Water Budget Project — Phase 1
Gabriola, DeCourcy, and Mudge Islands

Presentation of Results, DRAFT Final Report
Dec 13, 2012, Nanaimo, BC

SRK Consulting (Canada) Inc.
Thurber Engineering Ltd.

Prepared for
Regional District of Nanaimo
Authors:

Jacek Scibek, Consultant (Hydrogeology)

Dan Mackie, Senior Consultant (Hydrogeology)

Chad Petersmeyer, P.Geo., Hydrogeologist, Thur

Tim Sivak, G.I.T., Geologist, Thurber Engineering

Reviewers:

Michael Royle, P.Geo., Principal Consultant (Hydrogeology), SRK

Kevin Sterne, P.Eng., Thurber Review Principal, Thurber Engineering

Dr. Diana Allen, P.Geo., Professor (Hydrogeology), Simon Fraser University
Objectives:

• review existing hydrogeological information
• develop one **3D conceptual hydrogeological model**
• calculate **water budget** and assess groundwater extraction rates
• assess **groundwater extraction “stress”** on aquifers
• identify **data gaps** in conceptual model and water budget
• identify additional requirements for expansion of long term groundwater observation well network
Geological units

- Gabriola (sandstone)
- Spray (mudstone)
- Geoffrey (sandstone & conglomerate)
- Northumberland (mudstone)
- de Courcy (sandstone)
- Cedar District (mudstone, sandstone)
Section done by Earle & Krogh (2004)
Geological units and structure

- Gabriola Syncline shape in section view
- Gabriola Island
- Spray (sandstone)
- Geoffrey (sandstone)
- Northumberland (mudstone)
- de Courcy Fm.

Water wells are shown as black lines.

Cross-section view is shown above.

Geologic units are shown cut and land surface is exposed for visualization. Geologic units are not shown in eastern part of Gabriola Island.

Locations:
- Gabriola Island
- Mudge Island
- Lock Bay
- Silva Bay
- Degnen Bay
Hydro-Geological units (fractured rock)

- Gabriola Island
- Gabriola (AQUIFER)
- Spray (AQUIFER)
- Geoffrey (AQUIFER)
- Northumberland (AQUIFER)
- de Courcy Fm. (AQUIFER)
- Fault fracture zones (preferential flow paths)
- Sea level
- Sandstone
- Mudstone (shale)
- Fault zone
- Thin-bedded mudstone and sandstone aquifer
- Flow of surface water
Descanso Bay
outcrop of Geoffrey Fm. (sandstone)

outcrop of Gabriola Fm.

shale of Spray Fm. has been eroded here, forming a valley along Descanso Valley Road

Example of geologic data near Descanso Bay

- well lithologs from WELLS database
- variable quality of logs and positional accuracy
Simple 3D model can be built from geologic unit outcrops from surficial geology and ground surface model

- well logs are of limited value
- too much variability in log quality
Example of geology near Lock Bay on Gabriola Island.

- The shale of Northumberland Fm. has been eroded into a low-lying bench along shore.
- The shale of Spray Fm. has been eroded here, forming an upper bench.

There is a high density of residences and water wells in this area.
Clay layers (shown in blue) are very common in Northumberland shale, forming confining units for groundwater flow.

Groundwater discharge likely occurs away from shore along sea bed, and this area is resistant to salt water intrusion despite large pumping demand.
shale rock eroded by waves, sandstone forming cliffs

Shale rock layers in west part of Gabriola Island
3D geological model fitted to all data
Hydro-Geological units: properties

Geologic Formations:
- Gabriola
- Spray
- Geoffray
- Northumberland
- De Courcy
- Cedar District
- Faults

Tidal analysis wells:
- Diffusivity (T/s):
  - 5.1 - 26.0
  - 1.1 - 5.0
  - 0.6 - 1.0
  - 0.2 - 0.5
  - 0.0 - 0.1

Pump test wells:
- Transmissivity (m²/s):
  - 2e-004 - 1e-003
  - 2e-005 - 1e-004
  - 4e-006 - 1e-005
  - 3e-006

Types of tests in wells:
- Wells monitored for tide
- MOE obs.wells analysed for tides
- Test holes (Piteau, 1993)
2012 tidal monitoring in 10 residential wells
Example of results
Average water levels on islands
Average flow directions from high to low water levels

Actual flow is complicated (example of one conceptual picture) (from GSC poster by Denny et al 2007)

Figure 1. Ground water fills cracks and pores below the water table.
Depth to water

Legend
Depth to water
m
- 0 - 2
- 3 - 5
- 6 - 10
- 11 - 20
- 21 - 50
- 51 - 100

Average depth to water (3D model)
m (corrected for land surface)
- 0 - 3
- 4 - 5
- 6 - 10
- 11 - 20
- 21 - 50
- 51 - 100

- Lakes
- Sea shores
- Roads

Data sources:
"static" water levels:
- MOE wells database (compiled by SRK),
- test holes by Piteau (1993),
- water level measurements in residential wells in 2012 by SRK
- average static water level surface by SRK (2012)

(see inset map for DeCourcy Island)
Water table in cross-section

Gabriola (sandstone)
Geoffrey (sandstone)
Spray (mudstone)
Northumberland (mudstone)

Water table is shown as dashed line.

Water wells are shown as black vertical lines and water level points at blue dots.

Section done by Earle & Krogh (2004)
Fresh water lens – how deep?

Freshwater lens concept for “small” island, used in many reports
Fresh water lens – how deep?
Flow of groundwater

- Gabriola sandstone
- Spray mudstone
- Geoffreys sandstone
- Northumberland mudstone
- Clay aquitards and mudstone aquifer layers

Sea level

Sea water

Fresh water

~ Brackish old water at depth ~

~ Old sea water at large depth ~
Surface water
Existing water level monitoring wells
Water level seasonal / annual variation
Water use in sub-regions
Seasonal difference in water demand

- Sands
- Lock Bay
- Gabriola
- Silva Bay
- North Degnen Bay
- West Degnen Bay
- False Narrows
- Hoggan Lake
- Northumberland...
- South Descanso Bay
- Descanso Bay
- Mudge Island
- De Courcy Island

1000's m3/month

- Summer
- Winter
Residential water use type & seasonal differences

Summer
- Garden: 39%
- Faucets: 25%
- Showers: 21%
- Dishwasher: 8%
- Clotheswasher: 1%

Rest of Year
- Garden: 0%
- Faucets: 43%
- Dishwasher: 14%
- Showers: 31%
- Clotheswasher: 11%
Calculating water “stress”

The categories of aquifer “stress” due to groundwater extraction were:

• **low** stress = surplus is large > 10,000 m$^3$
• **moderate** stress = surplus is 0 to 10,000 m$^3$
• **higher** stress = deficit
## Monthly water surplus (recharge-demand) and water stress categories by water sub-region

### Water sub-regions

<table>
<thead>
<tr>
<th>Water sub-regions</th>
<th>Monthly surplus (recharge - demand) in 1000's m³/month and category of water stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jan</td>
</tr>
<tr>
<td>Sands</td>
<td>41.0</td>
</tr>
<tr>
<td>Lock Bay</td>
<td>93.6</td>
</tr>
<tr>
<td>Gabriola</td>
<td>157.5</td>
</tr>
<tr>
<td>Silva Bay Region</td>
<td>25.3</td>
</tr>
<tr>
<td>North Degnen Bay</td>
<td>2.2</td>
</tr>
<tr>
<td>West Degnen Bay</td>
<td>30.5</td>
</tr>
<tr>
<td>False Narrows</td>
<td>60.3</td>
</tr>
<tr>
<td>Hoggan Lake</td>
<td>115.1</td>
</tr>
<tr>
<td>Northumberland Channel</td>
<td>9.7</td>
</tr>
<tr>
<td>South Descanso Bay</td>
<td>21.5</td>
</tr>
<tr>
<td>Descanso Bay</td>
<td>36.4</td>
</tr>
<tr>
<td>Mudge Island</td>
<td>24.7</td>
</tr>
<tr>
<td>De Courcy Island</td>
<td>21.8</td>
</tr>
</tbody>
</table>

### Diagram

**Sands region**

- **demand > recharge**
- **1000's m³/month**
- **Month**
- **January**
- **February**
- **March**
- **April**
- **May**
- **June**
- **July**
- **August**
- **September**
- **October**
- **November**
- **December**

**10% recharge scenario**

**25% recharge scenario**

**30% recharge scenario**

**50% recharge scenario**

**75% recharge scenario**

**100% recharge scenario**

### Graph

- **x-axis**: Month
- **y-axis**: 1000's m³/month
- **Graph title**: Monthly water surplus (recharge-demand) and water stress categories by water sub-region

---

*Note: The table and graph provide data on monthly water surplus (recharge - demand) in 1000's m³/month and category of water stress for various water sub-regions. The graph illustrates the trend over the year for the Sands region, highlighting months where demand exceeds recharge.*
Sands region

10,000's m³/month

Month

Sands region demand > recharge
## Data Gaps and Recommended Data Collection

<table>
<thead>
<tr>
<th>Priority</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water-use surveys in all regions</td>
</tr>
<tr>
<td>2</td>
<td>Long-term observation wells in residential areas</td>
</tr>
<tr>
<td>3</td>
<td>Drawdown in residential wells around large production wells</td>
</tr>
<tr>
<td>4</td>
<td>Short-duration monitoring of water levels in residential wells</td>
</tr>
<tr>
<td>5</td>
<td>Survey and measurements of surface water flows</td>
</tr>
<tr>
<td>6</td>
<td>Additional hydraulic tests in representative locations in different hydrogeological units</td>
</tr>
<tr>
<td>7</td>
<td>Improved geological map along island steep slopes/cliffs</td>
</tr>
<tr>
<td>8</td>
<td>Data quality control of existing wells database.</td>
</tr>
<tr>
<td>9</td>
<td>Deep water levels and water quality</td>
</tr>
</tbody>
</table>
Conclusions:

Hydrogeological conceptual model:

• shared groundwater resource
• recharge from precipitation 10 to 25% of m.a. P.
• water levels show quick and small rise in water level after each rainy period (2 – 4m)
• water levels has repeating seasonal cycle
• large groundwater storage volume, used during dry season and recharged during wet season
Conclusions:

Groundwater system response to extraction:

- no consistent or significant long term trends
- locally large temporary drawdowns of groundwater level
- dense residential development along shores; narrow land penninsulas are most sensitive because of low recharge and shallower depth of fresh water
- geologic conditions and shallow depth of fresh water increases the chances of saltwater intrusion in some shore areas
Conclusions:

Groundwater system response to extraction:

• annual time scale $\rightarrow$ no significant water stress
  $\rightarrow$ recharge is sufficient to meet demand

• monthly time scale $\rightarrow$ “higher stress” during dry season
  $\rightarrow$ more water extracted than recharged
  $\rightarrow$ aquifer recharged easily in autumn

• no evidence from water levels of long term decline caused by increase of demand over time
Conclusions:

Limitations of water budget results:

• results are indicative, good initial assessment
• recharge can only be estimated (likely range is 10% to 25%)
• pumping demand uncertain (+/- ___% ?)
• water-use surveys are a small sample of users, those most interested in groundwater resource and conservation...
• few actual hard numbers on which to base estimates in commercial wells
• almost every resource is regulated and measured, why not groundwater?
Conclusions:

Recommended management plan:

- groundwater regulation (hopefully in future), for now voluntary water use reporting – increase community involvement
- issues: population growth, water use change, climate change, water quality
- increased monitoring and data collection but in cost-effective way
- increase awareness of occurrence of saltwater intrusion
- simple groundwater numerical model can be used to improve conceptual model and run scenarios, but these are not black boxes which give answers, completely depend on conceptual model and data available - see latest BC MOE guidelines for groundwater modeling in natural resource extraction
Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities

British Columbia
Ministry of Environment
Water Protection & Sustainability Branch

Prepared by:
Christoph Wels, Ph.D., M.Sc., P.Geo.

&
Daniel Mackie, M.Sc.
Jacek Scibek, M.Sc.

Robertson GeoConsultants Inc.
Consulting Engineers and Scientists for the Mining Industry
www.robertsongeoconsultants.com

srk consulting

April 2012