REVIEW OF ARTIFICIAL SUBSTRATES FOR BENTHOS SAMPLE COLLECTION

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ABSTRACT

A literature review on the techniques of sonar profiling and grid sampling, using a grab sampler was undertaken as an evaluation step for environmental lake sediment monitoring. The sonar systems to be evaluated include the subbottom acoustic profiling system with or without side-scan and the echo sounding system.

The subbottom acoustic profiling system operates at low frequencies with great sediment penetration depth (up to 100 m) and provides information on (1) morphological features present on the lake bottom, (2) paleofluvial regimes, (3) present day control on sedimentation and erosional processes and (4) tectonic activity. This information simplifies sediment sampling surveys and help to interprete geochemical results. The subbottom acoustic profiler in conjunction with the side-scan sonar system generate an accurate representation of the lake bottom recording vertical, lateral sedimentological variations along with topographical features present at the lake bottom. The echo sounding system is a high frequency system which records water depth. Most modern system combine low and high frequency sound range satisfying both resolution and depth penetration requirements for mapping lacustrine sediments. The incorporation of the side-scan sonar along with the subbottom acoustic profiling system is not a cost effective alternative for the purpose of lake sediment monitoring.

Grid sampling using a grab sampler can be used to assess the distribution of geochemical elements in a lake basin. Sampling over a regularly spaced square or triangular grid simplifies and helps to keep track on the sampling site location for a uniform coverage of the sampled area. The Wildco-Dredge or the Petite Ponar type grab sampler can be used to sample surficial lake sediments. The Petite Ponar sampler seems to be more reliable and flexible to sample all types of sedimentogical environments (shallow-deep waters and/or high inorganic sediments).

RÉSUMÉ

Une étude documentaire des techniques d'établissement de profils par so nar et d'échantillonnage sur quadrillage, à l'aide d'une benne, a été effectuée en tant qu'étape d'évaluation pour la surveillance environnementale des sédiments lacustres. Les systèmes à sonar à évaluer comprennent le sondeur de sédiment avec ou sans balayage latéral et le sondeur à écho.

Le sondeur de sédiment fonctionne à basse fréquence avec une grande profondeur de pénétration dans les sédiments (jusqu'à 100 m) et il fournit des informations sur : 1) les caractéristiques morphologiques présentes au fond du lac, 2) les régimes paléofluviatiles, 3) le contrôle actuel des processus de sédimentation et d'érosion, et 4) l'activité tectonique. Ces informations simplifient les études par échantillonnage de sédiments et facilitent l'interprétation des résultats géochimiques. Le sondeur de sédiment combiné au système à sonar à balayage latéral donne une représentation précise du fond du lac en enregistrant les variations sédimentologiques, verticales et latérales, ainsi que des données concernant les caractéristiques topographiques présentes au fond du lac. Le système de sondage par écho est un système à haute fréquence qui enregistre la profondeur de l'eau. La plupart des systèmes modernes combinent les portées acoustiques en basses et en hautes fréquences et satisfont aux exigences en matière de résolution et de pénétration en profondeur pour la représentation cartographique des sédiments lacustres. L'addition du sonar à balayage latéral au sondeur de sédiment n'est pas une option de rechange rentable pour la surveillance des sédiments lacustres.

L'échantillonnage sur quadrillage à l'aide d'une benne peut être utilisé pour évaluer la distribution des éléments géochimiques dans un bassin lacustre. L'échantillonnage sur un quadrillage carré ou triangulaire à espacements réguliers aide à suivre la piste de l'emplacement du site d'échantillonnage pour permettre une couverture uniforme de la zone échantillonnée. La benne de type Wildco-Dredge ou la benne de type Petite Ponar peut être utilisée pour échantillonner les sédiments lacustres superficiels. La benne Petite Ponar semble plus fiable et plus souple pour l'échantillonnage de tous les types d'environnements sédimentologiques (eaux peu profondes ou profondes, sédiments inorganiques hauts).

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INTRODUCTION

Lake basins are sinks for particles transported by air, water and ice. Lakes accumulate most hydrophobic organic contaminants, metal compounds, nutrients as they become associated with organic matter (Mudrock and MacKnight, 1991). Many studies have aimed to characterize the nature and property of lake sediments for a variety of purposes. In some instances, bottom sediments can be in place toxics which can pose a high risk and can be a serious and costly environmental issue (Mudrock and MacKnight, 1991). The importance of protecting the ecosystem from human activities which impact directly or indirectly on the hydrological system cannot be overemphasized. Anthropogenic influences on the lake basin often result in increased sedimentation rates in the lake basin due to construction/excavation and other human activities accelerating rates of weathering and erosion on surficial sediments and rocks of the lake's hydrological basin. Sampling lake sediments becomes essential for assessing the extent of anthropogenic and natural influences on lake sediments by mapping the distribution of various geochemical elements, evaluating their effects, providing a database for further investigations on the effects of these geochemical elements on the biota, and for remediation/monitoring studies.

This report summarizes a review of the literature on the techniques of sonar profiling and grid sampling, using a grab sampler identification and mapping of lake sediment facies for environmental effects monitoring. The methods assessed were predetermined by Aquatic Effects Technical Evaluation (AETE) committee as follows: sub-bottom acoustic profiling with or without side-scan sonar, echo sounding and systematic grid sampling, using a grab sampler.

Water is an excellent conductor of seismic energy and is an ideal medium for transmitting energy waves to the sedimentary/geological formations below. These waves are either reflected from hard surfaces or transmitted further down through the sediment column. Returned signals are captured at the water surface using geophysical instruments and recorded digitally or using a chart. These data provide information on lake sediment type and stratigraphy which is important for designing environmental surveys. Surface lake sediment samples can be obtained using the grid sampling technique with a grab sampler. When chemically analyzed these sediment samples can provide a picture of the bulk chemistry of surface lake sediment. Both sediment type and sediment geochemistry can be mapped and compared; a fundamental task when evaluating the effects of natural and anthropogenic influences on lake sediments.

SUB-BOTTOM ACOUSTIC PROFILER

I - PURPOSE

The sub-bottom acoustic profiler is used to precisely record continuous vertical sedimentary sequences of the lake basin. Signals ranging from 500 Hz to 12 kHz can usually penetrate the substrate to great depths (up to 100 m of sediment). The instrumentation records the reflectivity of sound off the different sedimentary units in the lake basin. The chart recorder transcribes the information received by the transceiver from the different sedimentary units which gives important information on: **(1)** morphological features present on the lake bottom (Bornhold and Prior, 1990; Buckley and Grant, 1985; Carlson and Karl, 1988; Clague et al., 1989; Finskh et al., 1984; Jackson et al., 1992; Larocque, 1985; Larocque and Shilts, 1986; Pickrill, 1993; Redbourn et al., 1993; Solheim, 1991; and Vail et al., 1977), **(2)** paleofluvial regimes (Eyles et al., 1990, 1991), **(3)** present day control on sedimentation and erosional processes (Carlson and Karl, 1988; Clague et al., 1991; Foster et al., 1984; and Van Andel et al., 1984) and **(4)** tectonic activity (Adams, 1982; Doig, 1991; Jackson et al., 1992; Shilts, 1984; Shilts and Clague, 1992; and Shilts et al., 1992).

The use of the data from the lake sediment profiles for identifying sediment facies provides direction for the design of sampling surveys aimed at interpreting the effects of natural and anthropogenic sources of metals. Sedimentary units such as gyttja (mature organic sediments), gas, proglacial laminated clays, bedrock or till can be precisely mapped. Sedimentary units are generally mapped using a 3.5-12 kHz sound emitter and a high frequency system (200 kHz), the latter is necessary to accurately record the sediment surface and therefore, the bathymetry of the surveyed lakes. The precise distribution of the various sediment facies simplifies sediment sampling surveys and provides information to help interpret the geochemical results.

II - DESCRIPTION

Different types of sub-bottom acoustic profiling systems are available. Table 1 lists other systems that have evolved from the basic Rathyeon 1000 sub-bottom acoustic profiler described below.

Rathyeon 1000 Sub-bottom Acoustic Profiler

The low frequency transducer (3.5/7 kHz) is responsible for vertical penetration of sound into the sedimentary column for sub-bottom acoustic profiling. The high frequency (200 kHz) transducer is a high resolution instrument that precisely records the sediment surface and is referred to in this report as the echo sounding profiler. A schematic of the Rathyeon 1000 sub-bottom acoustic profiler set up is shown in Figure 1. The instrument is mounted on an inflatable (Zodiak, 14-16 feet) or aluminum boat requiring a 15-20 Horse power (Hp) motor. The equipment consists of a transceiver (transducer-receiver, RTT-1000, a chart recorder (DE 719 A or C), a 12 volt fully charged automobile battery, an inverter and a 3.5/7 kHz transducer.

General Description

There are two criteria that need to be satisfied during a sonar survey: resolution and depth penetration. One is achieved at the expense of the other such that it is often necessary to run the two systems simultaneously. Resolution is strongly dependent on the frequency and pulse length of the transmitted signals. High resolution profiles require high frequencies that are quickly attenuated at the contact of an obstacle due to a rapid loss of energy. Deep penetration, up to 100 m, requires low frequency signals (3.5/12 kHz transducer), achieved at the expense of a reduction in resolution (e.g. Rathyeon 1000 system) (Sylwester, 1983). Newer models have combined dual-frequencies (high and low) into an FM waveform transmission signal permitting simultaneous dual-frequency operation. For example the CHIRP II system is an example of a system that transmits FM waveforms covering a wider spectrum of frequencies (500 Hz to 23 kHz) than previous profilers such as the Rathyeon. This optimizes the system configuration for sediment penetration and layer/object resolution.

The horizontal axis on the chart recorder is dependent on the boat speed over the distance covered which is the cause of the extent of the vertical exaggeration on the chart paper (5:1 to 20:1) (Sylwester, 1983). The boat is run at slow speed (2-6 km/hr) to permit good transmission and reception of the sound signals. The geographical position of a traverse can be achieved by land markings or, more accurately, using a **G**eographical **P**ositioning **S**ystem (GPS). The low-frequency profiling system does not allow water depth measurements, which requires higher resolution, but is essential for the identification of sedimentary units and their vertical distribution as it records the sediment surface.

III - ADVANTAGES (General: Sub-bottom Acoustic Profiler)

* portable
* easy to assemble
* provides a precise and continuous record of the lake bottom
* multipurpose
* supports geochemical information
* provides data on the spatial and temporal distribution of lake sediment facies (erosional and depositional zones)
* can be used on small to relatively large lakes
* penetrates through great water depths (6000 m)
* can operate in shallow water (0.5 m)

IV - LIMITATIONS (General: Sub-bottom Acoustic Profiler)

* expensive (varies depending on the type of system)
* operation of the system depends somewhat on the weather
* the equipment is bulky and can be costly to ship
* provides information on the physical characteristics of the sediments only

V and VI - COST AND COMMERCIAL AVAILABILITY

Table 1 indicates some of the systems available commercially with comparison of prices, advantages and limitations. Refer to Table 1 for all sonar systems discussed in the sections below.

VII - EXAMPLES OF USE

Sub-bottom acoustic profilers are often used in sedimentological and stratigraphical studies of lake basins as a tool for reconstructing geological events (Belknap, et al., 1977; Bornhold, et al., 1990; Carlson, 1989; Carlson and Karl, 1988; Cronin, et al., 1993; D'Anglejan, and Brisebois, 1978; Damtuh, 1980; Eyles et al., 1990; Eyles, et al., 1991; Forsgren et al., 1993; Foster and Colman, 1991; Gilbert, 1985, 1992; Gilbert and Desloges, 1992; Guigne et al., 1990; Hampton, 1985; Kelts, 1978; Klassen and Shilts, 1982; McCann and Kostaschuk, 1987; Mitchum et al., 1977; Schubel, 1974; Sexton, et al., 1992; Sharpe et al., 1990; Sharpe et al., 1992; Shilts et al., 1976; Sieck and Self, 1977; Solheim, 1991; Vail et al.,1977; and Wickham et al., 1978). See the list of references in section I and II of this section for more specific examples on the use of sub-bottom acoustic profilers.

VIII - RECOMMENDATIONS

Due to the high cost of these systems, sub-bottom acoustic profilers can be leased from the company or rented from its clients depending on their marketing policies. This approach is recommended for small scale studies. Environmental sampling studies, which require long term use of these instruments for regional scale surveys should consider purchasing a sub-bottom acoustic profiler. Some return on the investment could be achieved by renting the equipment to researchers undertaking smaller scale projects. Old systems, such as the Rathyeon profiler, can be upgraded by certain companies which greatly reduces the expense of a new system. Finally, a literature review on the previous work in the study area is essential when undertaking any scientific research.

SIDE-SCAN SONAR

I and II - PURPOSE AND DESCRIPTION

The side-scan sonar equipment transmits a sound beam as a fan-shaped array which intersects rough surfaces and is then recorded as sound reflectors on a sonograph at the water surface. The instrument provides a graphic map like plan view image of the lake bottom. side-scan sonars are useful tools for showing the relationship of sediment facies to bottom topography on the lake bottom (Berkson et al., 1975).

The aim of Side-Scan Sonar studies is to investigate small scale morphological features on the lake sediment surface. Combined with the echo sounder or the sub-bottom acoustic profiler, the instrument can provide a detailed morphological and sedimentary facies map of the lake bottom.

III - ADVANTAGES

* picture of the lake bottom
* useful for investigating morphological features on the lake bottom

IV - LIMITATIONS

* used on its own, it provides very little information for the design of lake sediment sampling programs
* side-scan sonar requires a non-uniform distribution of lake sediment type in order to allow identification of sediment facies based on contrasting brightness on the sonograph.

V and VI - COST and COMMERCIAL AVAILABILITY

Refer to Table 1

VII - EXAMPLE OF USE

Berkson et al. (1975) used a side-scan sonar instrument to investigate small scale features on the floor of southern Lake Michigan. The device was used in conjunction with high resolution seismic profiling, acoustic depth recording and sediment sampling. For more detail on the interpretation of sonographs refer to Chestman et al., 1958; Stride, 1961; Clay et al., 1964; Tucker, 1966; Sanders and Clay, 1968; and Mudie et al., 1970.

VIII - RECOMMENDATIONS

The cost of the combined sub-bottom profiling system with the side-scan sonar can be quite expensive (Table 1), however, such a combined system provides a detailed map of the lake bottom, precisely mapping the vertical and horizontal distribution of the sedimentary units.

ECHO SOUNDER

I and II - PURPOSE and DESCRIPTION

The echo sounder uses a 200 kHz (the CHIRP II uses a 23 kHz signal for the high resolution signal) high-frequency transducer to record the sediment surface and therefore, lake bathymetry. It is a high resolution system; waves are rapidly attenuated when they encounter the substrate and are absorbed by the sediments (Sylwester, 1983). The echo sounder is usually combined with a low-frequency transducer to give a full representation of the sediment surface.

III - ADVANTAGES

* accurately records topographic features (hence, bathymetry)

IV - LIMITATIONS

* signals attenuated at the sediment surface; small sediment penetration capability only in the order of a few centimeter

V and VI - COST and COMMERCIAL AVAILABILITY

Refer to table 1

VII -EXAMPLE OF USE

Mullins et al., 1991

VIII - RECOMMENDATIONS

It is essential to use the dual-frequency system in order to establish the distribution of sediment types on the lake bottom. Therefore, it is recommended that one purchase or at least lease a combined frequency system for lake sediment sampling surveys.

GRID SURVEY WITH GRAB SAMPLERS

I - PURPOSE

Another sampling method to be evaluated for this project consists of grid sampling with a grab sampler. This method is used when the lateral distribution of geochemical elements in a lake basin needs to be assessed for investigating the effects of natural and anthropogenic inputs of geochemical elements into a hydrological basin. The purpose of using a regularly-spaced grid is to simplify and keep track of the sampling site location and to provide uniform coverage of the surveyed area. This method is chosen to avoid extensive extrapolation between points as the importance of geochemical patterns developed on the bottom of the lake must be assessed. Ultra-low density of points in selected areas and extrapolation would be unfavorable for this type of survey as geochemical patterns of environmental significance could remained undetected (Howarth and Thornton, 1983). There are various strategies described in the literature for sampling lake sediments, however, for the purpose of this project the regularly spaced grid sampling using a grab sampler was selected as the most favorable sampling strategy.

II - DESCRIPTION

<u>Grab samplers</u>

Many types of grab samplers have been built and modified over the years to meet sampling requirements. They basically consist of a set of jaws or bucket to scoop the sediment; a vented top (screen) reducing disturbance caused by the sampler's descent to the sediment's surface; a line; and, a triggering mechanism (Fig. 2). The following will describe the main points for two grab samplers that should be considered for this project based on their maneuverability and effectiveness. The two grab samplers selected and some of the other types of grab samplers are described in *Mudrock and MacKnight (1991)* in a more detailed review of these bottom sediment sampling instruments.

1. Birge-Ekman Sampler (Standard size in brackets)
Sampled area: 15 X 15 cm (23 X 23 cm)
Cutting height: 15 cm (23 cm)

Sample volume: 3400 cm^3 (13, 000 cm^3)
Weight empty: 5 to 10 kg (13 kg)
Weight with the sediment: 10 to 15 kg (40 kg)

The Birge-Ekman (Wildco-Ekman) sampler consists of a stainless steel or brass box with a pair of jaws and free-moving hinged flaps (Fig. 3). The jaws are held open by stainless steel wires which lead to an externally-mounted trigger assembly, activated by a messenger. The flaps allows water to pass through the sampler during its descent diminishing the risk of disturbance at the sediment surface due to wave action. The Birge-Ekman sampler is suitable for sampling fine-grained, soft sediments (including gyttja) and a mixture of silt and sand. Due to its weight and the need to use an activated messenger, the sampler has to be used under low current conditions to in order to penetrate the sediment in a perpendicular orientation.

2. Ponar Grab Sampler
Sampled area: 23 X 23 cm
Weight: about 23 kg
Maximum sample volume:7250 cm^3
Required lifting capacity: 100 kg

The Ponar grab sampler, illustrated in Figure 4, is commonly used with a winch or a crane hoist due to its weight. However, the Petite Ponar grab sampler weighs only approximately 10 kg and samples an area of 15 X 15 cm and is preferable for hand line operations. The Petite Ponar sample and the standard Ponar sampler are suited for collecting coarse and firm bottom sediments as well as soft sediments. During the descent, water passes through a screen to minimize disturbance at the sediment-water interface. A special mechanism on the Ponar grab sampler prevents accidental closing during handling or transport and is released with a change in cable tension on the impact with the sediment surface. It is suggested that a messenger be to ensure the release of the protection mechanism and closure of the grab sampler. The messenger can be attached to the line in a similar fashion to the Birge-Ekman grab sampler. The sediment sample can be easily retrieved upon opening the jaws into a sufficiently large container.

3. Others

Other grab samplers include the Petersen, Van Veen, Smith-McIntyre and Shipek samplers which operate on the same basic principle but are not described due to the required lifting capacity for these grab samples (150 to 400 kg) which does not satisfy the basic requirement for easy handling of the sampler for this project. These other samplers are described in *Mudrock and MacKnight (1991).*

Regular grid sampling method

The grid sampling method consists of taking samples at equidistant intervals along a line or a grid. The grid can be squared, rectangular or triangular and each sample is located at the junction of the segments. Triangular intervals on a grid seem to be most effective for covering an area but almost match with the square pattern strategy (McBratney et al., 1981; cited in Gilbert, 1987).

The more complicated task involves the determination of a grid spacing which can be done using judgment or statistical parameters. Statistical means of defining spacing intervals are best suited in the case where a known hot spot exists and statistics can be used to calculate the probability of finding these hot spots. The choice of the spacing interval for sediment sampling studies aimed at assessing the distribution of geochemical elements is based mainly on judgment which strongly depends on budgets available for both the sample collection and geochemical analyses. Lake sediment sampling requires a strategy which will provide the best representative picture of the lake sediment geochemistry (Hakanson, 1984). Some researchers have developed a basic sample formula which includes two morphometric standard parameters: the lake area (a, km^2) and the shore development (F) which represents the relationship between the actual shoreline and the length of the circumference of a circle. The formula described below defines the number of samples (n) that should be collected from the study site assuming an even area coverage and then dividing this number by the total lake area in km^2 (A, includes islands) (Hakanson and Jansson, 1983)

$$n = 2.5 + 0.5\ (a\ F^{1/2})$$

$$\text{where} \quad F = I_o / 2\ (\pi\ A^{1/2})$$

and I_o = the normalized shoreline length in km

$$\text{square net side} = (A / n)^{1/2}$$

This method helps define the required number of samples for an even coverage of the lake bottom and for establishing the spacing intervals. The sample formula suggests that it is not advisable to take less than three samples in a lake ($n \geq 3$). This method may be problematic when the lake is composed of sub-basins where the sampling density would be greater if the sub-basins were treated as separate entities (F would be greater) than if considered as a single unit.

III -ADVANTAGES (Grid sampling using a grab sampler)

* provides sufficient samples for good determination of the distribution of geochemical elements
* permits a good coverage of the area in a relatively short time (10-20 min/sample)
* grab samplers are easy to handle and reliable
* large samples, excess available for other analyses

IV - LIMITATIONS (Grid sampling using a grab sampler)

* the grab sampling method does not provide any temporal variations of elements (vertical)
* spotty indication of the spatial variation of sediment type

V and VI - COST and COMMERCIAL AVAILABILITY

Refer to Table 2 for grab sampler information.

VII - EXAMPLE OF USE

Phaneuf and Shilts,1994; Thomas et al., 1972 used the grid sampling strategy with a grab sampler to demonstrate the distribution of chemical elements in surface lake sediments and assess natural and anthropogenic sources of these elements.

VIII - RECOMMENDATIONS

When selecting the sampling device, one should consider the reliability of the sediment sampler collection mechanism. A light sampler will be reliable in shallow, soft sediment but may be undesirable in large, deeper lakes which often have stronger currents and greater clastic material. The Petite Ponar is very flexible. It can collect sediments with relatively high inorganic contents (harder bottom) to gyttja and is heavy enough to descend vertically to the sediment surface in deep water lakes or higher current regime lakes. The purchase of a winch is recommended for use with any grab sampler in order to achieve constancy in speed during the sampling procedure (...and easier on your back!). The Petite Ponar is more reliable if a messenger mechanism is added to the sampler to ensure release of the closing safety mechanism.

The grid sampling method permits good coverage of the area in an even matter. It is important to consider at least one sampling station at the mouth of major rivers draining into the surveyed lakes, even though this does not follow the sampling strategy, as these areas may define depositional zones. An environmental survey using lake sediment sampling should define all possible point source of contaminants either natural (bedrock, surficial sediments: soils, drainage sediments, waters and vegetation) or anthropogenic (mining, tailings, mining effluents, smelters etc.., construction /excavation, waste water from municipalities, agricultural activities, damming activities). In order to successfully accomplish this task the extent of the study area should be defined. The study site or the lake to be assessed and/or monitored needs to be outlined. The study area is basically the area covering the hydrological basin of the study site.

GENERAL ESTIMATION OF COST

Cost items generally encountered in sediment sampling programs (refer to Mudrock and Macknight, 1991):

* Renting/leasing/purchasing and operation of vessels required for the sampling
* Renting/leasing and operation of cars and/or trucks
* Cost of shipping of sampling equipment
* Purchasing or renting essential equipment (sonar system, grab sampler, GPS, etc.), storage space, etc.
* Cost of accommodation
* Salaries, wages, and travel expenses for scientists and technical workers
* Hiring local labor
* Allowance for miscellaneous service and maintenance costs
* Laboratory analyses including shipping cost

GENERAL RECOMMENDATIONS AND SUMMARY

Sonar profiling systems can be used in sediment sampling studies to accurately map lake bathymetry, sediment facies, sedimentological patterns and ultimately to reconstruct the geological history of the lake basin and catchment area. The instruments available on the market can be expensive but can provide an important and essential base for environmental surveys. Most companies provide a system that combines both the echo sounder (high frequency) and the sub-bottom acoustic profiler (low frequency) in order to obtain satisfactory results in terms of resolution and depth penetration. The side-scan sonar can be purchased as an addition to the dual frequency system, but is not an essential component for determining the geochemistry of the surficial lake sediments.

The most suitable grab sampling device is Petite Ponar sampler with the addition of a release mechanism to increase its sampling flexibility in different sediment types. Either the triangular or square grid pattern suits lake sediment geochemical surveys. Both provide an even coverage of the study site and minimize interpolation between points. The spacing and number of sample points in the study site depends largely on personal judgment and experience which takes into account the funds available for the survey and the collection of representative samples from the site.

In order to understand the distribution of trace metals in surficial lake sediments it is essential that the background levels of all possible sources of each elements be assessed. Till geochemical surveys undertaken by the GSC in Canada primarily to assist mineral exploration can be used as a source of background information for environmental lake sediment sampling surveys. Also, the range of background metal levels could be assessed by sampling adjacent lakes which would provide information on the chemical variation within lakes lying in similar and/or different geological settings. The sampling strategy in adjacent lakes may not need to follow a regular grid pattern as in the study site but may be approached in a more general matter. A sonar survey, which would identify areas of deposition and erosion within the lake basin(s) is a useful tool for selecting irregularly distributed sampling sites.

In conclusion, sonar surveys and grab sampling techniques for lake sediment surveys should be used together to assess and evaluate the distribution of surficial lake sediments in order to design a sampling program for the geochemical evaluation of the lake sediments. These techniques provide a database from which natural and anthropogenic levels of contaminants can be assessed, evaluated and established. Lake basins are sediment sinks for naturally and anthropogenically derived chemicals. Complex water-sediment interactions, biological activity, gaseous activity and other associated processes are basic operating phenomena within lakes. The distribution of elements and the understanding of the patterns developed on the lake bottom could aid researchers in their understanding of the complexity of these interactions.

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SYSTEM	AVAILABILITY	COST	ADVANTAGES	LIMITATIONS
CHIRP II (see appendix for applications and description provided by the manufacturer)	Datasonics, Inc Cataumet, Mass., U.S. Datasonics provides interface build up for old sounders without changing the transducer	40, 000 - 62, 000$ U.S. + duty tax 1 year full guarantee for all parts supported with a 5-10 years guarantee for parts supply possibility for renting equipment at 10-15% of the total cost/month directly from the owner (not available with the company but contact can be made to access an owner's list)	* lightweight and protable * simultaneous dual- frequency operation * wide spectrum of frequencies (500 Hz-23 kHz) * the operator can optimize the system configuration for sediment penetration and layer/object resolution * user friendly windows graphics interface * continuous digital strorage and display (Chirp-DSP) * FM waveform	* expensive * does not penetrate hard bottoms and gas
SBP - 5000	Datasonics, Inc	35, 000$ U.S. + duty tax (guarantee and renting conditions same as above)	* portable * dual-frequencies operation, 200 kHz and 3.5 to 30 kHz * provides good sediment penetration and resolution * magnetic tape recording or input to digital acquisition system	* expensive * does not penetrate hard bottoms and gas
SPR - 1200	Datasonics, Inc	26, 200 $ U.S. + duty tax (guarentee and renting conditions same as above)	* bottom penetration through coarse sand, gravel tills, and other difficult to penetrate sediment types	* operates at one frequency; 400 Hz * poor to no resolution * long wave length does not record small vertical sedimentary changes
CHIRP II @ Side-Scan Sonar	Datasonics, Inc and Triton Technologies	140, 000$ U.S. + duty tax (guarantee and renting conditions same as above)	* provides a range of resolution and true scale mapping features * extended swath capability (up to 1500 m) with the side-scan sonar * high resolution subbottom profiling * software built by the two companies for target analysis and side-scan sonar mosaics * improved resolution compared to standard systems	* very expensive
BATHY-2000P (see appendix for applications and description provided by the manufacturer)	Ocean Data Equipment Corporation, East Walpole, Mass., U.S.	rentals non-available 1year guarantee	* portable * digital processor	* operates at one frequency only
BATHY - 1000 (see appendix for applications and description provided by the manufacturer)	ODEC, East Walpole, Mass, U.S.	rentals non-available 1 year guarantee	* portable * dual frequencies of operation (range=3.5 to 200 kHz) digital processor * eight external interfaces for shipboard integration and recording * plug compatible upgrade for old systems without changing the existing transducer	

Table 1. Sonar systems evaluated for the AETE literature review project

SYSTEM	AVAILIBILITY	COST	ADVANTAGES	LIMITATIONS
WI[DW1]LDCO -EKMAN	Wildco Sampling Equipment 4 weeks delivery 3 months guarantee	sampler: 207$ U.S. sampler & case: 275$ U.S. Wildco kit: 335$ U.S. (includes a line and a messenger)	* light weight sampler * reliable release mechanism * frontal shock waves action reduced with the flaps at the top * different sizes available	* poor to no sampling in high inorganic sediments * does not operate well under high current conditions due to its light weight
PETITE PONAR	Wildco Sampling Equipment 3-6 weeks delivery 3 months guarantee	sampler: 439$ U.S. sampler & case: 519$ U.S. line (100ft, 316' polyester): 23.50$ U.S.	* manoeuvrable, designed for hand line operations * all types of sediments, except very hard and cobbly bottoms * more stable under high current conditions * frontal shock waves reduced with the screen on top	* release mechanism may jam
BOX CORER Ekman type	John Glew at Queen's University, Biology Department, Ontario	sampler, line, extra weight 547$	same as the Wildco-Ekman * weight added to increase stability in deep water	* same as the Wildco-Ekman although the system has been modified to overcome the limitations encountered with the Wildco-Ekman type of grab samplers

Table 2. Sediment grab samplers evaluated for the AETE literature review project