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# THE GEOTHERMAL ENERGY PROGRAMME

# A REVIEW

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The Geothermal Energy Programme 1976-81 has had as its prime objective the identification and assessment of exploitable geothermal resources within Canada. During this five-year period it has been shown that an exploitable resource exists at Regina. It can be inferred that similar resources exist beneath wide areas of the western prairies, but their existence at any selected location is still subject to uncertainty. In the western mountains, the Mt. Meager project is probably within a year of proving a resource that may be used to generate electrical power, but if the south reservoir at Mt. Meager should fail the final test, there are other sites waiting to be probed.

As the Regina and Mt. Meager projects change character from research to demonstration, as the regional search in the interior of British Columbia acquires new focus, as the examination of existing data in the sedimentary basin of the prairies enters a new phase, and as the search begins in the Atlantic Provinces, it is a good time to review the Geothermal Energy Programme. The provision of new opportunities under the National Energy Policy has also required a reassessment of current projects, and so the close of the year 1980/81 symbolises a turning point, for which the new thinking has developed over the previous year or more.

## The Beginning

Although Energy Panel funds for Geothermal Energy R and D were first made available in April 1976, the foundations of the Programme precede that date. The Geological Survey of Canada (GSC) and the Earth Physics Branch (EPB) had already carried out some activities directly aimed at the examination of geothermal resources, using A-base funds. Of particular note were the collection and chemical analysis of hot spring waters (GSC, 1974) the drilling of shallow holes near the Meager Creek hot spring (GSC and EPB, early 1974), the first Sproule contract for the analysis of existing data in sedimentary basins (EPB, 1975/76), and the attendance of NATO-CCMS meetings on geothermal resources (EPB and GSC, 1973 et seq).

Beyond these specific activities the Geothermal Energy Programme was able to draw on the vast assembly of earth science information that had been built up by GSC, EPB, Provincial agencies and resource companies over the last 100 years. Of particular value were the geological mapping programme (GSC), the extensive studies of Tertiary volcanism in Canada (GSC) the systematic collection of records from oil or gas wells by governments of the western provinces, and the decision by the Scientific Committee for the Upper Mantle (SCUM) in 1961 that a Geothermal Section should be created at EPB. Without this background, the combination of activities designed either as a general resource exploration tool or as pure science, the Geothermal Energy Programme could not have begun productively.

Since the policy of 1976 was to supply money and no manpower, the money would have done nothing if there had not been a handful of scientists who had already made it their responsibility to educate themselves in the field of geothermal exploration. The new duties were accepted in substitution for basic research. Other new duties of high Departmental priority have also been superimposed, and time tends to be allocated by the individual in response to competing demands. Naturally, the least demanding voice is the one to be ignored and the remnants of the basic research programme yield the most. Since the Geothermal Energy Programme and other applied programmes rely heavily on the presence of active and up-to-date basic research, there is a limit to how far the Department can afford to allow such programmes to be suppressed. As in all technical fields, the boundary between pure and applied research is indistinct, but in fully absorbing existing capability now there is a danger that future needs will not be met.

The Geothermal Energy Programme has always been regarded as one of resource identification and assessment, rather than one of resource conversion and utilisation technology. Consequently the Programme has been made up of components of earth science and mineral exploration. This view is as valid in 1981 as it was in 1976. The technology of exploitation of geothermal resources has been developed elsewhere, and it should be imported rather than reinvented. The generation of electricity from vapour-dominated or fluid-dominated systems, the heating of domestic and horticultural space by hot water from volcanic zones or from sedimentary formations, and many industrial applications are available as working examples to be imitated. Only the exploitation of hot dry rock, by the creation of an artificial circulating system is under initial development. This programme, carried out by the Los Alamos Scientific Laboratories, has been followed by means of the NATO-CCMS meetings and by obtaining the reports of progress. The Federal Republic of Germany is now making a significant contribution in both money and effort to this multi-million-dollar programme, but our role as interested spectator is within our more modest budget.

The emergence of the Federal-Provincial Agreement (FPA) system for provision of funds for demonstration projects has supported the Geothermal R & D Programme in its role of resource identification and assessment. Funds for the adaptation of foreign technology to demonstrate the use of geothermal resources in Canada are available from the FPA system, and thus the two sources complement each other. Nevertheless, the R & D Programme has not been carried on without regard for the available technology for exploitation and the markets for the product. These factors have played a major part in determining the geographical areas of research.

## The mode of operation

The mode of operation within the Geothermal Programme has been the same throughout the period 1976-81, and since it works well there is no need to make major changes. The coordinator makes frequent visits, average about five each year, to Vancouver and other cities to consult colleagues. Each year a technical planning meeting is held, normally in Vancouver in January, during which plans for the coming financial year are finalised and a list of projects with activity leaders and estimated costs is produced. This list is circulated, and throughout the rest of the year changes imposed by unforeseen costs, availability of contractors, modifications on the job etc. are made by the activity leader and the coordinator in consultation. The coordinator writes reports summarising current finances, project changes and shifts in technical philosophy at irregular intervals, usually after a visit to colleagues, and about five times each year. This is far superior to a rigid calendar-dominated style of reporting, since it provides reports immediately after the Programme has been reviewed and modified by the active participants and not at pre-determined times that have no relevance to activities.

The key people in advising the coordinator and acting as project leaders are J.G. Souther (GSC, Vancouver) and T.J. Lewis (EPB, Ottawa 1976-79 and PGC, Sidney, 1979 - present). J.G Souther has made the volcanic aspects of the Programme, particularly the Mt. Meager project and now the Mt. Cayley activities, a major part of his professional duties, at a very high level of personal commitment. T.J. Lewis has similarly performed a project-leader role in the regional exploration of the cordillera. This has left the coordinator the freedom to concentrate on the sedimentary basin project. This team of three has provided the working impetus without which the Programme could not have progressed.

In addition to these M.J. Drury (EPB, Ottawa 1979-present) has now taken on a similar role in research in the Atlantic Region, and in the reformulation for 1981/82 this becomes a fourth project. Since we have been moving towards these project-leader roles, and since it is proposed to increase the work level, it is proposed to recognise formally these project leaders. In practice it will make little difference to our evolving mode of operation. Individual activities have been managed and valuable advice has been given by a number of others, including L.K. Law (EPB, Sidney), E.R. Niblett (EPB, Ottawa), L.S. Collett (GSC, Ottawa), G.C. Rogers (EPB, Sidney), and A.E. Taylor (EPB, Ottawa).

The Task Convenor at the National Research Council (NRC), and the member of the Office of Energy Research and Development (OERD) have contributed their administrative and technical guidance in a generally productive manner. They have kept to a minimum the demands for budget preparation, progress reports, and other routine paperwork. At the same time, they have been willing to listen sympathetically and to respond when possible to requests for extra funds to meet unforeseen opportunities or to complete an activity near the end of the financial year. The slightly anomalous situation of having an NRC office interposed between the levels of office within the same sector of EMR has worked out well, but it provided a few minor problems in the early days. There were occasions when the same set of instructions, passing downwards both through NRC and through the conventional hierarchical channels, arrived in two different forms, but no major problems arose by this means.

Most of the work has been done by consultants and other commercial agencies under contract. This, in theory, is a fully viable alternative to having work done by public servants in-house. In many activities, including some of the Geothermal Programme, this theory is correct provided that some scientist can be turned into a contract supervisor for the occasion. This means that any new work done under contract is done at the expense of part of an earlier activity. The contract process provides an amplifying factor to the work capability, not a free addition.

In a true scientific research activity, the personnel concerned are working at the level of the current state of the art, and it is not normal to find the regular field-survey or borehole-logging company working at this level. This can create difficulties in letting contracts, since a lengthy learning process, on the part of the contractor, is needed. In the field of geothermal energy, almost completely unknown in Canada in 1976, an entirely new concept had to be learned by the contractor, and the theory of obtaining routine services from contractors was invalid. Two consultants learned the subject quickly, Nevin, Sadlier-Brown, Goodbrand Ltd. (NSBG), of Vancouver, and Sproule Associates Ltd., of Calgary, in the cordilleran and sedimentary fields respectively. Once they had learned, during the first contract, they had a major advantage over others that had not had that first contract, since the activity leaders were reluctant to go through the initiation again. These two companies are still the major geothermal consultants, distinct from the specialised service companies that have undertaken specific surveys.

If major parts of future projects are to be contracted as research operations, with sub-contracting of service companies as appropriate, it is to consultants that we must turn, rather than to the service companies. We do not wish to be restricted to one company, since this implies no choice, it does not truly develop Canadian expertise, and it provides no incentive for a high standard of work. If we are to encourage new geothermal consultants any major contract of this sort will involve another learning process and will probably save nothing over running the project in-house with service contracts during the first year, but savings in man-hours could commence during the second year.

An increase in the size and scope of contracts is necessary to attract good contractors. Our present practice of letting contracts limited to sums of normally less than $50,000 does not attract many bids. One of the purposes of the proposed increase in funding is a more comprehensive contracting philosophy, which should improve the situation over a period of two or three years.

## The Substance

From 1976 to 1981 the Geothermal Energy Programme was described in three projects.

1. Delineation of regional geothermal anomalies. Objective - to acquire and interpret geological andd geophysical data from all parts of Canada, particularly the cordillera, in order to identify those areas most likely to have potential for geothermal development.

2. Identification and assessment of geothermal resources. Objective - to assess the potential of selected geothermal areas for the encouragement of geothermal energy exploitation with Canada.

3. Geothermal energy from sedimentary basins. Objective - to assess and demonstrate the potential low-grade geothermal resources located in sedimentary formations for future space-heating and other direct heat applications.

These divisions have served well, but over five years the programme has developed and a revision is needed. The division between projects 1 and 2 has evolved to a division between work at Mt. Meager (2) and work everywhere else (1). Several developments contribute to the need for restructure: 1. The Mt. Meager and Regina projects have been taken up by the Federal Provincial Agreement system; 2. a new volcanic centre, Mt. Cayley, is being examined in detail; 3. the regional work in the cordillera has acquired a focus; 4. work has begun in the Atlantic Provinces; and 5. the National Energy Policy permits an expansion.

It is proposed to revise the projects to reflect both the geological setting and the contributions of the key people as described in the previous section. Projects 1 and 2 will be replaced by projects that refer to areas devoid of recent volcanism and to identified recent volcanoes respectively. Project 3 already refers to sedimentary basins and need not be changed. A new project 4 is introduced to include all work in the Atlantic margin. This project is defined on a geographical rather than a geological basis, since it will include any work on the Cumberland Basin. This departure from a strictly geological division is justified on pragmatic grounds: it is easier to deal with the Cumberland Basin locally, in an 'eastern' contract, than it would be to include it with the predominantly 'western' context of project 3.

We thus have four projects for 1981-82:

1. Identification and assessment of geothermal resources in non-volcanic terrain. The term 'non-volcanic' refers to the absence of identifiable

volcanic centres of Quaternary age, and not to an absence of any rocks of volcanic origin. This project will focus on the small Tertiary basins and potassium-rich intrusive rocks of the southern cordillera, primarily within the area 118° - 122°W, 49° - 51°N, where the main population of the interior is located. Although the main aquifer formations are sedimentary, the geological setting is quite different from the sedimentary platform of the prairies. In the cordillera the basins are small, typically less than 50 km in width, and no data has been accumulated during exploration for hydrocarbon resources. The proposed level of funding will allow this project to proceed at a reasonable rate and to achieve results at a speed that is desirable but not possible at present. With the new funds it will be possible to let contracts for research packages to survey the temperature field of a region, to perform a seismic survey to determine the depth of a basin, or to analyse the hydrological condition of a basin. Some reasonable level of assessment within five years is aimed at. This project will be under the leadership of T.J. Lewis (EPB, Victoria).

2. Identification and assessment of geothermal systems associated with recent volcanic activity. Mt. Meager was the first volcanic centre to be examined in detail, but EMR association with this site is now limited to advice and assistance to B.C. Hydro and small scale experimental surveys. Mt. Meager is about to move on to the resource proving and demonstration phase, and EMR should be turning its attention elsewhere. This project will now include all work on Mt. Cayley, on the axis between Mt. Cayley and Mt. Meager, and on other volcanic centres such as Mt. Silverthrone, Mt. Edziza, etc. The proposed new funding will permit an enhanced rate of examination of volcanic centres, in order to show in a reasonable time how many sites like Mt. Meager

are available for development. This project will be under the leadership of J.G. Souther (GSC, Vancouver).

3. Geothermal energy from sedimentary basins. Since the Regina project has now moved on to the Federal Provincial Demonstration stage, this project will consist only of regional work until another embryo demonstration comes along. There is a great deal of data collection and mapping to be done, the University of Alberta has developed a good capability for this, and some form of combined activity, involving university and government personnel will be worked out. The proposed new funds will allow the resource mapping of the prairies to be done. Future projects may extend this mapping into remote areas such as the Mackenzie Valley and the Arctic Islands. The Programme Coordinator, A.M. Jessop, will retain the leading role in this project.

4. Geothermal resources of the Atlantic region. This is a new project, reflecting the fact that these studies began in a small way during 1980. Current work in the Chesapeake Bay area of the USA has been very encouraging, and an examination of this relatively mature geological area is indicated by the US results. Under the old system these studies were included in project 1, but the area of study is quite different, both geographically and geologically from the rest of project 1, and a separate project is needed. Research in the Atlantic margin has only just begun, and the new funding is needed to allow this work to reach a viable level. We regard it as important to push back the boundaries of known or probable geothermal potential into regions of marginal geological promise and high economic need, and the Atlantic margin is the obvious place to start. The Yukon is another area to be examined in turn. M.J. Drury will be the project leader.

The possibility of increased funding under the NEP comes at a most opportune time for the Geothermal Energy Programme. There is a general feeling that the first cautious steps are over and that it is time to take bolder initiatives. With the proving of the resource at Regina and the imminence of the crucial test at Mt. Meager it is time to broaden our effort.

The Output

Contractors produce reports. The Coordinator has a shelf full of reports, - blue ones, grey ones, fat ones, thin ones. Reports do not produce energy, unless they are burned. The reports may contain an account of a full season of activities at Mt. Meager, or they may contain the results of a magnetotelluric survey at several sites, expressed in terms of electrical resistance of layers of the earth's crust. Some reports are released to the public as open files, either by EPB or GSC. Others contain only data sets, some of them proprietary, and these are not released as open files: they are treated as working tools for the scientists concerned. The production of reports is an essential point of the contracting process, and these reports contain a great deal of valuable information, in a variety of formats, styles and levels of technicality.

The Geothermal R&D Programme is designed to 'identify and assess' the geothermal resources of Canada. In broader terms, it must produce information that will provide the basis for demonstration projects, prompt industrial agencies to consider geothermal energy as a viable and alternative energy source, prompt public utilities and local governments to consider geothermal energy as a possible source for heating buildings, and provide Provincial governments with the guidance necessary to enable them to write sound controlling legislation.

We must ask whether the present programme is achieving these total objectives, rather than just the narrow objective of 'identify and assess'.

There is no doubt in the minds of the scientific performers that an entirely appropriate programme of technical field work is being performed. There is continued thought and discussion to make sure that the relatively small financial and human resources are put to the best use. In general our contractors have also tried to give value for money and have performed in a creditable and honourable way, but we have had isolated problems. Up to this point we could say that the narrow objectives have been met, but the scientific performers are not satisfied that the broad objectives are similarly being fulfilled. Somehow these reports must be converted into knowledge and understanding of geothermal potential in the hands of industry, public utilities and all levels of government. The individual reports are to fragmented to provide this understanding to people who are called upon for the first time to consider an energy source that is entirely new to Canada. These people need summaries and digests of the reports - second generation reports that show what has been done, what the results have been, and what potential can be inferred in other locations. These second generation reports are not being written. The people that can write them most effectively are the scientific performers who have designed and expedited the activities, particularly the four project leaders named above. These people can only be free to perform this function if the load of detailed contract administration can be eased.

It is for this reason that the proposals to OERD for 1981/82 under the National Energy Programme include requests for man-years to provide assistance for the leaders of projects 1 and 2. If the money supply is increased and these man-years are not forthcoming, the existing scientific performers will continue to be fully occupied in initiating and supervising contracted surveys, with a continued inability to follow through to the logical conclusion of writing the second-generation and synthesising reports and papers. With the higher funding level the natural result will be that the quality of work and cost-effectiveness, so carefully controlled up to now, will begin to slip, and we shall be justly accused of 'throwing money at a problem'.

## The Results

The results of the first five years of the Geothermal Energy Programme are summarised in Table 1. This bare summary may give an unfairly jaundiced view of the achievements so far. For example, at Mt. Meager a temperature of 202°C has been encountered at a depth of only 367 m. This constitutes known hot dry rock. Since the rock cores show every sign of chemical alteration by water-borne minerals, we can deduce that we have found the roof of a hot water reservoir, but we do not know if water is present in exploitable quantities. The shallow depth indicates a distinct possibility of a dry steam reservoir, but these are rare and we cannot regard it as probable. At Regina we have proved the existence of an exploitable resource. It is virtually certain that similar resources exist below wide areas of the prairies, but at any specific location we can say no more than probable.

Table 2 summarises the progress at Mt. Meager, with the approximate levels of expenditures by EMR and B.C. Hydro. The B.C. Hydro projected installation cost of a 55MW pilot plant of about $1.00 per Watt is understood to be more expensive than some forms of water power but to be comparable with some other power sources.

Table 3 summarises the steps at Regina, again with associated expenditures. The total capital expenditure of about M$2 at Regina will produce a system able to produce heat at a rate of about 3MW, for a period of perhaps 40 years. With careful design, maintenance costs will be low and production costs will be only for pumping. This energy output is probably rather lower than the average for such systems. The water temperature is slightly lower than expected and the seven-inch casing limits the size of pump that may be used, but the output is suitable for the planned application. The use of heat pumps could also enhance the heat recovery, both in temperature and quantity.

The scientists concerned with both of these projects are of the opinion that the steps taken have shown consistently successful results. Not every experiment yielded all that was expected of it, and not every prediction has been vindicated precisely, but a logical series of steps has been followed in each project, and no false trails have been followed.

Table 4 summarises expenditures on the Geothermal Energy Programme, both historic and proposed. In assessing this programme on the basis of how much energy per research dollar, it should be remembered that such a question assumes the result of the research. We can look at the research components of Mt. Meager and Regina, but it is difficult to separate the essential site-specific costs from regional surveys that preceded, for example, the first Sproule contract contributed, but was not specific to Regina.

At Mt. Meager we can assume as an approximation that all expenditures up to and including the present year (1980-81) are research. This means that about M$5.2 has been spent on research to lead to the resource demonstration and pilot plant.

At Regina, only the initial k$59 was necessary research before the proving well was drilled. All the remainder is more properly classified as resource testing (pump and corrosion testing) or as research not essential to the specific site (hydro-fracture tests).

The Judgment

As shown earlier, the Canadian geothermal community is small, consisting of four project leaders and a half-dozen others in EMR, a smaller number in Provincial resource departments, two university scientists, one person in a provincial utility and two main contractors. In addition to these, a larger number of people have performed laboratory or field measurements without being concerned with the purpose and design of the work as a whole.

The project leaders have been conscious of a lack of people in Canada of whom they could ask advice and comment. There is nothing wrong in this, in fact scientists should be capable of breaking new ground and should in theory be prepared for failure. In an oil company, an exploration well that does not encounter oil or gas is written off as just another dry hole, part of the risk that is not truly a gamble since only a fraction of their wells will be successful. In our present geothermal context all attention will be focussed on the first large well at Mt. Meager. What will happen if the first deep well at Mt. Meager does not find steam? Will this be accepted in B.C. Hydro and EMR as part of the risk with continued hope for the second well, or will the whole project be stopped?

Two geothermal specialists from the USA were invited to Vancouver in March 1979 by B.C. Hydro, and a meeting was held to which EMR participants were invited. In general, the US specialists commented favourably on the Mt. Meager work and they considered that the prospects for exploitable resources were good.

It is possible that a fully experienced industrial team would have a proving well into the Mt. Meager reservoir by now, and probably more. Their technical team would have been more confident of their approach to the project, they would have committed larger resources immediately, and they would have interpreted their results with less conservatism. At Regina the initial pace of the project was very good. The first well was completed within two years of the first approach by the University to EMR to discuss the concept. The reinjection well will not be drilled within a further two years, but the first well has provided ample scope for other work. This has been a simple project compared with Mt. Meager, and one would expect faster progress. An industrial agency, with a definite energy load under construction, would have drilled both holes in one continuous operation.

Despite the inevitable conjectures on what might have been, the scientists concerned believe that they have spent their resources frugally and soundly, and that to have achieved so much on such a small budget is a major achievement.

Conclusions

1. The Geothermal Energy Programme has made a good start, based on the existing data compiled by scientific programmes over many years and through the efforts of a small number of scientists who have diverted their efforts from other programmes. It is time for the financial resources to be increased, but a corresponding increase of effort by the performers is not possible because there is little left of the other programmes to give up.

2. The Programme has been run on technically sound lines, but with a learning process that may have had a slowing effect. Results at Mt. Meager and Regina have been generally successful in a sequence of logical and careful steps.

3. The output from the various contracts has usually been of good quality, but it is not being adequately summarised and developed into second-generation documents that will tell the industrial and technological world about Canadian geothermal resources. Using the manpower requested for the coming year to provide assistance in new and continuing contracted projects, the Project Leaders will make publication of the results so far a high priority.

4. The extent to which a geothermal expertise is being developed in Canada is small. The size of the Geothermal Programme from 1976 to 1981 has not permitted a wide development of experience, and more must be done along these lines with the augmented budget of the next few years.

TABLE 1

LOCATIONS IN CANADA OF EXPLOITABLE GEOTHERMAL RESOURCES

1. DRY STEAM

| | | |
|---|---|---|
| Known | - | None |
| Probable | - | None |
| Possible | - | Mt. Meager, Locations in Garibaldi and Stikine Volcanic Belts, B.C. |

2. HOT WATER (above 180°C)

| | | |
|---|---|---|
| Known | - | None |
| Probable | - | Mt. Meager, Locations in Garibaldi and Stikine Volcanic Belts, B.C. |
| Possible | - | Locations in Anaheim, Pemberton and Wrangell Volcanic Belts, B.C. and Yukon. |

3. WARM WATER - A. VOLCANIC AREAS

| | | |
|---|---|---|
| Known | - | None |
| Probable | - | Locations in all Volcanic Areas of B.C. and Yukon. |

B. SEDIMENTARY BASINS

| | | |
|---|---|---|
| Known | - | Regina |
| Probable | - | Wide Areas of Great Plains in B.C., Alberta, Saskatchewan and Territories; Queen Elizabeth Islands, and Lower Mackenzie Valley, N.W.T., Tertiary Basins of Central B.C.. |
| Possible | - | Cumberland Basin, P.E.I., N.B., and N.S. |

| | | |
|---|---|---|
| 4. HOT DRY ROCK | - | A. Volcanic Areas |
| Known | - | Mt. Meager, Mt.Cayley |
| Probable | - | Locations in all Volcanic Belts of B.C. and Yukon. |
| | | B. Acid Intrusive Rocks |
| Known | - | None |
| Probable | - | Central B.C., including Okanagan and Kootenay |
| Possible | - | Locations in Maritime Provinces and Newfoundland. |
| | | C. Deep Crust |
| | - | The Deep Crust is known to be hot everywhere, but this heat is not exploitable economically with present technology. |

| | | |
|---|---|---|
| 5. HOT SPRINGS | | |
| Known | - | More than 100 locations in B.C., Alberta and Territories. |
| Probable | - | Others in remote or untravelled areas. |

TABLE 2

THE MEAGER MOUNTAIN PROJECT

| | | | $1000 units | |
|---|---|---|---|---|
| Identify the Heat Source | | | EMR | BCH |
| | 1973-74 | Selection of Research Area | | |
| | | Shallow Drilling | 20 | 94 |
| | 1974-75 | Geophysics, Shallow Drilling | 0 | 238 |
| | 1975-76 | Geophysics, Shallow Drilling | 0 | 119 |
| Outline the Reservoir | | | | |
| | 1976-77 | Geology, Geophysics | 39 | 23 |
| | 1977-78 | Geology, Geophysics, Shallow Drilling | 113 | 276 |
| | 1978-79 | Geophysics, Drilling | 222 | 289 |
| | 1979-80 | Drilling, Isotope Hydrology | 40 | 1,600* |
| | 1980-81 | Drilling, Geology, Hydrology | 38 | 2,100* |
| | | To Date | 472 | 4,739 |
| Proving the Reservoir | | | | |
| | 1981-82 | Large Scale Drilling | | 4,080 |
| Installation of Demonstration Plant to produce 55 MW | | | | |
| | 1982-89 | | | 40,000 |
| | | TOTAL | | 50,000 |

* with 50% funding by Federal-Provincial Agreement

TABLE 3

THE REGINA PROJECT

| | | |
|---|---|---|
| PHASE 1 | | $1000 units |
| 1977-78 | Feasibility Study | 39 |
| | Seismic Survey | 20 |
| 1978-79 | Drill Producing Well | 655 |
| 1979-80 | Hydro-Fracture Test | 134 |
| | Well completion and Pump Test | 102 |
| | Temperature Logs | 8 |
| | Corrosion Tests and Chemical Analysis | 15 |
| 1980-81 | Negotiations for Reinjection well | 0 |
| | To Date | 973 |
| PHASE 2 | | |
| 1981-82 | Drilling of Reinjection Well, Installation of Connecting Pipe and Pumps, Pump Tests. | 1,080* |
| PHASE 3 | | |
| 1982- | Connection to load | |

* 100% funding by Federal-Provincial Agreement

TABLE 4

ANNUAL EXPENDITURES OF GEOTHERMAL ENERGY

PROGRAMME

$1000 Units

| Year | A-base | Panel | NEP | Total |
|---|---|---|---|---|
| 1973-74 | 20. | | | 20. |
| 1974-75 | 5. | | | 5. |
| 1975-76 | 37.5 | | | 37.5 |
| 1976-77 | 42. (1) | 100. | | 142. (1) |
| 1977-78 | 34. (1) | 280. | | 314. (1) |
| 1978-79 | 40. (1) | 1002.5 | | 1042.5 (1) |
| 1979-80 | 60. (2) | 360. | | 420. (2) |
| 1980-81 | 62.5 (2) | 360. | | 422.5 (2) |
| 1981-82 | 65. (2) | 360. | 795. (2) | 1220. (4) |
| 1982-83 | 67.5 (2) | 360. | 1069. (2) | 1496.5 (4) |
| 1983-84 | 70. (2) | 360. | 1253. (2) | 1683. (4) |
| 1984-85 | 72.5 (2) | 360. | 1092. (2) | 1524.5 (4) |
| 1985-86 | 75. (2) | 360. | 1136. (2) | 1541. (4) |

man-years shown in brackets