Contaminant Loading to Marine Sediment

Stormwater Inputs to Sediments in Esquimalt Harbour, CFB Esquimalt

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Input from Anchor QEA: Derek Ormerod
Background
Background

Project Location

CFB Esquimalt Properties in Esquimalt Harbour

› Dockyard, Signal Hill, Yarrows, Naden, and Colwood
› All properties lie adjacent to Esquimalt Harbour
› Esquimalt Harbour is an active harbour and home to Canada’s Pacific Naval Fleet
Background

Historic Sources of Sediment Contamination in Esquimalt Harbour

› Historical industrial activity (former shipyards, marine industrial properties, sawmills)
› Active harbour with long history of use.
Background

Current Sources of Sediment Contamination in Esquimalt Harbour

- Stormwater Outfalls
- Groundwater Migrating from Contaminated Sites
- Bank Erosion
- Overland Flow
- Existing Structures
- Sediment Re-suspension
- Atmospheric Sources
Background

Sediment Recontamination Risk

Contaminant Sources to Stormwater

› Atmospheric Deposition (dust, industrial emissions, pollutants)
› Transportation Sources (tire wear, brake wear, exhaust)
› Building Materials (galvanized metals, paints, corroded metals)
› Transportation Infrastructure (roadway runoff, de-icing salt, sand)
› Landscape Management (pesticides, herbicides, fertilizers)
› Spills and Contaminated Sites

Sediment Contaminants of Concern for Esquimalt Harbour:

› Hydrocarbons
› PAHs
› Metals
› PCBs
› Dioxin / Furans
› Phenols
Background

Sediment Contamination in Esquimalt Harbour

Areas of Sediment Contamination in Esquimalt Harbour

› There are a number of Remedial Planning Areas (RPA) in Esquimalt Harbour including:
  › A/B Jetty,
  › C Jetty,
  › Y-Jetty/Lang Cove,
  › F/G Jetty,
  › D Jetty
Stormwater Study
Methods
Stormwater Desktop Review

- Reviewed previous stormwater sampling reports, stormwater data, spreadsheets and drawings
- Reviewed only areas of CFB Esquimalt properties adjacent to Remedial Planning Areas (A/B Jetty, C Jetty, Y Jetty/Lang Cove, D Jetty, F/G Jetty)
- Previous reports and studies reviewed:
  - *CFB Esquimalt Stormwater Sampling Program 2007 to 2014*, DND
  - *Core Area Stormwater Quality*, 2013 Annual Report, October 2014, Capital Regional District.
Stormwater Utility and Field Truthing

- Interviewed DND staff responsible for previous field sampling and collected all available information.
- Completed a detailed utility locate of all storm utility networks and traced storm water lines to storm outfalls from physical observations.
- Used observations from previous storm sampling events to determine outfalls that are not operational.
- A total of 36 stormwater outfalls were reviewed as part of the study.
Stormwater Field Truthing Challenges
Dockyard Storm Outfalls

DY-SW-831

DY-SW-832

DY-SW-832A

DY-SW-833

DY-SW-835B

DY-SW-837
Yarrows, Naden, Colwood Storm Outfalls

YR-SW-848A

ND-SW-849

ND-SW-851

ND-SW-854

COL-SW-910B

COL-SW-911E
Stormwater Drawing – A/B Jetty
Stormwater Drawing – C Jetty

C-Jetty and ML Floats RPA

C Jetty RPA Study
Catchment Area
Other Catchment Area
Sediment RPA
Outfall (No flow)
Stormwater Outfall
Stormwater Drawing – Y-Jetty / Lang Cove
Stormwater Drawing – F/G Jetty, D Jetty

F&G Jetty RPA

D-Jetty RPA

Legend:
- F&G Jetty RPA Study Catchment Area
- D-Jetty RPA Study Catchment Area
- Other Catchment Area
- Sediment RPA
- Outfall (No flow)
- Stormwater Outfall
# Stormwater Loading Calculation

**Various Models and Methods for Estimating Stormwater Loading**

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEPL</td>
<td>Watershed-scale, spreadsheet tool, user friendly</td>
<td>Tetra Tech</td>
</tr>
<tr>
<td>AVGWLF</td>
<td>GIS based. Evaluates land use</td>
<td>Penn State</td>
</tr>
<tr>
<td>WinSLAMM</td>
<td>Urban stormwater model of runoff and loading per rainfall event</td>
<td>PV &amp; Associates LLC</td>
</tr>
<tr>
<td>SEDLM</td>
<td>Empirical model based on data and statistics</td>
<td>U.S. Geological Survey</td>
</tr>
<tr>
<td>SIMPLE Method</td>
<td>Empirical technique for estimating stormwater loads</td>
<td>Schueler</td>
</tr>
</tbody>
</table>
Stormwater Loading Calculation

The Simple Method (Schueler, 1987)

Assumptions and Constraints:

› Provides general planning level estimate.
› Assumes that the first flush of a rain event transports the majority of upland source contamination and accounts for 90% of the total annual precipitation.
› Only estimates pollution loads generated during storm events and does not account for levels of background COCs associated with base flows.
› Assumes measured concentrations of COCs collected from stormwater sampling are representative of storm outflows and actual COC concentrations.
› May not account for all sampling variability associated with seasonality, timing, and sampling period.
Stormwater Loading Calculation

Equation 1: Calculation of Annual Runoff

\[ R = P \times P_j \times R_v \]

Where:
- \( R \) = annual runoff (m)
- \( P \) = annual rainfall (m)
- \( P_j \) = fraction of annual rainfall events that produce runoff (usually 0.9)
- \( R_v \) = runoff coefficient

Equation 2: Calculation of Runoff Coefficient

\[ R_v = 0.05 + (0.9 \times I_a) \]

Where:
- \( I_a \) = fraction of impervious surfaces
Stormwater Loading Calculation

Annual Rainfall

Annual Average rainfall calculated from one automated airport weather station and three Environment Canada weather stations near the project area.

Runoff Coefficient

The runoff coefficient was calculated based on the fraction of impervious cover within a catchment area.

- Impervious areas: Roads, buildings, roofs
- Pervious areas: Grass, landscaping, gravel, beaches and foreshore areas

Total catchment area, impervious area, and pervious area were measured using GIS mapping tools.
## Stormwater Loading Calculation

<table>
<thead>
<tr>
<th>Outfall ID</th>
<th>Impervious Area</th>
<th>Pervious Area</th>
<th>Total Catchment Area</th>
<th>Impervious Area Fraction</th>
<th>Annual Rainfall</th>
<th>Runoff Coefficient</th>
<th>Annual Runoff</th>
<th>Annual Runoff Volume</th>
<th>Annual Runoff Volume</th>
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</thead>
<tbody>
<tr>
<td>DY-SW-831</td>
<td>4773 m²</td>
<td>555 m²</td>
<td>5328 m²</td>
<td>0.90</td>
<td>813 mm</td>
<td>0.66</td>
<td>656 m³</td>
<td>3493 L</td>
<td>3493253 L</td>
</tr>
<tr>
<td>DY-SW-832A</td>
<td>4648 m²</td>
<td>2893 m²</td>
<td>7542 m²</td>
<td>0.62</td>
<td>814 mm</td>
<td>0.60</td>
<td>451 m³</td>
<td>3405 L</td>
<td>3404940 L</td>
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<tr>
<td>DY-SW-833</td>
<td>5825 m²</td>
<td>1458 m²</td>
<td>7283 m²</td>
<td>0.80</td>
<td>815 mm</td>
<td>0.77</td>
<td>586 m³</td>
<td>4271 L</td>
<td>4271359 L</td>
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<td>DY-SW-834</td>
<td>20278 m²</td>
<td>7200 m²</td>
<td>27478 m²</td>
<td>0.74</td>
<td>815 mm</td>
<td>0.71</td>
<td>541 m³</td>
<td>14871 L</td>
<td>14871152 L</td>
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<td>DY-SW-835</td>
<td>14735 m²</td>
<td>757 m²</td>
<td>15492 m²</td>
<td>0.95</td>
<td>816 mm</td>
<td>0.91</td>
<td>699 m³</td>
<td>10828 L</td>
<td>10827606 L</td>
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<tr>
<td>DY-SW-835A</td>
<td>2922 m²</td>
<td>2922 m²</td>
<td>9844 m²</td>
<td>1.00</td>
<td>817 mm</td>
<td>0.95</td>
<td>735 m³</td>
<td>2149 L</td>
<td>2148841 L</td>
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<td>DY-SW-835B</td>
<td>9667 m²</td>
<td>175 m²</td>
<td>9842 m²</td>
<td>0.98</td>
<td>818 mm</td>
<td>0.93</td>
<td>723 m³</td>
<td>7133 L</td>
<td>7132729 L</td>
</tr>
<tr>
<td>DY-SW-837</td>
<td>23842 m²</td>
<td>494 m²</td>
<td>24337 m²</td>
<td>0.98</td>
<td>820 mm</td>
<td>0.93</td>
<td>723 m³</td>
<td>17590 L</td>
<td>17590499 L</td>
</tr>
<tr>
<td>SH-SW-842A</td>
<td>527 m²</td>
<td>109 m²</td>
<td>637 m²</td>
<td>0.83</td>
<td>822 mm</td>
<td>0.80</td>
<td>612 m³</td>
<td>390 L</td>
<td>390020 L</td>
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<tr>
<td>SH-SW-843</td>
<td>748 m²</td>
<td>152 m²</td>
<td>900 m²</td>
<td>0.83</td>
<td>822 mm</td>
<td>0.80</td>
<td>615 m³</td>
<td>553 L</td>
<td>553492 L</td>
</tr>
<tr>
<td>COL-SW-911E</td>
<td>23315 m²</td>
<td>425 m²</td>
<td>23740 m²</td>
<td>0.98</td>
<td>835 mm</td>
<td>0.93</td>
<td>738 m³</td>
<td>17521 L</td>
<td>17520507 L</td>
</tr>
<tr>
<td>ND-SW-849</td>
<td>633 m²</td>
<td>753 m²</td>
<td>1386 m²</td>
<td>0.46</td>
<td>833 mm</td>
<td>0.46</td>
<td>342 m³</td>
<td>475 L</td>
<td>474818 L</td>
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<tr>
<td>ND-SW-850</td>
<td>12886 m²</td>
<td>2258 m²</td>
<td>15145 m²</td>
<td>0.85</td>
<td>834 mm</td>
<td>0.82</td>
<td>639 m³</td>
<td>9677 L</td>
<td>9676793 L</td>
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<tr>
<td>ND-SW-850A</td>
<td>1734 m²</td>
<td>425 m²</td>
<td>2159 m²</td>
<td>0.80</td>
<td>835 mm</td>
<td>0.77</td>
<td>603 m³</td>
<td>1303 L</td>
<td>1302608 L</td>
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<tr>
<td>ND-SW-850B</td>
<td>1486 m²</td>
<td>11 m²</td>
<td>1497 m²</td>
<td>0.99</td>
<td>835 mm</td>
<td>0.94</td>
<td>747 m³</td>
<td>1117 L</td>
<td>1117148 L</td>
</tr>
<tr>
<td>ND-SW-851</td>
<td>10448 m²</td>
<td>2274 m²</td>
<td>12722 m²</td>
<td>0.82</td>
<td>836 mm</td>
<td>0.79</td>
<td>618 m³</td>
<td>7860 L</td>
<td>7859534 L</td>
</tr>
<tr>
<td>ND-SW-852</td>
<td>501 m²</td>
<td>38 m²</td>
<td>539 m²</td>
<td>0.93</td>
<td>837 mm</td>
<td>0.89</td>
<td>699 m³</td>
<td>377 L</td>
<td>376949 L</td>
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<tr>
<td>YR-SW-848A</td>
<td>14958 m²</td>
<td>9346 m²</td>
<td>24304 m²</td>
<td>0.62</td>
<td>832 mm</td>
<td>0.60</td>
<td>461 m³</td>
<td>11195 L</td>
<td>11195380 L</td>
</tr>
<tr>
<td>ND-SW-853</td>
<td>493 m²</td>
<td>1103 m²</td>
<td>1596 m²</td>
<td>0.31</td>
<td>837 mm</td>
<td>0.33</td>
<td>233 m³</td>
<td>371 L</td>
<td>371173 L</td>
</tr>
<tr>
<td>ND-SW-854</td>
<td>57892 m²</td>
<td>20143 m²</td>
<td>78035 m²</td>
<td>0.74</td>
<td>839 mm</td>
<td>0.72</td>
<td>560 m³</td>
<td>43728 L</td>
<td>43728443 L</td>
</tr>
</tbody>
</table>
Stormwater Loading Calculation

Annual Contaminant Loading

Annual contaminant loading for each COC estimated from the product of annual runoff, catchment area, average contaminant concentration.

Equation 3: Calculation of Annual Loading (g/year)

\[ L = [R \times A] \times C \]

Where:  
- \( L \) = annual load per year (g/year)  
- \( R \) = annual runoff (m)  
- \( C \) = average COC concentration (mg/L)  
- \( A \) = catchment area (m²)
Stormwater Study
Results
Stormwater Results

Review of Analytical Results

› A total of 9 outfalls in the study area were identified as having no flow or negligible flow during heavy rain.
› A total of 86 sampling results from 27 outfalls were compiled in a data table.
› Stormwater from all 27 outfalls contained concentrations of at least one COC greater than the CCME Guidelines for Marine Aquatic Life.
› Exceedences included Total Aluminum, Total Mercury, Total Phosphorous, Dissolved Cadmium, Dissolved Manganese, Tributyl Tin, Phenols, TSS, pH.
Stormwater Results

Calculated Results for Annual Rainfall, Runoff Coefficient, and Runoff:

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Annual Rainfall (mm)</th>
<th>Runoff Coefficient</th>
<th>Annual Runoff (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>813</td>
<td>0.33</td>
<td>233</td>
</tr>
<tr>
<td>Maximum</td>
<td>853</td>
<td>0.95</td>
<td>747</td>
</tr>
<tr>
<td>Average</td>
<td>829</td>
<td>0.71</td>
<td>548</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>11</td>
<td>0.19</td>
<td>156</td>
</tr>
</tbody>
</table>
# Stormwater Results

Stormwater Model Results for Select Parameters (g/year)

<table>
<thead>
<tr>
<th>Outfall Area (Combined)</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>Total PAHs</th>
<th>Cr</th>
<th>Cu</th>
<th>Pb</th>
<th>Hg</th>
<th>Zn</th>
<th>Phenols</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/B Jetty Outfalls</td>
<td>7,374</td>
<td>7,646</td>
<td>110,605</td>
<td>15</td>
<td>108</td>
<td>879</td>
<td>362</td>
<td>0.47</td>
<td>3,891</td>
<td>178</td>
</tr>
<tr>
<td>C Jetty Outfalls</td>
<td>189</td>
<td>233</td>
<td>1,336</td>
<td>6</td>
<td>349</td>
<td>1,539</td>
<td>2,164</td>
<td>0.88</td>
<td>6,581</td>
<td>167</td>
</tr>
<tr>
<td>Y Jetty Outfalls</td>
<td>2,291</td>
<td>2,514</td>
<td>34,363</td>
<td>14</td>
<td>124</td>
<td>668</td>
<td>201</td>
<td>0.31</td>
<td>1,753</td>
<td>245</td>
</tr>
<tr>
<td>Lang Cove Outfalls</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>250</td>
<td>1,843</td>
<td>658</td>
<td>0.26</td>
<td>3,605</td>
<td>134</td>
</tr>
<tr>
<td>F/G Jetty Outfall</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>0.14</td>
<td>1.7</td>
<td>0.11</td>
<td>0.0006</td>
<td>66</td>
<td>-</td>
</tr>
<tr>
<td>D Jetty Outfall</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>70</td>
<td>1,499</td>
<td>140</td>
<td>0.35</td>
<td>1,191</td>
<td>-</td>
</tr>
</tbody>
</table>
Stormwater Recontamination Model – Anchor QEA

Anchor QEA has developed a Stormwater Recontamination Model for Esquimalt Harbour. The model is based on a mass balance of contaminants of concern.

- Recontamination pathways included in the model are:
  - Ongoing discharges from CFB Esquimalt;
  - Stormwater discharges;
  - Groundwater migrating from upland contaminated sites;
  - Propeller wash re-suspension of off-site sediments; and
  - Other recontamination sources (atmospheric, etc.)

The model will be used to mitigate recontamination of Esquimalt Harbour RPAs and identify problem areas for sediment contamination.
Summary

- CFB Esquimalt is a large industrial facility covering a large surface area adjacent to Esquimalt Harbour.
- Stormwater discharge draining from the CFB Esquimalt and adjacent properties bordering Esquimalt Harbour carries contaminants to the marine environment.
- The Simple Method is a useful tool for calculating contaminant loading in stormwater for planning and management decisions.
- Defining catchments areas and stormwater utilities at CFB Esquimalt was challenging based on available information.
- All 26 outfalls discharging stormwater contributed at least one parameter exceeding CCME guidelines.
- Based on the values of contaminant loading in g/year, stormwater is a source of contamination to marine sediment.
Summary

Next Steps

› SNC-Lavalin also completed a study of groundwater sources migrating from contaminated sites on CFB Esquimalt properties
› Stormwater inputs will be integrated into the remedial design (Anchor QEA) and risk management plan for addressing contaminated sediments in Esquimalt Harbour.
Questions?

Acknowledgements
› SNC-Lavalin, Faruk Bhuyian, Adrien Richardot, and Hawley Beauregard
› Defence Construction Canada, Scott Irwin and Raenelle Parker
› Department of National Defence, Michael Bodman and Jennifer Holder
› Anchor QEA, Derek Ormerod and Todd Thornburg

References
› 1987, Schueler
› 2015, Methods for Evaluating the Impact of Urban Stormwater on Sediment Quality, The Intelligence Group LLC.