Landslide activity 8: **Debris flows in British Columbia**

Description: In this activity, students discover the relationship between weather conditions and landslides by graphing and analyzing precipitation and runoff data prior to historic debris flow landslides. This lesson could be used independently, or could follow the lab demonstration to model a debris flow (activity 3).

Materials: Teaching notes on debris flows and North Vancouver events including 4 overheads:
1. Debris flow diagram
2. Location of Blueridge Escarpment Area
3. Photographs of the 2005 Berkely landslide
4. Precipitation and Discharge Data, 1979 and 2005

4 Student datasheets
Student worksheet 1 (Weather Conditions)

Teacher instructions:

1. Use the accompanying teaching notes to discuss debris flows. Materials, including diagrams suitable for overhead projection, are provided in the teaching notes on debris flows in general and the specific case of debris flow events in the District of North Vancouver, BC. The latter provides background for the graphing exercise that follows. The teacher should reserve overhead 4 for the final discussion of the students' results.
2. Distribute the worksheets and datasheets.
3. Students use data from the Environment Canada website (http://www.ec.gc.ca/default.asp?lang=En&n=FD9B0E51-1) to plot precipitation and discharge data for the period leading up to the debris flows of 1979 and 2005 in District of North Vancouver.

   Note: If access to computers is limited, the students can manually graph the data using the accompanying datasheets. With computers, students can access the data on-line and do the exercise in a spreadsheet software such as Excel.

   Environment Canada website (http://www.wsc.ec.gc.ca/)

   For discharge data: http://www.ec.gc.ca/rhc-sc/default.asp?lang=En&n=4EED50F1-1
   - Select Data Products & Services, then, under Online Search, choose Archived Hydrometric Data
   - To querry the database online, enter the station number 08GA030 for Seymour River near North Vancouver
   - Choose Obtain Record
   - Select Report Type: Daily and select the year.

   For climate data: http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=17A7AAB9-1
   - Select Data Products & Services, then choose Climate and Historical Weather and select Products and Services. Follow the links to Climate Data Online. Select Vancouver.
   - Choose Daily data online and choose the year.
4. Students answer questions about their graphs.
5. Results are discussed in class. Teacher may use overhead 4 to focus discussion.

Teaching Notes:
Mountainous slopes are vulnerable to many different types of slope failure. Landslide type is determined by local geological, topographical and trigger conditions. Two landslide types that have had devastating effects in BC are **debris flows** and **debris avalanches** (a debris avalanche is a very rapid debris flow). Both types are sometimes informally called mudflows.

What Happens?

- Water-saturated geological material on steep slopes looses physical strength or cohesion and a mass of sediment disintegrates or liquefies and flows downslope in a semi-liquid state (accompanying diagram of a debris flow can be printed as an overhead).
- These landslides move rapidly downslope in a continuous, fluid-like flowing motion involving a mixture of mud, water and other debris including trees and boulders. Such movements involve not only the original failed mass, but the flow destabilizes and incorporates new sediment as it moves downslope.

What Causes Them? Heavy rainfall events trigger many flows, however melting snowpack, improper drainage including seepage, irrigation, or sudden releases of water have also triggered debris flows.

What Stops Them? Eventually the displaced mass of mud and debris looses momentum and comes to rest in a flatter area or it is caught in a natural or man-made depression. (Man-made catchment basins are one method we use to control risk of debris flows.)

History of Debris Flows in North Vancouver

The District of North Vancouver, part of the North Shore of Greater Vancouver, has experienced numerous debris flows, some of which have impacted homes. These landslides happen on steep, forested, terrace slopes consisting of sand, silt and glacial till. The debris flows are commonly associated with extreme rainfall events.

An area of particular concern is the Blueridge escarpment, a terrace slope along the east side of Seymour River. This area experienced a number of debris flows in 1979 and 2005. (See accompanying map.)

1979: The Seymour-Riverside Landslide

During an extremely heavy rainstorm in December 1979, a layer of weathered sediment failed near the top of an 80 m high escarpment. The flow cut a swath through a thick stand of tall conifers and avalanched onto the terrace below. Two homes located on the lower terrace were demolished, and one home at the top of the escarpment was left partially unsupported. Two other slope failures occurred in the same area, but caused only minor damage.

2005: The Berkley Landslide

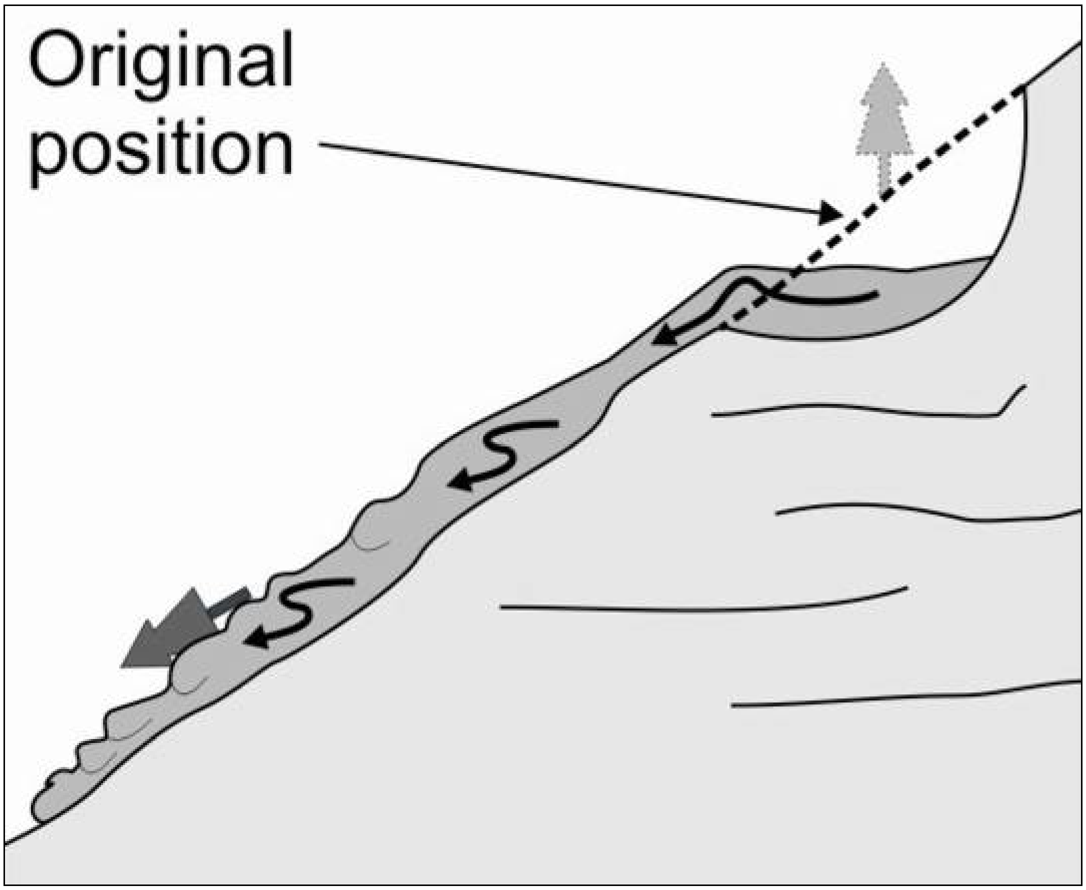
On January 19, 2005, a sudden rapid debris flow occurred along the same escarpment. Extremely heavy rainfall was blamed for the event. In the previous 48 hours, the Mt Seymour area had received more than 320 mm of rain.

A debris avalanche, a rapid flow of sediment, water and trees, that originated 80 m further upslope, swept down the slope into 2 houses near the bottom. (See diagram.) One house was destroyed, with one fatality. Debris partially buried a second house. (See photos.) A state of emergency was declared in the immediate area and over 100 homes were temporarily evacuated, some of which have never been reoccupied.

The District of North Vancouver has initiated planned risk reduction in their community, following the 2005 debris flow. A series of detailed hazard assessments on slopes in their community have identified slopes of potential instability and development is prohibited in these locations. In a few cases existing homes had to be permanently abandoned. A catchment basin was built to contain any future debris flow at the site of the 2005 event. For more information, consult the DNV website at
http://geoweb.dnv.org/Emergency/index.html

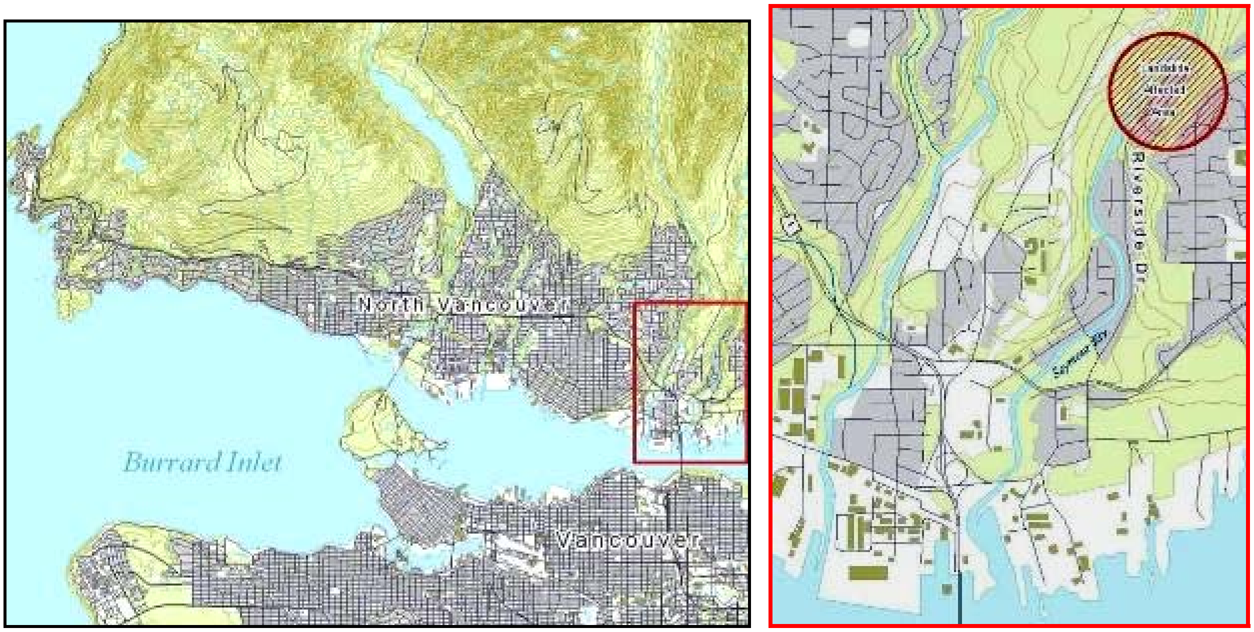
Overhead 1

Debris flow diagram

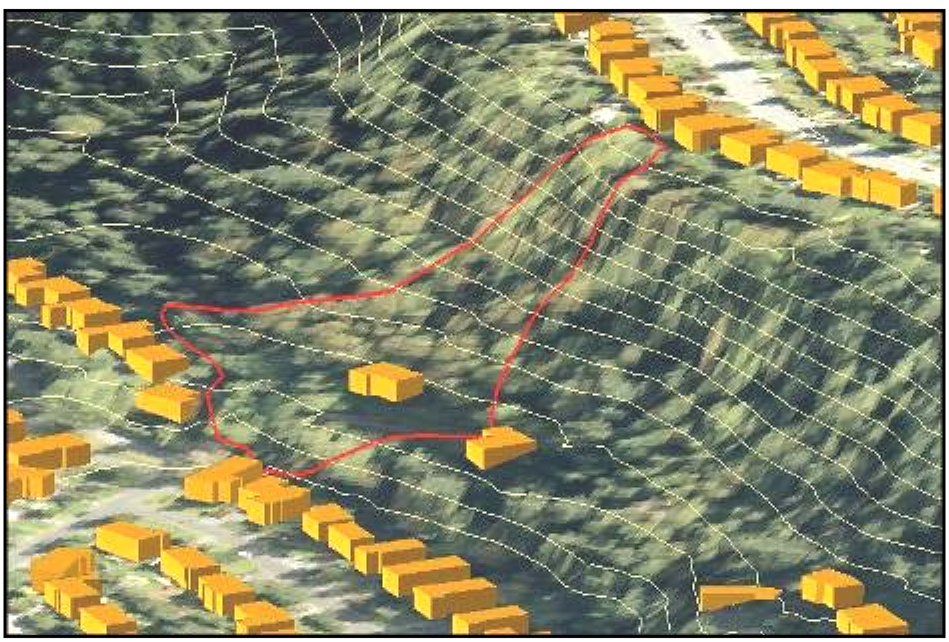


Overhead 2

Location of Blueridge Escarpment Area
District of North Vancouver



Digital Elevation Model of 2005 Berkley Landslide



(Source: District of North Vancouver)

Overhead 3

Photographs of the 2005 Berkley landslide
North Vancouver

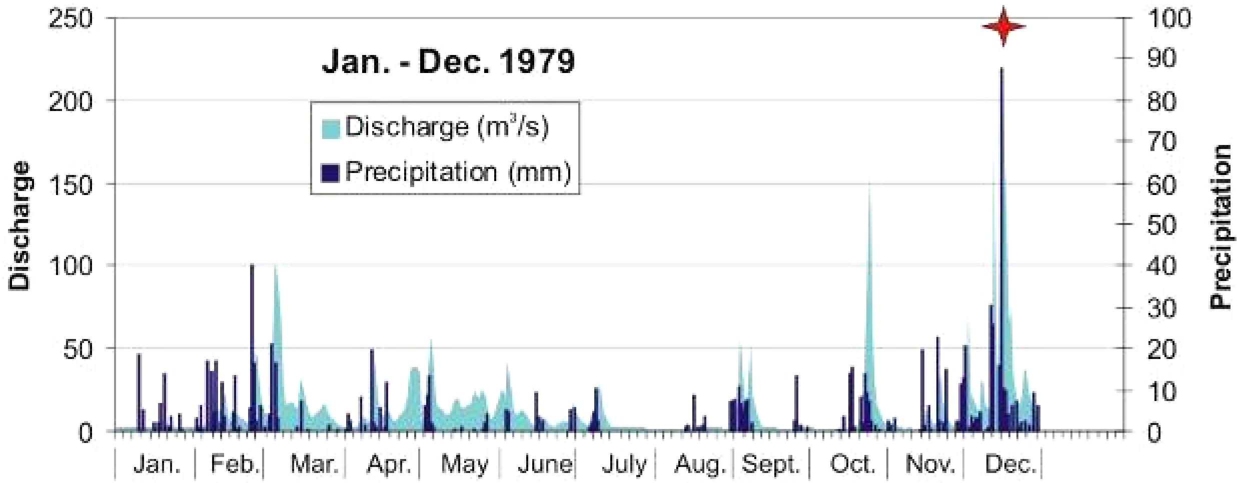

(photographer: D. Perret)

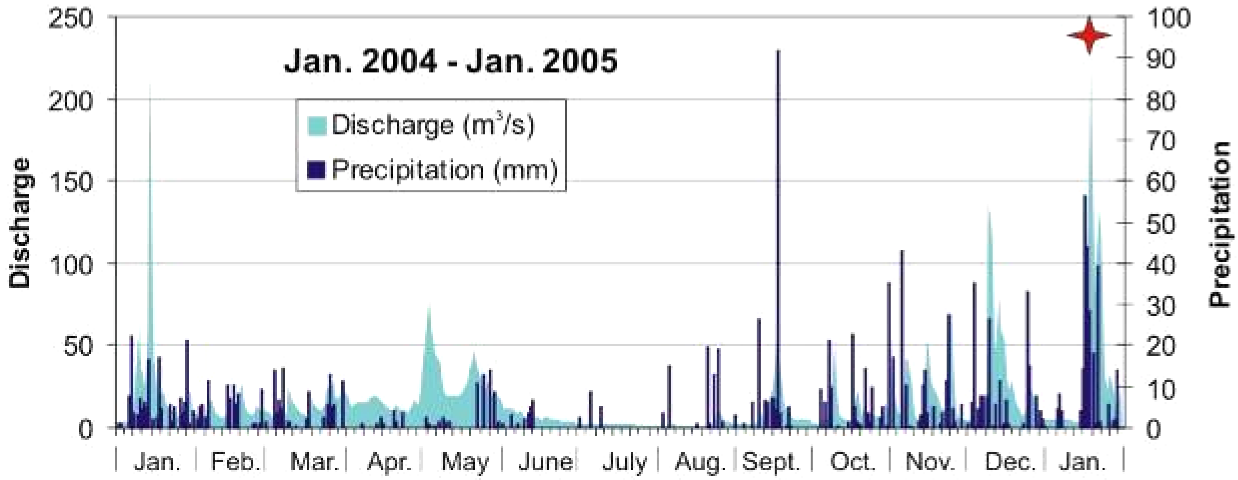
Catchment basin constructed by District of North Vancouver.

(photographer: A. Grignon)

Overhead 4

Precipitation and Discharge Data, 1979 and 2005
District of North Vancouver





Note: High discharge peak on the neighbouring Seymour River coincides with the precipitation and, in 2005, snow melt peaks at the time of the debris flows.

Student worksheet 1 Name: ____________________

Weather Conditions at the time of the 1979 and 2005 debris flows in North Vancouver.

Instructions

1. Refer to the data provided by your teacher or get the data from the Environment Canada website at http://www.ec.gc.ca/default.asp?lang=En&n=FD9B0E51-1

- **Weather data**. http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=17A7AAB9-1

  Select <Data Products & Services>, then choose <Climate and Historical Weather>

  Select Products and Services. Follow the links to Climate Data Online.

  Select Vancouver.

  Choose Daily data online and choose the year.

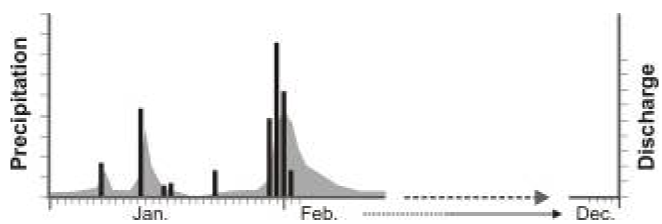
- **Runoff data**. http://www.ec.gc.ca/rhc-wsc/default.asp?lang=En&n=4EED50F1-1

  (Select <Data Products & Services>. Under Online search, select Archived Hydrometric Data – To query the database on-line, enter the station number – Seymour River near North Vancouver – Station 08GA030.

  On the next screen, select Obtain Report. Then, on the following screen, select Report Type: Daily and the year, and Refresh.

2. In an Excel datasheet chart, or drawn by hand, produce a graph for the time period of January to December 1979, and another for January 2004 to January 2005. Show precipitation as a column graph and river discharge as a shaded area graph on the same x axis. Include appropriate legends.

   eg:



3. Indicate the day of the landslide. The two debris flow events occurred on Dec. 17, 1979 and Jan. 24, 2005.

4. Study the finished graphs and answer the following questions.

   a) Describe the general relationship between precipitation and stream discharge.

   b) Why is there a high discharge in the spring, in spite of low precipitation amounts?

   c) Why does discharge remain low in the summer, in spite of days with precipitation?

   d) Explain the environmental conditions at the time of these landslides.

Student datasheet 1

1979 Daily Precipitation in mm, Vancouver International Airport

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	0	0	1	0	0	0	5.8	0	7.0	1.0	0	11.4
2	0	3.2	0	0.3	0	0	0	0	7.2	0	2.6	12.8
3	0	0.8	4.2	4	6.2	0	0	0	7.6	0	1.8	20.4
4	0	6.1	21.2	2.7	8.8	5.4	0.2	0	10.8	0	0	1.2
5	0	0.3	16.5	0	13.4	4.6	0	0	6.6	0	3	3.6
6	0	16.8	3.1	0	2.0	0	0	0	5.0	0	0	2.1
7	0	0	0	0	0.9	0	1	0	7.4	0	0	3.0
8	0	14.6	0	8.2	0	0	2.2	0	7.8	0	0	3.2
9	0	4.6	0	0	0	0	4.5	0	2.0	0	0	4.4
10	18.4	17	0	1.4	0	0	10.3	0	0	0	0	0
11	0	2.0	0	0	0	0	2.6	0	0	0	0	0.4
12	5.2	11.7	0	19.6	0	0	0	0	0	0	0	0.8
13	0.2	3.4	0	2	0	0	0	0	0	0	0	30.5
14	0	0	1.2	1.2	0	0	0	1.0	0	0.4	0	26.0
15	0	0.2	7.4	0	0.6	0	0	1.8	0	0	0.6	0
16	1.9	4.6	0.2	5.6	0	9.2	0	0	0	3.6	19.4	15.8
17	0	13.6	0	1	0	3.5	0	0	0	0	1.7	87.5
18	2.1	0.6	0.6	12.1	1.0	0	0	9	0	13.8	6.4	10.3
19	6.9	1.2	0	0	0	2.8	0	1.0	0	15.7	0.6	9.8
20	13.9	0.2	0	0	0	0	0	0	0	0.8	0	4.0
21	0	0	0	0	0	0	0	1.8	0	0	0	6.2
22	0.8	0	0	0	0	0	0	3.8	0	8.2	22.6	0
23	3.6	5.7	0	0	0.4	0	0	0.2	0	2.2	2.5	7.2
24	0	40.4	0	0	0	0	0	0	0	13.8	2	1.1
25	0	16.6	0	0	0	0	0	0	0	9.4	15.0	2.1
26	4.2	2.6	1.3	0	0.6	0	0	0	2.4	7.2	0	2.4
27	0.4	6.2	0	0	2	0	0	0	13.4	2.4	0	0
28	0	0	0	0	4	0	0	0	0	1.4	0	1.4
29	0		0	0	0	0	0	0	1.7	0	2.5	0.2
30	0		0.4	0	0	5.2	0	0	0	0.4	2.0	9.2
31	0		0		0		0	0		0		6.3

Source: Environment Canada

Student datasheet 2

1979 Discharge in m^3/s, Seymour River near North Vancouver (Station 08GA030)

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.3	2.0	10.4	2.9	35.6	18.9	17.4	1.9	1.8	2.1	5.0	2.9
2	2.2	2.0	6.3	2.6	6.9	23.9	11.2	1.8	2.2	2.1	3.7	3.7
3	2.1	2.0	5.2	2.5	6.8	24.2	7.7	1.8	11.2	1.9	3.7	12.6
4	2.1	2.0	50.7	2.7	16.7	21.2	5.3	1.8	20.4	1.9	5.3	79.7
5	2.1	3.3	102.0	2.6	57.6	42.8	4.6	1.9	58.1	1.8	4.2	23.7
6	2.1	4.8	98.0	2.9	48.8	24.7	3.4	1.8	23.9	1.8	2.9	20.8
7	2.0	4.8	70.3	3.2	27.9	13.3	2.7	1.8	12.4	1.7	2.2	14.4
8	2.0	5.8	31.7	6.8	16.8	10.3	9.0	1.8	32.1	1.7	2.0	11.0
9	2.0	32.7	18.6	8.9	14.8	10.9	11.0	1.8	55.6	1.6	1.8	31.8
10	2.0	14.0	15.2	7.2	12.9	13.4	20.1	1.8	21.3	1.6	2.0	28.7
11	2.0	13.0	17.5	5.6	10.7	12.6	29.9	1.8	10.7	1.6	2.0	15.0
12	2.0	12.3	16.7	7.2	10.1	10.2	22.8	1.8	6.7	1.6	1.9	12.7
13	2.0	23.1	14.1	45.9	10.6	7.7	12.0	1.7	3.7	1.6	1.8	33.7
14	2.0	11.2	14.7	26.7	13.6	5.4	6.9	1.8	2.4	1.6	1.8	185.0
15	2.0	7.0	32.6	14.4	18.2	3.6	4.2	1.9	2.1	1.6	1.8	53.3
16	2.0	5.4	27.8	10.2	20.3	4.4	3.0	2.1	2.2	1.6	2.7	24.6
17	2.0	7.0	16.3	9.1	15.9	9.3	2.6	2.1	2.1	1.6	12.0	238.0
18	2.0	11.7	11.3	11.7	13.6	9.3	2.4	2.2	2.1	3.4	14.2	158.0
19	2.5	7.9	9.2	11.6	14.5	7.7	2.3	2.3	2.0	3.8	8.4	128.0
20	9.2	7.6	9.2	8.3	15.1	7.6	2.2	2.2	1.9	3.5	5.4	65.5
21	6.6	6.5	10.6	6.7	16.4	5.6	2.2	2.2	1.8	2.6	3.9	75.5
22	4.4	4.7	12.0	6.7	21.5	3.9	2.1	2.3	1.7	8.9	27.8	32.9
23	3.7	6.3	14.6	8.8	25.1	3.1	2.1	2.2	1.7	20.3	35.8	18.2
24	3.2	10.9	16.4	11.9	21.2	3.5	2.1	2.2	1.6	24.7	19.3	15.1
25	2.8	47.5	14.9	14.8	20.4	4.5	2.0	2.2	1.6	118.0	11.0	21.8
26	2.6	45.5	11.9	19.6	25.5	5.7	2.0	2.2	1.6	159.0	6.7	39.2
27	2.4	28.7	9.0	31.5	20.7	5.8	2.0	2.3	3.5	63.3	4.3	36.3
28	2.3	16.6	6.7	38.7	12.3	5.6	2.0	2.1	3.5	31.3	3.4	19.2
29	2.1		5.2	38.3	8.1	4.9	2.0	1.8	2.4	16.9	3.1	13.0
30	2.1		4.0	39.1	7.2	10.7	1.9	1.8	2.2	10.6	3.0	10.5
31	2.0		3.5		12.0		1.9	1.8		7.1		18.5

Source: Environment Canada

Student datasheet 3

January 2004 to January 2005, Daily Precipitation in mm, Vancouver International Airport

Day	Jan 2004	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan 2005
1	0	0	0	0	0	1.0	0	0	3.2	0	35.0	0	0.4
2	0.8	2.2	0	0	2.8	0	2.4	0	0.2	0	17.2	1.2	0
3	1.0	5.2	13.8	0	1	0	0	3.6	0	0	0	6	0
4	0	5.6	3.4	0	0.6	0	0	0.2	1.0	0	0	35.4	0
5	0	2.6	6.8	0	0.4	3.2	0	0	0	9.2	0	0.4	0
6	8	11.4	4.6	0	0	0	9.0	15.2	0	6.2	43.2	4.8	4.8
7	22.2	0.2	14.4	1.2	1.4	1.0	0	0	0	0	10.6	7.8	8.4
8	3.4	0	1.6	0	0.2	0	0	0	6.2	21.0	0	7.8	4.0
9	3.2	0	1.6	0	2.6	0	0	0	0	10.0	0.6	7.8	0
10	7.0	0	0	0	1.4	2.2	5.2	0	26.4	0.2	0	26.2	0
11	4.6	0	0	0	1.4	3.6	0	0	0	0.4	0	0	0
12	6.4	0	0.4	0	0	5	0	0	0	0	1.4	0.4	0
13	5.4	0	0	0.8	0	6.8	0	0	6.8	0	3.2	5.8	0
14	16.6	10.4	0.2	2.4	0	0	0	0	6.0	0	10.6	11.6	0
15	2.2	7.0	0	0.8	0	0	0	0	7.0	0	13.8	0.6	4.4
16	0	10.2	2.2	0	0	0	0	0	7.0	1.6	3.4	1.2	14.4
17	2.6	5.8	8.6	0.2	0	0	0	0.8	4.6	22.8	0	6.8	56.6
18	17.2	8.4	0.2	0	0	0	0	0	91.6	5.0	5.0	1.2	44.2
19	4.8	0	0	4.2	0	0	0	0	3.4	1.8	0	0	28.4
20	0	0	0	1.6	0	0	0	0	0	0.8	0	0	18.0
21	0	0	0	0	0	0	0	19.8	0.4	0.4	0.8	0	1.0
22	5.6	0	0.2	0	10.8	0	0	1.0	5.2	14.6	3.4	0	39.4
23	1.8	0.2	2.4	3.6	0	0	0	0	0.4	3.6	11.6	0	1.6
24	5.2	1.2	5.6	0	0	0	0	13.2	0	1.8	27.6	1.0	0.2
25	0	0.8	12.8	0	12.8	0	0	19.2	0	9.6	0.4	33.4	0
26	7.0	0.8	5.2	0	0	0	0	0.2	0	0	4.8	14.8	5.8
27	3.4	9.4	5.8	0.2	14.2	0	0	1.8	0	0	1.4	0	0
28	6.4	0.2	0	0	0.2	0	0	0	0	2.4	0	0	1.6
29	21.2	1.8	0	0	8.6	0	0	0	0	5.4	5.6	7.8	2.2
30	1.0		11.4	0	0.6	0	0	0	0	0	0	4.2	14.2
31	4.4		0		1.8		0	0		0.4		2.0	0

Source: Environment Canada

Student datasheet 4

January 2004 to January 2005, Discharge in m^3/s, Seymour River near North Vancouver (Station 08GA030)

Day	Jan 2004	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan 2005
1	3.8	8.8	9.0	20.0	40.0	15.0	3.2	1.6	2.7	3.3	17.2	4.7	5.8
2	3.6	7.8	7.5	14.0	65.0	12.0	3.1	1.6	2.5	2.4	57.1	4.4	5.4
3	3.4	7.7	5.5	12.5	80.0	12.0	3.0	1.6	2.4	2.2	19.6	6.0	5.1
4	3.6	7.5	6.3	14.0	60.0	12.0	2.9	1.7	2.2	2.2	9.6	20.5	4.9
5	3.8	6.5	6.8	15.0	52.0	11.5	2.9	1.7	2.1	2.5	8.3	13.6	4.7
6	4.0	15.0	7.0	15.5	44.0	10.0	3.2	1.8	2.0	6.0	11.3	7.9	4.7
7	6.0	17.0	7.8	16.0	40.0	9.5	3.1	2.8	2.0	3.9	39.7	6.5	4.6
8	26.0	13.0	9.0	15.8	28.0	10.5	2.9	2.1	2.0	11.6	42.2	14.8	4.5
9	40.0	9.5	24.0	16.0	22.0	8.0	2.8	1.9	2.1	25.2	29.8	18.3	4.6
10	62.0	8.0	16.0	18.0	20.0	7.0	2.7	1.7	3.8	54.2	14.0	139.0	4.6
11	36.0	7.0	14.0	19.0	19.0	6.0	2.7	1.7	11.6	26.0	6.4	115.0	4.6
12	25.0	6.5	12.0	19.0	19.5	7.8	2.7	1.6	5.2	9.6	5.7	46.2	4.5
13	60.0	8.5	10.5	18.0	19.5	10.0	2.6	1.6	5.6	7.1	5.6	55.0	3.6
14	220.0	10.0	8.5	17.0	19.8	6.0	2.6	1.6	12.2	5.2	6.9	80.9	3.5
15	120.0	18.0	7.3	15.0	20.0	6.5	2.6	1.6	21.1	4.2	53.5	59.6	3.8
16	42.0	16.5	6.5	13.0	21.0	5.2	2.6	1.6	22.9	4.1	48.6	51.8	4.3
17	18.0	14.5	5.7	12.0	23.0	5.6	2.6	1.6	54.1	4.7	32.4	27.1	59.2
18	21.0	20.0	19.0	11.0	28.0	7.1	2.6	1.5	46.6	13.7	24.9	23.4	124.0
19	22.0	27.0	14.0	9.8	36.0	6.5	2.6	1.5	31.7	23.5	23.3	28.0	229.0
20	20.0	18.0	12.5	14.0	40.0	5.5	2.6	1.5	16.8	12.4	16.5	22.9	160.0
21	13.0	12.0	11.0	12.0	46.0	5.1	2.6	1.9	12.0	8.0	12.0	16.0	78.5
22	11.0	9.5	12.0	10.5	40.0	5.0	2.5	2.3	10.6	12.4	11.6	10.6	134.0
23	11.4	8.0	14.0	12.0	30.0	4.9	2.5	1.9	6.0	9.8	9.8	7.8	119.0
24	10.5	9.5	24.0	10.5	22.0	4.5	1.9	2.7	5.6	7.7	57.9	7.5	60.8
25	6.7	14.0	23.0	9.5	21.0	4.0	1.7	11.0	5.3	8.3	71.3	12.5	29.3
26	7.0	11.5	28.0	11.5	26.0	3.7	1.7	10.2	5.1	8.3	32.5	28.5	22.7
27	8.5	11.0	20.0	16.5	30.1	3.5	1.6	5.0	5.0	7.1	10.0	20.1	33.0
28	18.2	10.5	18.0	15.0	20.0	3.3	1.6	4.0	4.8	6.1	6.6	12.7	23.7
29	17.1	10.0	18.0	14.0	21.5	3.3	1.6	4.0	4.7	7.4	5.7	11.3	9.6
30	23.4		29.0	24.0	19.0	3.2	1.6	3.3	4.6	15.3	5.2	7.33	11.8
31	12.1		21.0		18.0		1.6	2.8		10.6		6.7	28.6

Source: Environment Canada