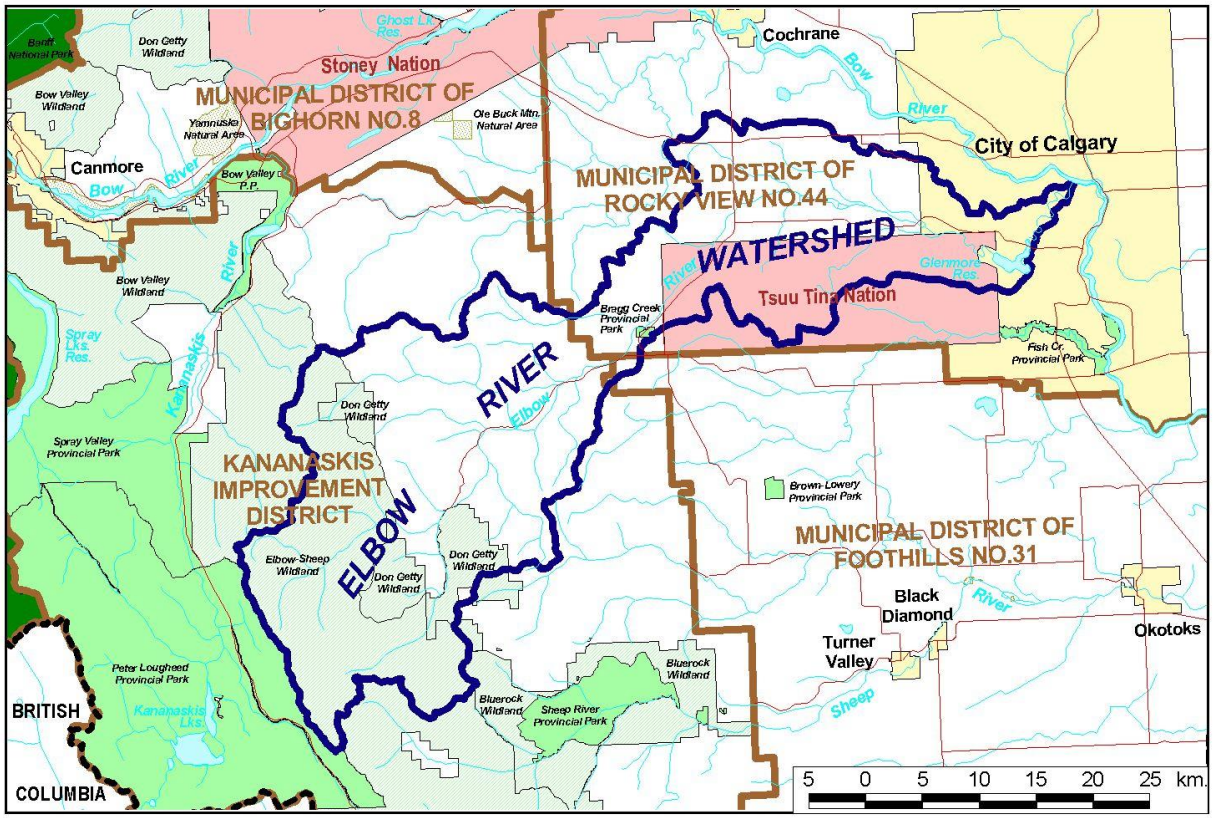
Aquatic Ecosystems:
The Elbow River

An educational field study for Biology 20 students



Acknowledgements

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This program is made possible through efforts of the following sponsors both past and present;

Aquatic Ecosystems: The Elbow River

Partnership program between:
Alberta Government – Tourism, Parks and Recreation
Friends of Kananaskis Country
Elbow River Watershed Partnership

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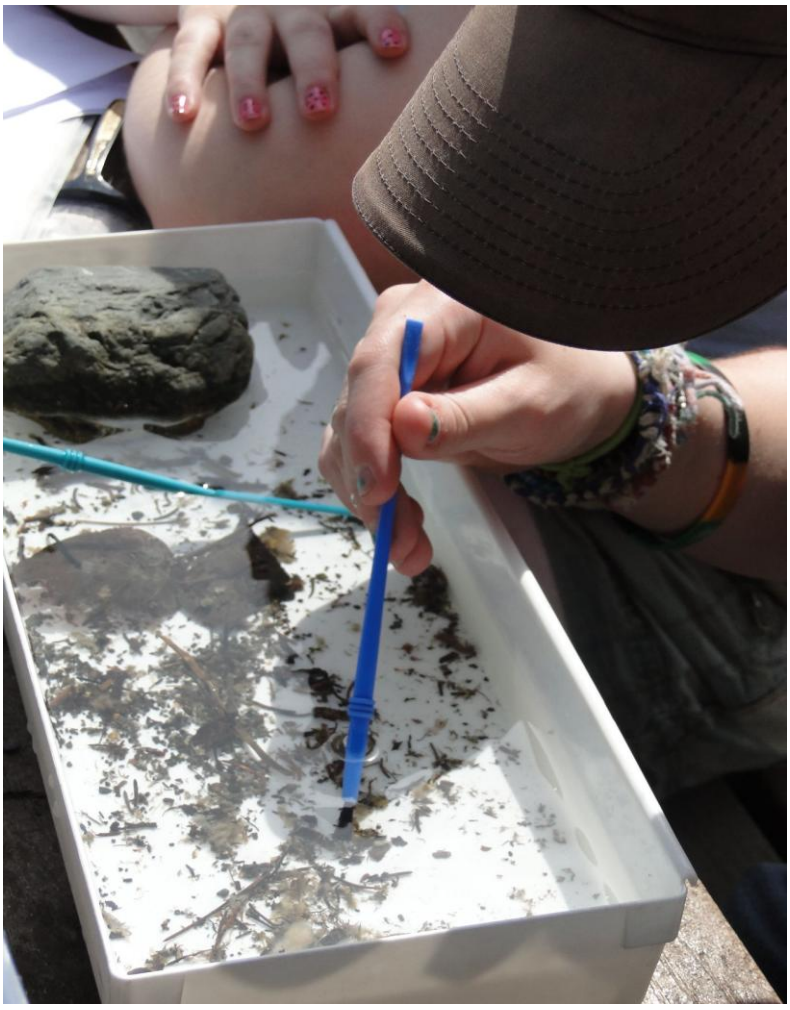
1.0
INTRODUCTION

1.1 PROGRAM AT A GLANCE

Curriculum Connections:	Biology 20: Ecosystems and Population Change
Adult Recommendations:	1 Environmental Educator (program facilitator) 1 teacher / educator 1 volunteer for each group of 5-6 students (a minimum of 3 adults is required – not including program facilitator)
Best Season:	Spring (May and June) Fall (from September until mid-November)
Suggested Location:	The program is designed for the Elbow River Watershed; however, adaptations can be made for other watersheds in Alberta



1.2 PROGRAM OVERVIEW

Welcome to ***Aquatic Ecosystems: The Elbow River***, a field study designed for Bio 20 students.

This is a curriculum-connected full-day study of the Elbow River with multidisciplinary post-activity support. The intent of this program is to provide a hands-on, engaging outdoor component, which will meet the needs of *Biology 20 Unit B: Ecosystems and Population Change*. This program is also written to achieve the mandate of the Alberta Government - Tourism, Parks, and Recreation and also addresses the four program goals of preservation, outdoor recreation, heritage appreciation, and heritage tourism.

The field study is designed to focus on testing and studying the abiotic and biotic factors of the aquatic ecosystem. Students are challenged to predict and then discover what the factors are indicating. Students will have the opportunity to monitor the Elbow River from the pristine waters of Cobble Flats in Kananaskis Country all the way to the City of Calgary. Traveling by bus, students will stop at key locations and test the water for dissolved oxygen, nitrates, phosphates, pH, turbidity, temperature, and aquatic invertebrates. They will also have an opportunity to observe and discuss complex land uses.

Post program activities are intended to bring the program to a close for the students. Students will compile all the data collected during the field study and discuss reasons for any variations observed. Activities are prepared for students to explore a case study of invasive species in the Elbow River Watershed and consider how this might impact the aquatic ecosystem.

2.0
PREPARATORY ACTIVITIES:
For Students

2.1 FIELD STUDY INTRODUCTION

Objectives:

- To introduce the concept of watersheds to students and to discuss where water is located in Alberta.
- To introduce the Elbow River watershed and the field study to students.

Materials:

- "Mean Annual Discharge" (Appendix 8.1 - overhead)
- "Where Alberta's Water Ends Up" (Appendix 8.1 – overhead)
- Elbow Watershed Map (included in binder)
- Blackboard or whiteboard
- PowerPoint CD "Monitoring the Elbow River"

Time Required:

Approximately 45 minutes to an hour.

Teacher instructions:

1. Class Review of Watersheds

- "Water on the Brain"– As a class, brainstorm words associated with watersheds and write those on the overhead, then have the class devise a possible definition for a watershed.
    - One definition is: *A watershed is defined as an area of land that drains into a body of water.*
    - Another definition is: "*The land catches water just like a big bowl or basin"…* which is why we often call a watershed a drainage basin.

- The Watersheds in Alberta (Appendix 8.1)
    - Make the "Mean Annual Discharge" visual into an overhead and discuss the major water arteries in Alberta. Compare where the majority of the water is in Alberta (60% is in the north) and where most of Alberta's population is (90% is within 100 km of the Canada / US border). Discuss what implications this might have for water management and conservation.
    - Show the overhead "Where Alberta's Water Ends Up" to further highlight where the river water in Alberta goes (water from the Elbow River ends up in Hudson Bay).

2. Examine Elbow River Watershed Poster

- Allow students to familiarize themselves with the area they will be studying. Introduce a variety of land uses in the Elbow River Watershed.

3. Introduce the Elbow River Field Trip (PowerPoint presentation)

- Play the PowerPoint presentation "Monitoring the Elbow River," which provides an overview of the field study locations, equipment to be used, and the amazing power and beauty of water.

2.2 VOCABULARY

Abdomen: The rear region of an invertebrate. See Figure 1.

Abiotic: Non-living characteristics of an ecosystem. In aquatic ecosystems this includes temperature, pH, turbidity and nutrients.

Anterior: The head end of an organism. See Figure 2.

Benthic Zone: The lowest level of an aquatic ecosystem, the sediment surface as well as within the sediment. In a freshwater system it is the region in the bottom of the river or lake. See Figure 3.

Biotic: Living characteristics of an ecosystem; the organisms living within an ecosystem.

Cerci: Appendages on the rear-most (abdominal) section of an invertebrate. See Figure 1.

Collector: Invertebrates that feed on small bits of organic matter (less than 1mm) by filtering them from passing water or gathering them from the stream bottom.

Community: The living organisms within an ecosystem that interact with each other.

Competition: Interaction between organisms that are attempting to use the same limited resource. This can take the form of many factors including: nutrients, oxygen, or space.

Dichotomous Key: Reference tool for identifying organism by choosing between two characteristics (usually presence/absence) in a sequence.

Diversity: Measure of the number of species and their abundance (or richness) in a community or ecosystem.

Dorsal: Refers to the back of the organism. See Figure 2.

Ecosystem: The interaction between biotic communities and their abiotic environment.

Grazer: Invertebrates that feed on algae attached to rocks or logs. Example: caddis fly.

Habitat: The area where an organism or community lives.

Invasive species: A non-native species that has been introduced into an area outside of its range where it has been able to out-compete native species and has had a negative impact on their ability to survive. Example: dandelions.

Limiting Factor: An abiotic characteristic that limits growth, distribution, or diversity of organisms within an ecosystem. The limiting factor is the resource that is in shortest supply in an ecosystem.

Limnetic Zone: Layer of open water in an aquatic ecosystem that is not influenced by the shore. This layer extends from the surface to the profundal zone. Light penetrates this layer so photosynthesis can occur here. Also known as the *pelagic zone*. See Figure 3.

Littoral Zone: This is the vegetated region of an aquatic ecosystem. It extends from the shore to where light is no longer sufficient to support rooted plants. This zone borders the limnetic zone. See Figure 3.

Niche: The role of an organism in an ecosystem.

Posterior: The hind end of an organism. See Figure 2

Predator: Invertebrates that feed on other animals in the stream.

Profundal Zone: The layer of water just above the benthic layer in an aquatic ecosystem. The light levels in this layer are too low to support photosynthesis. See Figure 3.

Shredder: Invertebrates that feed on large pieces of organic matter, such as leaves, that fall into the stream.

Tarsal: Referring to the last section of the legs. See Figure 1.

Thorax: The middle region of an invertebrate, between the head and abdomen. This region bears the wings and legs. See Figure 1

Ventral: Refers to the front or belly of the organism. See Figure 2.

Figure 1: General Anatomy of an Invertebrate

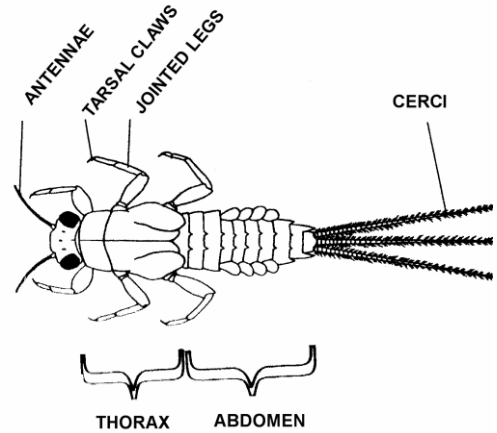


Figure 2: Dorsal-Ventral and Anterior-Posterior Orientation of an Invertebrate

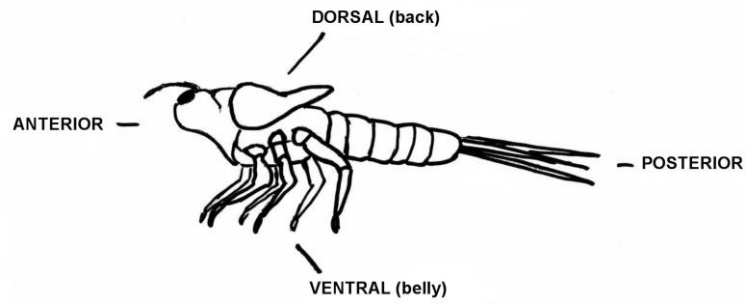
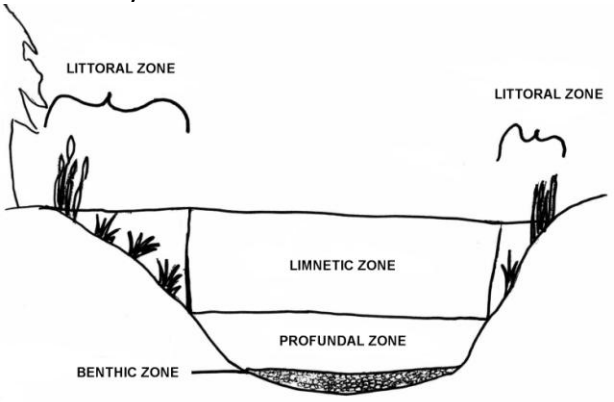
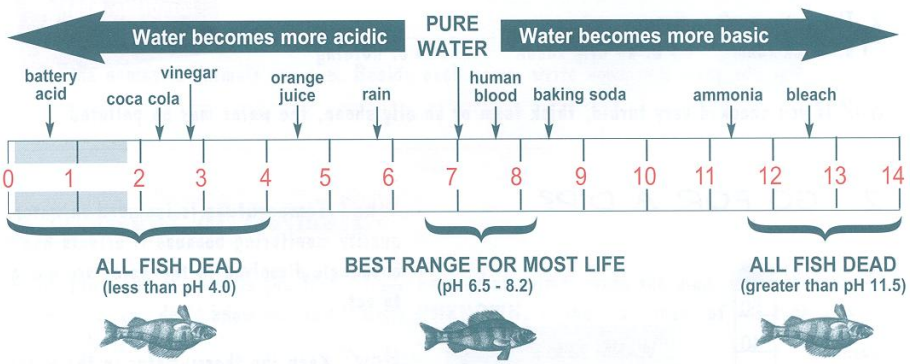


Figure 3: Zones of an Aquatic Ecosystem



What do the Water Tests Mean?

pH



Source: Water Watchdogs (Saskatchewan River Basin)

Temperature	Temperature is monitored because it affects how chemicals dissolve in the water and affects the amount of dissolved oxygen in the water. An increase in temperature indicates there is heat coming from: • An input source (e.g. effluent from a factory) • Loss of the riparian area (trees) surrounding the river, which means the sun is heating up the water more than it would with trees around it.
Turbidity	Increased turbidity or lack of clarity means there is a large amount of sediment in the water. An increase in turbidity results in: • Decreased fish egg survival. • Predators that rely on their eyes to hunt are ineffective. • Chemicals can attach to dirt and be dissolved in the river. • "A fish in turbid water is like a human in a smoke-filled room."
Dissolved Oxygen	• High oxygen content = many invertebrates • Low oxygen (eutrophication) = a dying ecosystem • As temperature decreases, dissolved oxygen increases.
Nitrates	• Nitrates (which are nutrients) occur naturally in small amounts from decomposition in the atmosphere. • Other sources come from pesticides, fertilizers, and manure. • Excess nitrates can cause too much plant and algae to grow in the water, which reduces oxygen and could cause death in some aquatic animals.
Phosphates	• Phosphates (also nutrients) occur naturally in small amounts from soils and rock that leach into the water. • Phosphates are also from detergents occurring in some soap, pesticides which are toxic to invertebrates, and fertilizers.
Invertebrates	• Invertebrates are environmental indicators (something that tells you whether the environment is healthy). • The presence of those invertebrates, which are only able to live in pristine conditions, indicates a high water quality. Examples of these invertebrates include: stonefly, mayfly, and caddisfly larvae. Examples of invertebrates that can tolerate low oxygen levels and high nutrient levels are: blackfly larvae, leech, bristleworm

2.4 SCIENTIFIC ROLES

Objective:

- To familiarize students with the group structure and students' roles during the field study.

Teacher Instructions:

1. Scientific Groups

- Divide students into 5 scientific research groups of about 6 students per group, assign roles.

Each student is required to complete their own data sheet

Phosphate or Nitrate Test (2 People):

- Responsible for completing **Phosphate** or **Nitrate** test at the site (each group will have one of these tests, not both).
- Also **assists** in the identification, measurement, and counting of invertebrates during the 10 minute wait period for the Phosphate or Nitrate test as well as when these tests are completed.

Turbidity Test (1 Person):

- Responsible for conducting the **Turbidity test**. When gathering water, please ensure there is someone spotting you for safety.
- Also **assists** in the identification, measurement, and counting of invertebrates during once their test is complete.

pH, Temperature, and Dissolved Oxygen (1 Person):

- Responsible for **pH, Temperature,** and **Dissolved Oxygen** tests.
- Also **assists** in the identification, measurement, and counting of invertebrates during once their tests are complete.

Invertebrate Collector (2 Person):

- **Collects Invertebrates** using net and containers. Rubber boots are required to be worn and will be provided.
- **Assists** in the identification, measurement, and counting of invertebrates.
- **Properly returns invertebrates** to the river by gently pouring the contents of the containers, with water to water contact, back into the Elbow River.

Once a group member has completed his/her role they must work together with other group members to complete any outstanding tests and reflect on the land use impacts up river from the sampling site.

All students are responsible for RIVER SAFETY and EQUIPMENT CARE.

2.5 CLASS DISCUSSION ABOUT THE FIELD STUDY

Objective:

- To conduct a class discussion focusing on the specifics of the actual field study day

Time Required:

- 20 minutes

Teacher Instructions:

Discuss this checklist of items, in class, prior to the field study day:

1. **Discuss behavioural expectations on the field study and important park rules**.
   The intent of parks and protected areas is to protect and preserve the natural environment. Have the class make a list of behaviours on the field study that would show respect for living things and a commitment to their care. An initial list could include:
   - Leaving nests, rotting logs, and ant hills alone and intact. These are homes for small animals.
   - Staying on the trails.
   - Do not litter. Litter should be placed in a garbage can or in your pocket.
   - Walking carefully, watching each step to avoid crushing small plants and trees.
   - Cutting, defacing, picking, or removal of any plant, fossil, rock, or other park material is prohibited.
   - Do not feed or harass wildlife. This includes decomposable food such as orange peels and other commonly disposed of items such as sunflower seed shells.
   - Brainstorm others with your class…be sure to discuss 'why' this rule is in place.

2. **Parks and protected areas have four main program objectives.**
   Initiate a conversation with your students as to how these objectives could be balanced:
   - **Preservation**: to preserve in perpetuity a network of parks and protected areas that represents the diversity of the province's natural heritage as well as related cultural heritage
   - **Heritage Appreciation**: to provide opportunities to explore, understand and appreciate the natural heritage of Alberta, and enhance public awareness and our relationship to and dependence on it
   - **Outdoor Recreation**: to provide a variety of outdoor recreation opportunities dependent on natural landscapes, as well as related facilities and services.
   - **Heritage Tourism**: to encourage residents and visitors to the province to discover and enjoy Alberta's natural heritage through a variety of outdoor recreation and nature-based tourism opportunities, facilities, and accommodation services.

3. **Discuss litter-free lunch concept**

Use reusable containers and cloth bags to reduce litter at lunch. Explain why an orange peel, while biodegradable, is still considered litter that should be packed out. Basically, if it didn't grow there, it doesn't stay there.

4. **Discuss water safety**:
   The following chart identifies some potential hazards to consider around water and the discussion that could take place on how to minimize these hazards:

Potential Hazards	Minimizing Hazards
Slippery Rocks	Step carefully Avoid algae-covered rocks
Falling into river	Be with a safety buddy when by the edge Don't lean too far over the edge.
Getting wet and cold	Bring proper wet boots Bring extra clothes or hand towel No splashing
Getting lost	Always stay with a buddy and by the group
Sunburn	Wear sunglasses, sunscreen and a hat
Broken Glass	Always wear shoes and be watchful. Notify teacher if glass is found Do not litter Avoid bringing glass containers in your lunch
Brainstorm other hazards with class…	

NOTE: The above hazards can be added to school board forms.

5. **Discuss appropriate clothing**
   Review how students should be appropriately dressed for the season and the activities of the day. Students should wear several layers of clothing, including a water resistant layer and a hat or hood. Boots provide more protection than sandals or canvas runners. Rubber boots will be provided for the stream study. If it's warm and sunny, students should have sunscreen, hats, and insect repellent (if sensitive to bites).

3.0
PREPARATORY ACTIVITIES:
For Teachers

3.1 CHECKLIST FOR FIELD STUDY DAY

Logistics:

- ❑ Discuss field trip plans with school administration.

- ❑ Consult off-site manual(s) and ensure all proper approvals have been established for off-site activities.

- ❑ Arrange transportation (bus or carpool) well in advance of the field study day. Confirm departure and pick up times. Some companies may not wish to travel into the Elbow (Hwy. 66).

- ❑ Sample itinerary (this can be adjusted by your school schedule)

    - 8:45 a.m.– depart from school
    - 9:45 a.m.– arrive at Cobble Flats
    - 11:30 a.m. – arrive at McLean Creek
    - 12:20 p.m.– arrive at Bragg Creek
    - 1:40 p.m.-arrive at Twin Bridges
    - 3:00 p.m.– arrive back at school

    9:15 a.m.– arrive at Bragg Creek
    11:00 a.m.– depart Cobble Flats
    12:00 p.m.– depart McLean Creek
    1:10p.m.–depart Bragg Creek
    2:30p.m.depart Twin Bridges

- ❑ Schedule the field study day with the Kananaskis Environmental Education program. Have cheque prepared for field trip and deliver it to the service provider on the day of the program.

- ❑ This program runs more efficiently if there is one adult with each group of students (5 groups, minimum of 3 not including program facilitator) while conducting tests on the river. Discuss the following with volunteers:
    - ❑ Describe the field study day
    - ❑ Orient them on activities and the plan for the day
    - ❑ Provide the volunteers with a map
    - ❑ Provide volunteers with any specific health or student concern, discipline issues, and general expectations.

- ❑ Send home and collect permission forms

- ❑ Ensure all students are dressed appropriately; check the weather prior to your field study http://www.theweathernetwork.com. Remember, rain gear for all students is essential.

- ❑ Conduct class discussion to review park rules, litter-free lunch, and behavioural expectations.

Photocopy (for the field study)

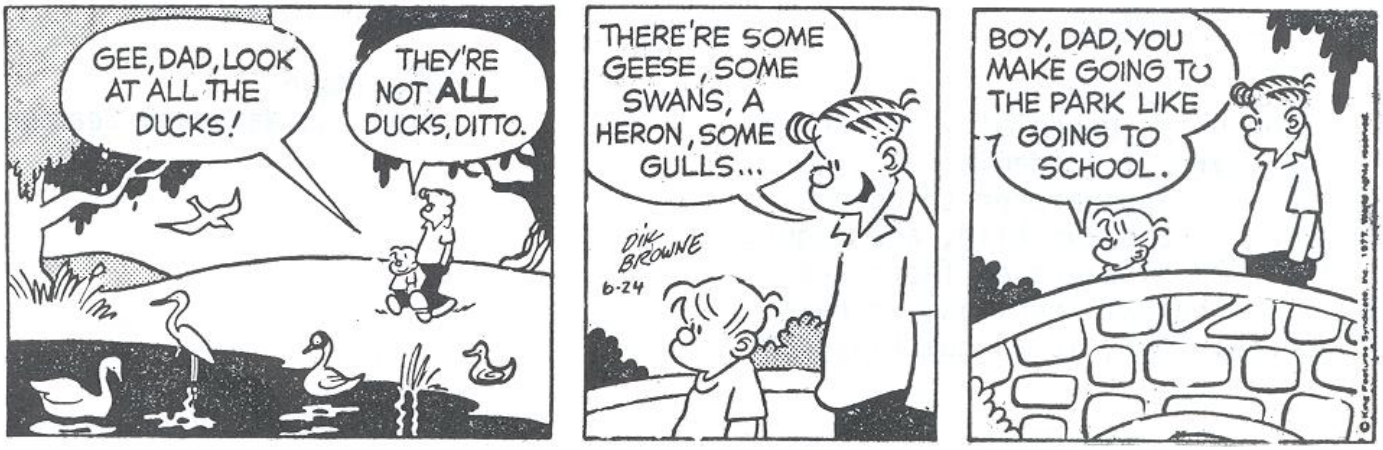
- ❑ Field study data sheets (one per student)
- ❑ Evaluation forms
    - Teacher evaluation of program

What to bring on the field study:

- ❑ Class list and list of students with health concerns.
- ❑ First Aid.
- ❑ Off-site communication (or make arrangements with service provider).
- ❑ Consult the off-site safety manual(s) for your board or school field trip requirements.

3.2 Sample Parent / Guardian Permission Form

The following page is a sample parent permission form. Simply add the specific information for your field study as outlined on the permission form. Copy the letter onto school letterhead and send home to parents / guardians. Be sure to allow two to three weeks for them to be returned to school and the information collected and collated.



Date: _____

Aquatic Ecosystems: The Elbow River
Biology 20 Field Study

Dear Parents / Guardians:

Presently we are working on Unit B: Ecosystems and Population Change. To accomplish some of the curriculum requirements for this unit, we will be going on a field study.

Field Study Description:
The students will be monitoring the water quality of the Elbow River using scientific testing equipment. This one-day field experience begins near the headwaters of the Elbow River within Kananaskis Country. From there, the students will follow the flow of the Elbow River, testing the river's water quality, and analyzing how it may change as it meets the city of Calgary.

Field Study Date: _____

Field Study Location: _____

Departure time from School: _____

Arrival time back at School: _____

Cost: _____

The cost of this program includes transportation, service provider (Kananaskis Country Environmental Education staff), field study equipment, and program development expenses. Please contact the field trip teacher if there are any concerns about the cost of this field study.
Please make cheques payable to: _____

Volunteers are required. The students will be organized into groups of approximately 5 students. Each group will have a volunteer leader. The role of the volunteers is to assist and facilitate student efforts in completing the field study activities. The environmental education staff and the teacher will provide all the field study instruction. There is no cost for volunteers. If you are interested in participating as a volunteer, please complete the lower portion of this sheet.
Complete and return the lower portion of this form on or before: _____

I _____ give permission for _____ to
(parent /.guardian) (student name)

attend the field study on _____ at _____
(date) (location)

_____ Yes, I am interested in volunteering for the field study

_____ No, I am not able to volunteer on the field study

_____
Signature

4.0
FIELD STUDY ACTIVITIES

4.1 Field Study Itinerary

Itinerary (including locations, discussion topics, and activities)

Stop #1: Cobble Flats – Introduction of the Aquatic Ecosystem, Testing Site #1

- ☐ What is an ecosystem?
- ☐ Discuss the protection of the headwaters and the role of Parks and Protected areas in the Elbow River watershed.
- ☐ Conduct sampling of abiotic and biotic characteristics of the testing site.
- ☐ Determine the diversity index for the site.
- ☐ Sketch the field study site and make visual observations of the site.
- ☐ Predict variations in the abiotic and biotic characteristics as we travel downstream.

Stop #2: McLean Creek – Investigating Human Impacts on an Aquatic Ecosystem

- ☐ Observe and discuss land uses and their affect on the ecosystem: forestry, oil and gas, recreation, agriculture, and municipal.
- ☐ Discuss mitigation efforts in relation to these land uses.
- ☐ Conduct land use debate.
- ☐ Washrooms (lunches to be eaten during travel time)

Stop #3: Bragg Creek or Redwood Meadows – Testing Site #2

- ☐ Conduct sampling of abiotic and biotic characteristics of the testing site.
- ☐ Determine the diversity index for the site.
- ☐ Sketch the field study site and make visual observations of the site.
- ☐ Predict variations in the abiotic and biotic characteristics as we travel downstream.
- ☐ Discuss the variation in results of the tests conducted from the first testing site to the second and the possible impacts of land uses previously discussed
- ☐ Discuss scientific/human error as well as equipment limitations.

Stop #4: Twin Bridges (City Limits of Calgary) – Testing Site #3

- ☐ Conduct sampling of abiotic and biotic characteristics of the testing site.
- ☐ Determine the diversity index for the site.
- ☐ Sketch the field study site and make visual observations of the site.
- ☐ Discuss the changes in the abiotic and biotic characteristics of the Elbow River from the beginning of the study to the end and hypothesize about the causes of these variations.

4.2

AQUATIC ECOSYSTEMS: The Elbow River

BIOLOGY 20 FIELD STUDY DATA SHEET

4.2 Field Study Data Sheet

Group Members: _____ _____

_____ _____

_____ _____

Information

Date: _____ **Time:** _____

Weather: _____

Important Student Reminders:

- ☐ Fill out all the required data at each sampling location, as well as any necessary calculations.
- ☐ Each group member must complete their own data sheet including a sketch at each sampling site.
- ☐ As a group, discuss the visually observable characteristics of each site, any upstream land uses, and predictions and record your conclusions in the observation sections of your data sheets.
- ☐ **Use care and attention when handling all sample equipment – your school will be charged for lost or broken items!**
- ☐ Have FUN – remember, you're not in a classroom today!

Scientific Team Roles:

Each student is required to complete their own data sheet

Phosphate or Nitrate Test (2 People):

- Responsible for completing **Phosphate** or **Nitrate** test at the site (each group will have one of these tests, not both).
- Also **assists** in the identification, measurement, and counting of invertebrates during the 10 minute wait period for the Phosphate or Nitrate test as well as when these tests are completed.

Turbidity Test (1 Person):

- Responsible for conducting the **Turbidity test**. When gathering water, please ensure there is someone spotting you for safety.
- Also **assists** in the identification, measurement, and counting of invertebrates during once their test is complete.

pH, Temperature, and Dissolved Oxygen (1 Person):

- Responsible for **pH, Temperature,** and **Dissolved Oxygen** tests.
- Also **assists** in the identification, measurement, and counting of invertebrates during once their tests are complete.

Invertebrate Collector (2 Person):

- **Collects Invertebrates** using net and containers. Rubber boots are required to be worn and will be provided.
- **Assists** in the identification, measurement, and counting of invertebrates.
- **Properly returns invertebrates** to the river by gently pouring the contents of the containers, with water to water contact, back into the Elbow River.

Once a group member has completed his/her role they must work together with other group members to complete any outstanding tests and reflect on the land use impacts up river from the sampling site.

All students are responsible for RIVER SAFETY and EQUIPMENT CARE.

TESTS FOR ABIOTIC CHARACTERISTICS IN THE ELBOW RIVER				
		HEADWATERS Cobble Flats	**MID-RIVER Bragg Creek**	**STUDY END Twin Bridges**
ABIOTIC CHARACTERISTICS	**pH**			
	Temperature (^{o}C)			
	Turbidity (cm)			
	Dissolved Oxygen (mg/L)			
	Nitrates (mg/L)			
	Phosphates (mg/L)			

*** REMEMBER to write down your observed characteristics for each testing site.**

TESTS FOR BIOTIC CHARACTERISTICS IN THE ELBOW RIVER

HEADWATERS - Cobble Flats

SAMPLE #1 - HEADWATERS				
Common Name	**Family Name**	**Ecological Role** (collector, grazer, predator, shredder)	**Number of Individuals**	**Average Length (cm)** Note very small or large individuals
Total Number of Individuals in Sample:				**N/A**

If you have time, do a second sample. Use the additional tables on the last page to record your results.

Once samples have been taken at this testing site, calculate the biodiversity index:

1. Record the number of families you identified
2. Count the total number of individuals you found
3. Divide the number of families by the number of individuals

Biodiversity Index -Headwaters	
Number of Families:	
Total Number of Individuals for Site:	
Diversity Index: $\frac{\text{\# of families}}{\text{\# of individuals}}$	

Testing Site #1: HEADWATERS - Cobble Flats Study Site

Sketch a cross section of the river at this site:

List any observable characteristics of this site:

List the land use impacts upstream from the study site:

What are your predictions for the next site regarding the abiotic and biotic characteristics tested:

What are some possible errors that influenced test results at this site?

TESTS FOR BIOTIC CHARACTERISTICS IN THE ELBOW RIVER

MID-RIVER - Bragg Creek

SAMPLE #1 – MID-RIVER				
Common Name	**Family Name**	**Ecological Role** (collector, grazer, predator, shredder)	**Number of Individuals**	**Average Length (cm)** Note very small or large individuals
Total Number of Individuals in Sample:				**N/A**

If you have time, do a second sample. Use the additional tables on the last page to record your results.

Once samples have been taken at this testing site, calculate the biodiversity index:

1. Record the number of families you identified
2. Count the total number of individuals you found
3. Divide the number of families by the number of individuals

Biodiversity Index – Mid-River	
Number of Families:	
Total Number of Individuals for Site:	
Diversity Index: # of families # of individuals	

Testing Site #2: MID-RIVER - Bragg Creek Study Site

Sketch a cross section of the river at this site:

List any observable characteristics of this site:

List the land use impacts upstream from the study site:

What are your predictions for the next site regarding the abiotic and biotic characteristics tested:

What are some possible errors that influenced test results at this site?

TESTS FOR BIOTIC CHARACTERISTICS IN THE ELBOW RIVER

STUDY END – Calgary City Limits

SAMPLE #1 – STUDY END				
Common Name	**Family Name**	**Ecological Role** (collector, grazer, predator, shredder)	**Number of Individuals**	**Average Length (cm)** Note very small or large individuals
Total Number of Individuals in Sample:				**N/A**

If you have time, do a second sample. Use the additional tables on the last page to record your results.

Once samples have been taken at this testing site, calculate the biodiversity index:

1. Record the number of families you identified
2. Count the total number of individuals you found
3. Divide the number of families by the number of individuals

Biodiversity Index – Study End	
Number of Families:	
Total Number of Individuals for Site:	
Diversity Index: $\frac{\text{\# of families}}{\text{\# of individuals}}$	

Testing Site #3: STUDY END - Twin Bridges Study Site

Sketch a cross section of the river at this site:

List any observable characteristics of this site:

List the land use impacts upstream from the study site:

What are your predictions for the next site regarding the abiotic and biotic characteristics tested:

What are some possible errors that influenced test results at this site?

VOCABULARY

Abdomen: The rear region of an invertebrate. See Figure 1.

Abiotic: Non-living characteristics of an ecosystem. In aquatic ecosystems this includes temperature, pH, turbidity and nutrients.

Anterior: The head end of an organism. See Figure 2.

Benthic Zone: The lowest level of an aquatic ecosystem, the sediment surface as well as within the sediment. In a freshwater system it is the region in the bottom of the river or lake. See Figure 3.

Biotic: Living characteristics of an ecosystem; the organisms living within an ecosystem.

Cerci: Appendages on the rear-most (abdominal) section of an invertebrate. See Figure 1.

Collector: Invertebrates that feed on small bits of organic matter (less than 1mm) by filtering them from passing water or gathering them from the stream bottom.

Community: The living organisms within an ecosystem that interact with each other.

Competition: Interaction between organisms that are attempting to use the same limited resource. This can take the form of many factors including: nutrients, oxygen, or space.

Dichotomous Key: Reference tool for identifying organism by choosing between two characteristics (usually presence/absence) in a sequence.

Diversity: Measure of the number of species and their abundance (or richness) in a community or ecosystem.

Dorsal: Refers to the back of the organism. See Figure 2.

Ecosystem: The interaction between biotic communities and their abiotic environment.

Grazer: Invertebrates that feed on algae attached to rocks or logs. Example: caddis fly.

Habitat: The area where an organism or community lives.

Invasive species: A non-native species that has been introduced into an area outside of its range where it has been able to out-compete native species and has had a negative impact on their ability to survive. Example: dandelions.

Limiting Factor: An abiotic characteristic that limits growth, distribution, or diversity of organisms within an ecosystem. The limiting factor is the resource that is in shortest supply in an ecosystem.

Limnetic Zone: Layer of open water in an aquatic ecosystem that is not influenced by the shore. This layer extends from the surface to the profundal zone. Light penetrates this layer so photosynthesis can occur here. Also known as the *pelagic zone*. See Figure 3.

Littoral Zone: This is the vegetated region of an aquatic ecosystem. It extends from the shore to where light is no longer sufficient to support rooted plants. This zone borders the limnetic zone. See Figure 3.

Niche: The role of an organism in an ecosystem.

Posterior: The hind end of an organism. See Figure 2

Predator: Invertebrates that feed on other animals in the stream.

Profundal Zone: The layer of water just above the benthic layer in an aquatic ecosystem. The light levels in this layer are too low to support photosynthesis. See Figure 3.

Shredder: Invertebrates that feed on large pieces of organic matter, such as leaves, that fall into the stream.

Tarsal: Referring to the last section of the legs. See Figure 1.

Thorax: The middle region of an invertebrate, between the head and abdomen. This region bears the wings and legs. See Figure 1

Ventral: Refers to the front or belly of the organism. See Figure 2.

Figure 1: General Anatomy of an Invertebrate

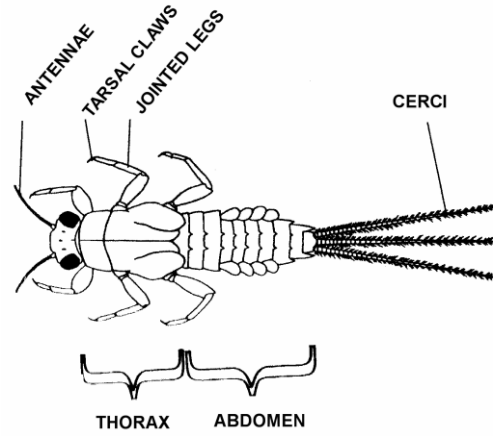


Figure 2: Dorsal-Ventral and Anterior-Posterior Orientation of an Invertebrate

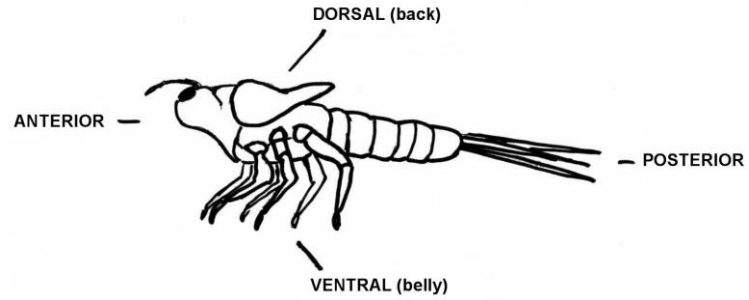
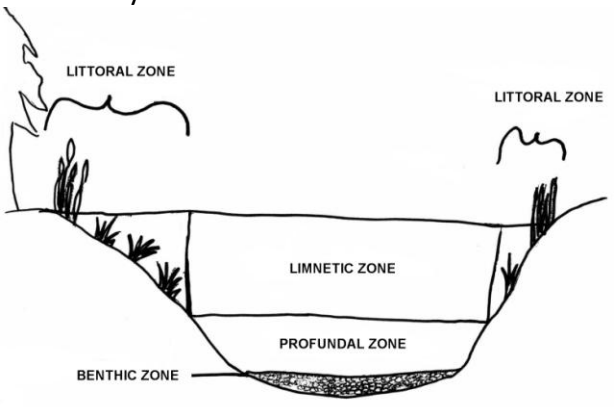


Figure 3: Zones of an Aquatic Ecosystem



TESTS FOR BIOTIC CHARACTERISTICS IN THE ELBOW RIVER

ADDITIONAL TABLES FOR SECOND SAMPLE

SAMPLE #2 **LOCATION:**				
Common Name	**Family Name**	**Ecological Role** (collector, grazer, predator, shredder)	**Number of Individuals**	**Average Length (cm)** Note very small or large individuals
Total Number of Individuals in Sample:				**N/A**

SAMPLE #2 **LOCATION:**				
Common Name	**Family Name**	**Ecological Role** (collector, grazer, predator, shredder)	**Number of Individuals**	**Average Length (cm)** Note very small or large individuals
Total Number of Individuals in Sample:				**N/A**

SAMPLE #2 LOCATION:				
Common Name	**Family Name**	**Ecological Role** (collector, grazer, predator, shredder)	**Number of Individuals**	**Average Length (cm)** Note very small or large individuals
Total Number of Individuals in Sample:				**N/A**

SAMPLE #2 LOCATION:				
Common Name	**Family Name**	**Ecological Role** (collector, grazer, predator, shredder)	**Number of Individuals**	**Average Length (cm)** Note very small or large individuals
Total Number of Individuals in Sample:				**N/A**

5.0
BIOLOGY 20 CLASSROOM ACTIVITIES

5.1 Consolidating the Class Data: Examining Predictions vs. Results

Objective: To work with data collected on the field study and to compare the predictions made with the results.

Materials: Consolidation chart as overhead or excel spreadsheet.

Instructions:

- Compile data from all groups onto the consolidation chart.
- Make averages of all the data, review consistencies and differences in measurements.
- Discuss why there is variation in scientific data (e.g.) scientific error, testing anomalies
- Have each group discuss the differences between their pre-field study predictions and the actual results, or do this as a class. What are the possible reasons for the differences?
    - ☐ Time of day, week, or year
    - ☐ Changes in water quality due to procedures by industry, municipalities, and recreation
    - ☐ Sampling error (how would you determine if this was the case?)
    - ☐ Compare class data to that of a single group

***Note:** this activity can precede the graphing activity (5.2) or students can be given this data to consolidate on their own during that activity.

If possible, please provide this class data to the instructors for the field study program so they can provide this consolidated information to future classes.

CONSOLIDATED DATA FROM THE ELBOW RIVER FIELD STUDY				
		HEADWATERS Cobble Flats	**MID-RIVER Bragg Creek**	**STUDY END Calgary City Limits**
TESTS FOR ABIOTIC CHARACTERISTICS				
pH	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				
Temperature (°C)	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				
Turbidity (cm)	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				
Dissolved Oxygen (mg/L)	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				
Nitrates (mg/L)	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				

CONSOLIDATED DATA FROM THE ELBOW RIVER FIELD STUDY				
		HEADWATERS Cobble Flats	**MID-RIVER Bragg Creek**	**STUDY END Calgary City Limits**
Phosphates (mg/L)	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				
TESTS FOR BIOTIC CHARACTERISTICS				
Total Number of Families Identified	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				
Average Length	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				
Total # of Individuals	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				
Diversity Index	Group 1			
	Group 2			
	Group 3			
	Group 4			
	Group 5			
	Group 6			
SITE AVERAGE				

5.2 Graphing Field Study Results for Analysis

Objectives: To build on the students' graphing and analysis skills. To formulate hypotheses about observed relationships between abiotic and biotic characteristics of the aquatic environment as well as examining the impacts of human activities on these characteristics. To understand adaptations and variations in organisms in response to their aquatic habitat. This project leads well into both the Build a Better Field Study and Stewardship Project Challenge activities because of the critical thinking involved.

Materials: Consolidated class data.

Instructions:

- Each group or individual will graph their results for each variable as well as the compiled or average data for the class (see: Consolidating the Data for information on a related classroom activity) in order to consider the differences between class data and data from an individual group. Alternatively, if time is a constraint, students could graph either the class or group data, with an in-class demonstration of the alternative data set to show the differences.
- Examine correlations between the abiotic and biotic factors tested during the field study.
- Using a spreadsheet program would facilitate the testing of several graphing methods if desired (e.g.) average data or scatter plotting. If only one graphing method is used, a line graph is recommended.
- In groups or as a class, have the students discuss their graphing results.

The following page contains a possible hand-out for the students; it can also be used as an in-class discussion guide.

Data Analysis for the Elbow River Field Study

Graph your results for each variable tested versus each of the 3 testing sites (it may not be necessary to graph all factors if some did not vary between the testing sites):

pH	Number of Families of Invertebrate
Temperature	% of Invertebrate in Each Ecological Role
Turbidity	Number of Individuals
Dissolved Oxygen	Average Length of Invertebrates
Nitrates	Diversity Index
Phosphates	

***Reminder:** label your graphs with the date your data was collected, as well as the variables on each axis.

Discussion Questions:

1. Based on your results and observations, what are your general conclusions about the health of the aquatic ecosystem studied as you travelled from the headwaters to the study's end?
2. Do any of the abiotic and biotic variables appear to be linked or correlated? If you do see correlations, what could be causing these interactions? How is one characteristic affecting another?
3. Do your results match any predictions you made before or during the field study? If they do not match, why not?
4. What outside pressures do you think affected the abiotic and biotic characteristics in the Elbow River?
5. For the invertebrates, what variations did you see in response to the abiotic characteristics of the river as you travelled downstream? What do you think are the most important limiting factors for organisms living in the Elbow River?
6. Did you notice variations in adaptations for invertebrates in different ecological roles or niches? Think about how this relates to what they eat or where they live in the river.
7. What zone or niche of the aquatic ecosystem were the invertebrates sampled from? Why does their ecological role make them ideal biological indicators for aquatic health?
8. When the Department of Fisheries and Oceans tests for aquatic health, they base the results on the diversity of invertebrate species identified at various sites? What does the biodiversity index you calculated tell you about the health of the Elbow River in the three test sites? What predictions can you draw from the diversity of invertebrates with regards to other species living in the Elbow River?

5.3 Invasive Species Case Study: Brook Trout in the Elbow River Drainage Basin

Objectives: Examine how an ecosystem functions by studying invasive species in the Elbow River. Use a real-life example of competition to flesh-out the concepts of niche, habitat, and limiting factors. Define invasive species and examine their impact on aquatic ecosystems.

Instructions: Discuss the concept of invasive species with the students and introduce the case study of Brook trout in the Elbow River. Have the students do a brief research project in groups or pairs with a web search to find information about native and non-native fish species in Alberta's rivers (suggested websites are listed below). Once students have collected their information, give them the background information provided. Then lead a discussion on the impacts suggested by their research and the information provided, as well as any other impacts that they can predict based on their knowledge of the interaction of biotic and abiotic characteristics of an ecosystem.

Background Information:

The introduction of species that are not native to Alberta can upset the balance of an ecosystem. When a non-native species is introduced to a new ecosystem which may not contain a natural predator, it is often the case that it can become an invasive species. **Invasive species** are those that can out-compete native species and may actually inhibit the ability of native species to survive in an ecosystem.

In 1940, brook trout (*Salvelinus fontinalis*), a species of fish native to Ontario, were introduced into the Elbow River drainage basin as stocked fish for sport-fishing. According to Trout Unlimited Canada, a non-governmental conservation organization, non-native fish species, brook trout in particular, are out-competing the native species of bull trout (*Salvelinus confluentis*) and westslope cutthroat trout (*Oncorhynchus clarkii lewisii*) in Quirk Creek, a major tributary of the Elbow River. In 1996, 94% of fish collected in Quirk Creek were brook trout. Few brook trout are seen in the Elbow River itself above Bragg Creek. This may be due to the cold temperatures in the Elbow River limiting their activity, but brook trout do much better in the shallower and warmer tributaries such as Quirk Creek, where native species have been adversely affected.

Brook trout reproduce at the same time and place as bull trout, so both species are attempting to occupy the same **niche** within their **habitat**, putting them in direct **competition** with each other. One of the reasons brook trout are able to out-compete native species is because they are able to reproduce as early as 18 months old, while slower growing bull trout rarely reach sexual maturity before 5 years of age. Earlier maturity may result in populations of brook trout overcrowding a habitat, resulting in a population of individuals that is stunted in size.

Elbow Lake, the headwaters for the Elbow, was historically stocked with brook trout by humans. Currently the biomass in Elbow Lake has been skewed from a few large individuals to many small individuals; what has been observed there is that there are no large size fish (stunting). Often in historically fishless high mountain lakes the addition of a fish species changes the dynamic of the **ecosystem**. An introduction of a top predator can lead to the removal the native predator insects that are present, because they are being consumed by the introduced species. This can cause a trophic cascade: take out the large bugs, then the

medium, and so on until it takes out the grazer bugs. Essentially there is a large population feeding on a very small resource and to compensate the population will stunt their growth so they can maintain a large population size. Now algal blooms are being seen, which is uncommon in high mountain lakes, which could be due to the removal of grazer insects that may be a **limiting factor** for the algae. The ecosystem may be "out of balance" because the brook trout that have been introduced there.

Organizations, such as Trout Unlimited Canada, can undertake programs to help suppress invasive populations. In Quirk Creek, for example, TUC is trying to ease the demand on capacity of the river through intensive electro-fishing and angling.

Background Information was adapted from:
Alberta Sustainable Resource Development Website
http://www.srd.alberta.ca/fishwildlife/fishingalberta/default.aspx
Conversations with Brian Meagher, Provincial Biologist with Trout Unlimited Canada
www.tucanada.org

Suggested websites for researching non-native fish Species in Alberta and their effect on native fish populations and the aquatic ecosystem:

Alberta Sustainable Resource Development – Fish Identification
http://www.srd.alberta.ca/fishwildlife/fishingalberta/fishidentification/

Alberta Sustainable Resource Development – Species at Risk Information
http://www.srd.alberta.ca/fishwildlife/speciesatrisk/default.aspx

Trout Unlimited Canada
www.tucanada.org

Trout Unlimited Canada National Projects – Brook Trout Suppression in Quirk Creek (a tributary of the Elbow River)
http://www.tucanada.org/NP_QuirkCreek.shtml

Suggested Discussion Questions (with suggested topics to cover):

1. What resources are brook and bull trout competing for in the Elbow River? What are the limiting factors in the Elbow River ecosystem?
   - food, space, a place to reproduce
2. How do biotic factors and abiotic factors create competition?
   - finite nature of abiotic and biotic factors
3. How can populations affect each other?
   - competition
   - predation

4. What impacts might a large population of an invasive fish species have on the aquatic ecosystem?
    - change in the size or number of individuals in the ecosystem (e.g.) stunted growth
    - loss of biodiversity
    - hybridization between invasive and native species
    - changes in the food chain can lead to imbalances (e.g.) algal blooms
5. What is the difference between introduced populations of brook trout in the Elbow River versus Elbow Lake?
    - in the Elbow River there have always been fish and the populations are now competing
    - in Elbow Lake there historically was no fish, so new pressures have been added to the insect species in that habitat, so predator insects that once occupied the highest trophic level have been displaced
6. Algal blooms have been noticed in some high mountain lakes in Alberta's protected areas that have always been fishless. If the introduction of brook trout isn't causing algal blooms in Elbow lake, what other changes to the abiotic and biotic characteristics could be causing them?
    - changes in temperature or pH due to global issues such as global warming or acid rain could be changing the ecological balance in these lakes
7. What measures might be taken to limit or monitor non-native populations? How effective do you think these measures are?
    - electro-fishing or angling to remove invasive species
    - control of fishing licences by the province as well as catch and release of threatened native fish species
    - citizen-based water quality monitoring programs
    - monitoring of native species and updating species at risk information
8. How might incorrect identification of fish species by fishermen impact populations?
    - removal of native species, especially if they are larger or more vulnerable to being caught

5.4 Stewardship Project Challenge

Now that student have had a chance to collect data and draw conclusions about the impacts of human activities on the abiotic and biotic characteristics of the Elbow River aquatic ecosystem, they should now be able to design and initiate a stewardship project based on their findings.

This project could take the form of:

- Designing and producing pamphlets to promote awareness of issues affecting the aquatic ecosystem in your area or a river closer to your school
- An article in a local newspaper or a "State of the Elbow" Report
- Planning and conducting a river clean-up or a garbage pick-up at your school
- Designing and creating a website
- Filming a commercial to inform others of impacts on the aquatic ecosystem
- A campaign for zero pesticide use at your school or a phosphate free classroom challenge

Encourage the students to brainstorm as a class or in their individual groups about what they believe the most significant impacts on the Elbow River was. Discuss what possible mitigation efforts could be undertaken to address these issues. From this discussion, have each group create a proposal for a stewardship project that includes the issue they want to address as well as their approach, including what logistics need to be considered in undertaking the project and how they would organize it. Each group will then create a presentation for the class and the class can vote on what project they would like to take on as the Stewardship Project Challenge.

For an information-based project, encourage the students to use the data they collected during their field study to convey the information; graphs would be particularly useful. This will make the field study even more meaningful. Also discuss who their intended audience is and whether they want the tone of the information they present to be scientific or whether they want to personalize the information for a different response from the recipients.

For a more action-based project, have the students consider creating signs or posters to inform others observing their project about why they are taking on this project. This can increase their effect by spreading the knowledge they have acquired on the Elbow River field study.

***Note**: the proposal chosen could be for an individual projects to be completed by each group. For example, if designing information pamphlets is chosen, each group could create their own pamphlet with a different theme, so the result is an entire information package created by the class. Example: land use impacts on the aquatic environment: each group will design a pamphlet based on a different land use.

Also, don't be afraid to merge projects. Creating information posters, hand-outs, or even a website to be distributed during a clean-up might be a great way of informing others about the project and become a stimulus for change.

5.5 Build a "Better" Field Study Challenge

Objectives:

The purpose of this activity is to think critically about the field study that was conducted and to examine the necessary factors for a successful field study. Students are to work cooperatively to choose a specific issue they want to examine in relation to aquatic ecosystems and create a set of testing parameters to meet their goal. This activity encourages students to find out what they personally want to know about an aquatic ecosystem.

Discussion Questions:

1. What did you learn from the field study on the Elbow River? What were the key conclusions you were able to make?
2. What were the limitations of the field study on the Elbow River?
3. What is the purpose of your study (i.e.) what do you want to know? This could take the form of a hypothesis or a statement of intent. It might be helpful to write down some focussing questions to help you design your study.
   For example, are you conducting a baseline study of abiotic and biotic characteristics or studying changes due to human impact?
4. How many testing sites will you visit? Are you doing an in-depth study in one spot or will you visit many frequent testing sites down the length of the river?
5. What is the time frame of your study? Will it be one day of testing or several throughout the year?
6. What equipment would you need to conduct your study successfully? What are the limitations of your equipment?
7. Do you have a baseline or control included in your study to compare your results to? How will you determine if your results are accurate?
8. Consider the budget you have for your study. How much might your time, travel, and equipment cost?

6.0
EVALUATIONS AND FEEDBACK

6.1 Program Evaluation - Teacher

*Thank you for participating in the **Aquatic Ecosystems Elbow Valley Field Study**. Your feedback is greatly appreciated and will help to improve this program.*

Pre-program	***not at all***		***neutral***		***yes***
1. The preparatory activities effectively prepared the students	1	2	3	4	5
2. The prep activities were educational and engaging	1	2	3	4	5
3. The teacher resource manual was easy to use and understand:	1	2	3	4	5

Did you conduct any **additional preparatory activities**? If so, describe_____

_____

Field Study	***not at all***		***neutral***		***yes***
	1	2	3	4	5
1. The water testing stops were educational and engaging for the students	1	2	3	4	5
2. The land use stops were educational and engaging for the students	1	2	3	4	5
3. The data sheet was a simple and effective teaching tool	1	2	3	4	5
4. The field study met and exceeded curriculum needs	1	2	3	4	5
5. The field study left students with meaningful, though-provoking questions	1	2	3	4	5

Any additional comments about the field study?

_____

_____

Which **post-program activities** did you complete with your class?

- ❑ Data consolidation
- ❑ Graphing Field Study Results
- ❑ Invasive Species Case Study
- ❑ Build a Better Field Study
- ❑ Stewardship Project Challenge

Did you conduct any **additional post-program activities**? If so, please describe _____

_____

Did you find the additional resources and contacts valuable? **YES** **NO**

Please add any additional comments, suggestions, resources or contacts which may benefit the program

_____

_____

Fax completed evaluation forms to:
Kananaskis Country Environmental Education – 403-678-5505

7.0
TEACHER'S RESOURCES

7.1 Resource List

- Kananaskis Country Environmental Education
  - Field trip bookings, information, and educational resources
  - 403-678-5500 Ext. 284
  - www.kananaskis-country.ca

- Elbow River Watershed Partnership
  - Resources, data, technical information, and stewardship possibilities
  - www.erwp.org

- Alberta Parks and Protected Areas
  - Information about the parks and protected areas system
  - http://www.tpr.alberta.ca/parks/

- Trout Unlimited Canada
  - Yellow Fish Road Program – paint storm drains with fish!
  - www.yellowfishroad.og

- Riverwatch
  - Rafting field trips for students on various rivers in Alberta.
  - http://www.riverwatch.ab.ca/

- South Saskatchewan River Basin
  - Water Watchdog program and resources
  - www.saskriverbasin.ca/

- Alberta Watersheds
  - Watershed Maps and information on watersheds. Highlights Alberta Watershed Awareness Day
  - http://www.waterforlife.gov.ab.ca/html/background3.html

- Cows and Fish: Alberta Riparian Habitat Management Society
  - Great information about riparian areas and about water stewardship and protection.
  - www.cowsandfish.org

- Ducks Unlimited
  - Teacher's resources, wetland connections
  - www.ducks.ca/

- What's happening to Alberta's water?
  - Information, maps, climate change research, connected with the University of Alberta
  - http://www.ualberta.ca/ERSC/water/

- Alberta Environment (water web page)

- Research, technical findings, resources, data, policies, manuals, and more
- http://environment.alberta.ca/

- Alberta Sustainable Resources
  - Forestry**:** http://www.srd.gov.ab.ca/
  - Off-Highway Vehicle Use – http://www.srd.gov.ab.ca/lands/default.aspx

- Fisheries and Oceans Canada**:**
  - http://www.dfo-mpo.gc.ca/index.htm

- United States Environmental Protection Agency for children
  - http://www.epa.gov/kids/

- International Year of Freshwater 2003: "Water for Life" decade
  - http://www.wateryear2003.org/

- Parks Foundation Calgary
  - http://www.parksfdn.com/abcalasnpfc/doc.nsf/doc/river_index.cm

- Glencoe Golf and Country Club
  - http://www.glencoe.org/glencoe/

- Tsuu T'ina Nation and Ecotourism
  - http://www.tsuutina.ca/

- Bow Riverkeeper
  - http://www.bowriverkeeper.org

- Living by Water
  - Landowner projects to protect water
  - http://www.livingbywater.ca/

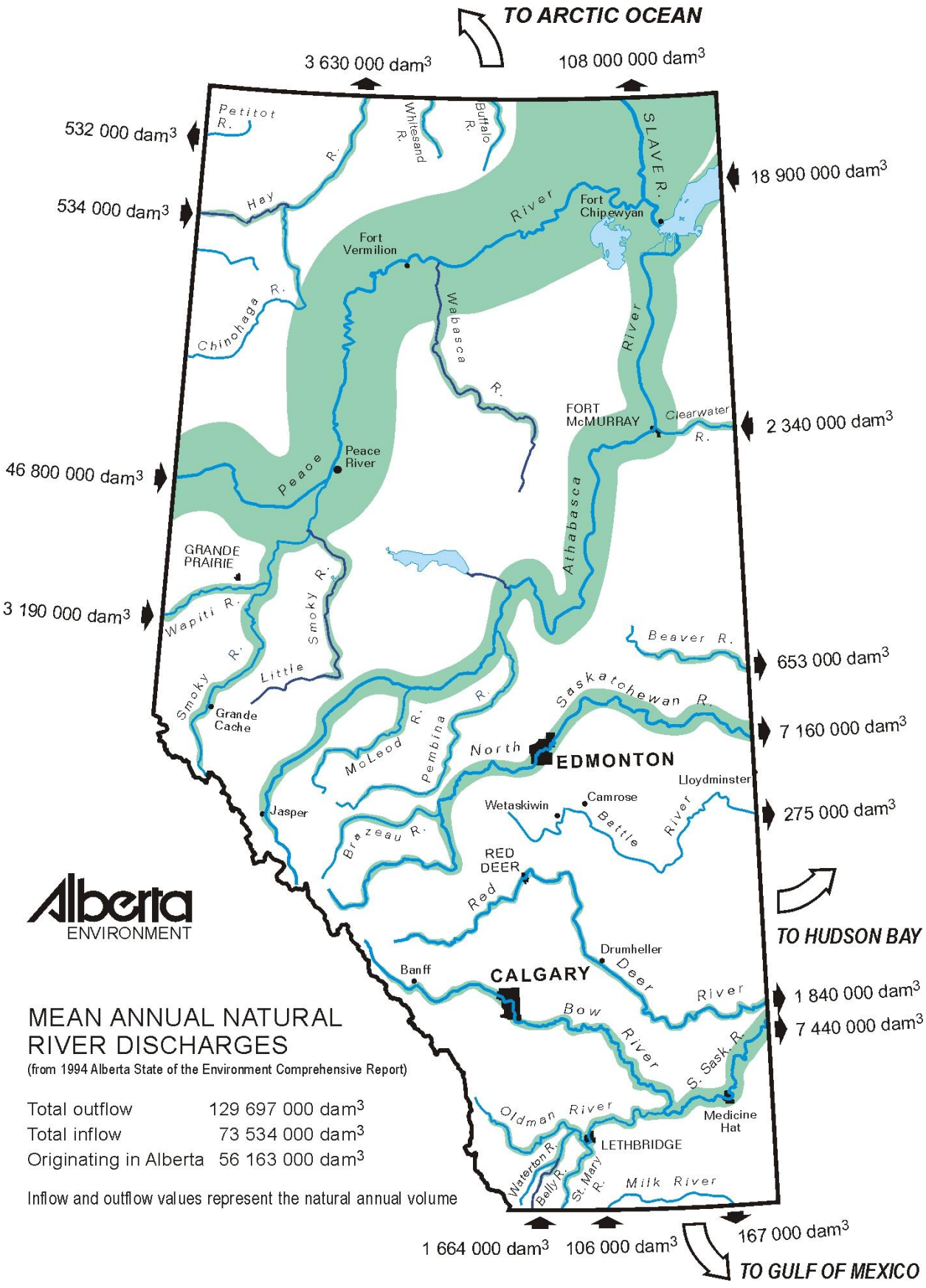
- Bow River Basin Council
  - www.brbc.ab.ca

- The Wonder of Water
  - Information and resources on the International Decade of Freshwater
  - http://www.wonderofwater.ca

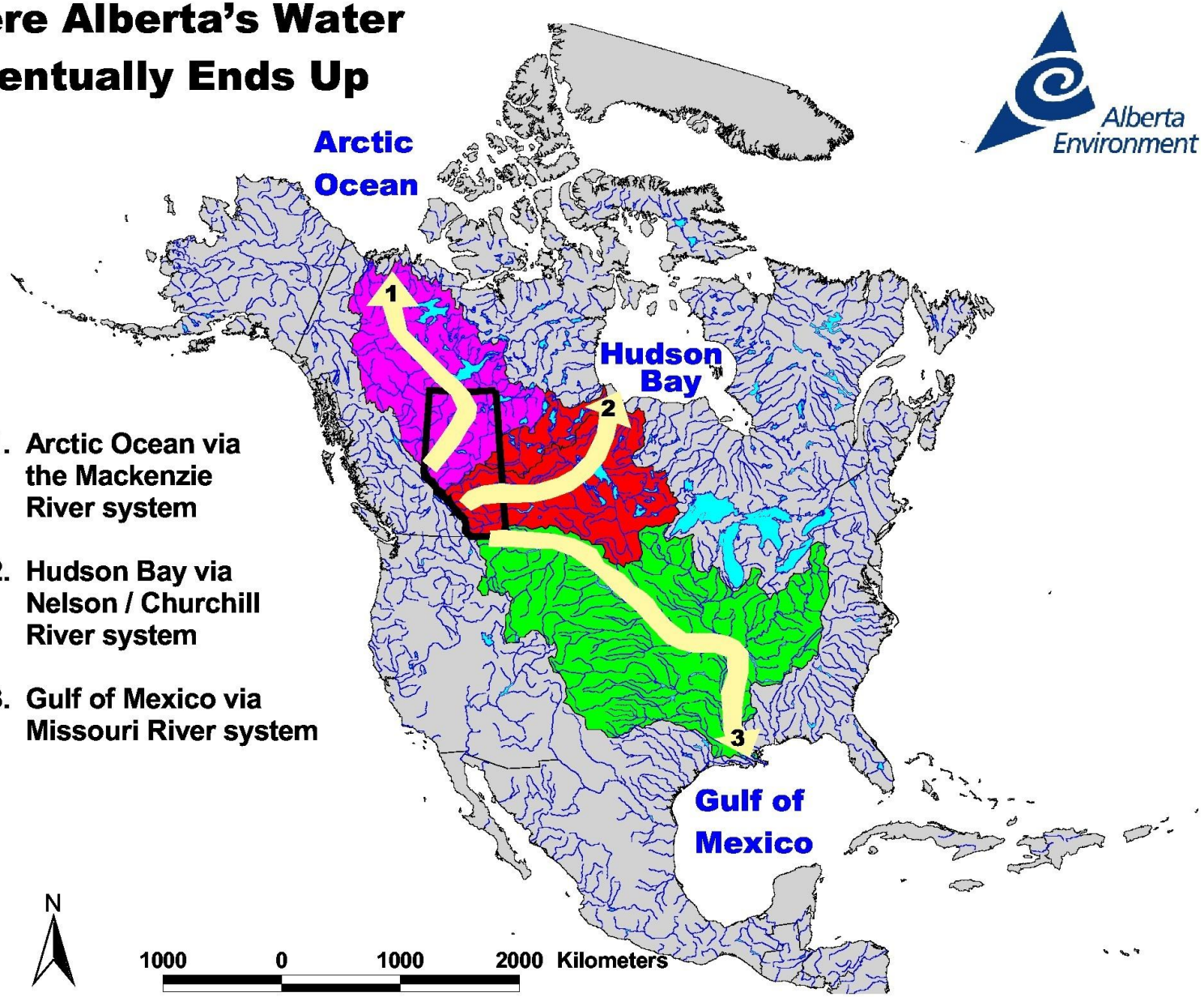
- Canada's Aquatic Environment
  - Provides a wealth of information on Canada's lakes, rivers, wetlands, and oceans; aquatic research in Canada; and human interactions on aquatic environments
  - http://www.aquatic.uoguelph.ca

8.0
APPENDIX

8.1 Mean Annual Discharge and Where Alberta's Water Ends Up


TO ARCTIC OCEAN
3 630 000 dam3
108 000 000 dam3
532 000 dam3
534 000 dam3
18 900 000 dam3
2 340 000 dam3
46 800 000 dam3
3 190 000 dam3
653 000 dam3
7 160 000 dam3
275 000 dam3
TO HUDSON BAY
1 840 000 dam3
7 440 000 dam3
167 000 dam3
1 664 000 dam3
106 000 dam3
TO GULF OF MEXICO
Petitot R.
Whitesand R.
Buffalo R.
SLAVE R.
Hay R.
River
Fort Chipewyan
Fort Vermilion
Chinchaga R.
Wabasca R.
River
FORT McMURRAY
Clearwater R.
Peace River
Peace
Athabasca
GRANDE PRAIRIE
Wapiti R.
Smoky R.
Little Smoky R.
Beaver R.
Saskatchewan R.
Grande Cache
McLeod R.
Pembina R.
North EDMONTON
Lloydminster
Jasper
Wetaskiwin
Camrose
Battle River
Brazeau R.
RED DEER
Red Deer River
Drumheller
Banff
CALGARY
Bow River
S. Sask. R.
Medicine Hat
Oldman River
LETHBRIDGE
Waterton R.
Belly R.
St. Mary R.
Milk River
Alberta
ENVIRONMENT
MEAN ANNUAL NATURAL RIVER DISCHARGES
(from 1994 Alberta State of the Environment Comprehensive Report)
Total outflow 129 697 000 dam3
Total inflow 73 534 000 dam3
Originating in Alberta 56 163 000 dam3
Inflow and outflow values represent the natural annual volume

Where Alberta's Water Eventually Ends Up



1. Arctic Ocean via the Mackenzie River system
2. Hudson Bay via Nelson / Churchill River system
3. Gulf of Mexico via Missouri River system

Alberta Environment