Essential Question 2

How Does the Lake Winnipeg Watershed Affect Our Ability to Take Care of the Lake?

Essential Question 2: How does the Lake Winnipeg watershed affect our ability to take care of the lake?

Introduction

Although students looked at watersheds in Grade 8, the topic was not context-specific. It only provided an introduction to the topic of watershed, and it provided just a brief opportunity to explore the terminology used to understand watersheds. In this section, students will be exposed to an in-depth look at watersheds and use Lake Winnipeg as their context for learning. This section will explore some ways to describe the Lake Winnipeg watershed, such as identifying stream order, looking at how to examine and predict flooding, describing the "topography of a lake" (bathymetry), and exploring the importance of maintaining a shoreline. Finally, students explore the Netley-Libau marsh wetland, as well as the impact wetlands have on a watershed. Students are asked to reflect on how each of these watershed features affects the way we can take care of a lake such as Lake Winnipeg.

Resources to Plan Your Teaching

- Soukhome, J., G. Peaslee, C. Van Faasen, & W. Statema. *Watershed Investigations: 12 Labs for High School Science*. Arlington, VA: National Science Teachers Association, NSTA Press, 2009. This valuable resource provides some excellent investigations. It can be ordered through the NSTA website at <www.nsta.org>. The investigation in Chapter 8, "Flood Frequency Analysis for a River," is included in this document with modifications to suit the Lake Winnipeg context. Other excellent investigations can be found in Chapter 6: Stream Channel Morphology. This is a great investigation on stream channel morphology that uses teacher-created styrofoam stream tables. This investigation looks at pollutants and invasive species.

- Carlesen, William S., Nancy M. Trautmann, & the Environmental Inquiry Team. *Cornell Scientific Inquiry Series Student Edition, Watershed Dynamics.* Arlington, VA: National Science Teachers Association Press, 2004. It can be ordered through the NSTA website at <www.nsta.org>. An overview of the publication and online resources to accompany the book are available at <http://ei.cornell.edu/pubs/wd.asp>. The following is an excellent investigation from *Watershed Dynamics*:

  Protocol 3, Delineating a Watershed: This is a simple activity that helps students map and draw watershed boundaries.

- Andrews, W.A., & S. J. McEwan. *Investigating Aquatic Ecosystems*: Scarborough, ON: Prentice-Hall Inc, 1987. Note: This book is out of print but is a very useful resource for this course.

- Taccogna, G., & K. Munro (eds). *The Streamkeeper's Handbook: À Practical Guide to Stream and Wetland Care*. Vancouver, BC: Salmonid Enhancement Program, Dept. Fisheries and Oceans, 1995. *The Streamkeeper's Handbook* provides comprehensive information on watershed ecology, decree, and provides stream and wetland modules. Available online at <www.pskf.ca/publications/download.html>
- *Globe Program-Hydrology Chapter*
  The GLOBE Program offers students an electronic environment to report and share collected data. The GLOBE Program provides educators with sets of protocols for various subject areas, including hydrology. Available online at <www.globe.gov/r>.

Lesson: Stream Order

Specific Learning Outcomes

- **SLO C7:** Evaluate the relevance, reliability, and adequacy of data, and the methods used to collect data. Include: discrepancies in data, sources of systemic error, precision versus accuracy.
- **SLO C8:** Interpret patterns and trends in data, and infer and explain relationships. *Examples: line of best fit, regression equations, statistical analysis, modes of representation (visual, numerical, graphical, symbolical)…*
- **SLO C9:** Analyze data or observations in order to draw conclusions consistent with the available results of an investigation, and identify the implications of these results. *Examples: cause and effect relationships, alternative explanations, support for or rejections of a hypothesis or prediction statement…*
- **SLO C10:** Identify new questions or problems that arise from an investigation.

Introduction

The stream order lesson helps students understand the complexity of the Lake Winnipeg issue by examining the sources of inflow into the lake. To this point, students have looked at the characteristics of the Lake Winnipeg watershed and delineated their local watershed. In this lesson, they will select a source of inflow to the lake and examine all the contributing water sources. This will help students reflect on the possible sources of nutrient influx to the lake, and on the challenges water stewards face in identifying specific areas for large nutrient loading.

Objectives

Students will interpret maps to determine major headwaters and subsequent stream order and flow direction for an area in the Lake Winnipeg watershed.

Teacher Background

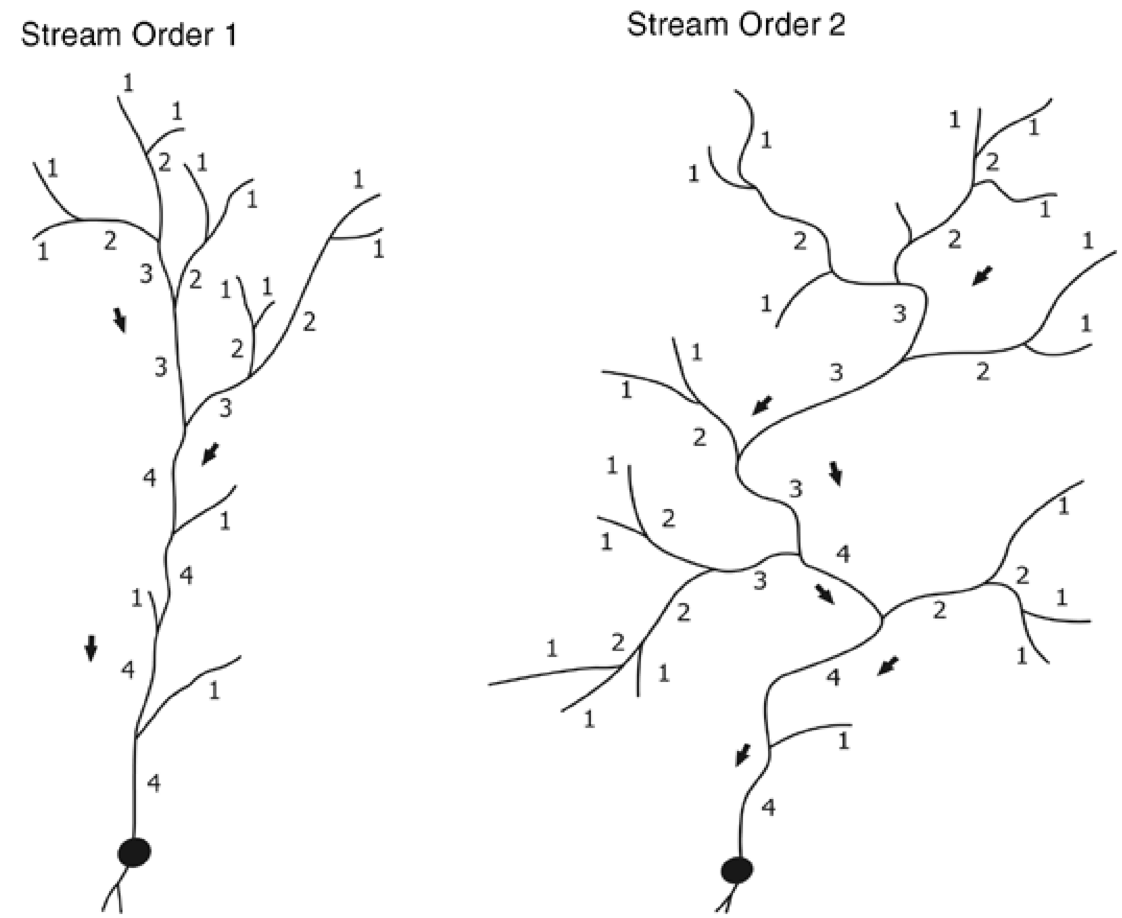
Stream order is a classification system that orders streams and rivers from smallest to largest. The stream order system was designed by Horton, and in the 1950s the classification system was improved upon by Arthur Newell Strahler to classify waterways by size.

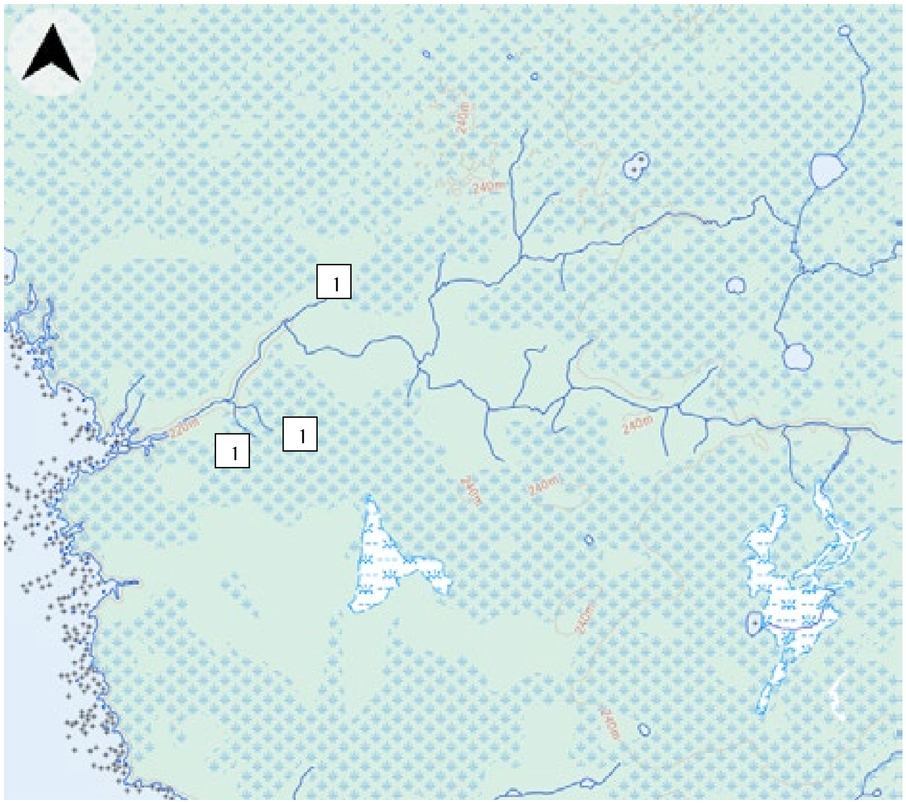
Small streams that have no tributaries are classified as first-order streams. Second-order streams are streams that unite two first-order steams. When two second-order streams come together, they form a third-order stream. However, if a first-order stream joins a second-order stream, the stream remains a second-order stream. **When one stream meets another stream of the same order, this is when the stream increases by an order.** For example, a third-order stream combining with a third-order stream would result in a fourth-order stream.

As streams increase in order, so do their velocity, width, depth, and the amount of water they discharge. Stream size is a result of the topography and geology of a region.

The stream classification system is important to scientists studying streams, as it can help to locate the best areas in which to collect data. Based on stream size, scientists can also delineate the types of aquatic organisms expected, which is part of the river continuum concept developed by Robin L. Vannote (1980).

STREAM ORDER EXAMPLE





Source: *Atlas of Canada*. Reproduced from <http://atlas.nrcan.gc.ca/site/english/maps/topo/map> under the terms for non-commercial reproduction as cited at <www.nrcan.gc.ca/important-notices>. (Stream order added.)

Resources to Plan Your Teaching

- *Maps of Canadian drainage basins, watersheds, physical components of watersheds, human components of watersheds, and current water levels*
  http://atlas.nrcan.gc.ca/site/english/maps/environment/hydrology
- *Manitoba Land Initiative*
  This resource is free to those who register with a user name and password. All maps are listed by the categories of Administrative Boundaries, Base Maps, Cadastral, Digital Elevation Models, Digital Imagery, Environment, Forest Inventory, Geographical Names, Geology Mapping, Hydrography, Land Use/Cover Maps, Municipal Maps, Provincial Highways and PTHs, Quarter Section Grids, Soil Classification, Spatial Referencing, Topographic Maps, and Town and Village Plans.
- *Provincial Park Maps*
  www.gov.mb.ca/conservation/parks/park_maps/index.html
- *Protected Areas Initiative Maps*
  www.gov.mb.ca/conservation/pai/pai_material.html

- *Legislative Library Virtual Reference Desk: Map Links*
  www.gov.mb.ca/chc/leg-lib/vrd/maps.html
- *Introductory Stream Order Resources*
  The US Environmental Protection Agency has a great website called *Watershed Academy Web*. It covers a variety of topics on watershed management. The section that is important for this lesson is called "Stream Corridor Structure." The section "A Longitudinal View along a Stream Corridor" also provides information on stream order and patterns.
  www.epa.gov/watertrain/stream/

The Three A's

Activate: Show students a map of Manitoba that includes all the rivers and streams contributing to Lake Winnipeg. Ask students to come up with ideas on how we could determine how much water each of these rivers and streams contributes to Lake Winnipeg, and why this information may be important.

Acquire and Apply: Have students look at a map of Manitoba or a map that shows a sub-basin to see whether they can spot any geometric patterns in the rivers and streams. Have students identify the major rivers that feed into Lake Winnipeg. They are the following:

- Red River
- Winnipeg River
- Dauphin River
- Fisher River
- Saskatchewan River

Have students use the topographic maps on the *Atlas of Canada* site to select an area in the Lake Winnipeg basin, remove all data that is not pertinent to stream order from the topographic map, and then identify the stream order for the rivers on the map. Ask students: "Where are the large rivers located?" "Do these rivers have lots of 'arms'?" "If so, where do these occur?" "Can you tell which way the river is flowing?" Have students record their observations and discuss.

> **NOTE:**
>
> You could also order a free road map of Manitoba from Manitoba Tourism, and cut the map into segments based on drainage basins. Have students determine the stream order for the selected basin.

Assessment

Assessment *for* Learning: Provide students feedback on their participation in discussion and their ability to identify stream order in one of the rivers in the Lake Winnipeg watershed.

Assessment *of* Learning: Evaluate the completed stream order worksheet.

Student Handout: Stream Order Questions

1. As stream order increases, what happens to the width of the stream?

2. As stream order increases, what happens to the slope of the stream?

3. As stream order increases, what happens to the drainage area of the stream?

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4. Looking at the contour lines, what do you think the terrain looks like?

5. How does stream order help us understand the complexity of reducing nutrients into Lake Winnipeg?

Stream Order Questions Answer Key

1. As stream order increases, what happens to the width of the stream?

   As stream order increases, so will the size and width of the stream.

2. As stream order increases, what happens to the slope of the stream?

   As stream order increases, the slope of the stream decreases.

3. As stream order increases, what happens to the drainage area of the stream?

   As stream order increases, the drainage area of the stream increases.

4. Looking at the contour lines, what do you think the terrain looks like?

   The answer to this question will vary depending on the map you are using. Generally, the terrain is going to be fairly flat, visible by a large distance between the contour lines.

5. How does stream order help us understand the complexity of reducing nutrients into Lake Winnipeg?

   Looking at the major rivers that flow into Lake Winnipeg and their tributaries helps identify the possible sources of nutrients to the lake. By looking at stream order, you can see how some rivers may contribute more nutrients. These rivers may not flow through dense agricultural areas, but their tributaries do. Larger streams will contribute a greater amount of nutrients; rivers with many different levels of streams would be more difficult to control for nutrient loading.

Lesson: Inflow to Lake Winnipeg and Flood Forecasting

Specific Learning Outcomes

- **SLO C3:** Design and conduct an investigation to answer a specific scientific question. *Examples: materials necessary, independent/dependent variables, controls, testable hypothesis or prediction, methodology, safety considerations, appropriate sampling procedures…*
- **SLO C6:** Estimate and measure accurately using Système International (SI) and other required standard units. Include: SI conversions, introversion of units, significant figures.
- **SLO C8:** Interpret patterns and trends in data, and infer and explain relationships. *Examples: line of best fit, regression equations, statistical analysis, modes of representation (visual, numerical, graphical, symbolical)…*
- **SLO C9:** Analyze data or observations in order to draw conclusions consistent with the available results of an investigation, and identify the implications of these results. *Examples: cause and effect relationships, alternative explanations, support for or rejections of a hypothesis or prediction statement…*
- **SLO C11:** Synthesize information obtained from a variety of sources.
- **SLO C12:** Evaluate information obtained to determine its usefulness for one's needs. *Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias…*

Introduction

Students have been exposed to watershed characteristics and stream order and now are introduced to a new watershed dynamic: flooding. The issue of flooding is important when studying Lake Winnipeg because it is in a watershed that is greatly affected by flooding. Understanding flooding and how to predict flooding is important when trying to prevent the influx of nutrients into a river and lake system. In this lesson, students will learn how to use water data to predict floods in the Lake Winnipeg watershed.

Objectives

Predict the recurrence intervals and percent chance of various flows for a river.

Teacher Background

There are many rivers that feed into the Lake Winnipeg watershed, and each of these rivers experiences periods of high and low levels. Floods are a source of nutrient influx into the Lake Winnipeg watershed because the rivers that flow into the lake are often bordered by agricultural land. When a flood occurs, a greater amount of nutrients are brought into the lake, which affects the lake ecosystem. It is helpful to know how often the rivers that flow into

Lake Winnipeg flood, and to have some way of forecasting when the next flood may occur in order to take some proactive measures. The following activity uses data from Canada's Water Survey to create graphs and predict the flood frequency of a river system. A sample river is provided and can be used as a model, but students can examine any river that is monitored by the Water Survey and in the watershed.

This lesson is a modified version of the "Flood Frequency Analysis of a River" activity found in the resource by Soukhome, et al., cited below.

Some terms used in the lesson include the following:

Recurrence Interval of a Flood: A recurrence interval of a flood is an estimate of the average time between past flood occurrences. For example, a 10-year flood, a 100-year flood, and the Flood of the Century.

Annual Exceedance Probability: The annual exceedance probability is a measure of the likelihood of a flood reaching or exceeding a certain magnitude. For example, a 10 percent flood has a 10 percent chance of occurring or being exceeded at a location in any year.

Resources to Plan Your Teaching

- Environment Canada's Water Survey website: www.wsc.ec.gc.ca/products/main_e.cfm?cname=products_e.cfm
- Soukhome, J., G. Peaslee, C. Van Faasen, & W. Statema. *Watershed Dynamics: 12 Labs for High School Science*. Arlington, VA: NSTA Press, 2009.

The Three A's

Activate: Show students a map of the Lake Winnipeg basin. Ask students from what major rivers the bulk of incoming water in Lake Winnipeg originates.

Answer:

- Red River
- Winnipeg River
- Dauphin River
- Fisher River
- Saskatchewan River

Acquire and Apply: Explain to students the two terms *recurrence interval* and *annual exceedance probability*. Explain to them that by looking at previous water data, we can get a clearer understanding of the fluctuations in water levels and use them to predict large flood events.

Probing Questions

1. Using the flood frequency chart, estimate the discharge of 10-year, 25-year, and 100-year floods. Read the years off the x-axis, and find the discharge that corresponds on the y-axis.
2. What was the highest peak stream flow for the river studies, and what year did it occur? What are the probability and the recurrence interval of this discharge?
3. Look at the peak discharge of the Red River at Emerson over the years. Has the peak discharge increased or decreased? Give a reason why or why not.
4. Explain why major flood events can benefit us in understanding how to care for Lake Winnipeg.

Assessment

Assessment *for* Learning: Using a checklist, provide students with feedback on their computer skills and their ability to work with electronic databases.

Checklist for Database Management

The student

- ❑ enters or downloads data into a spreadsheet
- ❑ manipulates data using a formula
- ❑ creates a graph using a data management program
- ❑ adds headings to the graph

Assessment *of* Learning: Assess the answers to the questions at the end of the lesson.

Notes

How to Obtain the Data Set from Water Survey of Canada:

1. Go to the Water Survey of Canada website at <www.wsc.ec.gc.ca/staflo/index_e.cfm>. This website address will bring you to the stream flow statistics site.

2. Type in the river for which you would like data. There may be several monitoring stations that come up with your search (e.g., if you type *Red River,* you will get 27 different stations). Select one of these stations by marking it with a checkmark and clicking on *Obtain report.* The report will give you information about the maximum and minimum flow of the river, and a historical set of data on peak flow. The historical data is what you want for your graph.

3. Cut and paste the historical data into *Excel* or another database program.

4. Insert a column in between the year and peak flow columns to calculate recurrence interval data. Calculate the recurrence interval (T) using the formula $T=(n+1)/m$, where m is the rank number and n is the total number of years in the data set.

5. Insert a column to the right of the peak flow column for the annual exceedance probability (AEP). Calculate the AEP by taking the inverse of the recurrence interval using the formula AEP = $m / (n + 1)$. Put the formula into the spreadsheet.

6. Make a semi-logarithmic graph of peak stream flow versus recurrence interval. (In *Excel,* this is done by selecting *Insert Chart* and selecting a scatterplot chart type.) Highlight the recurrence interval and peak flow columns for the data set. Select *Next* and then type in the names for the x-axis and y-axis. Select *Next* and *Finish*. Right-click on the x-axis, select *Scale*, and check *Logarithmic*. To add a best-fit line, right-click on the graphed data and select *Add Trendline,* and then select *Logarithmic*.

Student Handout: Flood Forecasting

Select a river in the Lake Winnipeg watershed that you would like to investigate.

How to obtain the data set from Water Survey of Canada:

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2. Type in the river for which you would like data. There may be several monitoring stations that come up with your search (e.g., if you type *Red River,* you will get 27 different stations). Select one of these stations by marking it with a checkmark and clicking on *Obtain report.* The report will give you information about the maximum and minimum flow of the river, and a historical set of data on peak flow. The historical data is what you want for your graph.

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5. Insert a column to the right of the peak flow column for the annual exceedance probability (AEP). Calculate the AEP by taking the inverse of the recurrence interval using the formula AEP = $m/(n + 1)$. Put the formula into the spreadsheet

6. Make a semi-logarithmic graph of peak stream flow versus recurrence interval. (In *Excel,* this is done by selecting *Insert Chart* and selecting a scatter-plot chart type.) Highlight the recurrence interval and peak flow columns for the data set. Select *Next* and then type in the names for the x-axis and y-axis. Select *Next* and *Finish*. Right-click on the x-axis, select *Scale*, and check *Logarithmic*. To add a best-fit line, right-click on the graphed data and select *Add Trendline,* and then select *Logarithmic*.

Probing Questions

1. Using the flood frequency chart (Figure 1 on page 82), estimate the discharge of 10-year, 25-year, and 100-year floods. Read the years off the x-axis, and find the discharge that corresponds on the y-axis.

2. What was the highest peak stream flow for the river studies, and what year did it occur? What are the probability and the recurrence interval of this discharge?

3. Look at the peak discharge of the Red River at Emerson over the years (Figure 2 on page 82). Has the peak discharge increased or decreased? Give a reason why or why not.

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4. Explain why major flood events can benefit us in understanding how to care for Lake Winnipeg.

Sample Data Set

Year	FEB	MAR	APR	Peak	JUN	JUL	AUG	SEP	OCT	NOV	DEC	PERIOD
1913	14.1	8.55	11.3	378	90.1	49.8	37.9	27.1	34.3	33.6	37.9	24.6
1914	15.3	13.9	22.7	117	91.9	125	98.7	39.1	37.8	39	39.5	28.5
1915	25.3	24.6	28.1	144	106	142	372	83.5	50.9	51.5	45.4	32.5
1916	25.4	22.3	26.1	820	588	225	304	145	120	91	79.4	56.5
1917	35.6	29.6	32.3	397	164	73.3	41.7	18.2	13.2	19.3	25.5	16
1918	6.75	6.27	30.3	68.9	51.4	65.1	28.2	20.7	18.9	11.6	19.1	16.3
1919	13.3	12	16.8	219	112	61	221	103	43.4	33	22.6	20.6
1920	23	25.6	82.8	520	119	138	95.1	43.7	32.1	34.3	35.1	28.7
1921	23	22.1	32.3	181	73.9	78.2	50.5	25	23.8	23.7	20.4	18.7
1922	13.2	10.7	56	361	227	95.6	42.3	18.2	16.9	14.2	20.7	10.6
1923	8.65	9.27	11.2	287	219	57	69.6	23.1	17	17.3	17.3	11.3
1924	6.38	6.71	8.67	80.2	87.5	38	25.4	11.5	10.1	20	15	5.91
1925	3.99	5.25	30.4	137	46.7	299	96.3	14.7	15.8	26.5	25.2	18.6
1926	13.2	14.7	47.8	150	38	72.9	59.7	13.8	12.8	27.6	23.1	14
1927	11.8	11.1	113	380	415	247	93.8	45.1	42	38.8	31.3	22.8
1928	17.1	19	55.3	215	80.7	93.4	128	54.4	68.6	51.6	45.3	30.9
1929	29.7	25	167	192	75.1	48	21.4	12	9.14	12.8	13.6	8.33
1930	5.67	5.07	81.9	247	146	54.5	30.1	10.3	6.1	6.56	7.57	6.68
1931	4.98	5.65	27.2	95.9	25	18.7	10.1	4.46	2.29	2.4	6.25	5.3
1932	4.71	3.91	38.6	221	54.5	16.6	7.25	1.77	1.13	1.3	3.44	2.52
1933	1.53	1.4	24.4	165	43.8	29	7.18	2.07	1.3	1.38	2.4	1.31
1934	1.54	0.923	13.9	61.7	18.8	5.55	3.91	1.32	0.673	1.33	2.19	1.18
1935	0.399	0.763	21.2	94.2	33.2	12.4	30.6	14.6	7.61	3.31	2.2	1.68
1936	1.61	1.53	1.65	191	73.7	16.5	3.41	2.24	1.89	0.811	0.672	0.947
1937	0.201	0.034	0.064	57.4	82.3	30	23.5	44.3	23.2	11.4	7.95	2.05
1938	1.51	2.15	41.2	36.3	138	73.1	24.2	6.16	5.48	5.66	5.87	5.15
1939	5.6	7.23	7.35	105	33.8	18.6	16	5.31	6.52	10.1	10.9	7.87
1940	3.83	4.2	6.35	144	63.2	29.8	10.1	7.23	5.29	6.68	11.1	8.38
1941	8.84	9.86	10.2	387	88.3	150	40.4	21.4	52.5	86.8	39.3	25.1
1942	16	18	55.5	468	254	119	51.2	35.5	88.1	46.5	32.1	21.9
1943	22.6	19.8	34.2	655	206	352	184	73.2	51.5	41.7	40.5	26.2
1944	18.8	20.8	21.7	123	107	197	193	170	167	82.3	114	77.3
1945	36.6	38.7	258	571	245	114	61.9	37.1	50.3	55.9	39.6	28
1946	26.8	22.4	162	414	117	62.9	69.1	36	33	47	45.8	33.1
1947	29.2	25.4	29.9	505	338	341	164	57.5	44.5	52.8	46.8	38.1
1948	30.7	23.9	24.1	704	568	109	88.9	47	28.6	19.1	20.2	15.8
1949	12.7	12.9	16.9	417	144	172	96.7	93.1	51.1	32.4	39.3	30.2
1950	23.4	21.2	26.2	751	2060	631	286	108	74.1	94.3	58.7	61.2
1951	58.1	51	64.8	556	308	140	77.6	41.4	55.4	44.8	40	54
1952	50.6	54.2	56.9	486	217	108	166	64.7	39	26.8	24.5	19.8
1953	17.3	17.3	38.6	115	89.2	252	157	65.2	37.3	25.3	27.2	26.5

(continued)

Year	FEB	MAR	APR	Peak	JUN	JUL	AUG	SEP	OCT	NOV	DEC	PERIOD
1954	23.6	24	38.9	165	120	121	83.8	40.7	25.4	23.1	23.5	20.3
1955	20.7	18.5	18.5	300	91.4	121	77.6	51.4	26.7	26.7	17.1	12.7
1956	12.2	12.9	14.4	361	412	154	116	32.7	57.4	19.3	37.5	17.4
1957	12.5	11.6	40.9	167	128	119	263	81.6	181	107	95.8	48.5
1958	39.2	37	52.9	94.3	46.7	40.3	115	28.5	13	12.2	13.8	10.1
1959	9.86	9.7	17.9	171	59.8	77.8	58.5	21.5	15.4	16	16.6	17.8
1960	17.5	15.8	13.4	468	147	88.1	64.6	16.7	17.5	9.68	15.7	10.7
1961	9.76	8.29	48.7	73.4	68	31.5	12.5	7.77	7.55	16.8	11.6	7.43
1962	5.6	5.66	6.37	418	340	720	455	204	95.3	69.4	61.6	46.3
1963	35.3	30.4	42.9	222	106	212	86.4	37.2	34.3	39.5	27.4	19.7
1964	21.7	21.4	19.4	240	155	269	103	37.4	19	48.2	39.3	25.8
1965	25.8	25.2	26.9	708	526	284	160	66.4	59.3	125	94.5	78.2
1966	53.2	46.7	165	1300	573	198	135	107	81.9	56.4	60.4	51.6
1967	46.2	41.8	59.1	720	566	185	102	42.1	26.9	25.7	27.3	19.1
1968	13.9	14	40.6	138	70.9	171	194	93.2	84.8	62.4	60.7	55.4
1969	48	45.7	61.5	825	777	183	114	58.8	46.9	59	57.8	44.5
1970	41.2	40	44.7	544	650	480	156	45.7	39.6	36.3	47.2	31
1971	29.3	28.3	55.5	410	155	92.1	82.4	41.4	42.4	114	146	75.9
1972	55.6	45.2	193	677	308	180	70.3	70.2	58.3	51.9	48.4	32.7
1973	31.5	31.6	165	76.7	48.6	37.1	17.6	22.1	72.7	118	74	58.9
1974	48.5	47.8	57.3	548	840	305	106	92.4	58.1	54.9	60.6	38.5
1975	37.2	40	46.7	367	773	196	794	133	72.5	68.8	68.2	44.3
1976	43.1	46.5	79.1	494	125	67.3	44	31.7	20.6	11	8.89	5.01
1977	5.11	5.38	11.3	59.5	34	24.4	18	7.38	15.1	40.3	31.9	36.6
1978	34.7	28	49.2	1020	290	110	102	49	31.7	27.1	24.7	18.3
1979	15.9	16.4	21.9	698	1390	229	182	95.5	63.1	49.6	55.4	43.3
1980	38.3	37.7	41.9	287	68	46.2	24.4	13.7	23.7	15.6	18.6	10.2
1981	8.27	8.4	41.6	51.2	39.3	44.8	77.5	43	51.2	68	55.6	31.3
1982	32.6	29.9	49.7	625	251	121	116	69.8	38.1	124	71.8	54.8
1983	45.7	39	265	355	114	144	184	74.3	79.9	63.1	60.5	48.8
1984	39.1	36.1	82	542	120	328	96.3	43.3	27.2	52.4	52.7	40.9
1985	34.2	32.7	183	209	258	225	209	208	166	128	79.5	59.4
1986	57	51.3	172	760	631	209	142	80.6	82.6	102	59	56.2
1987	51.1	45.7	195	637	120	104	88	74	31.4	23.5	23.7	19.9
1988	13.3	14.4	63.9	188	40.9	30.8	13.1	7.98	9.41	9.55	8.77	7.27
1989	7.45	10.8	11.2	608	195	76.2	32.2	12.2	29.6	12.8	10.6	7.31
1990	4.88	7.39	32.5	100	47.1	61.7	33.7	13.2	10.4	8.46	8.91	6.57
1991	5.02	6.95	16.8	59.4	79.9	65.3	112	36.7	44.7	24.4	25.2	16.2
1992	15.6	15.7	200	287	128	71.1	84.3	36.1	74.1	34.4	24.1	26.4
1993	24.3	28.8	37.1	425	117	131	298	765	283	120	78.7	57.8
1994	42.3	42.6	153	498	214	173	377	125	135	170	143	83.4
1995	55.4	50.4	434	950	405	171	236	107	77	97.9	91.1	64.7

(continued)

Year	FEB	MAR	APR	Peak	JUN	JUL	AUG	SEP	OCT	NOV	DEC	PERIOD
1996	53.5	50.9	107	819	1170	421	134	87.8	50.6	53.5	67.4	61.9
1997	55.9	59.1	65.3	1360	1550	306	535	122	83.6	111	97	77.5
1998	54.5	69.3	580	545	408	294	460	99.1	66.6	103	95.5	100
1999	63	59.2	212	1270	610	420	272	177	325	134	109	90.6
2000	61.7	49.1	239	173	125	329	461	99.6	96.9	76.7	390	115
2001	76	69.6	106	1120	861	325	202	257	77.6	65.5	107	80.3
2002	58.9	48.1	55.6	153	162	647	704	180	232	69.8	57.4	39.2
2003	33.2	27.1	70.9	139	158	162	208	47.5	19.7	18.7	17.9	15.2
2004	15.3	12.4	105	799	289	512	156	63.1	115	135	348	96.1
2005	60.8	61.4	88.9	663	249	700	787	232	172	124	111	104
2006	100	85.4	114	1490	567	159	59.8	44.4	41.7	43.3	32.9	26.2
2007	24.2	19.3	174	657	290	607	371	64	36.6	48.1	49.8	31.9
2008	30.8	24.8	30	244	169	274	103	78.4	88.1	260	313	82.1

Sample Table Created from Data Set

Rank	Year	Recurrence Interval	Peak Discharge	AEP
56	2008	1.732142857	244	0.577319588
20	2007	4.85	657	0.206185567
1	2006	97	1490	0.010309278
19	2005	5.105263158	663	0.195876289
11	2004	8.818181818	799	0.113402062
76	2003	1.276315789	139	0.783505155
72	2002	1.347222222	153	0.742268041
5	2001	19.4	1120	0.051546392
67	2000	1.447761194	173	0.690721649
4	1999	24.25	1270	0.041237113
28	1998	3.464285714	545	0.288659794
2	1997	48.5	1360	0.020618557
10	1996	9.7	819	0.103092784
7	1995	13.85714286	950	0.072164948
33	1994	2.939393939	498	0.340206186
38	1993	2.552631579	425	0.391752577
54	1992	1.796296296	287	0.556701031
93	1991	1.043010753	59.4	0.958762887
83	1990	1.168674699	100	0.855670103
24	1989	4.041666667	608	0.24742268
65	1988	1.492307692	188	0.670103093
22	1987	4.409090909	637	0.226804124

(continued)

Rank	Year	Recurrence Interval	Peak Discharge	AEP
12	1986	8.083333333	760	0.12371134
62	1985	1.564516129	209	0.639175258
30	1984	3.233333333	542	0.309278351
50	1983	1.94	355	0.515463918
23	1982	4.217391304	625	0.237113402
95	1981	1.021052632	51.2	0.979381443
53	1980	1.830188679	287	0.546391753
17	1979	5.705882353	698	0.175257732
6	1978	16.16666667	1020	0.06185567
92	1977	1.054347826	59.5	0.948453608
34	1976	2.852941176	494	0.350515464
47	1975	2.063829787	367	0.484536082
27	1974	3.592592593	548	0.278350515
88	1973	1.102272727	76.7	0.907216495
18	1972	5.388888889	677	0.18556701
42	1971	2.30952381	410	0.432989691
29	1970	3.344827586	544	0.298969072
8	1969	12.125	825	0.082474227
77	1968	1.25974026	138	0.793814433
14	1967	6.928571429	720	0.144329897
3	1966	32.33333333	1300	0.030927835
15	1965	6.466666667	708	0.154639175
57	1964	1.701754386	240	0.587628866
58	1963	1.672413793	222	0.597938144
39	1962	2.487179487	418	0.402061856
89	1961	1.08988764	73.4	0.917525773
37	1960	2.621621622	468	0.381443299
68	1959	1.426470588	171	0.701030928
85	1958	1.141176471	94.3	0.87628866
69	1957	1.405797101	167	0.711340206
49	1956	1.979591837	361	0.505154639
51	1955	1.901960784	300	0.525773196
71	1954	1.366197183	165	0.731958763
81	1953	1.197530864	115	0.835051546
35	1952	2.771428571	486	0.360824742
26	1951	3.730769231	556	0.268041237
13	1950	7.461538462	751	0.134020619
40	1949	2.425	417	0.412371134
16	1948	6.0625	704	0.164948454

(continued)

Rank	Year	Recurrence Interval	Peak Discharge	AEP
32	1947	3.03125	505	0.329896907
41	1946	2.365853659	414	0.422680412
25	1945	3.88	571	0.257731959
79	1944	1.227848101	123	0.81443299
21	1943	4.619047619	655	0.216494845
36	1942	2.694444444	468	0.371134021
44	1941	2.204545455	387	0.453608247
75	1940	1.293333333	144	0.773195876
82	1939	1.182926829	105	0.845360825
96	1938	1.010416667	36.3	0.989690722
94	1937	1.031914894	57.4	0.969072165
64	1936	1.515625	191	0.659793814
86	1935	1.127906977	94.2	0.886597938
91	1934	1.065934066	61.7	0.93814433
70	1933	1.385714286	165	0.721649485
59	1932	1.644067797	221	0.608247423
84	1931	1.154761905	95.9	0.865979381
55	1930	1.763636364	247	0.567010309
63	1929	1.53968254	192	0.649484536
61	1928	1.590163934	215	0.628865979
45	1927	2.155555556	380	0.463917526
73	1926	1.328767123	150	0.75257732
78	1925	1.243589744	137	0.804123711
87	1924	1.114942529	80.2	0.896907216
52	1923	1.865384615	287	0.536082474
48	1922	2.020833333	361	0.494845361
66	1921	1.46969697	181	0.680412371
31	1920	3.129032258	520	0.319587629
60	1919	1.616666667	219	0.618556701
90	1918	1.077777778	68.9	0.927835052
43	1917	2.255813953	397	0.443298969
9	1916	10.77777778	820	0.092783505
74	1915	1.310810811	144	0.762886598
80	1914	1.2125	117	0.824742268
46	1913	2.108695652	378	0.474226804

Figure 1

Red River at Emerson Flood Frequency Curve

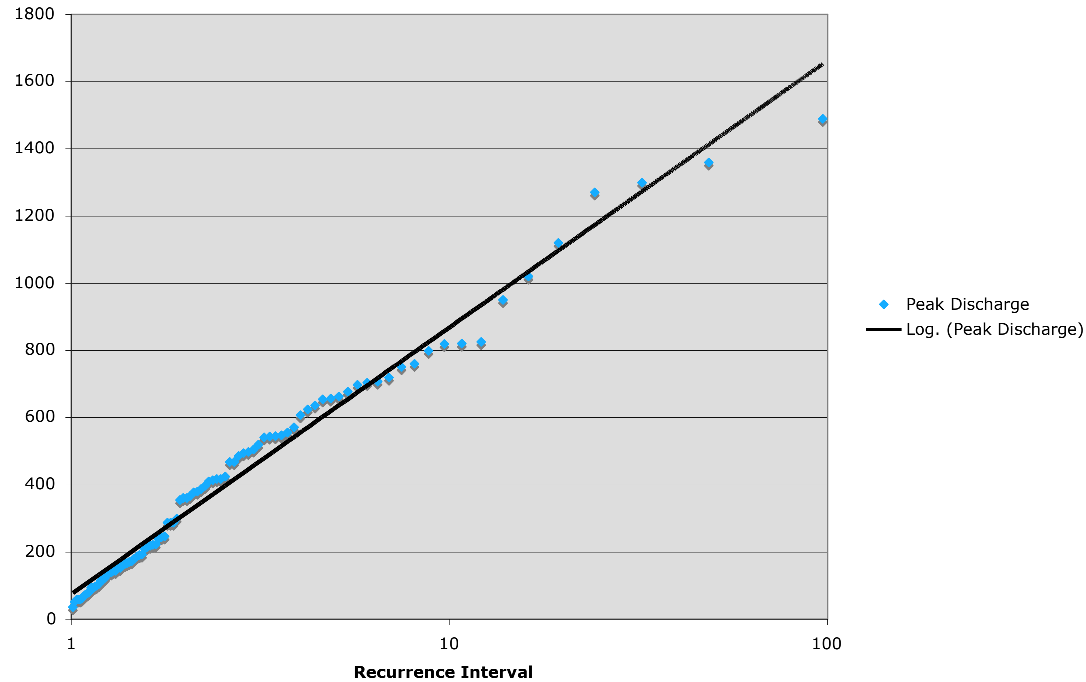
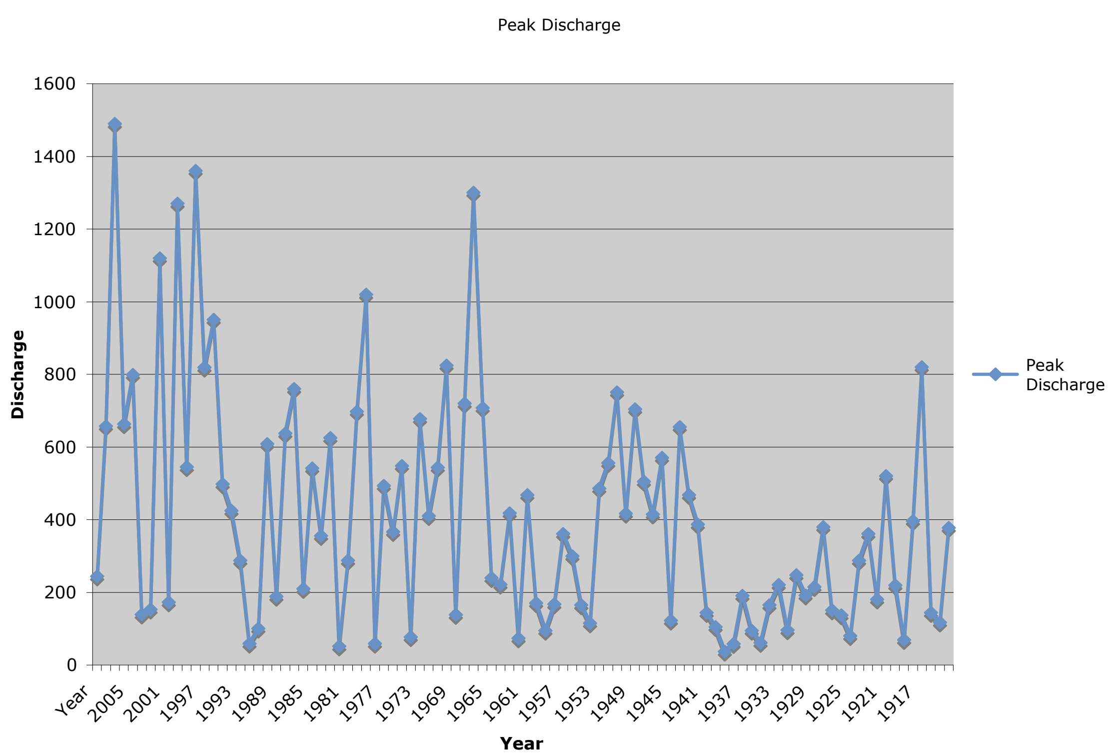


Figure 2

Red River at Emerson Peak Stream Flows



Lesson: Bathymetry of Lake Winnipeg's North and South Basin

Specific Learning Outcomes

- **SLO C6:** Estimate and measure accurately using Système International (SI) and other required standard units. Include: SI conversions, interconversion of units, significant figures.
- **SLO C8:** Interpret patterns and trends in data, and infer and explain relationships. *Examples: line of best fit, regression equations, statistical analysis, modes of representation (visual, numerical, graphical, symbolical)…*

Introduction

One of the characteristics of Lake Winnipeg is that the north and south basins have very different characteristics, and they are joined by a very narrow channel. This means that these areas of the lake are also affected by nutrient influx quite differently. Students have used topographic maps in previous lessons. In this lesson, students examine the characteristics of the north and south basins using bathymetric maps.

Objectives

Using the bathymetric maps of Lake Winnipeg's north and south basins, students will compare basin depths by profiling each basin.

Teacher Background

A topographic map displays Earth's elevational changes. A bathymetric map is similar to a topographic map in that it displays the changes in elevation for the floor of a body of water. Bathymetric maps use metres above sea level (MASL) as a reference point. A slope or relief is indicated by the distance between contour lines or, in the case of a bathymetric map, the distance between isobaths. For example, isobaths that are close to one another will indicate a steep slope.

There are a few techniques employed when creating a bathymetric map such as a sonar and eco sounder. The maps in this lesson were created in part by sonar transects done on Lake Winnipeg in 1969. They are part of G.J. Brunskill, S.E.M. Elliott, and P. Campbell's 1980 report "Morphometry, Hydrology, and Watershed Data Pertinent to the Limnology of Lake Winnipeg Western."

In this lesson, students will create a cross-section or profile of Lake Winnipeg's north and south basins. A bathymetric profile is a representation of the floor of any body of water between two points. It provides an overview of the changes in the depth within the two points.

A description of the geographical features of Lake Winnipeg's north and south basins can be found on page 8 (paper) or 12 (electronic) of *Restoring the Health of Lake Winnipeg, Technical Annex, Canada's Sixth Great Lake* by Terry Duguid and Norm Brandson. Available online at <http://manitobawildlands.org/water_lakewpg.htm>.

Terminology

Bathymetry: The measurement of changing depth in the bottom of a body of water.

Bathymetric Profile: This displays the changes in elevation for chosen points in a body of water.

Isobath: This is a contour line connecting points of equal depth under water.

Trace Line: This is a line connecting two points, which the bathymetric profile will represent.

The Three A's

Activate: Ask students if they know of ways we can visually represent depth in various regions in a lake. After discussing, provide students with the bathymetric maps of Lake Winnipeg (1 for the north basin and 1 for the south basin).

Acquire: Using the bathymetric maps, have students make observations and record their data on the Lake Winnipeg Bathymetric Worksheet.

Using an overhead, show students what a trace line is, and how to create a profile of the trace line.

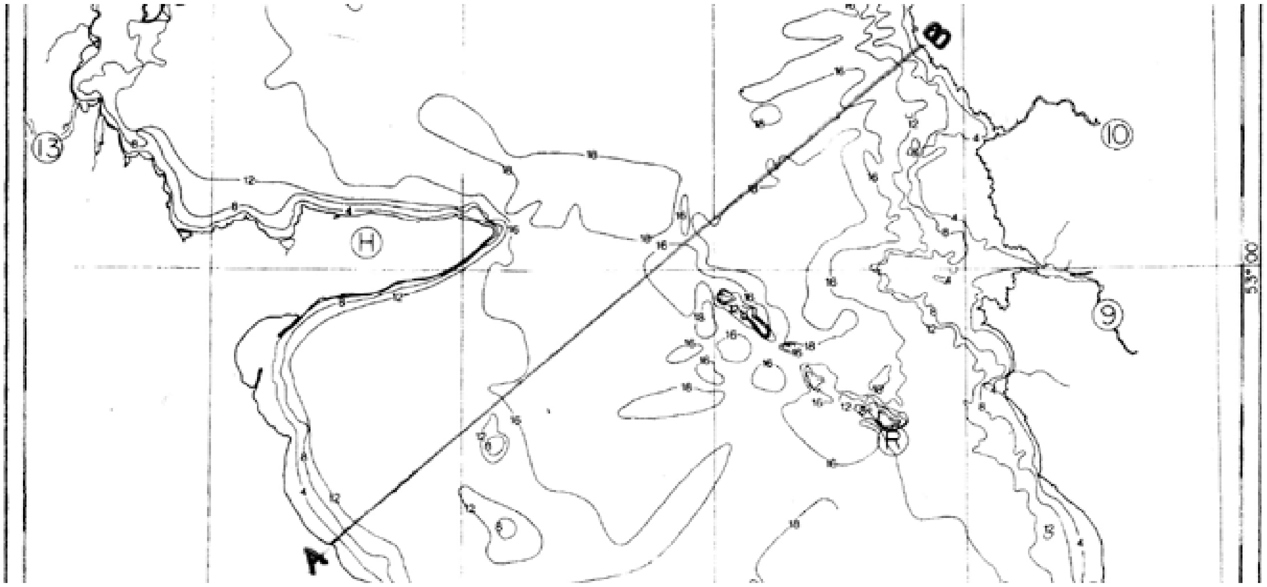
Apply: Have students choose a trace line for each map, and depict the results on graph paper. Let students know that they must include a title and properly label the x- and y-axes. After completing the profile, have students input the data into one graph using *Excel* (see the instructions on how to create a profile in *Excel* below).

Assessment

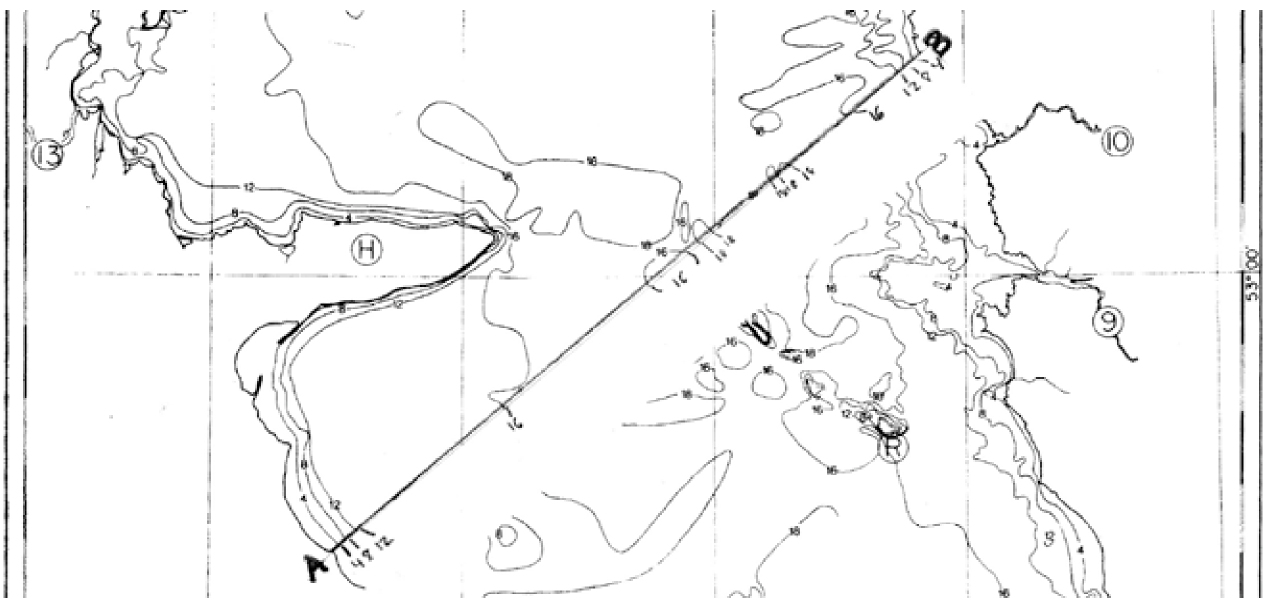
Assessment *for* Learning: Using a checklist, provide students with feedback on their computer skills and their ability to work with electronic databases.

Assessment *of* Learning: Collect student responses to questions, and provide feedback.

Steps to Create a Bathymetric Profile



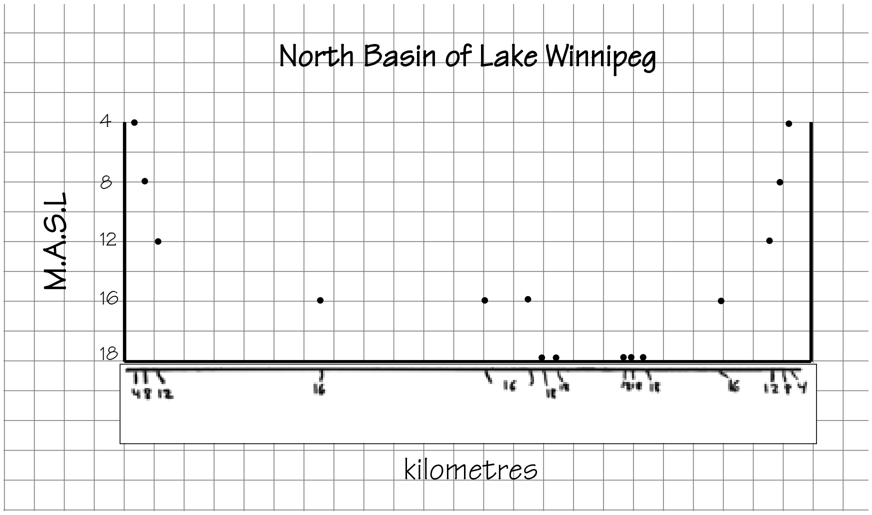
Create a trace line. This trace line should connect two points from shore to shore.



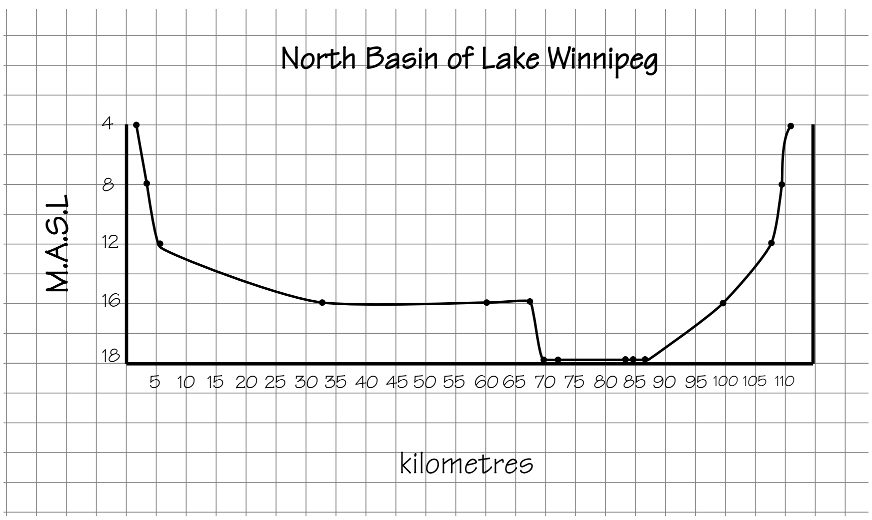
After creating the trace line, cut a piece of paper that stretches across the two points. Using this paper, match and mark off all of the isobaths.

Source: Brunskill, G.J., S.E.M. Elliott, & P. Campbell. *Morphometry, Hydrology, and Watershed Data Pertinent to the Limnology of Lake Winnipeg*. Winnipeg, MB: Minister of Supply and Services Canada, 1980. Available online at <www.dfo-mpo.gc.ca/library/74105.pdf>. Reproduced under the terms for non-commercial reproduction, as cited at <www.dfo-mpo.gc.ca/notices-avis-eng.htm>.

(continued)

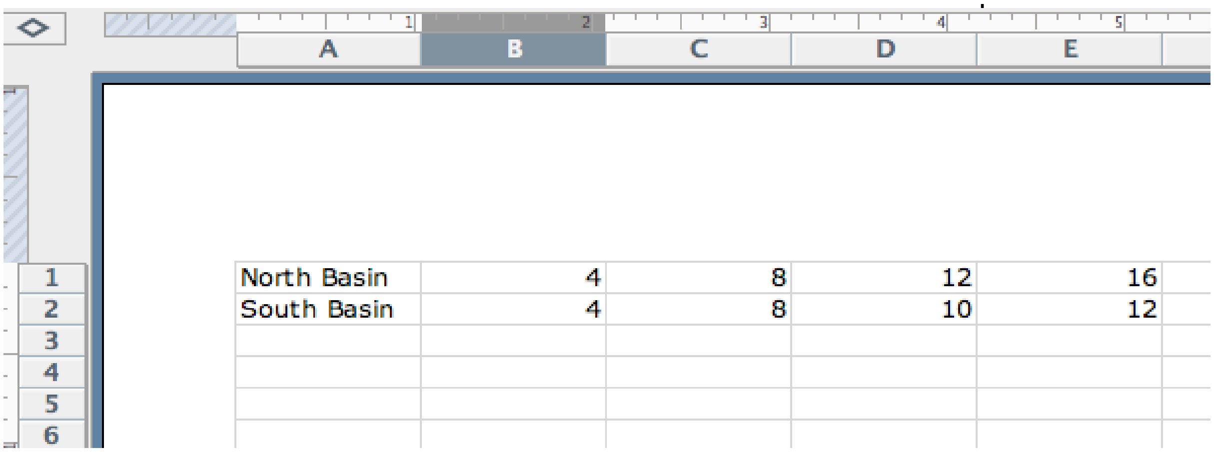


Place the paper that has the isobaths recorded on a piece of graph paper. Mark and label the x- and y-axes. Now graph the isobaths and connect the points. Make sure to title your map, and then you will have a finished profile, as seen below.

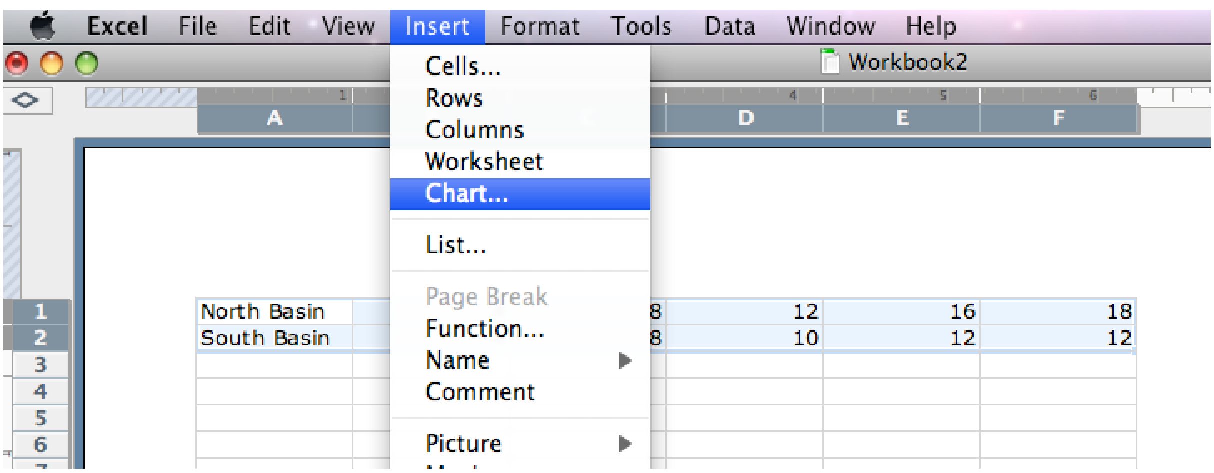


Creating a Profile in Excel

You will need to enter the isobaths for the north and south basins into separate columns.



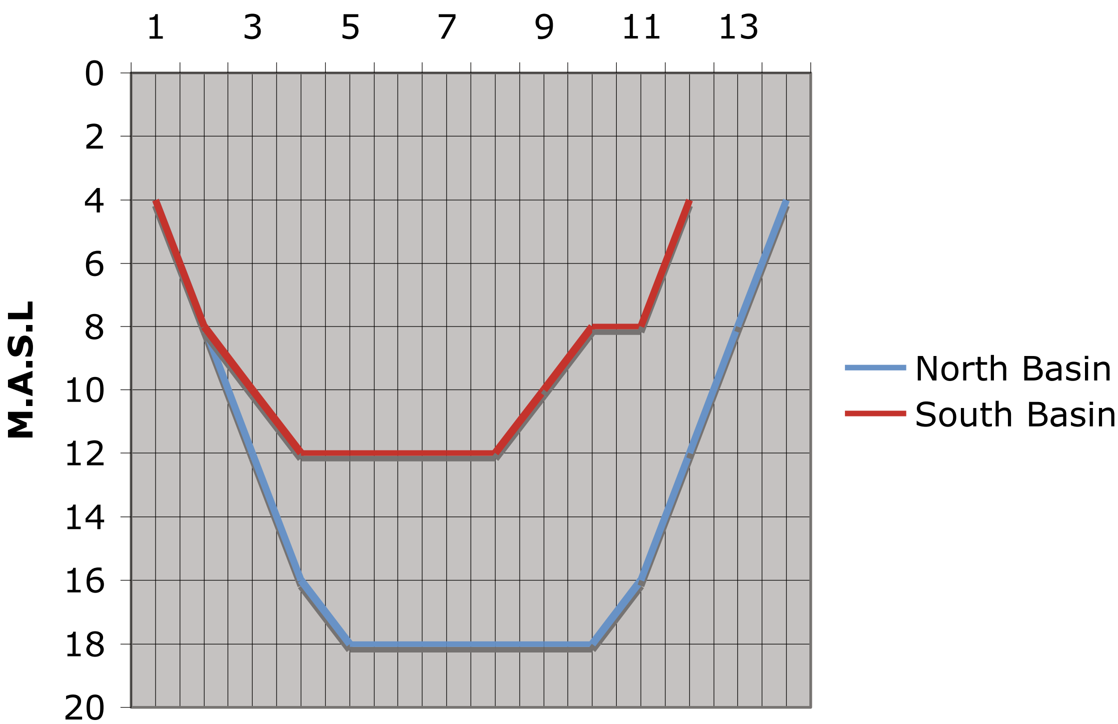
Then highlight all of your data, chose *Chart* under the *Insert* menu. Then choose the most appropriate chart type in which to display your data.



(continued)

An example of a finished profile:

A BATHYMETRIC PROFILE OF LAKE WINNIPEG'S NORTH & SOUTH BASIN



Bathymetric Worksheet 1

Student name:_________________________Date:____________

1. What are some of the unique and or interesting features of the maps on BLM 2-3-1?

2. What are the map scales?

3. What is the isobath (contour) interval?

4. What do the isobath (contour) lines indicate?

5. Is the north basin deeper or shallower than the south basin?

(continued)

6. How does the lake depth change around islands?

____

____

____

____

7. What does the map tell us about the narrows?

____

____

____

____

8. What are the major rivers that enter the north basin?

____

____

____

____

9. What are the major rivers that enter the south basin?

____

____

____

____

10. What distance does your trace line represent for the north and south basins?

____

____

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____

11. How does bathymetry contribute to our understanding of how to care for Lake Winnipeg?

____

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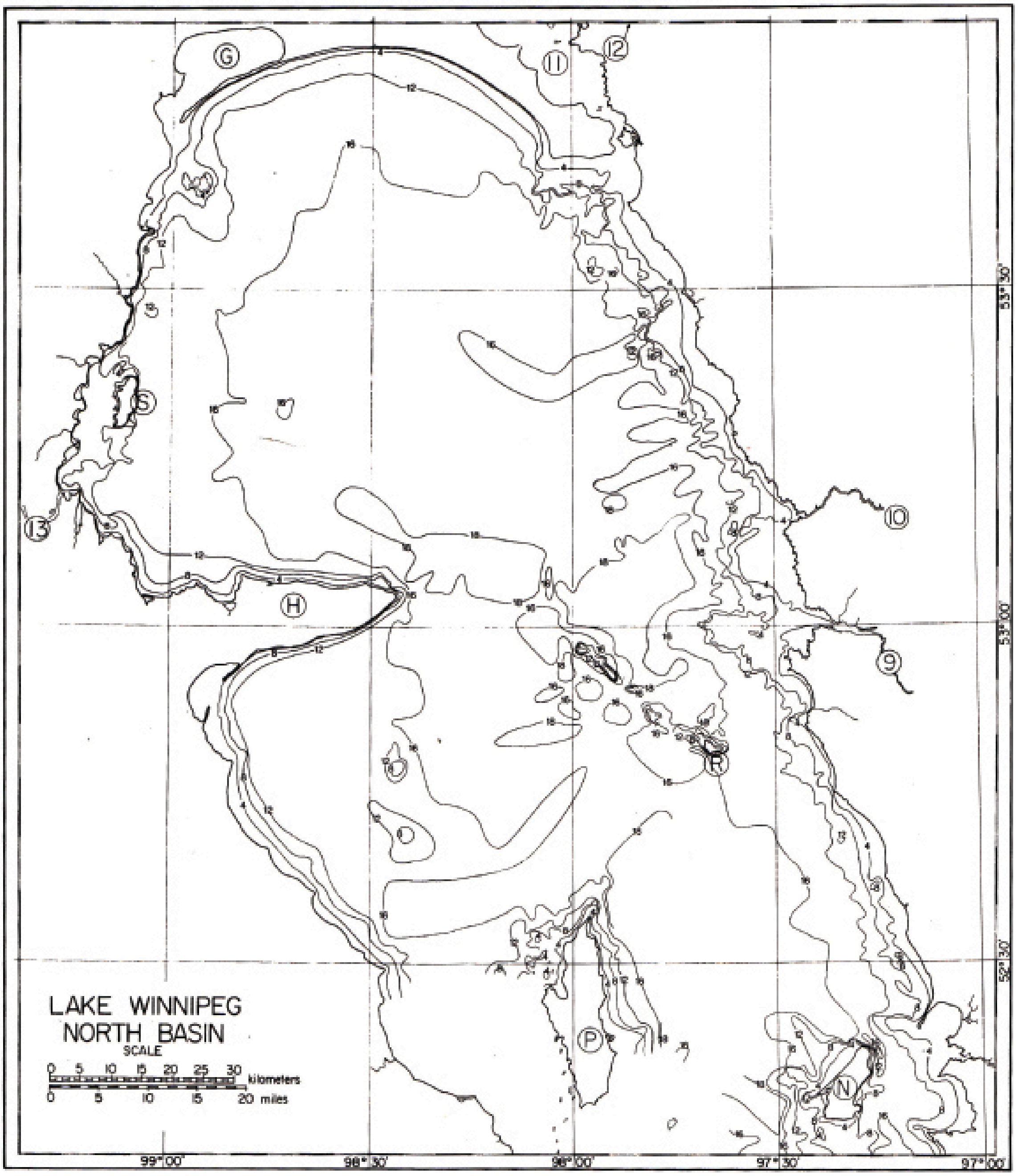
____

(continued)

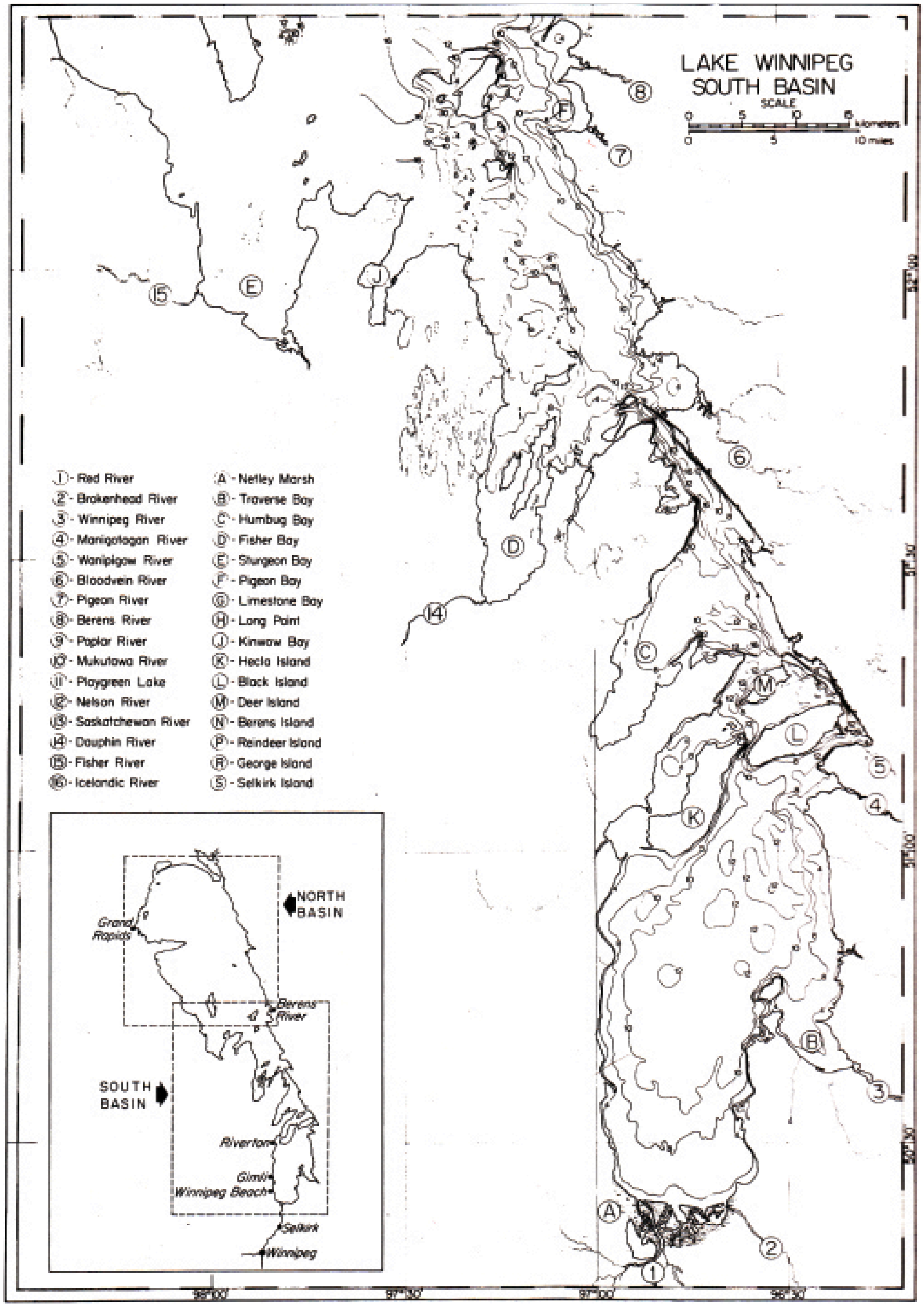
Lake Winnipeg's North Basin



Source: Brunskill, G.J., S.E.M. Elliott, & P. Campbell. *Morphometry, Hydrology, and Watershed Data Pertinent to the Limnology of Lake Winnipeg*. Winnipeg, MB: Minister of Supply and Services Canada, 1980, p. 25. Available online at <www.dfo-mpo.gc.ca/library/74105.pdf>. Reproduced under the terms for non-commercial reproduction, as cited at <www.dfo-mpo.gc.ca/notices-avis-eng.htm>.

(continued)

Lake Winnipeg's South Basin



Source: Brunskill, G.J., S.E.M. Elliott, & P. Campbell. *Morphometry, Hydrology, and Watershed Data Pertinent to the Limnology of Lake Winnipeg*. Winnipeg, MB: Minister of Supply and Services Canada, 1980, p. 26. Available online at <www.dfo-mpo.gc.ca/library/74105.pdf>. Reproduced under the terms for non-commercial reproduction, as cited at <www.dfo-mpo.gc.ca/notices-avis-eng.htm>.

(continued)

Lesson: How to Best Restore Lake Winnipeg from Shoreline Erosion

Specific Learning Outcomes

- **SLO C1:** Identify questions to investigate that arise from practical problems and issues.
- **SLO C3:** Design and conduct an investigation to answer a specific scientific question. *Examples: materials necessary, independent/dependent variables, controls, testable hypothesis or prediction, methodology, safety considerations, appropriate sampling procedures…*
- **SLO C11:** Synthesize information obtained from a variety of sources.
- **SLO C15:** Use bibliographic and electronic research tools to collect information on a selected topic. *Examples: keyword searches, search engine navigation, databases…*

Introduction

The erosion of a shoreline along a lake increases the amount of particulates and rotting vegetation that is released into the water. This decreases the clarity of the lake and inhibits light from penetrating into the water column. Therefore, it is important to reduce shoreline erosion on Lake Winnipeg. Students have previously been exposed to sources of nutrient loading into the lake. Examining shoreline erosion is important to understand nutrient loading.

Objectives

Identify the shoreline features of Lake Winnipeg, and investigate one shoreline management technique.

Teacher Background

There are many ways to try to prevent or stabilize eroded shoreline. "Soft" approaches are more environmentally friendly, as they work with the natural environment. Below is an overview of some "soft" approaches.

Preserve the Natural Shoreline

One of the most effective and easiest ways is to take a "do nothing" approach. It is as simple as not mowing the grass or cutting the trees and shrubs on the shoreline. This allows natural vegetation to grow or become re-established. A naturally vegetated shoreline has many benefits, such as preventing contaminants or excess nutrients from entering the water; preventing erosion caused by rain, wind, wave, and ice action; and supplying food, shade, and cover for fish in the shallow water. If some vegetation must be removed, limit the amount. Try to prune trees and shrubs back instead of removing them.

Shoreline Planting

The establishment of natural vegetation can be accelerated by selectively planting native deep-rooted species. Willow, alder, and red osier dogwood are some common species that have roots that extend deep into the soil, helping to keep the soil and shoreline together. The best time to plant is after the last frost in spring. When damage occurs, natural shoreline plants can re-establish themselves often without your assistance. Repairing damaged retaining walls or harder structures is usually difficult and more expensive.

Bioengineering

The planting of native species may not be sufficient to stop the erosion of a shoreline; in which case, a bioengineering approach may be more appropriate. Bioengineering incorporates plants in combination with natural materials (logs, live stakes, live brush bundles, etc.) into the shoreline stabilization design. It is sometimes referred to as a "living fence."

The advantage of bioengineering a shoreline is that the shoreline looks natural, can provide fish habitat, and allows natural vegetation a chance to root. Providing protection to enable vegetation to root increases the chances of long-term stability of the shoreline, and may prevent the need for hard structures such as rip-rap.

Hard Structures

In certain situations, hard structures are needed. While not as aesthetically pleasing as soft structures and much more expensive, they are useful in situations where soft structures by themselves do not provide enough protection. When hard structures are combined with soft structures, the results may be enhanced. The application of rip-rap is a common example of the use of a hard structure.

Rip-rap

Rip-rap is the use of boulders and rock to reduce erosion caused by wave action. In general, the boulders need to be heavy enough to resist movement by the waves and placed on an appropriate slope. The appropriate slope is generally 1 to 2. This means that for every metre in rise, there needs to be two metres of run toward the lakeshore. The size of the material deposited upon the bank needs to be large enough and sloped appropriately that the waves will "roll-up" the slope rather than crash into the materials. This helps to reduce the erosion force of the waves, and prolongs the stability of the rip-rap.

The use of filter cloth under the rock helps to prevent erosion of the finer particles under the rock. The planting of appropriate vegetation also assists in prolonging the stability of the rip-rap.

If done appropriately, the installation can enhance fish habitat by reducing sediment problems in fish habitat, and can also provide spaces for fish to feed, protected from large predators.

For a brief description of Lake Winnipeg's shoreline and its erosion issues, read pages 12 and 80 (electronic) of *Restoring the Health of Lake Winnipeg, Technical Annex, Canada's Sixth Great Lake* by Terry Duguid and Norm Brandson. Available online at <http://manitobawildlands.org/water_lakewpg.htm>.

Resources to Plan Your Teaching

- Pattimore, John H. *Outdoor Education Activity Program, Lakeshore Environment*. Winnipeg, MB: Manitoba Parks Branch Department of Natural Resources, 1980.

  This resource is very useful for those classrooms located close to a beach or shoreline. Many of the activities specifically look at wave action as a cause of shoreline erosion.

- Baird, W.F., & Associates Coastal Engineers LTD. Stantec Consulting LTD. Shoreline Erosion Advisory Group, Technical Report #5, Shoreline Erosion Study, Shoreline Erosion Advisory Group, September 2005.

- Grosshans, R.E., D.A. Wrubleski, & L.G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, Canada: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.

- Manitoba Natural Resources, & Canada Fisheries and Oceans. *Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat*. Winnipeg, MB: Manitoba Natural Resources, May 1996.

  This resource provides a number of definitions and diagrams that are very useful to understand terms used in erosion prevention and fish habitat enhancement. Available online at <www.gov.mb.ca/waterstewardship/fisheries/habitat/sguide.pdf>.

- Manitoba Education. *Lake Winnipeg Water Stewardship A Resource for Grade 8 Science.* Winnipeg, MB: Manitoba Education, 2010.

  This resource provides a starting point for an understanding of sustainability issues for Lake Winnipeg. It has a very extensive bibliography. Additionally, the 57 pages of blackline masters use photographs and/or diagrams to illustrate concepts, such as natural means of erosion prevention, rip-rap, bulkheads, and breakwaters/groynes and gabions. Available online at <www.edu.gov.mb.ca/k12/esd/water/index.html>.

The Three A’s

Activate: Have students discuss areas along a waterway that have been eroded and what they look like.

Acquire and Apply: Show a picture of the shores for the east and west side of Lake Winnipeg and for the south basin. Discuss the physical differences, such as geological, soil, and vegetation differences. Show an extremely eroded shoreline of Lake Winnipeg. Pinpoint the areas that are very eroded, and discuss reasons and possible solutions to this problem.

The Problem

Lake Winnipeg is extremely long, and the predominant winds from the north can result in extremely large waves along the southern shores—a phenomenon known as a **setup** or **wind tide**. Setups greater than 1 m above normal lake levels have been recorded along many of Lake Winnipeg’s southern beaches. Wind tides have caused considerable storm damage and shoreline erosion. The highest setups occur in the fall, when the northerly winds are strongest. If the winds die down suddenly, the waters rush northward, and then withdraw back in a process called **seiching**. The extreme energy of this wave action has resulted in tremendous damage to the shoreline, including the removal of vegetation, extensive loss of soil, and even property damage. You have been asked to consult on the best restoration solution for a cottage property on the northeast side of Lake Winnipeg.

This is the shoreline of the property:

Property Description

- Northeast shore of Lake Winnipeg
- 400 X 250ft
- Soil: Clay-loam
- pH: neutral
- Grade: gentle slope

You must provide the property owner with a project description, which includes the following:

- A description of the technique you have chosen
- The techniques benefits (provide supporting research)
- Estimated cost
- Ecological benefits, if any
- Any issues surrounding the use of your technique

Assessment

Assessment *for* Learning: Have students peer edit each other's reports prior to submitting them.

Assessment *of* Learning: Research reports on the shoreline erosion problem are collected and assessed using the rating scale provided.

Report Rating Scale	
1–poor 2–fair 3–satisfactory 4–very good 5–excellent	
Description of the technique is clearly identified and described	1 2 3 4 5
The benefits of the technique are identified using literature	1 2 3 4 5
The costs are identified and reasonably justified	1 2 3 4 5
The ecological benefits are clearly discussed	1 2 3 4 5
The issues associated with the technique are clearly discussed	1 2 3 4 5

Notes

Lesson: Changes in the Netley-Libau Marsh

Specific Learning Outcomes

- **SLO C6:** Estimate and measure accurately using Système International (SI) and other required standard units. Include: SI conversions, interconversion of units, significant figures.
- **SLO C9:** Analyze data or observations in order to draw conclusions consistent with the available results of an investigation, and identify the implications of these results. *Examples: cause and effect relationships, alternative explanations, support for or rejections of a hypothesis or prediction statement…*
- **SLO C10:** Identify new questions or problems that arise from an investigation.

Objectives

Students will

- become familiar with the geography of the Netley-Libau marsh
- determine dominant vegetative types/plants found in the Netley-Libau marsh
- calculate changes in vegetative cover and decline (1979–2001) in the Netley-Libau marsh
- identify some of the probable causes associated with changes in the Netley-Libau marsh
- compare calculated results with the emerging plant community study (*see* Grosshans, R.E., D.A. Wrubleski, & L.G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001*. Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, Winnipeg, MB: University of Manitoba, 2004. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.)

Teacher Background

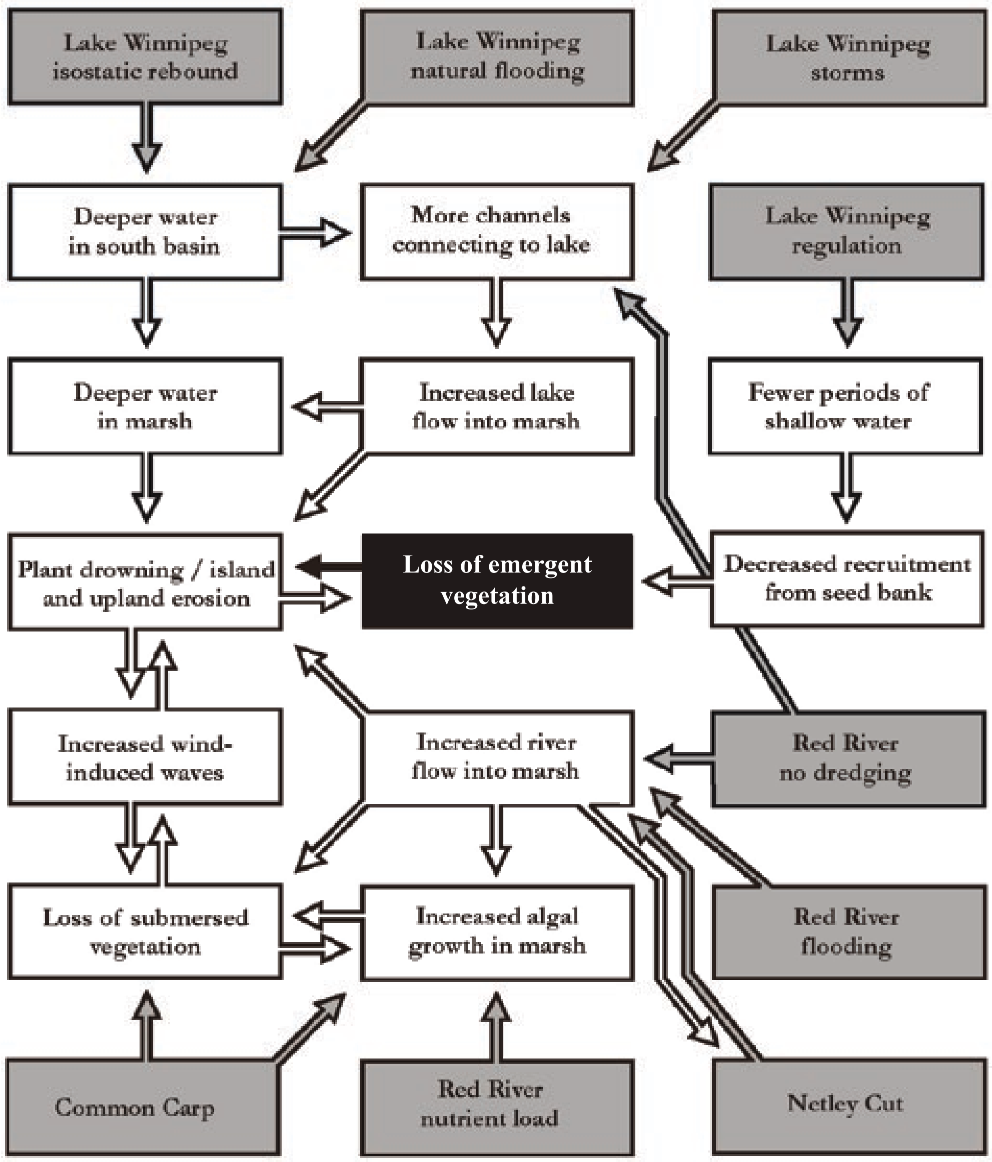
Marshes are the most productive type of wetlands and play an enormous role in the health of the planet and, in this case, Lake Winnipeg.

With the inception of agriculture, wetlands have excessively decreased throughout North America. Protecting existing wetlands and restoration efforts throughout the larger Lake Winnipeg basin are all crucial steps needed for a cleaner healthier Lake Winnipeg.

The Netley-Libau marsh is a remnant of glacial Lake Agassiz and one of the largest freshwater coastal wetlands in Canada. It is of significant importance as it lies at the mouth of the Lake Winnipeg's south basin where the Red River (contributor of 80 percent of nutrients entering Lake Winnipeg) enters the lake. Barrier Island, a narrow sand ridge, separates Lake Winnipeg from the marsh. The marsh is divided into two areas: east of the Red River and west of the Brokenhead River is the Libau side (Folsters Lake, Parisian Lake, Lower Devils Lake, Upper Devils Lake, Morrisson Lake, Oak Point Lake, Ramsay Lake, Hughes Lake, Passwa Lake, McKay Lake and Pruden Bay); west of the Red River is the Netley side (Goldeye Lake, Netley Lake, Cochrane Lake and Hardmans Lake).

In Canada, the marsh is designated as an important bird area (see <www.ibacanada.ca>), with over 100 species of birds. However, the Netley-Libau Marsh can hardly be called a healthy marsh, as it has undergone major geographical and vegetative changes over the last 40 years, reducing the marsh's productivity in reducing nutrients entering Lake Winnipeg.

In their study, Grosshans etal. demonstrate how changes in the marsh have led to a corresponding loss of emergent vegetation over the last 20 years.



Source: Grosshans, R. E., D. A. Wrubleski, & L. G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, Canada: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. p. 23. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.

In September 2009, the provincial and federal government dedicated $1 million (see <http://news.gov.mb.ca/news/index.html?archive=2009-09-01&item=6794>) to help Manitoba waterways though the protection and restoration of wetlands. Funding is allotted to policy development and conservation easements. Of the $1 million, $300,000 is earmarked for the restoration of the Netley-Libau and Delta marshes.

Resources to Plan Your Teaching

Netley-Libau Marsh

- Netley Marsh Waterfowl Foundation
  www.lssd.ca/netleymarsh/
- Nature Manitoba: Netley-Libau Marsh Brochure
  www.manitobanature.ca/birder/iba.htm

General Wetland Resources

Ducks Unlimited Canada

- Teacher curriculum and corresponding student handbooks on wetland education
  www.ducks.ca/resource/teachers/lesson_plans/high.html
- The Wetland Centre of Excellence program offers support to high school students in wetland education through enrichment and action-based programs.
  www.ducks.ca/resource/teachers/classroom/index.html

Oak Hammock Marsh

- General Information
  www.oakhammockmarsh.ca/
- Program information for in class and on-site wetland education, as well as descriptions of teaching kits available for lending.
  www.oakhammockmarsh.ca/programs/educators/resources/index.html

The Three A's

Activate: Teacher-led class discussion on what is a wetland.

Suggested questions:

- What is a wetland?
- What is the role of a wetland? (Compare to a kidney)
- What are the types of wetlands?
- What are the parameters for designating each type?
- Where in Manitoba would you find these types?
- What is the natural succession of a wetland?
- How do the soil, plant, and animal communities differ in each type?
- What are some of the plants you would expect to find in a wetland?
- What are emergent plants?

Acquire and Apply: Introduce students to the study (see Grosshans, R.E., D.A. Wrubleski, & L.G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, MB: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.) Have students read the summary page of this publication, and underline the reasons the researchers identify as the main contributing factors to changes in the Netley-Libau marsh. After reading the summary and classroom discussion, have students fill out the Changes at Netley-Libau Marsh Worksheet.

Using the 2001 map and associated vegetative zone key, have students determine the dominant plant species, the distribution of vegetation, and the approximate total area for each type, and record their findings on a transparent graph sheet. For students to become familiar with the region, have them label the names of the streams, rivers, and lakes for the Netley-Libau marsh.

Once students are familiar with the geography, have them make rough calculations for the apparent changes in the region by comparing the 1979 and 2001 maps. These maps can be printed on transparencies so that students can overlay the images for more dramatic results. Using the transparent grid paper and corresponding legend, students can make rough estimates on changes for indicators of their choices (see BLM 2-5-5).

Changes in Netley-Libau Marsh, 1979–2001:			
Indictor	1979	2001	Decline/Increase in %
Open Water	35%	51%	Decrease of:
Hard and soft-stem bulrush (schoenoplectus spp.)	13%	1%	Decrease of:

Table data reproduced from Grosshans, R.E., D.A. Wrubleski, & L.G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, MB: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. p. 13. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.

Have students write a summary paragraph describing how they think the changes to the Netley-Libau area will affect Lake Winnipeg.

Assessment

Assessment *for* Learning: Collect responses to questions and provide feedback, go through the answers to the questions as a class, or have students peer-review answers to questions.

Assessment *of* Learning: Have students submit completed maps and summary paragraphs, and assess responses according to clarity and use of the literature to justify any claims.

Summary

We used aerial photography combined with field observations to develop a detailed aquatic vegetation map for Netley-Libau Marsh in south-central Manitoba. This report describes the creation of a new geographically accurate map (georeferenced for use in a Geographic Information System - GIS), based on aerial photos taken in 2001, and construction of a detailed vegetation map for evaluating the changing state of Netley-Libau Marsh. This provides a basis for comparison with a 1979 vegetation map enabling a quantitative assessment of changes in the marsh over a 22-year period.

Comparisons between 1979 and 2001 reveal several significant changes in Netley-Libau Marsh. Loss of emergent vegetation and the erosion of separating uplands between adjoining water bodies has been extensive, resulting in the amalgamation and expansion of many marsh bays and ponds. Currently, half of the entire marsh (13,125 ha, 51%) is open water, compared to 35% (8,884 ha) in 1979. Cattail (*Typha* spp.) continues to be the dominant emergent plant in the marsh, showing little change between surveys. However, hard- and soft-stem bulrush (*Schoenoplectus* spp.) have declined ten-fold in abundance, from 3,247 ha (13%) to 317 ha (1%). The mixed river bulrush and sedge community, along with the wet meadow communities, have also declined in abundance. Plant communities at drier sites, however, have remained relatively unchanged.

Reasons for the observed changes in the marsh are not well known or understood, but change is not a recent development. Maps of the marsh from the 1920s to the present show a pattern of increasing open water area and loss of upland and island habitats. These changes are likely related to a number of factors, but the influence of Lake Winnipeg and the Red River are likely the most important.

Lake Winnipeg dictates water levels within Netley-Libau Marsh. Since the droughts of the 1930s and 1940s, water levels on Lake Winnipeg and the marsh have included few intervening dry periods. Without extended dry periods, to periodically allow the germination of new emergent vegetation, there has been a slow but consistent loss of emergent vegetation in the marsh. As this vegetation is lost, the protection that it provides for the soft sediments that make up island and upland habitats is also lost, and these habitats are slowly being washed away. The current management of Lake Winnipeg for hydroelectric production works to prevent low water levels on the lake and the marsh.

The Red River passes through Netley-Libau Marsh and it has likely contributed to some of the observed changes. High flow events on the river result in the erosion and collapse of weak points in the levees that border the river and other channels. Netley Cut, which was originally dredged in 1913, has been gradually eroded to a point where it now carries a substantial portion of the Red River flow into Netley Lake. The end of dredging on the Red River in 1999 has also likely contributed to the alteration of Red River flows through the marsh. High nutrient loads in the Red River, along with the arrival of common carp, may be contributing to enhanced algal growth and loss of submersed vegetation within the marsh. Loss of submersed vegetation results in the destabilization of bottom sediments and increased wind-induced wave action, which further helps erode island and upland habitats.

Without an ability to manage marsh water levels independently of Lake Winnipeg, only a prolonged drought will help restore the emergent plant communities of Netley-Libau Marsh. Dry conditions experienced in 2003 helped re-establish some of the emergent plant communities of the marsh, but the recent return to wet conditions may make this reversal short-lived.

We conclude that Netley-Libau Marsh resembles a shallow turbid lake more than a healthy coastal wetland. Any benefits to Lake Winnipeg which the marsh could provide as wildlife and fisheries habitat, and in removing and storing nutrients that would otherwise enrich the lake, have probably been degraded or lost.

Source: Grosshans, R. E., D. A. Wrubleski, & L. G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, Canada: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.

Student Handout: Changes at Netley-Libau Marsh Worksheet

1. Why are wetlands often considered to be the kidneys of Earth?

2. What techniques did the researchers of this study use to develop their hypothesis?

3. How does/can the Netley-Libau marsh contribute to a healthier Lake Winnipeg?

4. How has Netley-Libau marsh changed over the past 30 years?

(continued)

5. What are some of the factors contributing to the loss of emergent vegetation in the Netley-Libau marsh?

6. What can the changes in plant types teach us about Netley-Libau marsh? What do you think are the larger ecosystem implications of these changes in plant species?

7. What steps do you think government, scientists, and citizens should be taking to help deal with the unhealthiness plaguing the Netley-Libau marsh?

Sample Answers to the Changes at Netley Libau Marsh Worksheet:

1. Why are wetlands often considered to be the kidneys of Earth?

   Wetlands function as a natural filter, removing nutrients and contaminants and acting to prevent flood waters from soaking up runoff.

2. What techniques did the researchers of this study use to develop their hypothesis?

   Field studies combined with aerial photography.

3. How does/can the Netley-Libau marsh contribute to a healthier Lake Winnipeg?

   The Netley-Libau marsh provides an enormous service to the over 100 species of birds that breed and call the marsh home, helping to maintain the biodiversity of the region. The marsh acts as a filter for nutrients entering the lake. This is especially important as the Red River enters the lake here and is contributing over 80 percent of its nutrients, even though it only contributes 20 percent of the flow.

4. How has Netley-Libau marsh changed over the past 30 years?

   There has been significant erosion, increased open water, and changes in particular plant species.

5. What are some of the factors contributing to the loss of emergent vegetation in the Netley-Libau marsh?

   There are a number of reasons why the plant species at the Netley-Libau marsh have changed.

   - **Isostatic rebound, resulting in increased water levels in the south basin**
   - **Manitoba Hydro's Lake Winnipeg Regulation: the water is regulated within a four foot level; however, this has resulted in fewer low water cycles**
   - **Invasive species: carp (which destroy plants by pulling them out, resulting in vegetation loss and thus more turbidity and a decrease in water quality) and purple loosestrife (which chokes out endemic plant species)**
   - **Increased Flooding: Flooding along the Red River has increased, which results in more water entering the marsh (higher water levels/ less dry periods) and erosion, resulting in plant loss**

(continued)

6. What can the changes in plant types teach us about Netley-Libau marsh? What do you think are the larger ecosystem implications of these changes in plant species?
   - **Decreased genetic diversity among plant species**
   - **Increased nutrients entering the lake, resulting in eutrophication**
   - **Increased contaminants/toxins entering the lake, affecting the animal and fish populations/food chains and habitat health**
7. What steps do you think government, scientists, and citizens should be taking to help deal with the unhealthiness plaguing the Netley-Libau marsh?
   - **Increased funding for scientists/researchers into problems and plausible solutions for the Netley-Libau marsh**
   - **Increased public education on the benefits of wetlands**
   - **Increased public education**

Student Table

Changes in the Netley-Libau Marsh, 1979–2001			
Indictor	1979	2001	Decline/Increase in %

Source: Grosshans, R. E., D. A. Wrubleski, & L. G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, Canada: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. p. 7. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.

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Table 1. Interpretation key of vegetation signatures for colour infrared aerial photographs modified from Grosshans *et al.* (2005).

Vegetation Zone	Colour	Texture	Location/Comments
Open water	Blue/black	Smooth, rippled in some areas from wave action	Very dark and distinct
	White to green/white		Shallow water or reflections off water will often appear white to green/white
Sand (beaches, exposed)	White, usually quite bright	Smooth, flat appearance	Mostly devoid of vegetation, so appears bright white
Mudflat	White to blue/white, to greeny black	Navy/greeny black and white patches	Found bordering water, disturbed areas
Bulrush *(Schoenoplectus)*	Dark deep red, brick red to dark navy, to browny red	Blurry appearance and patchy; open water patches due to sparseness	Found in water, along water's edge, or deeper water areas; sparse patches appear as shadowed areas on open water
Cattail *(Typha)*	Medium to deep red	Smooth to grainy; pock marked appearance from open water, and inter-mixed patches of deadfall	Found mainly bordering open water to low water-filled areas; also borders whitetop, giant reed grass as well as sedges/rushes
Giant reed grass *(Phragmites)*	Pink to dark pink	Grainy to lumpy, shadows along edges gives depth to these patches appearing almost three-dimensional on photos, and much higher than surrounding areas with stereoscopes	Found bordering water, upland areas, cattail and whitetop; often a thin ring of cattail between giant reeds and water; also borders sedges and rushes, grasses, grasses with forbs.
Sedges and rushes *(Carex, Eleocharis, Juncus)*	Dark red to dark pink	Appears flatter on photos, does not have three-dimensional appearance as cattail does; with stereoscope appears flat	Usually occurs around/near whitetop areas, as well as cattail and fen grasses; also borders reed canary grass, grasses, and forbs; found in wet, waterlogged areas
Whitetop *(Scolochloa festucacea)*	White, to pale/light pink to green (shallow water)	Fine mottled appearance, white or green patches from open water areas	Often found bordering cattail, wet meadows, and giant reed patches; also borders fen grasses, sedges/rushes, and grasses

Source: Grosshans, R. E., D. A. Wrubleski, & L. G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, Canada: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. p. 9–11. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.

(continued)

Table 1. Continued

Willows	Burgundy, maroon to dark red	Lumpy, gravelly, dotted patches	Uplands, dikes, along river channels; borders and surrounds sedge patches
Reed canary grass	Dark pink to browny red, a darker pink than Whitetop	Grainy lumpy appearance, to smooth	Usually occurs between whitetop and grasses/forb areas; also occurs next to cattail and giant reed; is a wet meadow grass, found where soils are moist to wet
Salt flat species *(Hordeum, Puccinellia)*	Cream, brown to browny red	Flat smooth texture, low flat appearance with use of stereoscopes	Occurs all over, but usually associated with mudflats, white-top, sedges/rushes and fen grasses; occurs in grass/forb areas as well
Grasses (> 75% cover)	Light pink, light brown, to cream	Flat smooth texture, often more light pink to cream and not as patchy as Grasses/forbs	Low prairie areas found bordering wet meadows of whitetop, reed canary grass and sedges/rushes; slightly moister areas than grass/forbs
Grasses and forbs (< 50% forb cover)	Pink, light brown, gray and cream	Flat smooth texture, often patchy and mixed light pink, brown, gray to cream	Low prairie areas near wet meadows of whitetop, fen grasses and sedges/rushes; transition to upland areas of prairie grasses; presence of forbs cause mixed patches of browns and grays
Prairie (> 50% forb cover)	Medium pink to dark pink	Smooth to grainy	Upland areas, borders grasses and forbs, woodlands, cultivated fields and hayfields
Hayed grasses and forbs	White light green, to light pink	Lined, pinstriped, and patchy; can see haybales as large dots if already cut; hayed, fallen dead grasses and forbs appear white to light green	Low prairie areas which are hayed; often intermixed with grasses/forbs, as well as prairie; borders wet meadows and low prairie areas alike; many sedge/rush meadows are hayed as well
Grazed (prairie and shrubs)	Dark pink, cream, brown and gray	Smooth texture, patchy mixed dark pink, cream, brown and gray	Occur near and intermixed with woodlands while bordering cultivated areas and hayfields; patchy cream colors and browns from grazing

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Tabled 1. Continued

Cultivated	White, yellow, brown, gray, beige, yellow-green, red to pink; quite variable	Lined, pinstriped, patchy or smooth to grainy; can see rows of crops	Human disturbance is very distinct; found upland on higher ground
Trees (trees and shrubs)	Burgundy, maroon to dark red	Lumpy, patchy, gravelly with shadows; cauliflower appearance; tall, three-dimensional appearance with stereoscope	High upland areas, borders next to prairie, grass/forbs, and cultivated fields; willow bluffs appear as smaller, lumpy, dotted areas surrounding small cattail and fen grass marshes
Disturbed	Browny-gray, gray to white; light green	Smooth to grainy appearance; freshly disturbed bare soils and deadfall appear white to light green	Disturbed areas very distinct; usually found in grass/forb areas, or near trees

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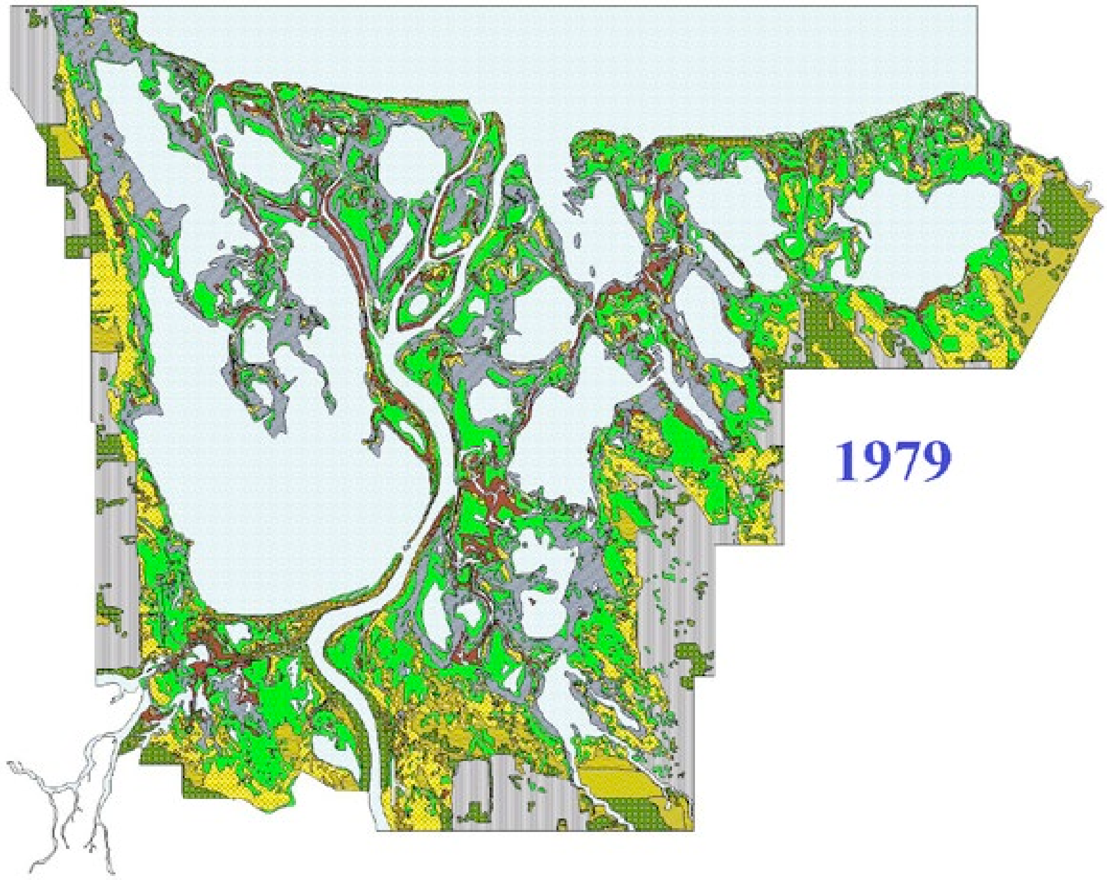

Source: Grosshans, R. E., D. A. Wrubleski, & L. G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, Canada: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. p. 14. Available online at <www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.

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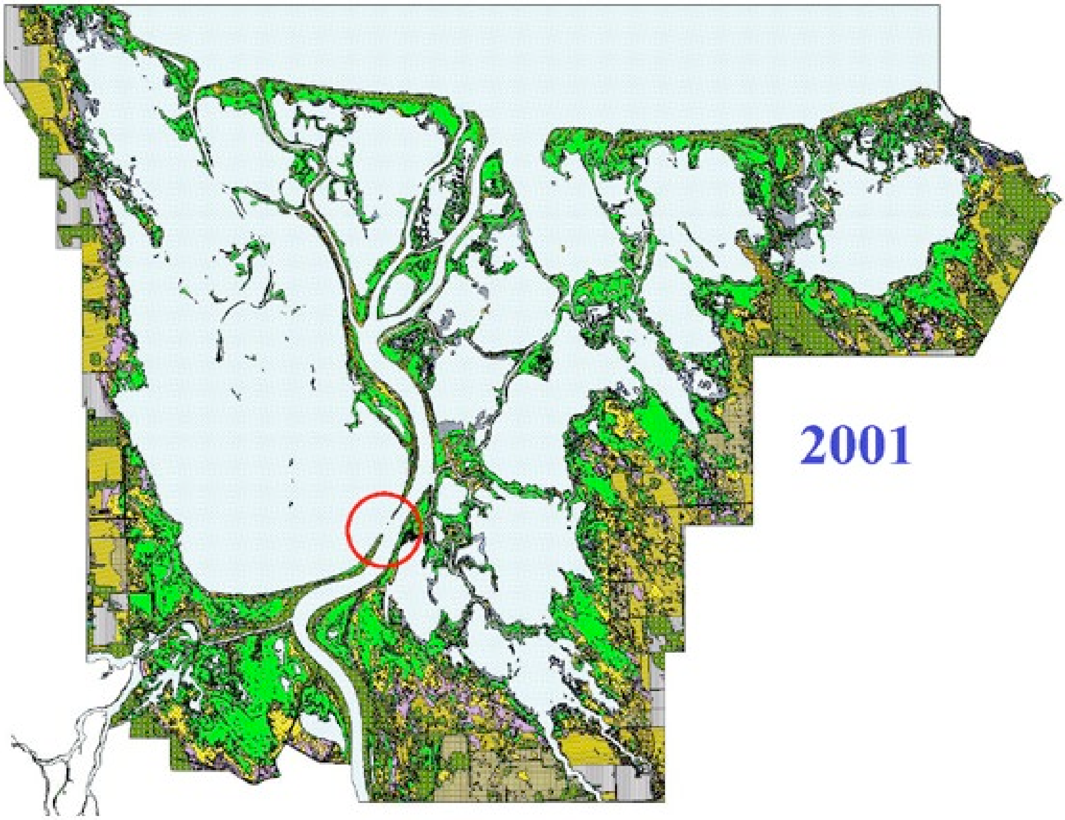

Source: Grosshans, R. E., D. A. Wrubleski, & L. G. Goldsborough. *Changes in the Emergent Plant Community of Netley-Libau Marsh between 1979 and 2001.* Winnipeg, Canada: Delta Marsh Field Station (University of Manitoba) Occasional Publication No. 4, 2004. p. 15. Available online at
<www.gov.mb.ca/waterstewardship/iwmp/netley/documentation/netley_libau_marsh_report.pdf>.