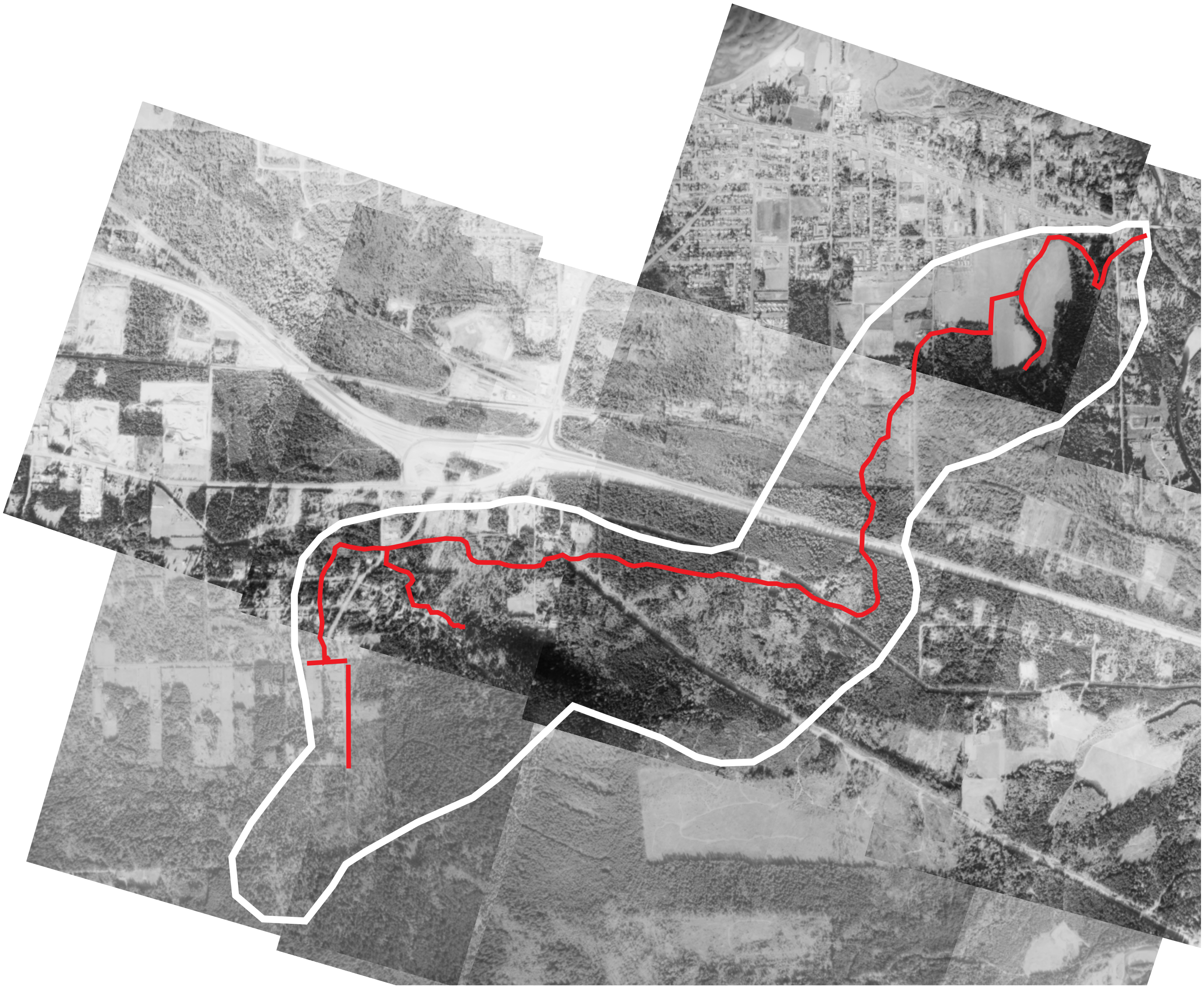
Changes of the of the watershed surface has also resulted in alterations to the boundary of the watershed when surface flows have been diverted by ditches and the grading associated with road construction and urban development. The alteration of the watershed boundary is shown on **Figure 3-4** and the alterations include:

- Rural development in the Errington area and construction of the Island Highway has added approximately 67 ha to the watershed area,
- Urban development in Parksville has diverted the flow from approximately 14 ha to drainage systems outside of the watershed, and
- Urban development in Parksville has added the drainage of approximately 1 ha to the watershed.

The original watershed area was 521 ha, with the additions and diversions the resulting Shelly Creek Watershed is now 575 ha.

▬ Shelly Creek Watershed

Watershed of 1968
Figure 3 - 1



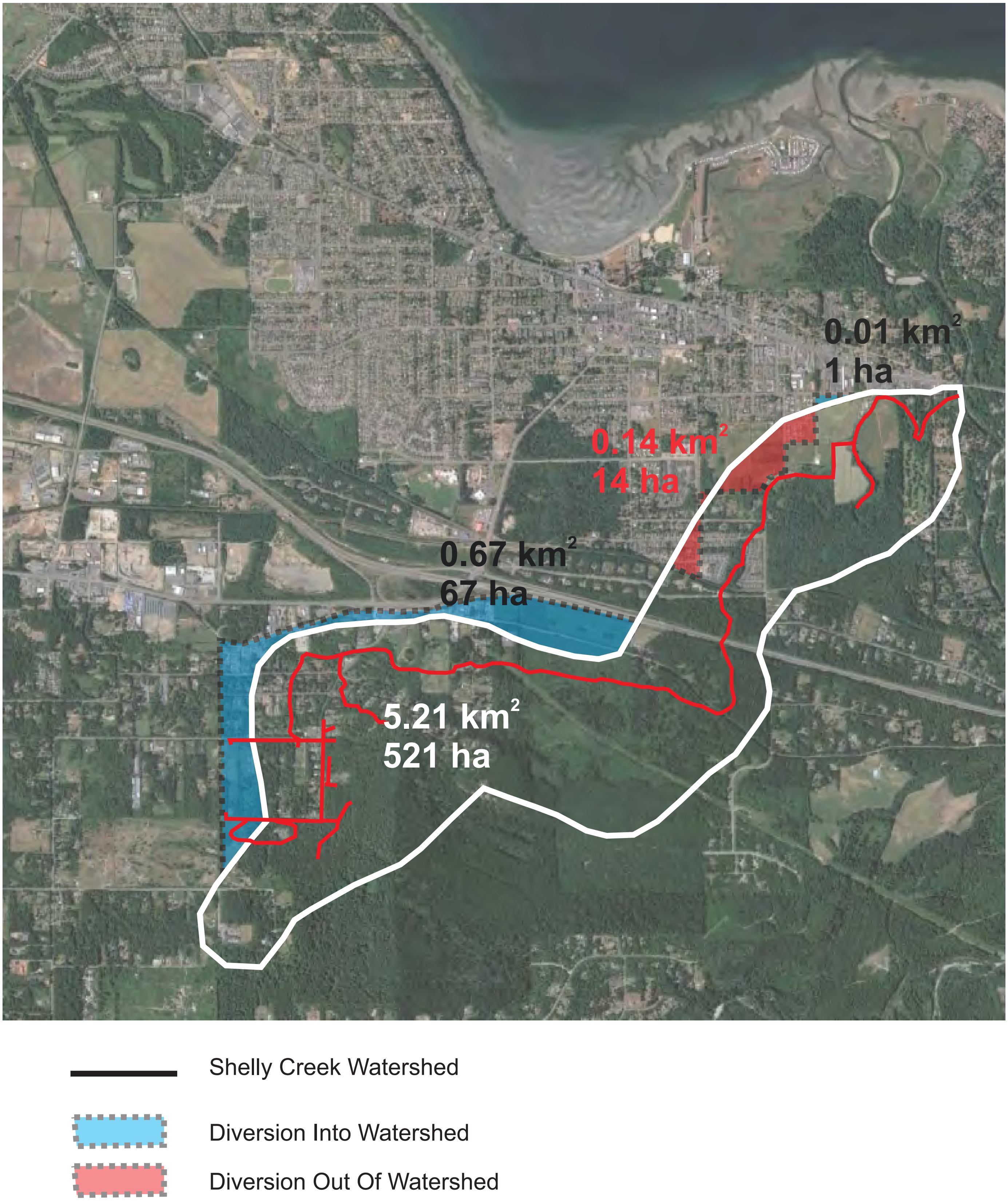
▬ Shelly Creek Watershed

Watershed of 1992
Figure 3 - 2

▬ Shelly Creek Watershed

Shelly Creek Watershed Plan

Shelly Creek Watershed
Figure 3 - 3



Shelly Creek Watershed Plan

Watershed Boundary Changes

Figure 3 - 4

The Shelly Creek watershed has been subjected to a series of human caused alterations, especially during the past 50 years. The original watershed was 521 hectares, and now with diversions, it is now 575 hectares. Future development is restricted by the Official Community Plans created by the City of Parksville and the Regional District of Nanaimo (for the two electoral districts)

3.2 Anticipated Future Watershed Alterations

Planning for future land use changes has occurred within both the City of Parksville and the Regional District of Nanaimo. Information regarding the visions has been included with Official Community Plans (OCP) that were created by both local governments. It is important to note that all of the watershed has been designated to be a part of Planning Zones that are defined in the Bylaws of the local government. The definition and allowed uses of the Planning Zones identified and the documents governing the land use zoning, specifically the local bylaws are identified in **Appendix A**.

The future of the watershed as envisioned by the City of Parksville has been documented within their OCP and is shown on **Figure 3-5**. A majority of the development in the Shelly Creek watershed within the City has already occurred with the following exceptions:

- The lowest reach of the watershed is designated Tourist Commercial. This area comprises the low lying wetland to the east of Martindale Road.
- A pocket of Single Unit Residential to the west of Martindale Road and south of Despard Avenue,
- Consolidation and redevelopment of properties south of Butler Avenue and east of Corfield Street into smaller footprint complying with Single Unit Residential zoning,
- A pocket of Transitional Residential located east of Bower Road and south of Stanford Avenue appears to have been allowed to extend beyond the limits as shown on the OCP map.
- The Agricultural Zone is not being completely used for farm production and could be cleared in the future to expand farm operation within the property.

The future of the Shelly Creek Watershed within the Regional District of Nanaimo is described within two OCP documents; the first the OCP for Electoral Area G, and the second being the Electoral Area F OCP.

The future vision of Electoral Area G includes portions of the Shelly Creek Watershed as shown on **Figure 3-6**. Some of the development and surface changes have already occurred however, a majority of the envisioned changes have yet to occur. The future changes include:

- Commercial and Rural Residential development along Martindale Road,
- Rural Residential 2 along Corfield Street south of Stafford Avenue,
- Rural to the east of Corfield Street,

- Rural Residential 2 along Butler Avenue east of Corfield Street, and
- Rural Residential 2 east of Butler Avenue south of the E&N Rail line,

The anticipated changes in the Shelly Creek Watershed land within Electoral Area F have already occurred. Shown on **Figure 3-7** are large areas have been identified as being Park Lands, and Resource Lands within the Agricultural Land Reserve or the Forest Land Reserve.

Future development is restricted by the Official Community Plans created by the City of Parksville and the Regional District of Nanaimo (for the two electoral districts). The areas that have two significant development constraints which include:

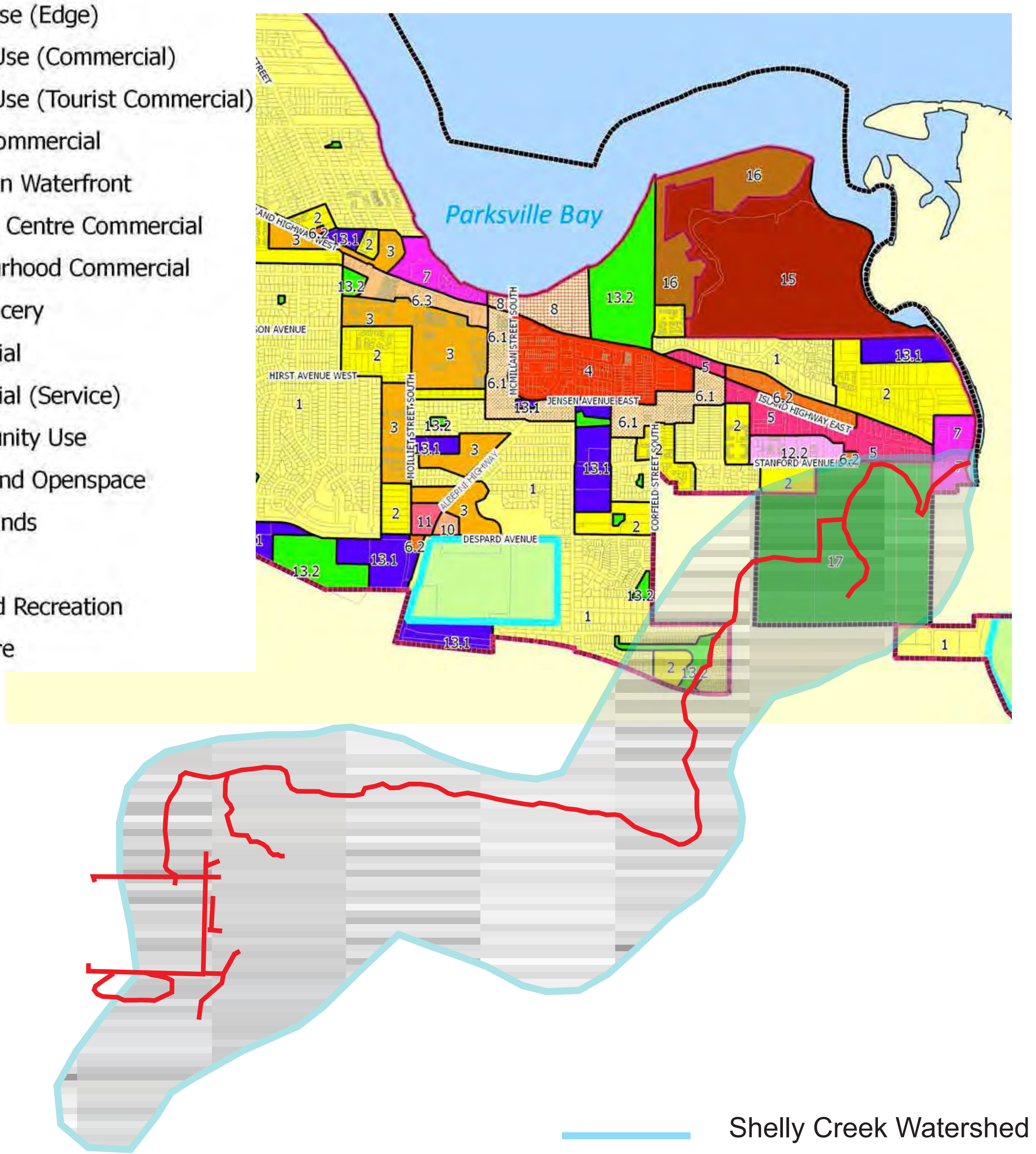
i. The Agricultural Land Reserve which is governed by the British Columbia Land Reserve Council. While the lands are subject to clearing and farming the potential for residential development can be considered to be minimal at this time. Although farming would generally retain the pervious surfaces there would be pressure by the property owners to enhance the drainage and to further alter the hydrology of the areas.
ii. The land use zone identified as Park within Electoral Area F would be subject to the any decisions of the RDN to modify the zoning or the land types and configuration of land surfaces within the area.

The future land use of the watershed is subject to decisions made by the City of Parksville and the RDN.

MVIHES
MID VANCOUVER ISLAND HABITAT ENHANCEMENT SOCIETY

Future Landuse Designation

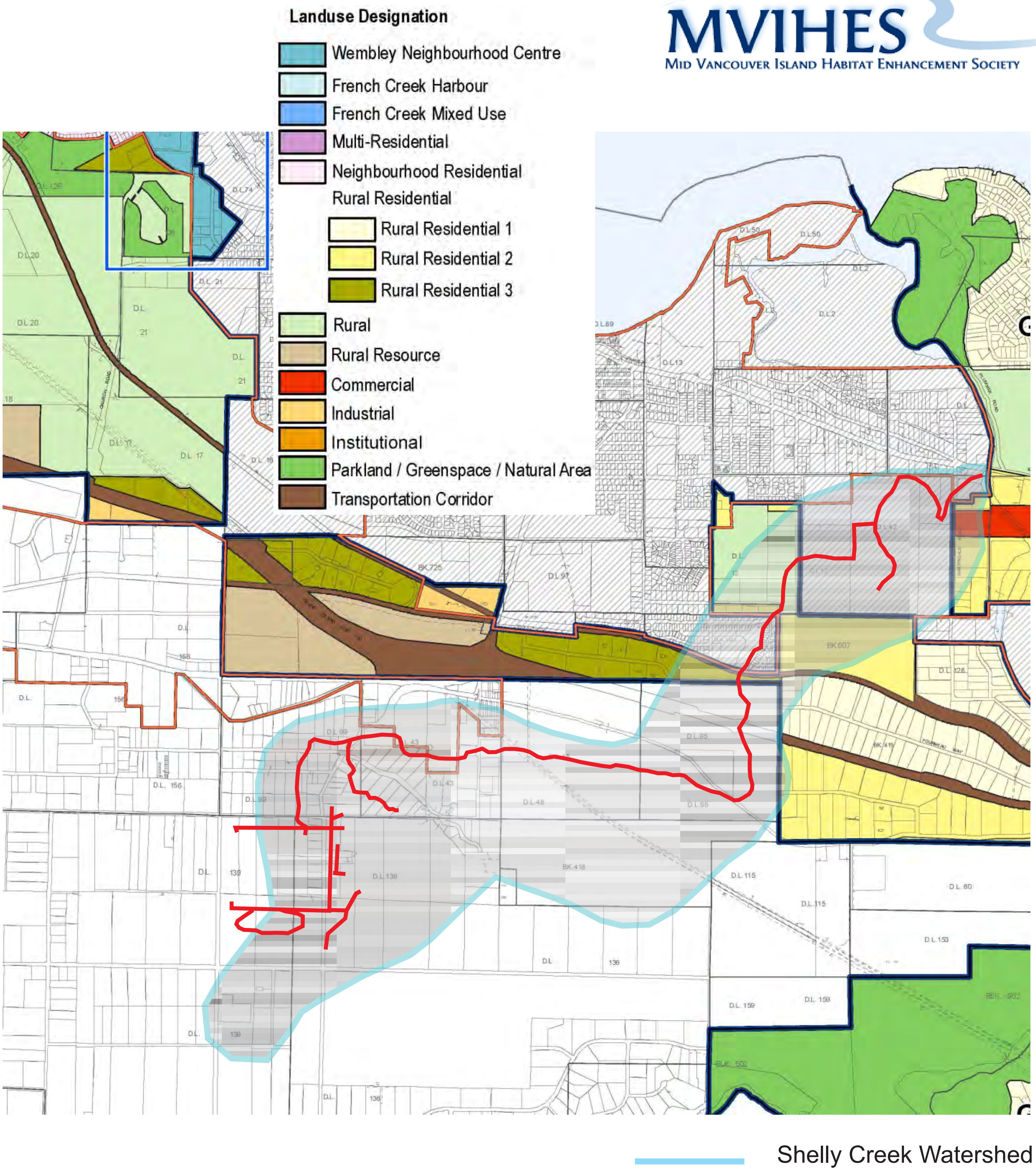
🟨 01 - Single Unit Residential
🟨 02 - Transitional Residential
🟧 03 - Multi-Unit Residential
🟥 04 - Downtown Core
🟥 05 - Commercial
▨ 06.1- Mixed Use (Edge)
🟧 06.2 - Mixed Use (Commercial)
🟧 06.3 - Mixed Use (Tourist Commercial)
🟪 07 - Tourist Commercial
▦ 08 - Downtown Waterfront
⬜ 09 - Shopping Centre Commercial
🟧 10 - Neighbourhood Commercial
🟥 11 - Local Grocery
🟪 12.1 - Industrial
🟪 12.2 - Industrial (Service)
🟦 13.1 - Community Use
🟩 13.2 - Parks and Openspace
🟩 14 - Resort Lands
🟥 15 - Estuary
🟫 16 - Restricted Recreation
🟩 17 - Agriculture



Shelly Creek Watershed Plan

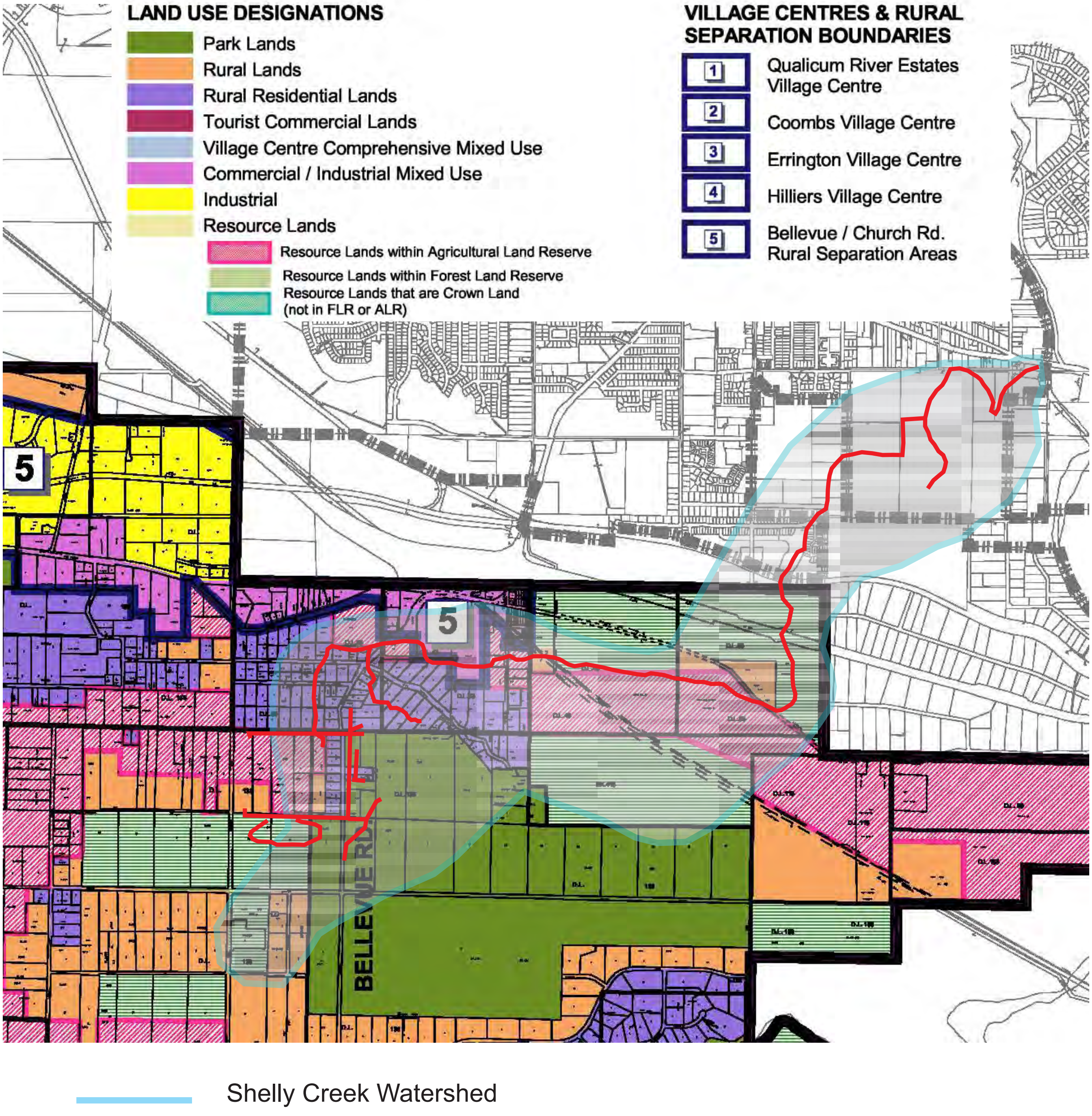
Parksville -OCP
Figure 3 - 5

MVIHES
Mid Vancouver Island Habitat Enhancement Society



Shelly Creek Watershed Plan

Electoral Area G -OCP
Figure 3 - 6



Electoral Area F -OCP
Figure 3 - 7

3.3 Sensitive Ecosystems Inventory

The information and mapping of sensitive ecosystems has been extracted from “Sensitive Ecosystems Inventory: East Vancouver Island and Gulf Islands, 1993 - 1997. Technical Report Series No. 320, Canadian Wildlife Service, Pacific and Yukon Region, British Columbia”. The information specific to the Shelly Creek Watershed is shown on **Figure 3-8** and summarized in the following sections describing individual ecosystem classifications.

The report indicates that the polygons were identified on air photos and while some were field verified, a majority have not been visited. Only three of the polygons have been visited and these include:

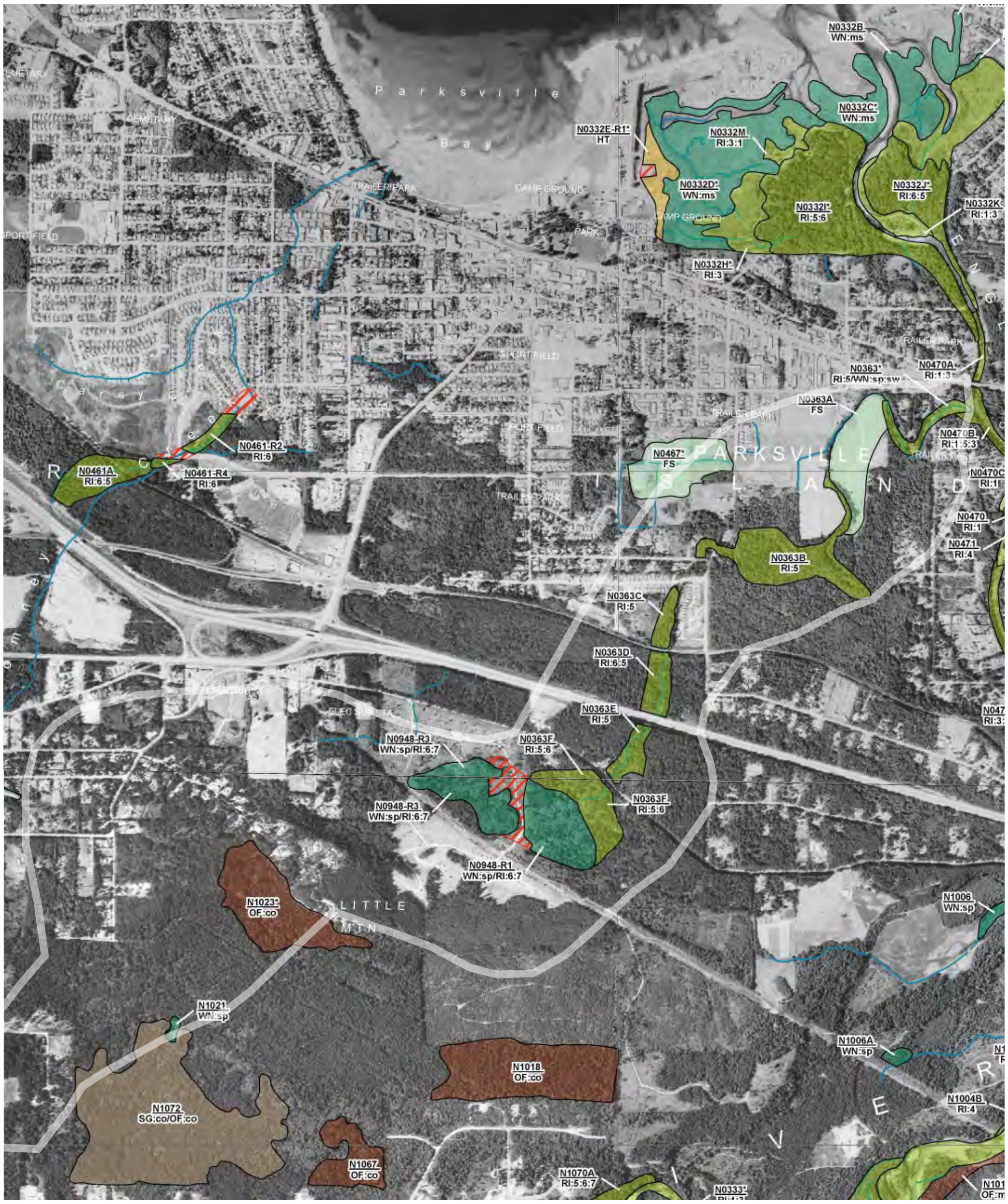
N0363*	a riparian area at just above the confluence with the Englishman River,
N0467*	a seasonally flooded agricultural field along the lower reach of Shelly Creek, and
N01023*	an older forest in the upper most portion of the watershed.

3.3.1 Riparian (RI)

A riparian ecosystem, as identified for this project, is a distinct ecological system and is not to be confused with the term riparian zone. A riparian zone describes a fixed width management area surrounding streams and wetlands, with no consideration of ecological boundaries. Riparian ecosystems vary in width, from less than one metre adjacent to a small stream with steep banks to more than 100 metres near large rivers, and are delineated by site-specific vegetation, soil, and elevation features.

For the SEI, riparian ecosystems are classified according to seven structural stages. Abbreviated descriptions of each structural stage are given below:

RI:g	riparian gullies that are often a complex of more than one stage because of their highly dynamic nature; the dominant stage is listed first (e.g., RI:4:5:6:g)
RI:1	Sparse/bryoid - moss and lichen dominated, <10% treed, <20% shrub/herb.
RI:2	Herb – herb dominated, <20% shrub, <10% treed.
RI:3	Shrub/herb – >20% shrub, <10% treed.
RI:4	Pole/sapling – trees >10 m tall, densely stocked, 10 - 40 years old.
RI:5	Young forest – self-thinning evident, 40 - 80 years old.
RI:6	Mature Forest – 80 - 250 years old.
RI:7	Older forest - >250 years old.



— Shelly Creek Watershed

Source: Sensitive Ecosystems Inventory:
East Vancouver Island and Gulf Islands
1993 - 1997

Sensitive Ecosystems Inventory
Figure 3 - 8

3.3.2 Seasonally Flooded Agricultural Field (FS)

Seasonally flooded agricultural fields (**FS**) are lands that have been modified for agricultural use but have important wildlife habitat value during specific times of the year. They are located primarily in low-lying areas such as the valley bottoms and deltas of large alluvial rivers and creeks. In some cases they are found on moisture-receiving sites, usually in association with lake shores, or lowlands adjacent to coastal bays. They are often former wetlands and in many cases are located adjacent to surviving wetlands such as marshes, swamps, and wet meadows. These sites form part of a ‘wetlands complex’, in conjunction with nearby freshwater marshes and the coastal estuarine marshes that are important to wintering waterfowl.

Winter flooding occurs naturally with poor drainage or constant seepage contributing to a gradual rise in the water table during the winter rainy season. This natural flooding provides an ideal mixture of shallow water, stubble, waste grain and produce, weed seeds, and invertebrates that provide habitat for wintering waterfowl.

3.3.3 Wetland (WN)

Wetland ecosystems are among the most productive environments in the world. Six classes of wetland are recognized for this project:

WN:bg	Bog,
WN:fn	Fen,
WN:ms	Marsh,
WN:sw	Shallow Water,
WN:sp	Swamp, and
WN:wm	Wet Meadow. They occur where the water table is at, or near, or above the soil surface and soils are saturated for sufficient length of time that excess water and resulting low soil oxygen levels are principal determinants of vegetation and soils development.

Some wetland categories are difficult to distinguish on air photos and so it is possible that, for example, an unvisited polygon marked as a marsh/open water complex might actually be a fen/open water complex. Swamps (**WN:sp**) may be over represented due to the fact that this sub-class was assigned to polygons during the air photo interpretation phase when a wetland classification was uncertain. A field inspection is the only way to confirm these classifications.

There is a discrepancy between the information provided by the surficial soils mapping and the information contained within the sensitive ecosystem inventory. Confirmation of the occurrence of the swamp within the upper portion of the Shelly Creek watershed may be important in formulation of the possible mitigation strategies.

3.3.4 Older Forest (OF)

Older forest is not necessarily old-growth forest. Whereas definitions of ‘old-growth’ vary by jurisdiction, it is often related to the lack of large scale human disturbance and a specific size or age of trees. Most remaining older forests in the SEI study area have been influenced by some form of harvesting. The minimum age of 100 years for this ecosystem type was selected because many of the features associated with high biodiversity values in older forests begin to develop after 80 years. Two categories are identified for this project:

OF:co	coniferous stands and
(OF:mx)	coniferous stands composed of more than 15% deciduous trees.

3.3.5 Older Second Growth Forest (SG)

Two categories of older second growth forest ecosystem are identified for this project: large stands of conifer-dominated forest between 60 and 100 years old with less than 15% deciduous trees (**OF:co**) and those with more than 15% deciduous tree cover (**OF:mx**). All older second growth forests have been influenced by logging or other human disturbance since settlement of Vancouver Island and the Gulf Islands began in the middle of the 19th century.

4. CORPORATE AUTHORIZATION

This document entitled:

Shelly Creek Water Balance
and
Sediment Reduction Plan

Phase 1 – Physical and Environmental Investigations

Client Name:

Mid Vancouver Island Habitat Enhancement Society

Was prepared by:

J.M.K. (Jim) Dumont, P.Eng., P.Ag.

It is intended solely for the use of the individual, company, government or other entity for which this document was prepared, and for the purposes and within the limitations stated in the document. The material in this report reflects the best judgement of J.M.K. (Jim) Dumont, P.Eng., P.Ag. in the light of the information available at the time of preparation. Any use of, or reliance placed upon, the material contained in this report by third parties, or decisions based upon this report are the sole responsibility of those third parties. J.M.K. (Jim) Dumont, P.Eng., P.Ag. accepts no responsibility for damages suffered by any third parties as a result of decisions made, or actions taken, based upon information contained within this report. Duplication or distribution of this report or any portion hereof is forbidden and requires approval from the client and J.M.K. (Jim) Dumont, P.Eng., P.Ag.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
J. M. K. DUMONT

June 23, 2017

Professional Seal

Appendix A Land Use Zoning

City of Parksville –

Zoning and Development Bylaw, 1994, No. 2000
Division 200 Zoning District Schedules

- Single Unit Residential
- Agricultural
- Tourist Commercial
- Transitional Residential

Available at https://parksville.civicweb.net/filepro/documents/19699

Regional District of Nanaimo

Land Use and Subdivision Bylaw No. 500

- Agriculture
- Commercial
- Rural Residential

Available at http://www.rdn.bc.ca/dms/documents/rdn-bylaws/land-use-and-subdivision---bylaw-no.-500,-1987/full_bylaw_500_consolidated_version.pdf

Electoral Area ‘F’ Zoning and Subdivision Bylaw No. 1285, 2002

- Resource Lands
- Park Lands
- Rural Lands

Available at http://www.rdn.bc.ca/dms/documents/rdn-bylaws/electoral-area-f-zoning-and-subdivision-bylaw-no.-1285,-2002/full_bylaw_1285_consolidated_version.pdf