Bathymetric Standards For Lake Inventories

Prepared by
Ministry of Environment
Ecosystems Branch
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Abstract

Bathymetric maps are maps that show the topography of the bottom of a lake. The topography is shown in the same way that topographic maps describe terrestrial landscape – with contours. The maps are based on depth soundings taken from a boat floating on the surface of the water body. These maps are used to calculate a variety of parameters for a lake such as area, perimeter, maximum depth, littoral area, and volume. Bathymetric maps are used for a wide variety of environmental assessment purposes.

This document presents the procedures and accuracy standards used to collect data and to create bathymetric maps for the Ecosystems Branch of the B.C. Ministry of Environment. This is the third version and builds on the work that has come before. Significant recent changes in depth sounder and GPS technology provided the impetus for this update. These changes have made this type of bathymetric survey easier, more efficient, more accurate and, finally, more affordable.

Acknowledgments

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The Resources Information Standards Committee evolved from the Resources Inventory Committee which received funding from the Canada-British Columbia Partnership Agreement of Forest Resource Development (FRDA II), the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC), and addressed concerns of the 1991 Forest Resources Commission.

For further information about the Resources Information Standards Committee, please access the RISC website at: http://ilmbwww.gov.bc.ca/risc/index.htm.

This document is a compilation of various works listed in the references and builds on an earlier version (Version 2.0, January 1999). Updates to version 2.0 are by Craig Mount, Ecosystems Inventory Section, B.C. Ministry of Environment.

Figures for this manual were created by Craig Mount and Byron Woods of the Ministry of Environment.

An initial draft of this version benefited greatly from reviews by a number of colleagues who have been involved in various forms of bathymetric surveying over the years. These included; Dan Grant, Don Philip, Dave McEwan, David Tesch, Albert Chirico, Rob Knight, Michelle Kehler, Arne Langston and Joe De Gisi.

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1. Introduction

This manual describes the standards and procedures for carrying out a bathymetric survey and producing a lake bathymetric map according to the B.C. Ministry of Environment Fish and Fish Habitat Inventory and Information (FFHII) standards. Bathymetric maps are based on depth soundings taken from a boat floating on the surface of the water body. These maps are used to calculate a variety of parameters for a lake such as area, perimeter, maximum depth, littoral area, and volume.

The British Columbia Ministry of Environment (MoE) and its contractors collect field data for producing bathymetric maps. The data collected can be used by different groups within the Ministry for a wide variety of purposes. For example, the Ecosystems and Fish and Wildlife groups use bathymetric information to identify sensitive habitats and to ascertain the potential of a lake to support fish based on the habitat available. The Water Stewardship Program requires bathymetric data for managing water licenses, monitoring existing or potential reservoirs, forecasting river flow, and managing watersheds in general. The information generated by bathymetric maps may also be used for managing Riparian Management Areas (RMAs), parks, and other land and water-related decisions. Finally, because of their description of habitat and shoal area, bathymetric maps are also highly utilized by anglers as an aid to recreational fishing activities.

This standard specifically presents the requirements for producing a bathymetric map that adheres to the Fish and Fish Habitat Inventory and Information (FFHII) standards as part of the reconnaissance (1:20,000) fish and fish habitat inventories. While the information presented here may be helpful in collecting bathymetric data for other applications (in the absence of their own specific standards, it does not officially cover other uses. The maps produced as part of this standard are not designed for navigation and should not be used for that purpose.

The technology for doing these surveys has evolved over the years. In the earliest days of lake bathymetry work in BC, rudimentary maps were created by rowing transects across a lake with a knotted, weighted line, lowering the line at set intervals (measured in oar strokes) and then recording these spot depths on a map. More recent incarnations of the method used sonar technology in the form of the Furuno and Lowrance X- 15 and X-16 sounders, which recorded depth readings on a paper (chart) strip. These readings were then manually transferred onto a paper map of the lake that was created through airphoto interpretation. In both of these methods, depth contours were manually interpolated from the point soundings.

The more recent incarnation of the method, presented here, takes advantage of the significant recent changes in Geographic Information Systems (GIS), depth sounder and Global Positioning System (GPS) technology that have made doing this type of bathymetric survey easier, more efficient, more accurate and, finally, more affordable. Recreational-grade fish finders and sounders that combine sonar and GPS technology and which can also digitally record data are now available for less than a thousand dollars (2009 prices).

This document outlines the steps involved in planning and carrying out a bathymetric survey in the field, post-processing the collected data and creating a final bathymetric map and associated data. Part 2 describes the pre-field work, including information on how to obtain the required background data / mapping, and how to produce lake outline maps. Parts 3 and 4 provide information on survey layout, equipment operation, and data recording. Parts 5 and 6 describe preparation of the final map, including data processing, bathymetric calculations, and map specifications. A project on Sowerby Lake is used as an example throughout the manual.

Standards and interpretive accuracies that the government requires from all contractors using GPS technology are described in *The British Columbia Standards, Specifications and Guidelines for Resource Surveys Using Global Positioning System (GPS) Technology*; Release 3.0, March 2001, Geographic Data B.C.

2. Production of the Lake Outline Map

2.1 Aerial Photographs and Satellite Imagery

Some type of remotely sensed image of the lake (either aerial photograph or satellite image) is required to gather information about a lake and to prepare a lake outline map. Hardcopy or digital images can be used but because the rest of the process is digital, using digital airphotos or satellite images that have been orthorectified will make the process much easier and will feed directly into the next phase. This is the recommended method and therefore the one that will be explained here.

2.1.1 Identifying the best image to work from

Given the choice, in most instances, working with a digital orthophoto is preferable to working from a satellite image. Orthophotos typically have a higher resolution and better detail for differentiating the features of a lake. However, if no digital orthophoto is available for the area, a satellite image may have to be used.

Regardless of the acquisition platform (plane or satellite) the best image will be selected using the following criteria:

1. the largest scale image available
2. the most recent coverage
3. an image with the least shadow, glare, and other obscurities (i.e., clearest definition of lake outline)
4. a colour image is usually better than black and white.

To identify the appropriate air photo or satellite image, first determine the location of the lake on the most current 1:20,000 TRIM (Terrain Resource Information Mapping) map base. This can be done in GeoBC's iMap by using the 1:20,000 mapsheet grid layer and then turning on the airphoto flight lines / coverage layer to see what the most recent and best resolution images are for the area. Whatever image is selected, it must be at a scale large enough and clear enough so one can accurately trace the lake outline and locate features when viewed in the GIS. This is also a good time to ensure that no bathymetric map already exists for the lake by checking the bathy lake layer (WHSE_FISH.BATH_SURVEY_MAP_SHEETS_SVW) in the Land Resource Data Warehouse (LRDW). This step can also be carried out using the Fish Information Data Query (FIDQ) for those that do not have access to the LRDW.

Once the best image has been identified, import it into the GIS platform (See Section 5.1 and Appendix D) and prepare it for digitizing. For government employees and contractors, the images can be found in the image warehouse. Other users can find and purchase the images through the GeoBC orthophoto discovery / order page.

2.2 Lake Outline Maps

Lake outline maps can be used for a variety of purposes as either a hard copy or digital map. For field use, a standard laser photocopy of the enlargement on waterproof paper may be used to show cardinal points and the location of other useful features associated with the lake (i.e., roads, trails, campsites, stream flow directions). This map can also be marked up while in the field to record field photo numbers and directions, lakebed substrate types, aquatic plant distribution, shoal areas, and location of net and minnow trap sets, limnostation sites, benchmarks, macrophyte beds, fish sightings and any other field observations. These points must be transferred to the final presentation version of the digital lake outline map at the end of the field survey. All of these types of features should also be captured electronically on the GPS / Sounder unit by using waypoints with comment notes.

A digital lake outline map (Figure 2.1) is created in the GIS environment by on-screen (or heads up) digitizing of the outline of the lake from the digital orthophoto or satellite image. This is saved as a polyline feature. This polyline will be used in the QA/QC process of checking the collected data and as a boundary in the surface interpolation phase.

For small to medium-sized lakes, enlarge or reduce the image to fit the standard 8.5" × 11" (21.6 × 27.9 cm) sheet (preferred) or 8.5" × 14" (21.6 × 35.6 cm) sheet, as required. An 11" × 14" outline map may be used to accommodate a long lake.

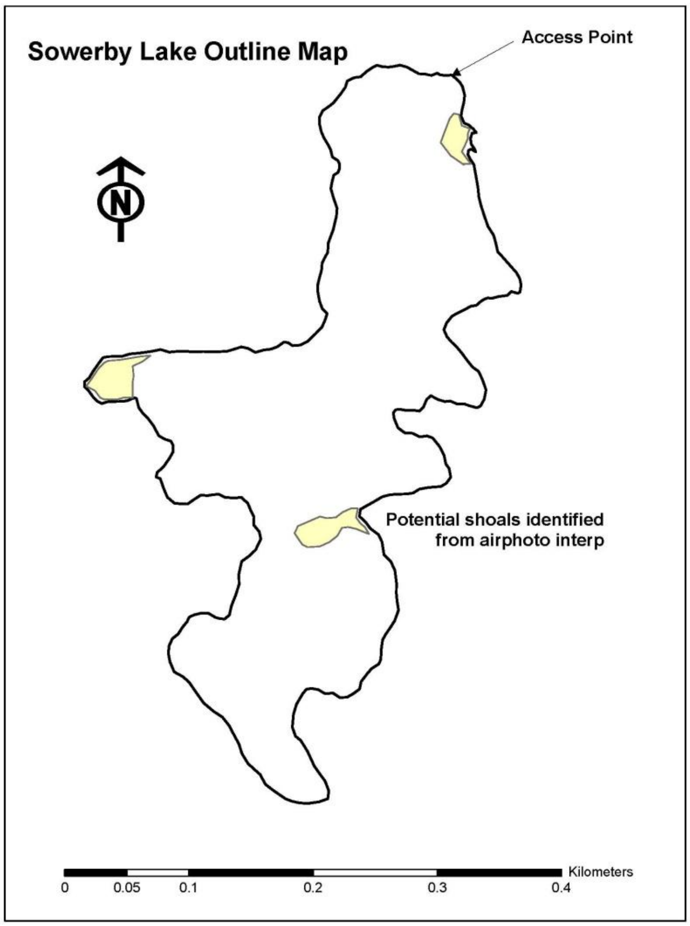


Figure 2.1 Example of an outline map of Sowerby Lake that could be taken into the field for writing notes on.

3. Field Equipment and Operation

A bathymetric survey requires a minimum of two people: one boat operator and one sounder operator. Comments and instructions in this document notwithstanding, users of this manual are required to comply with any safety policies, guidelines and practices required by their employers and/or WorkSafeBC. See Appendix C for bathymetry-related equipment and supply list. Some related requirements are described below.

3.1 Lake Survey Form

If the bathymetric survey is part of a Reconnaissance (1:20 000) Fish and Fish Habitat Inventory, then the Lake Bathymetry section (Figure 3.1) of the Lake Survey Form must be completed (see *Reconnaissance (1:20 000) Fish and Fish Habitat Inventory: Lake Survey Form Field Guide* - Version 2.0, 2008). The data required includes littoral area, maximum depth, benchmark height, maximum water level, and benchmark type and location comments.

LAKE BATHYMETRY		
TYPE OF SURVEY FL EL SS NO		LITTORAL AREA %
MAX. DEPTH m	BENCHMARK ht m	MAX. WATER LEVEL m
BENCHMARK TYPE / LOCATION/COMMENTS		

Figure 3.1 Lake bathymetry section of the lake survey form.

3.2 Boat and Sounder Requirements

A watercraft capable of safe operation on the lake being surveyed is required to carry out a bathymetric survey. While this could be a small self-propelled vessel such as a canoe, the most common setup is a boat of minimum draft (i.e., inflatable or small aluminum ‘car topper’) fitted with a short-leg outboard (gas or electric) motor. The configuration must be suitable for use in relatively shallow water conditions when near the shoreline but also large enough to handle any weather and water conditions that may arise on the lake being surveyed. This will be a larger vessel on larger lakes where wind and waves can come up quickly. Whichever type of watercraft is chosen, the transducer must be mounted so that it remains at a constant depth (to be accounted for during the data manipulation phase) and also far enough away from the propeller to avoid turbulence and potential interference in the sonar signal.

The sounder / GPS unit must also be capable of digitally logging (recording) the collected X, Y (surface location), and Z (depth) data for subsequent downloading and import into a GIS package. These standards have been developed using a Lowrance LMS-330C that was purchased for less than $1000 (2006). Any substitutes must have comparable functionality, features and setting capabilities in terms of the GPS (positional accuracy) and sounder (depth accuracy).

The GPS component of the instrument must be able to differentially correct its position by communicating with another reference system – be it the Coast Guard Referencing Network or the United States based WASS system. The positioning system must also record co-ordinates in a standardized format that can be easily translated into UTM co-ordinates. Finally, the data logging component of the system must allow for review and QA/QC of the data. In other words, there must be a data validity field as part of the recorded data string for both the horizontal (co-ordinate) and vertical (depth) which allows uncertain data points to be deleted from the dataset. See Step 2 of Appendix D for how to do this using the Lowrance system.

Before use, calibrate the sounder according to the manufacturer's instructions.

3.2.1 Boat Operation

For bathymetric surveys, data quality can be compromised by a number of factors. Excessive speed can cause turbulence under the transducer, resulting in poor soundings. Going too quickly near the shoreline may also increase the likelihood of damaging the boat, motor, or transducer by striking the lake bottom (rocks), submerged trees, or other debris. Going too close to the shore is also counterproductive because the sounder will often lose the signal in shallow water (<1-2 m, depending on the substrate and vegetation). With the Lowrance family of sounders, for example, a lost signal is indicated by a flashing depth value showing on the screen. Once this happens, the operator of the vessel must slow down and wait for the sounder to 're-acquire' a good signal and for the depth values to be valid again.

3.2.2 Sounder Operation

Consult the owner's manual for details on sounder operation. These will vary widely from one manufacturer and model to the next, but keep some general guidelines in mind:

1. Always test the unit before going in the field (particularly if surveying a remote lake) to become familiar with its operation and to ensure that the unit is tracking and recording both the location and depth data correctly. There will be many settings to adjust, such as depth alarms, chart speed, ping speed, keel / transducer offset, etc.
2. Set the operating frequency of the sounder to provide the best resolution and detail in the soundings. Many of the current Lowrance models feature dual frequency so that the operator can select the correct frequency, given the average depth of water that will be surveyed. For example, the Lowrance LMS-330C can be set to either 50 kHz or 200 kHz. The 200 kHz setting would be for water less than 100 m deep and the 50 kHz setting for deeper water because it has a wider cone angle.
3. Experiment with the sensitivity (also known as gain) settings to ensure that enough echoes are being picked up by the receiver. If the sensitivity is set too low, the signal from the bottom of the lake will be weak; if the sensitivity is set too high, the receiver will collect too much noise and it may be difficult to differentiate detail from the signals. Many new sounders have an autosensitivity function that can be handy, but be sure to test it and understand how to override it if necessary. Set the sounding frequency such that you are collecting enough data to get good coverage of the lake but not so much that you will be overwhelmed by the volume of data to process during map production. A good rule of thumb is a recording rate of one data point per second. This will result in closely spaced data points in areas where the boat speed was low and slightly wider spacing where the boat was travelling faster.
4. Manual spot soundings should be done at the beginning of a survey to calibrate the sounder and make sure the transom offset is correct. Spot soundings are depths taken manually using a metre stick or weighted measured line, depending on the depth.

4. Field Procedure and Data Collection

A bathymetric survey involves conducting soundings while traversing the surface of a lake and deriving a bathymetric map from the collected data. This was traditionally done by using transects that were typically straight lines running from one known point to another. Two types of transects were used in traditional bathymetry for sounding operations: E-line and transverse transects. An E-line (or Exploratory Line) is a sounding transect that traverses the full length of the lake along its main axis, and is used to roughly determine the maximum depth of the lake basin. Transverse transects were then run perpendicular to the E-line, traversing the breadth of the lake, as parallel to each other as permitted by lake morphology, to determine the lake basin topography.

With the new electronic equipment and software available now, this structured method of parallel transects is not strictly necessary. Although it does tend to ensure an even coverage, parallel tracks that run back and forth across the width of the lake do not need to be as structured as in earlier methods. For example, the transects do not need to be pre-planned on the lake outline map or run from one known point to another – they can go wherever the surveyor wishes so long as there is an adequate and even coverage of the surface of the lake in the end.

The difference between older methods and the current method is that when a GPS unit is integrated with the depth sounder and an X-Y coordinate is collected in the same data string as the depth at that location, the bottom of the lake is located in three dimensions. In the post-processing / map-making phase, the map maker does not have to make the manual connection between X-Y coordinate and the corresponding depth. As such, the data collection phase in the boat can be much more unstructured, allowing the surveyor to spend more effort on areas of particular interest (the deepest part of a lake or perhaps a unique, shallow spawning area by doing repeated passes). Similarly, if large areas appear quite uniform, the transect spacing can be increased without fear of misinterpreting the bottom profile.

4.1 Shoreline Cruise

To begin the depth sounding process, cruise around the lake shoreline to form an electronic outline of the lake on the sounder screen. Get as close as possible to the shoreline without hitting bottom or submerged rocks or logs. Do not venture into water so shallow as to lose the signal (less than 1m-2m depth depending on the substrate). All of the data logged during the shoreline cruise (also sometimes called the shoreline crawl) is used in the production of the final map. The depths between the shoreline crawl ‘data trail’ and the photo-interpreted shoreline (set at a depth of zero) will be interpreted so it is good to get as close to the shore as possible. Note all inlets and outlets, and a general layout of the surrounding terrain, including a good place to locate the benchmark if one does not already exist. Use this initial shoreline cruise to conduct a general inspection of the lake shore, bays, islands, etc., to identify factors that will affect the final sounding process – notably aquatic plant beds, logs and debris, and extreme shallow areas (including rocks) that may prohibit the use of an outboard motor. Record this information on the hard copy lake outline map.

4.2 E-line

The E-line is a minimum standard requirement of a fish and fish habitat inventory and must be completed even if a full bathymetric map is not a requested product of the inventory. As water samples and profile measurements must be taken from the deepest part of the lake (if possible), an E-line, at the most basic level, provides an indication of the most likely point of maximum depth(s) for locating the limnological station(s). Figure 4.1 shows the most appropriate choice for the E-line in a hypothetical lake; additional transects 1 and 2 may be used to determine depth of other basins.

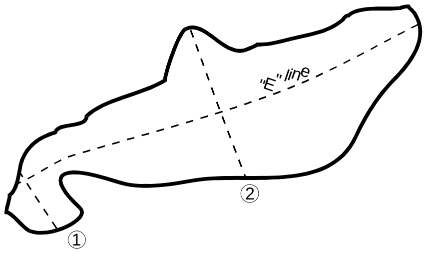


Figure 4.1 E-Line placement on a hypothetical lake.

4.3 Transect Coverage

Once the shoreline cruise and E-Line soundings have been completed, the survey team can begin doing transects back and forth across the lake, perpendicular to the E-line and working from one end of the lake to the other. The exact locations of these transects do not need to be predetermined as in previous methods, but some general rules will help to ensure good coverage of the lake. This in turn affects the quality and quantity of the data gathered and, therefore, the final bathymetric map. The following guidelines should be observed when planning the layout of transects.

1. Transects should be roughly parallel to each other and as close to perpendicular to the shore as possible.
2. The distance between transects is discretionary, but must always be close enough to allow for reasonable interpolation by the 3-D surface generating application during the final mapping process.
3. The more transects, the more accurately the depth contours can be mapped. Generally, the smaller the lake, the closer the transects can be. In the case of an irregular lake or one that appears to have a complex bottom profile, more transects are required to determine the shape of the lake bottom and water volume.
4. All areas of the lake must be mapped, but particular emphasis should be placed on headlands, bays, bedrock outcrops, rock pinnacles, shoals and islands, if any.
5. Where depth permits, transects should also provide good coverage of all significant embayments.
6. While establishing and completing the map, the survey team must continually monitor the results and conduct additional transects as required (e.g., in areas exhibiting dramatic differences in depths for two adjacent transects) to produce an accurate and detailed end product. If adjacent transects give highly disparate readings, speed should be reduced and, if necessary, readings confirmed with a weighted line. A transect or pass perpendicular to the original tracks can also be useful in corroborating or rejecting the data collected in the earlier tracks.

4.4 Spot Sounding

Spot soundings are depths taken manually (a metre stick or weighted measured line) in places where it is impractical, unsafe or impossible to run a transect. For example, spot soundings would be taken in a shallow area around a small island that has a shoal area covered by water, but too shallow for boat or sonar. Occasionally, spot soundings are used in densely vegetated aquatic areas because the sonar cannot pick up a signal. Generally however, in the case of the shallow areas between the shoreline cruise route and the actual shoreline, the interpolation routine sets the shoreline at 0 m depth and then interpolates between that and the first set of readings that may be offset by 2 to 5 m linear distance (average – depends on bottom profile) into the lake. Manual spot soundings should also be done at the beginning of a survey to calibrate the sounder and make sure the transom offset is correct.

4.5 Referencing Depth Soundings with a Benchmark

Depth soundings obtained from a lake are specific to the lake level at the time of the survey. Lake depth may vary through seasonal events such as flooding or evaporation or with developments over the course of time (e.g., development or breaching of beaver dams or natural debris plugs). Therefore, all depth data must be referenced to a permanent object, called a benchmark, which can be traced over time.

A benchmark can be any immovable structure around the lake, such as a permanent dock or booming chain anchor bolt. The preferred marking is a small eyebolt and tag, fixed in a bedrock crevice with epoxy resin, and this method should be used where possible. Another common method for establishing a benchmark in a fisheries survey is to drive a large spike, leveled horizontally, into a mature, healthy tree near the water's edge and to clearly mark it with a blaze and/or paint. A spike in a tree must be clearly marked because it can present a hazard to loggers or other users. If a benchmark already exists at a lake, then all new depth data must be referenced to it, even if a new benchmark is established. Generally, benchmark height is set 2.0 m above the current water level.

Precisely record the location of the benchmark (including height above and distance from shoreline at time of the survey) on the Lake Survey Form so that it is easy to locate and use as a reference point in future investigations. Also, photo-document and mark the benchmark location on the lake outline map.

After installing the benchmark, measure and record its vertical height above the water surface. The simplest and most appropriate method for lake surveys is to use a line level. This is a small (pocketsize) bubble level that can be suspended from light line. One end of the line is attached to the spike or eye at the benchmark and the other, with the level attached, is held parallel to and over the water surface. The level should be placed exactly in the middle of the line. This is to compensate for the sag in the line. The vertical distance is then measured using a metre stick or tape.

A sighting level (Locke level, Abney level, precise level) or a clinometer (Balkwill and Coombes, 1994) can also be used in lieu of a line level to measure the benchmark height. A clinometer should only be used if the benchmark is within 3 m of the observation point. For greater distances, more precise instruments should be used. The surveyor stands at the water edge and locates the benchmark placement from a horizontal sighting. The height above the water level will represent the distance between the level of the surveyor's eye and the ground or water surface.

4.6 High-Water Mark

Estimate the normal high water level of the lake also when taking benchmark height measurements. The high water level is usually considered the mean maximum over a two-year period, using staff gauge measurements. If gauges and the previous year's levels are not available, examine the shoreline for any plain rock faces or trees near the water that show evidence of water level heights.

A high water level that is often reached will leave a mark in the lichens on a rock face. Some lichen thrive on being submerged in vernal flooding while others expire on a day's inundation. Wave action will also clean away some weathering debris so there may be a band that is relatively plain with a few excursions above it that are faintly visible. Measure this band's height above the water level as accurately as possible. If there are no clear indicators on the rocks, then examine tree trunks for evidence. In many areas, ice will damage trees if the maximum levels are reached in cold weather. These marks are clearly visible, and their heights easily measured. If the survey is done shortly after spring freshet in an area where the trees are releasing pollen, mud, needle, or pollen lines may be visible. If you know whether this high water event is normal, subnormal, or above normal, then use the mud, needle, or pollen line to approximate a high water level, using other indicators as tools. Other indicators are driftwood berms, driftwood or floating grasses caught in shrubs, small wave-cut benches in side slopes, erosion under trees (where extreme shade has kept the ground bare) and small scars on the forest floor, as well as differences in vegetation, especially ferns, mosses, graminoids, and herbaceous plants.

4.7 Final Transect Map

The final transect map is produced in the office after all sounding observations and recordings have been gathered. It is based on the layout of the transects and spot soundings used and is created by overlaying the georeferenced data points on the digital image of the map. Figure 4.2 shows the final transect map for Sowerby Lake.

The transect map should show the following:

- Transects, shown as a series of data points, the separation between them will show the speed of the boat during different stages of the survey.
- The direction of travel, marked with a short arrowhead at regular intervals.
- Spot soundings, accurately positioned and depth shown.
- Shoals, rocks, and other stationary hazards.
- Benchmark location.

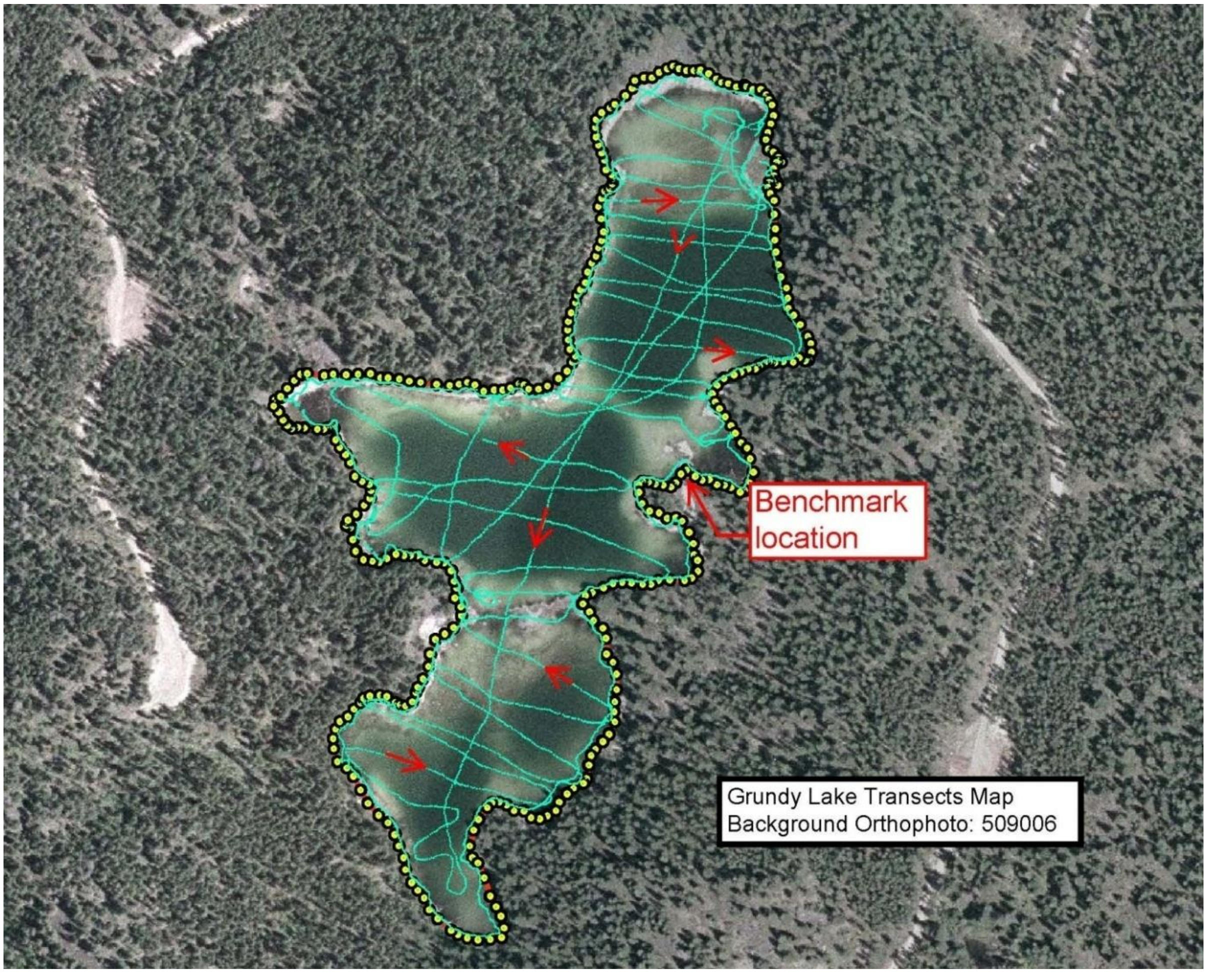


Figure 4.2 The final transect map for Sowerby Lake.

5. Preparation of Final Bathymetric Map

The final bathymetric map (hardcopy and digital version) is the main product of this process. It assimilates and displays all of the point data collected in an easily interpreted format that users are familiar with. Bathymetric maps use contours or lines of equal depth to illustrate the topography of the lake bottom that is hidden below the water.

5.1 Generating the Final Map

The final bathymetric map for Sowerby Lake is shown in Figure 5.1. This map was produced using the technique outlined in Appendix D, which uses various computer software packages to achieve the final result. Generally, the workflow involves the following steps:

Step 1. Collect the XYZ data while traversing the surface of the lake in a boat (Section 4).

Step 2. Export this data from the data logger / sounder/ GPS unit into a spreadsheet and prepare it for importing into a GIS package.

Step 3. Spatially overlay the data points on top of an orthorectified image in the GIS package to ensure the correct location for the data and to QA/QC all the data points.

Step 4. Export the 'cleaned' data points into a 3-D surface generating package (such as Surfer) and interpolate between all the points to create a 'grid' or 'wire frame' of the lake bottom.

Step 5. Use the 'grid' file to generate contours and then import the contours back into the GIS package. Select an appropriate contour interval and then overlay the contours on the digitized outline of the lake (shoreline) to create the final bathy map. The placement and smoothing of contours by computer is strictly mathematical, but may require some adjustment by a trained person with respect to the geomorphology of the basin. With respect to contour intervals, it is important to select an interval that is small enough to provide an adequate description of the lake's bathymetry, but not so small as to create a cluttered map. In every case, however, the 6-m contour must be mapped, where the lake is deep enough. In the example of Sowerby Lake, since this is a relatively shallow water body for its area, there is room to use a 1-m contour interval and show each of the 11 contours without too much crowding or clutter (Figure 5.1).

> **Note:** Although some bathymetric programs may use smaller contour intervals to derive more accurate lake volume measurements, the production maps should conform to the rule of thumb given above.

The detailed steps associated with this process with specific instructions for Lowrance (*SonarViewer*), ESRI (*ArcMap*), Microsoft (*Excel*) and Golden Software (*Surfer*) software packages are outlined in Appendix D. Although users are not required to use these specific software packages, they must be able to replicate the functionality and results generated in the examples.

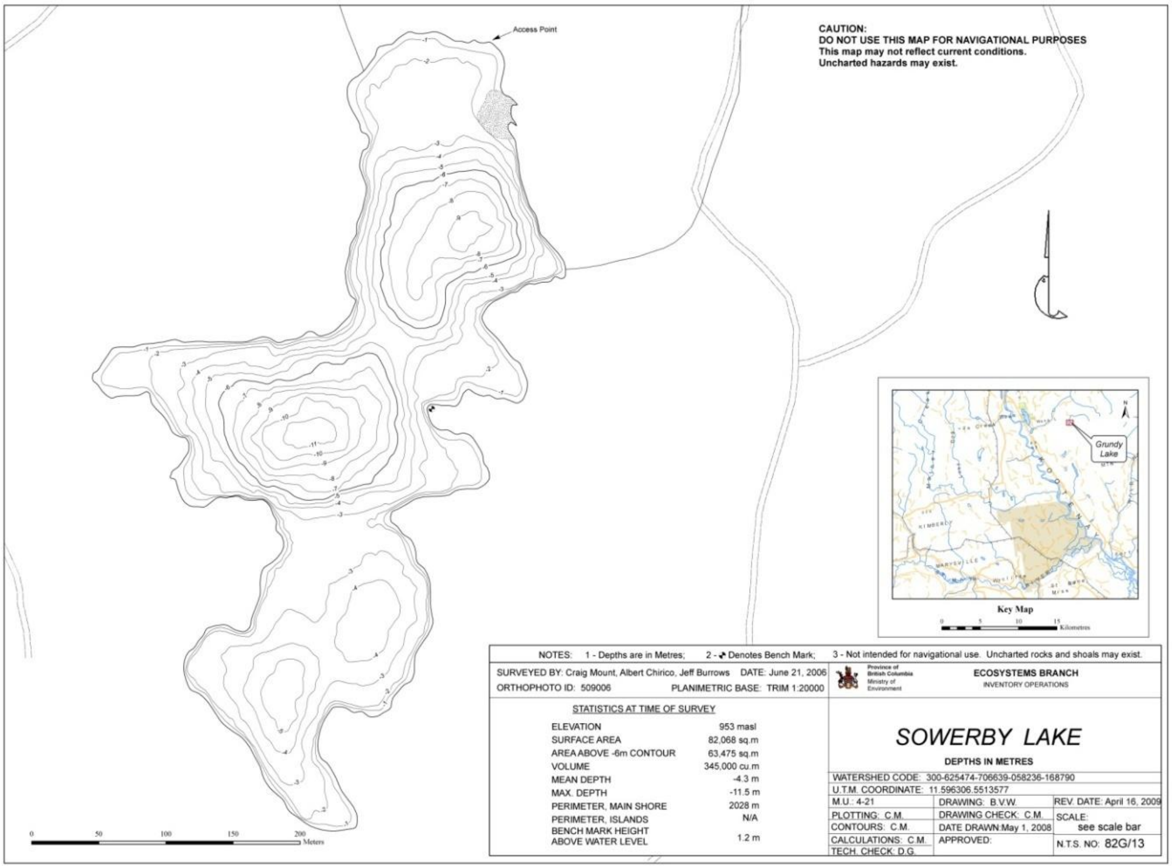


Figure 5.1 The final bathymetric map of Sowerby Lake.

The steps above will provide the basic outline of the lake and the contours that fall within that area, but the map also requires other components, including a text box, north arrow, index map, etc. The details of what is required to complete the map are included in Section 6.2 Bathymetric Map Checklist. An example of a final bathymetric map text box is shown in Figure 5.2.

NOTES: 1 - Depths are in Metres;	2 - Denotes Bench Mark;	3 - Not intended for navigational use. Uncharted rocks and shoals may exist.		
SURVEYED BY: Craig Mount, Albert Chirico, Jeff Burrows ORTHOPHOTO ID: 509006	DATE: June 21, 2006 PLANIMETRIC BASE: TRIM 1:20000	Province of British Columbia Ministry of Environment	ECOSYSTEMS BRANCH INVENTORY OPERATIONS	
STATISTICS AT TIME OF SURVEY		SOWERBY LAKE DEPTHS IN METRES		
ELEVATION	953 masl			
SURFACE AREA	82,068 sq.m			
AREA ABOVE -6m CONTOUR	63,475 sq.m			
VOLUME	345,000 cu.m			
MEAN DEPTH	-4.3 m	WATERSHED CODE: 300-625474-706639-058236-168790		
MAX. DEPTH	-11.5 m	U.T.M. COORDINATE: 11.596306.5513577		
PERIMETER, MAIN SHORE	2028 m	M.U.: 4-21	DRAWING: B.V.W.	REV. DATE: April 16, 2009
PERIMETER, ISLANDS	N/A	PLOTTING: C.M.	DRAWING CHECK: C.M.	SCALE:
BENCH MARK HEIGHT ABOVE WATER LEVEL	1.2 m	CONTOURS: C.M.	DATE DRAWN:May 1, 2008	see scale bar
		CALCULATIONS: C.M. TECH. CHECK: D.G.	APPROVED:	N.T.S. NO: 82G/13

Figure 5.2 The bathymetric map text box for Sowerby Lake.

5.2 Calculating Lake Volume, Area, and Mean Depth

An advantage of using computer software to produce a bathymetric map by generating a three-dimensional surface is that all area / volume calculations can be automatically obtained, both overall and by stratum.

The **total surface area** and **perimeter** of the lake is easiest to calculate in the GIS program. These are part of the basic parameters provided for all polygon features, which is the type of feature the digitized outline of the lake becomes in the GIS workflow. To calculate the **littoral area**, simply subtract the area of the polygon defined by the 6-m contour from the **total surface area.**

Surfer allows for calculation of lake **volume** through the **Grid | Volume** command, which gives the volume between an *upper* and *lower surface*. If the depth points for the lake are given in negative numbers, they represent the *lower surface,* which is then subtracted from the horizontal value chosen for the *upper surface*. For example, to calculate the entire lake volume, assign zero to the upper surface. Similarly, to calculate the volume of water below the 10-m contour, assign a value of 10 to the *upper surface.*

In providing results, the following must be included, with standard rounding procedures as indicated:

1. **Total surface area:** to the nearest 100m^2 or ±1.0% max.
2. **Surface area at 6m contour (littoral area):** to the nearest 100m^2 or ±1.0% max.
3. **Volume (by stratum, and total):** to the nearest 10,000m^3 or ±1.0% max.
4. **Shoreline perimeter (lake and islands):** ±10 m if lake <100,000m^2, and ±100m if lake >100,000m^2.
5. **Maximum depth:** to the nearest 0.5m if >6m, and to the nearest 0.1m if <6m.
6. **Mean depth:** (= total volume ÷ surface area) to the nearest 0.1m.

5.3 Bathymetric Equipment Data Sheet

If the bathymetric survey is part of a Reconnaissance (1:20 000) Fish and Fish Habitat Inventory, then the following data sheet must be completed for each full bathymetric survey on a primary lake, and submitted with the bathymetric map for that lake.

Bathymetric Equipment Data Sheet

Global Positioning System (GPS)		
Are locations differentially corrected?	Yes	No
Accuracy		
Equipment used		
Software used		

Bathymetry	
Location methods	
Sounder make and model	
Boat speed (km/hr *range*)	
Boat type (*optional*)	
Motor specifications (*optional*)	

Software/Method used	mapping:
	contouring:
	quantification:

6. Deliverables

All bathymetric mapping projects require a set of hard copy and digital deliverables.

6.1 General Project Submission Requirements

1. One complete digital copy of the deliverables must be submitted through the fish data submission process. One complete hardcopy and one complete digital copy of deliverables are to be sent to the appropriate Regional Ministry office.
2. Copies of the digital map, appendices, and applicable attachments must be provided in PDF format. The Ministry must be able to reproduce the entire hardcopy report from the PDF files submitted.
3. Please do not use special fonts in the hardcopy or digital reports and maps. Arial and Times New Roman (True Type fonts) or Helvetica and Times (PostScript fonts) must be used for all report and mapping text. Use only standard Mapping fonts provided by the Ministry for map symbols. (Appendix A)

For convenience, two checklists are provided in this section:

6.2. Bathymetric Map Checklist

6.3 Supporting Documents Checklist

6.2 Bathymetric Map Checklist

Hardcopy Map

- ☐ Final map produced in black on white, standard size (ANSI B or larger) paper
- ☐ Final map computer generated
- ☐ Outline and all contours completely closed, except for partial shoal definition contours
- ☐ All contour lines numbered and all numbers perpendicular to the bottom of the sheet
- ☐ All measurements in metres
- ☐ 6m contour interval included (in heavier line weight) for all lakes deeper than 6m
- ☐ Maximum depth included within each deepest contour
- ☐ North symbol "fish" right side up, not lying on its back and pointing to the top half of the sheet
- ☐ Direction of flow and a gazetted name (if available) for all streams
- ☐ Benchmark location indicated
- ☐ All symbols correspond to bathymetric mapping symbols listed in **Appendix A**

- ☐ Approximate position of lake indicated on the location map using an arrow and a star
- ☐ Linear scale on the map situated near the lake

Statistics at the time of survey section completed

- ☐ Lake Surface Elevation (*metres above sea level*)
- ☐ Surface area (*square metres*)
- ☐ Volume (*cubic metres*)
- ☐ Estimated annual fluctuation (*metres*)
- ☐ Mean depth (*metres*)
- ☐ Maximum depth (*metres*)
- ☐ Perimeter (*metres*)
- ☐ Area, 6m contour (*littoral area of the lake)*
- ☐ Height of benchmark above water level (*metres above sea level, if known*)
- ☐ Type of benchmark (*e.g., spike in tree, bolt in concrete, etc.)*

Header block

- ☐ Officially gazetted name *(if no official name exists, then use a local or alias name followed by an asterisk)*
- ☐ Watershed code number according to the Freshwater Atlas (FWA)
- ☐ Waterbody Identifier
- ☐ UTM co-ordinate for centre of lake (the standard UTM coordinate ZEN format of 7 digits easting and 8 digits northing defines 1 metre precision)
- ☐ MU (*management unit*)
- ☐ Method of preparation of final map
- ☐ Contour interval used
- ☐ Technical check
- ☐ Date of completion of final map (*month/day/year e.g., September 18, 2008*)
- ☐ Revision date

- ☐ Approved
- ☐ Scale decimal based and set to "100s" level
- ☐ NTS map sheet number is at 1:50 000 scale
- ☐ All NTS sheets used are recorded in full (e.g., 104 G/9, 104 G/10)
- ☐ Name of surveyor and company/agency
- ☐ Lake outline source
- ☐ Date of survey (*month/day/year e.g., July 17, 2008*)

6.3 Supporting Documents Checklist

Digital Products - GIS Files / Data

- ☐ Original Raw .SLG (or equivalent) files downloaded from the sounder
- ☐ 'LakeNameCleaned'.CSV file with cleaned XYZ data points
- ☐ Spatial polygon file showing outline of lake
- ☐ Spatial point file (Figure 4 -Transect Map) of cleaned and corrected XYZ data with UTM co-ordinates and depths in metres (extraneous / incorrect data removed)
- ☐ Spatial polygon file showing the area between the shoreline and the 6m contour line
- ☐ Digital Orthophoto or Satellite image
- ☐ ArcGIS .mxd file with all relevant layers included
- ☐ All maps must be in UTM projection
- ☐ TRIM 1 to be used as map base for sample plans and all mapping products
- ☐ Final bathymetric map in PDF format – showing all details outlined in Section 6.2 (contours, scale, north arrow, header block, statistics, etc.)

Calculations (specify what software was used to calculate these values)

- ☐ Lake volume calculation
- ☐ Surface area calculation
- ☐ Area to 6m contour calculation
- ☐ Mean depth calculation

Equipment

- ☐ Bathymetric equipment data sheet

Reference Data

- ☐ Bench mark reference
- ☐ High water mark reference
- ☐ Field notes (original hard copy)

7. References

Balkwill, J.A. (1991). Limnological and Fisheries Surveys of Lakes and Ponds in British Columbia 1915-1990. Fisheries technical circular No. 90, Ministry of Environment, Province of British Columbia. 157pp.

Balkwill, J.A. and Coombes, D.M.V. (1994). Lake Survey Procedure Manual for British Columbia. Environment Lands and Parks, Province of British Columbia. 179pp.

BC Ministry of Environment, Lands and Parks (1980). Aquatic Survey Terminology. T.W. Chamberlin, ed., ADP Technical Paper, Victoria, BC. 30pp.

Geographic Data BC (2001). British Columbia Standards, Specifications and Guidelines for Resource Surveys Using Global Positioning System (GPS) Technology; Release 3.0.

Golden Software Inc. (2002). Surfer 8 Contouring and 3D Surface Mapping for Scientists and Engineers User's Guide Golden Software, Inc. 809 14th St., Golden, Colorado. 640pp

Lowrance Electronics Inc. (2004). LMS-337C DF Fish Finding Sonar and Mapping GPS Installation and Operating Instructions Lowrance Electronics, Inc. 12000 E. Skelly Dr., Tulsa, Oklahoma. 206pp

Minami, M. (2000) Using ArcMap. Environmental Systems Research Institute (ESRI), Inc. 380 New York St., Redlands, California. 528pp

Resource Information Standards Committee (RISC) (2001). Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures. Version 2.0. 170pp

Resource Information Standards Committee (RISC) (2009). Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures. Version 2.0 Errata

Appendix A: Bathymetric Mapping Symbols

Appendix A provides the names, symbols and feature codes for the features needed to produce a bathymetric map according to B.C. Ministry of Environment Fish and Fish Habitat Inventory and Information (FFHII) standards. A “feature code” is used to identify the feature in a Geographic Information System (GIS), and remains linked to the feature even if the symbol does not translate into a graphic symbol in another GIS program.

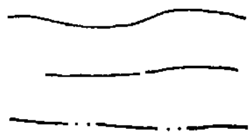
The majority of these symbols occur in the BC Environment style file (*bcenv.style*). If accessing the government GIS system, the bcenv.style file can be added to a GTS ArcMap session by going to Tools | Styles | Style Manager and then selecting the bcenv style in the Style Manager.

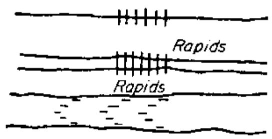
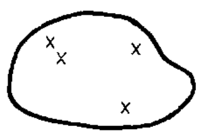
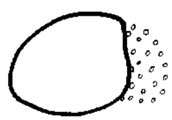
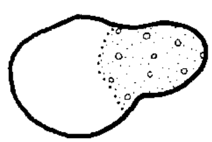
For contractors outside of government, the bcenv.style file can be obtained through:

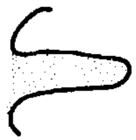
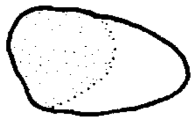
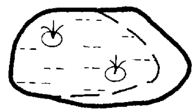
Scott Sharp
Spatial Technology Analyst - GIS Services Unit
GeoBC Infrastructure Services Branch
Integrated Land Management Bureau
Ministry of Agriculture and Lands

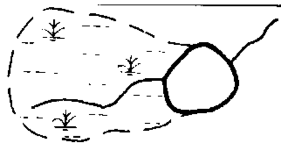
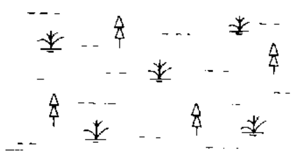
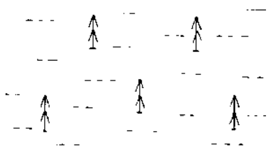
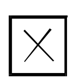
Scott.Sharp@gov.bc.ca

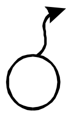
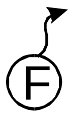
APPENDIX A: Bathymetric Mapping Symbols

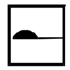
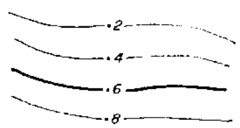
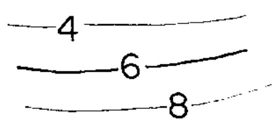
	Feature	Symbol	Feature code	Digital Drawing Specifications
1.	SHORELINE		**GA27110000**	Line weight - 0.8 mm
2.	WATER COURSE -definite -indefinite -intermittent		**GA24850000** **GA24850140** **GA24850150**	Line weight – 0.6 mm Line weight – 0.6 mm, L=15mm, S= 1mm Line weight – 0.6 mm, L=10mm, S=5mm
3.	DIRECTION OF FLOW ARROW		**KB14250000**	Line weight – 0.35 mm
4.	SPLIT DRAINAGE			Line weight – 0.35 mm
5.	FALLS	F	**PI30004000**	Line weight – 0.35 mm, Length – 2-4 mm, 9 point type
6.	FALLS ZONE		**PI30004000**	Line weight – 0.35 mm, Length – as required, 9 point type

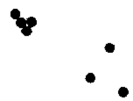
	Feature	Symbol	Feature code	Digital Drawing Specifications
				
7.	RAPIDS		**GA23500110** **GA23500000** **GA23500120**	Line weight – 0.35 mm, Length – 2-4 mm, Line weight – 0.35 mm, Length – 2 mm, area - as required, Italic 9 point type
8.	ROCKS OR BOULDERS		**GE25350000**	Italic 9 point type “X” uppercase
9.	COBBLES OR STONY BEACH		**GE01800130**	Irregular circles about 1.0 mm diameter, Line weight – 0.25 mm
10.	COBBLE OR STONY SHOAL		**GE27000130**	Dotted boundary, Line weight – 0.5 mm, Dots – 0.3 mm, Open Dots – about 1.0 mm diameter Line weight – 0.25 mm

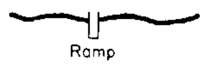
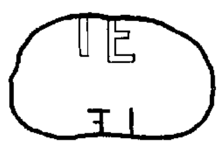
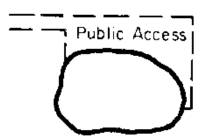
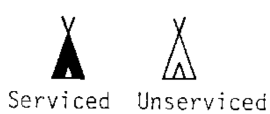
	Feature	Symbol	Feature code	Digital Drawing Specifications
11.	SANDY BEACH		**GE01800140**	Dotted pattern with 0.3 mm dots
12.	SAND SPIT		**GE01800150**	Dotted fill with 0.3 mm diameter dots
13.	SANDY SHOAL		**GE27000140**	Dotted boundary line Line weight - 0.5 mm Dotted fill with 0.3 mm diameter dots
14.	EMERGENT VEGETATION		**GB15300150**	Broken line weight – 0.35 mm, L=4mm, S=2m Symbols – line weight 0.25 mm, 2.5 X 3.0 mm ovals, 2 arcs – 4.0 mm axis, length – 3.0 mm, one 3.0 mm straight line or from code file

	Feature	Symbol	Feature code	Digital Drawing Specifications
15.	WETLAND, MARSH, SWAMPS		**Marsh: GC90100000** **Swamp: GC90200000**	Broken line weight – 0.35 mm, L=4mm, S=2m Symbols as shown in 0.25 mm line weight
16.	MUSKEG (TREED MUSKEG)		**GC18950000**	Symbol line weight 0.25 Broken line boundary: 0.35 line weight.
17.	FLOODED TREES		**GB11350000**	Symbols as shown in 0.25 mm line weight, dashed line segments in 0.30 mm line weight
18.	FLOATING LOGS		**WA00101120**	Partial arcs in pattern as shown of 0.5 cm circle in 0.35 mm line weight
19.	LOG JAM		**WA00101110**	0.7 cm wide square with “X” made of 0.5 cm intersecting lines, all in line weight of 0.35 mm

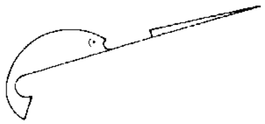
	Feature	Symbol	Feature code	Digital Drawing Specifications
20.	SPRING (unclassified)		**GA28750000**	0. 5 mm diameter circle and “tail” in line weight of 0.35 mm
21.	SPRING (classified)		**GA28750110**	0. 5 mm diameter circle and “tail” in line weight of 0.35 mm, 10 pt uppercase for classification
22.	DAM		**PI30007000**	0.7 cm wide square in line weight of 0.35 mm, Symbol in line weight of 0.5 mm, size – as required

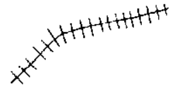
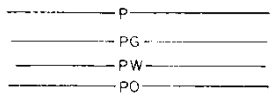
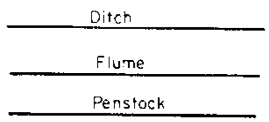
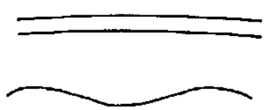
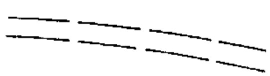
	Feature	Symbol	Feature code	Digital Drawing Specifications
23.	BEAVER DAM		**PI30002000**	Line weight - 0.5 mm, 6.0 mm circle, tangent 1.5 mm thick, 4 mm long. Length as requested.
24.	BEAVER HUT/LODGE		**GA08450110**	Line weight - 0.5 mm, 10 point type, one half ellipse (major axis 12.0 mm, minor 8.0 mm) tangent 1.5 mm thick, 4.0 mm long. Length as requested
25.	CONTOURS		**HA06200110**	Line weight - 0.3 mm. Line weight for the 6 m. contour only - 0.5 mm
26.	DEPTH NUMBERS		**KB14250110**	Dot - 0.5 mm diameter, numbers 8 point type italic, labeled parallel to bottom of sheet & right of dot
27.	CONTOUR NUMBERS		**HA06200000**	Numbers in 16 point type, parallel to sheet bottom edge.

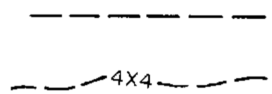
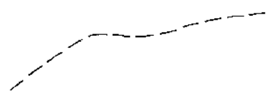
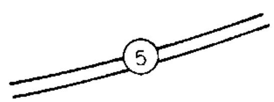
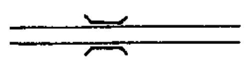
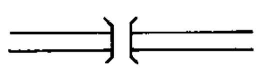
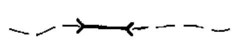
	Feature	Symbol	Feature code	Digital Drawing Specifications
28.	PILINGS OR DOLPHINS		**CR21300000**	1.0 mm diameter dots
29.	LOG BOOM		**WA00101130**	Line weight - 0.3 mm. Symbols – 1.0 X 5.0 mm rectangles, 5.0 mm apart, joined by a single line.
30.	FERRY ROUTE		**AQ10800000**	Symbol is filled Ogive, 5.0 mm long, 2.0 mm wide at the base, dashed line weight - 0.25 mm, line =2.0 mm, space = 1.0mm
31.	FLOAT PLANE BASE		**AQ00800110**	Symbol is 5.0 mm circle with anchor as shown in diagram. Line weight - 0.35 mm
32.	VESSEL ANCHORAGE		**AQ00800000**	Symbol of anchor as shown, in line weight - 0.35 mm anchor shaft 5.0 mm

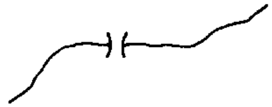
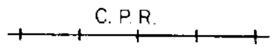
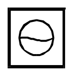
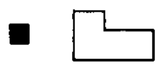
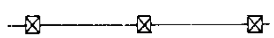
	Feature	Symbol	Feature code	Digital Drawing Specifications
33.	NAVIGATIONAL LIGHT		**GQ16350000**	Exclamation mark" symbol in 250 point type or as pictured.
34.	MARINA		**BL17000000**	Symbol 5.0 mm circle, 0.35 mm line weight, uppercase letter M in 10 point type
35.	BOAT RAMPS		**CQ15800000**	Symbol to match approximate scale in line weight 0.3 mm, word "Ramp" in 9 point type
36.	WHARF, DOCKS, BREAKWATERS		**Wharf: CQ33450000** **Breakwater:GE03050000**	Open wharf - to scale in line weight 0.3 mm. Solid wharf to scale in extent, line width 0.5 mm
37.	PUBLIC ACCESS RECREATION AREA, PARKS, etc.		**AL20150000**	9 point type text, line weight 0.35 mm, line segment 3.0 mm, space 1.0 mm
38.	CAMPSITE		**Serviced: AL03900000** **Unserviced: AL03900100**	Outline in 0.35 line weight, fill as shown

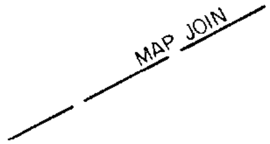
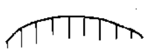
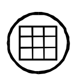
	Feature	Symbol	Feature code	Digital Drawing Specifications
39.	PICNIC SITE		**AL21150000**	Symbol drawn in line weight 0.35 mm
40.	BENCHMARK		**FB18650000**	Symbol 5 mm circle line weight 0.35 mm , fill as shown

	Feature	Symbol	Feature code	Digital Drawing Specifications
41.	NORTH ARROW		**WA00103110**	Line weight – 0.35 mm *For A1 Sheet:* Straight line of arrow 130.0 mm, oriented NS. Arrow point base 4.5 mm offset on upper side of line, arrowhead 60.0 mm long. Fish mouth semicircle and arc of gill arch 5.0 mm diameter, eye 1.0 mm dot at centre of gill arc. Dorsal line of fish and tail, part of 60.0 mm diameter circle, “hook” of tail, 12.5 mm diameter semicircle with lines connected to complete tail. *For A2 Sheet:* Same as for A1 sheet except: Straight line of arrow 95.0 mm, Arrow point base 3.0 mm offset, arrowhead 45.0 mm long. Fish mouth semicircle and arc of gill arch 4.0 mm diameter, dorsal line of fish and tail, part of 54.0 mm diameter circle, “hook” of tail, 9.0 mm diameter semicircle. Note: The "fish body" is placed on the upper part of the symbol. The symbol can be rotated in required. Right or left-hand orientation is acceptable if the arrow is vertical.

	Feature	Symbol	Feature code	Digital Drawing Specifications
42.	DYKE		**HB09450000**	Line weight - 0.3 mm, line segments 2.0 mm, extent as requested
43.	PIPELINE -Gas -Water -Oil		**P: EA21400000** **PG: EA21400270** **PW: EA21400450** **PO: EA21400120**	Line weight – 0.3 mm, extent as requested, identification letters in 9 point type every 5-10 cm.
44.	DITCH, FLUME, PENSTOCK		**D: GA08800000** **F: GA11500000** **P: GA21050000**	Line in 0.5 line width, text labels in 9 point type, First letter of word in uppercase, remainder in lowercase letters (Ditch, Flume, Penstock; as required).
45.	WOODED AREA		**JA33750000**	3.0 mm arcs, from 4.0 mm diameter circle segments, in line weight 0.25 mm
46.	PAVED ROADS		**DA25100000**	0.5 mm line weight. in two parallel lines to scale, minimum 2.0 mm separation
47.	GRAVEL & LOGGING ROADS		**DA25000120**	0.35 mm line weight. in parallel segments 10.0 mm long, spaces 1.0 mm, width to scale with a minimum 2.0 mm

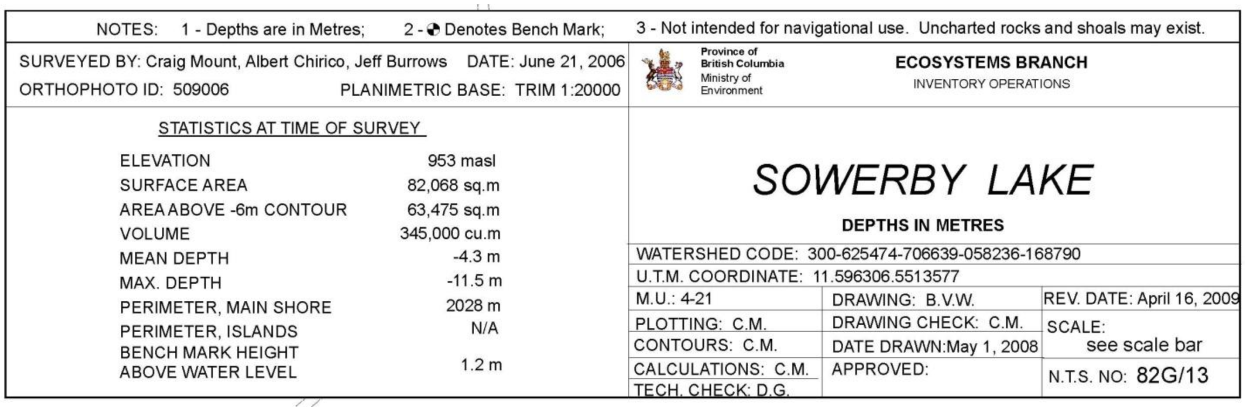
	Feature	Symbol	Feature code	Digital Drawing Specifications
	MAIN			separation
48.	GRAVEL & LOGGING ROADS - ROUGH AND SECONDARY		**DA25000110**	0.5 mm line weight, line segments 3.0 mm long, spaces 1.0 mm. If indicated by author label 4 x 4 in 10 point type
49.	TRAIL OR PORTAGE		**DC31700000**	0.3 mm line weight, line segments 3.0 mm long, spaces 1.0 mm. Label "Trail" in 10 point type where confusion may occur
50.	HIGHWAY NUMBER		**KA07950000**	Symbol is circle 6.0 mm diameter, in line weight 0.35 mm, number in 10 point type
51.	BRIDGE OR OVERPASS		**DD93250000**	Symbol in line weight 0.5 mm, with minimum length 7 mm, wings 45°
52.	TUNNEL OR UNDERPASS		**DD32200000** **DD93220000** **DD32350000** *(underpass)*	Symbol is in line weight 0.5 mm, with minimum length 7 mm, wings 45°
53.	FOOTBRIDGE		**DD03100000**	Symbol is in line weight 0.5 mm, minimum length 5 mm, wings 45°

	Feature	Symbol	Feature code	Digital Drawing Specifications
54.	FORD		**GA11600000**	Symbol in line weight 0.5 mm, part of 9 mm diameter circle
55.	RAILWAY		**DE22800000**	Track and ties in line weight 0.35 mm, ties 2.0 mm long, 10.0 mm between ties. Label in 10 point type text
56.	CULVERT		**PI30005000**	Symbol –7.0 mm square in 0.5 mm line weight. 6.0 mm circle and curve in 0.35 mm line weight
57.	BUILDING		**BR03300000**	Shown as filled black 3.0 mm square if when drawn to scale, it comes to an overall size of less than 3.0 mm. Otherwise shown in open outline done in 0.35 mm line weight (to scale).
58.	POWER LINES WITH POLE		**EA16400000**	Power line shown as line in line weight 0.25 mm, poles in solid fill circles 1.5 mm in diameter, centered on line and 20.0 – 50.0 mm apart
59.	POWER LINES WITH TOWERS		**CC90000000**	Power line in 0.25 mm line weight, towers - crossed 2.0 mm squares in 0.3 mm line weight, 20.0 to 50.0 mm apart or as shown by author

	Feature	Symbol	Feature code	Digital Drawing Specifications
60.	MAP JOIN LINES		**WA00105110**	Line weight - 0.50 mm, segments 15.0 mm long, spaces 2.0 mm, label in 10 point type uppercase text outside lake area
61.	RIVER AND CREEK NAMES		**KB14250000**	Labels in 10 to 14 point type italic upper/lower case text
62.	UNLISTED ANNOTATIONS		**KC90000000**	Labels in 9 point type upper/lower case text as required where noted by author
63.	CLIFF OR CUT		**HB05650000**	Outline in line weight 0.35 mm, hatching in 0.3 mm line weight with 2.0 mm separation, extent as shown by author
64.	WEIR OR COUNTING FENCE		**PI40002000**	5.0 mm diameter circle in 7.0 mm square or as set by author, in 0.35 mm line weight, labeled in 9 point type

Appendix B: Bathymetric Map Header Information

Appendix B provides information and specifications required to complete the header block of the final Bathymetric map.



NOTES: 1 - Depths are in Metres; 2 - ◕ Denotes Bench Mark; 3 - Not intended for navigational use. Uncharted rocks and shoals may exist.

SURVEYED BY: Craig Mount, Albert Chirico, Jeff Burrows DATE: June 21, 2006
ORTHOPHOTO ID: 509006 PLANIMETRIC BASE: TRIM 1:20000

Province of British Columbia
Ministry of Environment
ECOSYSTEMS BRANCH
INVENTORY OPERATIONS

STATISTICS AT TIME OF SURVEY

ELEVATION	953 masl
SURFACE AREA	82,068 sq.m
AREA ABOVE -6m CONTOUR	63,475 sq.m
VOLUME	345,000 cu.m
MEAN DEPTH	-4.3 m
MAX. DEPTH	-11.5 m
PERIMETER, MAIN SHORE	2028 m
PERIMETER, ISLANDS	N/A
BENCH MARK HEIGHT ABOVE WATER LEVEL	1.2 m

SOWERBY LAKE

DEPTHS IN METRES

WATERSHED CODE: 300-625474-706639-058236-168790
U.T.M. COORDINATE: 11.596306.5513577

M.U.: 4-21	DRAWING: B.V.W.	REV. DATE: April 16, 2009
PLOTTING: C.M.	DRAWING CHECK: C.M.	SCALE: see scale bar
CONTOURS: C.M.	DATE DRAWN:May 1, 2008	
CALCULATIONS: C.M.	APPROVED:	N.T.S. NO: 82G/13
TECH. CHECK: D.G.		

Title	Details	Font
Surveyed by	The name of the crew leader of the bathymetric survey	*12 point Medium Helvetica*
Date	The date or dates of the survey as month/day/year (mm/dd/yyyy).	*12 point Medium Helvetica*
Outline source	The source of lake outline. Outline source is usually an air photo (two or more for larger lakes over 400 ha), or a TRIM map, when a uniform set of photographs is not available. Record the date and specs of the orthophotograph. For TRIM map, record map number, map edition number and date.	*12 point Medium Helvetica;* *All headings: upper case;* *data: mixed upper and lower*
Elevation (lake) Surface Area (lake) Area above 6 m contour Volume (lake) Mean Depth (lake) Maximum Depth Perimeter -Main Shore Perimeter – Islands Bench Mark (height)	Rounding of value is applied before recording the information in the map title block. The uncertainty of the lake surface elevation and/or variance must always be noted, if known.	*Mixed upper and lower case 12 point Medium Helvetica*

Title	Details	Font
BC government logo Ministry of Environment		*11 point Medium Helvetica*
Branch name		*12 point Medium Helvetica (all upper case)*
Section name		*Mixed upper and lower case 11 point Medium Helvetica*
Lake name	In the case of a "name of record" or an alias name for an officially unnamed lake, an asterisk * is used to indicate that the name is not official.	*30 point Medium Helvetica Italic. Reduce font if Lake name too long*

The following section uses the font described here, unless noted otherwise:

Headings: Uppercase12 point Helvetica medium Italic

Data: Mixed upper and lower 12 point Helvetica medium Italic

Watershed code	Watershed code of the lake outlet to the first set of trailing zeroes (from the Freshwater Atlas)	
Waterbody ID	The Waterbody Identifier is a 5-digit, 4-character code given to each water body by the GIS section, and available from the web site	
UTM (Universal Transverse Mercator) co-ordinate	The UTM co-ordinates, to the nearest metre, at the lake outlet or at the geographic centre of the lake if no outlet is present. Record in Zone, Easting, and Northing sequence.	
Date	The date when the bathymetric map was completed. Record as month (written out) and year (in four digits).	
Scale	Record the numerical scale ratio (such as 1:3000, etc.) or "see scale bar". A scale bar is a scale with markings to indicate a zero point and a bar with metres marked on it that correspond to the scale. Use scale ratio on full (original)-sized plots and remove and replace with scale bar when map is reduced	*"see scale bar" in 14 point Medium Helvetica Italic*
Data QA / QC	Record the name of the GIS software package, and the initials of the person who reviewed and cleaned the point data.	

Title	Details	Font
Contours	If the contouring was done manually, record the initials of the person. If the contouring was done using a computer, record the name of the software package.	
Revision Date	Record the date when any revisions to the map were made. Revisions include any corrections of errors that were discovered at a later date, or any recalculations or changes to the map drawing.	
Tech. Check	Initialed by the person conducting the technical check for contour positions, all the location and volumetric data, and the feature and line placement on the map.	
Approved	Provide name of the government representative conducting the final check on the map.	
NTS No.	The NTS (National Topographic System) mapsheet number on which the lake is located, e.g., 82M/5.	*16 point Medium Helvetica Italic.*

Appendix C: Bathymetric Equipment Checklist

Reference Materials

- ☐ Air Photo
- ☐ Air Photo Enlargement
- ☐ Lake Outline maps on waterproof paper
- ☐ Maps (TRIM; NTS)
- ☐ Lake Survey Form (FDIS)

Boat and Motor

- ☐ Boat to suit lake size and access *
- ☐ Motor (electric or gas) **
- ☐ Fuel tank and fuel (if using gas motor)
- ☐ Oars (with half meter depth marks)
- ☐ Boating safety equipment (anchor and line, bailing bucket, PFDs)
- ☐ Tools and spare motor parts (prop, shear pins, spark plugs, etc.)

Sounding equipment

- ☐ Sounder with clear plastic rain-shield
- ☐ Lead line or pole marked in decimetre intervals, meters numbered

Battery

- ☐ 12V Marine Battery
- ☐ Spare 12V Marine Battery or Battery Charger

Benchmark

- ☐ Spike
- ☐ Fluorescent spray paint
- ☐ Other appropriate benchmark
- ☐ Hammer
- ☐ Level
- ☐ Tape measure

General

- ☐ Clipboard
- ☐ Pencils
- ☐ Ruler
- ☐ Rangefinder
- ☐ Compass
- ☐ First aid and communications as per WCB Regulations

* Aluminum, inflatable or folding boats can be used depending on logistics. Each has advantages and disadvantages in certain situations.

** Some lakes have boating restrictions. Electric motors may be required in these cases.

Appendix D: Lake Bathymetry Digital Data Manipulation

Workflow for taking data from Lowrance Depth Sounder and creating Bathymetric Products (Contours, Volume Calculations, Views, etc.)

In SonarViewer v1.2.2 from Lowrance Electronics

Open the file downloaded from the MMC card

Lowrance proprietary file format is .SLG

File > Output Chart Information > save it as a .CSV file format

Note: If this doesn't seem to be working, try opening the .SLG file from within Sonar Viewer by using ***File > Open Chart***. There seems to be a bug if the output operation is performed on a file that was opened by double clicking.

In Excel

Open the .CSV file and then clean out the bad data

Sort the data based on the DepthValid field and then Delete all of the (**F)**alse values. Do the same with the PositionValid field – delete all the bad records

Performing these two steps will greatly reduce the number of rows in the spreadsheet

Do conversion from Lowrance's proprietary co-ordinate system which shows up in the .CSV as columns

These formulas will give Lat Long values in decimal degrees – which will eventually need to be converted into UTM

PositionX=(DEGREES(A2))/6356752.3142

PositionY=DEGREES((2*ATAN((EXP(B2/6356752.3142))))-PI()/2)

Convert the depth from positive ft values to negative m values and add a foot (or however far below the surface of the water the transducer was mounted) for transducer depth

z=((C2+1)/3.28)*-1

Save this as 'LakeNameCleaned'.CSV

In ArcGIS

Find the most recent orthophoto for that mapsheet area and start a new project (MXD)

Add in the XY data as points – using the same projection as the photo (i.e. - NAD 83 UTM Zone 11 for the case of the East Kootenays)

Tools > Add XY Data

Because the XY points are in Lat/Long co-ordinates, they may have to be re-projected within ArcGIS.

Save this point file as a shapefile ***Export > Data > Shapefile***

QA / QC the data by making sure the points line up with the image of the lake and also that the values make sense for the relative position on the lake. Do this by symbolizing the points with graduated symbols

Properties > Symbology > Graduated Symbols > use the Z value – with largest circles for the deepest points and smallest circles for the shallow areas. This will intuitively allow the 'zingers' to be picked out where there are large symbols in shallow areas (or vise-versa) – these points can be deleted when they are obviously in error.

In ***ArcCatalog – create a new shapefile – polygon – with no Z values***

Digitize shoreline to create blanking file to be used in Surfer – save as a polygon file

Buffer this file inwards by -0.5m (linear unit)

ArcToolbox > Analysis Tools > Proximity > Buffer

To create another polygon that is slightly smaller.

Create point files for both of these polygons

XToolsPro > Feature Conversions > Convert Features to Points

Generate co-ordinates for these points

XToolsPro > Table Operations > Add X,Y,Z Co-ordinates

The co-ordinates for the outer ring of points will be used to create the blanking File (.BLN) in Surfer and the inner ring of points will be joined to the main XYZ point coverage to represent the shoreline.

ArcToolbox > Data Management Tools > General > Merge

Give a Z value of -0.5m (or some other shallow value) to all the perimeter points that have been appended to the others and have a default of 0. (in a Table Edit session)

This main point file now has XYZ values for all of the sounding points as well as the shoreline points in one file that will be brought into Surfer for the gridding operation.

In Excel

Open this .dbf file and then save X, Y and Z columns as a .CSV format for importing into Surfer

Generate the fault file by taking X and Y points from larger perimeter file , replace top row headings with code (#of rows, 0) and save as a .CSV file. Then go into Windows Explorer and change the file extension to .BLN format

In Surfer

Import the point data and prepare it for interpolation.

Grid > Data > (select your XYZ.csv file) and make sure the field mappings (X, Y and Z) match up and then select your interpolation method (only Inverse Distance to a Power, Minimum Curvature, Nearest Neighbor and Data Metrics support using faults which is required to create a break at the shoreline.)

Under Advanced Options, ***define the Fault file*** (second box down) to tell it not to interpret beyond the polygon defined by those points.

Execute – sometimes this can take quite a while depending on the interpolation method chosen and the number of data points – sometime many hours!

Save output as a grid (.GRD) file

Make contour and shaded maps as required - save as plot files (.SRF) to be opened again later if the graphics that have been created are satisfactory.

Export contours to take back into ArcMap (.shp file of contours is one of desired outputs)

Must have contour map open and be clicked on the 'Contours' layer and then go

Map > Contour Map > Export Contours

This will export a .DXF file which is a CAD file

Back in ArcGIS

Import this into– make sure to use the 'CAD Feature Dataset' which breaks down the file into its component parts. Once this is in ArcGIS, right click on the contours component and go ***Data > Export Data and then save it as a shapefile.***

Glossary

Air Photo Flight Index: Maps showing flight lines and aerial photograph numbers. These are available through GeoBC and viewable on iMap.

Bathymetry: The measurement of depth of any body of water e.g., streams, lakes, seas and oceans.

Benchmark: A mark on a permanent object indicating elevation and serving as a reference in topographical surveys (e.g., like measuring a lake's water level height).

Clinometer: A device used for measuring the slope angle to the horizontal in degrees or percentage.

Debris: Usually materials deposited near the shoreline or floating in the lake. In streams it may occur as clumps, jams, or scattered within the water course. This can be organic, such as logs, vegetation etc., or inorganic, such as boulders, etc., dislocated from the banks.

Depth (water depth): The vertical distance from the water surface to the bed of the water body.

Contour numbers: The depth in metres (for Fisheries purposes) of a particular contour line. For Water Management program, this refers to elevation above Geodetic Datum of Canada (mean sea level for Water Management).

Drainage: The flow of water in a particular area related to topography.

E-Line: A depth sounding transect along the longitudinal axis of a lake.

Embayment: A bay-like formation on the shoreline of a lake.

Ford: A shallow area in a stream or lake used for crossing.

Landmark: A distinctive surface feature used to identify locations, etc.

Line level: Carpenter's level bubble that hangs on a line.

Littoral zone: Shallow area around the edge of a lake, typically the area less than 6 metre deep.

Marsh: A tract of soft wet land identifiable by particular herbaceous marsh plants like marsh marigold, sphagnum moss, skunk cabbage and sedges, bulrushes, etc.

Muskeg: A thick deposit of partially decayed vegetable matter of wet regions with a sparse coniferous tree cover. In BC, the dominant plant-cover contains sphagnum species of mosses and black spruce.

Perimeter: The length of the boundary of a particular area, e.g., a watershed, lake etc.

Primary lake: In Reconnaissance (1:20 000) Fish and Fish Habitat inventories these are lakes that play a dominant role. These generally have the largest surface areas, and (or) are central in a cluster or chain of lakes.

Shoal: A shallow area of the lake bottom, usually ~ 0.75m, which may pose as an obstruction to small watercraft.

Snag: (a) A standing dead tree. (b) Sometimes a submerged, fallen tree. The top of the tree is usually exposed or only slightly submerged.

Spot sounding: A depth sounding obtained at a known spot (often by a marked oar, tap, lead line or sounder.

Surface area: The total area of the water surface within the lake shoreline minus the area occupied by islands, if present.

Swamp: Wet spongy land saturated and sometimes partially or intermittently covered with water. In BC, swamps are often associated with shrubs, like willows, and wetland plants like bulrushes, cattails etc.

Transect: A set of readings (depth, temperature, pH, etc.) along a straight line across a feature (e.g., lake, river, hill slope) from a known start point to a known end point.

Turbulence: The motion of water where local velocities fluctuate and the direction of flow changes abruptly and frequently at any particular location, resulting in disruption of laminar flow.

Volume (of lakes): The amount of water a lake contains, measured usually in cubic metres (also quoted in dam^3, acre-feet or litres, depending on the size of the lake and/or the date of survey).