THE CANADIAN SEISMICITY PROJECT -

- A REVIEW OF STAFFING AND OUTPUT PRODUCTS

by

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INTRODUCTION

The determination of the parameters of all significant Canadian earthquakes, the Canadian seismicity project, or as described in the 1979-80 Earth Physics Branch Program Book, Project 5.1.3.1 "Determination of Canadian Seismicity", is one of the most important continuing projects undertaken in the Branch. The present project and the predecessor projects over the past 25 years have produced essentially all of the data employed in current assessments of the nature and distribution of Canadian earthquakes and of the nature and distribution of earthquake risks throughout the country. It is the kind of project that requires careful management of a strict routine for processing incoming data and distributing results in order to keep abreast of continuing seismicity and to avoid the accumulation of any significant back-log of unprocessed data. Thus, within the Seismological Service, the routine processing of earthquake data has a high priority in terms of staffing assignments on a day-to-day basis.

The purpose of this report is to provide an overall review of this project with specific reference to manpower allotment and output products. The review was requested at the 1978 Program Evaluation Exercise, and is timely for a number of reasons:

a. the Canadian seismograph network has undergone significant expansion in the past four years in active regions of the St. Lawrence Valley and western Quebec, the British Columbia lower mainland and southern Vancouver Island, and, more recently, in southwestern Yukon;

b. the ECTN and WCTN are, or will shortly be, of a size and number of stations that will allow a significant number of earthquake parameters to be derived from the on-line data;

c. there is a plan under development to recommence the determination of Western Canadian seismicity at the Pacific Geoscience Centre during 1979 and staffing assignments will change when this takes place;

d. in the light of the relatively large number of projects with which the seismological staff are now associated, it is useful to review the proportion from among the total manpower pool that should continue to be devoted to the routine aspects of Canadian seismicity;

e. given the expansion of the Canadian network and the concomitant increase in the numbers of earthquakes that can be detected, it is appropriate to review the forms of the output products and the nature of the demands for these products.

A BRIEF HISTORY OF CANADIAN EARTHQUAKE DETERMINATIONS

To put the current and future status of the Canadian seismicity project in perspective, it is useful to consider the history of this project, a brief review of which is given in the following paragraphs.

The principal catalogue of historical western Canadian earthquakes for 1841-1951 was prepared by W.G. Milne and published in 1956. Milne and co-workers prepared annual catalogues of western seismicity for 1951-54, which were published in the time period 1953-55, and a five-year catalogue for 1955-59, published in 1961. W.E.T. Smith prepared the historical catalogues for eastern Canada, publishing the 1534-1927 events

in 1962 and the 1928-1959 events in 1966. S.S. Meidler published the 1899-1955 historical Arctic catalogue in 1962 and Smith completed the pre-1960 period with publication of the 1956-59 Arctic events in 1961.

Since 1960, all of Canadian seismicity has been published together in annual catalogues. Milne and Smith worked together on the seismicity for the period 1960-1965, publishing the annual catalogues in 1961 through 1970. At the time of the death of W.E.T. Smith in 1970, the data reduction for Canadian seismicity was 5 years in arrears and a substantial effort was started to reduce this backlog. A.E. Stevens and co-workers analysed eastern and northern data and Milne western data for the 1966, 67 and 68 catalogues which were published in 1972, 73 and 76, respectively. R.B. Horner analysed eastern and northern data and Milne and G.A. McMechan western data for the 1969, 70 and 71 catalogues which were published in 1974, 75 and 76, respectively. Basham and co-workers completed the back-log with the publication of the 1972 catalogue in 1977.

Starting with the 1973 data, all Canadian seismicity determinations were undertaken at Ottawa with coordination and development of the current procedures by R.J. Wetmiller. The 1973, 74 and 75 catalogues were published in 1976, 76 and 77, respectively. The coordinating role was shared with Horner for the 1976 data and this catalogue was published by Wetmiller and Horner in 1978. The 1977 catalogue, the first one in a bilingual format, is in final stages of preparation by Horner, Stevens and Wetmiller at the time of writing this report.

STATISTICS FROM 10 YEARS OF CANADIAN EARTHQUAKES CATALOGUES

For purposes of discussing both the workload and the output products of the Canadian seismicity project, it is useful to consider the numbers of earthquakes that have been located in recent years. Statistics are presented in the following paragraphs and accompanying tables for the period 1968, when the basic standard network and a few regional stations were in operation, to mid-1978, with the WCTN, ECTN, Charlevoix array and additional regional stations in place.

The numbers of earthquakes located in the four regions of Canada in the annual Catalogues from 1968 to 1977 are given in Table 1. Each of the four regions includes adjacent territory of the United States and, in the case of the North, western and northern Greenland; the numbers of earthquakes in adjacent territory are listed separately. Between 1968 and 1974 the numbers of located events in each region varied from year to year by a factor of about two. This is mainly a reflection of variations in natural seismicity and there does not seem to have been significant influence from the addition of five regional stations (WHC, QCC, CHQ, POC and UNB) in the 1971-72 time period. The number of earthquakes with magnitudes ≥ 4 in each of the regions is given in Table 2. Again, there is variation from year to year of about a factor of two; this is clear reflection of variations in seismicity because the capability to locate $M \geq 4$ events was essentially constant over this 10-year period. The numbers of events in Tables 1 and 2 are strongly affected by swarm activity and by large events for which numerous aftershocks can be located. For example, the large numbers of events in the North in 1969 and 1971 (Table 1) resulted from swarm activity on Baffin Island, swarms that did not produce unusual numbers of $M \geq 4$ events (Table 2). The relatively large numbers of western events $M \geq 4$ in the period 1971-73 are due mainly to aftershocks of M 5-6 events west of Vancouver Island and in southeastern Alaska. y contrast, the largest event in Canada in 1977 was M 4.6 near the Queen Charlotte Islands; 1977 had the smallest number of $M \geq 4$ events since 1968.

A strong influence on numbers of located events in Table 1 can be seen following installation of the ECTN (February, 1974), the WCTN (September, 1975) and the Charlevoix array (October, 1977). A breakdown by magnitude of the numbers of earthquakes located in three regions most strongly affected by these installations is given in Table 3, for the time period through to June, 1978. The Charlevoix region includes that zone along the St. Lawrence and on the north shore in which the lower magnitude events have been located in recent years. The Western Quebec Zone is that region of western Quebec and eastern Ontario defined by Basham et al. for purposes of risk analysis, but excluding the portion of the zone in northern New York and Vermont States. The Georgia Str.-Puget Sd. region sampled is from 48° to 49.5° N and 122° to 124° W, i.e., southern Georgia Str. and northern Puget Sd., but a majority of events in this region are in U.S. Territory.

The installation of the Maniwaki station (MIQ) of the ECTN increased the numbers of $M < 2$ earthquakes located in western Quebec, and the installation of the La Malbaie regional station (LMQ) in 1976 increased the numbers of small Charlevoix events, but the most dramatic increases followed installation of the WCTN and the Charlevoix array. Small events in the Georgia Str.-Puget Sd. and Charelvoix zones now constitute significant fractions of the events being located in all of the western and eastern regions.

STAFFING AND PROCEDURE SUMMARY FOR 1977-78 SEISMICITY DATA

The procedures and staff assignments that handled the 1977 and first half of 1978 data and were in place at the end of 1978, are those most usefully summarized. A number of minor changes have been made in early 1979 and are described below.

Horner, as project coordinator, has responsibilities for managing input data flow, coordinating data reduction by other staff, completing data reduction where necessary, computing final earthquake parameters, preparing bimonthly summaries and bulletins, and preparing annual catalogues.

Wetmiller has responsibility for rapid earthquake determinations and associated public relations, liaison with NEIS, NEUS network, Lamont, etc. and computer program maintenance and development for the seismicity project. He has primary responsibility for isoseismal maps, for sending Canadian data annually to the ISC and is the backup for Horner when the latter is on leave or outside duty. He prepares preliminary Canadian and world-wide seismicity summaries and makes contributions to preparation of annual catalogues. During part of 1978, Wetmiller prepared monthly Canadian earthquake summaries for distribution to Canadian newspapers, but this has been discontinued and will be reinitiated as a semi-annual (Jan. and June) summary.

The rest of the Ottawa seismicity staff (F.M. Anglin, Basham, J.P.S. Mercure, Stevens and Wetmiller) prepare "Local Earthquake Monthly Summary Sheets" (LEMSS) from scanning eastern and northern regional station records and contribute 1-2 days per month each to data reduction. Although assignments have varied somewhat, Anglin and Mercure have concentrated on eastern Canadian events, Basham and Wetmiller on northern and western events, and Stevens on eastern and northern events. Anglin has the additional responsibility for data reduction from the Charlevoix array and the input of these data as appropriate to the current seismicity project, and for maintenance of the computer mapping program. Stevens assists Horner with the French material in the

bimonthly summaries and had responsibility for the French text of the 1977 catalogue. In addition, Ottawa staff become involved with aftershock and isoseismal field surveys.

The PGC staff prepare LEMSS for the WCTN and western regional stations. PGC staff also compute preliminary epicentres for their own and public relations purposes, but final solutions for all western events are made in Ottawa. PGC staff often become involved with aftershock and isoseismal field surveys. Standard station operators prepare LEMSS for their stations.

It is difficult to estimate accurately the total manpower devoted to this program because of the large number of associated and special projects. For example, how much of Wetmiller's time chasing "booms" and "bumps" or Anglin's time with Charlevoix microearthquake studies or Horner's time with special Yukon studies, should be counted as part of the general current seismicity project? However, a rough estimate for one year of seismicity, with the procedures used for 1977-78 data, would be 0.7 of Horner, 0.7 of Wetmiller, 0.2 PGC staff and 0.1 of each of Anglin, Basham, Mercure and Stevens, for a total of 2.0 manyears.

To summarize the procedures and schedule being employed for current seismicity, Table 4 shows the steps in the treatment of January, 1977 data and the schedule leading to preparation of the 1977 annual catalogue. It will be obvious to the reader, but nevertheless worth stating, that the process is continuous and a number of the scheduled tasks are occurring at the same time for different data months.

There is one month of grace prior to scheduled record analysis, May in the Table 4 sample schedule for January, 1977 data. This allows some flexibility, for example, if microfilming is delayed. It also allows an advance of the schedule, for example, when possible and desirable prior to known absences of key staff on summer vacation and/or field programs. However, a catch-up is usually required in the Autumn, in spite of the best effort to keep the process on schedule during the summer months.

It has been stated, by both the seismicity staff and management, that the annual catalogue should not require much more effort than simply "stapling together" six bimonthly summaries. This inevitably turns out not to be the case for the catalogue in its current Seismological Series format. As shown in Table 4, preparation of the annual catalogues usually does not begin until about November, and the task is in addition to ongoing work associated with current seismicity and other research projects. Involved is about four weeks of effort (five weeks for bilingual 1977) distributed over about four months. The principal tasks associated with the preparation are the following:

- final preparation of earthquake tables, including addition of data made available after the bimonthly issue and computation of the final hypocentre and magnitude parameters, elimination of blasts that have come to the staff's attention and preparation of final comments;

- preparation of figures, e.g., of P-nodal solutions and isoseismals, and computer plotting, draftsman touch-up and checking of final epicentre maps;

- preparation of text, half of which is standard from year to year and half of which is a summary description of the seismicity; beginning with the 1977 catalogue the text is bilingual;

- word-processor typing and proof-reading of final manuscript and camera-ready layout for Seismological Series publication.

There was one staffing change and one procedural change made in the seismicity project early in 1979. The staffing change was the addition of A.J. Wickens to the seismicity group in February, 1979. This represents a mutually agreed change in Wickens' duties within the Division and an increase in the Ottawa-based staff associated with seismicity, in anticipation of Horner's move to PGC in the Autumn of 1979. Wickens' time spent with seismicity during the first half of 1979 will be used contributing to the overall project and gaining experience to assume additional responsibilities (described below) after Horner's move.

Another staff addition was C. Crosby in late 1978 with specific responsibilities under Horner for the analysis of data from the new southwestern Yukon stations. This, at the moment, is being treated as a special project (with two year funding), but the results will be incorporated as appropriate into the bimonthly and annual files.

Although not described above, it will be known to readers familiar with the bimonthly and annual catalogues that these publications have in the past included lists of unlocated events detected at each station. These earthquakes are well recorded at one or two stations, but cannot be located. They have traditionally been listed in catalogues, by origin time, magnitude and distance to detecting station, since the earliest western catalogues prepared by Milne. The value of these lists is that they supplement the located seismicity by giving an indication of the numbers of low magnitude events in the vicinity of each station. However, it was found that this information was not often used by the seismicity staff, or by outside agencies to our konwledge and the decision has been made to discontinue the listings. This decision was made effective for the 1977 annual catalogue and for the May/June, 1978 bimonthly, and represents a small, but significant, saving of staff time (for measuring, coding, punching, printing and checking of final lists). Thus, during record analysis under the revised procedure, an event that is not detected at three or more stations and cannot be located has no permanent record beyond the LEMSS stage.

As an illustration of the volume of unlocated events in the recent catalogues, these events occupied 26, 20 and 17 pages in 1974, 1975 and 1976, respectively. There were 21, 27 and 24 pages, respectively, of located events in these same catalogues. Beginning with the May/June, 1978 bimonthly, the geographical comments accompanying the smaller located events have been reduced and standardized, saving additional staff time and catalogue space.

PLANNED 1979 PROCEDURAL CHANGES ASSOCIATED WITH WESTERN SEISMICITY DETERMINATION AT PGC

As part of the staff relocations from EPB Ottawa to PGC to expand the overall PGC Earth Physics Service staff to a viable size, it is planned that Horner move to PGC in the Autumn of 1979 and, as his primary duty, become involved with analysis and research on western seismicity. This necessitates significant procedural and staffing changes to the handling of Canadian seismicity and, with the expanded PGC staff, it is planned to recommence the determination of western seismicity at PGC.
There are three aspects to this planned change that require careful consideration: the logistics of having seismograms and derived data in the right place (PGC or Ottawa) at he right time, the PGC staffing to handle western seismicity and the Ottawa staffing

to handle eastern and northern seismicity.

The logistics may prove the most troublesome, but it appears practical to accommodate new procedures within the data analysis schedule shown in Table 4. Again considering a January data month, western regional station seismograms would be mailed from the stations directly to PGC. Western standard station seismograms (PHC, PNT, EDM, SES and FFC) would be mailed to Ottawa for quality control and microfilming and shipped to PGC by the end of April. During May, January record analysis would be undertaken at PGC, producing western event files with associated data. During June, all records (WCTN, regional and standard) would be returned to Ottawa with the event files. January data for eastern and northern seismicity would be analysed in Ottawa during July and data merging would take place for events recorded in common. Bi-monthly reports, e.g., in September for Jan/Feb., would be prepared and distributed in Ottawa.

The PGC seismicity staffing remains to be decided in detail, but the plan is for Horner to act as coordinator in a way similar to his present role in Ottawa. G.C. Rogers would logically be involved with Horner in producing the final edited monthly lists of western earthquakes. Rogers, D.H. Weichert, and perhaps others, could be involved in record analysis. Guerin and Bunyan could be involved with seismogram and data management tasks.

In Ottawa the overall coordinating role would be assumed by Wetmiller with responsibilities for liaison with Horner, merging of regional event files and preparation of bimonthly bulletins. Wickens would coordinate the eastern and northern input data flow and event analysis. Record analysis would be shared by some or all of the staff currently involved. Should the USNRC funding of an expanded ECTN take place, Wetmiller would have primary responsibility for data analysis and liaison with USNRC and the NE US network. It is planned tht the southwestern Yukon data analysis remain in Ottawa under Crosby, at least until the PGC seismicity program is operating efficiently, and we know of any additional Yukon monitoring that may be associated with studies of the Dempster lateral.

The total manpower that will be required under this revised PGC/Ottawa procedure is difficult to estimate until some experience is gained, but a rough estimate would be 0.5 of Horner, 0.2 of, e.g., Rogers and Weichert combined, 0.8 of Wickens, 0.5 of Wetmiller and 0.2 of, e.g., Stevens and Anglin combined, for a total of 2.2 manyears, after the procedures are working efficiently.

CURRENT CANADIAN SEISMICITY OUTPUT PRODUCTS AND CUSTOMERS

The foregoing sections have presented a brief history, a summary of current staffing and procedures and some planned changes to the Canadian seismicity project. This section will describe the output products of the project as they currently are produced, and the real and perceived customers for these products. Two of the principal seismicity output products, the bimonthly reports and the annual catalogues, have been mentioned a number of times above. There are two additional products, the rapid information services and the digital tape file of Canadian earthquakes; each of the four products is described below.

Rapid information services are provided from both the Ottawa and PGC offices, primarily by Wetmiller and Rogers, respectively, but backed up by other staff as necessary. These are rapid determinations of the locations, magnitudes and effects of earthquakes of public concern or particular scientific interest. Most reports are made to the media, but requests are also received from the public, government agencies and other institutions. The requirements are ad hoc by the very nature of the service but on the basis of experience in recent years both the Ottawa and PGC staff are prepared as well as possible to handle these situations, in spite of these events in recent years seeming to occur more often on weekends than on working days. A minor problem, the solution to which is being sought through discussions with INFO EMR, is the difficulty in always receiving appropriate credit for the Branch efforts in providing this information.

The rapid determination of earthquake parameters often involves an exchange of information over the telephone with agencies in the eastern and western U.S. In the east this is usually with Lamont-Doherty or Boston College for events near the border and/or well recorded at stations in the other country. A similar exchange takes place between PGC and Washington State for events in the Georgia Str.-Puget Sd.-Juan de Fuca Str. region. For the 28 February, 1979 southeastern Alaska earthquake, a rapid exchange took place with USGS Menlo Park, who operate the southeastern Alaska network, and with NEIS, Boulder, for teleseismic epicentre and magnitude determinations.

Considered part of rapid information services is Wetmiller's weekly summary of events as determined above and others that can be located using data available from the network telex file in the central computer. These summaries were used for the (discontinued) monthly newspaper report and are used for the bimonthly Provisional Summary described below.

The distributed bimonthly reports are of four different types: "Bimonthly Summary", "Bimonthly Bulletin", "Provisional Summary" and "Worldwide Summary". The Bimonthly Summary contains lists of located earthquakes in the four regions of Canada, a brief text, a station map, a country-wide epicentre map and isoseismal maps of any widely felt earthquakes. The Bimonthly Bulletin contains the same lists, plus accompanying lists of phase times and amplitude measurements used in the determinations. The Provisional Summary is a preliminary list of all earthquakes that have been located from the time period covered by the Bimonthly Summary to the date of its issue. The Worldwide Summary is for distribution mainly within the Branch and lists significant global earthquakes, and their effects, that have occurred during approximately the previous year.

The distribution list for the Bimonthly Summary is given in Table 5, which also indicates the Branch staff and other agencies receiving the other three reports. Most of the agencies that have requested the Summary have done so for general information and to have on hand the most current lists of Canadian events. Some, e.g. Foothills and its consultants, are undertaking special studies with these data. The agencies receiving the Bulletin do so primarily because of the Canadian data it contains on events in adjacent regions of the eastern U.S., Washington State and Alaska. If data on Canadian events from these agencies have not been made available prior to the preparations of the Bimonthly Summary, the agencies are asked to send them prior to final event determinations for the annual catalogue.

The Seismological Series annual catalogues of Canadian earthquakes are presumably well known to the readers of this report, and will not be described in any detail here.

There are a number of issues related to these catalogues that will be discussed in the following section: their format, their contents and whether they should continue to be produced. In recent years these catalogues have contained lists of final parameters of all earthquakes that have been located in Canada and adjacent regions, and through 1976, lists of unlocated events as described above. Also described above, the preparation of these catalogues requires approximately four man-weeks distributed over approximately 4 months, after completion of the bimonthly series for the year. About half of this time (2 weeks) is spent on editing the final lists (adding new data, eliminating blasts, etc.) and the other half can be described as cosmetic, i.e., preparation of text and figures of publishable quality for the Seismological Series.

The Branch orders 200 copies of these catalogues. About 70 are distributed on the DOM. O. ALL free list and 5 to senior staff members. The DOM. O. ALL list includes most governmental geophysical institutions in North America and the major institutions throughout the world. The remainder are retained in the Branch Publication Office for use of staff and for distribution through the Index of Publications notices. Many of the Seismology staff keep private copies in their offices and authors of recent catalogues have indicated they have given a few (less than 10) to outside colleagues. A check of the Branch Publication Office has revealed that for the past six published catalogue years (1971-1976), the number of copies that remain on the shelves varies from zero for 1973 to 80 for 1976. Mrs. Bradfield does not have accurate figures on the numbers sold in recent years, but the numbers seldom exceed 10 for a given catalogue.

Three hundred to four hundred copies of each catalogue are also purchased by DSS. Sixty are distributed on the "List of Full Depository Libraries", 47 in Canada and 13 throughout the rest of the world. DSS advertizes on the "Daily Check List" and distributes free copies on request to public, federal, university, and college libraries, members of parliament, etc. A contact with the DSS Inventory Control office has revealed that for the same six catalogue years (1971-1976), DSS ordered 300 of the 1971, 73 and 74 catalogues and 400 of the 1972, 75 and 76 catalogues. Between 225 and 300 were distributed free on the List of Full Depository Libraries and Daily Check List, between 20 and 50 were sold (list of purchasers not available), and between zero and 150 remain in stock.

There is no doubt that the annual catalogues receive wide distribution! The proportions of serious users and dead storage in libraries is a separate question.

The Canadian earthquake data file is a digital tape file containing the parameters of all known earthquakes in Canada and adjacent regions. A copy of the file is kept at both Ottawa and PGC. The file is updated twice per year, once for the addition of the most recent year's data at the time the annual catalogue goes to press and once approximately six months later for purposes of correcting errors or making changes to earthquake parameters that have come to the attention of the staff. The existence and availability of this file is announced in each annual catalogue and station operations bulletin and in the most recent Branch Index of Geophysical Publications.

By far the largest users of this file are the seismological staff, for a large variety of studies of Canadian seismicity and seismic risk. A list of the last 13 requests for data from this file handled from Ottawa under the cost recovery policy is given in Table 6, which covers the past three years. The requests are not frequent, but seem to be increasing. The file is also used, both at Ottawa and at PGC, for all tandard seismic risk calculations based on the most recent earthquake data.

DISCUSSION

The foregoing provides an overall summary of the Canadian seismicity project and leads to the main purpose of this report, a discussion and consideration, by the seismicity staff, Branch Management and perhaps other Branch staff with fewer vested interests in the traditions of the project, of its merits, its manpower utilization and its probable need for change. In this section I can only put a summary of some of the seismicity staff's thoughts on these questions to paper. Not that there are any significant disagreements among the staff involved, but simply that the preparation of this report has led to a large number of detailed discussions, not all of which can usefully be summarized. The main purpose is to provide the appropriate background material so that Branch Management can consider and guide the future of the project.

We do not believe there can be any serious quarrels with two aspects of the project:

1. that the determination of the parameters of all "significant" Canadian earthquakes must be undertaken on a continuing basis; and

2. that two of the present output products, the rapid information services and the digital file of Canadian earthquakes, must be continued more-or-less in their present form.

Thus, there are three principal aspects for discussion:

1. what are the significant Canadian earthquakes;

2. the overall manpower utilization in the project, in particular in the routine day-to-day and month-to-month tasks associated with current seismicity; and

3. the format, contents, quality, schedule and distribution of the principal output products, the bimonthly reports and annual catalogues.

It is these three aspects that will be addressed briefly in the following discussion.

The low magnitude events, which as described in an earlier section are beginning to dominate the bimonthly and annual lists for the eastern and western regions, have generated much discussion prior to and during the preparation of this report. The simple fact of the matter is that if we are not interested in these events, then we should not be wasting money and effort operating dense networks in Charlevoix, Georgia Str. and, more recently, the southwestern Yukon. Clearly, we <u>are</u> interested in these events and there is general agreement that they are handled most efficiently at the present time by incorporating their determination into the general seismicity project. This may change in one or two years when interactive programs are available for the ECTN and WCTN that can process the data for events detected only by the on-line stations. Thus, while the larger earthquakes obviously are more significant in terms of scientific interest and public perceptions, the smaller ones are also important to our understanding of seismicity patterns and seismotectonics. The principal question to be addressed is the nature of the repository and distribution of the information on the low magnitude events, and this will be discussed further below.

If the seismicity and the other associated projects are worth doing as part of the overall Division program, then the essential questions related to manpower utilization are:

- do we have the right types (i.e., classifications) and numbers of personnel associated with routine determinations of Canadian earthquakes?

- is it done as efficiently as possible?

- is the time well spent achieving the current quality of the determinations?

- is an unnecessary amount of time being devoted to the low magnitude events?

With respect to personnel, the present tasks are handled mainly by staff in the RES classifications, and will be for the foreseeable future because these are the only available staff with the training to do the work. An alternative is possible only with a major organization change that brings in lower-salaried classifications to be trained to take over.

In some aspects, the present procedures for handling seismicity are not the most efficient. One person working full time on a given task will usually be more efficient than 5 people working part time; and we can, for example, compare the present procedures with that of Horner working essentially on his own to complete the 1969, 70, and 71 catalogues. The present procedure of sharing the workload is justified by: the project requiring more than one manyear continuing; time being available for Horner and Wetmiller to undertake additional research projects, of importance to their own career development and to the overall Branch program; allowing the rest of the seismicity staff, whose primary responsibilities are directly related to some aspect of Canadian earthquakes, to gain and retain the very basic knowledge that can come only from reading seismograms. However, it is also essential that a significant proportion of staff maintain a familiarity and degree of expertize so they can respond sensibly and quickly to rapid earthquake location requirements, public and press inquiries and aftershock and macroseismic field surveys.

There are plans under discussion that will make the computational aspects of the project somewhat more efficient. Associated with plans for ECTN expansion is an interactive computer program for data display, phase picking and epicentre computation in the Seismological Data Lab. Once this program is operational, the concept is to have a terminal in the seismogram reading room so that the analyst can compute epicentres concurrently with reading the data and produce final earthquake determinations on the spot. The present procedure requires coding, key-punching, CSC processing, and often 2 or 3 runs for some events before an acceptable solution is found. The total staff time required would not be greatly reduced, but final solutions would be available sooner. Procedures for interactive editing and updating of the bimonthly are being developed on the CSC Cyber in preparation for the ECTN interactive system.

The question of the quality of earthquake determinations is a difficult one and touches on matters of professional satisfaction and work habits. There is clearly a limit to the amount of time that should be spent extracting and massaging the seismic seismic data to get the "best" (often subjective) solution, and this will vary with the importance (e.g., magnitude and location) of the earthquake. There is also an obvious trade-off between quality and quantity given a fixed amount of staff time. With the present range of Division interests and concerns, it is, for example, more important to get an accurate epicentre for a low magnitude earthquake in the region of Chats Falls and Gentilly than for a larger magnitude event in some other

more seismic region of the country. Very few concrete suggestions can be made and this question of quality must be left to the discretion of the experienced staff involved, as they know better than anyone the demands on their time.

The format and contents of the Bimonthly Summary and Bulletin seem to be appropriate and it can be inferred from the description in the previous section that these are the output products employed by agencies with serious continuing interests in current Canadian earthquakes and seismic data. These bimonthlies are generally, but not always, produced later than bulletins from agencies in adjacent regions, e.g., the Lamont-Doherty quarterly bulletin, the NEUS Network quarterly bulletin and the University of Alaska, Geophysical Institute quarterly bulletin. Washington State does not have a fixed routine for earthquake determination, but does provide rough phase lists for the more significant earthquakes prior to preparation of the bimonthlies. It would not necessarily be an advantage to publish in advance of these agencies, and it would also be difficult to make a significant advance on the schedule shown in Table 4, which depends on the availability of standard and regional station records. It should also be noted that there is a large difference in scale between the Canadian project and these regional networks. There is however a plan, pending USNRC funding of ECTN expansion, to advance the schedule for the eastern region to more closely conform to that of the NEUS Network. Preliminary bulletins are also being prepared now in advance of the bimonthlies for the southwestern Yukon to accommodate data exchange with the USGS-operated southeastern Alaska stations. Charlevoix data is being extracted from the array tapes and microearthquake hypocentres computed in advance of the bimonthly schedule. Even if and when final bulletins for some regions of the country are prepared in advance of the present bimonthly schedule, it may still be advantageous to include these events in the Bimonthly Summary and/or Bulletin.

The future of the annual catalogues is a key question to be addressed in this report. Preparation of the catalogue is the seismicity task that seems to produce the most difficulties, mainly because it is imposed once per year on top of all other on-going activities, and deadlines are often optimistically set and missed. There are a large number of options that can be discussed and these are briefly set out below in three general categories: arguments for keeping the catalogue in more-or-less its present form, arguments for discontinuing it, and arguments for modifying its format and contents.

Arguments to keep the annual catalogue in its present form

- It is the hard-copy archival record of Canadian earthquakes of a durability and quality that will survive for many decades.

- It is a relatively high quality, bilingual and visible (in the PR sense) product of one of the most important Branch projects.

- As a complete annual summary, it is a work instrument that most of us keep on our office shelves for instant reference for a large variety of purposes.

- In spite of it occupying much dead storage space on library shelves throughout the world, it is a similar work instrument for a number of external agencies and individuals. For example, Milne reports that he often receives inquiries from individuals who neither have nor want access to the bimonthlies or digital tape file; he refers them to the nearest library containing the annual catalogues.

- The low magnitude earthquake determinations are generally completed at the bimonthly stage, have few if any additional data to be added at the annual catalogue stage and require little or no editing. Their transfer from the bimonthly file to the annual catalogue is a simple matter of computer listing; if they number in the few hundreds, they will occupy a total of a few pages in the annual catalogue.

- Most users of Canadian earthquake data, whether from the bimonthlies, the annual catalogues or the digital tape file, would prefer to have lists of all available events even to the lowest magnitudes. Studies of these data, to determine seismicity patterns, recurrence relations, etc. can benefit greatly from the low magnitude information, which can be later discarded if necessary. This is true even though the low magnitude location threshold is far from uniform throughout the country. However, if the catalogue lists are cut off at some arbitrary lower magnitude level it becomes an arbitrarily incomplete record of information available on Canadian seismicity.

Arguments to discontinue the annual catalogue

- It presents an image of wasted effort by Branch staff because ~ 500 earthquakes per year are listed, when so few are felt or cause damage.

- It is not required because most external agencies with a serious interest in Canadian earthquakes use the bimonthlies or the digital tape file.

- Seismicity staff, for most of their work, could use the bimonthlies or the digital tape file.

- It would save a small but significant amount of time and effort by seismicity staff.

Arguments to modify contents and/or format

- Its most important contents are the descriptions, isoseismal maps, etc. of the larger earthquakes and it could be reduced in size to include a summary description of only those earthquakes above a certain magnitude threshold, e.g., magnitude 4.

- Keeping all located earthquakes in the catalogues presents a biased relative picture of Canadian seismicity because of the uneven location threshold for the low magnitudes. Thus, the lists could be reduced to include only those events above the estimated location thresholds in the different regions, e.g. magnitude 2 near the dense networks, magnitude 3 throughout the remainder of southern Canada and magnitude 3.5 in the north.

- Its purpose would be served with the present or reduced contents if the publication quality were reduced to a simple, stapled, mimeographed format, saving some of the preparation time associated with the Seismological Series format. It would then not be available to DSS, but produced in-house, mailed on the DOM. O. ALL free list, and advertized in the Branch Index of Geophysical Publications. Alternatively, there could be an annual notice in the Publication Index that data from the digital file or on hard-copy are available as an open-file report.

RECOMMENDATIONS

1. It is recommended that the rapid information services of the Canadian seismicity project continue in their present form, seeking through INFO EMR and by other means to make the Branch better known as the national agency for earthquake information.

2. It is recommended that the bimonthly report series continue in its present format and on its present schedule. It is further recommended that the Bimonthly Summary and Bulletin continue to contain lists of all earthquakes that have been located by the seismicity project. It is recognized that the bimonthly series does not need to be widely advertized as all of the appropriate agencies are now receiving it, and the xeroxing task is already rather heavy (see Table 5). It can be made known privately to any additional agencies we would wish to receive it. It is recommended that a notice be circulated annually to ensure that recipients wish to remain on the circulation list.

3. It is recommended that the digital Canadian earthquake data file be continued in its present form, and that it continue to be updated twice per year. It is further recommended that this file contain all events that have been located by the seismicity project.

4. It is recommended that the annual catalogue be continued in its Seismological Series format with contents equivalent to the 1977 catalogue (i.e. bilingual and with no further lists of unlocated events). This recommendation does not have the unanimous agreement of the seismicity staff.

5. It is recommended that the next two annual catalogues (1978 and 1979) continue to contain lists of all earthquakes located by the seismicity project, including the low magnitude events located by the denser networks in Charlevoix, Georgia Str. and the southwestern Yukon. However, as in the past, it is not recommended that the catalogues contain all events located by special, short-duration field projects, e.g., the Baffin Island/Bay experiment and the forthcoming Yukon micro-earthquake survey. The LG-2 events would be treated like the Manic events were in 1975, i.e., listing only the larger induced earthquakes. The treatment of the 28 February 1979 St. Elias Mts. earthquake aftershocks will depend on the contents of open-file reports and publications currently in preparation.

6. It is recommended that the seismicity staff make every possible effort to reduce the workload associated with preparation of the catalogue after completion of the bimonthly series for the year, including editing the bimonthly lists as new data becomes available rather than waiting until the end of the bimonthly series and standardizing to the maximum degree the text, tables, figures and layout so that they are easily copied from year to year.

7. It is recommended that the decision to continue the current catalogue style for 1978 and 1979 be reconsidered prior to preparation of the 1980 catalogue, and that any decision for further continuation be based, inter alia, on experience that has been gained from preparation, usage and distribution of more rapid event lists as may have been determined using interactive programs on the ECTN and WCTN.

Table 1. Numbers of earthquakes located in the four Canadian and adjacent regions 1968-1977.

	East		North		West		Central		
Year	Can.	Adj.	Can.	Adj.	Can.	Adj.	Can.	Adj.	Total
1968	18	1	88	55	73	36	4	2	277
69	18	3	166	20	59	44	0	1	311
70	30	0	113	44	48	30	2	6	273
71	38	8	177	49	72	21	1	1	367
72	30	2	142	14	42	36	2	0	268
73	20	7	113	25	39	42	0	0	246
74	35	4	72	23	59	23	0	0	216
75	42	9	122	10	91	46	1	6	327
76	64	14	136	25	167	80	4	0	490
77	106	18	104	36	176	86	0	0	526

Table 2. Numbers of earthquakes $M \geq 4$ in the four Canadian and adjacent region 1968-1977.

Year	East	North	West	Central	Total
1968	0	5	15	0	20
69	2	13	12	0	27
70	0	10	17	0	27
71	3	22	34	0	59
72	1	38	26	0	65
73	1	24	30	0	55
74	0	22	16	0	38
75	6	19	20	1	46
76	3	24	32	0	59
77	2	14	8	0	24
				Average:	42

Table 3. Magnitude Distribution of Earthquakes Located in Three Active Zones, 1968-Jun 1978.

Year	Charlevoix			Western Que Z.			Georgia Str.-Puget Sd.		
	M<2	M2-2.9	M≥3	M<2	M2-2.9	M≥3	M<2	M2-2.9	M≥3
1968	0	1	3	1	0	2	0	10	1
69	0	1	4	0	6	2	1	5	2
70	0	2	1	0	12	3	0	2	1
71	1	1	1	0	5	9	0	1	1
72	4	4	0	2	10	4	0	1	3
73	8	1	2	0	2	0	1	4	1
74	3	1	1	1	15	4	0	1	2
75	5	4	1	7	10	4	9	11	5
76	18	6	3	8	3	2	51	11	5
77	35	4	2	5	7	5	46	10	4
78 (to June)	41	0	1	2	2	2	35	9	1

Table 4. Sample Schedule for Determination of Current Seismicity

1977	Jan	– data month (Jan) considered in example
	Feb	– seismograms and LEMSS arrive Ottawa
	Mar	– quality control on Jan records
	Apr	– Jan records microfilmed
	May	
	Jun	– seismogram scanning and preparation of Jan LEMSS input data
	Jul	– Jan records analysed
	Aug	– Feb records analysed
	Sep	– Jan/Feb bimonthlies distributed
	Oct	
	--	
	--	
1978	May	– Nov '77 records analysed
	Jun	– Dec '77 records analysed
	Jul	– Nov/Dec bimonthlies distributed
	Aug	
	Sep	– catch-up after summer holidays and field programs
	Oct	
	Nov	
	Dec	
1979	Jan	– preparation of 1977 annual catalogue
	Feb	
	Mar	

Table 5. Distribution List for Bimonthly Summary

	Also Receive		
	Bimonthly Bulletin	Provisional Summary	Worldwide Summary
Earth Physics Branch			
M.J. Berry		X	X
K. Whitham		X	X
R.B. Horner	X	X	X
Staff (circulate & post)	X	X	X
A. Lambert	east	east	X
R.J. Halliday		X	X
P.H. Serson		X	X
J.G. Tanner		X	X
Pacific Geoscience Centre	X	X	X
MBC Station		X	X
RES Station		X	X
Others			
Weston Observatory	east	east	
Lamont-Doherty	east	east	
Washington State	west		
USGS Menlo Park	north & west		
College Jean-de-Brébeuf	east	east	X
University of Alaska	north & west		
U. of Saskatchewan		X	X

R. Benson, Klohn Leonoff Consultants
F. Yip, Foothills Pipe Lines Ltd.
W. Slusarchuk, R.M. Hardy and Associates
G. Lipsett, Foothills Pipe Lines Ltd.
G. Leblanc, Weston Geophysical
P. Lecomte, Hydro-Quebec
E. Kanasewich, University of Alberta
R. Ellis, University of British Columbia
D. Hall, University of Manitoba
R. Mereu, University of Western Ontario
E. Deutch, Memorial University
R. Ledoux, Laval University
D. Smylie, York University
G. Ranalli, Carelton University
N. Rasti, University of New Brunswick
L. Sykes, Lamont-Doherty
R. Price, Queens University
D. Clay, Library of Parliament
Director, International Seismological Centre
National Earthquake Information Center, Colorado
R. Page, USGS Menlo Park
T. Hjortenberg, Geodetic Institute, Denmark
J. Landers, Lincoln Laboratory, M.I.T.
J. Bowlby, Ontario Hydro
P. Barosh, Boston College
F. Guerra, Iron Ore Co. of Canada, Sept-Iles

Table 6. Requests for Data from the Canadian Earthquake Data File

Agency	Region (Date of Request)
Woodward-Clyde Consultants, San Francisco, California	complete file (Oct. 78)
Teknekron Energy Resource Analysts, Berkley, California	complete file (July 78)
Ontario Hydro, Toronto	complete file (July 78)
Michael Clarke (priv. citizen) Toronto	southern Ontario (June 78)
Trevor Fitzell (grad. student) Imperial College, London	western Canada (June 78)
Lincoln Laboratory, MIT Cambridge, Mass.	eastern Canada (75-76) (Apr. 78)
Foothills Pipe Lines Ltd.	Yukon (Sep. 77)
Woodward-Clyde Consultants, Clifton, New Jersey	complete file (Aug. 77)
A.G. Davenport, University of Western Ontario	complete file (June 77)
Weston Geophysical, Westborough, Mass.	eastern Canada (June 76)
NGSDC, EDS, Boulder, Colorado	complete file (May 76)
E.R. Kanasewich, University of Alberta	complete file (May 76)
Gaz Metropolitain Inc., Montreal	St. Lawrence region (Mar. 76)