95-77 (MASTER) c.

NATIONAL WATER RESEARCH INSTITUTE

INSTITUT NATIONAL DE RECHERCHE SUR LES EAUX

DEPOSITIONAL HISTORY OF SEDIMENTS IN LEGEND AND WEEKES LAKES: GEOCHRONOLOGY AND BULK PARAMETERS

R.R. Bourbonniere, S.L. Telford and J.B. Kemper

NWRI CONTRIBUTION NO. 95-77

DEPOSITIONAL HISTORY OF SEDIMENTS IN LEGEND AND WEEKES LAKES: GEOCHRONOLOGY AND BULK PARAMETERS

R. A. Bourbonniere, S.L. Telford and J.B. Kemper

Environment Canada
National Water Research Institute
867 Lakeshore Road, P.O. Box 5050
Burlington, Ontario L7R 4A6

and

Alberta Environmental Protection
9820 - 106th Street
Edmonton, Alberta T5K 2J6

NWRI Contribution No. 95-77

MANAGEMENT PERSPECTIVE

This report covers research conducted for NRBS Study Nos. 2113-B1 and 2113-C1, including results from several laboratories at NWRI and contract laboratories. It is the first of several reports which will attempt to interpret sediment core data with the goal of identifying significant historical trends in the input of contaminants to lakes which have small watersheds containing no industrial development. The intention is to use these data to assist in apportioning the relative influence of atmospheric and riverine sources of contaminants to Lake Athabasca.

Sediment cores were collected in March, 1993 from Legend Lake, which is southwest of Lake Athabasca, and Weekes Lake to the northeast. Age-depth relationships can be assigned to cores both lakes but with more certainty for Weekes Lake. The depositional history of sediment bound contaminants can be inferred from Weekes Lake cores after the application of a carefully designed, and iteratively implemented analysis scheme. Results on bulk parameters tend to confirm the view from geochronological studies that the depositional environment has been stable for at least the last 100 years for Weekes Lake but Legend Lake experienced a change in sedimentation rate around 1982.

Biogeochemical marker analyses can assist in answering the remaining questions concerning continuity of sedimentation and changes in organic matter sources. PAH distributions are worth profiling as indicators of atmospheric input of contaminants. Depending upon the results for biogeochemical markers and PAHs, then a few selected sections from Weekes Lake should be analyzed for contaminants. Only surficial Legend Lake sediments should be analyzed for contaminants. Priority for these analyses should be given to those contaminants which are likely to be atmospherically transported (PCBs, dioxins and furans), but to be a true reference for the Lake Athabasca cores, all of the same components analyzed there should also be determined in Legend and Weekes lakes.

SOMMAIRE À L'INTENTION DE LA DIRECTION

Ce document fait état de la recherche menée dans le cadre des études NRBS 2113-B1 et 2113-C1. Il présente les résultats obtenus dans plusieurs laboratoires de l'INRE et dans des laboratoires qui ont fait de la recherche à contrat pour le compte de cet Institut. Il s'agit du premier d'une série de rapports où l'on tentera d'interpréter des résultats d'analyse de carottes de sédiments afin de mettre en évidence des tendances historiques importantes des charges en contaminants déversées dans des lacs alimentés par des bassins hydrographiques ayant une superficie réduite et qui sont à l'abri du développement industriel. Nous comptons que ces données nous aideront à déterminer quelle part de la charge en contaminants déversée dans le lac Athabasca est attribuable au transport atmosphérique et laquelle est attribuable à des sources fluviatiles.

En mars 1993, nous avons prélevé des carottes de sédiments dans les lacs Legend et Weekes, situés l'un au sud-ouest, l'autre au nord-est du lac Athabasca. Il est possible de déterminer la relation entre l'âge et la profondeur dans les carottes provenant des deux lacs, mais avec plus de certitude dans le cas du lac Weekes. Il est possible de retracer l'évolution du dépôt des contaminants fixés dans les sédiments du lac Weekes à l'aide d'un plan d'analyse élaboré avec soin et appliqué de manière itérative. Les résultats de l'analyse des paramètres associés à la matrice tendent à confirmer l'interprétation suggérée par les examens géochronologiques à l'effet que le milieu sédimentaire du lac Weekes est stable depuis au moins un siècle, mais que le taux de sédimentation du lac Legend s'est modifié vers 1982.

L'analyse des marqueurs biogéochimiques peut nous aider à résoudre les problèmes restants sur la stabilité des taux de sédimentation et sur les changements au niveau des sources de matière organique. La distribution des HAP constitue un bon indicateur de la charge atmosphérique en contaminants. Compte tenu des résultats de l'analyse des marqueurs biogéochimiques et des HAP, on pourrait procéder au dosage des contaminants dans quelques parties du lac Weekes. Dans le cas du lac Legend, les contaminants ne devraient être dosés que dans les sédiments superficiels. Il faut traiter en priorité ceux qui sont probablement d'origine atmosphérique (BPC, dioxines et furanes), mais pour que les résultats des lacs témoins puissent servir véritablement de valeurs de référence pour les analyses des carottes du lac Athabasca, tous les constituants dosés dans ce dernier lac devraient l'être aussi dans les lacs Legend et Weekes.

ABSTRACT

Sediment cores were collected in March, 1993 from Legend Lake, which is southwest of Lake Athabasca, and Weekes Lake to the northeast. Cores were dated by the ^{210}Pb method and age-depth relationships can be assigned for both lakes but with more certainty for Weekes Lake. Cs-137 results tend to confirm the ^{210}Pb geochronology for Weekes Lake but not for Legend Lake. The depositional history of sediment bound contaminants can be inferred from Weekes Lake cores after the application of a carefully designed, and iteratively implemented analysis scheme.

The dated cores were analyzed for bulk carbon and nitrogen (C & N) species and companion cores for particle size distribution. Results on bulk parameters (porosity, particle size and C & N) tend to confirm the view from geochronological studies that the depositional environment has been stable for at least the last 100 years for Weekes Lake but Legend Lake experienced a change in sedimentation rate around 1982.

Both Legend and Weekes lakes show C and N data which confirm the highly organic nature of these cores noted in the core descriptions (Appendix B) and what would be expected from a headwater lake with limited mineral input from its watershed. Legend Lake exhibits a lower atomic C/N ratio and that suggests a greater proportion of planktonic (autochthonous) input to this lake relative to Weekes. Alternatively there may be some vegetational component of the Legend Lake watershed which contains an unusually high proteinaceous content. If the cause is planktonic, then it should show up in alkane and fatty acid biogeochemical markers.

Biogeochemical marker analyses can assist in answering the remaining questions concerning continuity of sedimentation and changes in organic matter sources. PAH distributions are worth profiling as indicators of atmospheric input of contaminants. Depending upon the results for biogeochemical markers and PAHs, then a few selected sections from Weekes Lake should be analyzed for contaminants. Only surficial Legend Lake sediments should be analyzed for contaminants. Priority for these analyses should be given to those contaminants which are likely to be atmospherically transported (PCBs, dioxins and furans), but to be a true reference for the Lake Athabasca cores, all of the same components analyzed there should also be determined in Legend and Weekes lakes.

RÉSUMÉ

En mars 1993, on a prélevé des carottes de sédiments dans le lac Legend et dans le lac Weekes, situés l'un au sud-ouest, l'autre au nord-est du lac Athabasca. Les carottes ont été datées au ^{210}Pb; il est possible de déterminer la relation entre l'âge et la profondeur dans les carottes provenant des deux lacs, mais avec plus de certitude dans le cas du lac Weekes. La datation au ^{137}Cs tend à confirmer la géochronologie obtenue au moyen du ^{210}Pb dans le cas du lac Weekes, mais pas dans celui du lac Legend. Il est possible de retracer l'évolution du dépôt des contaminants fixés dans les sédiments du lac Weekes à l'aide d'un plan d'analyse des carottes élaboré avec soin et appliqué de manière itérative.

On a soumis les carottes datées à des analyses pour déterminer la teneur en carbone et en azote de la matrice (C et N), et les carottes compagnes à des études granulométriques. Les résultats relatifs aux paramètres applicables à la matrice (porosité, granulométrie et C + N) tendent à confirmer l'interprétation suggérée par les examens géochronologiques à l'effet que le milieu sédimentaire du lac Weekes est stable depuis au moins un siècle, mais que le taux de sédimentation du lac Legend s'est modifié vers 1982.

Dans les deux lacs, les données sur le C et sur le N qui figurent dans les descriptions des carottes confirment l'origine fortement organique de celles-ci (Annexe B), et elles correspondent à ce qu'on s'attend à trouver dans un lac d'amont peu alimenté en sels minéraux par son bassin hydrographique. Le rapport du C élémentaire au N élémentaire du lac Legend est inférieur à celui de l'autre lac; cela pourrait correspondre à une contribution d'origine planctonique (indigène) à la chimie du lac plus importante que celle du lac Weekes. Il se pourrait aussi qu'un constituant végétal dans le bassin hydrographique du lac Legend contienne des matières protéiniques en quantité inhabituelle. La thèse de l'origine planctonique devrait être confirmée par les marqueurs biogéochimiques que sont les alcanes et les acides gras.

L'analyse des marqueurs biogéochimiques peut nous aider à résoudre les problèmes restants sur la stabilité des taux de sédimentation et sur les changements au niveau des sources de matière organique. La distribution des HAP constitue un bon indicateur de la charge atmosphérique en contaminants. Compte tenu des résultats de l'analyse des marqueurs biogéochimiques et des HAP, on pourrait procéder au dosage des contaminants dans quelques parties du lac Weekes. Dans le cas du lac Legend, les contaminants ne devraient être dosés que dans les sédiments superficiels. Il faut traiter en priorité ceux qui sont probablement d'origine atmosphérique (BPC, dioxines et furanes), mais pour que les résultats des lacs témoins puissent servir véritablement de valeurs de référence pour les analyses des carottes du lac Athabasca, tous les constituants dosés dans ce dernier lac devraient l'être aussi dans les lacs Legend et Weekes.

ACKNOWLEDGEMENTS

The authors appreciate the assistance in field collections from D. Allen, B. Jackson and J. Kraft. B. Hilson assisted with laboratory work-up and preparation of samples for submission to contract laboratories. The Parks Canada office in Fort Chipeweyan allowed use of their facilities for core extruding and general logistical support, thanks especially to Gord Antoniuk. The Government of Alberta provided access to helicopter services. A draft version of this report was reviewed by Drs. D. Delorme, M. Dick, M. Evans, J. Lawrence and J. Marsalek and their efforts are appreciated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The history of natural changes and contamination events which occur in a drainage basin are recorded in the sediments of depositional zones. Studying sediment cores, can lead to an understanding of recent trends in industrial and atmospheric contamination, a comparison of modern contaminant deposition with the magnitude of past events, a comparison of the relative magnitude of natural vs. anthropogenic changes in the basin, and an indication of how changes in the hydraulic regime can influence the distribution of sediment bound contaminants.

Almost all of the sampling and monitoring being done for the NRBS program is occurring on the mainstem Athabasca or Peace Rivers or their tributaries with some level of industrial, agricultural or municipal development, with concomitant effluent inputs. To differentiate among contaminants which may come from effluents and those which come from atmospheric or natural sources, a series of reference samples is required. The reference samples should come from sites with little or no human influence, particularly no direct effluents. The sites chosen should be similar physically (soil, climate) and biologically (diverse flora and fauna, isolated) to the main areas of study within the NRBS.

A requirement for reference cores has been identified by preliminary analyses of the Lake Athabasca cores collected in March 1992. Atmospherically transported contaminants (e.g. PAHs and PCB congeners) can come from medium and long range sources. Lakes in the Birch Mountains may be affected by emissions from the oil sands extraction and upgrading facilities near Fort McMurray. Lakes on the Canadian Shield northeast of Fort Chipewyan are more remote and can be referenced to a large portion of the Lake Athabasca watershed.

1.1 QUESTIONS POSED

The following questions guided this study throughout. They represent questions which have direct and indirect bearing on certain NRBS guiding questions as well as some which are necessary for a scientifically valid study.

1. Can cores from headwater lakes be used to track atmospherically transported contaminants and naturally produced biomarkers?
2. Is there a difference between atmospherically sourced contaminants in the Birch Mountains and on the Canadian Shield?
3. If any differences are found, can they be related to medium range and long range transport processes?
4. Is it possible to use contaminant and biomarker data from the reference sites to apportion sources of contaminants which may be transported to Lake Athabasca sediments by more than one mode?

1.2 FRAMEWORK FOR INVESTIGATION OF REFERENCE SEDIMENTS

The most important first step is the formulation of a credible sampling plan and the mounting of a sampling expedition. After surveying available reports two lakes were chosen based on their proximity to Lake Athabasca and their relative proximity to Fort McMurray, the centre of the oil sands industry, where medium range sources of industrial atmospheric emissions may be important. Legend Lake, in the Birch Mountains, was chosen as representative of lakes which may be receiving regional atmospheric contaminant input, and has been monitored by Alberta Environmental Protection in its LRTAP program. Weekes Lake is on the Canadian Shield north of Lake Athabasca and should be representative of lakes which are impacted only by long range contaminant transport. This lake was chosen based on its morphology from among candidate lakes studied by Alberta Fish and Wildlife. More details on the sampling methods and implementation are given in section 2.2.

Once cores were successfully collected and judged to be of good quality, the next important step was to establish a geochronology (time reference) for each site. To do this successfully requires high quality undisturbed cores, which we were able to collect at both sites. We expect that sedimentation rates in headwater lakes will be low, so cores were sectioned to attain maximum time resolution (see Section 2.2). Pb-210 dating was used to determine whether cores from each of these lakes represent continuous deposition and what time scale can be applied to them. Geochronological results and a discussion of how they can be used for interpreting contaminant results are explained in Sections 4.1 and 5.1.

Since the primary concern of NRBS with respect to reference sediments is to determine whether they record evidence of past and current anthropogenic activity, the primary period of interest is the past 100 years. This period is within the range where reliable dates can be assigned using the ^{210}Pb method (Anderson et al., 1987). Use of the 100 year interval limits the number of samples that are analyzed. Reliable geochronology which demonstrates whether or not modern deposition was continuous is a necessary step.

Once the geochronology is established analysis strategies will be formulated to make best use of the sediment available, insure the tightest time resolution possible, and determine appropriate chemical species. Before contaminants are determined on these cores, it is important to analyze for bulk parameters such as particle size distribution and organic carbon and nitrogen species. Profiles of these parameters can give indications of the consistency of the depositional environment in the reference lakes.

The bulk character of lake sediments can be used to indicate major changes in depositional environment. Sediment particle size is related to the energy of the environment of deposition, fine grain sizes accumulate in low energy environments which are less prone to disturbances, and also tend to contain higher organic matter contents. Contaminants are usually associated with fine grain sediments containing organic matter. The bulk character of the organic matter can indicate changes in the sources of sediment to the lake. Total organic carbon and nitrogen and total inorganic carbon concentrations can be influenced by source and depositional changes. The character of organic matter is further indicated by the atomic C/N ratio.

2.0 STUDY AREA

2.1 GEOLOGICAL SETTING

Legend Lake (Lat: 57° 24' 41" N; Lon: 112° 55' 53" W) is a headwater lake in the Birch Mountains southwest of Lake Athabasca and northwest of Fort McMurray. The lakes in these mountains drain through a myriad of streams into the Peace-Athabasca Delta. Legend Lake feeds the delta indirectly through the Mikkwa River, a tributary of the Peace River.

Weekes Lake (Lat: 59° 42' 52" N; Lon: 110° 01' 11" W) straddles the Alberta-Saskatchewan border in the far northeastern part of Alberta. It is situated on the Canadian Shield among many similar lakes with small watersheds. Both of these lakes are remote with no shoreline development of any kind. Their locations with respect to Lake Athabasca is shown in Figure 1.

2.2 SAMPLING STRATEGY AND IMPLEMENTATION

Our initial coring strategy was based on the desire to obtain cores which would lead to information regarding potential dispersion, deposition and burial of contaminants. As these lakes are headwater lakes they are expected to contain only those contaminants which are transported atmospherically. The sediments collected should then be appropriate for referencing Lake Athabasca results in terms of which components are transported by atmospheric and which by riverine processes. Other natural compounds, biogeochemical markers, can however be transported to these lakes by runoff, even from their relatively small watersheds.

A sampling expedition was mounted by helicopter in March, 1993 from a base at Wood Buffalo National Park in Fort Chipewyan. The choice of March for coring was intentional since the stable ice platform provides ideal conditions to obtain high quality cores. Cores were extruded vertically back at the Fort Chipewyan base. Although sectioning on site is the most ideal for preservation of sample integrity, the short daylight hours available and safety considerations made this impractical. Our experience in the previous year showed that transport of the cores by helicopter was smooth and disturbance of the cores was minimal, so we continued with this protocol.

2.2.1 Summary of Samples Collected

Six cores were collected and sectioned from Legend Lake at a site with a water depth of 10 m (Figure 2). Five cores were collected from Weekes Lake at a location that was 32 m deep (Figure 3). All cores were highly organic and "peaty" looking. Colour was dark brown to grey throughout, with a hint of lighter brown colour in the upper sections. Although the surface was fluid and there was no hint that the surface sediment was anoxic, neither was there any fluid brown oxidized layer that is common in sediments from larger lakes which are lower in organic content and higher in mineral composition (Bourbonniere et al., 1986; 1995). Descriptions of the core sections were recorded as they were sectioned and summaries of these descriptions are given in Appendix B.

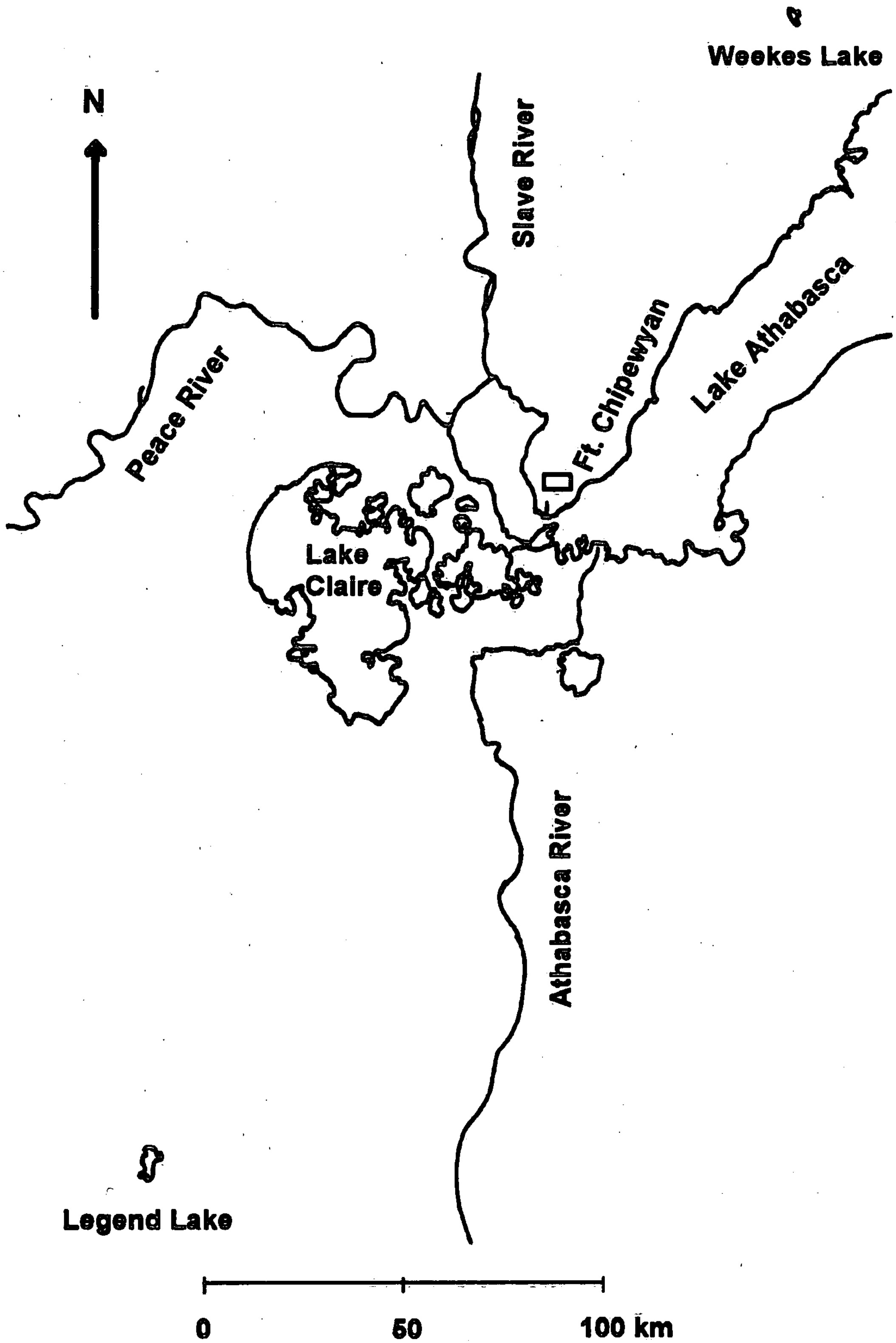


Figure 1: Location Map for Legend and Weekes Lakes.

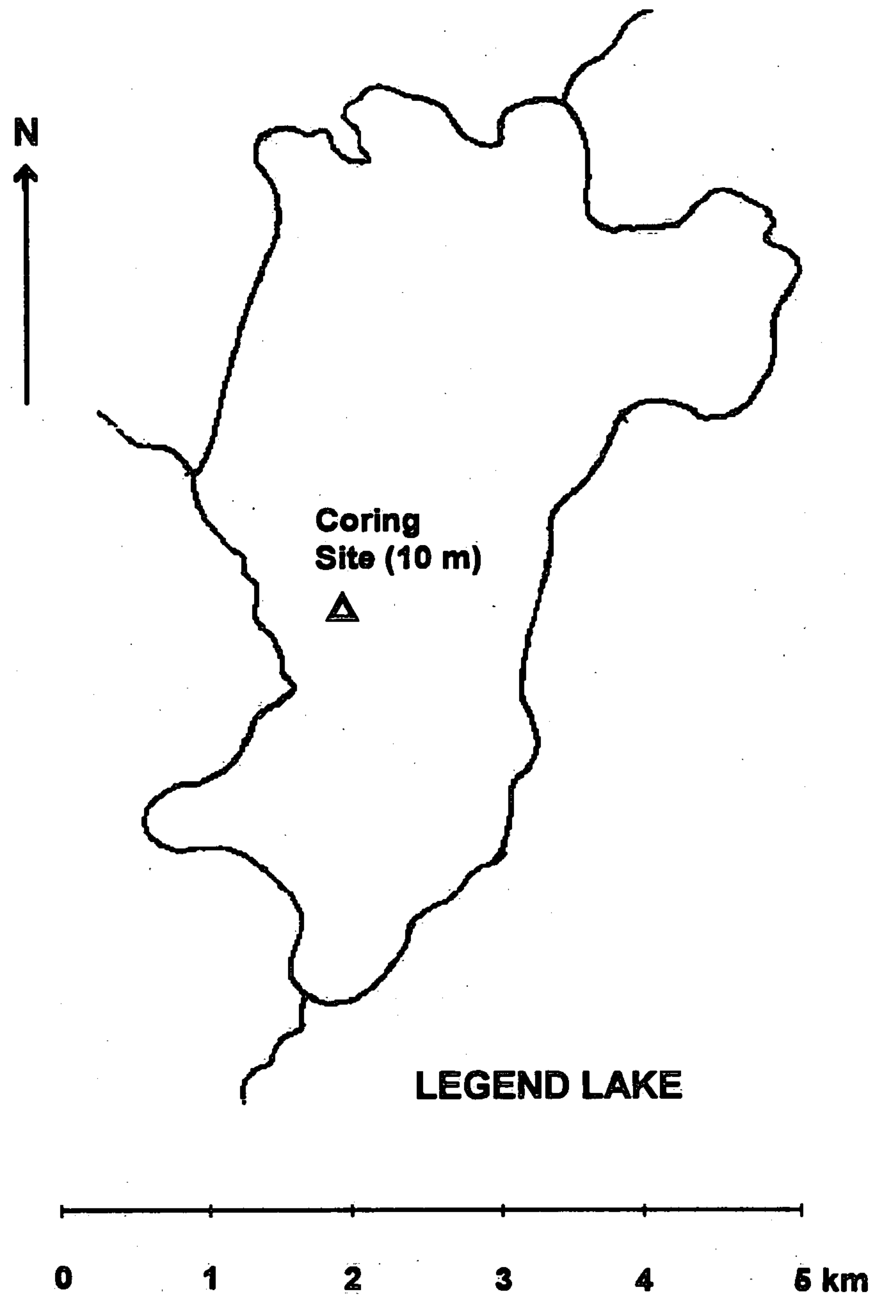


Figure 2: Outline Map of Legend Lake.

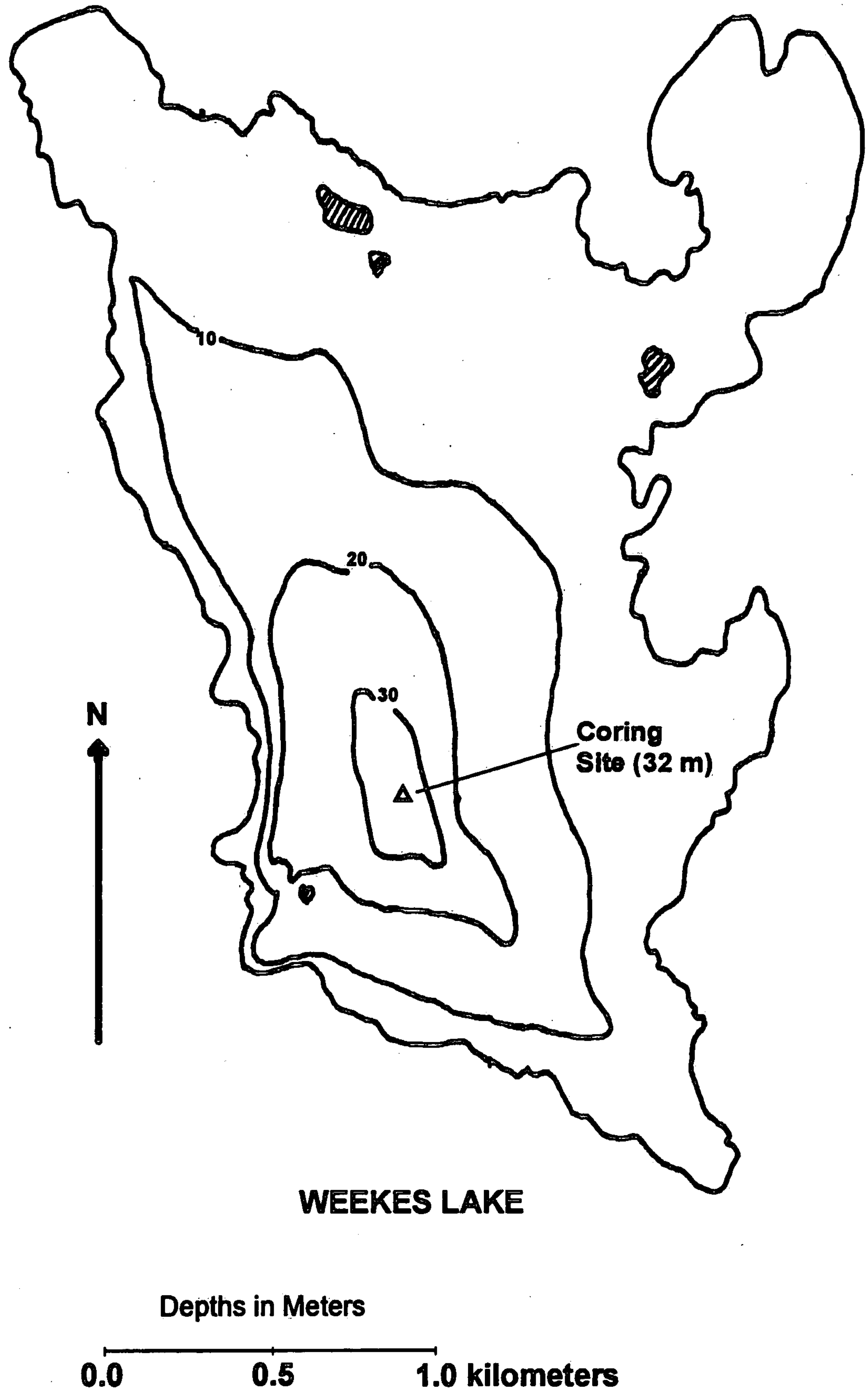


Figure 3: Bathymetric Map of Weekes Lake.

3.0 MATERIAL AND METHODS

3.1 SEDIMENT SAMPLING

Cores were collected from depositional zones using a 10.1 cm ID gravity corer provided by the Technical Operations Division (Mawhinney and Bisutti, 1987) of NWRI. Cores were extruded vertically using an hydraulic device commonly used by NWRI scientists. They were sectioned as follows:

Table 1: Sectioning Intervals Used During Core Extrusion.

Depth Interval (cm)	Section Thickness (cm)
0 - 1	1.0
1 - 12	0.5
12 - 24	1.0
24 - 50	2.0
50 - Btm	5.0

Sediment samples from the entire diameter of the 10.1 cm ID butyrate core tube were stored in wide mouth screw-capped glass jars with Teflon® cap liners. Jars were pre-cleaned and quality-assured by the manufacturer (Eagle-Picher®). Samples were frozen (-20° C.) immediately after sectioning and stored frozen until thawed just prior to analysis, or where appropriate, freeze dried.

3.2 ANALYSES FOR GEOCHRONOLOGY

3.3.1 Po-210 for Pb-210 Geochronology

Determinations for ^{210}Pb geochronology were made under contract at NWRI using the method described by Turner (1990). Po-210, a granddaughter nuclide of ^{210}Pb, is determined as a surrogate after careful preparation, spiking with a known quantity of ^{209}Po, plating on a silver disk, and counting with an alpha spectrometer. Po-209 was identified by its 4.88 MeV alpha particle and ^{210}Po by its 5.305 MeV alpha particle. In addition to Po determinations, the geochronology required porosity and dry bulk density determinations. Dry bulk density (also termed specific gravity) was determined using a Micromeritics multivolume pycnometer, and the results were provided by the contracted laboratory (Turner, 1993a, b).

3.3.2 Cs-137 for Geochronology

Flett Research Ltd. was contracted to determine ^{137}Cs on the same dry core samples that were used for ^{210}Pb geochronology. Activity of ^{137}Cs was determined by non-destructive gamma counting on a 3" x 3" NaI(Tl) detector for Legend Lake Core E. The counting period was generally 48 hours or longer over weekend periods. Due to small sample sizes, the dry sediment from Weekes Lake Core A was counted for 24 hours or more on a 29% PGT Ge(Li) detector.

3.3 ANALYSES FOR PARTICLE SIZE DISTRIBUTION

Particle sizes were determined by the Sedimentology Laboratory at NWRI using the Sieve and Sedigraph Method (Duncan and LaHaie, 1979). The freeze-dried samples are quantitatively split, dispersed in sodium metaphosphate and wet sieved at 4.0 PHI (0.063 mm). The sand and gravel percentages are determined gravimetrically on the dried contents of the sieve. The remaining suspension is applied to the Sedigraph Analyzer to obtain the distribution of silt and clay sized particles. Results are reported as percentages of various size fractions and several statistical measures (Duncan, 1994).

3.4 ANALYSES FOR BULK C & N SPECIES

Bulk determinations C and N species are made at the National Laboratory for Environmental Testing (NLET) at NWRI using a CHN analyzer at 950° C. An aliquot of the freeze-dried total sediment sample is combusted in the presence of CoO catalyst, measuring the resulting combustion gases (CO_2 and NO_x, which is reduced to N_2) chromatographically. The results are "total carbon" and "total nitrogen". Another aliquot is treated with hydrochloric acid to remove inorganic carbon, dried and combusted as before. The results of the second run are total organic carbon (TOC) and "total organic nitrogen" (TON). Total inorganic carbon (TIC) is determined by difference (total carbon - TOC). There is a potential interference in the TON determination due to hydrolysis effects on certain organic components of the sediments. The atomic C/N ratio of the organic matter is calculated by dividing the TOC and TON results expressed as mg-atoms.

3.5 DETECTION LIMITS AND QA/QC

3.5.1 Detection Limits

We have depended on the laboratories to report data with their appropriate detection limits. For all of the data presented in this report, laboratories reported either observed values or values as "< MDL", where MDL represents the "Method Detection Limit". As a rule data reported here are above detection limits. However, in some cases a data set contains several values that are at or below detection limits. Whenever such a situation arises, we have chosen to plot "ND" values as equal to the MDL rather than as zero. In the case of ^{137}Cs it is indeed possible and expected to obtain true zero activity at depth in a core, so such values are plotted for this parameter.

3.5.2 QA/QC

Contract laboratories which performed the analyses reported here have passed a certification exercise prescribed by NRBS. Certification was under the control of the Quality Assurance Working Group, and labs were certified only for specific parameters on specified media (sediments in this case). As well many of the labs used hold accreditation from other private sector organizations.

Each laboratory has its own internal, or commonly used certified "standard" references. Good laboratory practice requires that every batch of samples be accompanied by runs of certified references. In most cases laboratories report these results along with the contracted analyses so that the client can have confidence in their work. Depending upon the parameter and the method chosen, surrogate or internal standards, recovery spikes and blank determinations are commonly used. Wherever sample size allowed it, we included blind replicates in batches of samples so that we could get our own feeling for quality control. Whenever this was done, average values appear in this report.

Blank subtraction is commonly used in some determinations as a routine part of a particular instrumental technique. Here we assume that laboratories have applied appropriate instrumental corrections to the data before it is reported. However, this does not extend to "blank samples" or "method blanks". Such determinations are frequently reported as separate determinations, and are also frequently nil or small. If a significant blank value is routinely encountered, then either the sample data are discarded, or if a correction can be (or has been) made, then such is reported.

4.0 RESULTS AND DISCUSSION

4.1 GEOCHRONOLOGY

For any results from core studies of contaminants and biogeochemical markers to be interpretable, the sediment cores must be dated. For this study the "proving" of each site by ^{210}Pb geochronology was the first step taken after collection. The geochronology serves to put a time scale upon the core profile so that each section can be assigned an approximate deposition date. The profiles of ^{210}Pb and other radionuclides used in geochronology (e.g. ^{137}Cs) not only provide data for producing a time scale, but also yield information about the continuity of deposition. Both of these are important considerations if one is to make accurate judgements about temporal trends in contaminant inputs or degradation. The ^{210}Pb method was chosen as the first method to use because it was readily available at NWRI, more straightforward in most cases than ^{137}Cs, gives better accuracy for dates greater than 40 years (up to about 100-150 years) and discontinuities in deposition or changes in sedimentation rates can be readily identified. Subsequent analyses of the same cores for ^{137}Cs yields profiles which can be used to check on the accuracy of the ^{210}Pb geochronology.

As discussed in a previous section multiple cores were taken from each lake. Ideally, it would be best to date every core but that is impractical, expensive and time consuming. As well, some of the processing required for radionuclide determinations could compromise the utility of samples for other parameters. Here we dated a single core from each lake, and used selected sections from a second core from Legend Lake. For parallelism among the replicate cores we must rely on the descriptions which appear in Appendix B and some replicate determinations. Generally it is assumed here that replicate cores are sufficiently parallel that the geochronology developed for one core can be applied to all cores from the same lake. Deviations from core to core have been observed in the range of 1-2 cm.

One core from each lake was processed for determination of ^{210}Po by the geochronology laboratory at NWRI. This isotope is the granddaughter nuclide of ^{210}Pb and is determined by alpha counting. Details of the methodology, including assumptions, quality control, calculations and ancillary measurements are given in Turner (1993a, b). The theory of ^{210}Pb dating has been discussed in many publications (e.g. Robbins and Edgington, 1975; Matsumoto, 1975; Robbins, 1978; Farmer, 1978) and will not be repeated here. The method used by Turner (1993a, b) is patterned closely to that of Matsumoto (1975) and assumes that the concentration of ^{210}Pb on the particles settling to the bottom of the lake remains constant, the CIC model.

The same core that was used for ^{210}Pb geochronology was also used for ^{137}Cs geochronology. Cs-137 is a tracer of the input of atmospheric fallout from nuclear testing and has a well described source function dependent on the frequency of atmospheric testing (Robbins and Edgington,1975). The distribution of ^{137}Cs, when plotted against deposition dates generated from ^{210}Pb distributions, can give independent evidence to confirm or qualify the ^{210}Pb geochronology.

4.1.1 Legend Lake

4.1.1.1 Pb-210 geochronology. Core E was selected for dating and was processed in the normal manner. The total ^{210}Pb profile from this core was anomalous in the upper sections, and could not be fitted to the normal model used by the geochronology lab, so before reverting to a different model, selected sections of another core (Core B) were analyzed for ^{210}Po activity to confirm the shape of the profile from Core E. The resulting profiles are compared in Figure 4a where total ^{210}Po activity is plotted against depth in the core. The validity of the measurements for the upper sections from Core E were confirmed, and analysis indicated that Core E contains layers with two different sedimentation rates. The lower sections of Core B gave higher values than the corresponding depths from Core E. These Core B results suggest that the high sedimentation rate found for the upper part of Core E continues deeper in Core B, but more importantly they violate the assumption of parallelism among the cores from this lake. This is a serious concern.

As a test the data from Core E were treated as two separate cores one over the other with an inflection at the junction. The upper section was treated in the normal way for the geochronology lab (Turner 1993b; Matsumoto, 1975), i.e. the assumption of constant initial concentration and constant sedimentation rate (CIC model). The linear sedimentation rate based on "uncompacted depth" (Delorme, 1991) was used to assign dates to the upper 6.5 cm ("natural depth") of the core. The lower part of the core was treated as if it had been collected before the upper 6.5 cm had deposited over it (i.e. in 1982). It was assumed that the "lower core" would have exhibited the same initial porosity as the current conditions which exist for the "upper core" and the calculation was carried on as usual from there. The dates assigned to the "lower core" were takes as "years before 1982" using (lower) linear sedimentation rate and the "uncompacted depth". All of this is explained with an admonition of caution in the use of these data in Turner (1993b).

4.1.1.2 Concern over dual sedimentation rates and parallelism. Whenever the geochronology of a core indicates a change in sedimentation rate, then there is always concern whether the core has actually recorded continuous deposition in time. Has there been an erosional event recorded which confounds the geochronology? What is the possibility that apparent discontinuities result from coring artifacts (cf. Anderson et al., 1987)? To assist in discerning if erosion is the cause of the discontinuity rather than a change in sedimentation rate as modelled above, the other parameters which were determined in the cores from the same lake are considered. In this section the remaining parameters that were used in determining the geochronology are presented, and other bulk parameters which may have a bearing on this concern will be presented in Sections 4.2 and 4.3.

4.1.1.3 Cs-137 geochronology. Cs-137 activities for Core E are plotted against core depth in Figure 4b. The distribution with depth indicated is difficult to reconcile with the known source function (Robbins and Edgington, 1975). The high and nearly constant values for the upper six centimetres could have arisen from postdepositional mixing caused by physical or biological mechanisms, or due to friction effects during coring. The gradual increase from 5-20 dpm/g moving up core from nine to six centimetres could arise from displacement of sediment from the upper layers downward during coring. Such smearing is more likely with the high porosity and highly organic sediments found in Legend Lake. A comparison of the ^{137}Cs results within the context of ^{210}Pb geochronology appears in 4.1.3.

4.1.1.4 Specific gravity and porosity. Specific gravity was measured on a subset of the sections of Core E for use in geochronological modelling. Although only 11 sections were chosen, one of them (4.5-5 cm) appears significantly higher than the rest (Figure 5a), but that section is in the layer of the core represented by the higher modern sedimentation rate (Turner, 1993b). If this section has a specific gravity which is typical of several of the following sections, then concern over whether

Figure 4: Total Po-210 and Cs-137 Activities in Legend Lake Cores.

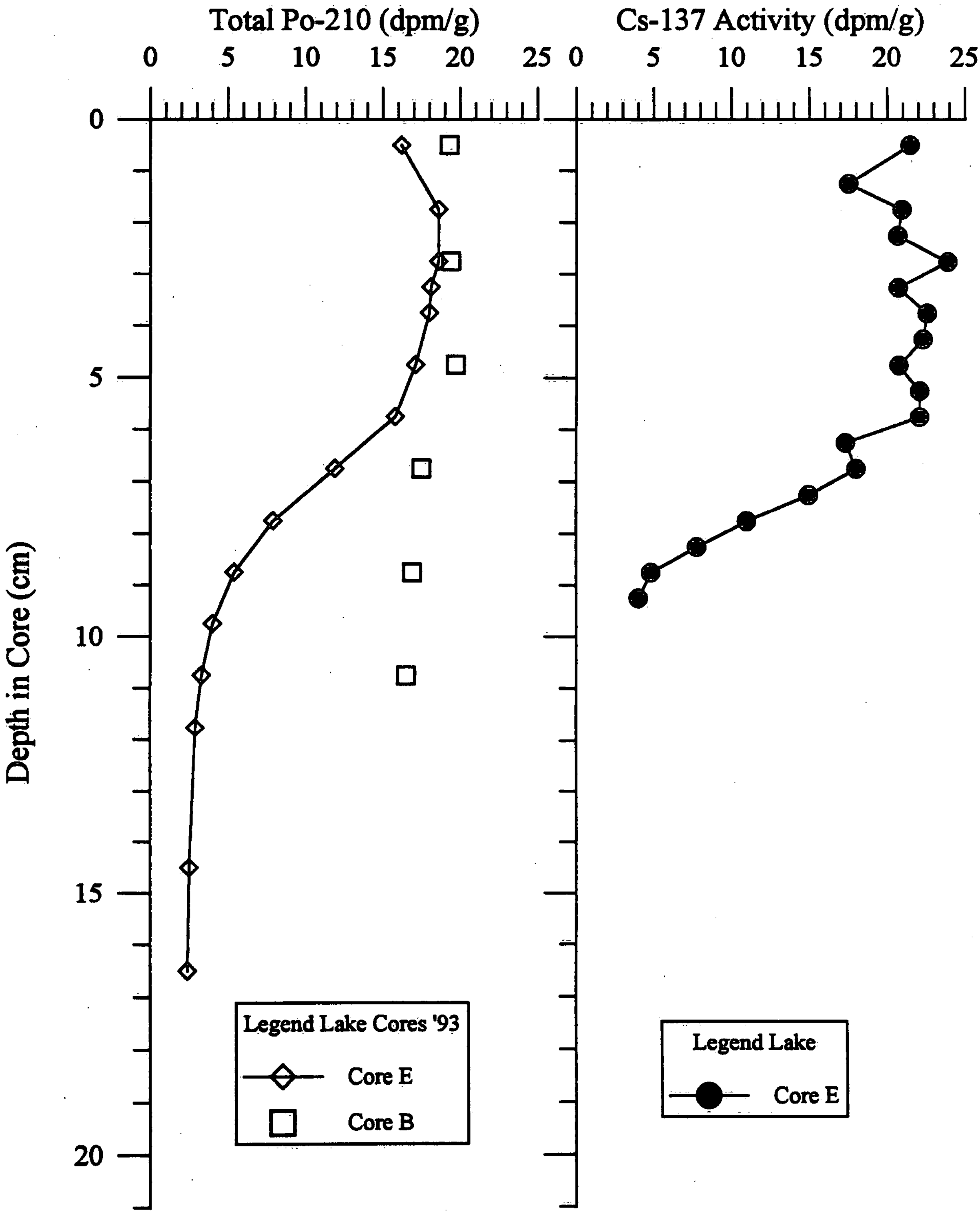
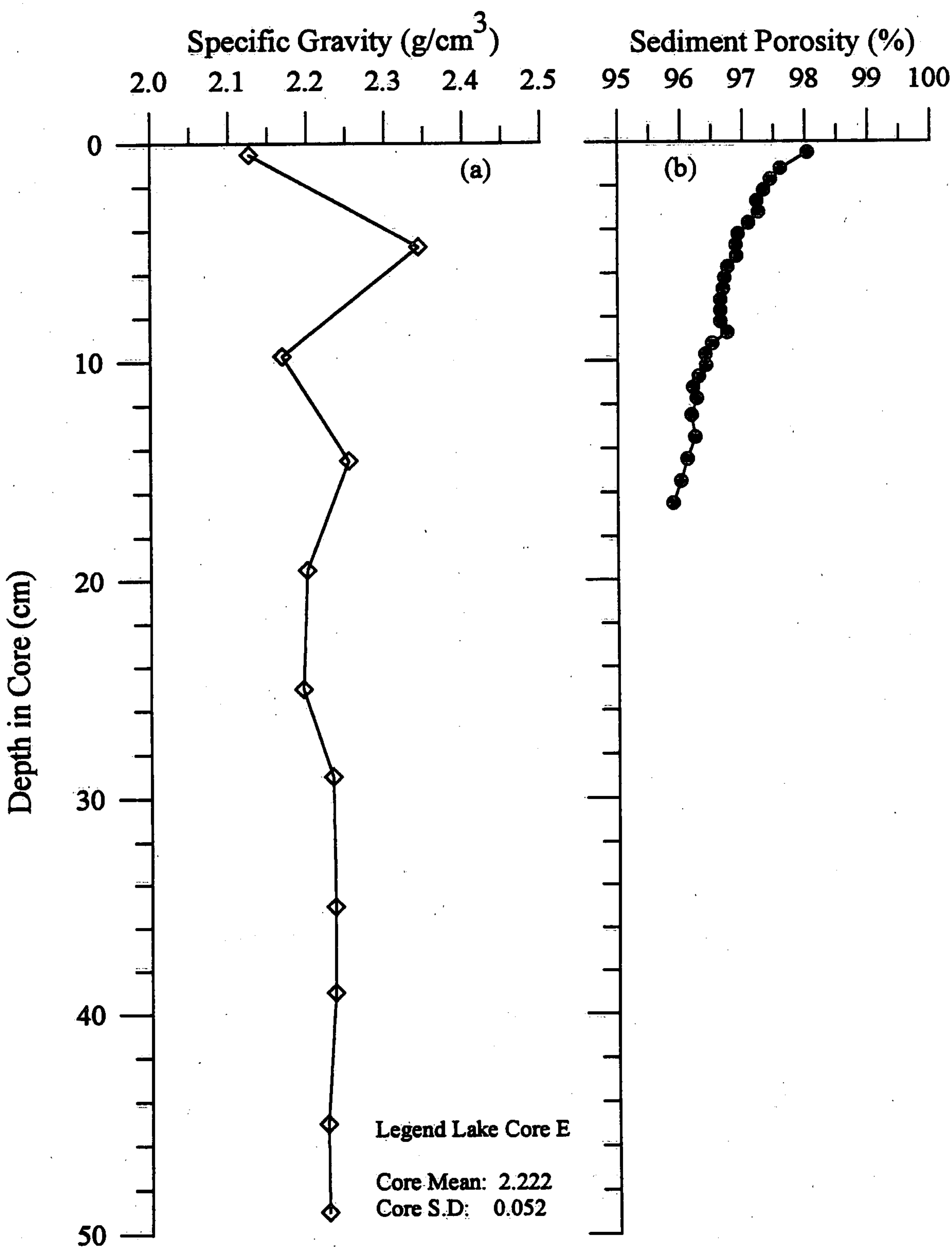


Figure 5: Specific Gravity and Porosity - Legend Lake Core E.



the discontinuity was caused by more than a change in sedimentation rate is warranted. Sediment porosity calculated for Core E from gravimetric data and the average specific gravity exhibits a fairly smooth curve with no evidence of the discontinuity (Figure 5b).

4.1.2 Weekes Lake

4.1.2.1 Pb-210 geochronology. Core A was processed for dating as usual by the ^{210}Pb method (Turner, 1993a). The ^{210}Po activity profile was as expected for a lake which has undergone continuous sedimentation in the past 100 years (Figure 6a). The geochronology was modelled by the usual methods used at the NWRI Geochronology Lab (the CIC model) using linear sedimentation rates based on "uncompacted depth" for assignment of ages to sediment sections (Turner, 1993a). A summary of the geochronology parameters appears in Table 2.

4.1.2.2 Cs-137 geochronology. The same sediment from Core A used above was also submitted for ^{137}Cs determinations. Results of these analyses are plotted against core depth in Figure 6b. The depth profile is consistent with the interpretation that this site has a low sedimentation rate and that there is a horizon below which no ^{137}Cs was transported to the sediment. The gradual downcore decrease in ^{137}Cs activity in the upper two centimetres could be a result of several processes - a modern source input, diffusion, bioturbation or coring effects. These will be revisited when the ^{137}Cs activity is put in the context of the ^{210}Pb geochronology below.

4.1.2.3 Specific gravity and porosity. Specific gravity was measured as part of the geochronology method and a profile appears in Figure 7a. Sediment from this lake exhibits a specific gravity which is lower than cores from larger lakes probably reflecting the higher organic matter content of the sediments. The profile varies more regularly than that from Legend Core E (Figure 5a), and would not be judged anomalous from these data alone. The sediment porosity profile for Weekes Core A is shown in Figure 7b and is reasonably smooth except for a single section at ten cm depth.

4.1.3 Age-Depth Relationships

Table 2 contains a summary of the geochronology parameters used to assign a time series to each core. A graphical`presentation of the last 100 or so years of each core is given in Figure 8. The curves represent the time scales that the remainder of age related data will be plotted against. The depositional dates assigned for Legend Lake were those from the two sedimentation rate analysis described above.

4.1.4 Cs-137 Activity in the Pb-210 Geochronology Context

Cs-137 and ^{210}Pb have independent source functions and their distributions in the sediments are controlled by some different processes. Pb-210 is the preferred dating method for the purposes of the intended work because it is reliable down to 100 years. The distributions of ^{137}Cs, when plotted against ^{210}Pb assigned dates, can serve to confirm the geochronology. The onset of atmospheric testing of nuclear weapons resulted in the first measurable flux of fallout around 1953-1954. This horizon should correspond to the deepest occurrence of ^{137}Cs in a core. The greatest frequency of testing occurred around 1963, and this date should correspond to the maximum ^{137}Cs activity in a

Figure 6: Total Po-210 and Cs-137 Activities - Weekes Lake Core A.

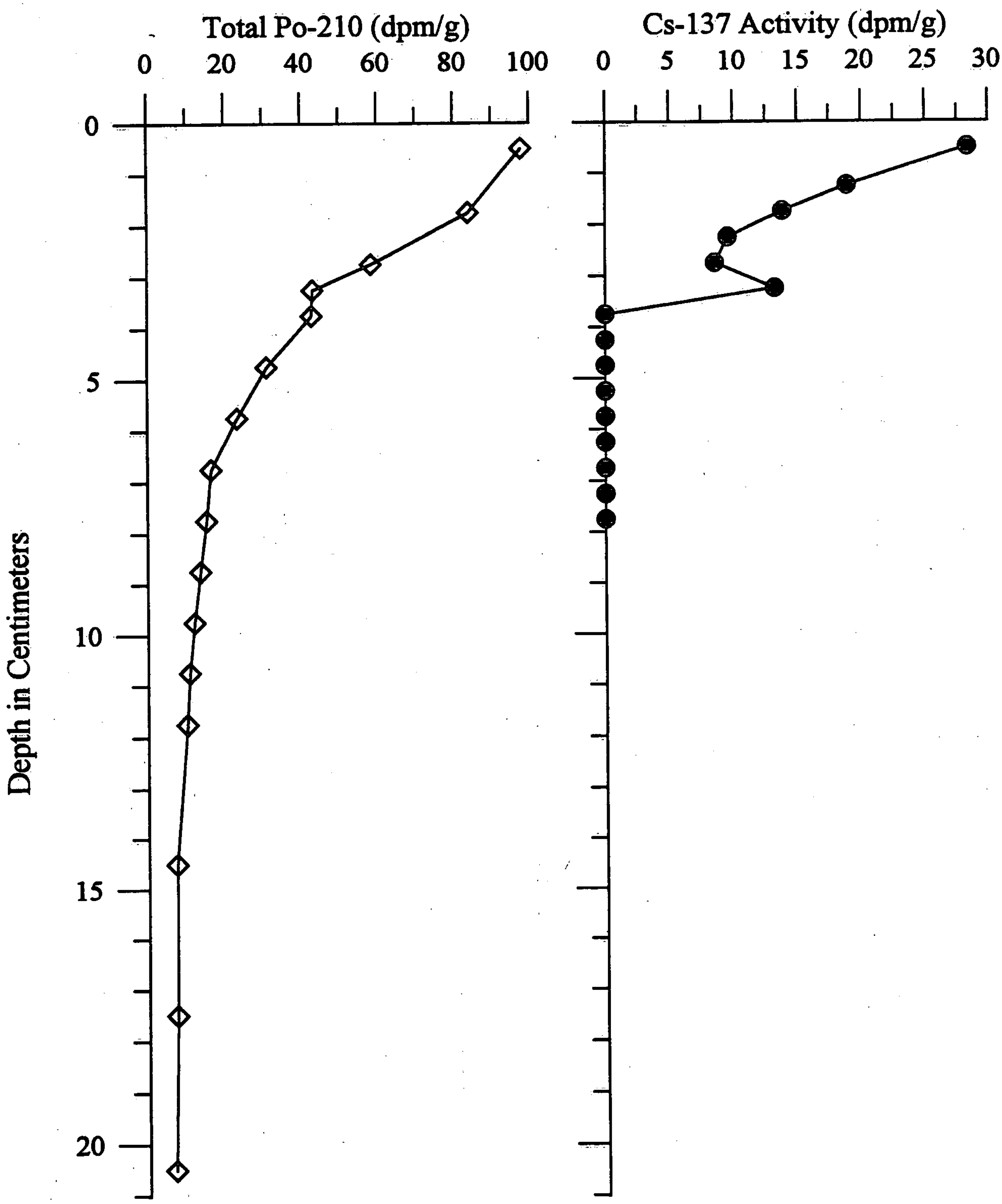


Figure 7: Specific Gravity and Porosity - Weekes Lake Core A.

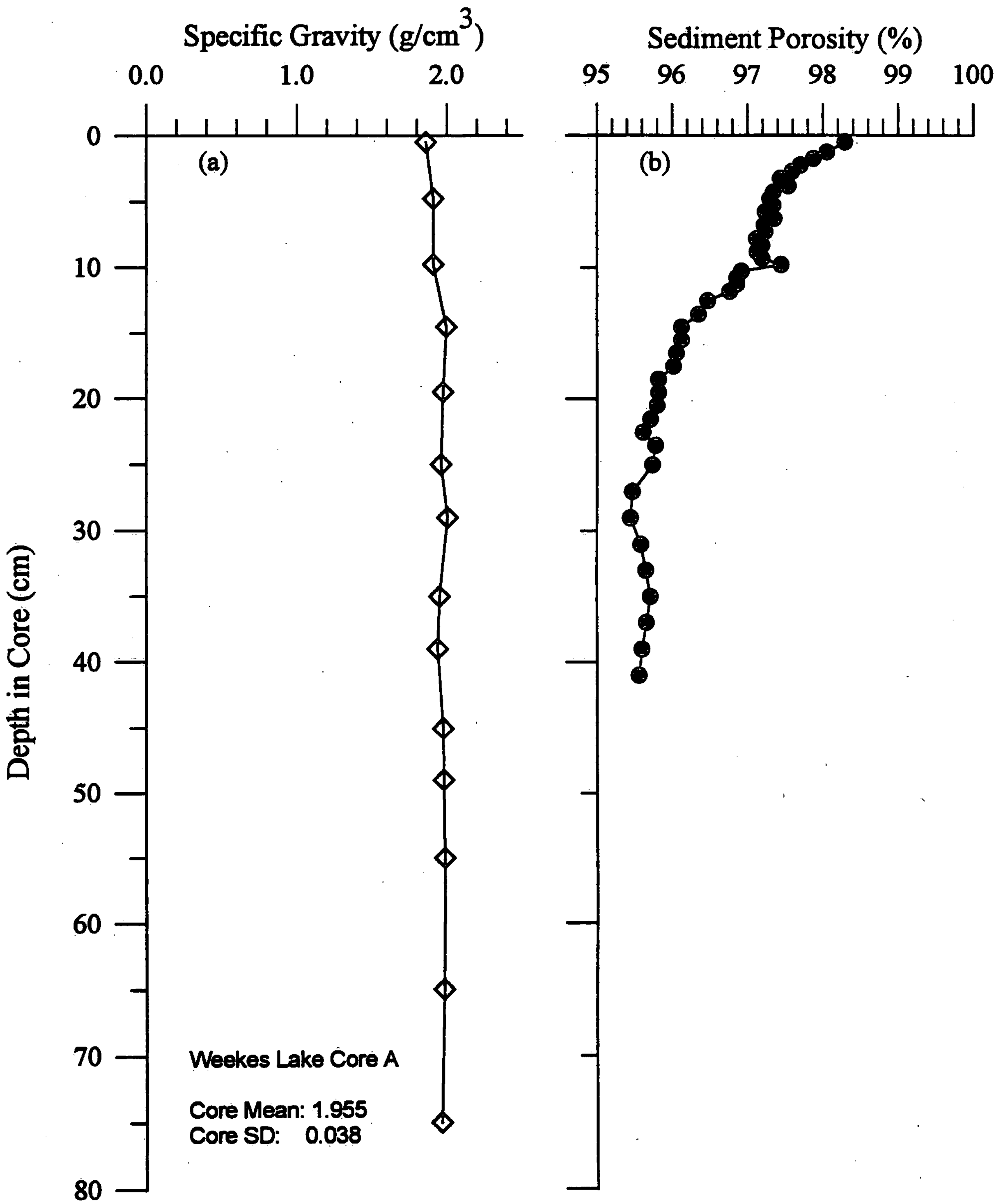
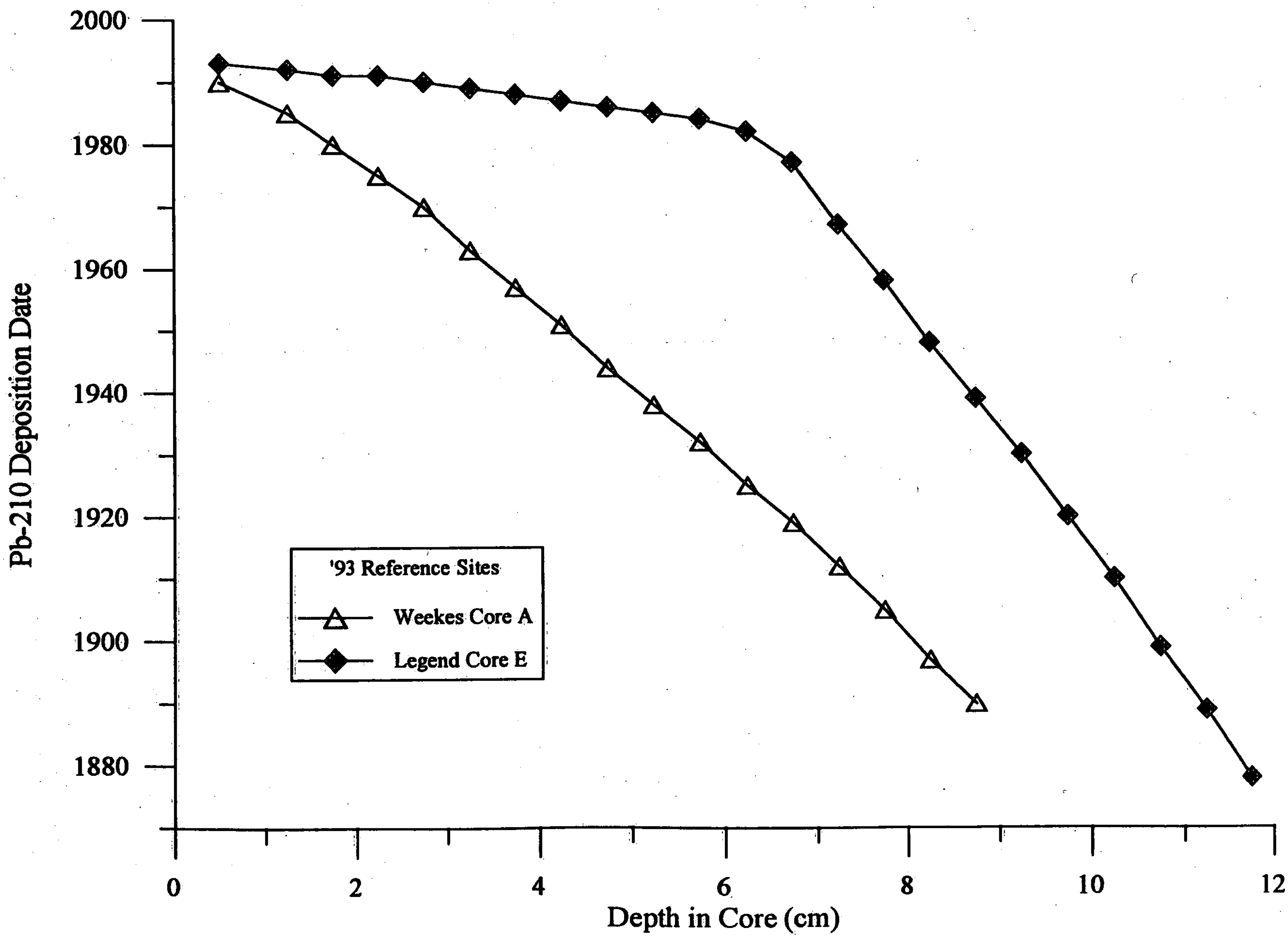


Figure 8: Age vs. Depth Plots for Reference Sites. Depths are plotted against deposition date according to Pb-210 geochronology. See text for explanation, especially for Legend Lake.



core (Robbins and Edgington, 1975). There were also increased activities corresponding to testing in the late 1970s (J.A. Robbins, pers. comm.) and the most recent input corresponds to the Chernobyl power plant accident (Joshi et al., 1989).

Table 2: Sedimentation Rate Parameters. Measured, calculated and derived parameters for two cores after application of the Pb-210 dating method[a].

Core Date and Location	Initial Porosity %	[b]Specific Gravity g/cm^3	[c]Mass Sed. Rate $g/cm^2/yr$	[d]Linear Sed. Rate cm/yr	[d]Time Resolution yr/cm	Depth to 100 years cm
'93 Legend E upper	98.45	2.222	0.053	0.59	1.7	---
Legend E lower	98.45	2.222	0.007	0.05	19	11
'93 Weekes A	98.67	1.955	0.006	0.09	11	8.7

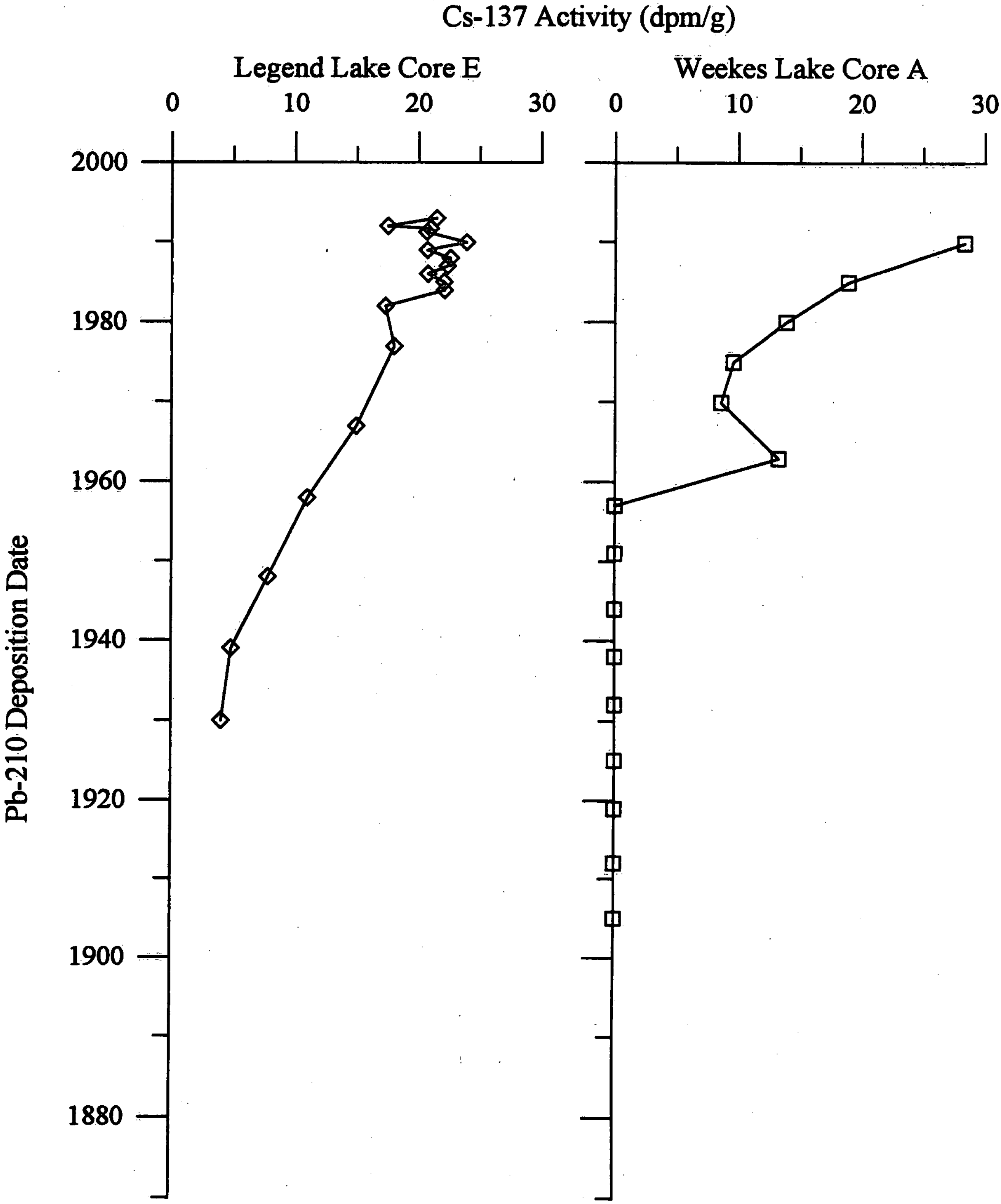
[a]Source Turner (1993a, b)
[b]Averaged from 11 and 14 samples respectively representing the entire length of each core
[c]From top of core, assumed constant throughout by CIC model, see text for special treatment of Legend Lake Core E (upper/lower)
[d]Averaged over 100 years of sedimentation, uncorrected for compaction, 11 years for Legend upper

Figure 9a shows the ^{137}Cs distribution from Legend Lake Core E plotted against the deposition date determined by ^{210}Pb geochronology - two rate model (Figure 8). Cs-137 activity is evident at depths purportedly corresponding to 1930, 25 years before expected. Activity increases steadily from layers assigned a date of 1940 up to one assigned to 1980, with no suggestion of a peak around 1963. The highest activities occur in a cluster corresponding to the last decade. This distribution of ^{137}Cs in no way correlates with the expected distribution, suggesting strongly that the ^{210}Pb assigned dates are grossly in error.

The ^{137}Cs distribution in Weekes Lake Core A is shown in Figure 9b plotted against ^{210}Pb assigned dates. These results agree more with the expected distribution. The onset of activity could be as early as 1958 with zero values below that layer. A peak is evident at a depth corresponding to 1963 with decreased activity in the early 1970s. Cs-137 activity increased slightly at a depth assigned to the late 1970s and continues to increase progressively for the depths corresponding to the last decade. This final trend is not predicted, but has occurred in several other cores from small lakes in the Experimental Lakes Area of northern Ontario (Anderson et al., 1987). It is possible that a signal from Chernobyl could have diffused upwards and may have undergone downward smearing during coring and extrusion of this high porosity sediment.

The Legend Lake results, especially when considered in addition to the lack of parallelism discussed previously, strongly argue against the use of cores from this lake for depositional history studies where dating confidence is required. On the contrary, the Weekes Lake geochronology results are much more favourable. Correspondence between the ^{210}Pb and ^{137}Cs results for Core A is sufficient to give credence to the depositional dates assigned and illustrated in Figure 8.

Figure 9: Cs-137 Activity Plotted Against Pb-210 Dates. Legend and Weekes Lakes.



The remaining data to be presented in this report will be presented against the assigned dates for Weekes Lake with confidence. Even though the dates assigned to Legend Lake lack such confidence, they will be used for plotting the remaining data. Readers must know that the only thing certain for the Legend Lake cores is the order of deposition - youngest to the top and oldest to the bottom of the core.

4.2 PARTICLE SIZE ANALYSIS

Three cores were analyzed for particle size distribution. Core A from Legend Lake was clay or silty clay throughout, the mean particle size varying between 2.5 and 5.5 µm over 50 cm of core length. The mean particle size shows a very slight increasing trend from the bottom to the top of the core and that trend is also shown for the past 100 years, where the mean size ranges from 3.5 to 4.5 µm (Figure 10).

Legend Lake Core F (Figure 11) is similar in overall texture (silty clay) to Core A except that the mean particle sizes are higher than that core (Figure 11b). The mean size shows a general increase from bottom to top, with a pronounced drop to less than 1.5 µm at the 5-7 cm interval. This depth corresponds to the inflection point found for ^{210}Po activity in Core E. These two cores look pretty much the same in overall texture (clay and silty clay) but their mean particle sizes are slightly different and one shows a significant discontinuity.

The texture of Weekes Lake Core B is more variable over its entire length than were either of the two Legend Lake cores. It is overall coarser (Figure 12) at the lower portion (silty clay to clayey silt) and becomes finer at the top (silty clay to clay). A progressive increase in the clay content is evident from about 45 cm up to the top (Figure 12a) and this is also evident in the upper 25 cm where the mean particle size decreases towards the surface (Figure 12b). It was at 25 cm where the porosity increased in slope towards the surface (Figure 7b), and this is in agreement with the increased clay content. Unfortunately the resolution of the particle size data with respect to time does not allow much to be said for the past 100 years.

4.3 BULK C & N SPECIES

The same two cores that were used for dating, were also sent for TOC, TON and TIC analysis. The highly organic nature of these cores was confirmed by the very high TOC values found. TIC was low or non detectable (MDL = 0.1 mg/g) for most sections of both cores and will not be discussed further.

TOC, TON and atomic C/N profiles are shown for Legend Lake Core E in Figure 13. TOC drops from a value of about 170 mg/g at the surface to about 140 mg/g at the purported 1950 level and remains relatively constant below that level. There is no evidence in the TOC data that the discontinuity was particularly important.

The TON profile (Figure 13b) shows a distinct discontinuity at the 1982 inflection point. The upper portion is generally 1-3 mg/g higher in TON than the layers laid down earlier than 1982. This discontinuity does not necessarily indicate an erosional feature however since it is consistent also

Figure 10: Legend Lake '93 Core A Particle Size. Relative composition of clay, silt and sand size particles, and mean particle size in sediment from Core A sampled in 1993. Composition is plotted against intervals sampled and mean particle size against mid depth of the interval.

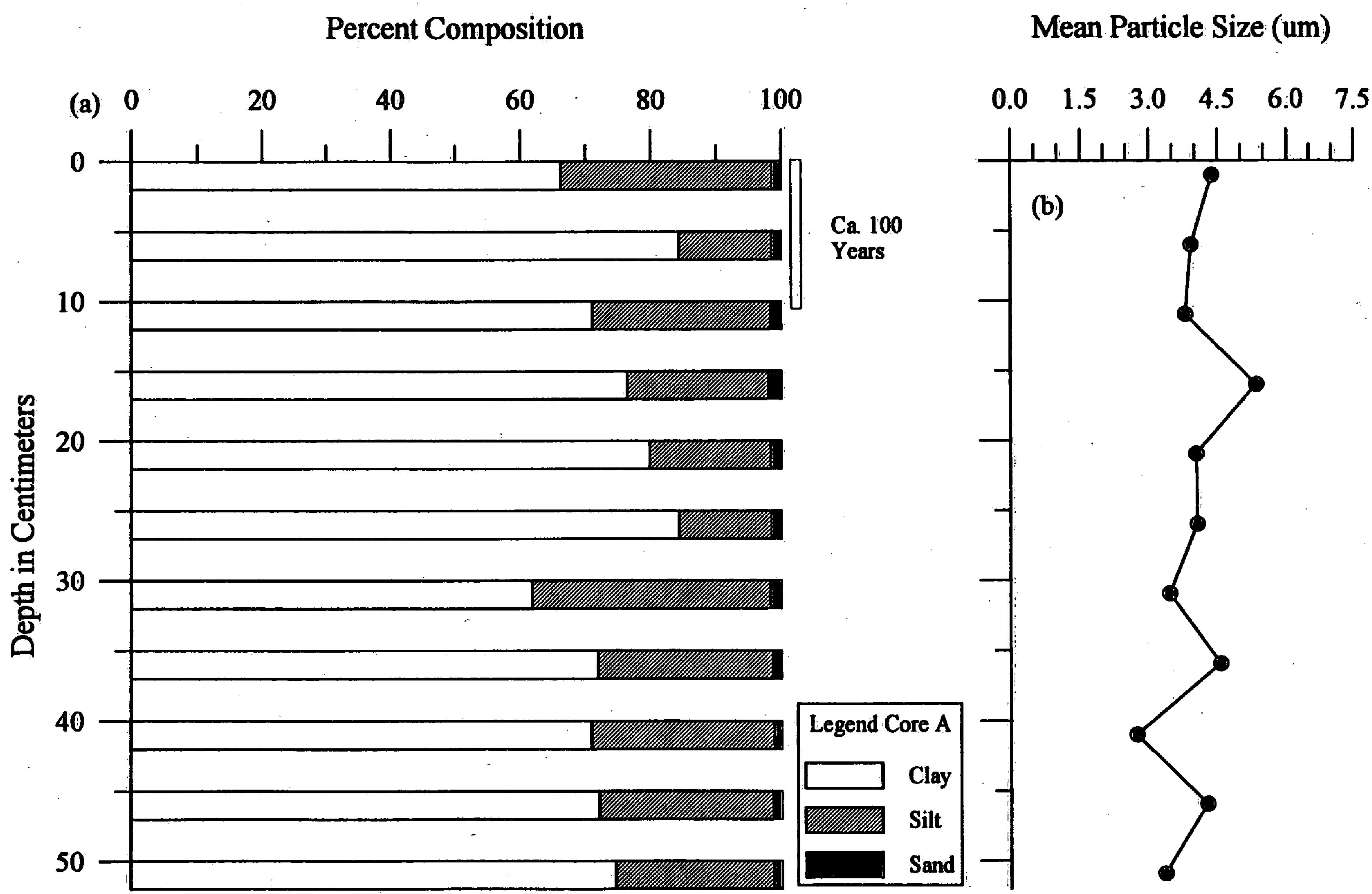


Figure 11: Legend Lake '93 Core F Particle Size. Relative composition of clay, silt and sand size particles, and mean particle size in sediment from Core F sampled in 1993. Composition is plotted against intervals sampled and mean particle size against mid depth of the interval.

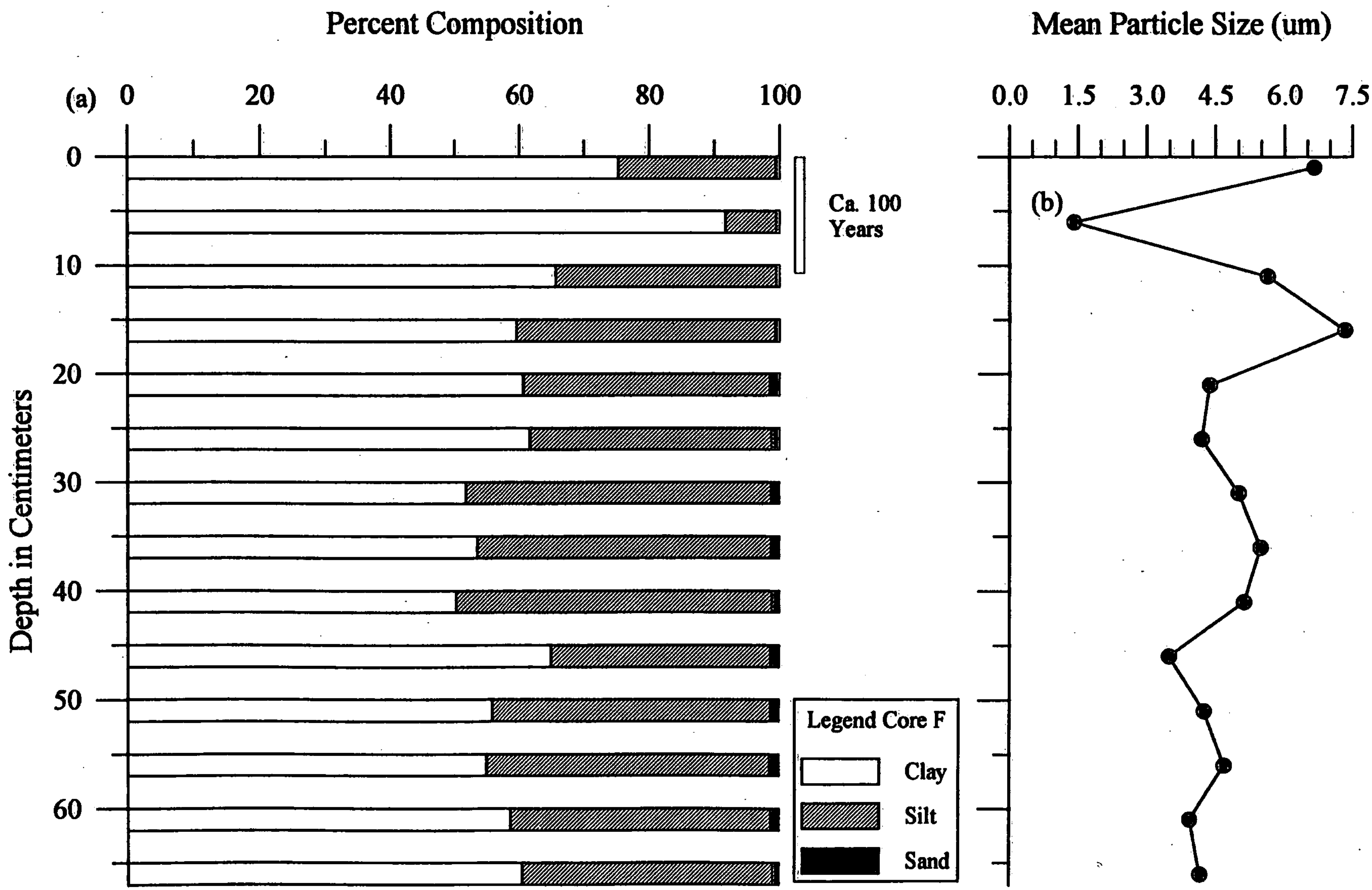


Figure 12: Weekes Lake '93 Core B Particle Size. Relative composition of clay, silt and sand size particles, and mean particle size in sediment from Core B sampled in 1993. Composition is plotted against intervals sampled and mean particle size against mid depth of the interval.

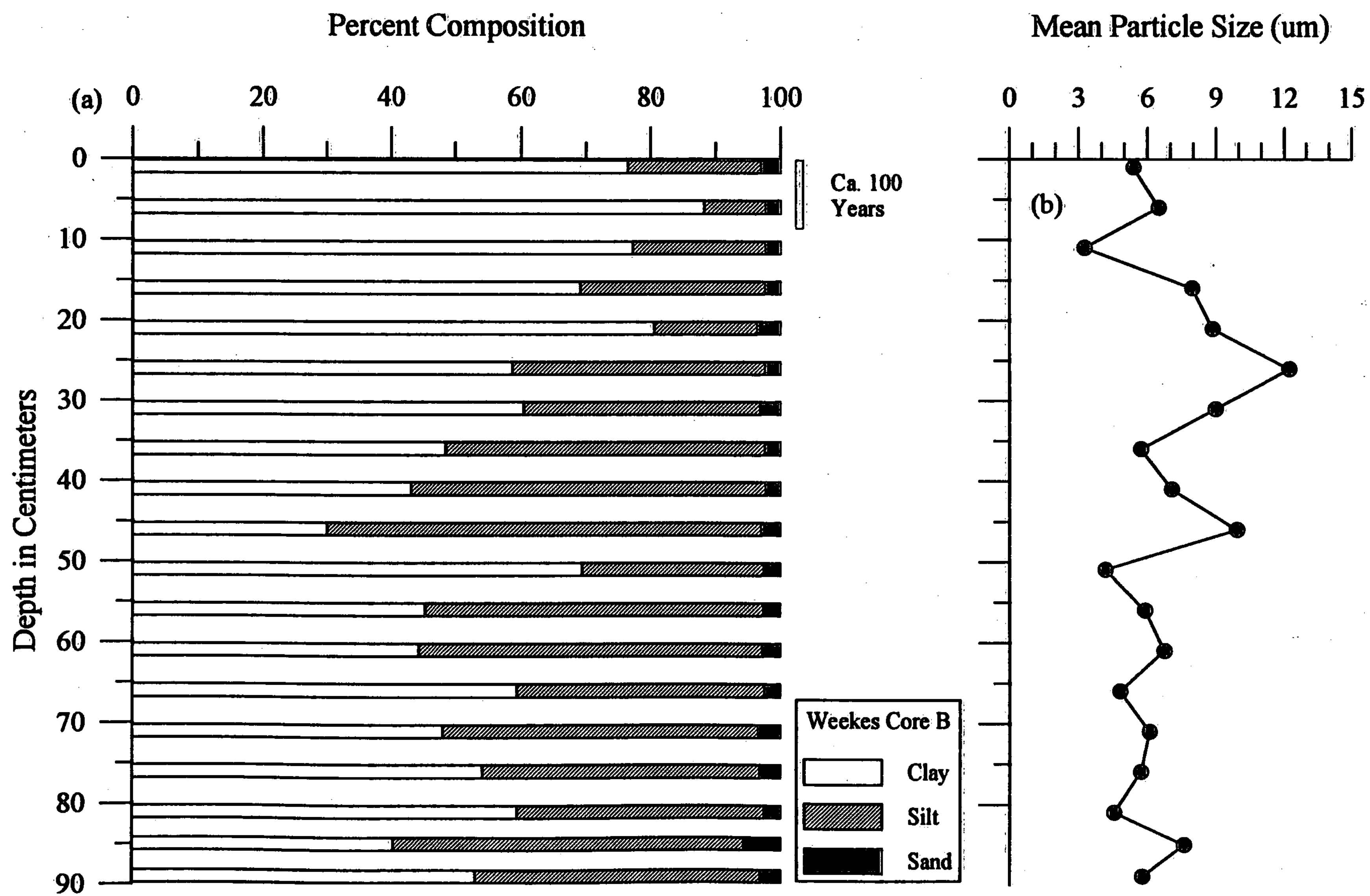
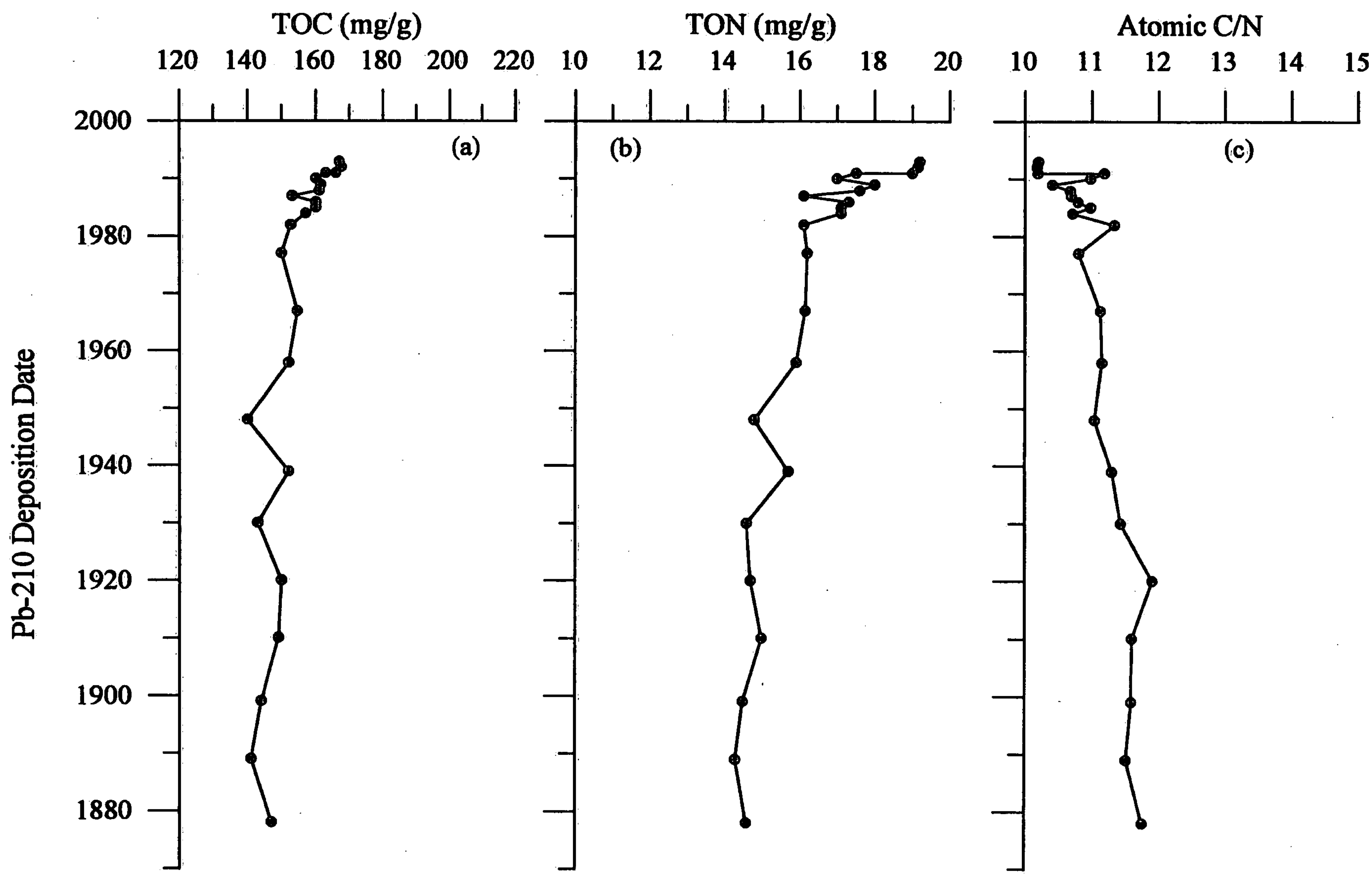


Figure 13: Legend Lake '93 Core E, TOC, TON and Atomic C/N. The date axis is tentative for this lake (see discussion).



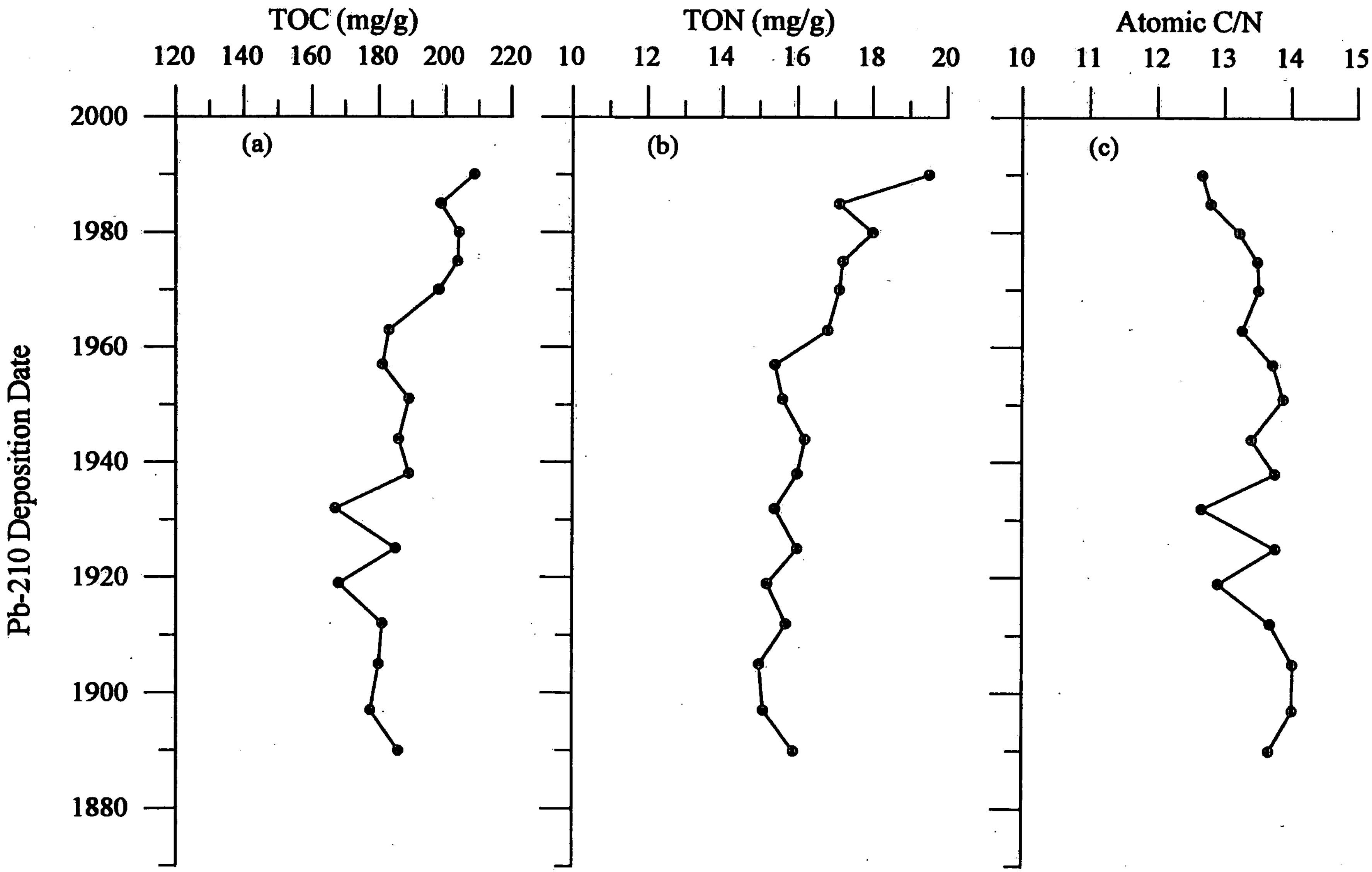
with an increased sedimentation rate. Bulk organic nitrogen is much more labile than organic carbon, and is frequently higher at the top portions of a sediment column (Meyers and Ishiwatari, 1993). If the inflection in sedimentation rate is the correct interpretation for this core then there was a ten-fold increase in linear rate (Table 2), a change that could have resulted in preservation of TON.

The atomic C/N profile (Figure 13c) is of course made up of data from TOC and TON and shows an intermediate profile. The general trend towards the present from the purported date of 1920 is a decreasing one and the slope crosses the discontinuity more or less unchanged.

The Weekes Lake bulk C & N data are shown graphically in Figure 14. Again TIC was low or ND for this core. The TOC at Weekes lake is even higher than for Legend, and about an order of magnitude higher than that found in Lake Athabasca sediments (Bourbonniere et al., 1995). The profile for TOC (Figure 14a) decreases from the present value of about 210 mg/g down to 170 mg/g at the 1930 level. The TON profile also shows a considerable decrease from 19.5 to 15 mg/g from the present back to 1960, and remains constant below that.

The atomic C/N ratio is generally higher between 13 and 14 for sediment sections representing the past 50 years. These values hint at a greater proportion of terrestrially sourced material to this lake than that for Legend. The increasing trend back towards the past is typical and suggests that TON is lost by degradation at a faster rate than TOC. This is reasonable when the proteinaceous nature of TON is considered (Meyers and Ishiwatari, 1993).

Figure 14: Weekes Lake '93 Core A, TOC, TON and Atomic C/N.



5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 GEOCHRONOLOGY

As discussed at length in Section 4 the Legend Lake geochronology assigned by the two sedimentation rate model is suspect. Cs-137 data yield the strongest evidence that Core E was suspect, and the lack of agreement between Cores B and E from Legend Lake for their ^{210}Pb profile also is damaging. The utility of the bulk parameters (specific gravity, porosity, particle size, texture, TOC, TON and C/N) varied somewhat in their ability to assist in deciding whether or not to believe the dual sedimentation rate hypothesis.

Since it was the bulk organic matter character (TOC, TON and C/N) which was on balance the most convincing evidence for confirming the dual sedimentation rate hypothesis, then it would be useful to run biogeochemical marker analyses for n-alkanes and fatty acids. These usually vary continuously and should be sensitive to major character changes. For expensive contaminant analyses, where dates are important to the ultimate interpretation, Legend Lake should not be used as a core.

The Weekes lake geochronology is much more believable with the ^{137}Cs data largely confirming the ^{210}Pb geochronology on Core A. The age-depth relationship shown in Figure 8 can be used with confidence. Note that the sedimentation rate for Weekes is more like that for the bottom of the Legend Lake core. Time resolution is limited for the lower sedimentation rates found here, but the use of a 0.5 cm sectioning interval maximizes resolution. For Weekes Lake each 0.5 cm section represents about 5 years of sedimentation. This is the same as the resolution which was determined for each 1 cm section from Lake Athabasca Site 1 (Bourbonniere et al., 1995).

5.2 PARTICLE SIZE ANALYSIS

The two cores that were analyzed for particle size and texture for Legend Lake show generally that texture and size don't change too dramatically over the last few centuries. One core does show a significantly low mean particle size at the inflection point for geochronology, but it is an isolated occurrence. Weekes Lake is more variable than Legend when one considers the entire core length. The upper part, which represents the past 100 years may be in a relatively stable zone. Based on particle size alone this would be a weak conclusion.

5.3 BULK C & N SPECIES

Both Legend and Weekes lakes show C and N data which confirm the highly organic nature of these cores noted in the core descriptions (Appendix B) and what would be expected from a headwater lake with limited mineral input from its watershed. Legend Lake exhibits a lower atomic C/N ratio and that suggests a greater proportion of planktonic (autochthonous) input to this lake relative to Weekes. Alternatively there may be some vegetational component of the Legend Lake watershed which contains an unusually high proteinaceous content. If the cause is planktonic, then it should show up in alkane and fatty acid biogeochemical markers.

5.4 UTILITY OF THE CORES FOR REFERENCE

The locations at which cores were collected are ideal for the purpose of tracking regional and long range transport of contaminants by the atmosphere. The continuity of the sediment record is good for Weekes Lake but not for Legend Lake. The utilization of 0.5 cm sectioning intervals at the top of these cores will prove valuable for maintaining time resolution in analyses to be undertaken.

Biogeochemical marker analyses can assist in answering the remaining questions concerning continuity of sedimentation and changes in organic matter sources. Since PAH distributions come out of the same analyses as biogeochemical markers, it is worth profiling them as an indication of atmospheric input of contaminants. Depending upon the results for biogeochemical markers and PAHs, then selected sections from Weekes Lake and only the surficial layer from Legend Lake should be analyzed for contaminants. Priority for these analyses should be given to those contaminants which are likely to be atmospherically transported (PCBs, dioxins and furans), but to be a true reference for the Lake Athabasca cores, all of the same components analyzed there should also be determined in Legend and Weekes lakes.

6.0 REFERENCES

Anderson, R.F., S.L. Schiff and R.H. Hesslein. 1987. Determining sediment accumulation and mixing rates using ^{210}Pb, ^{137}Cs, and other tracers: Problems due to postdepositional mobility or coring artifacts. Canadian Journal of Fisheries and Aquatic Sciences 44(Suppl. 1):231-250.

Bourbonniere, R.A., B.L. VanSickle and T. Mayer. 1986. The great lakes sediment bank - I. Lakes Huron and Ontario. NWRI Rpt. No. 86-151. 75pp.

Bourbonniere, R.A., S.L. Telford and J.B. Kemper. 1995. Depositional history of sediments in Lake Athabasca: Geochronology, bulk parameters, contaminants and biogeochemical markers. NWRI Rpt. No. 95-76. 131pp.

Delorme, L.D. 1991. The preparation of lacustrine sediment samples for use in dating and paleolimnology. NWRI Rpt. No. 92-188. 18pp.

Duncan, G.A. and G.G. LaHaie. 1979. Size analysis procedures used in the Sedimentology Laboratory. NWRI Hydraulics Div. Manual, September, 1979.

Duncan, G. 1994. Lake Athabasca particle data report. NWRI Rpt. No. RAB-TN-93-51. 64pp.

Farmer, J.G. 1978. The determination of sedimentation rates in Lake Ontario using the ^{210}Pb method. Canadian Journal of Earth Sciences 15:431-437.

Joshi, S.R., D.T. Waite and R.F. Platford. 1989. Vertical distribution of uranium mill tailings contaminants in Langley Bay, Lake Athabasca sediments. Science of the Total Environment 87/88:85-104.

Mawhinney M.R. and C. Bisutti. 1987. Common corers and grab samplers operating manual available through technical operations. N.W.R.I. Technical Note Rev.3.87. 33pp.

Meyers, P.A. and R. Ishiwatari. 1993. Lacustrine organic geochemistry - an overview of indicators of organic matter sources and diagenesis in lake sediments. Organic Geochemistry 20(7):867-900.

Robbins, J.A. 1978. Geochemical and geophysical applications of radioactive lead. Pages 285-393 in J.O. Nriagu, ed. The Biogeochemistry of Lead in the Environment. Elsevier/North Holland, Amsterdam.

Robbins, J.A. and D.N. Edgington. 1975. Determination of recent sedimentation rates in Lake Michigan using Pb-210 and Cs-137. Geochimica et Cosmochimica Acta 39:285-304.

Turner, L.J. 1990. Laboratory determination of ^{210}Pb-^{210}Po using alpha spectrometry. Second Edition. NWRI Tech. Note LRB-90-TN-07, 63pp.

Turner, L.J. 1993a. ^{210}Pb dating of lacustrine sediments from Weekes Lake (Core 045, Station A), Alberta. NWRI Tech. Note RAB-93-27, 17pp.

Turner, L.J. 1993b. ^{210}Pb dating of lacustrine sediments from Legend Lake (Core 044, Station E), Alberta. NWRI Tech. Note RAB-93-37, 19pp.

APPENDIX A: TERMS OF REFERENCE

A.1 Project 2113-B1

NORTHERN RIVER BASINS STUDY

TERMS OF REFERENCE
(Draft)

Project 2113-B1: Reference Sites - Sediment Coring

I. Objective

The purpose of this project is to obtain sediment cores from lakes within the Northern River Basins Study Area that are not influenced by water-borne inputs so that an estimate of atmospheric contribution can be made to compare with sediment samples from Lake Athabasca and elsewhere in the Study Area. A secondary purpose of this project is to take additional sediment cores from Site 1 on Lake Athabasca (project 2332-B1). This work is required to obtain sufficient volumes of samples to complete contaminant analyses from the site.

II. Requirements

The contractor is to collect sufficient 10 cm I. D. gravity cores from three different sites. Four cores are to be collected from each site, one for geochronology, metals and radionuclides; two for organic contaminant analyses; and the fourth for archiving. Cores should be extruded on site to eliminate disturbance during transport. Frozen core section will be stored for future analyses, which are tentatively planned for the spring of 1993.

Sediment cores are to be collected from the following locations:

1) Legend Lake in the Birch Mountains;

2) An as yet, undetermined lake (possibly Whaleback Lake or Weeks Lake) in the Shield region northeast of Fort Chipewyan; and,

3) Lake Athabasca Site 1 (project 2332-B1).

Costing for this project assumes that a Government of Alberta Bell 222 helicopter will be available to the contractor for transport during field work.

Freezer space for storing core samples in Fort Chipewyan can possibly be arranged with Steve Catto, Warden, Wood Buffalo National Park ([403] 697-3662) or Larry Bergerom, District Officer, Fish and Wildlife Division, Alberta Environmental Protection ([403] 697-3511).

Mr. Lloyd (Sonny) Flett, Traditional Knowledge Group Leader, Northern River Basins Study ([403] 697-3733, is to be advised of the contractors work plan prior to the initiation of field work.

III. Reporting Requirements

1) The contractor is to submit a draft report to the Project Liaison Officer (Greg Wagner, Office of the Science Director, Northern River Basins Study - phone (403) 427-1742, fax (403) 422-3055) by March 31st, 1993.

2) Three weeks after the receipt of review comments on the draft report, the contractor is to submit two unbound, camera-ready originals of the final report to the Project Liaison Officer. The final report is to include the following: 1) a brief introduction outlining the scope and intent of the project; and, 2) a results section containing tables with pertinent information, including the latitude and longitude of the collection sites, on the sediment cores. The report is also to include a table of contents, list of tables (if appropriate), list of figures (if appropriate), acknowledgements section and appendix containing the Terms of Reference for this project. If photographs are to be included in the report they should be high contrast, black and white.

A.2 Project 2113-C1

NORTHERN RIVER BASINS STUDY

TERMS OF REFERENCE

Project 2113-C1: Reference Sites - Sediment Analyses (Geochronology, Bulk Properties and Biogeochemical Markers)

I. Introduction

As part of the 1992/93 NRBS fall/winter program, sediment cores were collected from Weekes and Legend Lake in March 1993 to investigate the long-range transport of airborne contaminants into the northern river basins. The purpose of this contract is to carry out geochronology, bulk parameter and preliminary biogeochemical marker work on these cores.

II. Requirements

1) Sediment preparation, geochronology and bulk properties of Legend and Weekes Lakes cores collected in March 1993.

   - freeze-drying, sediment preparation, density (2 cores);
   - Pb^{210} dating (2 cores);
   - TOC, TIC and TN (2 cores);
   - Grain size (2 cores).

2) Preliminary biogeochemical marker work on selected samples from each lake.

   - to include hydrocarbons, including those atmospherically transported.

3) Summer sampling of Birch River

   - to include the sampling of suspended and bed sediments, water, soil and flora. Collections will be made from two sites and the work will be coordinated with a PERD project sampling trip.

4) The following results are to be included in an electronic database (dBase IV and/or Quattro Pro) as outlined by the component coordinator.

   - Core sediments
   - Bulk parameters, Pb^{210}, Cs^{137}, biogeochemical markers

III. Reporting Requirements

1) Submit a report, which includes information on the Birch River field collections and a description of the Weekes and Legend Lakes sediment cores, by August 1st, 1993.

2) Submit a report on the geochronology and bulk parameters of the sediment cores from Weekes and Legend lakes by October 15th, 1993. The report is to include recommendations for how to approach further analyses.

3) Submit an electronic database of all relevant results to the component coordinator by October 15th, 1993.

IV. Project Administration

The Component Coordinator for this contract will be Greg Wagner, Northern River Basins Study, 690 Standard Life Centre, 10405 Jasper Avenue, Edmonton, Alberta T5J 3N4 (phone: (403) 427-1742, fax: (403) 427-3055).

APPENDIX B: CORE DESCRIPTIONS

<table>
<tr><td colspan="3">Core Description</td><td>Site: Legend Lk - Core A - Collected 23Mar93</td></tr>
<tr><td colspan="3">ID: 6.7 cm</td><td>Location (d-m-s): Lat 57-24-41, Lon 112-55-53</td></tr>
<tr><td colspan="3">PHOTO CORE</td><td></td></tr>
<tr><td colspan="4">Split & photographed by RA Bourbonniere 26 Mar 93</td></tr>
<tr><td colspan="4">Total length 54 cm, top cm disturbed by cutting</td></tr>
<tr><td colspan="4">Colour is 2.5Y4/4 throughout</td></tr>
<tr><td colspan="4">"Grey-brown" from top to bottom</td></tr>
<tr><td colspan="4">No laminations throughout the core</td></tr>
<tr><td colspan="3">Top is watery</td><td></td></tr>
<tr><td>UpD</td><td>LwD</td><td>Colour</td><td>Other Comments AFTER removing section</td></tr>
</table>

Core Description			Site: Legend Lk - Core B - Collected 23Mar93
ID: 10.1 cm			Location (d-m-s): Lat 57-24-41, Lon 112-55-53
Transcribed by R.A.B. - Sept 1993 (?)			
Extruded & described by JB Kemper 23 Mar 93			
Gray-Brown from top to bottom			
Tot L: T --> BB = 82.5 cm at start			
Top is watery			
No laminations throughout the core			
UpD	LwD	Colour	Other Comments AFTER removing section
0	0.5	Gray - brown	"Soupy flocc"
0.5	1	Same	Also soupy tiny bit firmer
1	1.5		Sl Firmer "pea soup"
1.5 to 3	2 3.5		More accurate slicing because its firmer
3.5	4		Partial chironomid body removed - likely rem
			part in 3-3.5 cm section
4	4.5		"tad" > .5cm - more like mud
4.5	5	Sl reddish colour - same consistemcy	
5 to 8	5.5 8.5		Smelled something - 3 or 4 holes chironomids? Red Stain at 6-6.5
8.5	9	Light grey	Occas streak (blk?) - chir holes
9	9.5		
9.5	10		Removed 2 chironomids - along w/ some sed
10	10.5	Sl Gray	Removed 1 chironomid - prev odour gone
10.5	11	Same	Same consist - 1 lg chironomid - no odour
11	11.5		
11.5	12		1 sm chir - more tubeways than prev
12	13	Same	no red strks - no chir holes

13	14		Chir removed
14	16		Little thicker and clayey - no odour
16	17		Faint anoxic? smell - no holes - thicker
17	18	Same	No holes - sl sulf smell - same consistency
18	19		Noticeable but not strong odour
19	20		Smell gone
20	21		
21	22		Air spaces on side
22	23		Sulfide smell disappears quickly
23	24	Same - uniform	Same - uniform - chironomid rem
24 to 28	26 30		Sl firmer - v fnt anoxic but not sulf odour
30	32		Removed chironomid - mixing this deep?
32	34	Same	More colsolidated - no chir
34	36		
36	38		"Blood worm" removed
38 to 48	40 50	Uniform	Firm
50	55		Disc ca. 1/3 - ** not for dating **
55	60		thick
60	65		same - no animals
65	70		Left 7 mm of mud on top of bung
			T --> BB 8.4 cm at end
5.5		(100% - (70 cm / (82.5 cm - 8.4 cm) *100)) = % compression	
			NOT for dating becaude 5 cm intervals not
			all saved so as not to break jars

Core Description	Site: Legend Lk - Core C - Collected 23Mar93
ID: 10.1 cm	Location (d-m-s): Lat 57-24-41, Lon 112-55-53
Transcribed by R.A.B. - 06 March 94	
Extruded & described by RA Bourbonniere 23 Mar 93	
Gray-Brown from top to bottom	
Tot L: T --> BB = 78.0 cm at start	
Top is watery with flocc	
No laminations or layering throughout the core	

UpD	LwD	Colour	Other Comments AFTER removing section
0	0.5	Dk. Brown	Almost all water, dk brn flocc
0.5	1	Dk. Brn	Significantly more mud than 1st half cm
1 to 2	1.5 2.5	Maybe Lter Brn	still very fluid
2.5	3	same	maybe a hole or tube, vertical
3	3.5	same	Brn chunks in middle
3.5	4	same	maybe v. sl thicker
4	4.5	same	2 holes, earthy odour, maybe some grey specks?
4.5	5	v. brn with maybe some grey - finer looking, odour slight	
5	5.5	same	thin red worm - left in
5.5	6	same	holes
6	6.5	maybe a little grey, lots of holes, chirlnomid source JBK	
6.5	7	definitely getting greyer	
7	7.5	grey	fine mud
7.5	8	grey	v. little odour
8	8.5	grey brn	little thicker
8.5	9		
9	9.5	same	noticeably big holes in middle
9.5	10		noticeably thicker

10	10.5	same	same, maybe sulfide smell
10.5	11		
11	11.5		little thicker, bit sulfide
11.5	12		large live chironomid
12	13	more grey, very little brown - large chironomid	
13	14		chironomid w/ holes
14	15	grey mud - don't smell sulfur as much	
15	16	greyish slightly brn, chironomids	
16	17		
17	18	same	chironomid w/ white stuff in him
18	19	same	no chir - sulfide smell
19	20	cheesy grey	sulfide smell - chir on top
20 to 22	21 23	greyish brn	sulf, chir
23	24	same	different worm, vertically oriented
24	26	same	chir w/ red junk
26	28		less sulfur odour
28	30		
30	32		red slimy worm, noticeably thicker
32	34	maybe lighter	noticeably thicker
34	36	same	same
36	38	same	no worms
38	40		maybe stiffer, no odour
40	42	maybe lighter	getting former
42	44		thicker, some air holes
44	46		slight sulfide smell
46	48	same colour	noticeably thicker, cracks develop
48	50	same	no worms, v. little odour
50	55	same	only kept ca. 75% of section, vertically

55	60	maybe lighter grey, noticeably heavier, thicker, certainly drier	
60	65		much thicker, maybe sulfide smell
65	70		
			T --> BB 9.8 cm at end
-2.6		(100% - (70 cm / (78.0 cm - 9.8 cm) *100)) = % compression	
		This core EXPANDED upon extrusion	
			NOT for dating becaude 5 cm intervals not
			all saved so as not to break jars

Core Description			Site: Legend Lk - Core D - Collected 23Mar93
ID: 10.1 cm			Location (d-m-s): Lat 57-24-41, Lon 112-55-53
Transcribed by R.A.B. - 06 March 94			
Extruded & described by JB Kemper, 23 Mar 93			
Gray-Brown from top to bottom			
Tot L: T --> BB = 75.5 cm at start			
Top is watery			
UpD	LwD	Colour	Other Comments AFTER removing section
0	1	uniform	no odour
1	1.5	greenish olive	uniform consistency
1.5	2		
2 to 3	2.5 3.5	same with red streak - uniform texture	
3.5	4		more stiff
4	4.5		red chironomid
4.5 to 5.5	5 6	slight red streak	
6	6.5		a bit of staining
6.5 to 9.5	7 10		uniform texture
10 to 11.5	10.5 12	uniform olive colour	
12	13	same	two chironomids
13 to 15	14 16	uniform olive	a little muddier, no streaking
16	17		no odour, sl stiffer
17	18	same	

18	19		
19	20	same	one chironomid
20	21	uniform	a little firmer
21	22		maybe a little off measurement
22	23		also off measure on this section
23 to 30	24 32	consistent	
32	34	exactly the same with cracks in sed due to "dryness"	
34	36		
36	38	uniform	
38	40		
40	42		v faint odour, firmer
42	44		
44	46	same	same, cracks
46	48	same	
48	50	somewhat lighter	
50 to 60	55 62		stiffer
			T --> BB 9.4 cm at end
6.2		(100% - (62 cm / (75.5 cm - 9.4 cm) *100)) = % compression	
			NOT for dating becaude 5 cm intervals not
			all saved so as not to break jars

<table>
<tr><td colspan="3">Core Description</td><td>Site: Legend Lk - Core E - Collected 23Mar93</td></tr>
<tr><td colspan="3">ID: 10.1 cm</td><td>Location (d-m-s): Lat 57-24-41, Lon 112-55-53</td></tr>
<tr><td colspan="4">Transcribed by R.A.B. - 06 March 19</td></tr>
<tr><td colspan="4">Extruded & described by RA Bourbonniere, 23 Mar 93</td></tr>
<tr><td colspan="4">Gray-Brown from top to bottom</td></tr>
<tr><td colspan="4">Tot L: T --> BB = 70.0 cm at start</td></tr>
<tr><td colspan="3">Top is watery</td><td></td></tr>
<tr><td colspan="4">No laminations throughout the core</td></tr>
<tr><td colspan="4">"Strange" formation on top, not flat,starfish shaped chunk in middle - A dome</td></tr>
<tr><td>UpD</td><td>LwD</td><td>Colour</td><td>Other Comments AFTER removing section</td></tr>
<tr><td>0</td><td>1</td><td>olive brown</td><td>Structure collapsed when water taken away, silty flocc</td></tr>
<tr><td>1</td><td>1.5</td><td>olive brn</td><td>soupy, silty</td></tr>
<tr><td>1.5</td><td>2</td><td>olive brn</td><td>soupy</td></tr>
<tr><td>2</td><td>2.5</td><td>same</td><td>same, no odour</td></tr>
<tr><td>2.5</td><td>3</td><td>same</td><td>same still fluid, not loose water</td></tr>
<tr><td>3</td><td>3.5</td><td>same</td><td>same</td></tr>
<tr><td>3.5</td><td>4</td><td>same</td><td>slight smell</td></tr>
<tr><td>4</td><td>4.5</td><td>uniform colour</td><td>same w/ no odour</td></tr>
<tr><td>4.5
to
5.5</td><td>5

6</td><td>same</td><td>same</td></tr>
<tr><td>6</td><td>6.5</td><td>same</td><td>same, slight sulfide odour</td></tr>
<tr><td>6.5
to
8</td><td>7

8.5</td><td colspan="2">uniform maybe greying out a little, sl sulfide odour</td></tr>
<tr><td>8.5</td><td>9</td><td>same</td><td>v. sl odour</td></tr>
<tr><td>9</td><td>9.5</td><td>same</td><td>same</td></tr>
<tr><td>9.5</td><td>10</td><td>same</td><td>v. sl odour, no organisms</td></tr>
<tr><td>10</td><td>10.5</td><td>same</td><td></td></tr>
</table>

10.5	11	same	chironomid found, potentially oily thing stuck in mud
11	11.5	same	
11.5	12	same	chir
12	13	uniform colour maybe a little greyer, no orgs, no smell	
13	14	same	same
14	15		evidence of chir, no smell
15	16	same	
16	17	same	little thicker, smell the sulfide odour
17	18	same	good size chir hole, sl smell, bit more consolodated
18 to 22	19 23		noticeably more consolidated
23 to 27	24 29	uniform g-b	pulling away from tube, drier looking
29	30		consistent, more consolidated
30	32		sl sulfide odour
32	34	same	same
34	36	same	no sunfide small
36	38		noticeably thicker, cracking
38	40		stiff, no sulf odour
40	42		stickier
42 to 54	44 56	more grey than brown, same consolidation	
56	58	same	contact with bung, exactly 2 cm
			T --> BB 7.7 cm at end
6.9		(100% - (58 cm / (70.0 cm - 7.7 cm) *100)) = % compression	

Core Description			Site: Legend Lk - Core F - Collected 23Mar93
ID: 10.1 cm			Location (d-m-s): Lat 57-24-41, Lon 112-55-53
PHOTO CORE			
Split & photographed by RA Bourbonniere, 27 Mar 93			
Total length 71 cm, top 1-2 cm disturbed			
Difficult to choose betw/ 10YR3/2 and 2.5Y4/2			
"Grey-brown" from top to bottom			
No laminations throughout the core			
Top is watery, lost a lot after opening			
This core was disturbed by air bubble so NOT for extrusion			
Suitability for palaeomagnetics is questionable			
UpD	LwD	Colour	Other Comments AFTER removing section

Core Description			Site: Weekes Lk - Core A - Collected 24Mar93
ID: 10.1 cm			Location (d-m-s): Lat 59-42-52 Lon 110-01-11
		Date: 25Mar93	Extruded and described by Bryan Kemper
Top saw reddish tube worm case? JBK Photo. Total Length (T --> BB) 85cm at start. Uniform "peaty" granular or "aggregate" at top - fibrous			
UpD	LwD	Colour	Other Comments AFTER removing section
0	1	"peaty"	Darker brown watery - poured into jar
1	1.5		Thickens a little sl darker areas not blk
1.5	2		
2	2.5	sl drkr brown	A few darker stains
2.5	3		Sl thicker - still slumps - amorph decayed peat
3	3.5		
4 to 5.5	4.5 6	Same	Same little firmer - decayed peat odour
6 to 9	6.5 9.5	Same	Sl Thicker - no black flecs
9.5 to 11	10 12	Dk Brown still	Uniform in texture
12	12.5		Consistency thicker
12.5	13		Lt green plant material - stem fr aq plant
			1.25-1.5 in long x 1/8th in diam - left in
13	14		
14	15		Another pc of plant - left in
15 to 22	16 23	same colour and thickness	
23	24		Brian Jackson - thicker
24	26		Firm - slices nicely

26	28		
28	30		
30	32	Darker Brown	Black Patches
32	34		Black streaks
34	36	Dk Brwn - Gray	Black Streaks
36	38		Tearing in middle of section
38	40		Maybe less blk streaks
40 to 44	42 46	Sl darker	Gelatinous easy slicing - Recomm for dating
46	48		Larger black chunks - also gelatinous
48	50		More black streaks - separating
50	53	Sl Dkr Gray	Less Blk streaks
53	56	Same	Same
56	59		Drier and cracking - small pc of plant left in
59	62	Same	More denser & compact - clay?
62	65	Same	Same
65	68	Uniform dk gray	Large cracks - looks like tofu
68	71		Lots of cracks - more dry
71	74	V. Dk Gray	Very dry
74	76		Last slice - can see stopper
			T --> BB at end 7.7 cm
			77.3 cm extruded in 76 cm of slices
			--> 1.7% EXPANSION <--
			Recommended to use for dating

Core Description - Photo			Site: Weekes Lk - Core B - Collected 24Mar93
ID: 10.1 cm			Location (d-m-s): Lat 59-42-52 Lon 110-01-11
Date: 25Mar93 - Split for Photo and subsampling			Total length 90 cm Totally organic, no banding, only difference is consolidation
		7.5YR3/2 or 10YR3/2 cannot tell	
UpD	LwD	Colour	Other Comments AFTER removing section
49 cm			Twigs noticed after splitting
67 cm			Twigs noticed after splitting
Samples for Sedimentology			
0	2		
5	7		
10	12		
15	17		
20	22		
25	27		
30	32		
35	37		
40	42		
45	47		
50	52		
55	57		
60	62		
65	67		
70	72		
75	77		
80	82		
84	86		
88	90		

CORE DESCRIPTION	Lake: Weekes Lake
Date: March 25, 1994	Site: Deep Hole Core C
Lat (d-m-s): 59-42-52	Lon (d-m-s): 110-01-11
Core ID: 10.1 cm	Initial Length: 74.3 cm
Extruded & Described by (date):	Final Length: 24.8 cm
Rick Bourbonniere (Mar. 25, 1994)	Cmp/Exp (%):
Transcribed by (date):	Kathryn Bourbonniere (Nov. 6 1994)

Notes: This core stayed outside all night. It stayed pretty cold and did not freeze We have already moved up the core to get rid of the surficial water which is quite clear. Any of the flock that had moved arround yesterday in transport has settled nicely and is nice and flat. This site the surface sediment is extremely low density flock and floats and gets disturbed quite easily . Any of these cores the top half centimeter or so was mixed and leveled out just in transport.

UpD	LwD	Colour @ Section	Texture & Other Comments @ Section
0	1	medium brown	surface extremely watery,lighter medium brown flock, a lot of the materal and water was lost in the top centemeter
1	1.5	darker brown	highly organic, less water noticeable,darker, little black specks in the middle, watery , looks like a wet peat suspension
1.5	2	medium brown	black or dark brown specks,highly fluid organic material, peat looking material
2	2.5	medium brown	very fluid, black specks
2.5	3	about the same	about the same
3	3.5	medium brown	maybe a little bit more consolidated, black chunks in it
3.5	4		slightly less soupy still very soupy material but it is maybe a little bit more consoilidated
4	4.5	dark brown	noticably darker at this cut
4.5	5	dark brown	less water than before,but still highly organic peaty looking material
5	5.5	dark brown	same as above
5.5	6		larger darker pieces evidence of a little piece of twig or piece of grass

6	6.5		same as one above but no piece of leaf or thing like that
6.5	7		same as above but I did notice sort of a sulfide odor at this level it is not to say I first noticed it here I really havn't been looking been smelling for sulfide in the last few cm.
7	7.5	same as above a dark brown	a few darker chunks or streaks inside,slighly sulfide smell
7.5	8		darker brown streaks in there a stronger sulfide smell on this one
8	8.5	same as the one above	same as the one above
8.5 to 10	9 10.5	same thing dark brown	a few darker streaks in it, slight sulfide smell, noticably less water content
10.5	11	still dark brown	has darker specks,less water than before
11	11.5	dark brown	darker streaks in it,slight sulfur odour,same consistency as above
11.5	12	dark brown again	same as before
12	13	dark brown	same as above, slight sulfur odour, a few darker areas, water content about the same
13	14	dark brown	look is the same, can not smell any sulfide odor and I tried hard to smell it
14	15	same as above	same as above, but I can smell a little bit of sulfide odour
15 to 19	16 20	even dark brown, maybe a bit darker than it was before	seems a bit darker and more evenly coloured previously we were getting a dark brown with some darker almost black streaks now it looks like just an even dark brown maybe just a little darker than the background was before, couldn't smell sulfide in this particular section so it must have been very faint in the other ones
20	21	lighter in color than the others, more uniform in color	a little less water content here, more uniform in colour as well
21	22	same as one above, seams lighter in color than ones before	same as above

22	23	same as above	same as above, nice evenly colored a little lighter brown than the ones several cm away
23	24	no change	no change , note we are going to continue on this core to 50 cm but it is longer than that
26	28		noticably more consolidated, no particular sulfide odour, seams to be a little hole in the middle could be some sort of air bubble or gas bubble that was released
28	30	consistant brown color	no really noticable sulfide odor, a bit more consolidated than before, you can see the mud separating from the tube a bit
30	32	same as above	same as above, a slight sulfide odor this time
32	34	same as above	same as above, the sediment is pulling away from the core tubing about 2/3 way arround
34	36	dark brown background with mottled darker specks	noticiably stiffer, sulfide odor, mottled color some darker specks mixed in with the dark brown background
36	38	dark brown somewhat mottled few specks of a darker material	75 % arround the core is separating from the tubing, dark brown somewhat mottled few specks of a darker material, wetter on the edges, it is not water coming across the bungs but it may have been water slopped down during the coring operation
38	40	same as above	same as above
40	42	same as above	same as above, about 90% of the core is separated from the core liner, we still have dark brown with some darker mottling, sufide odor probably none, stuff is pretty consistant peaty looking material
42	44	same as above	same as above 95% of material is away from the core and probably the part that is touching the core is because I pushed in that direction
44 to 48	46 50	same as above	same as above, it is getting more consolidated, the little separation that occur when you move the slider in remaining when you pull it away

CORE DESCRIPTION	Lake: Weekes Lake
Date:	**Site:** Core D
Lat (d-m-s):	**Lon (d-m-s):**
Core ID: 10.1 cm	**Initial Length:** t-bb 86.5 cm
Extruded & Described by (date):	**Final Length:**
Rick Bourbonniere	**Cmp/Exp (%):**
Transcribed by (date):Kathryn Bourbonniere (Nov. 13, 1994	

Notes: Weekes Lake core D the last one we extrude. The overall appearance is pretty much like the other ones very soft watery flock at the top a few pieces of leaves and stuff sticking out. The colour on top is a lighter brown lighter than you see further down.

UpD	LwD	Colour @ Section	Texture & Other Comments @ Section
0	1	medium brown with some darker brown to black flakes very small	Very watery, lots fresh organic material on top. Did quite a good job collecting that top cm this time much better than we did with core C. After the cut at 1 cm down we got all the water out of the first cm. It is a very very wet fluid , very loose, hardly at all compacted material
1	1.5	lighter brown colour and dark brown mix with some even darker smaller chunks in it	Very fluid, at the cut slight smell of something could be sulfide odors.
1.5	2	same as above	there is an odor may maybe not sulfide
2	2.5	same as above	same as above
2.5	3	same colour	same consistancy, same odor, same black flecks
3	3.5	same as above mottled brown colour	same odor, pungent but not sulfide, black streaks material in it
3.5	4	no discription	no discription
4	4.5	little black flecks, mottled brown colour	quite fluid, odor is there but not really sulfide,
4.5	5	same as above	same as above
5	5.5	same colour	no smell
5.5	6	same as above	same as above

6	6.5	same as above	same as above
6.5	7		darker areas seem a little larger not such small specks any more, and I did notice that odor that is maybe like sulfide
7	7.5		same as above
7.5	8	dark bands	dark bands showing up. I call it a sulfide smell, dissagreement by Kemper, His nose touched the sediment
8	8.5	same as above	same as above without the nose contact
8.5	9	same as above	same as above
9	9.5	little darker averall in colour	same as above sulfide smell, dark chunks seem a bit larger than they were before
9.5	10	a little darker than a couple of cm ago	same as above
10	10.5	almost evenly coloured darker than before	still a little bit of sulfide smell, not too mottled almost evenly coloured and darker than before
10.5	11	same as above	same as above
11	11.5	dark banding	sulfide smell, dark banding, otherwise the same
11.5	12	same as above	same as above
12	13	same as above	same as above
13	14	about the same	about the same, maybe a litte more noticably consolidated at this depth

CORE DESCRIPTION	Lake: Weekes Lake
Date: 24 March 1993	**Site:** Deep Hole - Core E
Lat (d-m-s): 59-42-52	**Lon (d-m-s):** 110-01-11
Core ID: 10.1 cm	**Initial Length:** 73.8 cm
Extruded & Described by (date):	**Final Length:** 28.8 cm
Richard Bourbonniere	**Cmp/Exp (%):**
Transcribed by (date):	Kathryn Bourbonniere (6 November 94)

Notes: (Prior to beginning extrusion) This core has warmed up a lot and has a lot of gas bubbles. The core is highly organic and as we are moving the core upward gas is coming up the side and bubbling like crazy on the side and disturbing the surface. It is taking some of the deeper sediment from maybe two to three centimeters down floating it in a flocc and that flocc is settling on top of the core. There is no question that the top of the core is disturbed. We are bringing it up very slowly so that we let that stuff settle. After a while the bubbling settled down and we are ready to do the first section of this core.

UpD	LwD	Colour @ Section	Texture & Other Comments @ Section
0	1	dark brown	very watery, fibrous, light brown plant chunk material
1	1.5	dark brown	very watery, not as much free water but still quite fluid
1.5	2	dark brown	little less watery
2	2.5	darker brown than one on surface	highly highly organic, looks like peat suspension,
2.5	3	dark brown	quite watery, very fluid, vibrations in the floor show up
3	3.5	dark brown	same as before
3.5	4	dark brown	same as before, highly organic, shiny looking stuff
4	4.5	dark brown	same, fibrous, shiny, maybe a slight sulfide smell here
4.5	5	dark brown	difinitely sulfide smell, highly organic very fluid material
5	5.5	dark brown	bit of sulfide odor, not much change from above
5.5	6	dark brown	very faint sulfide smell, still quite jellylike, as you shake the floor it wiggles

6	6.5	same as above	same as above
6.5	7	dark brown	same as above, fiberous material, highly fluid, slight sulfide odor
7	7.5	dark brown	same texture, odor is a bit more noticeable here
7.5 to 9.5	8 10	same as above	same as above
10	10.5	same as above	same as above there has not been any change in consistancy in the top ten centimeters except the first two
10.5 to 12	11 13	same as above	same as above
13	14	same as above	pretty much the same maybe a little less water, but no major change
14	15	same as above	same as above
15 to 18	16 19	same as above	looks the same, same kind of consistancy but I noticed a stronger smell but it did't smell like a sulfide smell but it was quite strong
19 to 23	20 24	same as above	same as above, this whole core from the top 20 centimeters has been pretty much the same consisitency, does not change even in porosity
24	26	same as above	same as above, we are getting water on the side of the core, it looks like it is water that has come out of the sediment as the gas bubbles are moving so it is wetter on the edges
26	28	same as above	same as above
28	30	same as above	same as above, I see the water more on the outside than I did before
30	32		It may actually getting a little thicker

32	34		definitely more consolidated but there is lots of water coming from the side, I am starting to think this water is coming by the bungs, on top of the next section half of the section is covered by loose water. We are getting to a point here where there is an awful lot of water coming out of this core and it is most definitly getting by the bungs. Definitly this core (section) is suspect because it is loaded with Ft. Chip tap water.
36 to 44	38 46		same thing happened again water is coming up the sides. Explanation - older bung manually inserted using the gloves instead of using the bung inserter
46	48		bottom what looks like a piece of wood maybe
48	50		about the same no more evidence of the twig, we have saved the twig that was found at the 48 level
50	55		saved entire section in a jar it is more than 3/4 full but it looks like this material is quite airy
55	60		lots of water is getting into the core, tempted to stop extruding
60	65		few pieces of twigs in it, I separated one of the pieces in the same jar as the other one
65	70		quit after this section, all these bubbles could have not been methane gas, but air caught under the bungs as it went by. The bung is inserted at an angle and it is probably why we are having most of the trouble with water. The top 20 to 30 cm had less water, below 30 centimeters I am suspect because there is a lot of Ft. Chip water there.

National Water Research Institute
Environment Canada
Canada Centre for Inland Waters

P.O. Box 5050
867 Lakeshore Road
Burlington, Ontario
Canada L7R 4A6

Institut national de recherche sur les eaux
Environnement Canada
Centre canadien des eaux intérieures

Case postale 5050
867, chemin Lakeshore
Burlington, Ontario
Canada L7R 4A6

Environment Canada | Environnement Canada

Canada