Appendix I –
Understanding Lake Basics

Summer Village councillors and administrators continually make decisions that ultimately affect the lake, its stewardship, and their residents' quality of life. To do this properly councillors should, therefore, have a basic understanding of how a lake and its ecosystem functions, as many of their governance issues dealing with surrounding land use practices will directly impact the lake and the lifestyle quality of those living near it.

What is a Lake?

A lake is a body of standing water entirely surrounded by land, with no sustained directional flow detectable to the naked eye. Within its watershed, a lake is often the largest collection point for surface water from the surrounding drainage area.

In general, a lake has sufficient depth that light does not penetrate all the way to the bottom in the deepest parts of the lake (Figure 1), and often separates into three distinct layers of water during the summer (Figure 7).

Alberta's lakes were formed 10,000 to 20,000 years ago when the retreating glaciers formed lake basins by gouging holes in bedrock or loose (glacial) till, or by leaving buried chunks of ice whose melting shaped and filled lake basins with water. More recently, humans have created lakes and reservoirs by damming rivers and streams.

Lake Zones

A typical lake has distinct zones of biological communities linked to the physical structure of the lake.

The Littoral Zone

The **littoral zone** is the shallow near-shore area where sunlight penetrates all the way to the sediment, allowing large aquatic plants (macrophytes) to grow. This is a highly productive area within a lake. The plants in this zone provide food and habitat for fish and other organisms, and protect shores from wave action that may cause erosion.

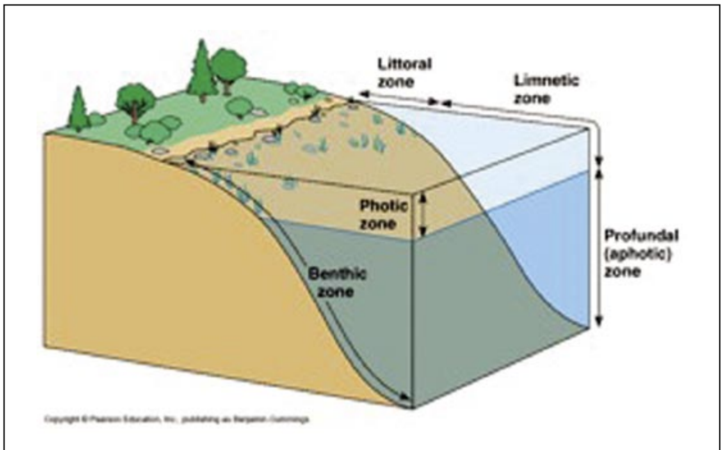


Figure 1. Zones within a lake.

Source: http://www.io.uwinnipeg.ca/~simmons/16cm05/1116/50-18-LakeZonation-L.gif

The Limnetic Zone

The **limnetic** (or **pelagic**) zone is the well-mixed surface water layer in offshore areas, beyond the influence of the shoreline. Within this open water area you have the **photic** (or **euphotic**) zone of the lake, which is the layer from the surface down to the depth where light levels become too low for photosynthesis to occur. The **profundal** (or **aphotic**) zone is also located within the open water area of the limnetic zone, and is that area deep within a lake where light levels are too low for photosynthesis to occur.

The limnetic zone is a very productive region of the lake and is dominated by free-floating microscopic plants and animals (e.g., planktonic algae, cyanobacteria, phytoplankton and zooplankton) suspended in the water (Figure 2).

The Benthic Zone

The **benthic** zone is composed of the bottom sediment of the entire lake basin. In shallower areas it is abundant with organisms that are collectively referred to as **benthos**. In the deepest regions of the lake, the sediment supports a large population of bacteria that break down organic matter and release inorganic nutrients back into the lake. This nutrient rich area is where oxygen is in limited supply, and where available oxygen is quickly consumed.

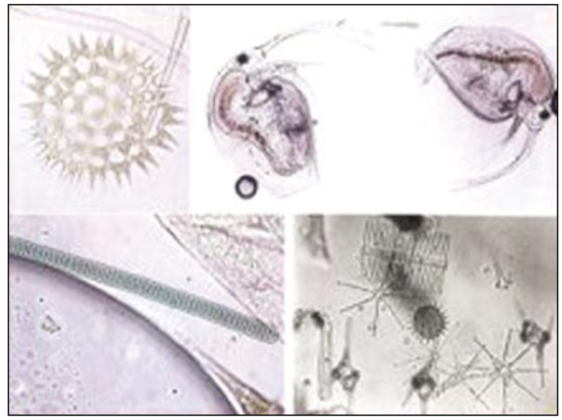


Figure 2. Phytoplankton (algae and cyanobacteria) and zooplankton in lake water.

Source: www.chemie.hu-berlin.de/linscheid/sommer/studenten/bilder/23.jpg

Water Clarity

Water clarity is an important area of concern for people living at, or visiting lakes. They want to know how "green" the lake is and how the water quality compares to other lakes. The abundance of phytoplankton in the lake is one measure of general lake productivity. High numbers of phytoplankton indicate high lake productivity. Phytoplankton can be found in the euphotic zone. The depth of this zone increases throughout summer as the sun's rays penetrate further into the water, allowing a greater area for photosynthesis and therefore phytoplankton growth. A device called a Secchi disk can be used to measure the depth of the euphotic zone and give an indication of lake productivity. For information on using a Secchi disk, contact the Alberta Lake Management Society (ALMS), or visit their web-site at: http://www.alms.ca. Lake productivity is discussed further under the **Eutrophication** heading of this section.

The Water Cycle: Water Comes and Water Goes

Water continually cycles through our environment (Figure 3). Water evaporates from soils, vegetation, lakes and other bodies of water; accumulates as water vapour in clouds; returns to the Earth, oceans and other bodies of water as rain and snow; and runs off as river flow, or through the soil and aquifers as groundwater flow, back into lakes and other bodies of water.

Residents are often concerned with the water level at the lake, as it can affect their enjoyment of the lake, the amount of available shore area, the potential for flooding and erosion, and their perceptions of water quality in general.

Water levels within a lake are a function of the amount of water received from the watershed through precipitation and inflows (inputs), and from what is lost through evaporation and outflows (outputs). Most of the water is lost through evaporation from the surface of the lake. In north central Alberta, the average annual evaporation is about 640mm, or just over two feet of lake depth. Normally this is offset by precipitation, groundwater, and other inputs.

Water levels are also affected by changes in climate. In the absence of inputs (e.g., during a drought), water levels can recede noticeably within a short time simply through evaporation.

Water also cycles within the lake. Under normal climatic conditions, water entering the lake will eventually replace water leaving the lake. The average time required to completely replace the total volume of water within a lake is called the **residence time** (or renewal time). Residence time may be short in lakes with large watersheds, as the volume of inflow is high. In contrast, lakes with small watersheds may have long residence times, due to smaller inflows requiring greater time to replenish the lakes' volume. Most lakes in Alberta have a water residence time greater than 50 years. This is important, because surface runoff from within the watershed carries sediment, nutrients and pollutants into the lake.

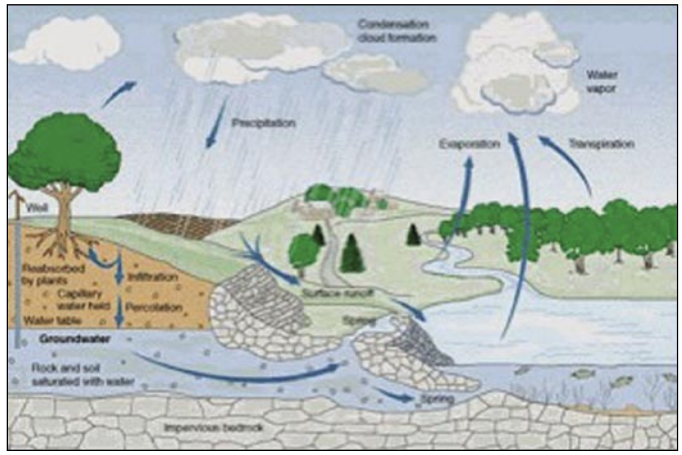


Figure 3. Hydrological Cycle of a Lake.

Source: http://www.ldeo.columbia.edu/~martins/climate_water/slides/hydrol_cycle/jpeg

What goes into a lake generally stays in the lake.

Eutrophication: The Life Cycle and Aging Process of a Lake

Like all living things, lakes age with time. The process by which lakes gradually age and become more biologically productive is called eutrophication. This is a natural process by which a lake fills in over geologic time, with erosional materials carried in by streams and overland flows, materials deposited directly from the atmosphere, and materials produced within the lake itself.

The aging, or filling-in process, begins from the time that a lake is created. Wind and water move soils from the watershed into a lake, which then settle on the bottom. Large plants and phytoplankton grow seasonally, die off, settle and decompose on the lake's bottom. With time, these processes cause a lake to become increasingly shallow. The natural succession is from lake to pond, pond to marsh, marsh to wet meadow, and wet meadow to dry land. This natural process can take thousands of years.

Human activities, however, can dramatically change lakes, for better or worse, in a much shorter time. This accelerated transition is called **cultural eutrophication**. Land use changes can result in significant changes in nutrient runoff. Nutrients from agricultural areas, stormwater runoff, urban development, fertilized yards and gardens, failing septic systems, land clearing, shoreline modification, municipal and industrial wastewater, runoff from construction projects, and recreational activities all contribute to accelerated enrichment (i.e. increased plant and phytoplankton growth) and thus, eutrophication, of the lake.

Four Lake "Ages"

Lakes are divided into four **trophic** categories: oligotrophic, mesotrophic, eutrophic, and hypereutrophic. An **oligotrophic** lake is typically a large deep lake with crystal clear waters and a rocky or sandy shoreline. There is little growth of rooted plants or plankton and the lake can support cold water fish like trout. These are thought of as "young" lakes.

A **eutrophic** lake, on the other hand, is typically shallow with a soft, mucky bottom. Rooted plant growth is abundant along the shores and out into the lake, increased algae growth and blooms of cyanobacteria are not unusual. Water clarity is not great and the water often has a green color. These are "older," very productive lakes.

A **mesotrophic** lake has an intermediate trophic state with characteristics between oligotrophic and eutrophic. A **hypereutrophic** lake is very nutrient rich (very productive). A hypereutrophic lake is an "old" lake, well into the process of transforming from open, clear water to wetland, and eventually to dry land.

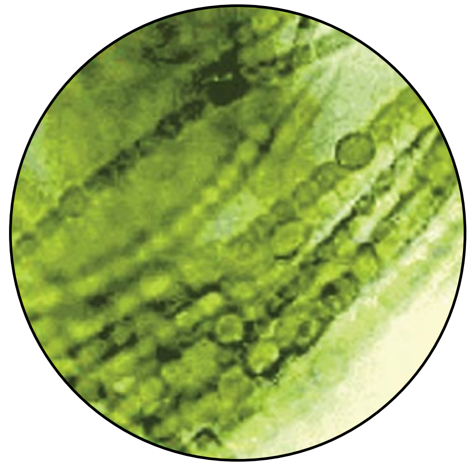


Figure 4. Free floating cyanobacteria

Measuring Trophic Status

The nutrient, or trophic status of lakes and their biological productivity can be determined by measuring two water quality parameters – the amounts of **chlorophyll** a and **phosphorus** in the lake.

Chlorophyll a is a measure of the green photosynthetic pigment found in phytoplankton (figure 4). Chlorophyll a values can be used to estimate the amount of phytoplankton in a lake. The more phytoplankton, the more productive the lake.

Figure 5 groups various Alberta lakes and their trophic status using Chlorophyll a.

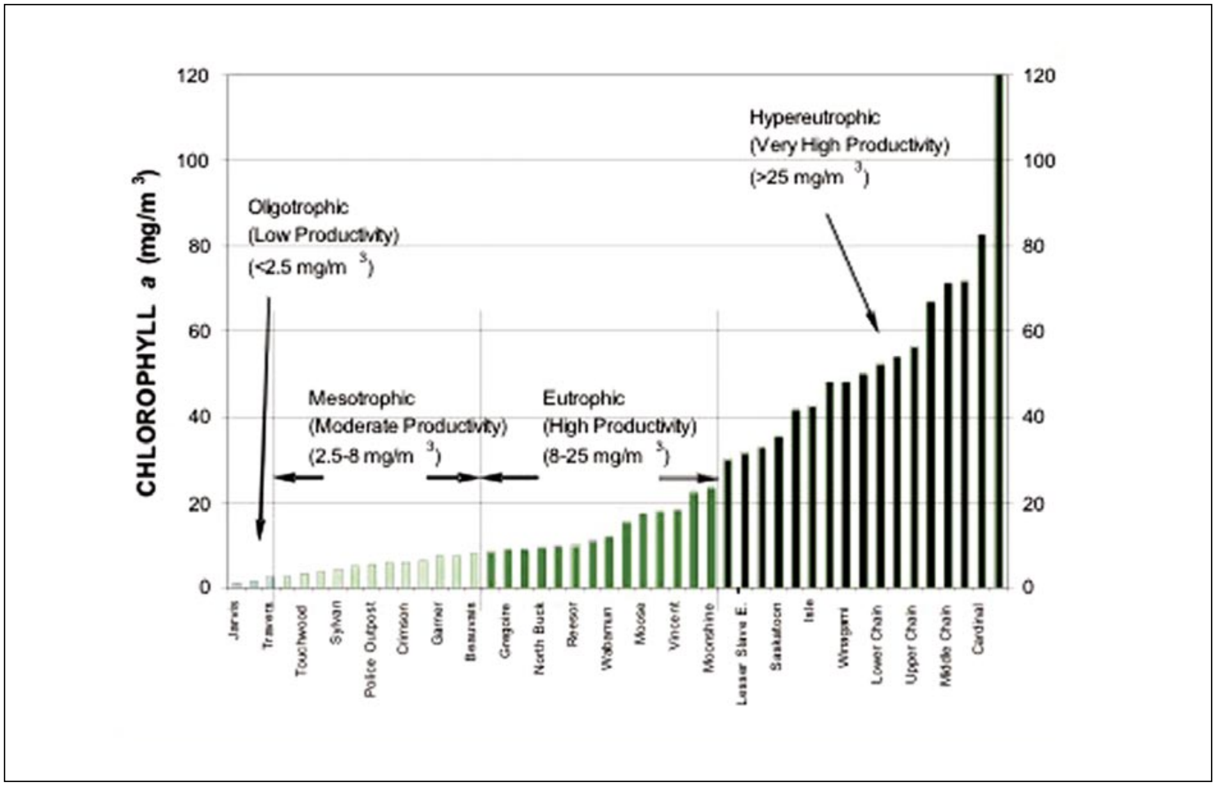
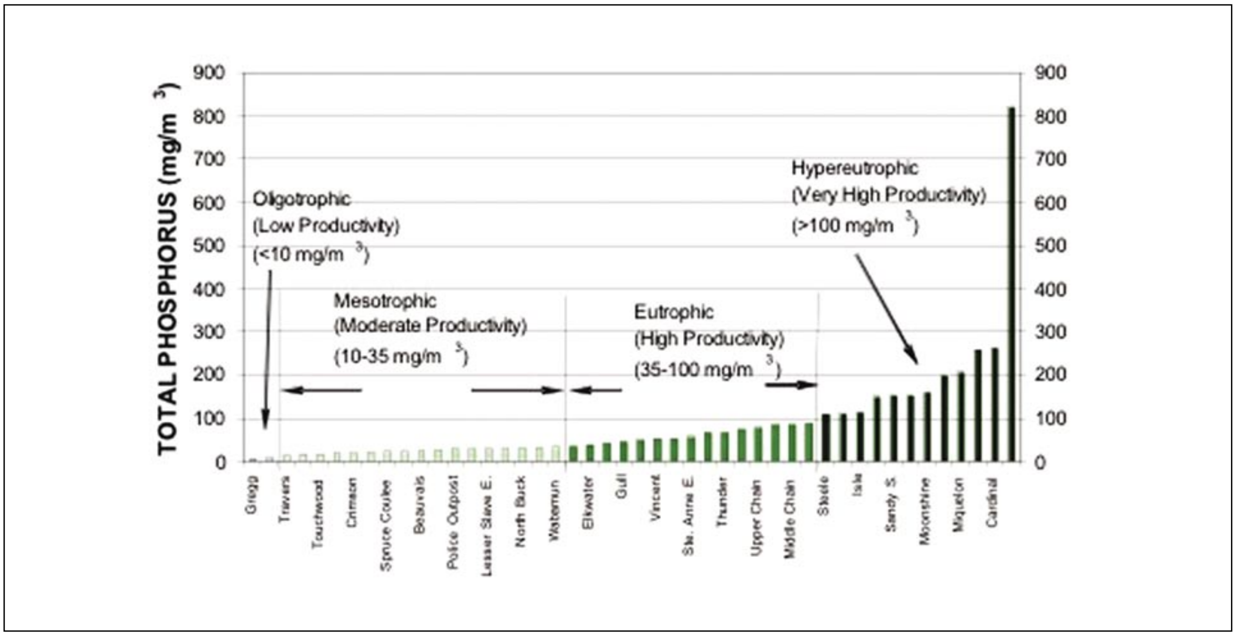


Figure 5. Eutrophic status of various Alberta lakes measured by chlorophyll a in algae.

Source: Alberta Environment

The other parameter frequently used to measure water quality is phosphorus. Phosphorus is a plant nutrient. Nutrients in a lake serve the same basic function of nutrients in a garden, that is, to promote the growth of plants. The amount of phosphorus determines the potential for plant and phytoplankton growth. The more phosphorus, the more productive the lake.

Figure 6 groups various Alberta lakes and their trophic status using phosphorus.



Stratification: Layers of a lake and Turnover

Water in North American lakes tends to stratify or form layers, especially during summer, because the density (weight) of water changes as its temperature changes (Figure 7).

Water is most dense at 4 degrees Celsius. Above and below that temperature, water expands and becomes less dense.

Spring Turnover

In spring, as ice melts, the surface waters warm and sink until the temperature and density of the water become similar from top to bottom. This allows surface water to mix completely with the deeper water, recharging bottom water with oxygen and bringing circulating nutrients up to the surface. This process is called spring turnover (Figure 8).

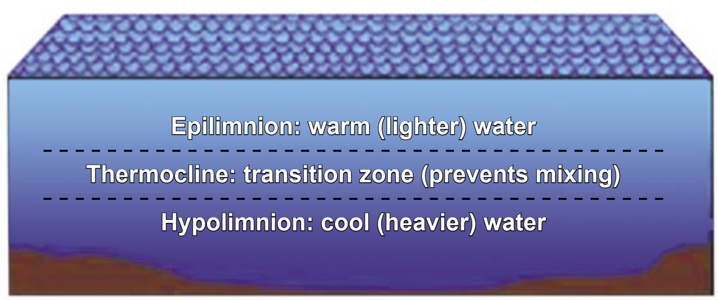


Figure 7. Lake Stratification.

Source: http://www.pca.state.mn.us/artwork/water/lakes/pic1.jpg

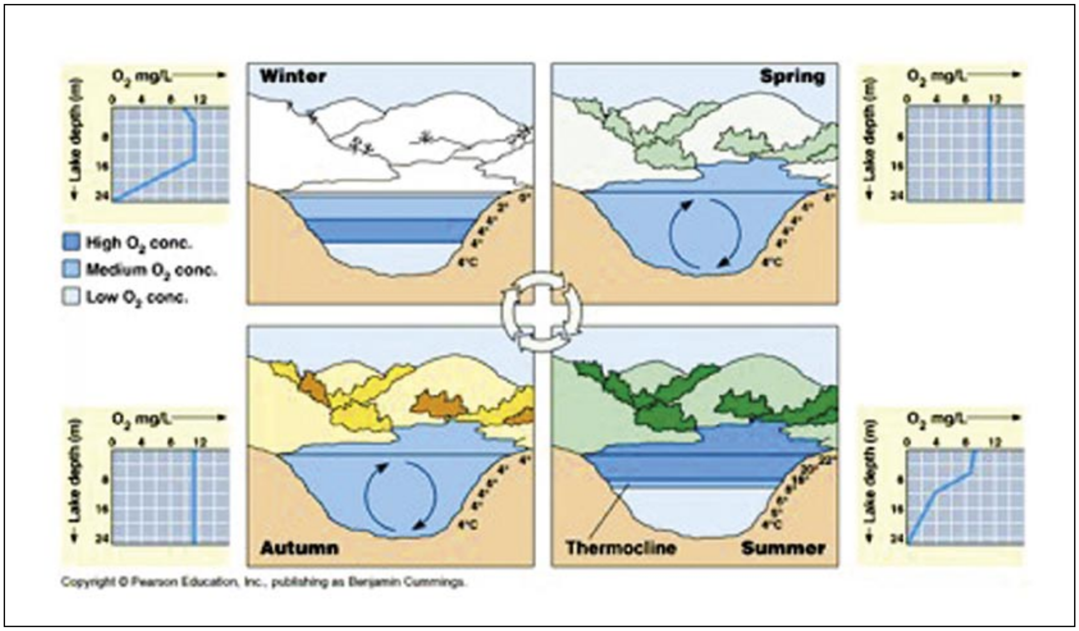


Figure 8. Lake Mixing and Turnover.
Source: http://www.io.uwinnipeg.ca/~simmons/16cm05/1116/50-15-LakeStratification-L4.gif

In the Summer

As summer progresses, the temperature difference (and density difference) between surface and bottom water becomes more distinct, and most lakes of moderate depth (greater than 10 meters deep) form, or stratify, into three layers.

The upper layer, the **epilimnion**, is characterized by warmer (less dense) water and is the zone of light penetration. Here is where the bulk of productivity or biological growth occurs. In this layer wind and waves mix freely, oxygenating the water.

The next layer, the **metalimnion** (or **thermocline**), is a narrow band of rapidly declining temperature (and rapidly increasing density). It is colder than the upper water layer and warmer than the lower layer. This layer prevents mixing between the upper and lower layers of water.

The third, or bottom layer, the **hypolimnion**, has much colder water and usually has lower oxygen levels, because the oxygen-rich upper water is unable to mix below the thermocline.

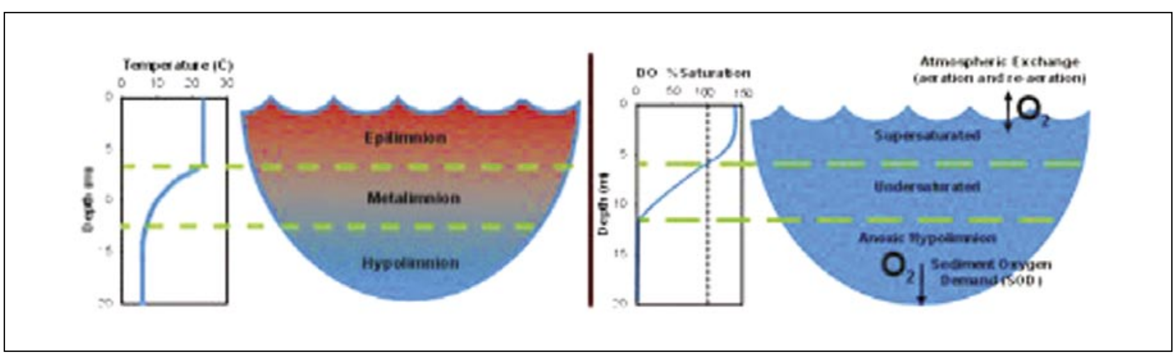


Figure 9. Temperature and Oxygen.
Source: www.ourlake.ord/html/termperature.html

Why There Are Fish Kills in the Summer

Dying plants, including phytoplankton, sink, accumulate, and decay in the stagnant bottom layer of lake water. The process of decomposition requires oxygen. The extensive and rapid decay of these plants can result in large reductions in the oxygen content of lakes. In small, shallow lakes this may lead to complete **anoxia** (absence of oxygen) and result in the death of large numbers of aquatic animals, including fish. This is known as "summerkill."

Fall Turnover

During the fall turnover, surface waters cool until they are as dense as the bottom waters and wind action mixes the lake so that water temperature from surface to bottom is the same. The eventual total mixing, or overturn, of the waters in a lake is of great importance because only then can nutrients and oxygen be uniformly distributed. This process of oxygenating the water before it freezes over is a huge deciding factor in whether a lake will have winterkill of fish. The more complete the fall turnover, the higher the oxygen levels in the water, and the better chance of fish surviving the winter.

During the fall turnover of water, cyanobacterial blooms can also occur when nutrients are mixed and brought to the surface and made directly available for algae growth.

Fish Kills in the Winter

Many lakes separate into layers in winter because ice covers the lake's surface and prevents wind from mixing the water. This also results in no new oxygen added to the water from the air. This problem may be aggravated when snow cover prevents light penetration and slows oxygen production through photosynthesis during the winter. Winterkills of fish can occur when levels of oxygen are depleted under the ice. Winterkill is common in shallow, productive lakes.

Figure 10 summarizes the seasonal changes in temperature and oxygen levels throughout the water column of a lake.

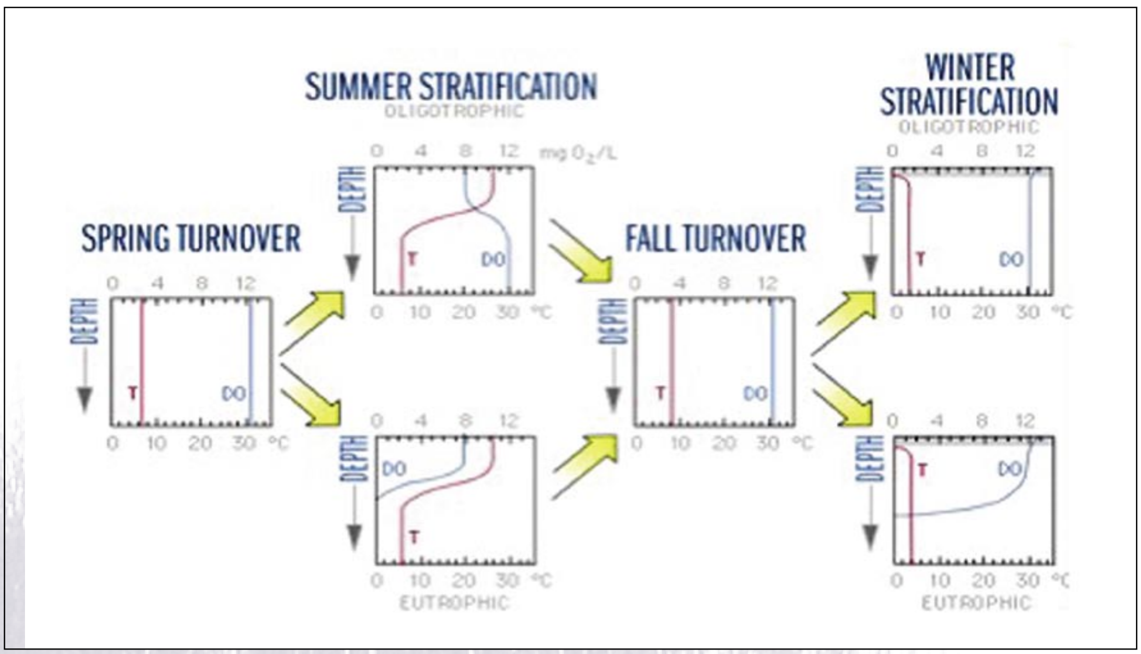


Figure 10. Seasonal Temperature and Oxygen Profiles.

Source: http://waterontheweb.org/under/lakeecology/art/oxygenchart.gif (adapted from Figure 8-1 in Wetzel, R.G. 1975. Limnology. W.B. Saunders Company)

Water Movement: Waves, Currents and Littoral Drift/Transport

Winds (and boats) generate waves that interact with the shores and bank of a lake. These waves have energy and are able to change the landscape. If you have ever been knocked over when you were small from someone tossing a bucket of water at your body, you will understand the force that water can have. Waves have the power to erode lake banks and remove material from the shores of a lake. Modifying lake banks and shores can increase the potential for erosion.

Eroded material is carried by near-shore currents in the downwind direction along the shore and re-deposited elsewhere through a process known as **littoral drift** or **transport** (Figure 11). This is how natural beaches form and are maintained. It also explains how wave action can cause poorly constructed erosion protection projects to fail.

Any interference or interruption of this transport of material can have significant consequences to owners of waterfront property. The construction of breakwaters can trap sand in front of one property, but can also seriously erode adjacent banks, depriving neighbours of their naturally occurring lakeshore area as well as creating the potential for erosion of private property.

Additional Resources

Additional and more detailed primers on lakes are available on the following web-sites, or from the following documents:

- **A Citizen's Guide to Understanding and Monitoring Lakes and Streams**, Washington State Department of Ecology, 1991
- **Atlas of Alberta Lakes,** P. Mitchell and E. Prepas. 1990. University of Alberta Press. Edmonton, Alberta. ISBN 0-88864-214-8. Found on line at: http://sunsite.ualberta.ca/Projects/Alberta-Lakes/characteristics.php
- **A Citizen's Guide to Lake Management** http://www.shorelandmanagement.org/depth/citizen.pdf
- **Caring For Shoreline Properties; Changing the Way We Look at Owning Lakefront Property in Alberta,** P. Valastin. 1999. Alberta Conservation Association. P.O. Box 40027. Baker Centre Postal Outlet. Edmonton, AB T5J 4M9. Ph. 1-877-969-9091, or on line at: www.ab-conservation.com/about_us/reports_publications/Caring_for_Shoreline_Properties.pdf
- **Managing Lakes and Reservoirs**, Third Edition, North American Lake Management Society, 2001
- **Minnesota Shoreland Management Resource Guide** http://www.shorelandmanagement.org/index.html
- **The Lake Pocket Book (2000)** N. Phillips, M. Kelly, J. Taggart and R. Reeder. Produced by the Terrene Institute in cooperation with US Environmental Protection Agency Region 5. http://www.mwpubco.com/lakepocketbook.htm
- **Water On the Web: Understanding Lake Ecology Primer** http://www.waterontheweb.org/under/lakeecology/index.html