CRD Region-wide Infiltration Mapping Project Report

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1. PROJECT PURPOSE

The purpose of this project is to enable the Capital Regional District (CRD) assist local governments manage storm water runoff through the development of a reliable and consistent regional digital soil infiltration map and dataset.

2. BACKGROUND AND INTRODUCTION

With the onset of climate change it is predicted that the west coast of Vancouver Island will experience an increase in extreme weather events, from long dry summers to severe winter rain storms. This change in climate is putting pressure on communities around the Capital Region to better manage their water resources, including rainwater capture and release. The effective management of rainwater will enable these communities to work together to better manage flooding as well as ground water and aquifer replenishment.

This project provides the CRD with a solid foundation upon which to plan and manage storm water runoff. This includes a rationalised and integrated soils dataset along with a derived regional soil infiltration map to enable planning and management at both the strategic and operational levels. The supporting tables and models used to develop the soil infiltration map have intentional built-in versatility. This versatility enables their use for other CRD and local government initiatives, including urban development, environmental and wildlife management, and land use planning. As well, this 'tool' can be applied to better understand the cumulative effects of land use changes on regional water retention and runoff.

Project Objectives

The primary objectives for the project were to:

- Deliver a infiltration potential digital map depicting rainwater runoff
- Create most current and accurate seamless digital soils data layer
- Comply with Provincial data/mapping standards, where possible
- Develop an infiltration model based on recognised/cited models

Project Scope

Develop a regional infiltration potential digital map, using the methodology and tables provided by the CRD, to depict the infiltration capacity of the soil and storm water runoff for the CRD and surrounding areas, as outlined in Appendix A.

3. PROJECT APPROACH

The project approach, the data, the models, and the infiltration tool are all based on current jurisdictional and professionally-adopted standards. The primary models and conversion tables used in this project are those cited by the CRD project team. However, these models and tables have been modified slightly for consistency with provincial and national soils classification standards. Consistency with provincial and federal classification and data standards enables the development of products that facilitate ease of data and model integration for regional planning and management purposes.

Fundamental to the project's success was the need to acquire the best available (most accurate and detailed) soils information for developing the look-up tables and ultimately the infiltration model. Having the best soils data provides the ability to use the data for other purposes. Several soils, surficial geology, and geology maps reviewed, including the 1:100 000 soils map produced in 1959, and soils mapping available at the Ministry of Energy and Mines data warehouse, called Map Place http://www.empr.gov.bc.ca/Mining/Geoscience/MapPlace/Pages/default.aspx

4. DATA ACQUISITION AND INTEGRATION

Upon reviewing the various soil mapping options, the decision was to go with the Provincial Comprehensive Soils Dataset (CSD)[1]. The reason is because these data are the most current and accurate (included 1:20 000 and 1:50 000), provide the greatest coverage, conforms to provincial data standards, and will therefore be compatible with current and future soils data. The CSD was established as the primary dataset and, as such, all naming conventions, data capture standards, and structures have been mirrored.

The only area not covered by the CSD was the Victoria core. The two options considered for filling this data gap were the 1:100 000 1959 Soils Map and the 1:25 000 Quaternary Geological Map of Greater Victoria. The latter option was selected because it provides greater polygonal detail. However, the 1959 Soils Map along with the CSD were referenced in developing the soils to geology crosswalk table.

The crosswalk tables and lookup tables (business rules) were established for integrating the 1:25 000 Quaternary Geological Map with the CSD, and the development of the Hydrological Soils Groups (HSG) for the various soil types in the region.

Geological to Soils Crosswalk Table

Building the crosswalk table (Appendix B) for integrating the 1:25 000 Quaternary Geological Map (QGM) was primarily based on the soil names and corresponding characteristics used in the CSD. The corresponding soil types were readily used in building the table; the biggest challenge was determining the proportion of associated soil type(s) within each QGM polygon. Although the 1959 Soils Map was considered rather course, the map and corresponding legend was referenced in developing the crosswalk table. Local soils professionals were also consulted.

[1] The CRD's project team endorsed the use of the CSD for the project.

5. HYDROLOGIC SOILS GROUP (HSG) AND INFILTRATION MODEL

Several hydrologic models were reviewed, including those cited by the CRD, to develop the infiltration/percolation model for the project. The models cited by the CRD's project team include: the MTO, TR-55, and a variation of the TR-55 for the CRD's Water Supply Area. These models identify the hydrologic grouping for each soil type primarily according to texture, and course fragment content or bulk density. In some applications of the models, the soil percolation rate (ksat) has also been used to determine the infiltration level within the HSG.

Although relatively simplistic, the HSG table is used extensively across the USA and Canada for models used to manage storm water runoff.

Hydrologic Soils Group (HSG)

The TR-55 model and the associate HSG table originates from the United States Department of Agriculture (USDA) Natural Resources Conservation Service Part 630 Hydrology National Engineering Handbook Chapter 7 Hydrologic Soil Groups, (210–VI–NEH, January 2009).

General description of the hydrologic soils groups in the HSG table are as follows:

Group A Soils. Have *low* water runoff potential, *high* infiltration and transmission rates, even when thoroughly wet. Group A soils are deep, well-drained to excessively well-drained, and typically have <10% clay and >90% sand. Soils having loamy sand, sandy loam, loam, or silt loam textures may be place in Group A if they are well aggregated, of low bulk density, or have >35% coarse fragments.

Group B Soils. Have *moderately low* runoff potential, and *moderate* water infiltration and transmission rates, even when thoroughly wet. These soils are generally moderately well to well-drained soils with loamy sand or sandy loam textures. The texture tends to be between 10% - 20% clay, and 50% - 90% sand. Soils having loam, silt loam, silt, or sandy clay loam textures may be placed in Group B if they are well aggregated, of low bulk density, or contain > 35% coarse fragments.

Group C Soils. Have *moderately high* runoff potential, and *slow* water infiltration and transmission rates, even when thoroughly wet. The soils tend to have restrictive layers that impede the rate of water movement in the soil. Group C soils typically have between 20% - 40% clay, and <50% sand. Soils having clay, silty clay, or sandy clay textures may fall in this group if they are well aggregated, of low bulk density, or have >35% coarse fragments.

Group D Soils. Have *high* runoff potential, and *very slow* water infiltration and transmission rates, even when thoroughly wet. This group is primarily made up of clay soils with a high swelling potential, permanent high water table, or impervious pan or clay layer at or near the surface. These soils typically have >40% clay and <50%sand, and contain <35% coarse fragments.

CRD Infiltration Model - Lookup Table
As mentioned above, the Infiltration Model for the CRD is based on the HSG that has been modified slightly to be more consistent with the provincial/federal soils classification standards. In particular, the proportions of sand, silt and clay ranges were adjusted in defining each hydrological soils group. There were no changes made to the course fragment content, soil permeability (ksat), or bulk density values defined in the cited models.

Data used in developing the model were extracted from the Provincial comprehensive soils database, which provide a breakdown of texture (sand, silt, clay), course fragment content, permeability, and bulk density by horizon. For purposes of this study, these physical characteristics for each soil horizon have been proportionately averaged for the upper 50 cm and the lower 50 – 100 cm. The averaged soils characteristics for the upper 50 cm have been applied against the modified HSG lookup table (Appendix C) to produce the infiltration model and resultant output map[2].

Additional conditions that were applied to determining the HSG value was permeability (ksat), and course fragment content. The permeability value was determined for those soils where the soils have a water table present between 60cm – 100cm during most of the year. These soils were given a permeability value as defined USDA's Hydrology National Engineering Handbook Chapter 7 Hydrologic Soil Groups, (210–VI–NEH, January 2009). This look up table is Appendix C.

The infiltration model output provides core water runoff planning and management information. However, the project team and soils/geoscience professionals consulted agree that the assumptions be documented, and that output from the model be augmented with additional pertinent data to support decision-making. These data are included in the dataset provided to the CRD, including:

- Drainage
- Parent material and general soil texture
- Rooting restricting layer
- Percolation and bulk density

Assumptions:
There are numerous factors that will impact water infiltration that are not included in determining hydrologic soils groupings. Assumptions include:

1. Vegetative cover: the infiltration will vary according to ground cover. For example:
    - The infiltration rate in a marine clay soils with be far greater (i.e. moderate, B) in a mature forest than a hay field (i.e. low, D); or similarly with established grass cover versus cultivated hay fields;

[2] This approach and criteria have been reviewed and endorsed by local and Provincial soils professionals, as well as a CRD geosciences professional (Sharon Scott).

2. Soil Structure: many of the soils in the CRD have been disturbed, which does destroy soils structure. Man-made areas of hard surfacing, compaction, and fill will reduce infiltration and through-flow rates.
3. LFH Horizon: this horizon is primarily a forest/vegetation litter layer at various stages of decomposition that has a moderate to high available water storage capacity, and a high water infiltration and transmission rate. These characteristics coupled with high nutrient holding capacity makes this horizon a crucial factor in rainwater management.
4. Bedrock type/age: the ancient bedrock in the area is fractured to varying degrees. Fracturing will increase the infiltration rates. Also, topography of bedrock can also create (mainly seasonal) upwelling of water in imperfectly drained and in saturated soils. For example, saturated sandy soils having a high infiltration rate (i.e. group A) can have upwelling where there is a lift in the bedrock causing the water moving through the soil to be forced to the surface.
5. Slope: infiltration rate is dependent on slope, i.e. steeper slopes contribute to increased run-off even in sandier soils (i.e. group A). Most lands in the CRD are sloping; during our heavy winter rains many soils saturate and water perches on the impervious layers causing water to flow on very gradual slopes (e.g. 3% to 7%).

6. DISCUSSION

The CRD Infiltration Tool for is intended as a decision support tool to enable improved planning and management of rainwater runoff. It has been built with versatility in mind, to enable it to be applied to other land and natural resource management purposes. The versatility also enables future refinement of the table/model to provide greater confidence in the output. Tools of this nature must be recognised as supporting relative objectivity to decision making, thereby establishing areas of required focus.

When running the infiltration model for the CRD area, one must consider the fact that there may be soil infiltration anomalies that are inconsistent with the dominant infiltration rates within defined polygons. The landscape and soils of Vancouver Island have been influenced by numerous surficial and pedogenic processes that have resulted in a very complex landscape. This means that even where there are dominant soil types there may be inclusions of very different soils. For example, the marine clay dominated landscapes (polygons) may have lenses of glacial fluvial outwash and ice-rafted sands and gravels.

Water does not flow through the soil (and bedrock) in an even manner. Considering downslope water flows within glacial till soils, the soil water usually finds cracks, large pores and old root channels. This is common in our forested lands and much of this ‘saturated soil’ water flows into small ephemeral streams and roadside ditches. The deeper percolation and flows into bedrock is variable and complex. Consider, for example inflow and outflow streams and ephemeral streams in rocky hill areas during high winter rainfall; i.e. the many small seasonal drainages seem to carry a fair amount of water for a distance, and then the water disappears.

7. RECOMMENDATIONS

The model provides an excellent relative measure of infiltration across the CRD, but it can be progressively refined. Although the best possible soils data have been used along with a refined HSG, more work should be done to improve the confidence in the infiltration model's output.

In order to improve the model, we would recommend the following:

1. Leverage data being captured through drilling of wells. This is a great opportunity to provide ground truthing. The soil characteristics that impact water infiltration and transmission need to be captured from 0 – 50cm, and for 50 – 100cm. At this time, soils data capture is inconsistent and not necessarily available for the first 100 cm.
2. Fine tune the infiltration model. There are ongoing efforts by the Province and Federal government to improve their soils (as well as other relevant) data that should be incorporated into the model. There is an opportunity to establish a data exchange agreement among the levels of government.
3. Use the infiltration model output in conjunction with additional qualifying data and information. Additional data has been provided by the consultants that will provide the ability to integrate additional soil characteristics into a refined model to enable visual analysis. Other factors that should be considered and can be easily integrated include:
   - vegetative cover
   - slope – the CRD's detailed slope classes
   - land use

SCOPE – STUDY AREA

As identified in the CRD's RFP, the lands in-scope for the regional infiltration map are the core areas of the CRD including:

1. Langford, Colwood, View Royal, Esquimalt, Saanich, Victoria, Oak Bay, Esquimalt First Nation & Songhees Nation (not including Chatham & Discovery Islands); see quick reference map for 1 & 2
2. All of the Saanich Peninsula (Highlands, Central Saanich, North Saanich, Sidney, JDFEA (small part by Brentwood bay/Todd Inlet) peninsula], Tseycum Nation, Pauquchin Nation, Tsarlip Nation and Tswaout Nation)
3. All Southern Gulf Islands and Salt Spring Island; see quick reference map
4. All of Sooke, and the communities/land areas within OCPs of JFEA (East Sooke, Malahat, Otter Point, Port Renfrew, Shirley & Jordan River, Willis Point and the JFEA Rural Resouces Lands), Pacheedaht First Nation, T'Souke Nation, Scia'new First Nation; see quick reference map

Geo-logy	Soil Name 1	%	Soil Name 2	%	Parent Mat	Quarternary Geology Description
VICTORIA CLAY						
C1	Tagnar	60	Saanichton	40	marine	Greater than **5 metres of Victoria clay**, but where the thickness of the lower grey clay facies is less than 3 metres. In regions of poor subsurface control, the unit is commonly assigned to areas of sloping ground between units R2 and C2, and to small low-lying areas tha cannot be confidently mapped as unit C2
C2	Tagnar	50	Saanichton	50	marine	THICK SOFT CLAY: More than **3 metres of the grey clay** facies of the Victoria clay. The thickness of the grey clay facies is commonly greater than 10 metres
C2a	Saanichton	60	Tagnar	40	marine	Lower slopes of the **Colwood delta are overlain by the Victoria clay**. Little is known about the thickness or geotechnical properties of the Victoria clay in these areas. However, the land is low-lying and organic soils locally occur at surface (unit O1), indicating that thicknesses of sof clay greater than 3 metres could be present.
C3	Saanichton	85	Quamichan	15	marine	THIN CLAY OVER THICK OLDER PLEISTOCENE DEPOSITS: This unit occurs in areas with less than 5 metres of **Victoria clay overlying older Pleistocene deposits** greater than 10 metres thick. It generally occurs on the upper flanks o drumlinoid ridges.
C4	Saanichton	70	Tagnar	30	marine	INTERMEDIATE BETWEEN UNITS C3 AND C5, INCLUDING UNDIFFERENTIATED AREAS: This map unit includes areas with more than **5 metres of Victoria clay but less than 3 metres of the grey clay** facies
C4a	Saanichton	70	Tagnar	30	marine	Consists of **more than 5 metres of Victoria clay but less than 3 metres of the grey clay** facies. The only area assigned to this unit is located in a gentle depression on the top of a Pleistocene drumlinoid ridge in the vicinity of the University of Victoria
C4b	Saanichton	70	Tagnar	30	marine	**Areas of sloping ground** with poor subsurface control between units C3 and C4. In this map unit, the **Victoria clay overlies thick older Pleistocene deposit**s and may be greater than metres, but the thickness of the **grey clay facies is interpreted to be less than 3 metres.**
C5	Tagnar	80	Saanichton	20	marine	UNIT C5; THICK SOFT CLAY OVER THICK OLDER PLEISTOCENE DEPOSITS: This unit consists of Victoria clay with more than 3 metres of the grey clay facies overlying older Pleistocene deposits thicker than 10 metres. It occupies small low-lying areas on the crest and flanks of the drumlinoid ridge at the University of Victoria

FILL						
F	MD				FILL	FILL - Only the larger and thicker deposits of anthropogenic fill of which the authors are aware are included in this map unit. The principal areas are **shoreline settings and reclaimed gravel pits**. The thickness of fill can exceed 1 metres
FC1 FC2					FILL	Unit FC1 is assigned to areas where fill overlies unknown or variabl thicknesses of Victoria clay (unit C1) Unit FC2 is assigned to areas where fill overlies unit C2. In shoreline settings, fill may overlie soft Holocene marine mud that in turn overlies the Victoria clay, in which the brown and grey clay facies are both present.
FR2					FILL	Unit FR2 is assigned to areas where fill overlies bedrock or thin native soils (unit R2). **** Poor structure in soil = uncosolidated soil - tendency to compact**
Colwood Sand and Gravel						
G4	Beddis	50	Chemainus	50	Glacial Fluvial	GLACIOLACUSTRINE DEPOSITS MARGINAL TO THE COLWOOD DELTA: This unit occurs in small valleys adjacent to the Colwood Delta anoutwash plain. Borehole control in these areas is poor. Where Highway 1 crosses Millstream Creek, a borehole encountered 14 metres of stiff silt and clay with interbedded compact to dense sand, overlying 3 metres of very dense gravelly till. Downstream, thinly bedded to laminated fine sand and silt were observed in a small exposure. The surface expression of this unit is flat or gently sloping, as in Millstream Creek valle
G3	Beddis	80	Chemainus	20	Glacial Fluvial	GLACIOFLUVIAL CHANNEL: Colwood delta outwash plain in the vicinit of Colwood Creek. Sediments consist of fine sand and silt a few metres thick, and elsewhere the deposits are interpreted to be finer. Parts o the channels are filled with peat and are assigned to map unit O3.
G2	Beddis	50	Quamichan	50	Glacial Fluvial Fluvial	SAND AND SILT OF THE COLWOOD DELTA: Primarily interbedded silt and sand that are interpreted to be distal and lateral deposits of the Colwood delta, overlain by a few metres of the brown clay facies of the Victoria clay. In most areas it forms a regularly sloping surface that descends from the surface of the Colwood delta and outwash plain.
G1	Ragbark	50	Quamichan	50	Glacial Fluvial	SAND AND GRAVEL OF THE COLWOOD DELTA AND OUTWASH PLAIN: Interbedded sand and gravel outwash plain (Colwood), 60 and 90 metres elevation. Thickness of these deposits is 30 metres. Silts occur locally in abandoned channel deposits. Happy Valley Road outwash sand and gravel are overlain by 1 to 2 metres of silt.
HOLOCENE PEATS						
O1	Metchosin				organic	PEAT OVER SOFT CLAY: This map unit is defined as Holocene peat and organic soil overlying the Victoria clay. The thickness of peat varies from less than 1 metre to a maximum known thickness of metres immediately northwest of the Saanich Public Works Yard

O2	Metchosin				organic	UPLAND PEAT: This unit consists of upland peat deposits above 60 metres elevation. The **peats in this unit are commonly less than a few metres** thick, but locally exceed 5 metres. In boreholes, these deposits have been observed to overlie up to 3 metres of soft clayey silts and sands
O3	Metchosin				organic	PEAT OVER SAND AND GRAVEL OF THE COLWOOD DELTAAND OUTWASH PLAIN: This unit consists of peat deposits overlying sand and gravel of the Colwood delta and outwash plain. Peat deposits are generally less than 4 m thick, but locally reach 7 metres. These deposits occur in low-lying areas on the delta
O3a	Metchosin				organic	Closed depressions, mainly interpreted to be kettles, on the surface of the Colwood delta and outwash plain and in which peat may occur.
O4	Metchosin				organic	HOLOCENE PEAT OVER GLACIOLACUSTRINE DEPOSITS: This unit consists of peat overlying glaciolacustrine deposits marginal to the Colwood delta a outwash plain (unit G4). The presence of peat is documented in soil surveys (Day et al., 1959 Jungen, 1985)
O5	Metchosin				organic	PEAT OVER HOLOCENE BEACH SAND: This unit is assigned to areas where peat overlie Holocene sand in a shoreline setting. At Cadboro Bay, where borehole data are available, the peat unit is 2 to 6 metres thick and the underlying sand is 3 to 9 metres thick. These deposits in turn overlie over 30 metres of Holocene marine mud and the grey clay facies of the Victoria clay
BEDROCK AT or NEAR SURFACE						
R1	RO	90	Sprucebark	10		BEDROCK: This unit consists of **nearly continuous outcrop** and generally occurs in hilly and mountainous areas.
R2	Somenos	70	Sprucebark	30		THIN SOIL COVER WITH SCATTERED BEDROCK OUTCROP: **Generally includes areas with less than 5 metres of Victoria Clay overlying thin older Pleistocene deposits or bedrock.** Scattered **outcrops** occur throughout, and bedrock is commonly found in the upper few metres. Older Pleistocene deposits in most places is < a few metres; up to 10 m in areas adjoining the Colwood delta and outwash.
R2 - 1/2	Sprucebark	100				
R2a	Somenos	100				Areas of unit R2 where thicknesses of older **Pleistocene deposits between 5 and 10 metres.**

HOLOCENE SANDS						
S1	Beddis	80	Qualicum	20	Fluvial	ALLUVIAL FAN AND FAN DELTA DEPOSITS This unit consists of small alluvial fans and fan deltas. No borehole data are available in this unit, but the fans probably consist of sand and gravel, particularly where they occur along the **lower flanks of sandy and gravelly drumlinoid ridge**s from which they have been derived.
S2	Beddis	70	Chemainus	30		GOLDSTREAM DELTA DEPOSITS: The Goldstream **River delta** at the head of Saanich Inlet. The landward part of the delta plain consists of **pebble to cobble gravel alluvial deposits**, and the seaward part consists of predominantly sandy tidal flats. The gravel alluvium is interpreted to have prograded over finer deltaic deposits, including tidal flat deposits.
S3	Qualicum	50	Beddis	50		STREAM DEPOSITS: **Sandy alluvial deposits** have been mapped only where they are interpreted to be more than a few metres thick or are extensive enough to be mapped. Observations along most streams indicate that they are generally **downcutting or have a boulder and cobble gravel bed**.
S4	**BEACH**					BEACH SANDS: This unit include modern beach sand . These deposits are up to several metres thick at Ross Bay and the northern part of Cadboro Bay, but elsewhere thicknesses are unknown.
OLDER PLEISTOCENE DEPOSITS AT SURFACE						
T	Somenos	80	Quamichan	20	Moraine	THICK OLDER PLEISTOCENE DEPOSITS: This unit occurs where older Pleistocene deposits are greater than 10 metres thick and are exposed at the surface. The surficial deposits are commonlythe Vashon till or the Quadra sand but, where th drumlinoid ridges have been subjected to Holocene erosion, older
T/C3	Somenos	60	Saanichton	40	Moraine	Areas intermediate between units T and C3, typically areas with a discontinuous cover of Victoria clay over older Pleistocene deposits
Ta	Saturna	70	Sprucebark	30	Moraine Bedrock	Areas that have smooth surface topography, comparable to areas with thick older Pleistocene deposits (unit T), but where borehole data indicate that **bedrock is locally shallow**

Texture Lookup Table

The following lookup table is the primary filter to determining HSG. Textures for each soil horizon were averaged for the proportion of sand, clay and silt. As identified in the report the ranges of sand, clay, and silt for determining the HSG are based on the TR-55 model. These ranges were modified slightly to be more fitting to the local landscape.

hsg_code	hsg_name	runoff_potential	sand_content	clay_content	silt_content
A	Soils having a high infiltration rate when thoroughly wet.	Low	80-100	0-10	
B	Soils having a moderate infiltration rate when thoroughly wet.	Moderately Low	50-90	10-20	<40
C	Soils having a slow infiltration rate when thoroughly wet.	Moderately High	0-50	20-40	40-65
D	Soils having a very slow infiltration rate when thoroughly wet.	High	0-45	40-100	>65

Permeability Lookup Table

Permeability was the next logic applied. This was applied to soils have a water table present for most of the year between 60cm – 100cm. The HSG category has been determined based on permeability, i.e. ksat measured in cm/hr.

Soils: 60cm - 100cm water table (YB)

Ksat	ksat	HSG
	>14.4	A
3.61	14.4	B
0.36	3.61	C
0	0.36	D