LAB 8: MAPPING FLUVIAL LANDSCAPES

Lab Structure

Assignment	Yes – submit fluvial features map
Recommended additional work	Yes – Practice Exercise 8.3
Required materials	Tracing paper, pencil, pencil crayons, ruler, printed Elbow River Map Area base image

Learning Objectives

After reading the background information in this chapter, and completing the exercises within it, you should be able to:

- Understand and interpret maps as a geologist.
- Identify erosional and depositional features associated with fluvial environments.
- Describe the evolution of a meandering stream.
- Locate topographic maps within Canada using the National Topographic System (NTS).
- Describe locations using UTM coordinates.
- Understand map scale and how to determine distances on a map.
- Understand how elevation data are presented on a topographic map as contour lines.
- Create a surficial geology map of fluvial features.

Key Terms

- Meandering stream
- Braided stream
- Stream gradient
- Stream channel
- Flood plain
- Discharge
- Erosion
- Deposition
- Cut bank
- Point bar
- Oxbow lake
- Meander scar
- Scroll bar
- Delta
- Levée
- Legend
- Map scale
- UTM coordinates
- National Topographic System (NTS)
- Topographic contour lines
- Contour interval

Streams are the most important agents of erosion and transportation of sediments on Earth's surface. They are responsible for the creation of much of the topography that we see around us. They are also places of great beauty and tranquility, and of course, they provide much of the water that is essential to our existence. But streams are not always peaceful and soothing. During large storms and rapid snowmelts, they can become raging torrents capable of moving cars and houses and destroying roads and bridges. When they spill over their banks, they can flood huge areas, devastating populations and infrastructure. Over the past century, many of the most damaging natural disasters in Canada have been floods, and we can expect them to become even more severe in the near future as the climate changes.

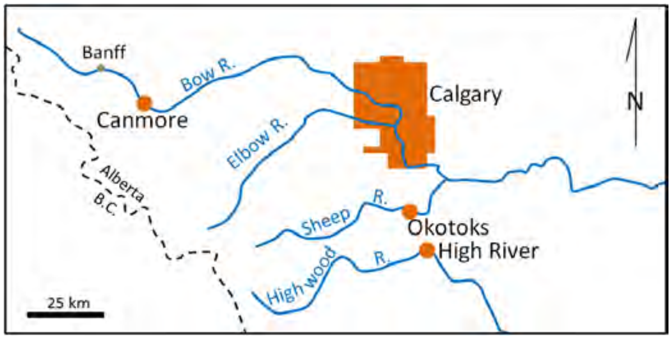


Figure 8.0.1: Map of the communities most affected by the 2013 Alberta floods (in orange).

Canada's most costly flood ever was the June 2013 flood in southern Alberta, affecting the communities of Canmore, Calgary, Okotoks, and High River (Figure 8.0.1). The flooding was initiated by snowmelt and worsened by heavy rains in the Rockies due to an anomalous flow of moist air from the Pacific and the Caribbean. At Canmore, rainfall amounts exceeded 200 millimetres in 36 hours, and at High River, 325 millimetres of rain fell in 48 hours.

In late June and early July, the discharges of several rivers in the area, including the Bow River in Banff, Canmore, and Exshaw, the Bow and Elbow Rivers in Calgary, the Sheep River in Okotoks, and the Highwood River in High River, reached levels that were 5 to 10 times higher than normal for the time of year! Large areas of Calgary, Okotoks, and High River were flooded and five people died. The cost of the 2013 flood is estimated to be approximately $5 billion.

One of the things that the 2013 flood on the Bow River teaches us is that we cannot predict when a flood will occur or how big it will be, so in order to minimize damage and casualties we need to be prepared. Some of the ways of doing that are as follows:

- **Mapping flood plains** and not building within them
- Building dykes or dams where necessary
- Monitoring the winter snowpack, the weather, and stream discharges
- Creating emergency plans
- Educating the public

Media Attributions

- Figure 8.0.1: © Steven Earle. CC BY.
- Elbow River Map Area satellite image used under the following Google Maps and Google Earth guidelines.

8.1 Stream Erosion and Deposition

As we discussed in Lab 5, flowing water is a very important mechanism for erosion, transportation and deposition of sediments. Water flow in a stream is primarily related to the stream's **gradient**, but it is also controlled by the geometry of the **stream channel**. As shown in Figure 8.1.1, water flow velocity is decreased by friction along the stream bed, so it is slowest at the bottom and edges and fastest near the surface and in the middle. In fact, the velocity just below the surface is typically a little higher than right at the surface because of friction between the water and the air. On a curved section of a stream, flow is fastest on the outside and slowest on the inside.

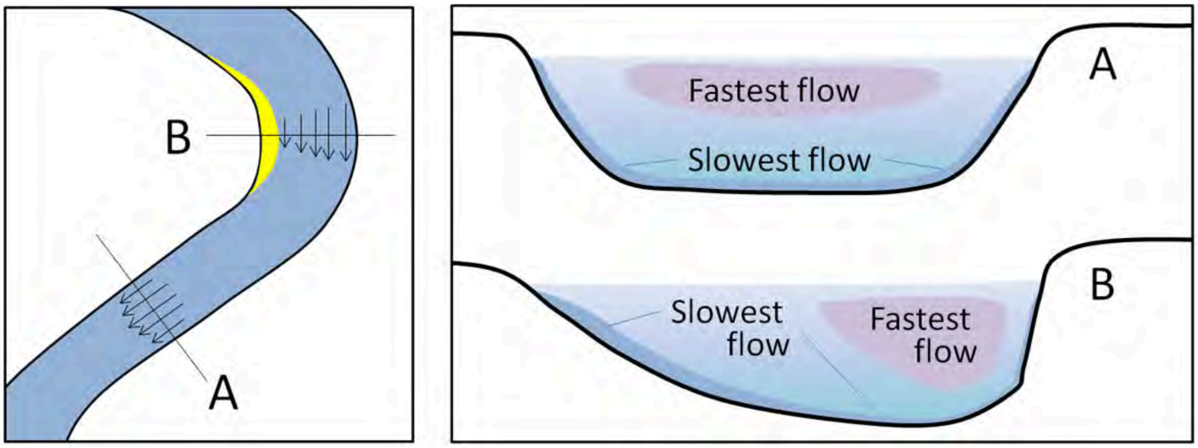


Figure 8.1.1: The relative velocity of stream flow depending on whether the stream channel is straight or curved (left), and with respect to the water depth (right). [Image Description]

Other factors that affect stream-water velocity are the size of sediments on the stream bed—because large particles tend to slow the flow more than small ones—and the **discharge**, or volume of water passing a point in a unit of time (e.g., cubic metres (m^3) per second). During a flood, the water level always rises, so there is more cross-sectional area for the water to flow in, however, as long as a river remains confined to its channel, the velocity of the water flow also increases.

Figure 8.1.2 shows the nature of sediment transportation in a stream. Large particles rest on the bottom—**bed load**—and may only be moved during rapid flows under flood conditions. They can be moved by **saltation** (bouncing) and by **traction** (being pushed along by the force of the flow).

Smaller particles may rest on the bottom some of the time, where they can be moved by saltation and traction, but they can also be held in suspension in the flowing water, especially at higher velocities. As you know from intuition and from experience, streams that flow fast tend to be turbulent (flow paths are chaotic and the water surface appears rough) and the water may be muddy, while those that flow more slowly tend to have laminar flow (straight-line flow and a smooth water surface) and clear water. Turbulent flow is more effective than laminar flow at keeping sediments in suspension.

Stream water also has a dissolved load, which represents (on average) about 15% of the mass of material transported, and includes ions such as calcium (Ca^{+2}) and chloride (Cl^{-}) in solution. The solubility of these ions is not affected by flow velocity.

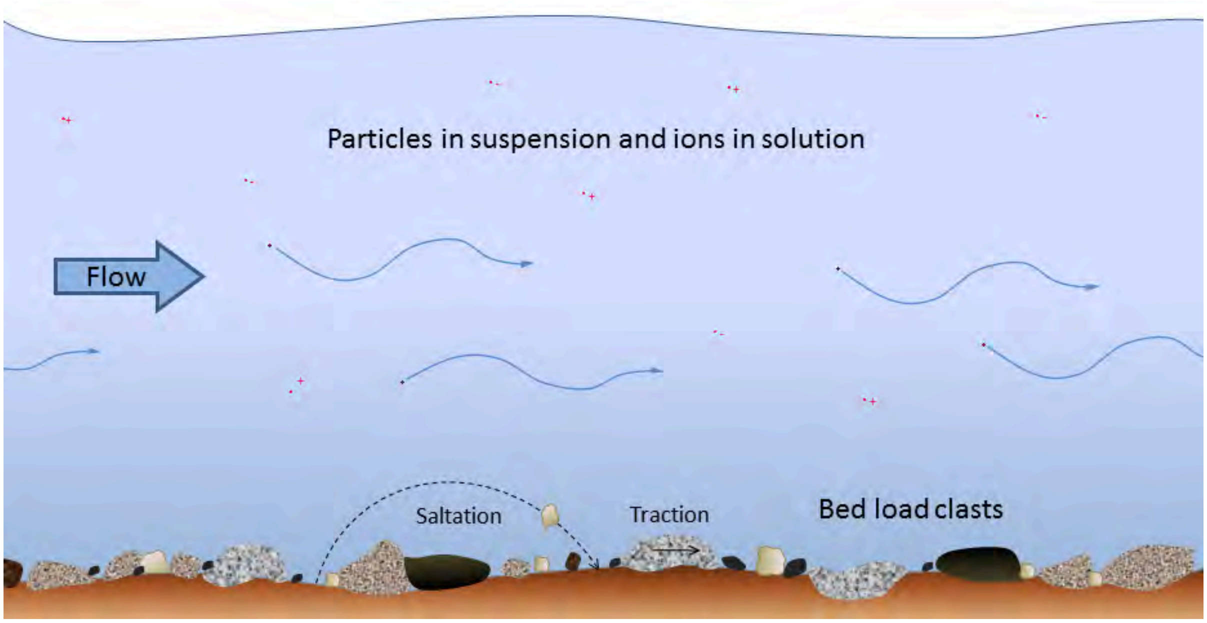


Figure 8.1.2: Modes of transportation of sediments and dissolved ions (represented by red dots with + and – signs) in a stream.

The faster the water is flowing, the larger the particles that can be kept in suspension and transported within the flowing water. However, as Swedish geographer Filip Hjulström discovered in the 1940s, the relationship between grain size and the likelihood of a grain being eroded, transported, or deposited is not as simple as one might imagine (Figure 8.1.3). Consider, for example, a 1 millimetre grain of sand. If it is resting on the bottom, it will remain there until the velocity is high enough to erode it, around 20 centimetres per second (cm/s). But once it is in suspension, that same 1 mm particle will remain in suspension as long as the velocity doesn't drop below 10 cm/s. For a 10 mm gravel grain, the velocity is 105 cm/s to be eroded from the bed but only 80 cm/s to remain in suspension.

On the other hand, a 0.01 mm silt particle only needs a velocity of 0.1 centimetres per second (cm/s) to remain in suspension, but requires 60 cm/s to be eroded. In other words, a tiny silt grain requires a greater velocity to be eroded than a grain of sand that is 100 times larger! For clay-sized particles, the discrepancy is even greater. In a stream, the most easily eroded particles are small sand grains between 0.2 mm and 0.5 mm. Anything smaller or larger requires a higher water velocity to be eroded and entrained in the flow. The main reason for this is that small particles, and especially the tiny grains of clay, have a strong tendency to stick together, and so are difficult to erode from the stream bed.

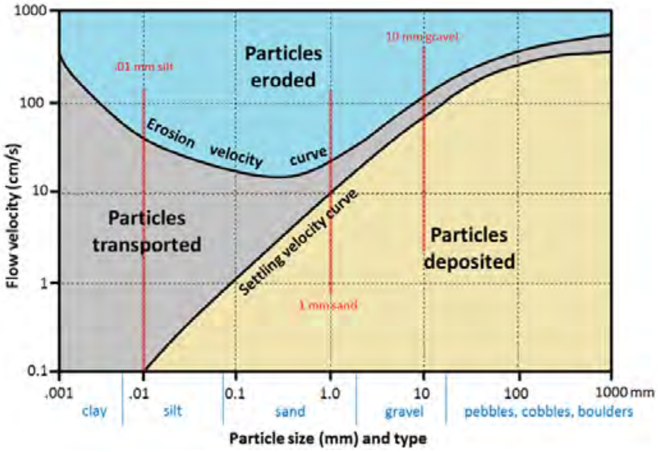


Figure 8.1.3: The Hjulström-Sundborg diagram showing the relationships between particle size and the tendency to be eroded, transported, or deposited at different current velocities. [Image Description]

It is important to be aware that a stream can both erode and deposit sediments at the same time. At 100 cm/s, for example, silt, sand, and medium gravel will be eroded from the stream bed and transported in suspension, coarse gravel will be held in suspension, pebbles will be both transported and deposited, and cobbles and boulders will remain stationary on the stream bed.

Practice Exercise 8.1: Understanding the Hjulström-Sundborg diagram

Refer to the Hjulström-Sundborg diagram (Figure 8.1.3) to answer these questions.

1. A fine sand grain (0.1 millimetres) is resting on the bottom of a stream bed.
    1. What stream velocity will it take to get that sand grain into suspension?
    2. Once the particle is in suspension, the velocity starts to drop. At what velocity will it finally come back to rest on the stream bed?
2. A stream is flowing at 10 centimetres per second (which means it takes 10 seconds to go 1 metres, and that's pretty slow).
    1. What size of particles can be eroded at 10 centimetres per second?
    2. What is the largest particle that, once already in suspension, will remain in suspension at 10 centimetres per second?

See Appendix 2 for Practice Exercise 8.1 answers.

A stream typically reaches its greatest velocity when it is close to flooding over its banks. This is known as the bank-full stage, as shown in Figure 8.1.4. As soon as the flooding stream overtops its banks and occupies the wide area of its flood plain, the water has a much larger area to flow through and the velocity drops significantly. At this point, sediment that was being carried by the high-velocity water is deposited near the edge of the channel, forming a natural bank or **levée**.

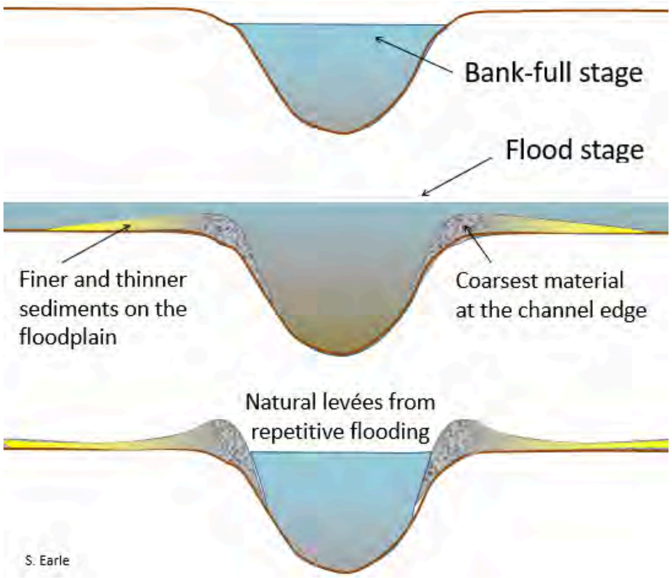


Figure 8.1.4: The development of natural levées during flooding of a stream. The sediments of the levée become increasingly fine away from the stream channel, and even finer sediments — clay, silt, and fine sand — are deposited across most of the flood plain.

Image Descriptions

Figure 8.1.1 image description: When a stream curves, the flow of water is fastest on the outside of the curve and slowest on the inside of the curve. When the stream is straight and a uniform depth, the stream flows fastest in the middle near the top and slowest along the edges. When the depth is not uniform, the stream flows fastest in the deeper section. [Return to Figure 8.1.1]

Figure 8.1.3 image description:

- Erosion velocity curve: A 0.001 millimetre particle would erode at a flow velocity of 500 centimetres

per second or greater. As the particle size gets larger, the minimum flow velocity needed to erode the particle decreases, with the lowest flow velocity being 30 centimetres per second to erode a 0.5 millimetre particle. To erode particles larger than 0.5 millimetres, the minimum flow velocity rises again.
- Settling velocity curve: A 0.01 millimetre particle would be deposited with a flow velocity of 0.1 centimetre per second or less. As the flow velocity increases, only larger and larger particles will be deposited.
- Particles between these two curves (either moving too slow or being too small to be eroded or deposited) will be transported in the stream.

[Return to Figure 8.1.3]

Media Attributions

- Figure 8.1.1, 8.1.2, 8.1.3, 8.1.4: © Steven Earle. CC BY.

8.2 Stream Types

Stream channels can be straight or curved, deep and slow, or rapid and choked with coarse sediments. The cycle of erosion has some influence on the nature of a stream, but there are several other factors that are important including gradient, discharge, and sediment load. A few key types of streams are described below.

Youthful streams that are actively down-cutting their channels tend to be relatively straight and are typically ungraded (meaning that rapids and falls are common). They also have steep gradients and steep and narrow V-shaped valleys—in some cases steep enough to be called canyons.

Figure 8.2.1: The Cascade Falls area of the Kettle River, near Christina Lake, B.C. This stream cuts a deep narrow channel through the bedrock

In mountainous terrain, such as that in western Alberta and B.C., steep youthful streams typically flow into wide and relatively low-gradient U-shaped glaciated valleys. The youthful streams have high sediment loads, and when they flow into the lower-gradient glacial valleys where the velocity isn't high enough to carry all of the sediment **braided** patterns develop, characterized by a series of narrow channels separated by gravel bars.

Figure 8.2.2: Red River in Lake Clark National Park, Alaska, is an example of a sediment-laden braided stream. This braided stream transports glaciofluvial sediments from the Red Glacier, an alpine glacier formed on Iliamna Volcano (highest peak to the left of the stream), to Cook Inlet.

Braided streams can develop anywhere there is more sediment than a stream is able to transport. One such environment is in mountainous areas, where streams carry **glaciofluvial sediments** from alpine glaciers (Figure 8.2.2). Another such environment is in volcanic regions, where explosive eruptions produce large amounts of unconsolidated material that gets washed into streams. Streams in the volcanic Mt. Meager area of southwestern British Columbia are good examples of this.

A **meandering** stream that occupies a wide, flat **flood plain** with a low gradient typically carries only sand-sized and finer sediments and develops a sinuous flow pattern. As you saw in Figure 8.1.1, when a stream flows around a corner, the water on the outside has farther to go and tends to flow faster. This leads to erosion of the **cut banks** on the outside of the curve, deposition on the inside, and formation of a **point bar** (Figure 8.2.3). Over time, the sinuosity of the stream becomes increasingly exaggerated, and the channel migrates around within its flood plain, forming a meandering pattern. As point bars develop over time, their surfaces form ridges called **scroll bars.** There is even evidence of these scroll bars and meandering channels on Mars (Figure 8.2.4)!

A well-developed meandering river is shown in Figure 8.2.3. The meander in the middle of the photo has reached the point where the thin neck of land between two parts of the channel is about to be eroded through. When this happens, an **oxbow** lake will form. When an oxbow lake dries up, it leaves behind a curved **meander scar** filled with muddy sediment.

Figure 8.2.3: The confluence of the Alatna and Koyukuk Rivers near the western border of the Kanuti National Wildlife Refuge in Alaska. Both rivers pictured are examples of meandering streams, with sinuous channels, deposition of sediment on point bars, and erosion along the cut banks. Notice the narrow neck separating the channel in the foreground. When this neck is eventually eroded away, the meander in the foreground will be abandoned and will create an oxbow lake. [Image description]

At the point where a stream enters a still body of water—a lake or the ocean—sediment is deposited and a delta forms. The Fraser River has created a large delta, which extends out into the Strait of Georgia (Figure 8.2.5). Much of the Fraser delta is very young in geological terms. Shortly after the end of the last glaciation (10,000 years ago), the delta did not extend past New Westminster. Since that time, all of the land that makes up Richmond, Delta, and parts of New Westminster and south Surrey has formed from sediment from the Fraser River.

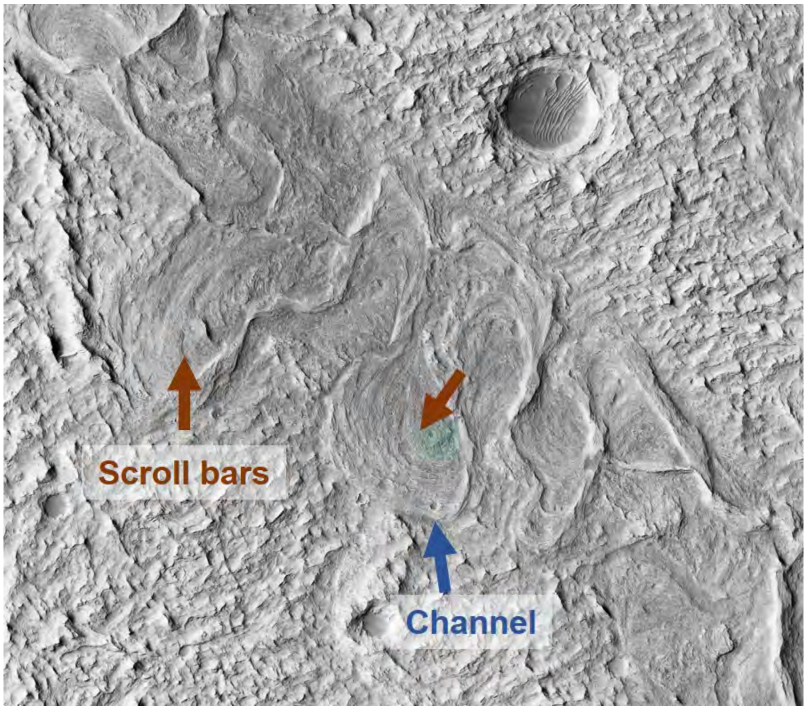


Figure 8.2.4: A sinuous channel in the Aeolis Planum region of Mars taken by the HiRISE camera on the Mars Reconnaissance Orbiter. Blue arrow indicates the sinuous channel-like form, and orange arrows indicate areas with scroll bars (curved ridges).

Figure 8.2.5: The delta of the Fraser River and the plume of suspended sediment that extends across the Strait of Georgia in British Columbia. The land outlined in red has formed over the past 10,000 years.

Image Descriptions

Figure 8.2.3 image description: A part of the Alatna River near its confluence with the Koyukuk River has curved around so sharply that it almost forms a circle before curving the other way again. Eventually, as the barrier between these two parts of the channel erodes, they will be joined and form an oxbow lake. [Return to Figure 8.2.3]

Media Attributions

- Figure 8.2.1: © Steven Earle. CC BY.
- Figure 8.2.2: Braided Rivers Lake Clark National Park by K. Lewandowski (NPS). Taken June 2017. Public domain.
- Figure 8.2.3: Alatna and Koyukuk River confluence near Allakaket by Steve Hillebrand (USFWS). Taken August 2006. Public domain.
- Figure 8.2.4: Yardangs and Ridges of the Edge of Aeolis Planum by NASA/JPL/University of Arizona. Taken December 2007. Public domain.
- Figure 8.2.5: Delta of the Fraser River by NASA. Taken September 2011. Adapted by Steven Earle. Public domain.

8.3 What Makes a Map?

The purpose of a map is not limited to navigation. Maps are used in the geosciences to show data or information in a spatial context. Maps are used to convey information about where observations were recorded in the field, or to show a geologist's interpretations of the materials exposed or deposited on the Earth's surface. Geologists often use topographic maps as a base on which to display the geological information or data they wish to share. A topographic map is a graphic two-dimensional representation of the three-dimensional surface of the Earth. The features shown on a topographic map may be divided into three groups:

- Relief – hills, valleys, mountains, and plains
- Water features – lakes, ponds, rivers, canals, swamps, and streams
- Cultural features – roads, railways, buildings, and land boundaries

You were introduced to some important concepts about maps in the Google Earth Tutorial and Lab 1 Exercises. You learned that all maps are drawn to scale; that is, a designated distance on the map is equal to a corresponding real distance on the actual surface of the Earth. You also learned that locations on maps are specified using **grid systems** that might include the **geographic** or **UTM** systems. This lab will build upon those concepts to give you a deeper understanding of what elements make a map and what information you can convey in a map.

Map scale

Map scale refers to the fixed ratio between the distance you measure on a map (or in satellite imagery or air photos) and the actual distance on the ground, in the real world. You were introduced to the concept of scale at the beginning of the term, when you completed the Google Earth Tutorial and Lab 1 Exercises. In that tutorial, you used a **scale bar** to understand distances in Google Earth. Scale bars, also called graphic scale, are one way to represent scale on a map. Graphic scales are used to quickly determine the distance between two points on the map, by comparing the length you measure on the map with your ruler to the scale bar. In Figure 8.3.1 below, each of the long bars on the scale is 2 cm long and represents a distance of 1 km on the ground. Let's say you measured the distance between two points on a map to be 5 cm. By comparing that length to the scale bar, you can see that 5 cm on the map represents 2.5 km on the ground. Note that the scale bar may be distorted by your screen if you are reading this on an e-reader, smartphone or computer depending on your display settings.

Figure 8.3.1: An example of a scale bar, or graphic scale.

Another way to represent map scale is using a **representative fraction** (R.F.). The representative fraction is a ratio written in numbers on a map. Two of the common scales for topographic maps in Canada are 1:250,000 and 1:50,000. A R.F. of 1:250,000 means that 1 unit of measurement on the map represents 250,000 of the same unit of measurement on the ground. You can use any unit of measurement (centimetres, inches) as long as you are consistent! A map with a scale of 1:250,000 means that 1 **cm** on the map is equal to 250,000 **cm** on the ground, and that 1 **inch** on the map is equal to 250,000 **inches** on the ground.

Practice Exercise 8.2

What R.F. is shown by the scale bar drawn above? Assume that each of the long bars on the scale bar is 2 cm in length. Hint: you will have to do some unit conversions!

See Appendix 2 for Practice Exercise 8.2answers.

Determining the scale of an air photo or satellite image

In some cases, you may want to create a map using a base ***image*** rather than a base ***map***. Base images could include air photos, captured by a low-flying aircraft along a set flight path, or satellite imagery like the images available in Google Earth Pro. While images can provide valuable details not captured on a topographic map, they typically lack scale. You can calculate the scale of your base image by comparing the length of a distinctive feature in the base image and a topographic map using a simple formula:

$$Your\ map\ scale = \frac{(length\ of\ the\ feature\ on\ topographic\ map)\ x\ (map\ scale)}{length\ of\ the\ feature\ on\ your\ map}$$

National Topographic System (NTS)

Standard topographic maps, published by the provincial and federal governments, are usually bounded and divided by **parallels of latitude** and **meridians of longitude.** In Canada, topographic maps are subdivided into numerous sections and subsections for the purpose of indexing all of the topographic maps of the nation in the **National Topographic System** (NTS). All topographic maps have a National Topographic Index Number that indicates the scale of the map and helps catalogue all the NTS maps of Canada. For example, the 1:1,000,000 NTS map sheet 82 covers most of southern Alberta, and is divided into indexed subsections as shown in Figure 8.3.2. The relationship between map scale and index number is outlined in table below.

Map index number	**Map scale**
82	1 : 1,000,000
82 NE	1 : 500,000
82 O	1 : 250,000
82 O/1	1 : 50,000

You should always begin the study of a map by observing the title which gives clues to the location of the map in its wider setting. For your reference, the 1:50,000 scale topographic map that covers the city of Calgary is located on NTS map sheet 82 O/1.

Three-dimensional relief on a two-dimensional map

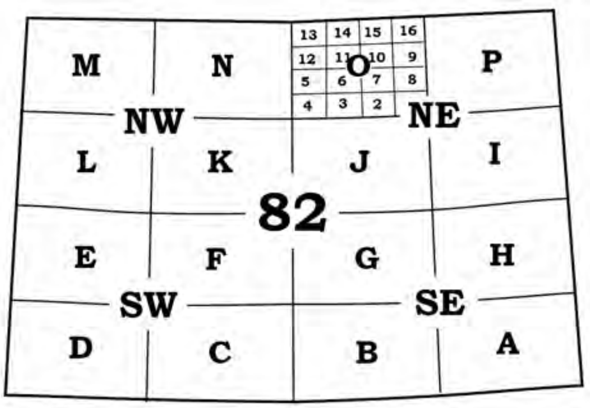


Figure 8.3.2: Example of the National Topographic Index Numbers of map sheets within the primary quadrangle number 82. Map sheet 82 is subdivided into four quarters (NE, SE, SW, NW). These quarters are further subdivided into four parts each designated with a letter, beginning with A in the southeast corner and ending with P in the northeast corner. Finally, each of these parts is divided into 16 parts numbered 1 through 16.

Relief on a topographic map is illustrated using **contour lines.** These are imaginary lines drawn on a map to join points of equal elevation. Every point on a contour line is at the same elevation. Elevation is measured from a pre-determined **datum line**: mean sea level, which is assigned an elevation of 0. Contour lines separate points of higher elevation (uphill) from points of lower elevation (downhill), therefore points between two contour lines are no lower than the contour line below and no higher than the contour line above. Contour lines never intersect or cross, except in very rare cases of overhanging cliffs. Contour lines always close; this closure may take place outside the map area as shown for the 50 m contour line in Figure 8.3.3. The **contour interval** (C.I) of a map is the difference in elevation between two adjacent topographic contour lines. The space between adjacent contour lines on a map reflects how steep or gentle the slope is: the closer the contour lines, the steeper the slope. Evenly spaced contour lines represent a uniform slope.

Practice Exercises 8.3

Examine the example topographic map in Figure 8.3.3. The map shows two hills separated by a small valley that has two streams.

1. Which hill is the tallest? Or, in other words, which hill has the highest elevation?
2. What is the approximate elevation of the red star?
3. Toward which direction is each stream flowing?
4. Can you see anywhere on the map where topography would be relatively steep?
5. Can you see anywhere on the map where topography would be relatively gentle or flat?
6. How can you tell the difference between areas with steep versus gentle topography using the contour lines?
7. Notice that the 50 m and 100 m contour lines forms a "V" shape as they cross the stream. **Topographic contour lines always form a "V" shape as they cross a stream, and the point of the "V" always points upstream.** Imagine there is a third stream that originates at the red star and flows toward the NE. Draw in this third stream and using dashed lines, modify the contour lines where they cross this stream.

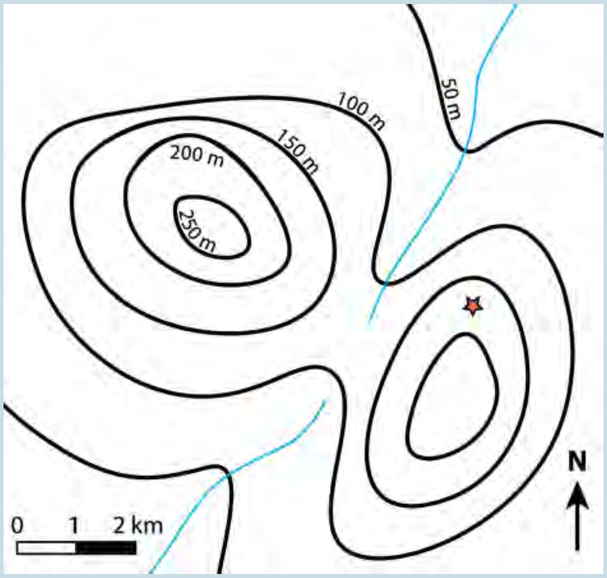


Figure 8.3.3: Example of a topographic map including contour lines with a contour interval of 50 m.

See Appendix 2 for Practice Exercise 8.3 answers.

Media Attributions

- Figures 8.3.1, 8.3.2, 8.3.3: © Siobhan McGoldrick. CC BY.

Lab 8 Exercises

In this activity you will learn to identify features of a stream using satellite imagery in Google Earth Pro. You will create a hand-drawn map of the fluvial features you identify along a segment of the Elbow River in Calgary, Alberta on the homelands of the Niitsitapi (the Siksika, Piikani, and Kainai), the Îyârhe Nakoda and Tsuut'ina Nations. Located just south of Mount Royal University's campus, this segment of the Elbow River was one of the areas affected by the 2013 flooding. Elbow River also plays a crucial role in supplying Calgary's drinking water.

You have been provided with the following starting materials to complete this mapping activity:

- A base image from Google Earth satellite imagery (Elbow River Map Area) that you must print out
- A digital copy of the 082J-16 NTS Priddis map sheet on which your map area resides (do not print this)

The purpose of your map is to show your reader the locations of erosional and depositional features of the Elbow River. To convey that information in a way that is useful, your map needs to include some standard **cartographic elements** including:

- Title
- Scale
- North arrow
- Legend
- Sources (e.g., satellite imagery, base map, reference map)
- UTM coordinates for a reference point on your map
- Refrence to the National Topographic System (NTS) map sheet on which your map resides

Title

Your map should have a succinct but descriptive title that includes some reference to the geographic area. This could include the name of the river, the NTS map sheet on which your map resides, or the name of a prominent local landmark that is featured on your map. Your title must also include what type of map you have drawn, e.g., topographic map, geological map, map of glacial landforms, map of population distributions, etc.

Scale

Your map must indicate scale using both a scale bar and a representative fraction. Remember, you can calculate the scale on your map by comparing the length of a distinctive feature on your map and a topographic map of the same area. But first, because you are examining an electronic version of the topographic map on a computer screen rather than a printed version you need to ensure that you are viewing the topographic map at the correct scale (as your device may distort the size of the image on the screen).

To check if your topographic map PDF is being displayed correctly, measure the scale bar on the map. For a 1:50,000 map sheet like the one you are using, 1 cm on the scale bar should represent 500 m on the ground. By holding up a ruler to measure, zoom in and out until this is true on your computer screen before you follow the steps below.

1. Measure a feature that is visible and distinctive on both your map and the topographic map. Record your measurements in the same units for both. The distance between intersections along a road, or in a straight line between two distinctive features are good places to measure.
2. Use the formula below:

$$Your\ map\ scale = \frac{(length\ of\ the\ feature\ on\ topographic\ map)\ x\ (map\ scale)}{length\ of\ the\ feature\ on\ your\ map}$$

For example, for a feature 5 cm long on your map and 2.5 cm-long on the 1:50,000 topographic map:

$$Your\ map\ scale = \frac{(2.5\ cm)\ x\ (50{,}000)}{5\ cm} = 1{:}\,25{,}000$$

The scale of the base image in this example is therefore 1:25,000. This result is not particularly realistic as air photo or satellite imagery scales rarely work out to such a nice, even number.

North arrow

Exactly as it sounds: a north arrow on a map shows the reader the direction of north in the area.

Legend

The purpose of a legend is to define all symbols, abbreviations or colours used on a map to the reader. Every feature that you draw or label on your map should be explained or defined in the legend. For example:

Abbreviation or symbol on the map	**Meaning**
Fp	Flood plain
Ms	Meander scar
——-	Trail

Feel free to create your own abbreviations or symbols for features on your map, but make sure you choose unique abbreviations or symbols for each feature.

Reference location

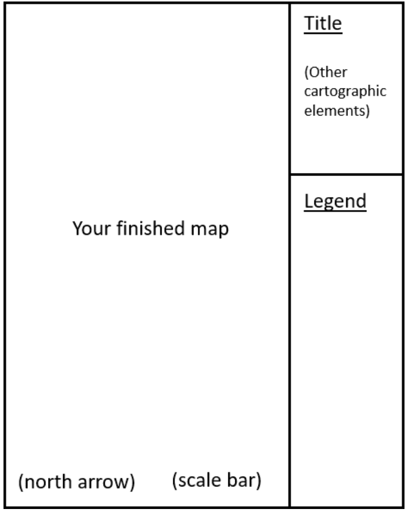
To help your reader put the information from your map into a real-world context, you should provide the UTM coordinates for a reference location on your map. You may want to refresh your memory on grid coordinates by reviewing the Google Earth Tutorial. This location should be something visible and distinctive on both your map and the topographic map provided. Furthermore, this location should be a feature that is unlikely to move over time, e.g., a point bar would be a poor choice as the shape and position of the point bar migrates over time. You will also need to tell your reader where your mapped area fits into Canada's National Topographic System (NTS).

Instructions

1. Examine the area you will be mapping (Elbow River Map Area).

2. Open Google Earth Pro on your computer and navigate to this area. Spend some time examining the features of this area using the 3D capabilities of Google Earth Pro.

3. Attach a piece of tracing paper to your printed satellite imagery with a paper clip or piece of clear tape. Be gentle; tracing paper tears easily! Be very careful when erasing!



4. Set up your map area. Make sure that you have enough space on your tracing paper set aside for your legend and other cartographic elements (see checklist below). The example shown here illustrates one possible layout, but feel free to choose a layout that works with your map area.

5. With a pencil, lightly and neatly draw in the major landforms that you see in the satellite imagery. Focus on fairly large-scale structures; don't clutter up your map with a lot of detail. Think about what features are relevant to the fluvial features map you are drawing, and then make a judgement call for yourself about what features to include. For example, is it important to your map to draw in every building? Or to highlight areas with different types of vegetation? Probably not. But is it important to have a few key roads on your map to help a reader situate your map? Yes, it is.

6. Think about neatness. Examine the topographic map provided. What characteristics make it neat and easy to read? It is drawn carefully and the features are not shaded in. Remember: you are producing a map, which is drawn in plan view. It should not have any 3D aspect to it, including shading. Your finished product should be a line drawing only.

7. Use the topographic map provided to help you identify named geographic features.

8. Trace out the different fluvial features that you have interpreted, and assign each feature a unique abbreviation or symbol. Keep track of the abbreviations or symbols that you use on a spare sheet of paper to help format your legend once you have finished your map.

9. If the feature you are tracing is a polygon (an enclosed area that defines the borders of the specific feature), make sure your polygon is fully closed and labeled with an abbreviation, symbol or colour. Make sure every polygon you draw is labeled.

10. Review the checklist below and ensure that your finished map contains all the required information.

Fluvial Features	**Cultural Features**	**Cartographic Elements**
Active channel	Roads	Title
Cut bank	Bridges	North arrow
Point bar	Buildings or subdivisions	Scale bar
Abandoned channel		Scale as representative fraction
Oxbow lake		Legend
Delta		Reference to NTS sheet on which this map resides
Flood plain		Reference point in UTM coordinates
Meander scar		Elevation of reference point in metres (estimate using the topographic contours)
		Date of satellite imagery and source of satellite imagery
		Author's name (your name)

Summary Questions

1. What is the National Topographic Index Number for the topographic map provided? ___________
2. What is the National Topographic Index Number for the topographic map directly to the north of this map? ___________
3. What colour are grid lines for UTM Zone 11 on the topographic map sheet provided? ___________
4. What colour are the topographic contour lines on the topographic map sheet provided? ___________
5. What is the contour interval (C.I.) on this topographic map? ___________
6. Examine the spacing between adjacent contour lines on the topographic map provided. In what general part of the map do you see relatively steep topography? In what general part of the map do you see relatively gentle topography? How can you tell the difference using the contour lines?

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7. Draw a sketch of a few contour lines, with elevations labeled, as they cross a stream. On your sketch, indicate the direction of stream flow with an arrow.
8. Where would you expect to find the fastest water flow on a straight stretch of a stream? _______________ ______________________________
9. Sand grains can be moved by traction and saltation. What minimum stream velocities might be required to move 1 millimetre sand grains? _____________
10. Under what circumstances might a braided stream develop?

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11. What do you think controls the variability in the colour of the water in Glenmore Reservoir in this satellite image?

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12. What factors or forces influence the behaviour of the Elbow River? Hint: Examine the most recent satellite imagery for your map area in Google Earth Pro.

If you have the opportunity to do so, and provincial health authorities deem it safe, you are encouraged to safely and respectfully visit this area, called Weaselhead Flats, yourself. Walk around the Weaselhead Flats and see what fluvial features you can identify in person. Grab a handful of sediment from a point bar and examine the size, shape and composition of the grains. As for any field work, always:

- Stay on the trails, be mindful of other trail users and maintain 2 m of physical distancing.
- Dress appropriately for changing weather conditions. Think layers!
- Bring water, a hat and sunscreen.
- Wear appropriate footwear that covers your foot completely, provides some ankle support, and has a good tread in case the path is slippery.
- If you are exploring along the river bank, walk cautiously and be mindful of loose soil or sediment that may collapse.
- Make a plan! Make sure you tell someone when you are expected home and check in with them once you return.

Media Attributions

- Elbow River Map Area and Glenmore Reservoir and area satellite images used under the following Google Maps and Google Earth guidelines.
- 082J-16 NTS Priddis topographic map: © Natural Resources Canada. The Government of Canada retains the copyright of this image but allows for reproduction for non-commercial use.
- Example map layout: © Siobhan McGoldrick. CC BY.

Summary

The topics covered in this chapter can be summarized as follows:

Section	Summary
8.1 Stream Erosion and Deposition	Erosion and deposition of particles within streams is primarily determined by the velocity of the water. Erosion and deposition of different-sized particles can happen at the same time. Some particles are moved along the bottom of a river while some are suspended in the water. It takes a greater velocity of water to erode a particle from a stream bed than it does to keep it in suspension. Ions are also transported in solution. When a stream rises and then occupies its flood plain, the velocity slows and natural levées form along the edges of the channel.
8.2 Stream Types	Youthful streams in steep areas erode rapidly, and they tend to have steep, rocky, and relatively straight channels. Where sediment-rich streams empty into areas with lower gradients, braided streams can form. In areas with even lower gradients, and where silt and sand are the dominant sediments, meanders are common. Deltas form where streams flow into standing water.
8.3 What Makes a Map?	Maps are used to share spatial data, and geologists often create maps using a topographic base map. All maps contain standard cartographic elements such as a title, scale, north arrow, legend, and other ancillary information that helps the reader understand the map. Topographic maps in Canada are indexed in the National Topographic System. Contour lines are drawn to show relief of the landscape on a topographic map.
Lab 8 Exercises	The best way to learn about important cartographic elements and mapping is to make a map yourself! Fluvial features along a meandering segment of the Elbow River in Calgary, Alberta can be identified and mapped based on satellite imagery. A good map conveys information about your interpretations to your reader. Adding a reference point with a UTM coordinate and a reference to the NTS map sheet on which your map resides helps your reader situate your interpretations in a larger context.