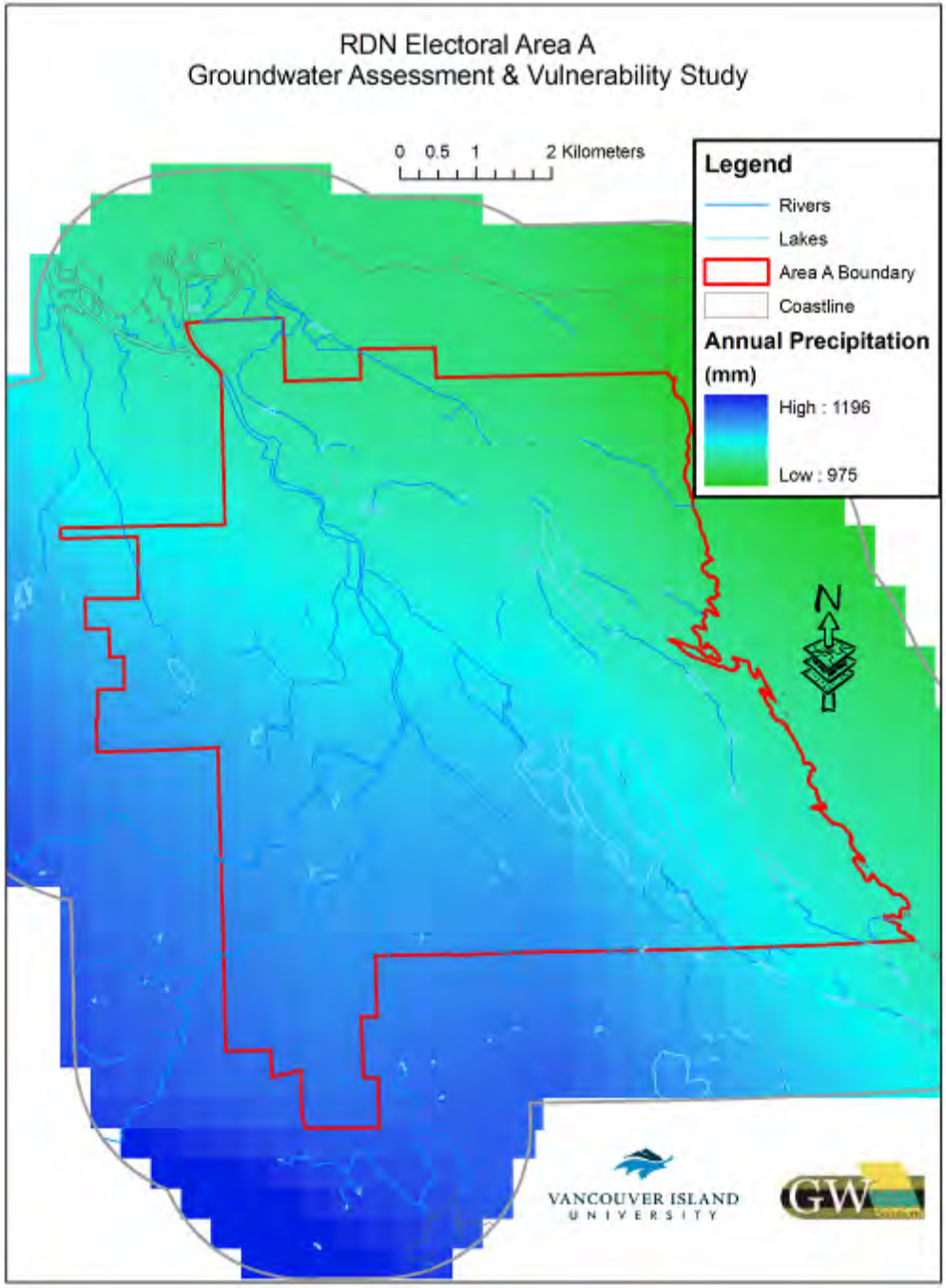
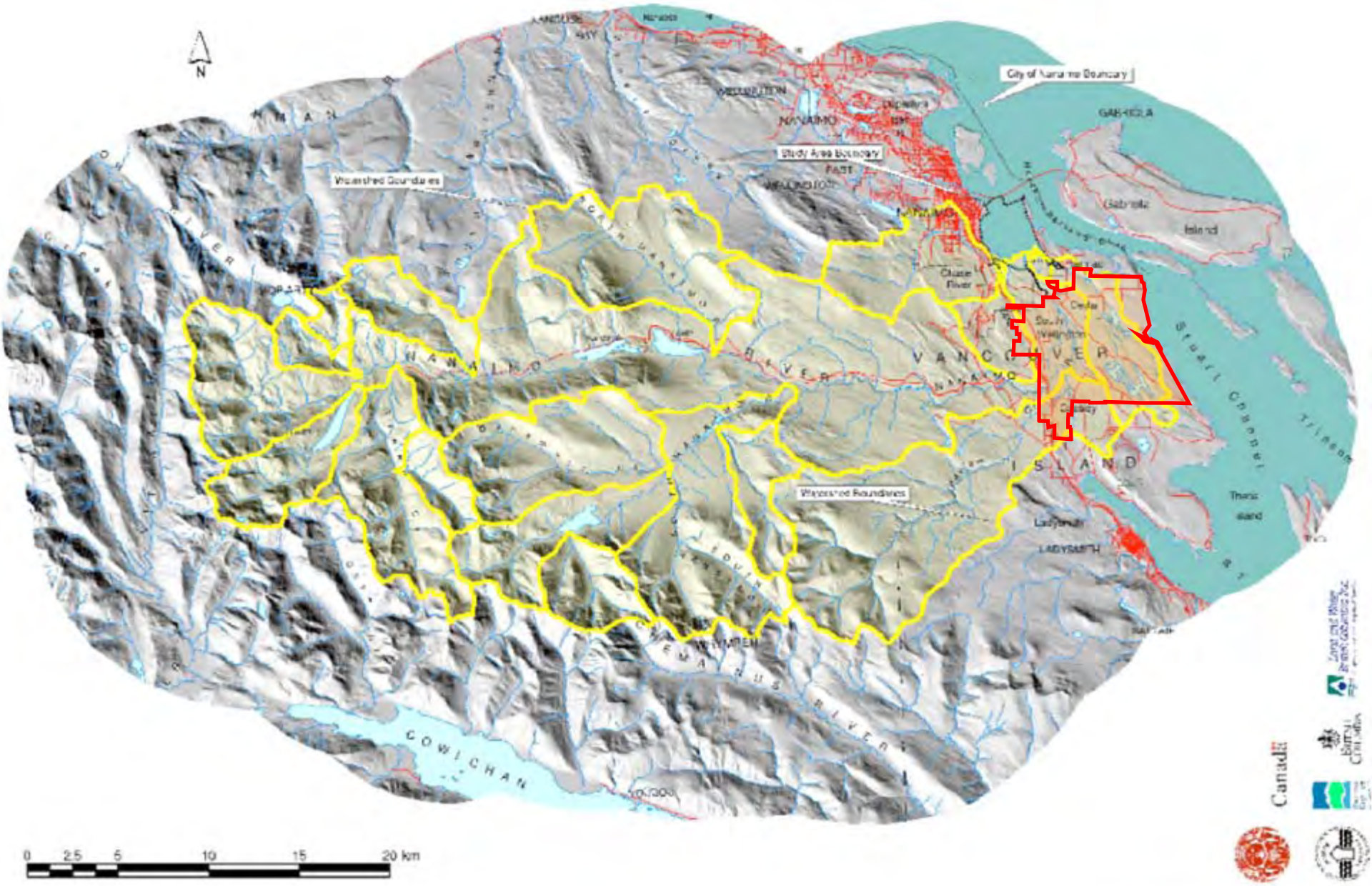
# Area A Hydrogeology and Vulnerability of Water Resources

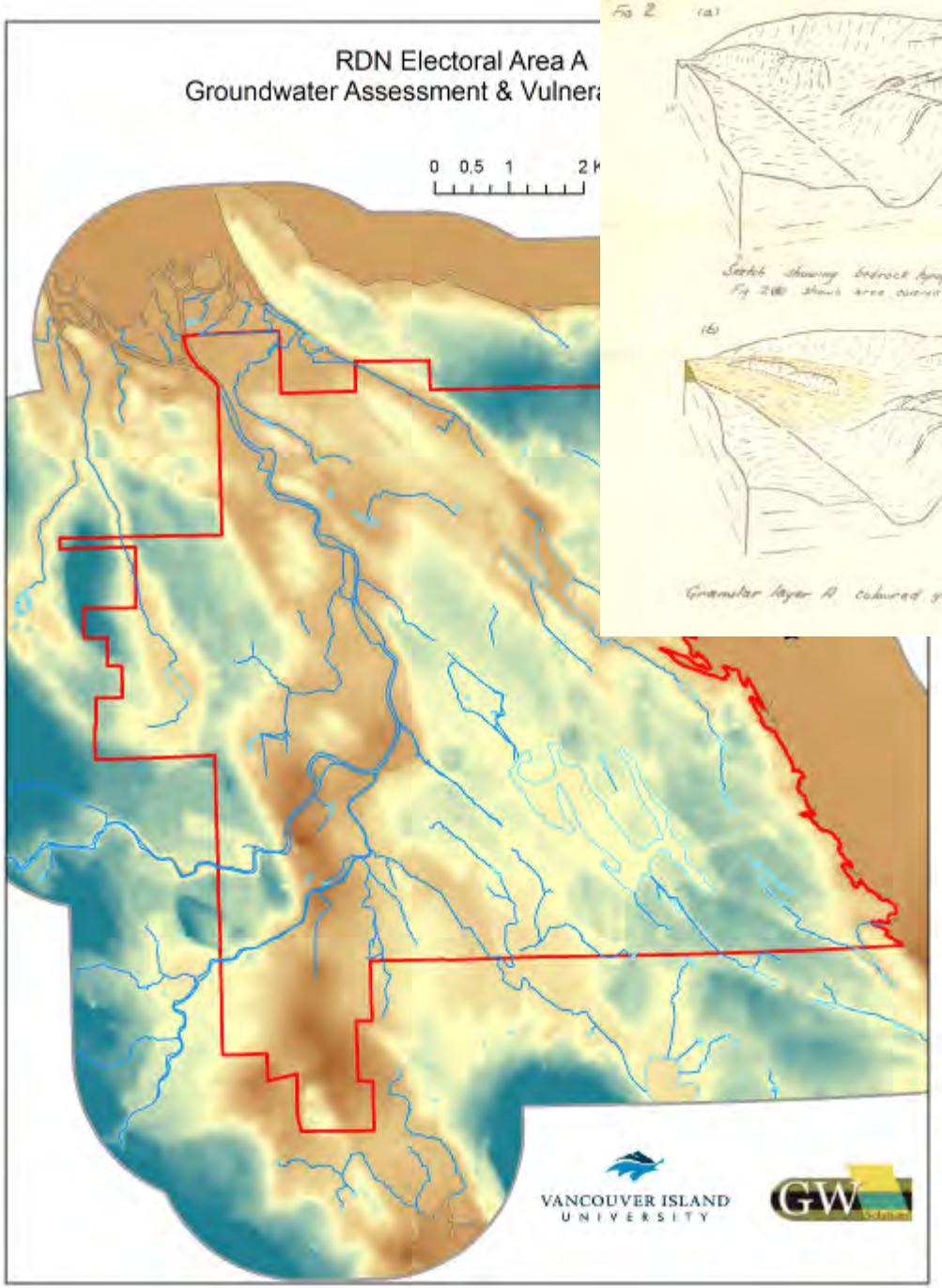
Dr. Gilles Wendling

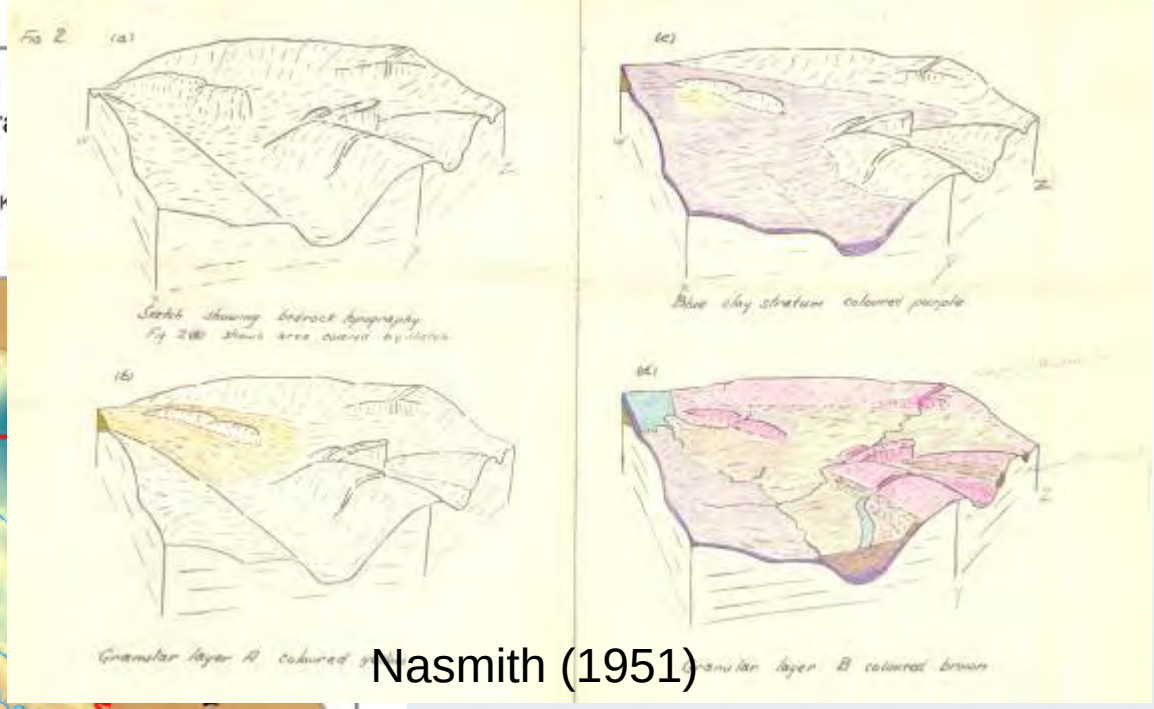
Where is the water?

…and how does it move?

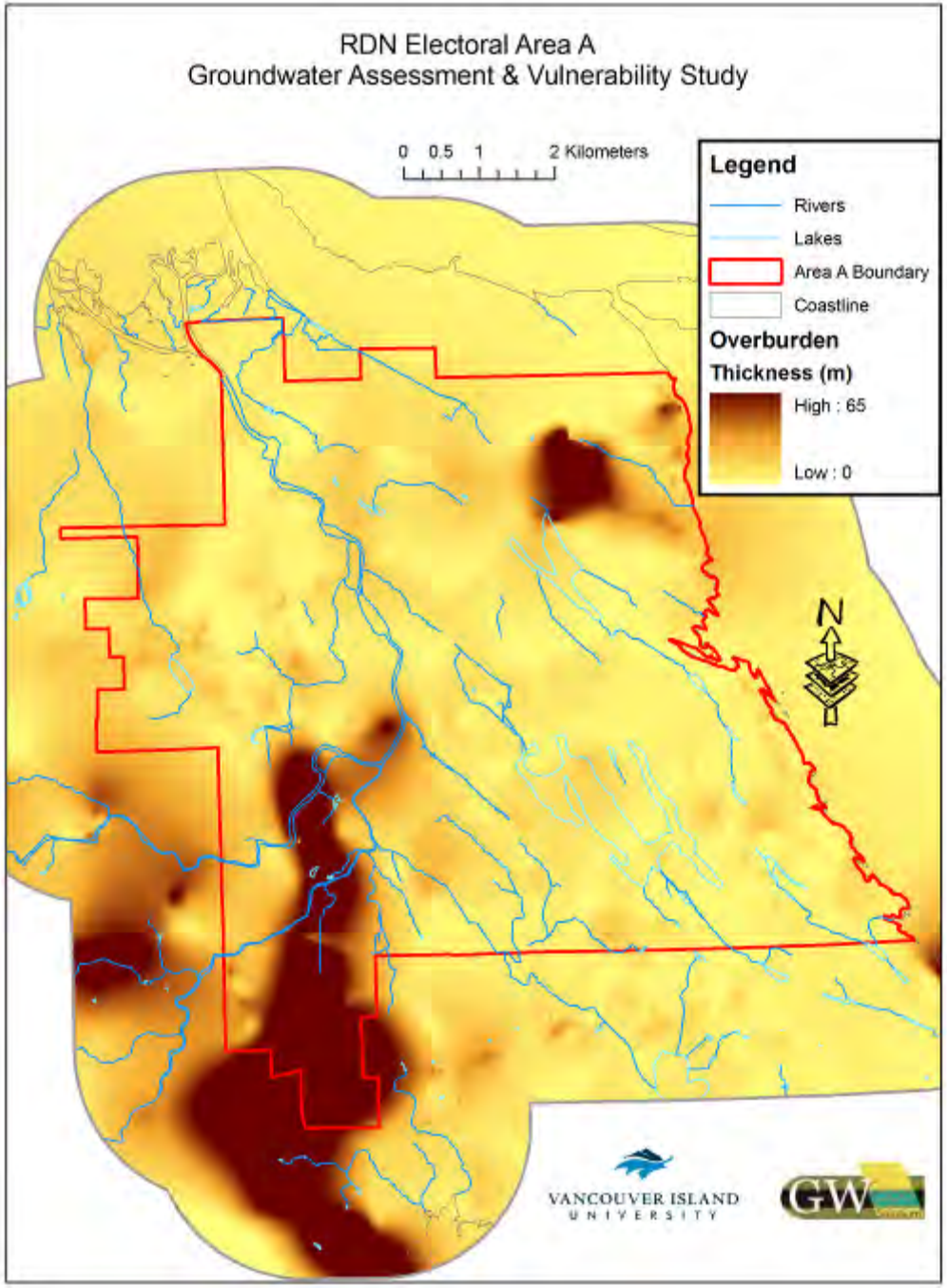

RDN Electoral Area A
Groundwater Assessment & Vulnerability Study
0 0.5 1 2 Kilometers
Legend
Rivers
Lakes
Area A Boundary
Coastline
Annual Precipitation
(mm)
High : 1196
Low : 975
N
VANCOUVER ISLAND
UNIVERSITY
GW


N
City of Nanaimo Boundary
Study Area Boundary
Watershed Boundaries
NANAIMO
GABRIOLA
Gabriola Island
Chase River
South Wellington
Cedar
Ladysmith
LADYSMITH
Thetis Island
NANAIMO RIVER
VANCOUVER ISLAND
Stuart Channel
COWICHAN
COWICHAN RIVER
0 2.5 5 10 15 20 km




Nasmith (1951)


RDN Electoral Area A
Groundwater Assessment & Vulnerability Study
0 0.5 1 2 Kilometers
Legend
Rivers
Lakes
Area A Boundary
Coastline
Overburden
Thickness (m)
High : 65
Low : 0
N
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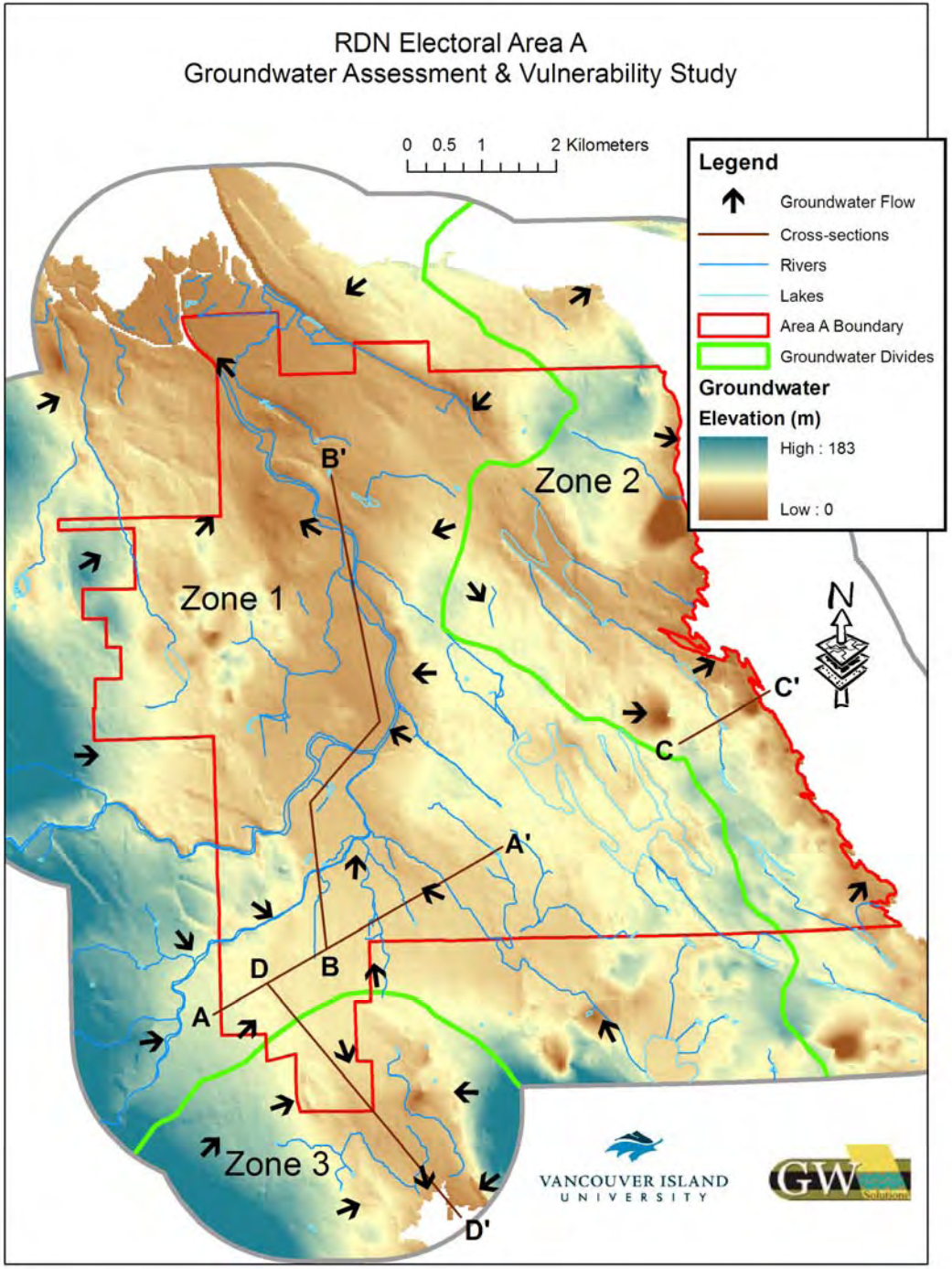
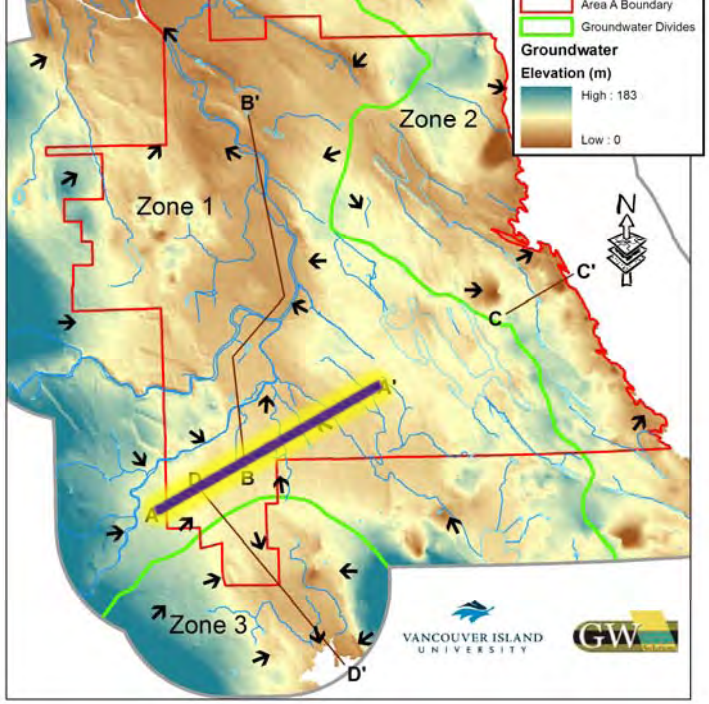
UNIVERSITY
GW


RDN Electoral Area A
Groundwater Assessment & Vulnerability Study
0 0.5 1 2 Kilometers
Legend
Groundwater Flow
Cross-sections
Rivers
Lakes
Area A Boundary
Groundwater Divides
Groundwater Elevation (m)
High : 183
Low : 0
Zone 1
Zone 2
Zone 3
A
A'
B
B'
C
C'
D
D'
N
VANCOUVER ISLAND UNIVERSITY
GW Solutions


Area A Boundary
Groundwater Divides
Groundwater
Elevation (m)
High : 183
Low : 0
Zone 1
Zone 2
Zone 3
A
A'
B
B'
C
C'
D
D'
N
VANCOUVER ISLAND UNIVERSITY
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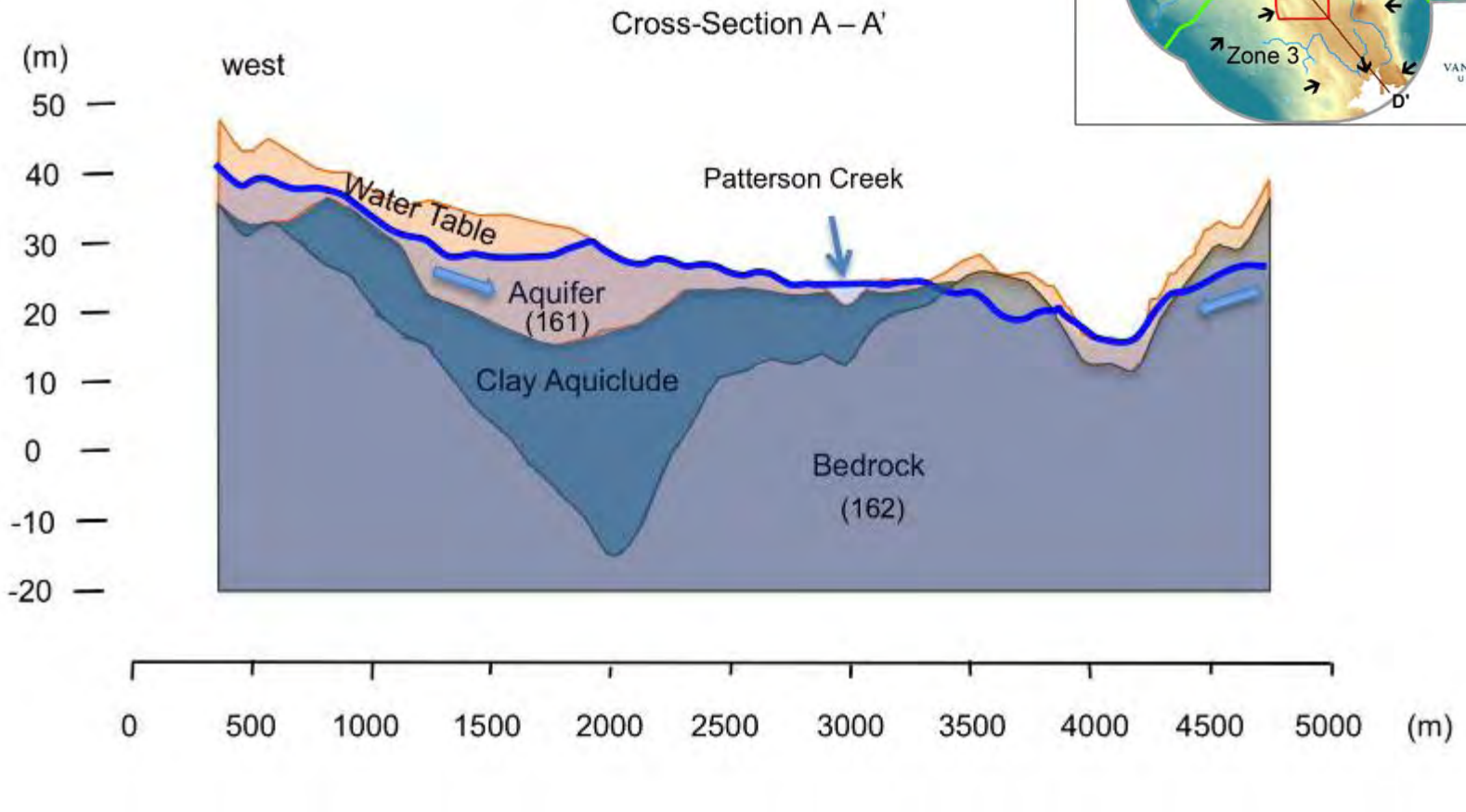
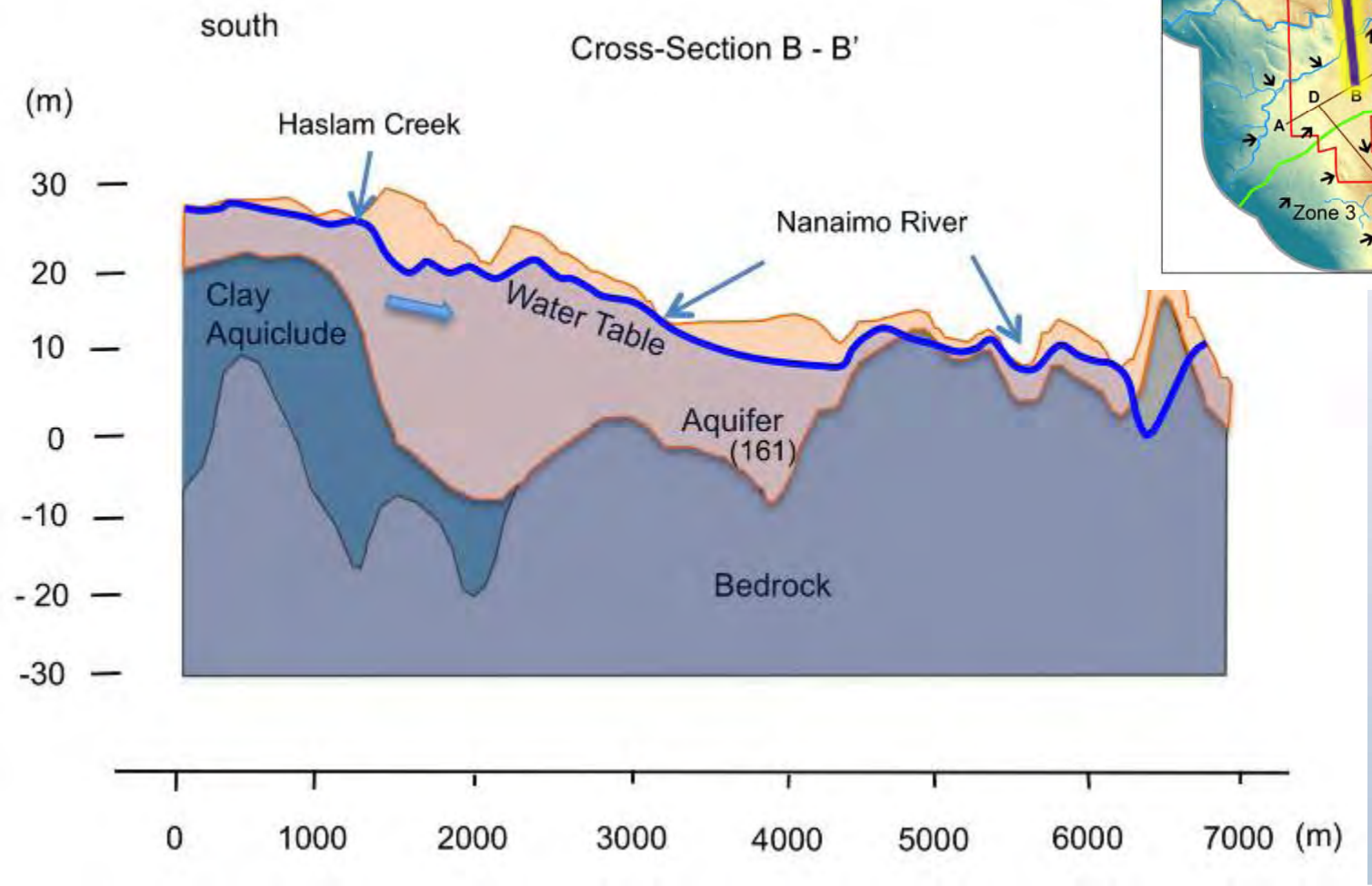
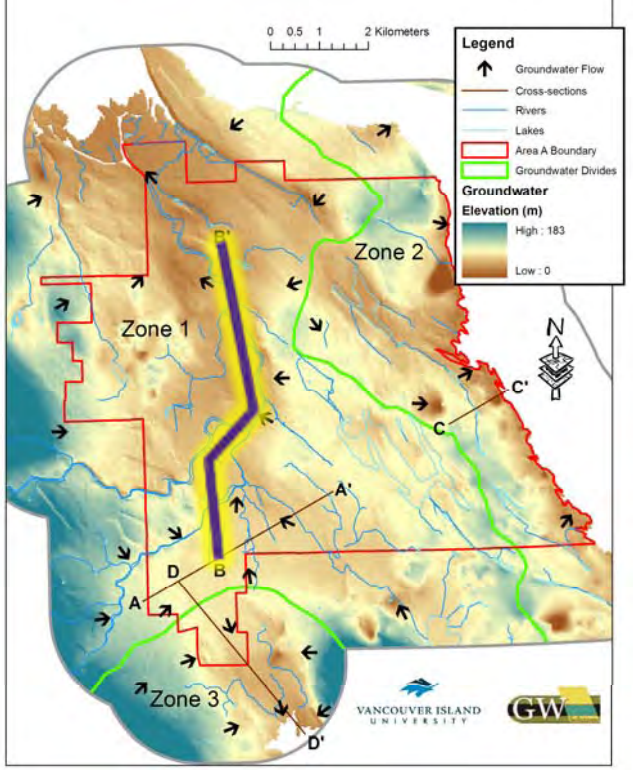
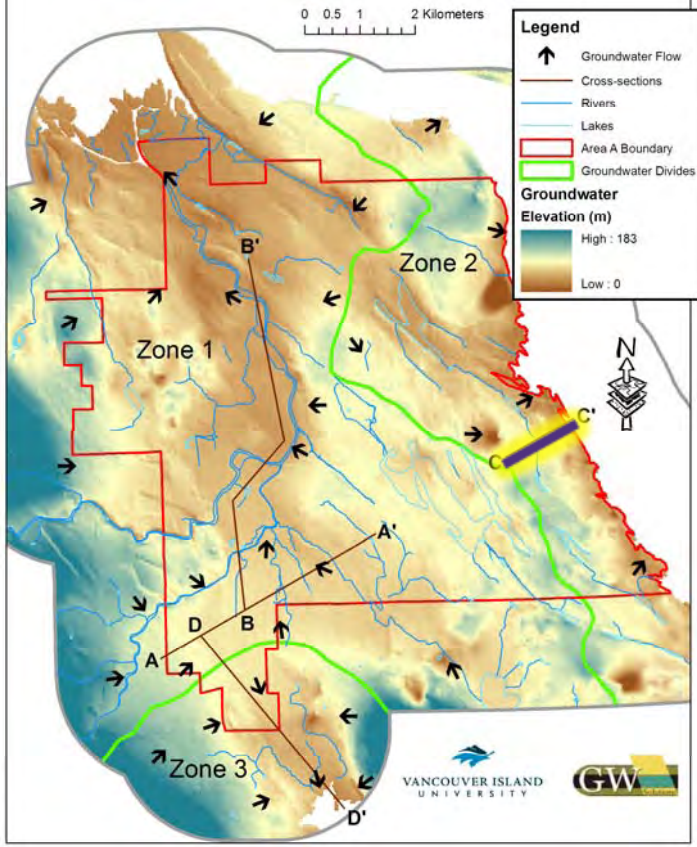
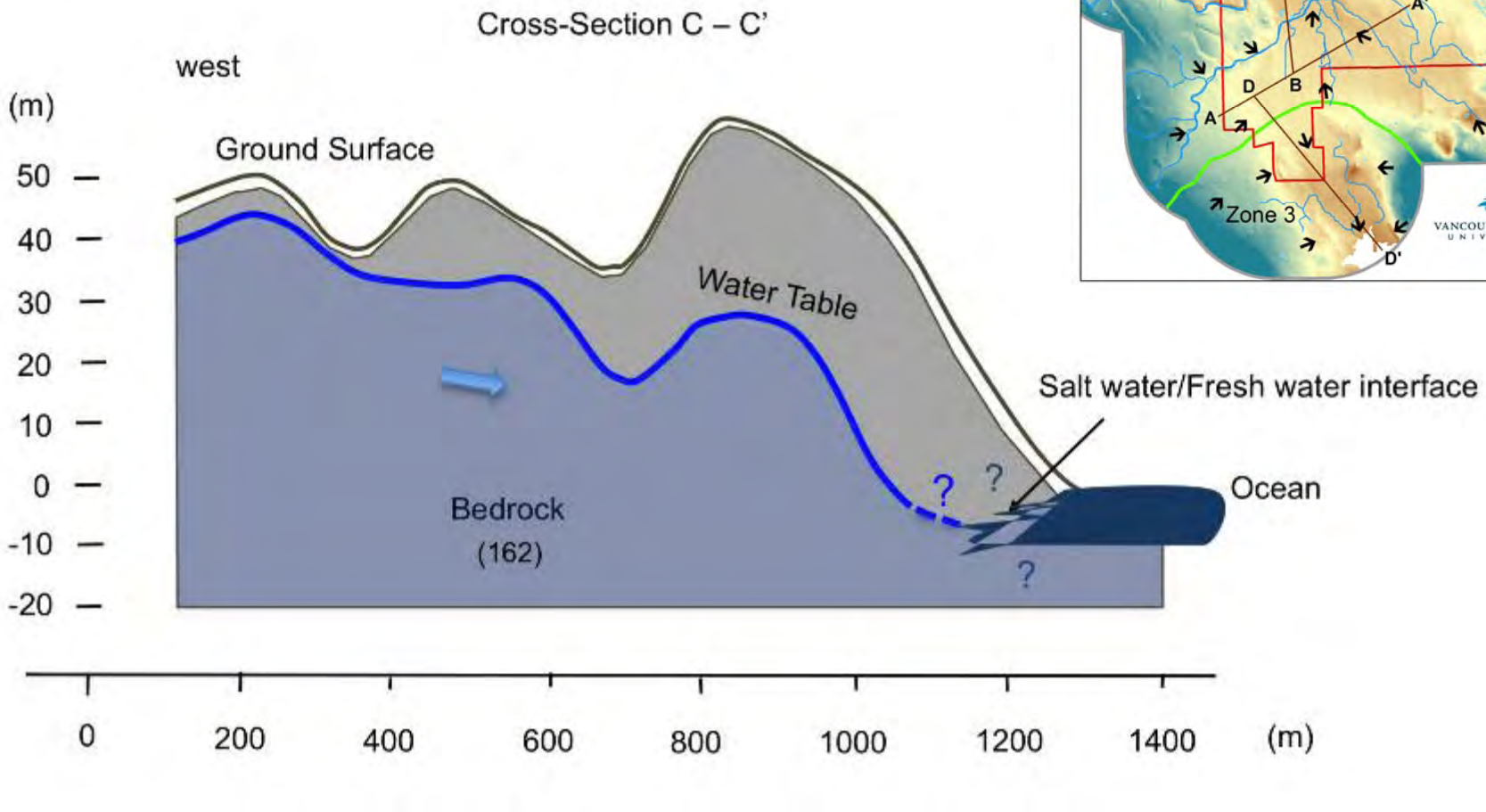
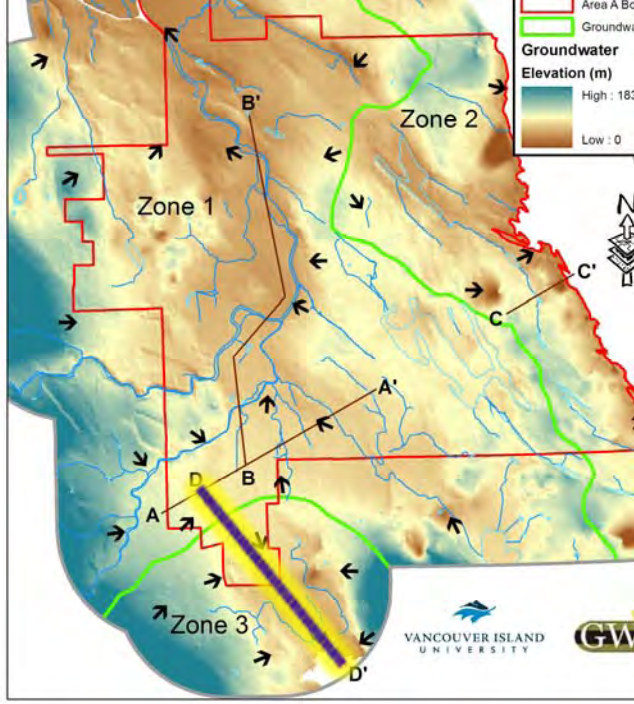

Cross-Section A – A'
(m)
west
50
40
30
20
10
0
-10
-20
Water Table
Patterson Creek
Aquifer
(161)
Clay Aquiclude
Bedrock
(162)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
(m)

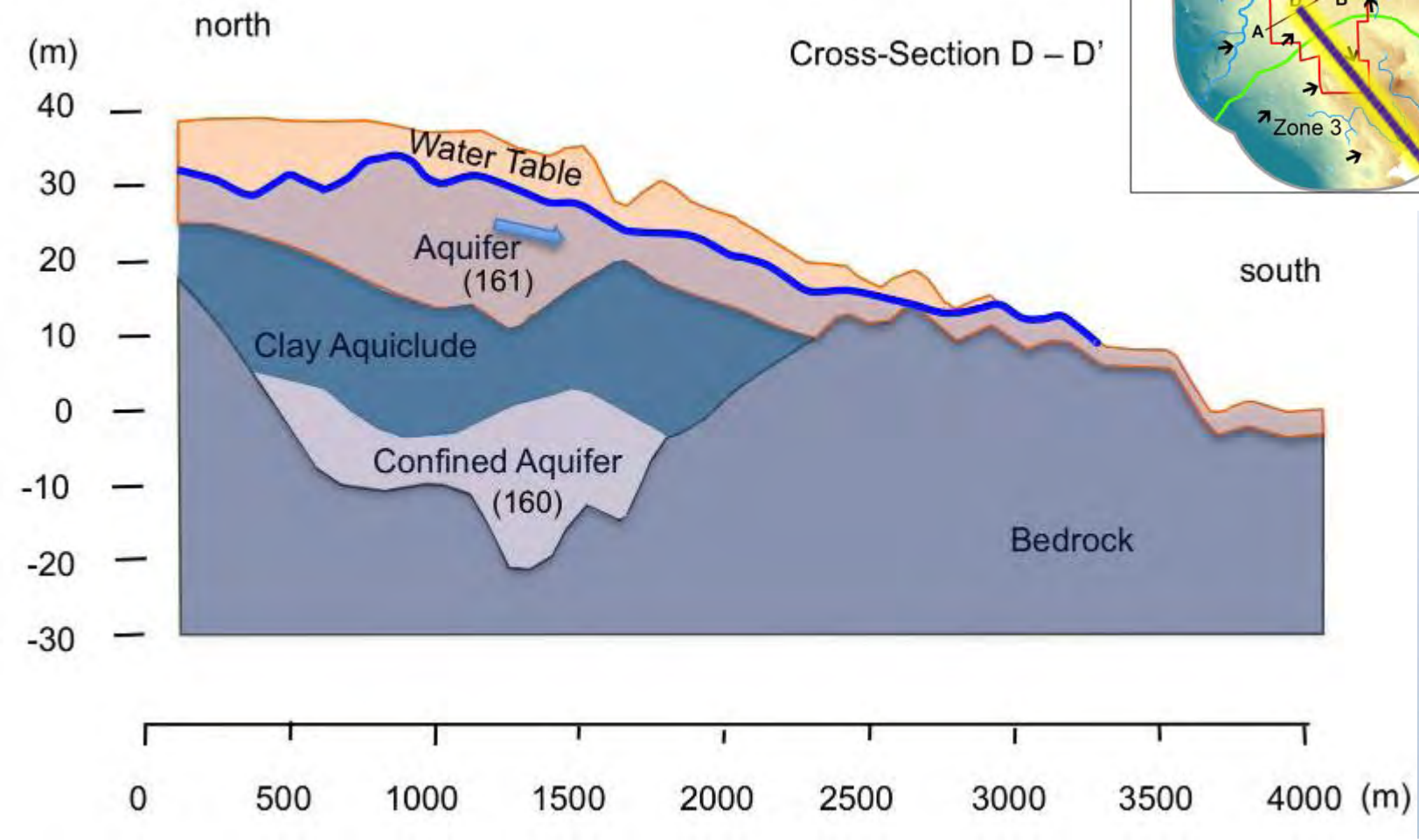

south
Cross-Section B - B'
(m)
Haslam Creek
Nanaimo River
30
20
10
0
-10
- 20
-30
Clay
Aquiclude
Water Table
Aquifer
(161)
Bedrock
0
1000
2000
3000
4000
5000
6000
7000
(m)

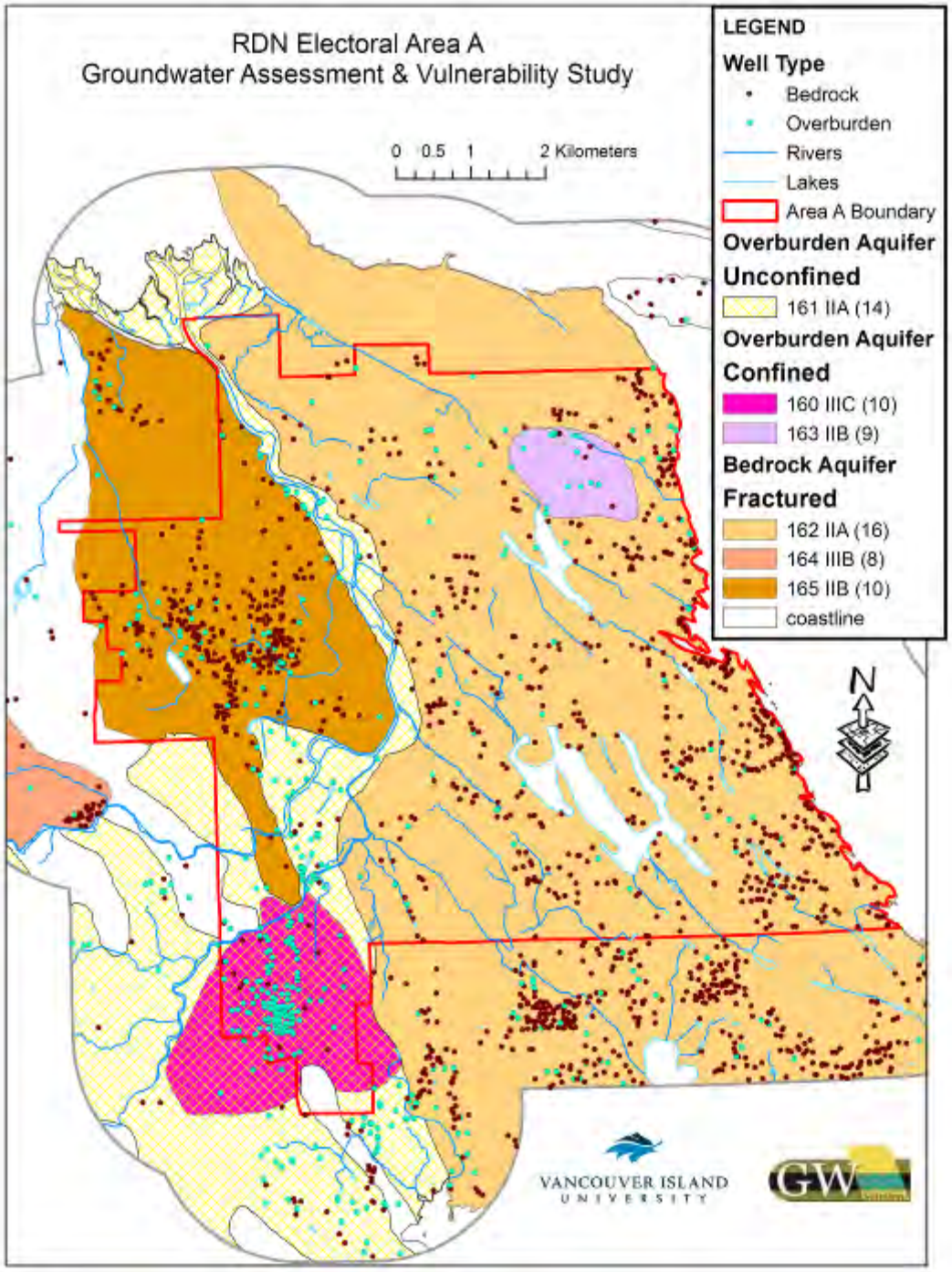

0 0.5 1 2 Kilometers
Legend
Groundwater Flow
Cross-sections
Rivers
Lakes
Area A Boundary
Groundwater Divides
Groundwater
Elevation (m)
High : 183
Low : 0
Zone 1
Zone 2
Zone 3
B'
B
A
A'
C
C'
D
D'
N
VANCOUVER ISLAND UNIVERSITY


0 0.5 1 2 Kilometers
Legend
Groundwater Flow
Cross-sections
Rivers
Lakes
Area A Boundary
Groundwater Divides
Groundwater
Elevation (m)
High : 183
Low : 0
B'
Zone 2
Zone 1
N
C'
C
A'
D
B
A
Zone 3
D'
VANCOUVER ISLAND UNIVERSITY
GW


Cross-Section C – C'
west
(m)
Ground Surface
Water Table
Salt water/Fresh water interface
Ocean
Bedrock
(162)
50
40
30
20
10
0
-10
-20
0
200
400
600
800
1000
1200
1400
(m)


Area A Bo
Groundwa
Groundwater
Elevation (m)
High : 183
Low : 0
Zone 1
Zone 2
Zone 3
A
A'
B
B'
C
C'
D
D'
VANCOUVER ISLAND
UNIVERSITY


north
south
(m)
Cross-Section D – D'
40
30
20
10
0
-10
-20
-30
Water Table
Aquifer
(161)
Clay Aquiclude
Confined Aquifer
(160)
Bedrock
0
500
1000
1500
2000
2500
3000
3500
4000
(m)




Cassidy

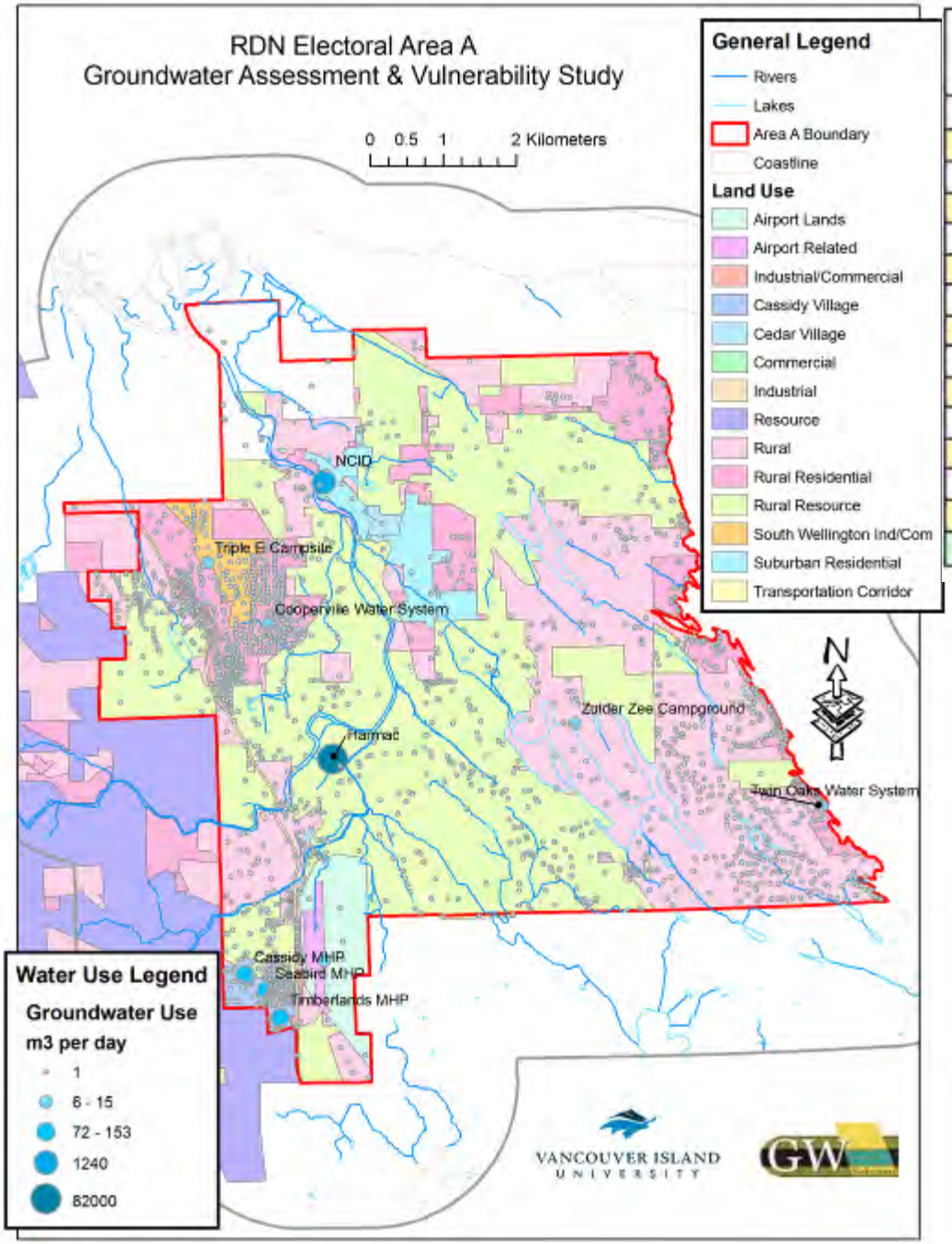
Lower Cassidy
Cedar, North Holden Lake

Cedar, Yellow Point & North Oyster

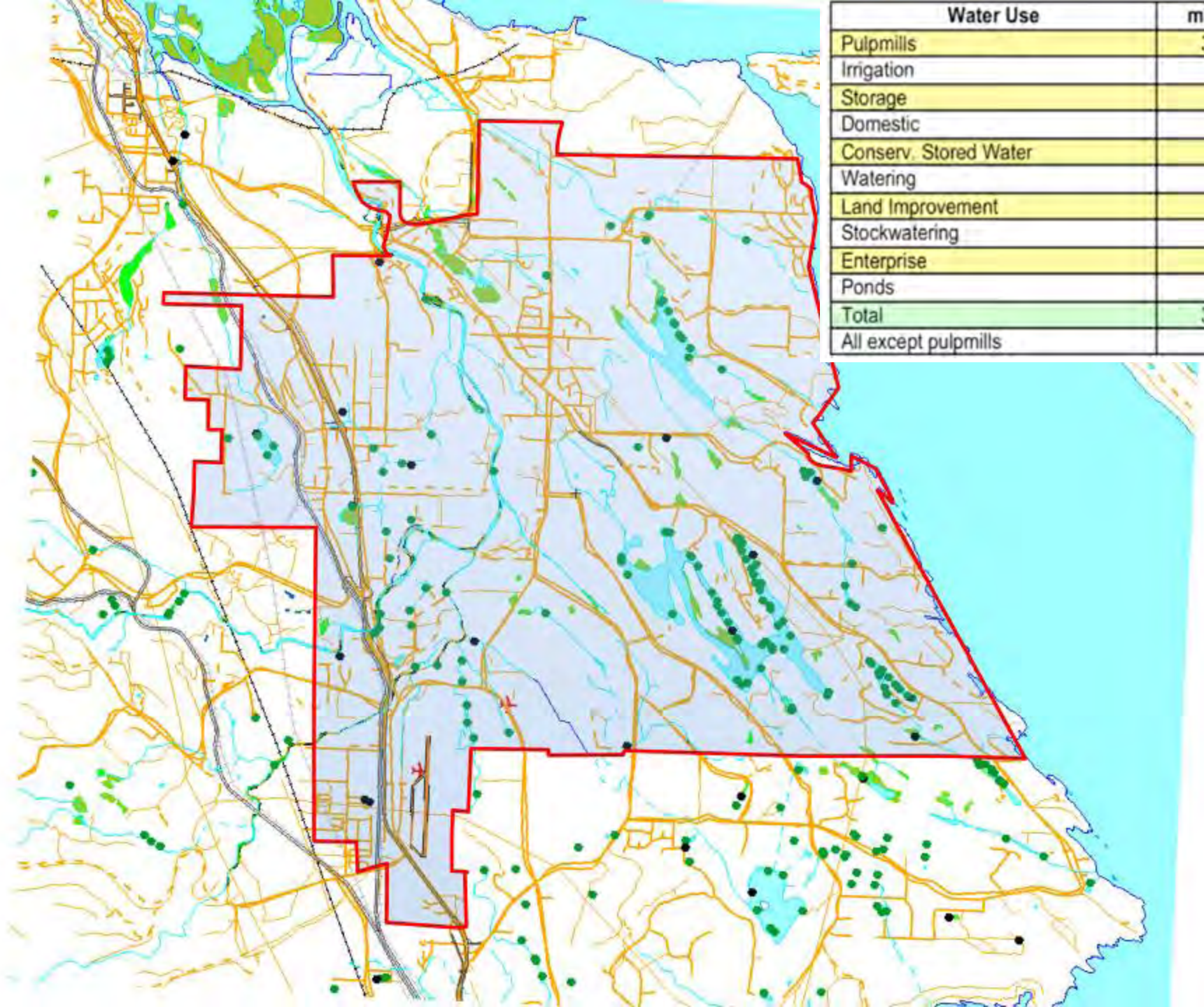
South Wellington

# Who is using the water?

# …and how much?



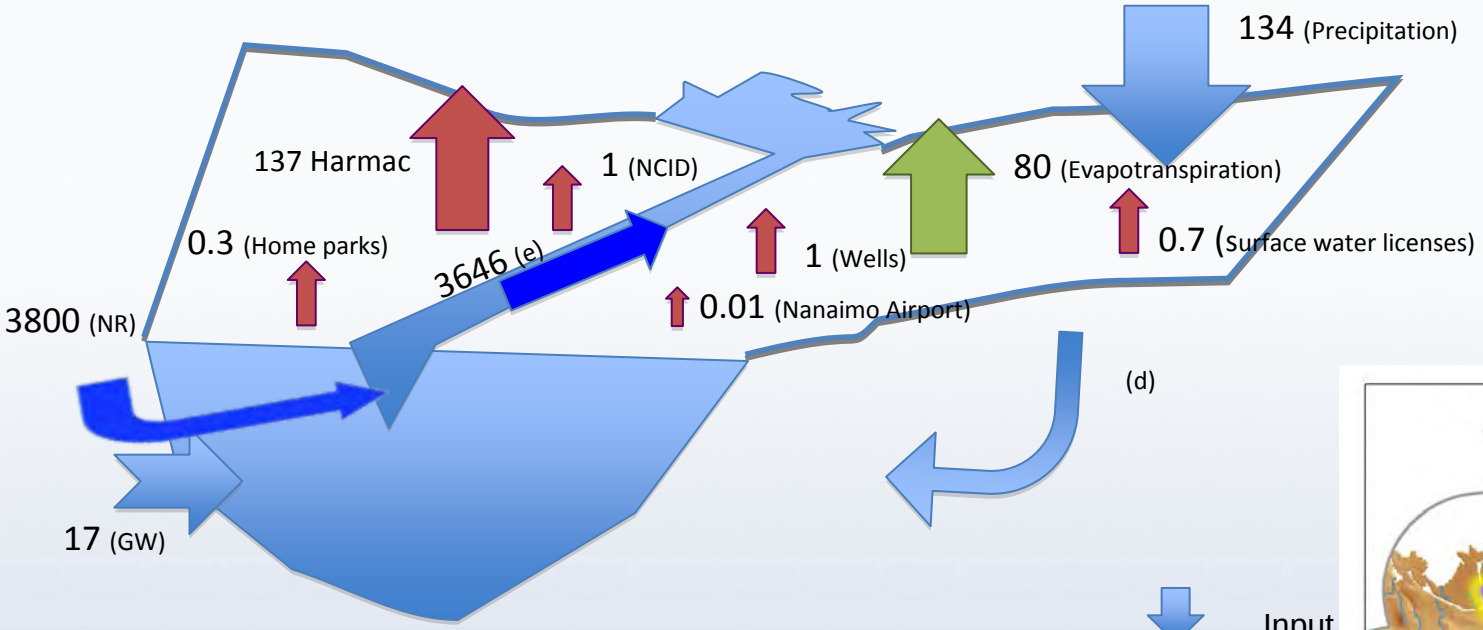

| Water purveyors | Volume pumped (groundwater) | Volume pumped (surface water) |
|---|---|---|
| | ($m^3$ per day) | ($m^3$ per day) |
| North Cedar Improvement District | 1,240 | |
| Decourcey Water Service Area | 5 | |
| Harmac - Nanaimo Forest Products | 82,000 | 54,500 |
| Triple E campsite | 6 | |
| Cooperville Water System | 11 | |
| Boat Harbour Water Users Society | | 43 |
| Zuider Zee Campground | 9 | |
| Twin Oaks Water System | 11 | |
| Cassidy Manufactured Home Park | 72 | |
| Seabird Manufactured Home Park | 78 | |
| Timberlands Manufactured Home Park | 153 | |
| Nanaimo Airport | 15 | |
| Individual wells | 1,500 | |
| Total | 83,599 | 54,543 |



| Water Use | $m^3$/day |
|---|---|
| Pulpmills | 330,288 |
| Irrigation | 1,157 |
| Storage | 288 |
| Domestic | 195 |
| Conserv. Stored Water | 35 |
| Watering | 20 |
| Land Improvement | 19 |
| Stockwatering | 13 |
| Enterprise | 10 |
| Ponds | 1 |
| Total | 332,026 |
| All except pulpmills | 1,738 |

Are we using too much?
Are there areas under stress?

# Water Model – Zone 1 – Average Over Year

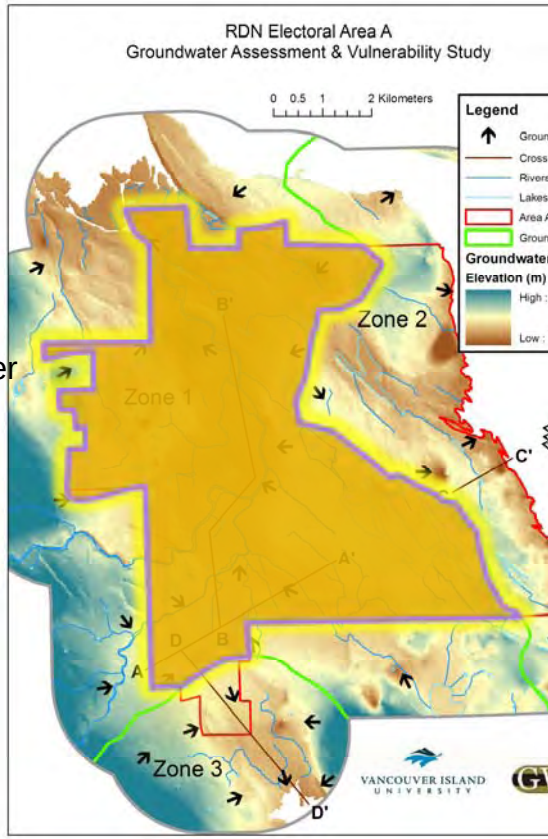



Input

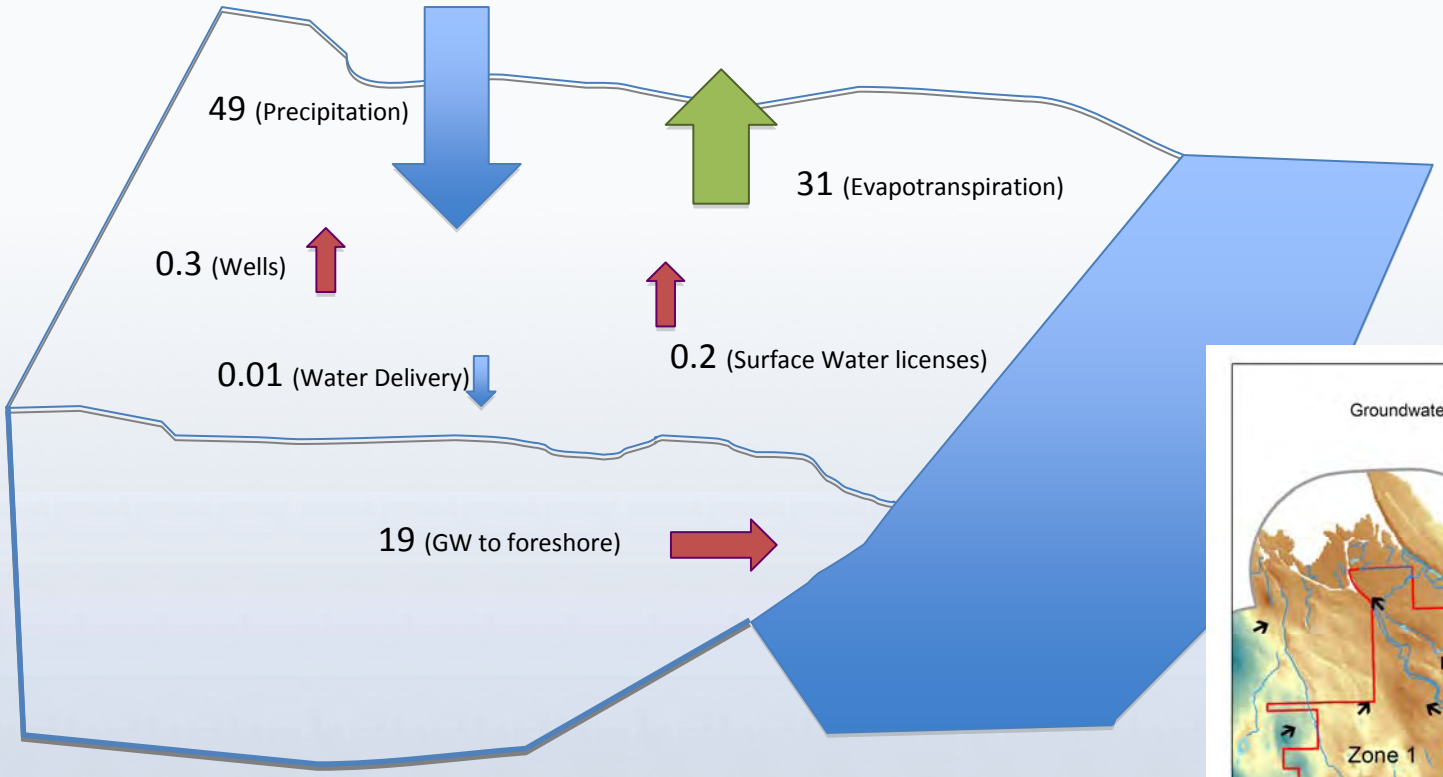
Output

Transfer

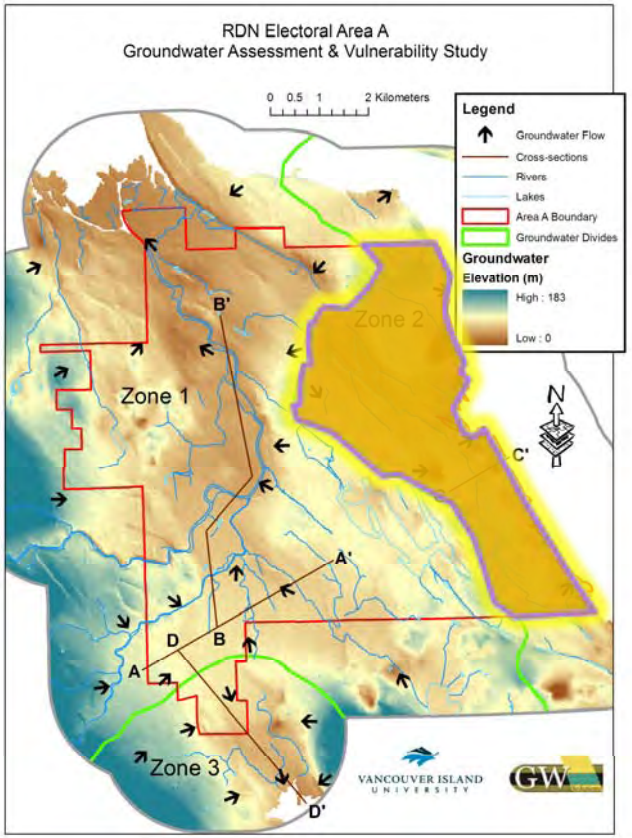
Note: Values in 1000 $m^3$/day



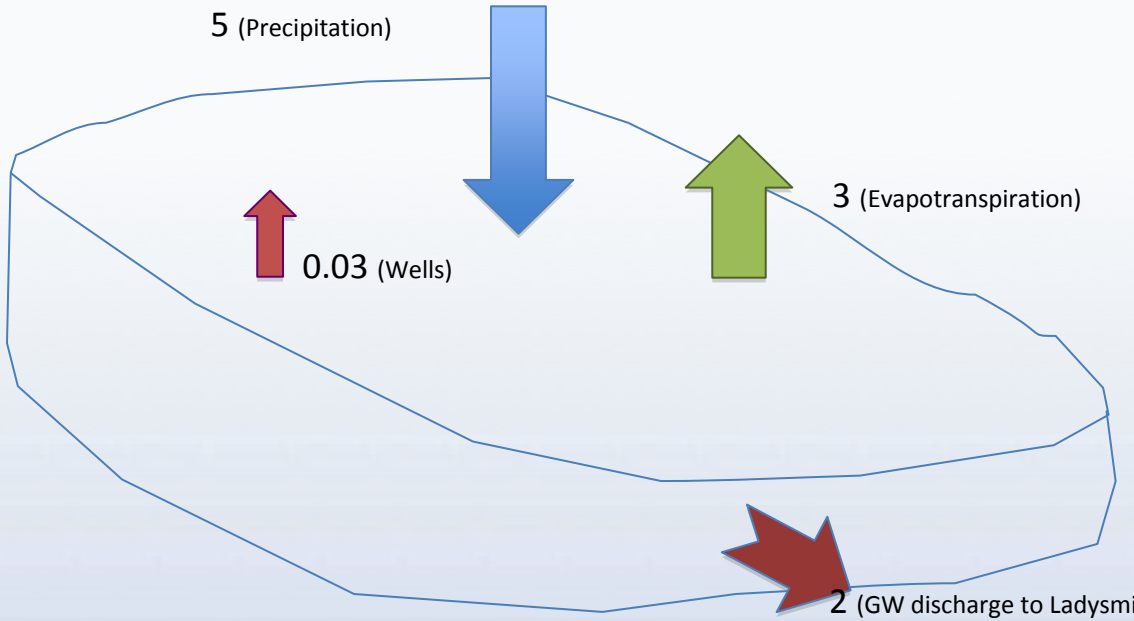
# Water Model – Zone 2 – Average Over Year

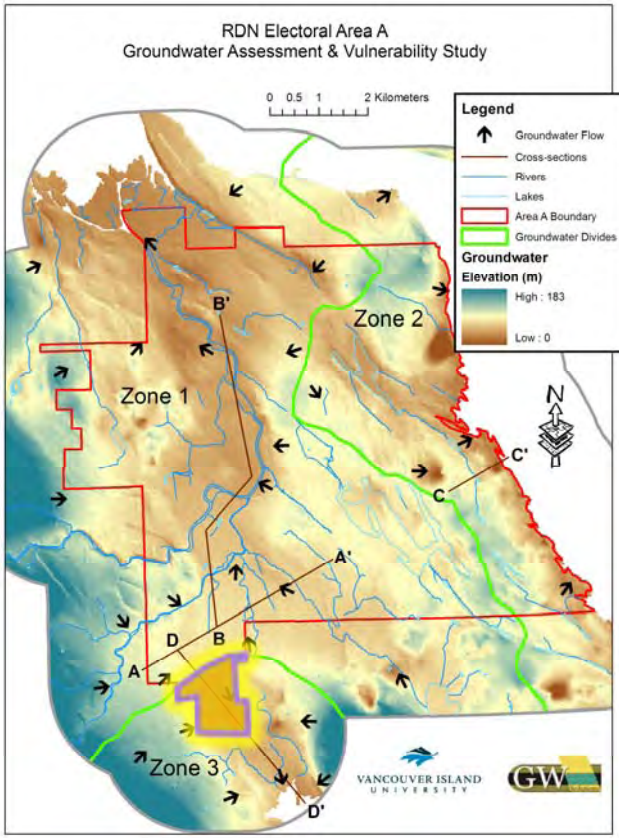



Note: Values in 1000 $m^3$/day



# Water Model – Zone 3 – Average Over Year



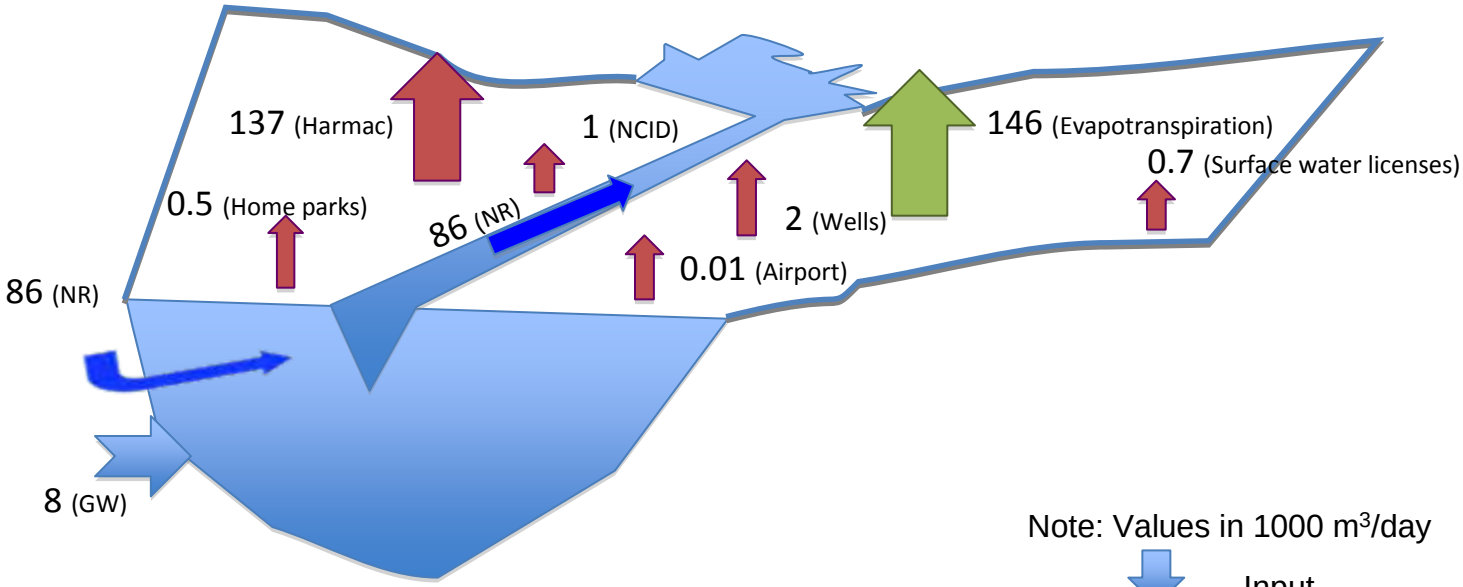




Input

Output

Note: Values in 1000 $m^3$/day

# Water Model – Zone 1 – Critical Period of the Year (September – October)




Note: Values in 1000 $m^3$/day

Input

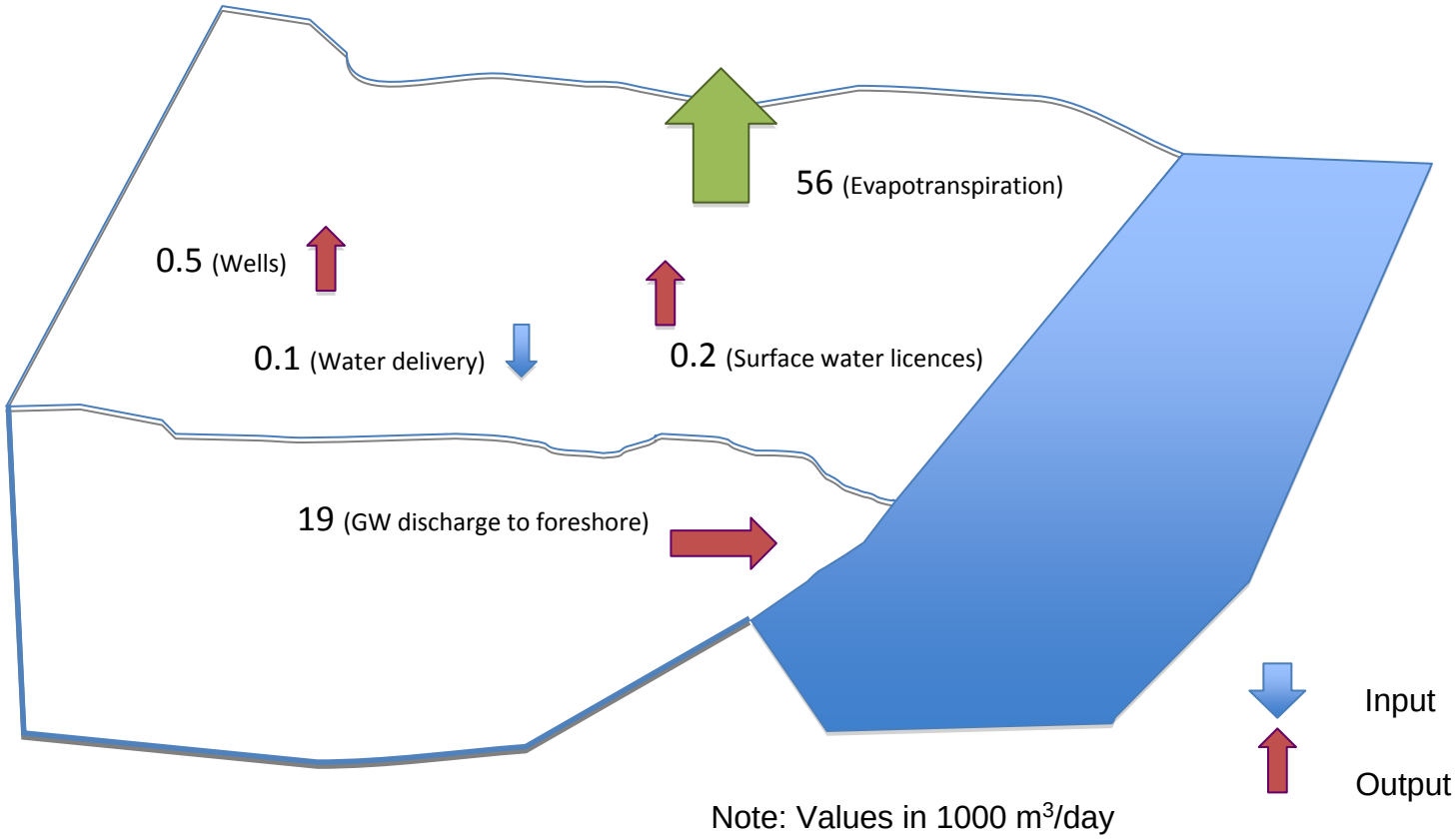
Output

Transfer

Note: Values in 1000 $m^3$/day

Water Deficit: Output = 4 x Input

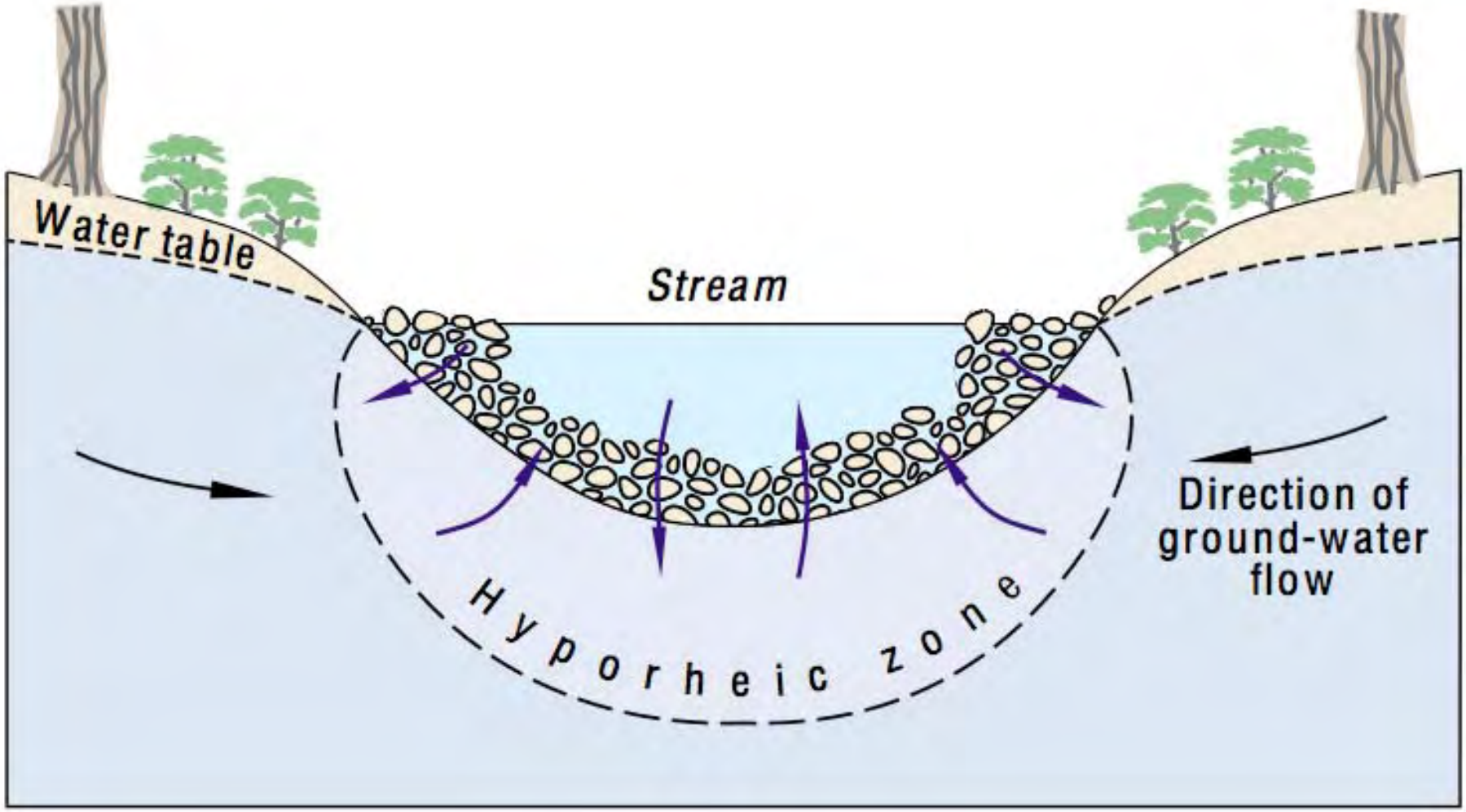
# Water Model – Zone 2 – Critical Period of the Year (September – October)




Water Deficit: Very large – no input

# Water - Zone 1

- Large amounts of water in transfer
- Large and very permeable aquifers
- Nanaimo River and Cassidy Aquifer = 1 system
  - Hyporheic zone

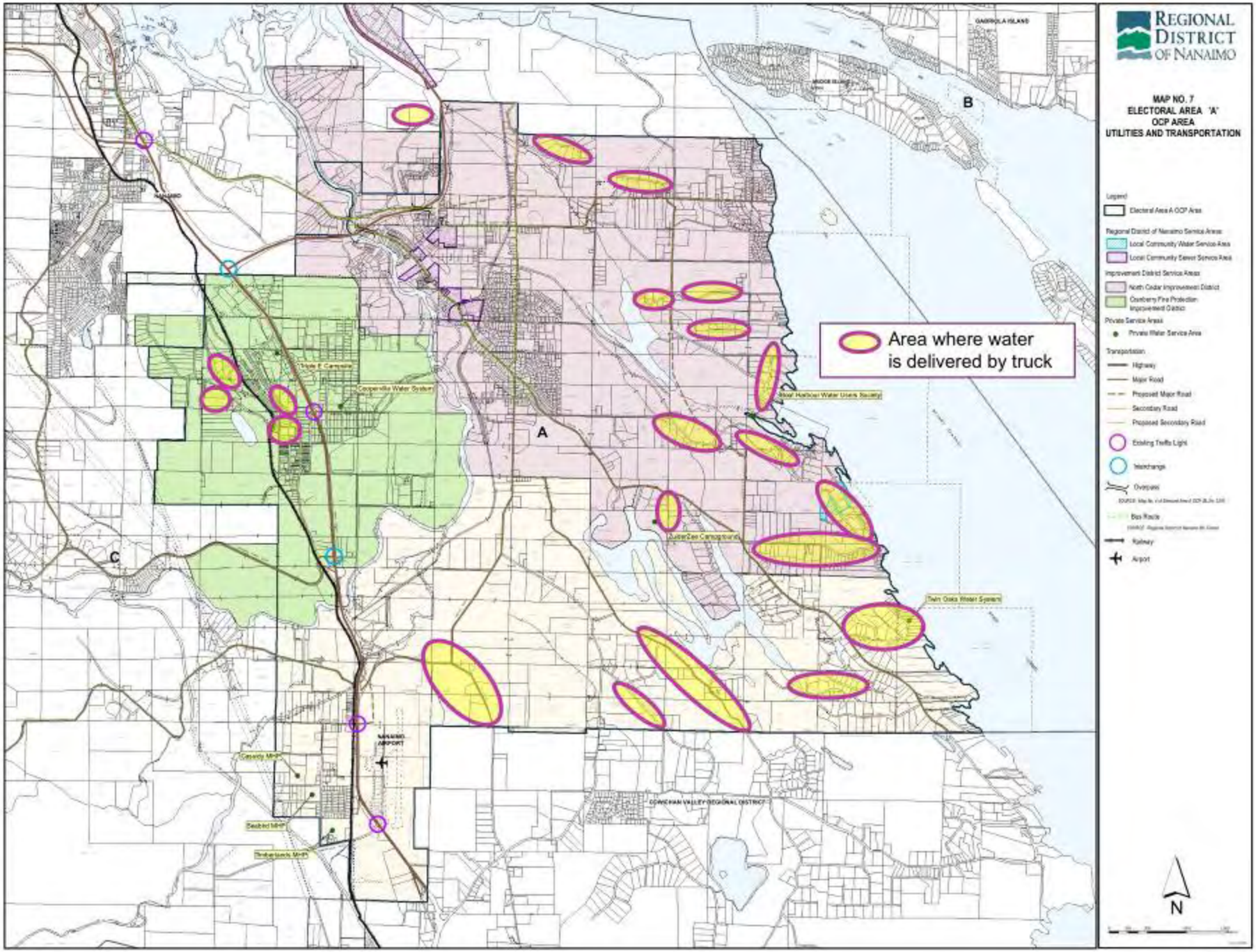

Water table
Stream
Direction of ground-water flow
Hyporheic zone

# Water - Zone 1

- Large amounts of water in transfer
- Large and very permeable aquifers
- Nanaimo River and Cassidy Aquifer = 1 system
  - Hyporheic zone
- Harmac is largest user + water is  extracted
- Late summer early fall:  identified water deficit

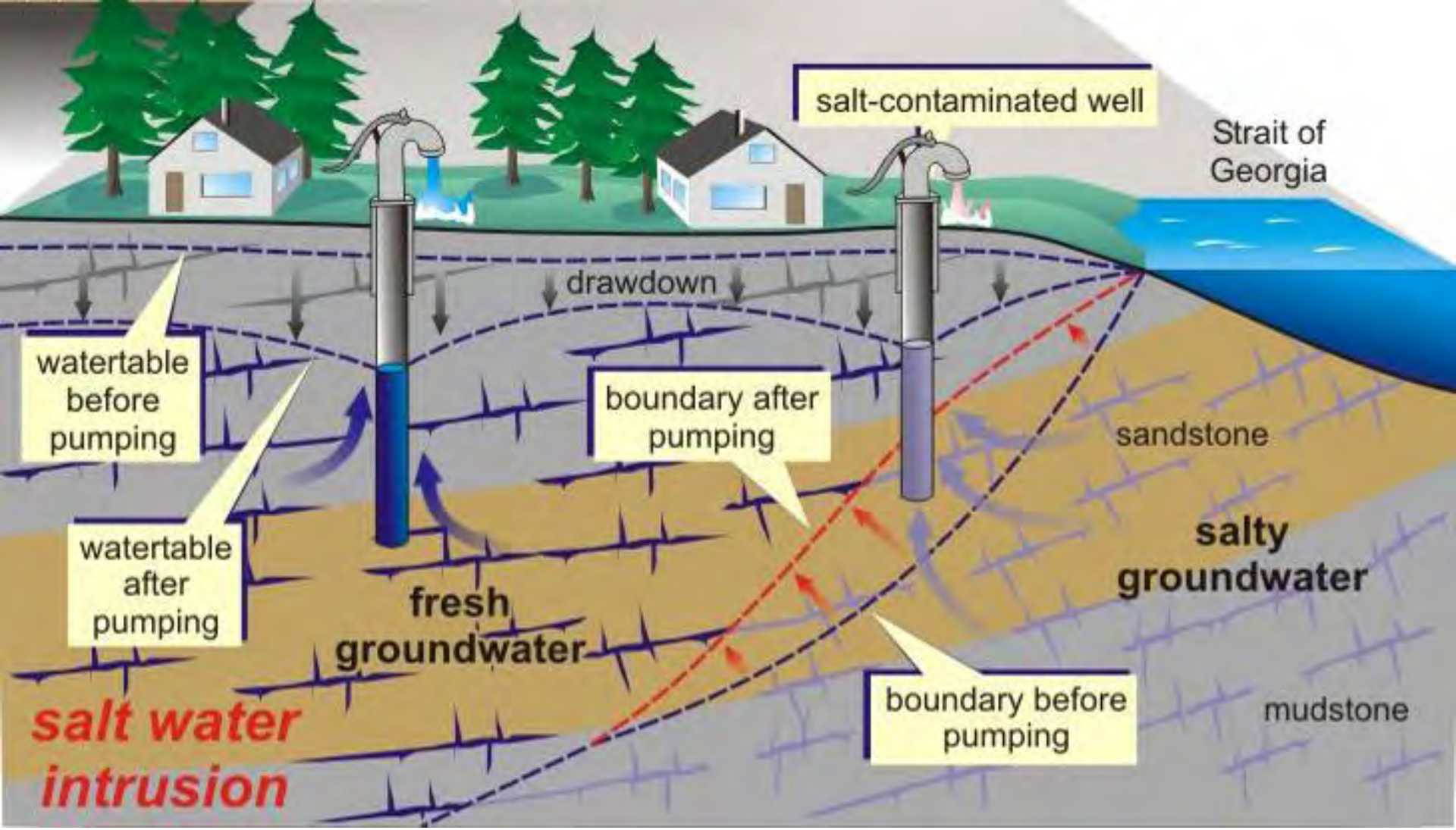
# Water - Zone 2

- Thin veneer of soils
- Main aquifer is the fractured bedrock
- Limited storage capacity
- Summer early fall:  identified water deficit
  - Need for water import


REGIONAL DISTRICT OF NANAIMO
MAP NO. 7
ELECTORAL AREA 'A'
OCP AREA
UTILITIES AND TRANSPORTATION
Area where water is delivered by truck
GABRIOLA ISLAND
B
A
C
Cooperville Water System
Twin Oaks Water System
NANAIMO AIRPORT
COWICHAN VALLEY REGIONAL DISTRICT
N

# Water - Zone 2

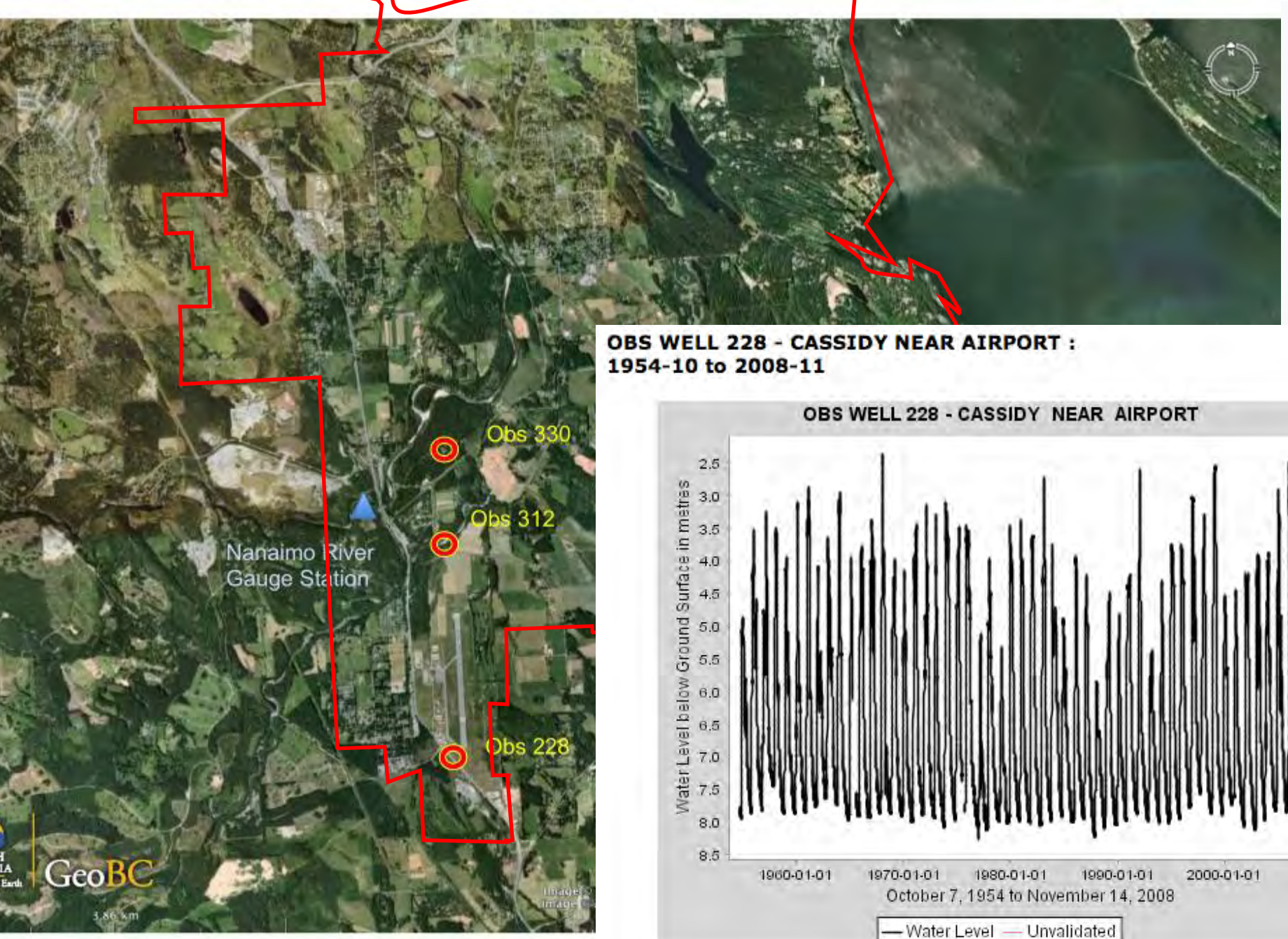
- Thin veneer of soils
- Main aquifer is the fractured bedrock
- Limited storage capacity
- Summer early fall:  identified water deficit
  - Need for water import
  - High risk of degradation of water near coast due to salt water intrusion


salt-contaminated well
Strait of Georgia
drawdown
watertable before pumping
boundary after pumping
watertable after pumping
sandstone
salty groundwater
fresh groundwater
boundary before pumping
mudstone
salt water intrusion

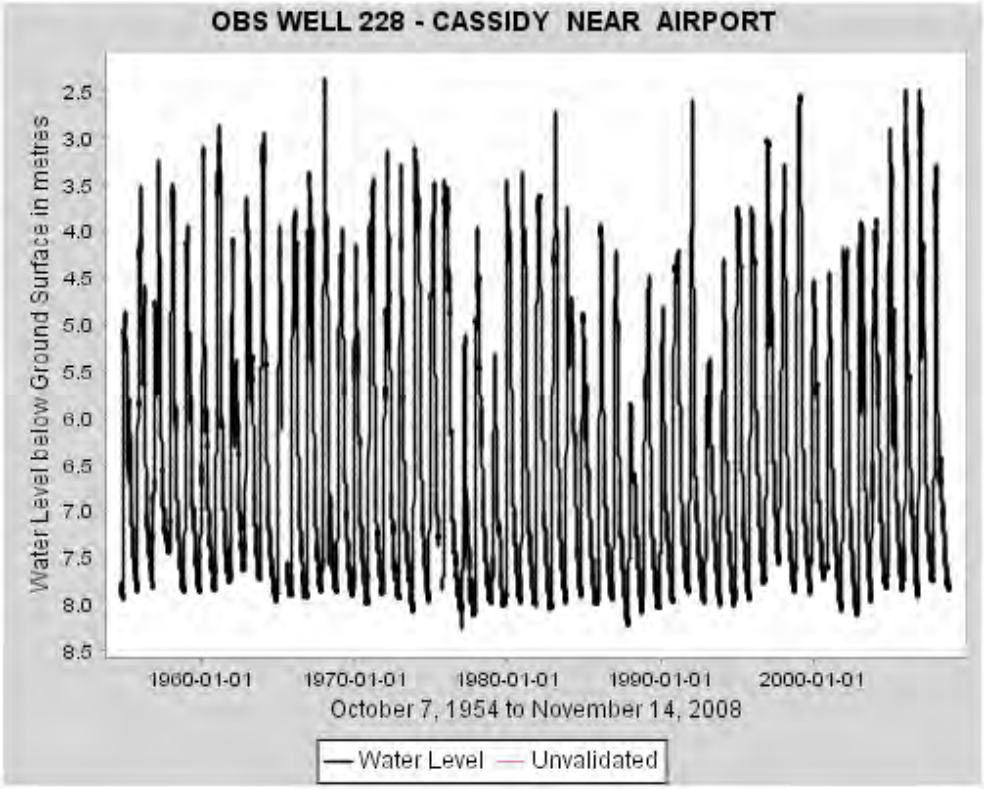
# Water - Zone 3

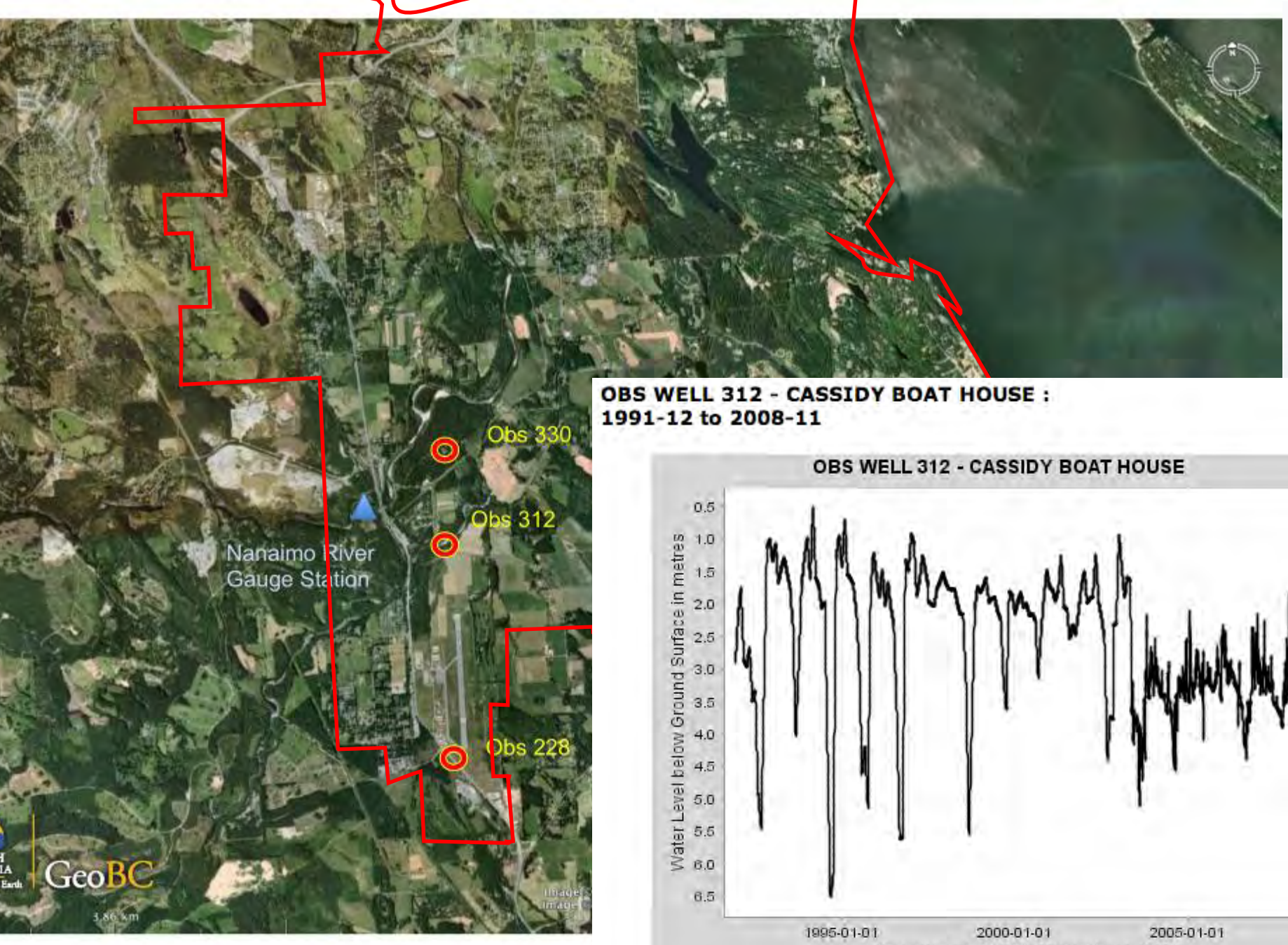
- Large and very permeable aquifers
- Relatively  small usage
- Critical situation: Not identified

# What we know, still don't know….and should know!

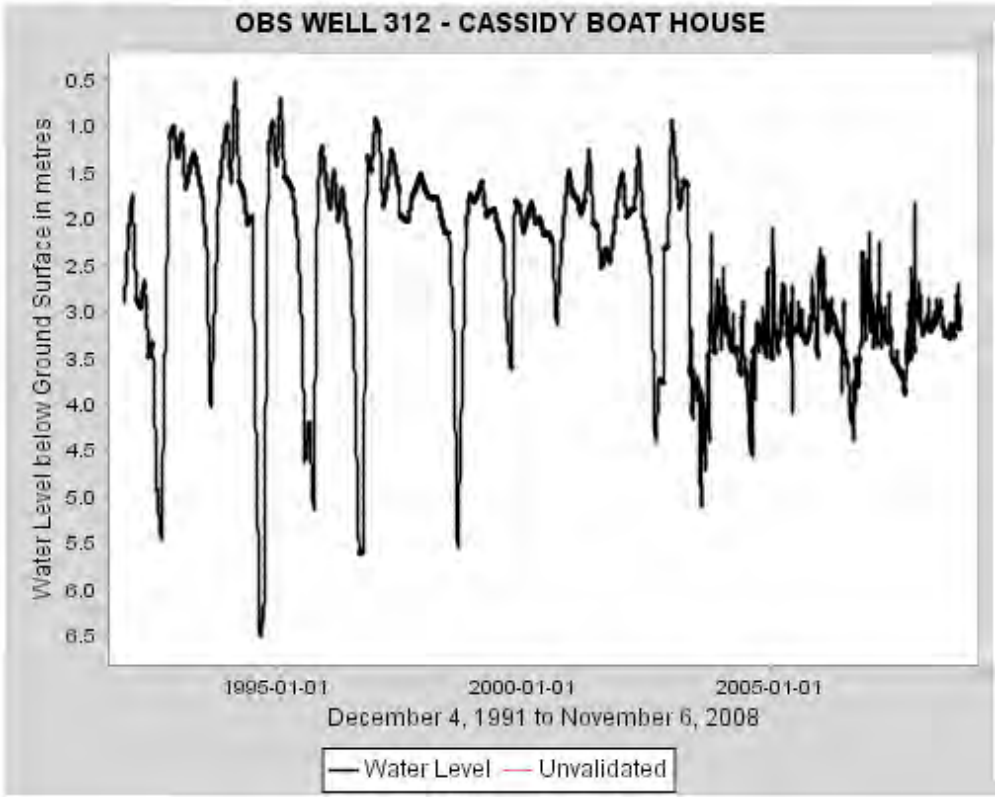


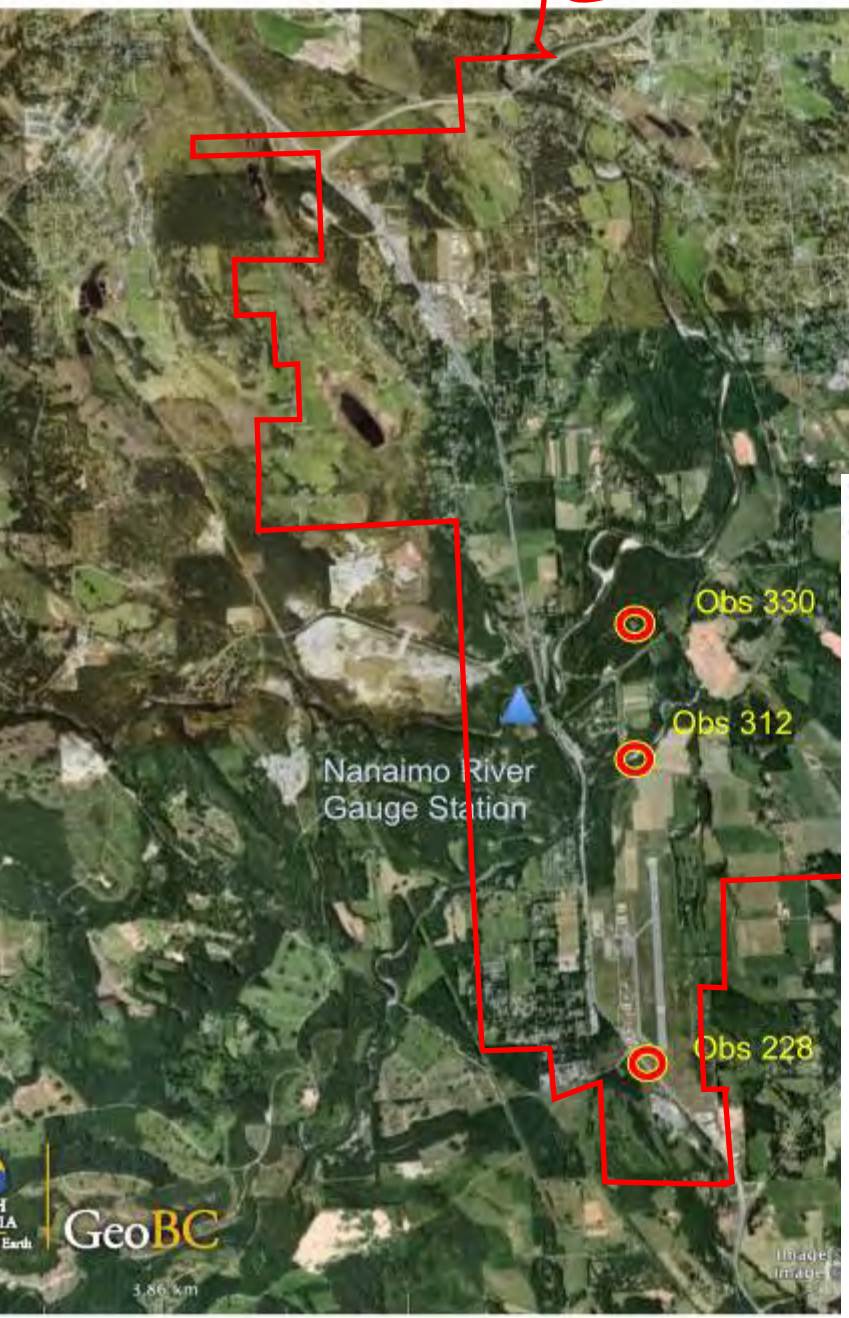

**OBS WELL 228 - CASSIDY NEAR AIRPORT :**
**1954-10 to 2008-11**

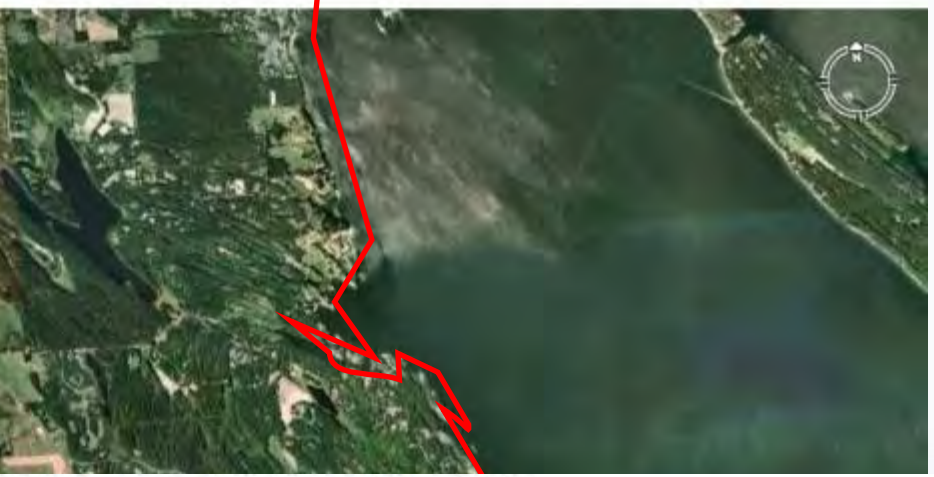




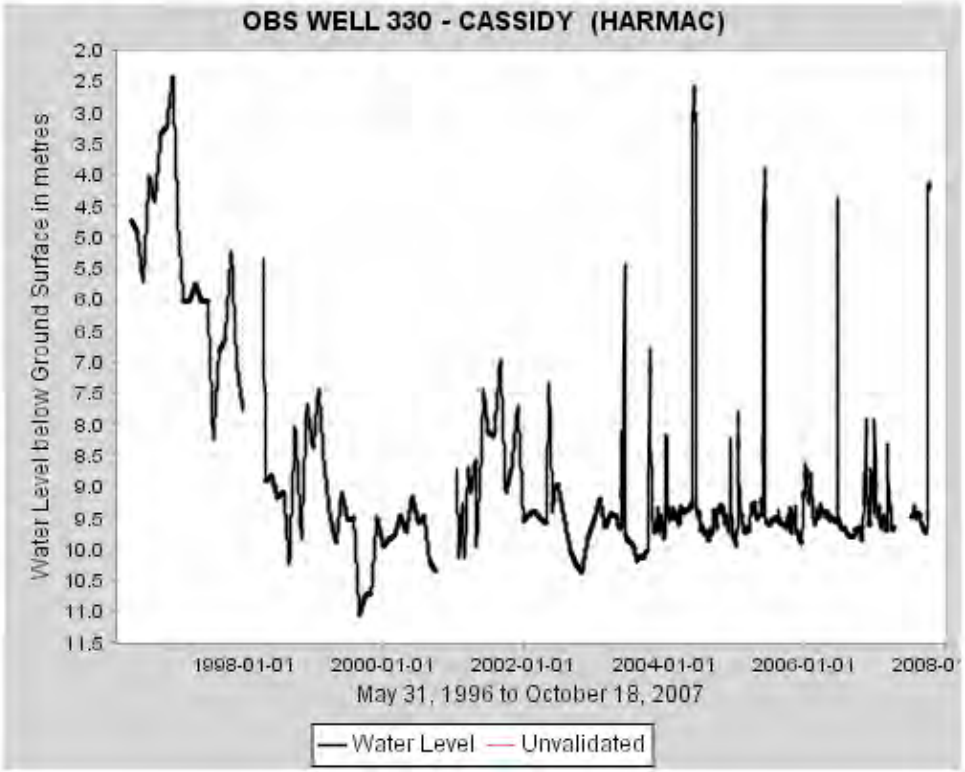

**OBS WELL 312 - CASSIDY BOAT HOUSE :**
**1991-12 to 2008-11**

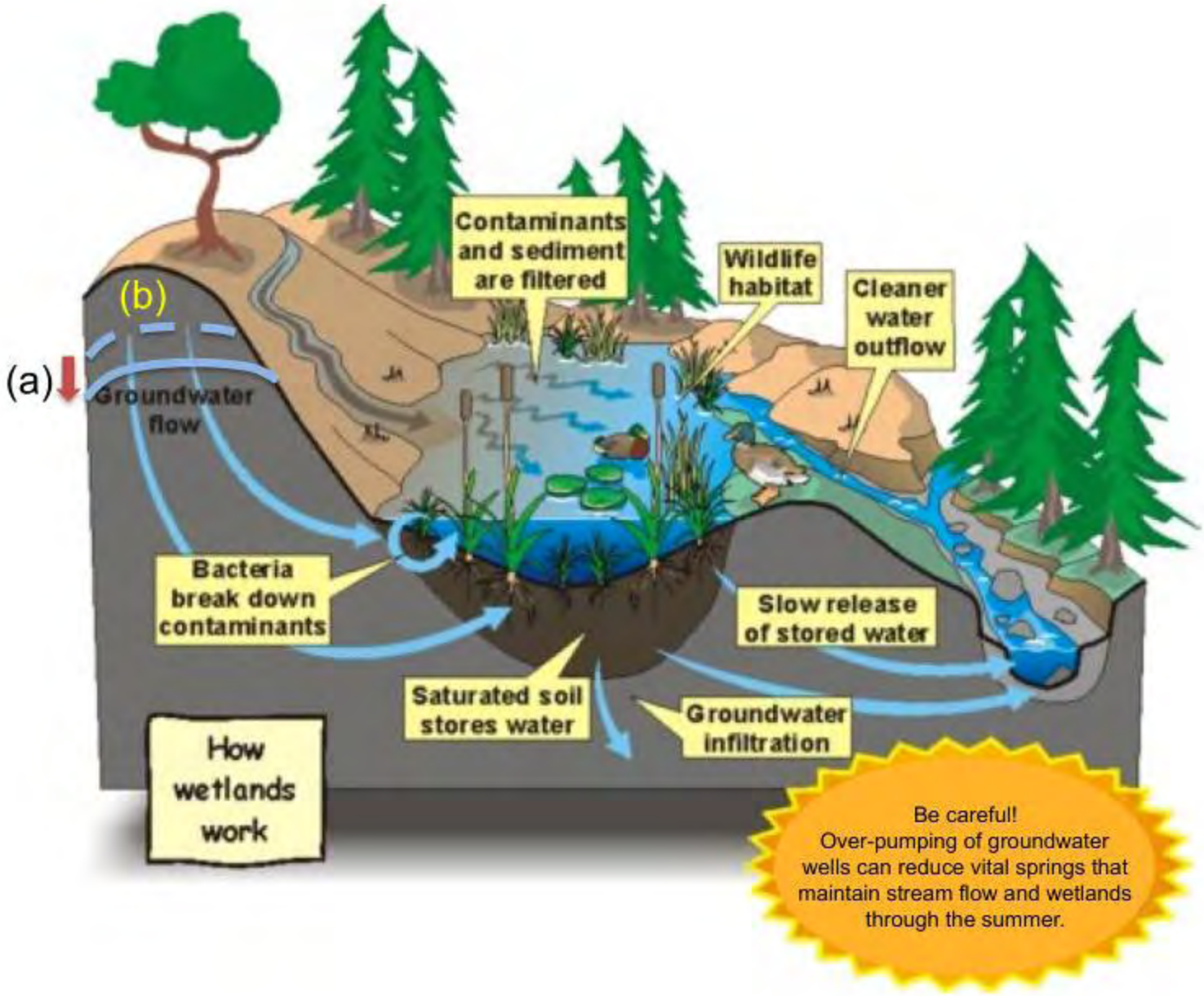


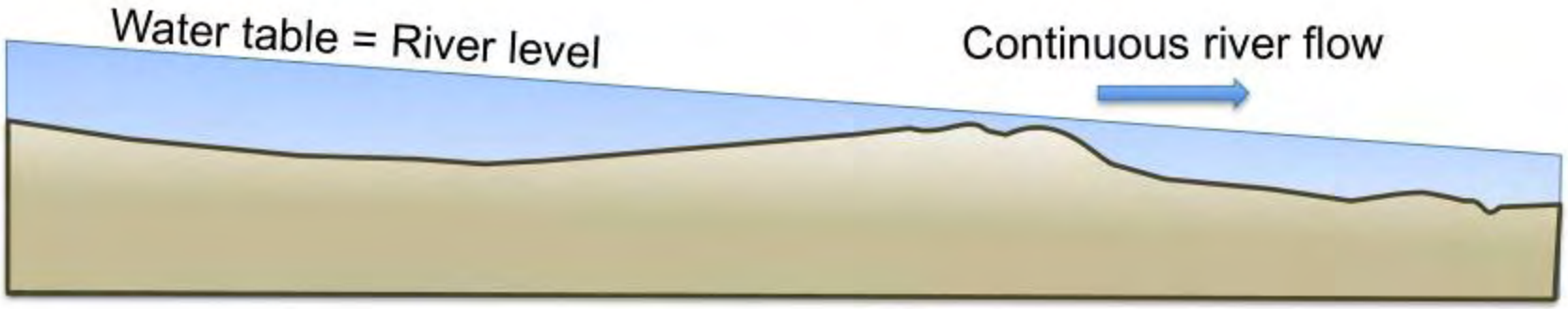


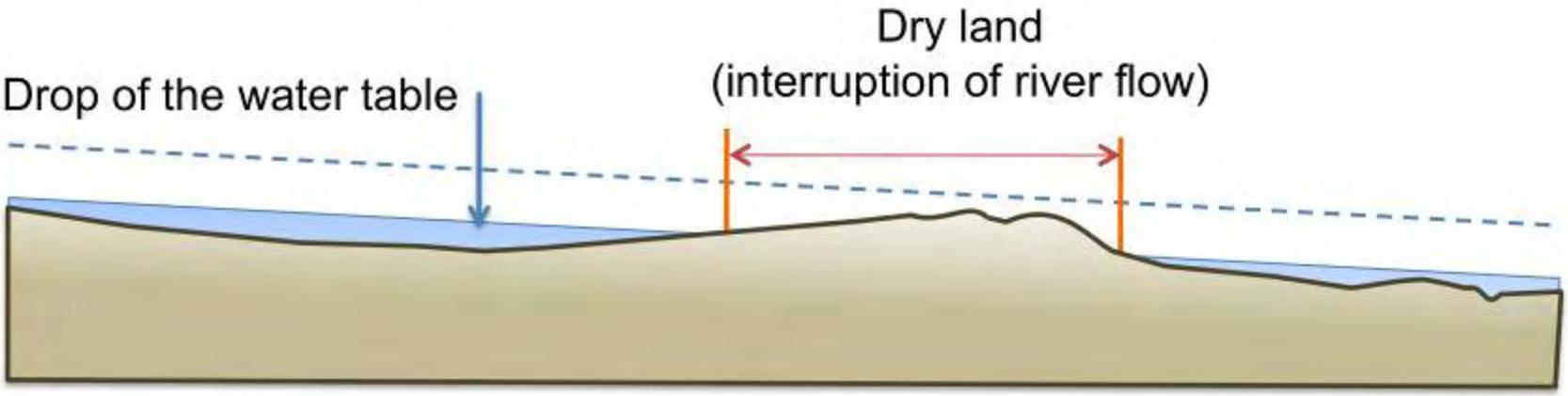
**OBS WELL 330 - CASSIDY (HARMAC) :**
**1996-05 to 2007-10**



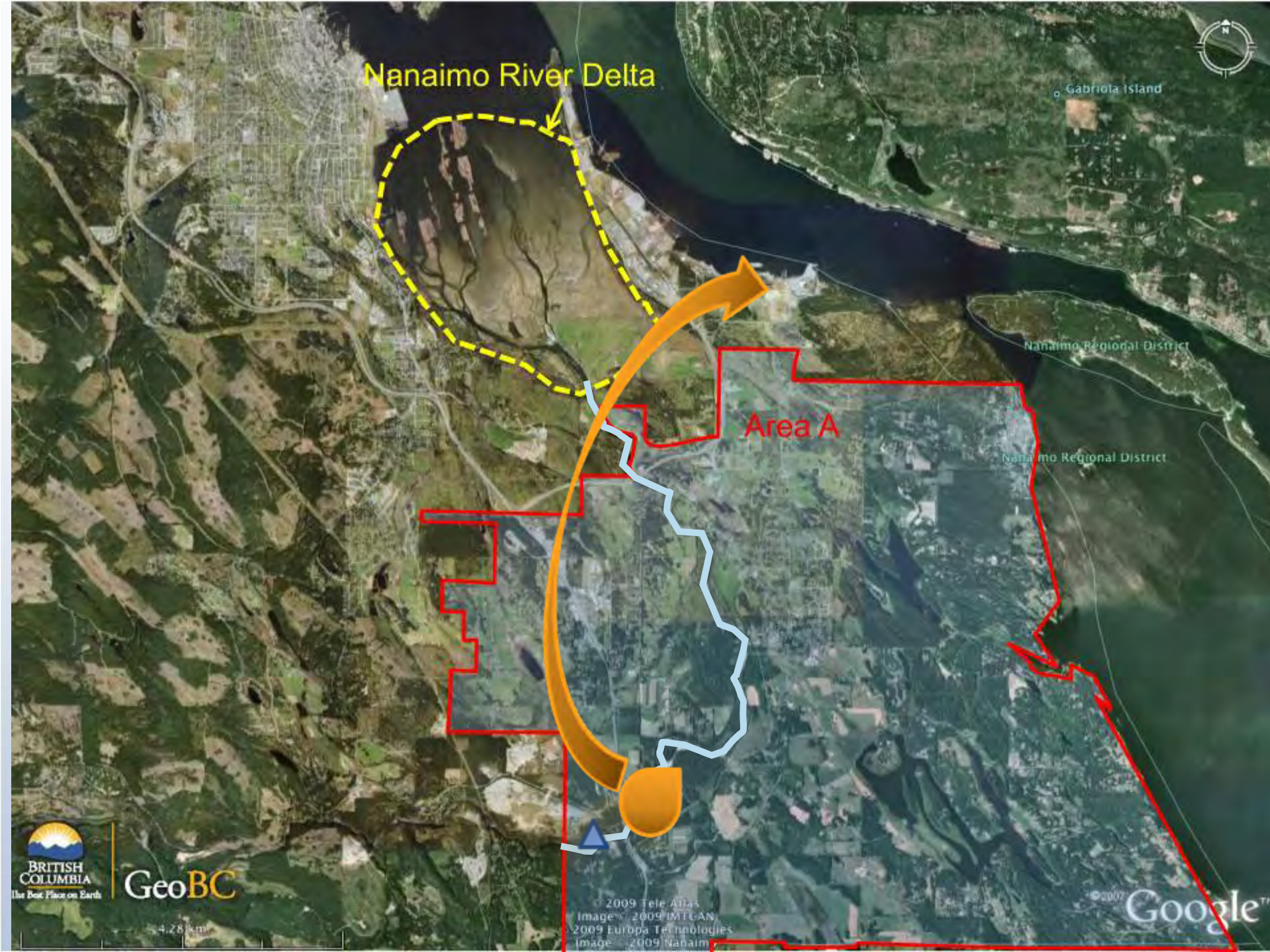

Contaminants and sediment are filtered
Wildlife habitat
Cleaner water outflow
(b)
(a)
Groundwater flow
Bacteria break down contaminants
Slow release of stored water
Saturated soil stores water
Groundwater infiltration
How wetlands work
Be careful!
Over-pumping of groundwater wells can reduce vital springs that maintain stream flow and wetlands through the summer.


Water table = River level
Continuous river flow

(a)

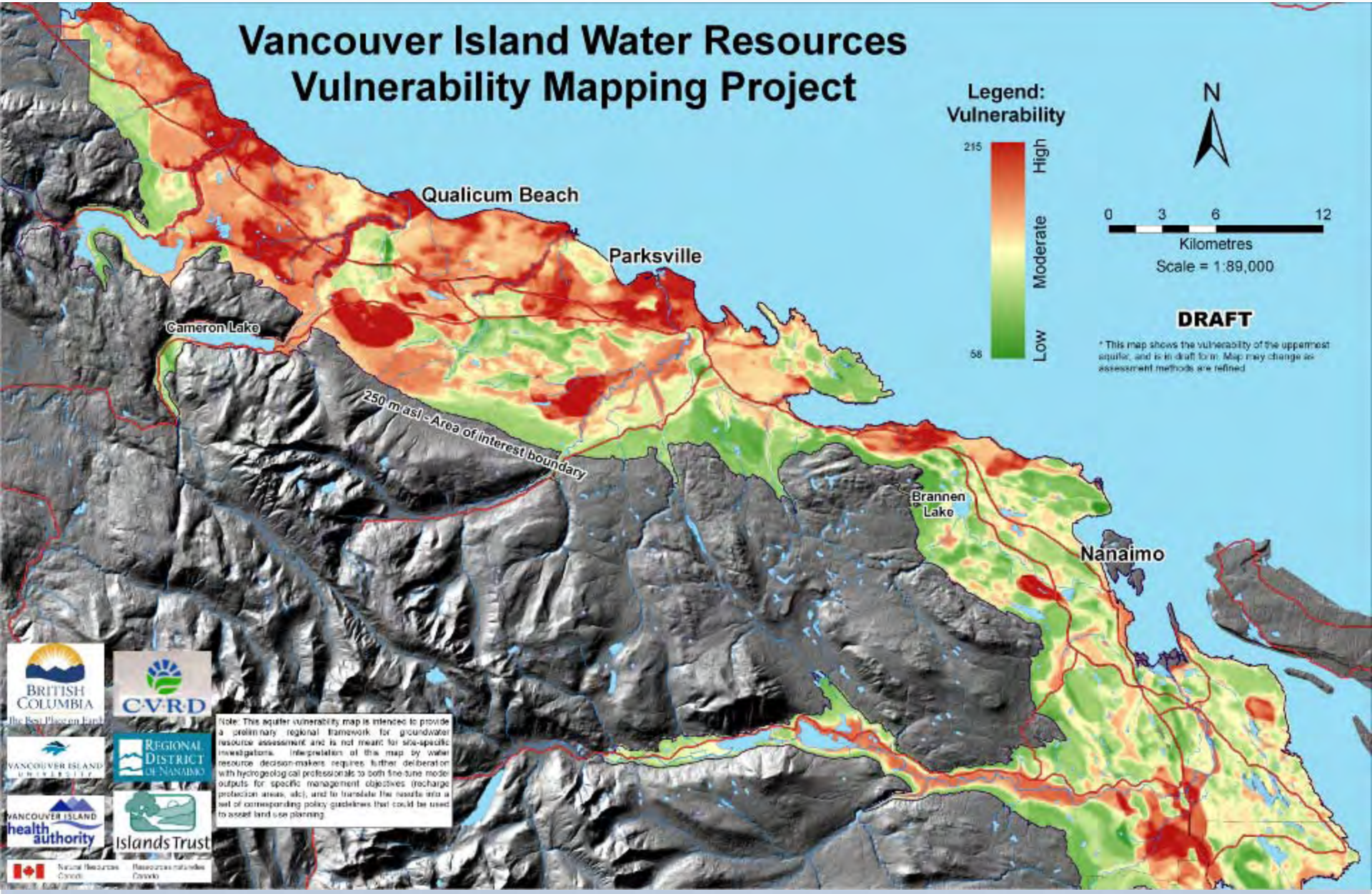

Dry land
(interruption of river flow)
Drop of the water table

(b)

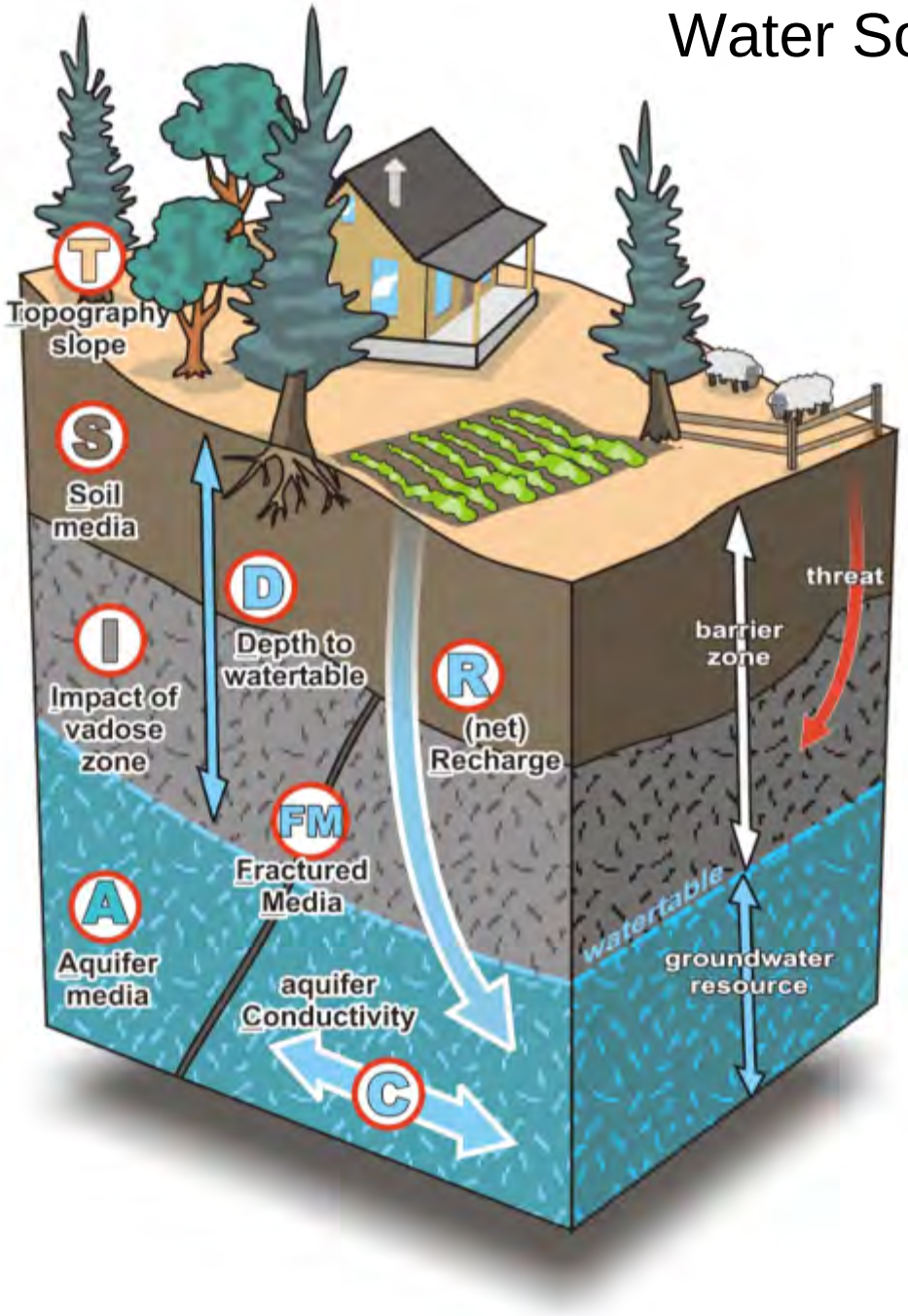

Nanaimo River Delta
Gabriola Island
Nanaimo Regional District
Area A
Nanaimo Regional District
BRITISH COLUMBIA
The Best Place on Earth
GeoBC
4.28 km
2009 Tele Atlas
Image © 2009 IMTC-AN
2009 Europa Technologies
Image © 2009 Nanaimo
©2007
Google

# Important info still needed

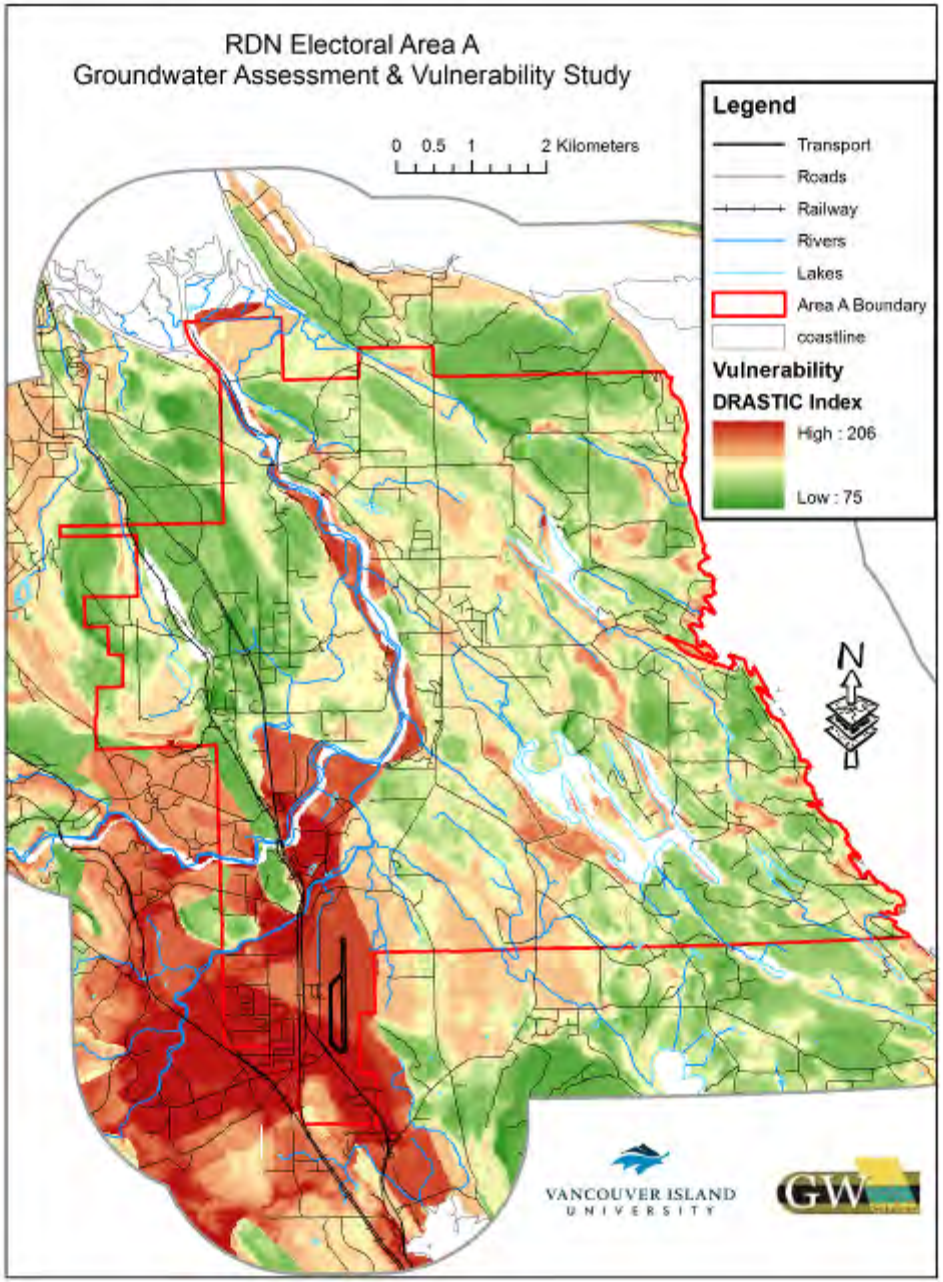
- Nanaimo River flow at mouth
- Response of aquifer to groundwater extraction (monitoring wells)
- Better definition of water demand, mostly during most critical times of the year
- Identification and characterisation of systems (wetland, small tributaries, river banks) most sensitive to lowering of the water table.
- Characterisation and monitoring of complex fresh water/salt water interface

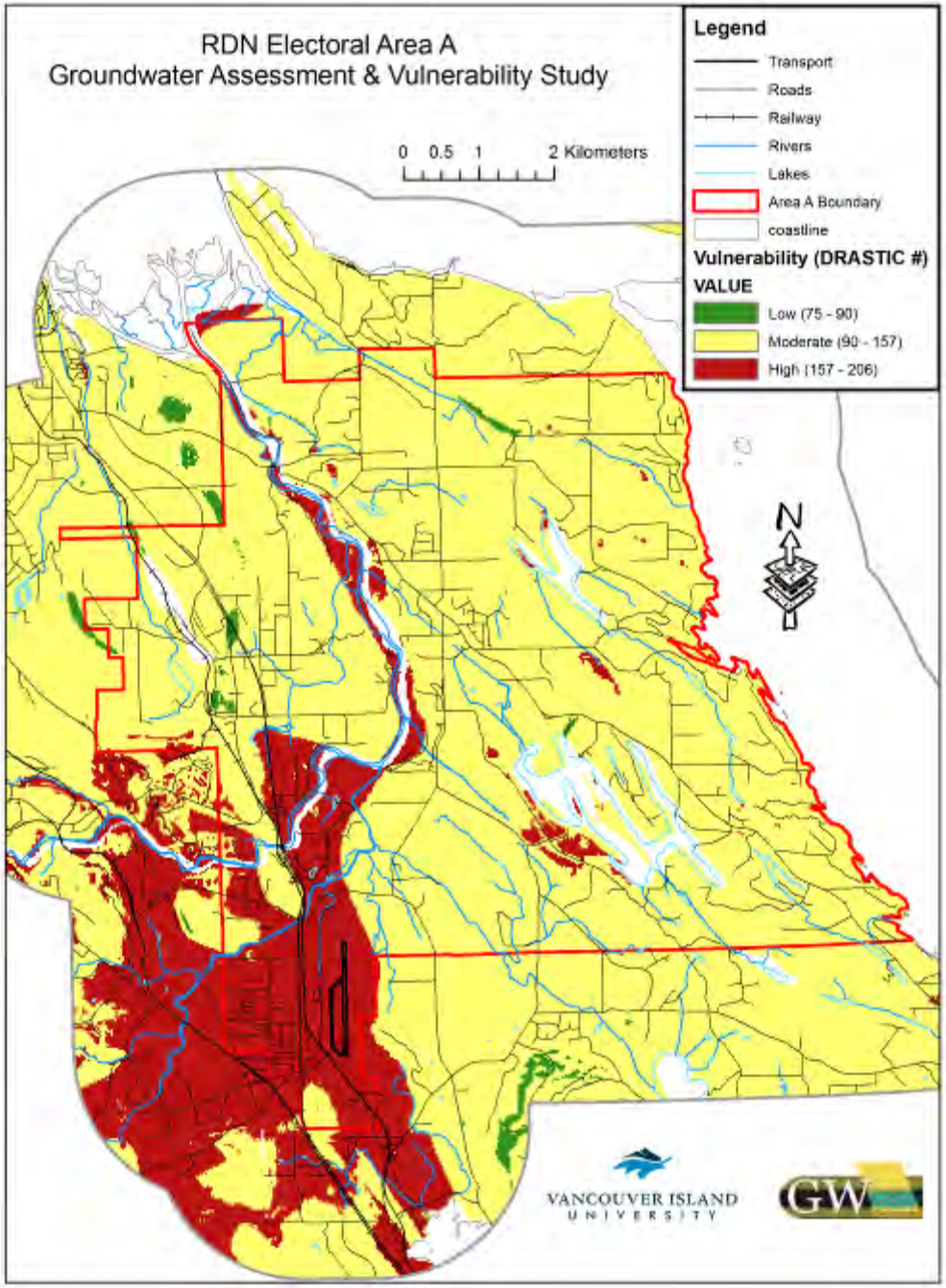

Vancouver Island Water Resources
Vulnerability Mapping Project
Legend:
Vulnerability
215
58
High
Moderate
Low
N
0 3 6 12
Kilometres
Scale = 1:89,000
DRAFT
* This map shows the vulnerability of the uppermost aquifer, and is in draft form. Map may change as assessment methods are refined
Qualicum Beach
Parksville
Cameron Lake
250 m asl - Area of interest boundary
Brannen Lake
Nanaimo
BRITISH COLUMBIA
C·V·R·D
REGIONAL DISTRICT OF NANAIMO
VANCOUVER ISLAND UNIVERSITY
VANCOUVER ISLAND health authority
Islands Trust
Natural Resources Canada
Ressources naturelles Canada
Note: This aquifer vulnerability map is intended to provide a preliminary regional framework for groundwater resource assessment and is not meant for site-specific investigations. Interpretation of this map by water resource decision-makers requires further deliberation with hydrogeological professionals to both fine-tune model outputs for specific management objectives (recharge protection areas, etc), and to translate the results into a set of corresponding policy guidelines that could be used to assist land use planning.

# Water Source Vulnerability Mapping using DRASTIC




Schematic diagram of DRASTIC vulnerability mapping method (courtesy of B. Turner and R. Franklin)


RDN Electoral Area A
Groundwater Assessment & Vulnerability Study
0 0.5 1 2 Kilometers
Legend
Transport
Roads
Railway
Rivers
Lakes
Area A Boundary
coastline
Vulnerability
DRASTIC Index
High : 206
Low : 75
N
VANCOUVER ISLAND
UNIVERSITY
GW


RDN Electoral Area A
Groundwater Assessment & Vulnerability Study
0 0.5 1 2 Kilometers
Legend
Transport
Roads
Railway
Rivers
Lakes
Area A Boundary
coastline
Vulnerability (DRASTIC #)
VALUE
Low (75 - 90)
Moderate (90 - 157)
High (157 - 206)
N
VANCOUVER ISLAND
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GW

# Vulnerability Map

- Tool to visualize the vulnerability of water resources
- Tool to identify where caution and care should be considered
- Tool to be used in combination with Best Management Practices

# BMPs – Examples

| Sources of Contamination | | Aquifer Vulnerability | | | Responsible Parties | | |
|---|---|---|---|---|---|---|---|
| | | Low | Moderate | High | Senior Governments | RDN & Municipalities | Individuals & Businesses |
| Regional District | *Sewer leakage* | 6 year inspections | 4 year inspections | 2 year inspections | ✓ | ✓ | ✓ |
| | *Liquid wastes* | Irrigation, infiltration-percolation, and overland flow allowed | No irrigation or infiltration-percolation allowed, but overland flow is allowed | No irrigation, no infiltration-percolation, no overland flow | ✓ | ✓ | ✓ |
| | *Solid wastes* | Landfill permitted | No landfill | No landfill | ✓ | ✓ | |
| Agricultural | *Irrigation* | Irrigation is allowed- water management and conservation plan recommended | Irrigation is allowed - water management and conservation plan recommended | Irrigation is allowed - water management, monitoring, and conservation plan required | ✓ | ✓ | ✓ |
| | *Animal wastes* | Livestock raising is allowed | Livestock raising is allowed | Livestock raising is not allowed | ✓ | ✓ | ✓ |
| | *Fertilizer application* | Fertilization is allowed | Fertilization is allowed with groundwater monitoring | Fertilization is not allowed | ✓ | ✓ | ✓ |
| | *Pesticide application* | Pesticides are allowed | Pesticides are not allowed | Pesticides are not allowed | ✓ | ✓ | ✓ |
| Miscellaneous | *Spills* | Containment is required | Containment is required | Containment is required | ✓ | ✓ | ✓ |
| | *Stockpiles* | Containment is required | Containment is required | Containment is required | ✓ | ✓ | ✓ |
| | *Septic tanks and disposal fields* | Inspections every 2 years | Inspections every 2 years | Inspections every 2 years Monitoring well installed downgradient of field at property boundary and groundwater quality monitoring every 3 years | ✓ | ✓ | ✓ |
| | *Roadway de-icing* | Use of sand recommended. Road de-icing is allowed | Use of sand recommended. Road de-icing is not allowed | Use of sand recommended. Road de-icing is not allowed | ✓ | | |
| | *Cross-contamination of wells* | Abandoned wells plugged and new wells properly sealed | Abandoned wells plugged and new wells properly sealed | Abandoned wells plugged and new wells properly sealed | ✓ | | |

# Thank You!

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