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Geothermal Service of Canada

Service géothermique du Canada

FEASIBILITY STUDY IN THE USE OF GEOTHERMAL ENERGY TO HEAT LARGE FACILITIES

UMA Engineering Ltd.
17007 - 107 Avenue
Edmonton, Alberta

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ABSTRACT

This study evaluates the technical and economic potential of using low temperature geothermal energy to heat large buildings in Edson, Alberta.

Geological studies have indicated the presence of low temperature geothermal energy. Saline water lying in aquifer formations at depths of 1.5 to 3.5 kilometres has temperature of 49°C to 95°C respectively. A large area in the northern part of Edson was identified containing some large buildings including a hospital and 6 schools. The area is capable of accommodating at least three more large buildings. The municipality owns land suitable for pipeline corridors to connect these facilities to a geothermal energy hot water distribution system.

None of the geothermal systems examined are found to be cost effective in terms of pay-back of capital costs by displacement of natural gas energy use. A small scale research oriented project using low cost abandoned gas wells appears to be a logical first step in developing a full scale prototype system.

RÉSUMÉ

Le potentiel économique et technique de l'utilisation de l'énergie géothermique à basse énergie pour le chauffage d'immeubles à Edson a été évalué. Les études géologiques indiquent la présence d'énergie géothermique à basse énergie sous forme d'eau salée à des températures de 45°C à 95°C, dans les formations aquifères profondes de 1.5 à 3.5 kilomètres.

Une région dans le nord d'Edson où se situent quelques immeubles y compris un hôpital et six écoles a été identifiée. Cette région pourrait rendre service à trois autres grands immeubles. La municipalité possède des terres qui seraient convenables pour le droit de passage de pipelines reliant ces édifices à un système de distribution d'eau chaude géothermique.

Aucun des systèmes géothermiques étudiés a été jugé économique, en comparant les frais de remboursement des coûts capitaux avec le déplacement de l'utilisation du gaz naturel. Un project de recherche à petite échelle qui se servirait des puits de gas abandonnés semble être la première étape logique vers le développement d'un système prototype à grande envergure.

The Town
of Edson

FEASIBILITY STUDY
IN THE USE OF
GEOTHERMAL ENERGY
TO HEAT LARGE FACILITIES

JULY, 1985

UMA Engineering Ltd.
Engineers, Planners & Surveyors

REPORT ON

THE USE OF GEOTHERMAL ENERGY TO HEAT LARGE BUILDINGS IN EDSON, ALBERTA

CONTRACT NO. 1AQ84 - 00138

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JULY, 1985

REPORT ON THE USE OF
GEOTHERMAL ENERGY TO HEAT
LARGE BUILDINGS IN EDSON, ALBERTA

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LIST OF ABBREVIATIONS AND SYMBOLS

a - annum or year
cap - capita
°C - degrees Celsius
cm - centimetre(s)
d - day
ha - hectare(s)
h - hour(s)
I.D. - inside (pipe) diameter
kg - kilogram
kJ - kilojoules
km - kilometre(s)
kPa - kiloPascal(s)
kV - kilovolt(s)
kW - kilowatt(s)
L - litre(s)
m - metre(s)
m^2 - square metre(s)
m^3 - cubic metre(s)
mg - milligram(s)
min - minute(s)
mL - millilitre(s)
mm - millimetre(s)
O.D. - outside (pipe) diameter
s - second(s)
W - watts

METRIC-IMPERIAL CONVERSION TABLE

1°C	= 1.80 °F
1 ha	= 2.471 acre
1 km	= 0.6214 miles
1 kJ	= 0.9478 Btu
1 kPa	= 0.1450 psi
1 kW	= 1.341 hp (mechanical)
	= 1.340 hp (electrical)
	= 3.412 Btu/hr
1 L	= 0.2200 Imp. gal
1 L/s	= 13.20 Imp. gal/min
1 m	= 3.281 ft
1 m^2	= 10.76 ft^2
1 m^3	= 35.31 ft^3
1 mm	= 0.03937 inch

SUMMARY

OBJECTIVES

This study evaluates the technical and economic potential of using low temperature geothermal energy to heat large buildings in Edson, Alberta. Geothermal heating systems typically consist of supply wells drilled into a hot water aquifer; well pumps; a distribution system of insulated pipes; heat exchangers to remove heat from the geothermal water; and disposal wells usually drilled into the same formation as the supply well at a distance of one kilometre from the supply well. Heat extracted by the heat exchangers is used for space heating, and often for pre-heating fresh air and heating domestic water at each building connected to distribution system. An area was identified in Edson that contains 11 large municipal buildings that could be heated by such a system.

BACKGROUND

Edson is located in west central Alberta and is situated over the Western Sedimentary Basin. Studies of the Basin have indicated the presence of low temperature geothermal energy. High salinity water lying in aquifer formations at depths of 1.5 to 3.5 kilometres has been found with temperatures of 45°C to 95°C respectively. The hot water is a usable energy source when pumped to the ground surface from wells and circulated through heat exchange units.

Low temperature geothermal energy has been used extensively in some cities in Ireland, Europe, Japan, USSR and the USA for central heating systems for over 100 years. There are no operating systems in Canada although test wells have been drilled in Regina and interior B.C.

A large area in the northern part of Edson was identified containing some large buildings including a hospital and 6 schools. The area is capable of accommodating at least three more large buildings. The municipality owns land suitable for pipeline corridors to connect these facilities to a geothermal energy hot water distribution system.

STUDY APPROACH

The approach used to assess the technical and economic potential of geothermal energy usage in Edson for space heating can be summarized as follows:

- determination of applicable system and design parameters by a literature search and inspection of existing system,
- detailed examination of hydrogeologic conditions in and around Edson to define the geothermal resource,
- examination and analysis of existing heating systems in buildings in the study area,
- assessment of planning aspects of the study area to determine the potential for more buildings,
- development and economic analysis of various geothermal - central heating system models,

- examination and assessment of applicable provincial and federal regulations pertaining to the development of geothermal resources, and

- examination of application, provincial and federal capital cost funding programs.

GEOTHERMAL RESOURCES

The sedimentary subsurface geology of the Edson area was examined in detail using records of exploratory and development wells drilled by the oil and gas industry within a nine township block centered on Edson. Analysis of some 235 well records produced information on aquifer characteristics.

Although temperatures are fairly well defined, data produced on aquifer conditions requires considerable interpretation. Assumptions made on supply well flow rate, drawdown, and reliability had a profound affect on the economic analysis.

Two formations were selected as having the greatest potential.

Belly River Formation

The Belly River Formation, at depths of 1,250 to 1,500 metres, gives evidence of being able to produce large quantities of water. Temperatures are expected to range from 35 to 40°C at 1,250 metres and from 45 to 50°C at 1,500 metres. The Belly River water salinites are expected to be 3,000 to 5,000 p.p.m. total solids.

Beaverhill Lake Formation

Good water production should be anticipated, but not assured, because of lack of data, from depths of about 3,500 metres. Temperatures of 95 to 105°C are indicated with salinites of 160,000 to 200,000 p.p.m. total solids.

REGULATORY ASPECTS OF GEOTHERMAL DEVELOPMENT

There is no legislation in Alberta that specifically addresses geothermal energy development. Ownership of groundwater is vested in the Crown, however, and usage is regulated under the Water Resources Act by Alberta Environment. Their primary concerns are protection of aquifers from damage and the inference of groundwater diversion on existing users. Since geothermal wells in the Edson area would go below a depth of 150 m, the Energy Resources Conservation Board would also regulate development under the Oil and Gas Conservation Act and Regulations. Withdrawal and re-injection of brine could affect reservoir pressures and hence production. A surface lease will be required to gain access to drill and test production wells and a licence will be required from the E.R.C.B. to drill the wells, and withdraw and re-inject brine. Well construction must meet E.R.C.B. regulations that govern location, drilling methods and procedures, casing installation, blow-out equipment, development, testing and abandonment. There are no royalties presently on the use of the resource.

TECHNICAL AND ECONOMIC EVALUATION

In order to complete a technical and economic evaluation of the use of geothermal heat in Edson, it was necessary to establish system parameters or models on which to base the analyses.

Since a group of larger buildings in the northern part of Edson were identified as having potential for geothermal heating, it was logical to analyse a model involving retrofitting of these buildings for geothermal heating. The model was based on use of the higher temperature source since initial analysis showed that it would be uneconomical to retrofit for low temperature use. Initially the model consisted of existing retrofitted buildings only, however early analysis showed that it would be necessary to incorporate cascading use to new facilities to maximize the use of the resource and thus optimize the system.

In order to consider the low temperature resource for heating of new facilities it was logical to analyse a low temperature model, which would necessitate the use of heat pump to raise the heating medium to a suitable temperature.

Because of the suitability of greenhouse heating by use of a relatively low temperature heating medium without the use of a heat pump, a greenhouse model on its own, and as a cascading use, was analysed.

A variety of types of well pumps, pumping control methods, technical refinements, etc. were considered with a view to optimizing the system to maximize cost effectiveness of each model. The following model descriptions and analysis outline the system components and design selected and the results of the technical and economic investigation.

MODEL 1 - LOW TEMPERATURE BUILDING HEATING WITH HEAT PUMP

Description:

This system envisages heating 41,400 m^2 of new apartment buildings consisting of eleven - 30 suite - 3 floor apartment buildings, or other types of new facilities requiring 4,500 kW total peak heating capacity. One of the facilities planned for completion in 1986 is a recreational complex for the Alberta Winter Games, which may include a swimming pool, an ideal user of geothermal heat. This facility may be considered as one of the new facilities to be heated geothermally.

The system consists of 1,500 m deep supply well, constant speed well pump, natural gas engine drive heat pump, 150 mm diameter buried piping to the disposal well, 1,500 m deep disposal well, circulation pumps and 150 mm diameter buried insulated circulation piping to the above buildings.

Analysis:

Estimated Total Capital Cost	$2,978,000
Estimated Total Annual Operating & Maintenance Cost (Capital Cost Repayment not Included)	191,000
Estimated Total Annual Capital, Operation & Maintenance Cost	494,000
Estimated Total Annual Heating Cost Using Natural Gas	156,000

Analysis Results:

Heat pump capital and operating costs are a significant factor in this application. The analysis shows that a geothermal heating system would result in additional costs of $35,000 per year over natural gas heating, not allowing for capital cost repayment, and a loss of $338,000 per year with capital cost repayment.

MODEL 2 - LOW TEMPERATURE GREENHOUSE HEATING

Description:

This system envisages heating a 5,270 m^2 conventional (double plastic pane) greenhouse, requiring 2,900 kW total peak heating capacity.

The system consists of a 1,500 m deep supply well, constant speed well pump, heat exchanger, 150 mm diameter buried piping to the disposal well, 1,500 m deep disposal well, circulation pumps and 150 mm diameter insulated circulation piping to the greenhouse.

Analysis:

Estimated Total Capital Cost	$2,384,000
Estimated Total Annual Operating & Maintenance Cost (Capital Cost Repayment not Included)	129,000
Estimated Total Annual Capital, Operating & Maintenance Cost	372,000
Estimated Total Annual Heating Cost Using Natural Gas	90,000

Analysis Results:

The analysis shows that a geothermal heating system would result in additional costs of \$39,000 per year over natural gas heating, not allowing for capital cost repayment, and a loss of \$282,000 per year with capital cost repayment.

MODEL 3 - HIGH TEMPERATURE BUILDING AND GREENHOUSE HEATING

Description:

This system envisages firstly heating existing buildings retrofitted for this purpose. These buildings would consist of the following or any combination of existing larger buildings in the study area requiring a total 3,470 kW total peak heating capacity:

St. John's Hospital
Pine Grove School
Parkland High School
Parkland Lodge
A.H. Dakin Elementary School
Jubilee Junior High School

Secondly, by "cascading" from the retrofit use, this system would heat a total of 25,300 m^2 of new apartment buildings consisting of seven - 30 suite - 3 floor apartment buildings, or other types of new facilities requiring 3,060 kW total peak heating capacity.

Thirdly, by cascading from the new building use, this system would heat a 9,670 m^2 conventional greenhouse, requiring 5,310 kW total peak heating capacity.

The system consists of a 3,500 m deep supply well, variable speed well pump, heat exchanger, 150 mm diameter buried piping to the disposal well, 3,500 m deep disposal well, circulation pumps and 150 mm diameter buried insulated circulation piping to existing retrofitted buildings, to the above new buildings and to the greenhouse.

Analysis:

Estimated Total Capital Cost (Including $840,000 for Retrofit)	$12,636,000
Estimated Total Annual Operating & Maintenance Cost (Capital Cost Repayment not Included)	409,000
Estimated Total Annual Capital, Operating & Maintenance Cost	1,696,000
Estimated Total Annual Heating Cost Using Natural Gas	438,000

Analysis Results:

The analysis shows that a geothermal heating system would result in a savings of $29,000 per year as compared to natural gas heating, not allowing for capital cost repayment and a loss of $1,258,000 per year with capital cost repayment.

MODEL 4 - HIGH TEMPERATURE GREENHOUSE HEATING

Description:

This system envisaged heating a 21,500 m^2 conventional greenhouse requiring 11,800 kW total peak heating capacity.

The system consists of a 3,500 m deep supply well, variable speed well pump, heat exchanger, 150 mm diameter buried piping to the disposal well, 3,500 m deep disposal well, circulation pumps and 150 mm diameter insulated circulation piping to the greenhouse.

Analysis:

Estimated Total Capital Cost	$10,761,000
Estimated Total Annual Operating & Maintenance Cost (Capital Cost Repayment not Included)	352,000
Estimated Total Annual Capital, Operation & Maintenance Cost	1,448,000
Estimated Total Annual Heating Cost Using Natural Gas	366,000

Analysis Results:

The analysis shows that a geothermal heating system would result in a savings of $14,000 per year as compared to natural gas heating, not allowing for capital cost repayment and a loss of $1,082,000 per year with capital cost repayment.

CONCLUSIONS

The major conclusions of the study are summarized as follows:

- The study was based on test data available from petroleum exploration wells. Because testing for this purpose does not provide all the information necessary for geothermal development, significant assumptions had to be made that had a profound influence on the economic analysis.

- Two prospective aquifers at depths of 1,500 and 3,500 m were identified at temperatures of 45°C and 95°C, respectively. The brine has salinities of between 3,000 and 200,000 ppm, respectively, that necessitates re-injection into deep wells for disposal.

- The cost of doublet supply and disposal wells is very high, being $1,100,000 for a 1,500 m depth and $7,200,000 for a 3,500 m depth exclusive of pumping and related equipment.

- The basic geothermal system envisaged would consist of a supply well, heat exchanger and disposal well 1 km from the supply well. Heat would be supplied to users by a distribution system using glycol or treated water. This approach will minimize potential scaling and corrosion caused by the brine.

- The use of the geothermal supply well must be maximized to optimize the economics of space heating because of the high cost of the supply system.

- Maximization of the resource can be achieved by extracting the maximum amount of heat from the geothermal water by cascading the heating fluid in the distribution system from user to user; and by using geothermal energy to provide a base load and trimming with natural gas fired furnaces and/or boilers.

- None of the geothermal systems are found to be cost effective in terms of pay-back of capital costs by displacement of natural gas energy use.

- Although the capital costs for the low temperature systems (in the range of $2.4 to $3.0 million) are less than for the high temperature systems, the low temperature systems would operate with a net operating loss (not allowing for repayment of capital) of $35,000 per year for the new building heating system and net loss of $39,000 per year for the greenhouse heating system.

- The high temperature heating systems would operate with a net operating gain (not allowing for repayment of capital) of $29,000 per year for the building and greenhouse cascading heating system and a net gain of $14,000 per year for the greenhouse heating model, however these annual operating cost savings are very small in comparison with the capital costs for the high temperature systems (in the range of $10.8 to $12.6 million).

- Based on assumptions that had to be made on supply well and aquifer water characteristics, geothermal energy exploitation does not appear to be economically viable in the Edson area at the present time or in the forseeable future given the high capital cost of the systems, the substantial costs of pumping the geothermal water from significant depths, and the relatively low natural gas and relatively high electrical energy costs in the area.

- The project does not appear to be suitable for any existing federal or provincial energy conservation grant programs for capital cost sharing because this is not a significant displacement of fossil fuel, and because of non-existent or long duration payback periods.

- A test well is required to better define aquifer characteristics. An abandoned petroleum exploration well cased to a depth of 2,760 m and sealed with cement grout plugs is located in Edson, and may offer inexpensive access for testing and possibly development of a geothermal supply well compared with a new test well. Other opportunities may arise because oil and gas exploration is active in and around Edson.

- Further research and development is required in the use of geothermal energy in Canada particularly with regard to a prototype operating system, retrofit use, and high salinity considerations. The Edson situation offers a number of advantages that warrants consideration in the selection of a site for development of a prototype test facility. Some advantages are active petroleum exploration providing a good data base and possibly low cost test wells, and the unique combination of low temperature geothermal energy and gas driven heat pumps.

- Considering the high costs of the systems examined, a smaller scale research oriented project using low cost abandoned gas wells would appear to be a logical first step in developing a full scale prototype system.

RECOMMENDATIONS

Advancement of the use of geothermal energy in Edson will require the development and testing of a supply well to prove up the resource; specifically, temperature, flow rate, pumping head, and aquifer extent. Testing of the abandoned well in LSD 4-21-53-17W5M and/or using some other existing or future exploration well(s) should be investigated.

A staged advancement of the project would appear to be appropriate for the Edson area:

- Investigate abandoned wells in more detail; determine the feasibility of pump testing a well or wells; and determine the feasibility of using the geothermal energy for a small scale heating system.

- Conduct a pump test on a selected abandoned well.

- Develop a pilot geothermal heating system (probably a single large building).

- Expand system to a full scale prototype (a central multi--building system).

SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

1.1 OBJECTIVES

This study evaluates the technical and economic potential of using low temperature geothermal hot water energy to heat large buildings in Edson, Alberta. Geothermal heating systems typically consist of supply wells drilled into a hot water aquifer; well pumps; a distribution system of insulated pipes; heat exchangers to remove heat from the geothermal water; and disposal wells usually drilled into the same formation as the supply well at a distance of one kilometre from the supply well. Refer to Plate 2 in Section 3.0 Heat extracted by the heat exchangers is used for space heating, and often for pre-heating fresh air and heating domestic water at each building connected to distribution system. An area was identified in Edson that contained 11 large municipal buildings that could be heated by such a system.

The specific objectives of the study were to:

- define the geothermal resources available in Edson,
- define heat loads in existing buildings in the study area and estimate heat loads for future buildings that the study area could accommodate,
- develop a central district heating concept based on geothermal heating systems,
- evaluate the economics of such a system and compare to conventional gas and electric heating systems,
- identify and assess provincial and federal regulations pertaining to the geothermal resource, and
- identify applicable capital funding programs.

1.2 BACKGROUND

Edson is located in west central Alberta and is situated over the Western Sedimentary Basin. Refer to Figure 1 in Appendix D. Studies of the Basin (Jessop, Jones, Sproule) have indicated the presence of low temperature geothermal energy. Studies of subsurface temperature gradients conducted by the University of Alberta have indicated above world average gradients in the Edson area. High salinity water lying in aquifer formations at depths of 1.5 to 3.5 kilometres has been found with temperatures of 45°C to 95°C respectively. While temperatures are fairly well defined, aquifer conditions require detailed site-specific study to produce parameters for technical and economic analyses.

Low temperature geothermal energy has been used extensively in some cities in Iceland, Europe, Japan, the USSR and the USA for central heating systems for over 100 years.

As part of this study, geothermal systems in operation in Klamath Falls, Oregon, and Boise, Idaho were examined. In both centres, large central and district heating systems are currently in-place and expanding due to substantial cost savings in space heating and proven system reliability. These systems typically consist of shallow supply wells (100 - 200 m) under artesian pressures; low salinity (500 - 1,000 ppm) geothermal water at 80 to 100°C; insulated, in-ground delivery systems; heat exchangers in individual buildings; an un-insulated return piping system; and surface disposal of geothermal water. In each application substantial savings in annual heating costs are being realized. These systems are economic because of the relatively low cost of developing the resource, low pumping heads, high delivery temperatures and relatively high natural gas costs. Geothermal energy is currently being used for a wide variety of uses in addition to space heating office and residential buildings such as heating domestic water, fresh air intake, heating side-walks and parking areas, heating greenhouses, industrtial uses and cooling.

There are no similar central or district heating systems in Canada presently although test wells have been drilled at the University of Regina and in interior B.C. by B.C. Hydro. There are a number of factors that make the use of geothermal energy for a central heating system of large facilities in Edson appear attractive:

- A large site, shown on Figure 2 has been identified in the northern part of Edson, and contains some large existing buildings and is suitable for three or more additional large buildings.

- The site is at the north limit of present development, permitting future expansion.

- One of the facilities planned for completion in 1986 is a recreational complex for the Alberta Winter Games which may include a swimming pool, an ideal user of geothermal heat.

- There are nine existing schools and other civic buildings within 100 m of the site that could be retrofitted to accept geothermal heat.

- The municipality owns land suitable for a pipeline corridor connecting these facilities.

- Petroleum exploration is active in the immediate vicinity offering a good source of subsurface information and the possibility of acquiring abandoned wells for testing for a geothermal source and for disposal of used water.

The following sections outline the approach taken to meet the objectives of the study and summarize results.

SECTION 2.0

STUDY APPROACH

2.0 STUDY APPROACH

The following flow chart identifies the components of the study and the interaction of these components. The study was executed in two steps in a preliminary feasibility assessment followed by a detailed study. The components of the preliminary study consisted of:

- a hydrogeologic study to define the geothermal resource options;
- the definition of relevant parameters for the technical and economic analysis of heating systems;
- preliminary evaluation of present and future heating loads in the study area; and
- a cursory examination of the economics of a small low temperature central heating system.

The study indicated such a system could be economically viable and warranted further study and optimization.

The detail study followed and included:

- an in-depth literature search including the recent Government of Canada studies in geothermal energy;
- detailed assessment of the heating systems and heat load characteristics in existing buildings;
- investigation of funding programs and regulatory aspects;

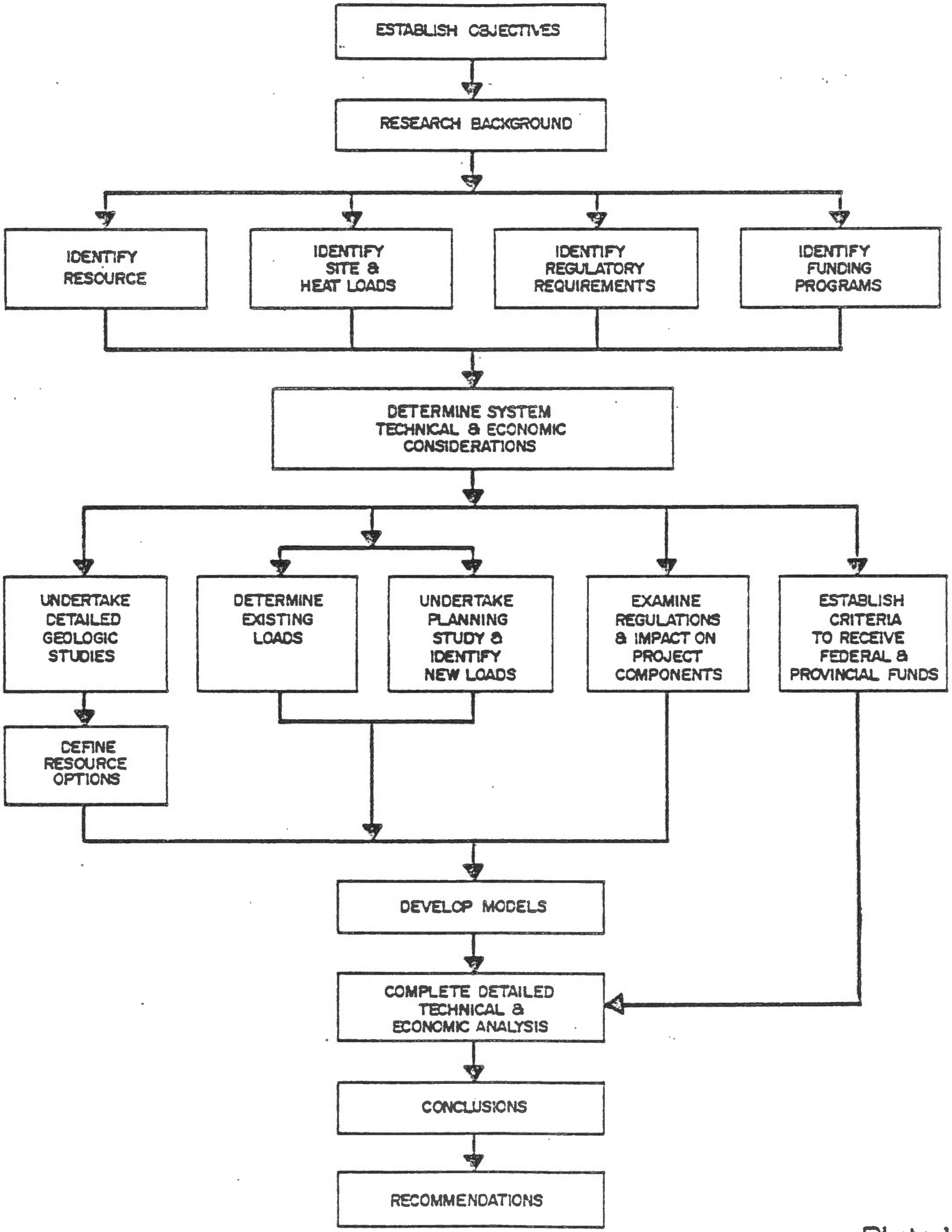


Plate 1

EDSON GEOTHERMAL FEASIBILITY STUDY

STUDY APPROACH FLOW CHART

the uma group

- an inspection of existing geothermal systems in Klamath Falls, Oregon and Boise, Idaho; and

- the development and technical and economic analysis of four heating models - a low temperature, cental heating system; a low temperature greenhouse model; a high temperature system involving retrofit of existing buildings and cascading to other facilities; and finally a high temperature greenhouse model.

Based on these analyses, conclusions were drawn and recommendations advanced for follow-up research.

SECTION 3.0

GEOTHERMAL SYSTEM TECHNICAL AND ECONOMIC CONSIDERATIONS

3.0 GEOTHERMAL SYSTEM TECHNICAL AND ECONOMICS CONSIDERATIONS

3.1 GENERAL

The overall objective in considering the use of geothermal energy is to conserve conventional fossil fuel energy use, natural gas for heating purposes in this case, while at the same time hopefully achieving an economic benefit in terms of reduced heating costs. A financial analysis approach must therefore be used, taking into account the incremental capital, operating and maintenance costs of the alternate or substitute geothermal heating system over and above those of a conventional natural gas heating system and balancing these costs against the cost of conventional natural gas heating energy. The following are thus obviously an essential part of the analysis:

- Identification of the components of the geothermal system in order to determine capital costs.

- Determination of characteristics of the geothermal system and components in order to determine operating and maintenance costs.

- Natural gas energy unit costs.

Once the above factors are determined the economics of the geothermal system can be considered by several criteria, as has been done in this study:

- Unit cost of geothermal versus natural gas energy.

- Total annual savings or loss using geothermal versus natural gas energy.

- Total present value savings or loss using geothermal versus natural gas energy.

- Simple payback period to re-pay the incremental capital cost of the geothermal system based on total annual cost saving, if applicable, using geothermal heating in place of natural gas, i.e. total incremental capital cost of geothermal system divided by total annual cost saving using geothermal energy.

3.2 RESOURCE AND SYSTEM CHARACTERISTICS

Geothermal Resource

Geothermal aquifer resource or stratigraphic formation characteristics to be considered at a potential development site, all of which affect economic viability, include the following:

- Depth to aquifer.

- Water temperature.

- Water quantity available or well production flow rate in relation to well water level drawdown (affected by reservoir thickness, continuity, pressure, porosity, permeability, storage characteristics and replenishment characteristics, and to a lesser degree by well design and diameter).

- Water quality available, including dissolved and undissolved solids content and type, dissolved and free gas content and type, corrosion, scaling and abrasion characteristics.

Geothermal water temperature will be a function of the subsurface temperature gradient in the area, rather than the depth to the particular aquifer formation, unless affected by vertical movement of water upward or downward through permeable formations or faults.

As shown later, the wells are the most expensive single capital cost item and, within limits, the flow capability is not necessarily related to well cost. Well flows will vary from formation to formation and from different locations within the same formation. Well water drawdown level, within limits of the pump suction setting depth within the well, is roughly proportional to the extraction rate for a given well. Extraction rates must be limited so as to maintain the water drawdown level above the pump suction. Thus, the pump setting depth has a limited affect on the production flow capability of the well.

Only certain stratigraphic sedimentary formations or beds, below a potential site, may have the prerequisite characteristics for a suitable geothermal energy source. Resource characteristics for the Edson site will be considered further in Section 4.0.

Geothermal Fluid Chemistry

Scaling and corrosion tendencies of the brines from the prospective formations cannot be conclusively determined from the water analysis data contained in the Geologic Report - Appendix B, however, it is certain that these characteristics are more severe with production from the deeper formations.

Considerable information has been published on the effects and treatment of geothermal water, and guidelines for material selection have been formulated. Information of note applicable to brines from formations of the Western Sedimentary Basin, in which Edson is located, is summarized as follows:[1.]

- The typically high concentration of non-condensible gases and toxic constituents in the highly saline geothermal brines may present corrosion and scaling problems.

- Short term testing (103 hours) of mild steel in the Regina Geothermal Well Fluid (also in the Western Sedimentary Basin) has indicated acceptable corrosion rates of 0.2 to 0.25 mm annually. Long term corrosion effects have yet to be determined.

- The tendency for calcium carbonate to precipitate can be controlled by maintaining the fluid under pressure causing the carbon dioxide gas to remain in solution. Pressure required will depend on carbon dioxide solution concentration, which is unknown.

- Because of high salinity, the brines cannot be disposed of at the surface, and thus re-injection to the producing formation will be necessary. Re-injection is also beneficial in that it helps to maintain aquifer pressure in the producing formation.

- The potential for corrosion and salt precipitation to occur is not foreseen to present insoluble problems.

- Flow velocities influence corrosion and scaling tendencies. In the presence of oxygen a fluid velocity of less than about 2 m/s is desirable to limit corrosion attack. On the other hand, very low flow rates promote scaling.

Main System Components and Arrangement

A schematic of a typical geothermal heating (doublet) system is shown on Plate 2. The main components consists of:

- supply well and wellhead
- supply well pump
- primary heat exchanger
- surface pipeline to disposal well
- disposal well
- building to house heat exchanger and pumping equipment
- secondary (circulation) surface distribution piping to building heat users

The time for the spent geothermal fluid to "break-through" from the disposal well to the supply well at a particular site depends on the separation distance of the wells and the permeability of the rock formation. A separation distance of 1 km, which is consistent with computer modelling studies of the Regina hydrologic conditions[1.], has been assumed for purposes of this study.

It has also been assumed that injection into the producing formation will occur by gravity so that an additional "booster" or "injection" pump is not required.

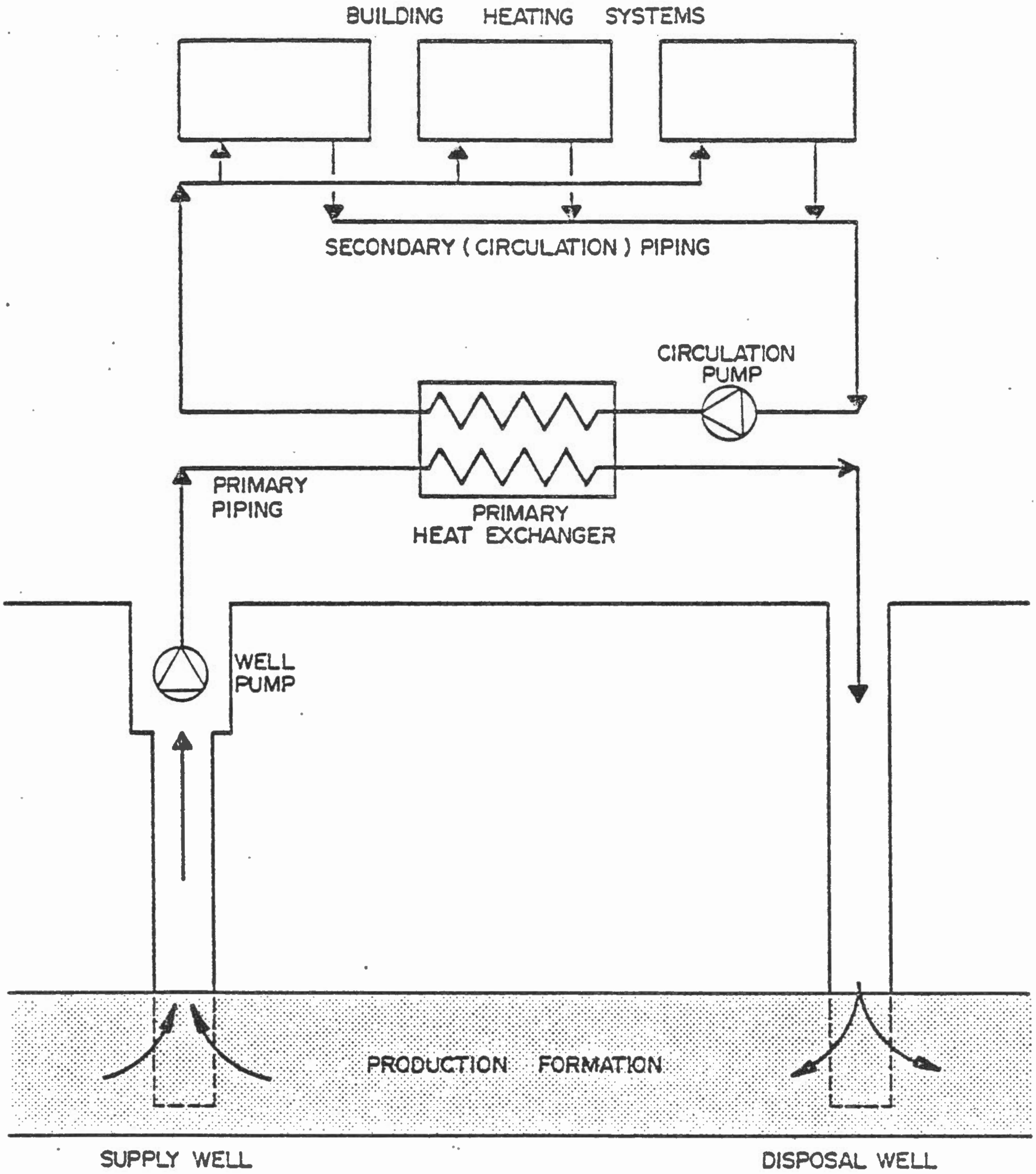


Plate 2

EDSON GEOTHERMAL FEASIBILITY STUDY

TYPICAL GEOTHERMAL SYSTEM

Because of the high cost of deep well doublets, it is more economical to provide full standby capacity by means of conventional gas fired boilers and/or furnaces within each building than by means of a spare doublet. Existing gas fired heating units would serve as full standby in existing buildings to be retrofitted for geothermal heating. Gas fired units to meet peak demand conditions and thus provide full standbye heating would be installed in new buildings to be heated geothermally. Gas fired units of the same capacity are required by either means of heating, and are thus not considered to be an incremental cost in the analysis.

Primary and Secondary Fluid Transmission

The high salinities, and potentially corrosive and scaling tendencies of the geothermal fluid requires special consideration of primary piping materials and process equipment used and treatment and operational measures carried out to limit deterioration and maintain proper operation of the geothermal system. These factors have a bearing on system cost and thus must be taken into account in the analysis. For purposes of this analysis, special alloy metals have not been allowed for in the well casing, head and discharge piping. Allowance has been made for extra heavy wall thickness mild steel pipe materials. Asbestos cement pressure pipe has been allowed for the buried surface piping to the disposal well, and also for the buried surface distribution piping. The operating costs provided in this study allow for some chemical addition, filtration, etc. for corrosion and scale inhibiting. Should very extensive treatment be required, the economic viability shown would be reduced further.

Because of the hostile nature of the geothermal fluid, it is essential to minimize the amount of piping exposed to the geothermal fluid. Thus, heat is extracted immediately by use of a heat exchanger, and the spent fluid returned to the aquifer through the disposal well. The geothermal heat is then distributed in the secondary circulation piping system by use of a closed system treated water heating medium, buried below frost depth and insulated to minimize heat loss.

3.3 SYSTEM DESIGN CHARACTERISTICS

Heat Load Variation

Building space heat load varies with outdoor temperature, reaching a peak at minimum outdoor winter design temperature (-35°C for Edson), and reaching zero at an outdoor temperature equal to the design indoor space temperature (approximately 20°C).

In constant flow systems, the temperature drop between the geothermal water supply and disposal or between the secondary water supply and return varies with heat load, whereas with variable flow systems the flow varies with heat load while the temperature drop remains relatively constant. Thus, pumping costs are somewhat reduced with reduced heating load using variable speed pumps on variable flow systems.

Considering the seasonal load variation and the cost of pumping geothermal water from significant depths, it is necessary to examine the cost effectiveness of various geothermal system pumping control methods. Those considered are as follows:

- Constant speed and variable speed year round operation
- Constant speed and variable speed seasonal (heating season) operation
- Constant speed on/off operation with accumulator tank

Constant speed and variable speed seasonal operation has been selected for the models in this study because of capital and operational cost considerations as will be discussed in Section 8.

Base Load/Peak Load Optimization

In any heating system it is necessary to design the heat supply system to meet the peak system load. However, because of the high capital costs of a geothermal system, it is more economical if the geothermal system is designed to supply the base load, with a standbye gas fired boiler or furnace provided as part of the building heating system to provide peak load trimming and to serve as standbye should the geothermal system be out of operation.

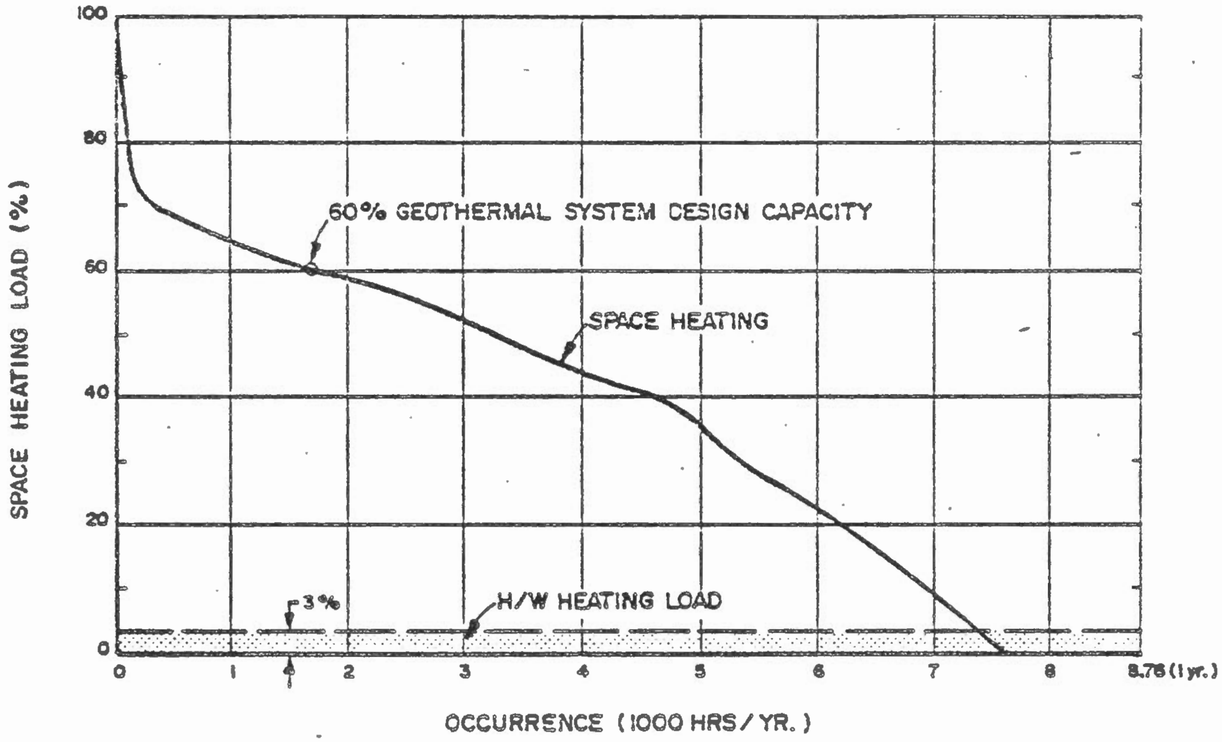
In practice, the geothermal system design base load capacity is set to achieve economic optimization. In this study, this capacity was selected at 60% of the peak load requirement.

Heat Load Profiles

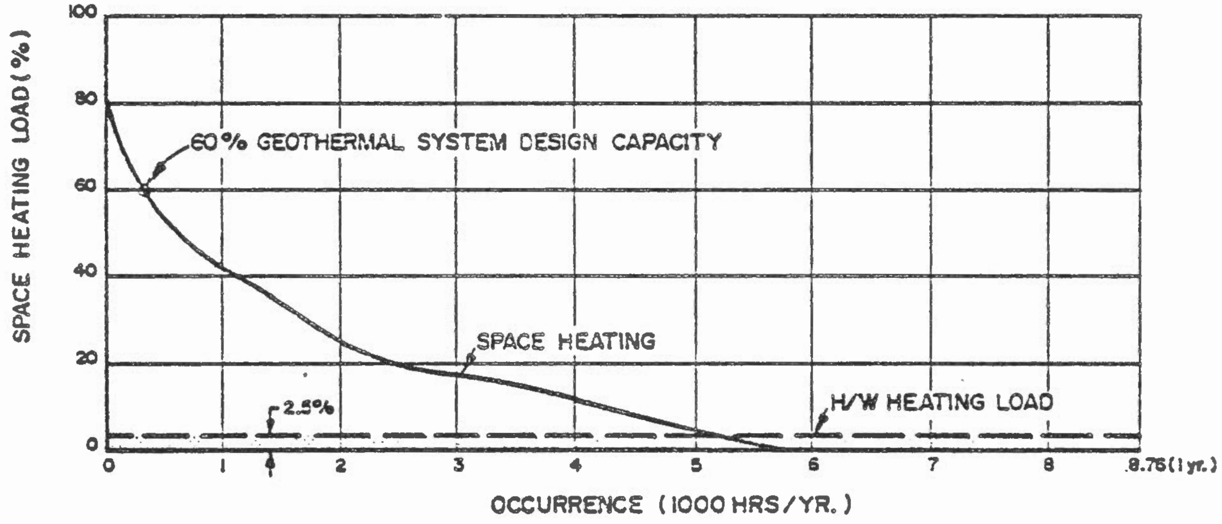
For various types of buildings, typical load profiles or histograms have been developed which represent the locus of loads and the accumulated time occurences during the year. Typical load profiles or curves for a Residential Townhouse Complex, Commercial Office Complex and Greenhouse Heating are shown on Plates 3 and 4. The area under the curve represents the total annual energy demand. Representative annual domestic water heating annual energy demands are also shown. Knowing the peak load of a building, these load profiles were used in this study to:

- determine the total annual building (space and domestic water heating) energy demand,
- determine the annual geothermal building heat energy supplied versus that supplied by natural gas trimming at the selected 60% of peak load well capacity,
- determine the optimum point in the season at which to shut-down the geothermal system, and
- determine the "Annual Geothermal Supply System Utilization Factor" or ratio of actual annual energy delivered to maximum annual energy available, referenced to an injection (sink) temperature of 20°C and unity load factor for each model.

Referring to the load profiles, it can be seen that the area under the curve below the 60% (of peak load) line represents the total annual building heat energy supplied by the geothermal system. The area under the curve above the 60% line, represents the total annual building heat energy supplied by natural gas trimming. As can be seen by comparing areas on the load profiles, by designing the geothermal system to supply only 60% of the peak load, the geothermal system will be supplying approximately 95% of the total annual energy requirements. The 60% of peak load capacity was selected arbitrarily, however it is expected to be very close to the economic optimization point for these systems.



RESIDENTIAL TOWNHOUSE COMPLEX



COMMERCIAL OFFICE COMPLEX

NOTE:

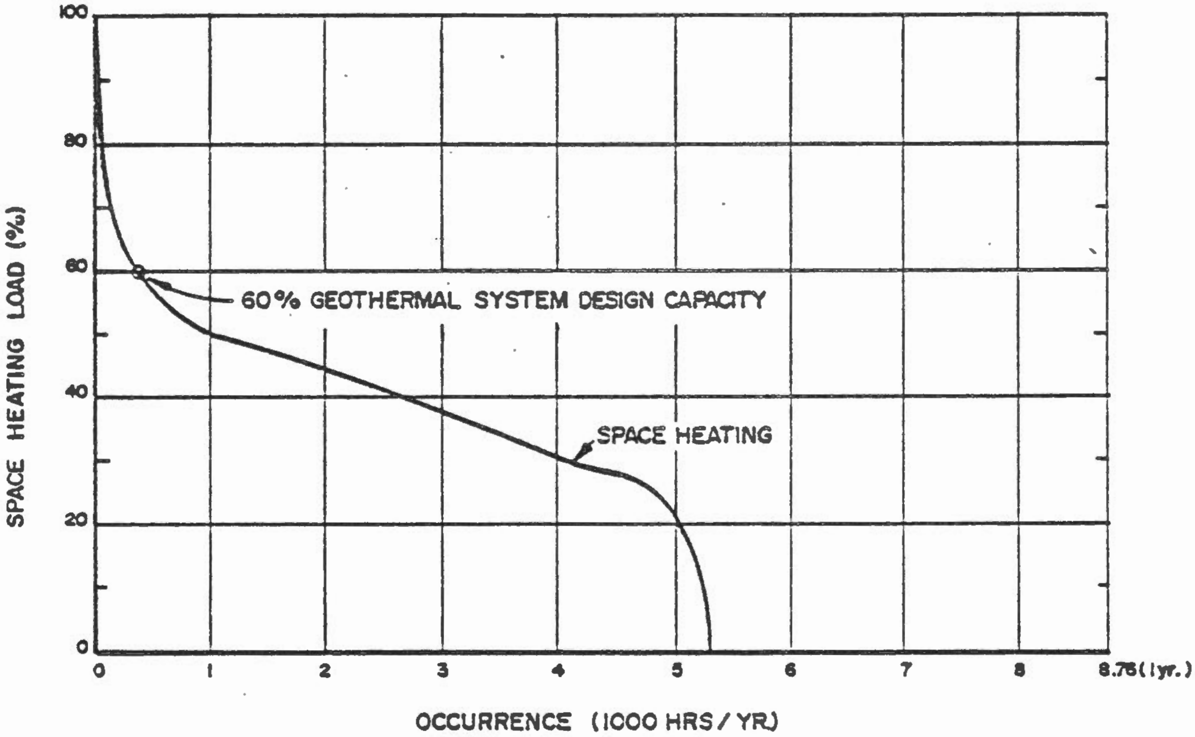
INFORMATION AS OBTAINED FROM NATIONAL RESEARCH COUNCIL OF CANADA REPORT, LOW TEMPERATURE GEOTHERMAL ENERGY APPLICATIONS, MARCH, 1983.

Plate 3

EDSON GEOTHERMAL FEASIBILITY STUDY

TYPICAL BUILDING HEATING LOAD PROFILES

the UMA group



GREENHOUSE HEATING

NOTE:

INFORMATION AS OBTAINED FROM NATIONAL RESEARCH COUNCIL OF CANADA REPORT, LOW TEMPERATURE GEOTHERMAL ENERGY APPLICATIONS, MARCH, 1983.

Plate 4

EDSON GEOTHERMAL FEASIBILITY STUDY

TYPICAL GREENHOUSE HEATING LOAD PROFILE

3.4 UNIT ENERGY COSTS AND RELATIONSHIPS

The 1985 unit electrical energy cost of 5.351 cents/kWh (input) used in this study was derived as the average of 24 electrical meter billing readings from four Town of Edson buildings during 1984. Each of the four buildings have an installed electrical demand capacity of 50 kW minimum and are on an Industrial Rate. The 5.351 cents/kWh unit rate allows for a 5% increase in 1985 power costs over 1984 as indicated by Trans-Alta Utilities Ltd.

Because of complex pricing structures and the preliminary nature of this study, a detailed calculation of power costs was not warranted. It is expected that the average kWh unit price method used in this study to determine power costs would be accurate to within 10% of those determined by detailed calculations and thus would not affect the end economic results by more than 1%.

In the analysis of a specific system design, actual kW demand and consumption, and rate structures should be considered.

The 1985 unit natural gas cost of $2.807/GJ input or 1.0106 cents/kWh used in this study is based on a 1985 rate for school and hospital type facilities, as indicated by Northwestern Utilities Ltd.

On this basis, the ratio of electrical energy input cost to natural gas input energy cost is 5.295 to 1.

Allowing for an electrical (average motor) efficiency of 88% and a natural gas (average boiler) efficiency of 70% the ratio of electrical energy output cost to natural gas output energy cost is 4.212 to 1. This could be considered as the effective energy cost ratio taking into account usual efficiencies involved.

These costs and relationships are useful when considering natural gas versus electrical energy options and for comparison with geothermal energy unit costs shown in Section 9.0.

In future, rising fossil fuel costs in relation to electrical power costs will improve the economic viability of a geothermal system for Edson, whereas a reduction in fossil fuel costs in relation to electrical power costs will have the opposite affect. Future capital and operating cost trends in relation to fuel and power costs also have an affect on the economic viability. Because of the difficulty in accurately predicting these trends, and the conceptual nature of this work, the study has been carried out entirely based on 1985 dollars and costs, with no attempt made to project quantitative effects of these trends on future economic viability of the proposed systems.

SECTION 4.0

GEOTHERMAL RESOURCE

4.0 GEOTHERMAL RESOURCE

4.1 GENERAL

The sedimentary subsurface geology of the Edson area was examined in detail by Sproule Associates Limited of Calgary, to determine the potential of obtaining low temperature geothermal water. Appendix B contains their detailed report. The primary source of information was records of exploratory and development wells drilled by the oil and gas industry. All of the wells drilled in a nine township block centred on Edson, for which data have been released through the Energy Resources Conservation Board, were considered. There are some 235 wells in the area which extends approximately 15 kilometres in all directions from the Town of Edson. The data for each well was reviewed with particular attention being paid to drill stem tests. Analysis of these test results produced information on aquifer characteristics, potential production rates, pressures, and temperatures.

4.2 REGIONAL GEOLOGICAL SETTING AND STRUCTURE

The Edson areas lies on the east flank of the Alberta Basin. Dips in the general area are to the southwest and range from about 10 metres per kilometre in the relatively shallow Belly River Formation to about 16 metres per kilometre in the deeper units. Dips are relatively uniform and there is no indication of any major folding or faulting.

The eastern edge of the Foothills disturbed Belt is some 100 kilometres to the southwest although important thrust faulting in the upper beds begins about 65 kilometres to the southwest.

In the general area there is major oil production from the Cardium Sand at about 1,900 metres depth. To the west and southwest of Edson, major gas production is obtained from the Elkton Member of the Turner Valley Formation at about 2,600 metres depth. Some oil and gas is also produced from the Cadomin and Gething Formations at depths of about 2,500 metres. Most of the traps appear to be stratigraphic rather than structural.

4.3 STRATIGRAPHY

The general stratigraphy of the Edson area is shown on Figure 3, a northeast-southwest trending diagrammatic cross-section. The line of section is shown on Figures 4 to 7 and passes a short distance north of the Town of Edson. The projected postion of the Town is shown on the cross-section. It is reasonable to assume that the cross-section will represent the stratigraphic sequence underlying the town.

The sequence immediately below the surface consists of deposits of Recent and Pleistocene age (these are not shown on the cross-section) which consist of surface and glacial soil deposits.

Underlying the glacial deposits is the Paskapoo Formation of Tertiary age, consisting primarily of sandstone with some interbedded shale and limestone concentrations. The unit is about 500 to 600 metres in thickness.

The geologic study concentrated on sedimentary formations from the Cretaceous age, underlying the Paskapoo to the Cambrian age at depths of 3,700 metres. A detailed description of formations sequentially examined is given in Appendix A.

4.4 PROSPECTIVE ZONES

After a review of the prospects of all units, several sequences were selected as having some degree of potential. These include the following units:

1. Belly River Formation - Cretaceous age.
2. Elkton Member of the Turner Valley Formation - Mississippian age.
3. Beaverhill Lake Formation and Swan Hills Member - Devonian age.
4. Upper Cambrian Sands - Cambrian age.

For each unit a map has been prepared showing pertinent data (Figures 4 to 7).

These units are discussed below in descending order. The amount of information available for study generally decreases downward.

Belly River Formation

The Belly River Formation, at depths of 1,250 to 1,500 metres, gives evidence of being able to produce large quantities of water. Because it is a non-marine unit there may be some lack of reservoir continuity, but we expect several different sand bodies to be present and view the potential as very good.

Temperatures are expected to range from 35 to 40°C at 1,250 metres and from 45 to 50°C at 1,500 metres.

The Belly River water salinites are expected to be 3,000 to 5,000 p.p.m. total solids.

The water in this formation is expected to rise to between 0 and 250 m below ground surface.

Elkton Member

The Elkton Member of the Turner Valley Formation has good porosity and permeability to the west and southwest of Edson but gas is produced at the unit's erosional edge near Edson. The presence of commercial gas and the distance to a water-bearing section downgrades this prospect.

Elkton temperatures are expected to be 75 to 80°C at depths of about 2,700 metres. Salinites are expected to be about 80,000 p.p.m. total solids.

Beaverhill Lake Formation

The Beaverhill Lake Formation, including the Swan Hills Member, is a good potential reservoir but the limited control increased the difficulty of making accurate predictions and hence, the risk.

Good water production would be anticipated, but not assured, from depths of about 3,500 metres. Temperatures of 95 to 105°C are predicted with salinites of 160,000 to 200,000 p.p.m. total solids.

The water is excpected to rise to 450 mm below ground surface in this formation.

Cambrian Formation

The Cambrian sands also have a very good potential for production but a considerable degree of risk is present. Temperatures of about 110°C would be anticipated at depths of 3,650 metres. Salinities are expected to be over 150,000 p.p.m. total solids.

4.5 SELECTED ZONES

Two formations - the Belly River at a depth of 1,500 m and the Beaverhill Lake at 3,500 m were selected for provision of geothermal water for the following analyses. The temperature is quite low in the Belly River Formation, however there are a number of advantages in using this formation:

1. There appears to be large quantities of water available.

2. The depth to the water is relatively low at about 0 to 450 m below surface. (Both these facts were confirmed by drilling contractors.)

3. The depth of drilling required is relatively shallow at 1,250 to 1,500 m, minimizing capital costs for wells, and pumping and piping equipment.

4. Indications are that suitable wells could be drilled anywhere in the Edson area i.e., the well could be drilled adjacent to users, substantially reducing piping costs.

5. The water salinities are low at 3,000 - 5,000 p.p.m., substantially reducing difficulties in designing and operating mechanical equipment.

As a consequence of these four factors, the risk, and capital of obtaining a geothermal source are signifigantly less than with the other deeper formations.

The Beaverhill Lake Formation was selected because temperature is high enough for direct retrofitting of existing facilities and because there appears to be an ample quantity of geothermal water.

4.6 TEST WELL

A test well was drilled in LSD4-21-53-17-W5M on the west edge of Edson about 1 km north of the airport by Champlin Oil and Refining Ltd. in 1968. The well extended to a depth of 2761 m and was completed as a Elkton gas well. In 1977 the well was abandoned with 4 1/2 inch casing in place and cement plugs installed at various elevations. It may prove to be economic to re-enter the well, drill out plugs, down-hole perforate and pump test the well to determine aquifer parameters in the Bully River Formation. The same well may be usable for production or re-injection for a prototype demonstration project. The well is now the property of the Alberta Government. Gulf Canada Limited now hold the gas rights within the Elkton Member, and all other rights are held by Atlas Yellowknife Resources Ltd. and Coachwood Resources Ltd. as of February 20, 1985.

SECTION 5.0

PRESENT AND FUTURE HEAT LOADS

- Hot air heating	18°C/50°C
- Outside air preheating	-40°C
- Domestic water heating	5°C/60°C

Because of the above range of temperature requirements, retrofitting of existing buildings would not be feasible using low temperature geothermal water at 45°C even if boosted to 73°C by a heat pump. These buildings can be retrofitted to accept heat extracted from geothermal water at 95°C. (Refer to Figures 8, 9, 10, and 11.) Initially, it was intended to examine a model consisting of existing retrofitted buildings only, however, it soon became evident that using the geothermal well to provide heat to just these buildings would not be cost effective when compared to the capital cost investment. This is as a result of having to maintain return heating water temperatures above 70°C and thus, not being able to extract the maximum amount of heat available from the resource. The use of the geothermal resource can be maximized by cascading the hot water from these existing buildings to new facilities designed to accept cooler hot water and finally to a greenhouse facility.

Building Heat Load Calculations

Average monthly and average yearly heat energy and peak heating requirements for building heating and for domestic water heating for St. John's Hospital, Parkland Composite High School and Pine Grove Elementary School were determined on the basis of monthly natural gas utility billings for these facilities, and average monthly temperatures for the years 1981, 1982, 1983 and 1984. The utility billings show the combined requirements for building heating and domestic water heating. In order to relate average monthly

SECTION 6.0

REGULATORY ASPECTS OF GEOTHERMAL DEVELOPMENT

Building Heat Load Calculations

Peak and annual building heat load requirements and annual heat consumption at 60% of peak load for new buildings, were determined on the basis of building peak heat load calculations in accordance with ASHRAE standards,[6.] and typical building heating load profiles (histograms) for a Residential Townhouse Complex, and Greenhouse Heating, (Plate 3). Refer to Figures 12 and 13 for typical low temperature heating schematics for office buildings and walk-up apartments.

6.0 REGULATORY ASPECTS OF GEOTHERMAL DEVELOPMENT

Regulatory aspects of geothermal development were investigated through discussions with Energy, Mines and Resources Canada, Alberta Environment, the Energy Resources Conservation Board (ERCB) and a report prepared on the subject for the Government of Canada[3.]. There is no legislation in Alberta that specifically addresses geothermal energy development. Ownership of groundwater is vested in the Crown, however, and usage is regulated under the Water Resources Act by Alberta Environment. Wells extending more than 150 m below ground surface also come under the jurisdiction of the ERCB which administers the Oil and Gas Conservation Act and Regulations.

Alberta Environment's primary concerns would be aquifer damage and interference with existing well users. In this case, there probably are no existing users of the prospective aquifers identified for supply of geothermal water, and pumping from and re-injecting water into the same aquifer is unlikely to cause damage provided the wells are constructed in such a manner as to not contaminate overlying aquifers. A permit to drill a test well or test an existing well will be required. A licence to divert groundwater and to re-inject brine will be required. The licence application will require the completion of a hydrogeologic investigation documenting testing and analysis of the impact of development on the groundwater regime. Presently, there are no royalties levied on the use of groundwater.

The ERCB would be concerned about the impact of withdrawal and re-injection of brine on oil and gas reservoir pressures and hence, production. Well construction would have to meet

ERCB regulations that govern location, drilling methods and procedures, casing installation, blow-out equipment, development, and testing and abandonment should the well not be usable. An application would have to be prepared detailing the above with a report indicating the impact of the proposed development on adjacent oil and gas reservoirs. It is unlikely that withdrawal and re-injection of brine from the same aquifer will have any significant impact. Re-injection of brine into an aquifer at a higher elevation than the supply aquifer could result in an impact on both aquifers and possibly adjacent reservoirs and would require detailed study. The owner of mineral rights above or below the prospective geothermal aquifer can appeal a licence granted to an applicant for use of the aquifer but cannot prevent access to the aquifer nor levy royalties if a licence is granted. A surface lease will be required to gain access to land for drilling purposes.

Entering an existing casing, such as exists in LSD 4-21-53-17W5M, drilling out plugs, perforating, and testing would require a licence. Disclosure on the details of the existing well and intented program would be required.

SECTION 7.0

FUNDING PROGRAMS

7.0 FUNDING PROGRAMS

Funding programs for energy resources conservation projects were investigated to identify grants applicable to construction of new systems, retrofitting existing systems, and engineering design. Of the many programs in place, the following have been identified as possibly being applicable depending on the results of the technical and economic analysis:

ENERDEMO-CANADA

The program is administered by Energy, Mines and Resources Canada, and provides grants of up to 50% of project costs. Industrial and commercial, institutional and municipal government organizations are elgible. The main objectives of the program are as follows:

- To demonstrate promising new applications, techniques, and systems that use alternative energy, conserve energy, or make its use more efficient.

- To develop broad public awareness and acceptance of conservation and renewable energy technologies.

- To create employment in new or existing industries.

Project approval is subject to the following criteria:

- energy impact - short and/or long term;
- potential for cost-effectiveness and/or commercial viability;

- technical soundness and the applicant's competence to carry out the demonstration including information transfer;
- impact on public acceptance and incentive for adoption;
- private sector participation including cost-sharing;
- wide geographical and sectorial coverage; and
- potential contribution of the technology to Canadian energy, industrial trade, regional and environmental objectives.

ENERDEMO could be applied to construction of a demonstration facility consisting of a supply well, heat exchanger, disposal well, distribution system, and retrofit of a few buildings. ENERDEMO may also be applicable to retrofitting and connecting in existing buildings to an existing distribution network.

A/CERRF (ALBERTA/CANADA ENERGY RESOURCES RESEARCH FUND)

Although the A/CERRF program is intended to encourage waste heat recovery, it is our understanding that geothermal energy research may be eligible for grants. The project must meet the following criteria:

a) Proposed technology demonstrations must show potential for cost effectiveness for commercial applications, i.e. commonly recognized measures such as Return on Investment or payback periods must be in line with usual market standards and practices.

   For example, payback periods, as a simplified measure of cost effectiveness, should generally not exceed three years for the industrial and commercial sectors or approximately five years for non-profit organizations. Credit will be given to first case applications and respective incremental costs, which are, however, to be estimated and identified within the project proposal.

b) Technologies proposed for demonstrations must have potential for multiplication within Alberta.

c) Proposed technology demonstrations will be judged on their significance of potential overall cost savings for Alberta.

Other selection criteria include the quality of the proposal, competence, technical and financial capability of applicants to perform proposed projects.

It is our understanding that a grant of up to $200,000 may be applicable to engineering analysis and design.

ACCA (ACCELERATED CAPITAL COST ALLOWANCE)

The program is administered by Energy, Mines and Resources Canada and National Revenue and provides accelerated tax write-off against corporate income for a range of conservation and renewable energy equipment. Accelerated write-offs apply to machinery and equipment defined in Class 34 of the Income Tax Regulations. Write-offs are made over three years on a 25%, 50%, 75% basis. This program would be of interest to a commercial venture such as a greenhouse operation in which geothermal energy was used for heating, cooling, or some process displacing the use of oil.

ALBERTA EDUCATION - SCHOOL BUILDINGS SERVICES

Alberta Hospitals and Medical - Standards & Evaluations

These government departments provide funds for improvements to building heating systems where energy cost savings resulting from the improvements allows for a 5 year, or less, payback period. These department are accordingly interested in alternative energy systems, such as geothermal heat recovery, that are economically viable.

NATIONAL RESEARCH COUNCIL

Further funds may be available from the National Research Council for follow-up research and development, specifically test wells, researching new technology and further engineering analysis.

SECTION 8.0

GEOTHERMAL SYSTEM MODEL PARAMETERS

8.0 GEOTHERMAL SYSTEM MODEL PARAMETERS

8.1 DEVELOPMENT OF MODELS

In order to complete a technical and economic analysis of the use of geothermal heat in Edson, it was necessary to develop system parameters and models on which to base the analysis, and then to carry out the economic analysis.

Because of the availability of the 45°C low temperature resource, and because the preliminary report analysis indicated possible economic viability, it was logical to investigate a low temperature model, using a heat pump to raise the heating medium to a temperature suitable for use on heating of new facilities. Thus, Model 1 (Low Temperature Building Heating with Heat Pump) was included.

A relatively low temperature heating medium or a relatively large temperature drop in the heating medium can be used for greenhouse heating without the use of a heat pump. Thus an analysis of a greenhouse model, Model 2 (Low Temperature Greenhouse Heating) and Model 4 (High Temperature Greenhouse Heating) was carried out.

Since a group of existing larger buildings with a relatively large total heat load, is available in the northern part of Edson, it was logical to analyse a model involving retrofitting of these buildings for geothermal heating. Because of prohibitive costs involved in retrofitting for low temperature use, the higher temperature geothermal water only was considered for this use. Initially the model consisted of existing retrofitted buildings only, however early analysis showed that it would be necessary to incorporate cascading use to new facilities to maximize the use of the resource and thus optimize the system. Model 3 (High Temperature Existing Buildings, New Buildings and Greenhouse Heating) was thus developed to analyse this system.

8.2 SYSTEM OPTIMIZATION AND ANALYSIS APPROACH

General

As part of the economic analysis of an intended optimal geothermal heating system it was necessary to select components on the basis of cost effectiveness of the overall system. Based on a system (or model) comprised of these components, capital costs, and operating costs of the system (or model), over and above those applicable to a conventional natural gas heating system, (i.e. incremental costs), were determined. The displacement of natural gas consumption by use of the geothermal system was then determined and the resultant annual natural gas cost savings evaluated against the incremental capital and operating costs.

Well Characteristics

Two of these models utilize the low temperature Belly River Formation at a source temperature of 45°C and a well depth of 1,500 m, and two of these models utilize the higher temperature Beaverhill Lake Formation at a source temperature of 95°C and a well depth of 3,500 m. Both the low temperature and high temperature systems are assumed to be capable of producing 100 m^3/hour of geothermal water, with a long term drawdown to 100 metres below the surface for the low temperature system and a long term drawdown to 550 metres below the surface for the high temperature system. These 'assumed' well characteristics, although yet to be proven, are considered to be reasonable based on study work carried out for this purpose by Sproule Associates Ltd. and detailed in Appendix B.

Well Capacity Versus Peak Heating Load

Because of the very high capital and operating cost of the well and well pump, conceptual design is based on the geothermal well capacity being able to supply 60% of the peak heating load of the buildings involved, with natural gas heating being provided within the buildings for 100% back-up and peak heat "trimming". Characteristic building heating load profiles show that approximately 95% of the total annual building heat energy requirements could be provided at a geothermal system capacity of 60% of peak building heat load, thus improving the cost effectiveness of the system. It was assumed that adequate building area as shown here, can be obtained to make use of the full (100 m^3/hour) well capacity to supply 60% of the peak building load.

Geothermal Disposal Temperature

In order to optimize the system and for consistency in the evaluation, the design of the system allows for the geothermal water to be cooled to a minimum practical temperature suitable for greenhouse heating, or building space heating using a heat pump. The minimum disposal temperature selected for purposes of this study is 30°C (at 60% or greater of peak building heating load). Thereby, the maximum amount of heat is extracted in all cases prior to disposal in the re-injection well.

Economics of Analysis

Since the system was optimized in this fashion, the model analyses carried out reflect the economics of a heating system extracting the maximum geothermal heat energy available for the specific heating load involved.

8.3 SYSTEM COMPONENTS

Wells

Production and disposal well costs are the single most expensive capital cost item in the geothermal system. Both production and disposal well requirements are largely determined by conditions related to the aquifer, and to some extent by the intended design capacity of the geothermal supply system. The depth of the wells is the most important factor with respect to well costs. Historical data have shown that drilling costs are strongly dependent upon depth, increasing roughly exponentially with depth.[1.] Optimum well diameter appears to be about 200 mm hole diameter, which uses a nominal 175 mm outside diameter casing.[1.] This size is adequate, and has been selected for the well flow rate considered in this study.

Capital cost estimates for the production and disposal wells considered in this study are based on geothermal well-cost-versus-depth data presented in Figure 3-4 of the report on Low Temperature Geothermal Energy Applications (Acres, 1983). Information obtained on existing geothermal well costs indicate a good correlation with this chart (i.e. Peter Bawden Drilling Azores Geothermal Project, Boise State System, Energy Mines and Resources study in Chilliwak, B.C.).

Well Pumps

Well pumps, particularly for the pumping depths and heads anticipated for the Edson situation, are also a significant capital and operating cost element in the geothermal system. Factors to be considered which affect pump selection include:

- Head and flow requirements
- Fluid temperature
- Depth of pump setting
- Fluid chemical and physical characteristics, i.e. dissolved solids, salinity, specific gravity, suspended particles
- Duty, i.e. continuous, on-off or variable speed

These factors, in combination affect pump life and operating cost.

Multi-stage vertical turbine 'down-hole' pumps were selected because of depth of pump, head and flow requirements, and because of proven use of these for similar down-hole production use.

Well Pump Operation and Control

The following methods of operation of the well pump were considered:

- Constant speed and variable speed year round continuous operation
- Constant speed and variable speed seasonal operation (on during heating season only)
- Constant speed on/off operation with accumulator tank.

A comparative capital and operating cost analysis was carried out on each alternative using selected pump and drive system characteristics for each. An accumulator tank vessel with a pressurized nitrogen blanket system was considered for the on/off operation because of the requirement to maintain the fluid under pressure and not exposed to oxygen for corrosion and scaling protection. The on/off alternative with accumulator tank was eliminated because of possibly reduced well pump life due to cycling operation.

Constant speed seasonal operation was selected for the shallower, lower temperature (Belly River Formation) system, with variable speed seasonal operation for the deeper, higher temperature (Beaverhill Lake Formation) system, on the basis of lower total capital and operational cost than the other alternatives in each case.

The points at which the geothermal system should be shut off each spring and started up each fall were determined on the basis of an economic analysis of pumping cost versus gas cost savings using the typical building heat load profiles (Plates 3 and 4). For residential, recreational and institutional type buildings the geothermal system would be shut down for approximately 3 months during the summer. For greenhouse heating the system would be shut down for approximately 5 months over the summer period.

In order to protect the system during the summer season, special steps must be taken such as "water-logging" of the well and primary piping system. This would be carried out by allowing a large flow of fresh water down the well casing, while operating the well pump until the entire primary system is flooded with fresh water. The system would be left in this state during the summer season.

Distribution (Circulation) System

In order to minimize the amount of piping exposed to the potentially harsh geothermal fluid, heat is immediately extracted by use of a heat exchanger, and the fluid returned to the aquifer through the disposal well. The geothermal heat is then distributed in a secondary circulation piping system to all users using a closed system treated water or glycol heating medium.

With respect to the distribution of the geothermal heat by circulation piping, aspects to be considered include:

Piping material
Insulation
Bury depth
Circuit design (direct versus reverse return) and layout
Heating medium (treated water or glycol)
Line sizing

Urethane insulated asbestos cement pressure pipe buried below frost level, using treated water, was selected and allowed for in the cost analysis.

Heat Exchangers

Primary heat exchangers capable of low approach temperatures are necessary for geothermal application in order to be able to extract as much heat as possible from the geothermal fluid. The primary heat exchanger must also be fairly resistant to scaling effects, considering the high dissolved solid contents of the geothermal fluid. Stainless steel titanium coated plate type exchangers, although expensive, have been shown to be effective for this use (i.e. Klammath Falls, Oregon), because of low approach temperature (5°C or less), low scaling, expandability, ease of dismantling for cleaning and small size. This type rather than the shell and tube type has thus been considered for this application.

Heat Pumps & Absorption Cooling Units

In the low temperature applications (i.e. 45°C geothermal source), it was found necessary to consider the use of a heat pump to raise the secondary heating medium to a temperature suitable for use on heating of new facilities.

Natural gas engine driven compression type heat pumps were considered as well as electric driven. The coefficient of performance of commercially available units (ratio of useable heat energy output from the condenser, to required mechanical energy input to the compressor) is in the order of 5.5. It is possible to recover approximately 50% of the total gas energy heat input to a natural gas engine using jacket water and exhaust gas exchangers, and using the recovered heat for space heating. Considering a coefficient of performance of 5.5 and use of waste heat recovery, use of a natural gas engine driven heat pump with waste heat recovery was found to be more cost effective than an electric driven unit. Thus a natural gas engine driven heat pump, with engine waste heat recovery exchangers, was used for the economic analysis of a heat pump system in this study.

Commercially available natural gas fired absorption type heat pumps were also considered, as were natural gas fired absorption type refrigeration units for cooling of a cold room in conjunction with a greenhouse operation. However, coefficient of performance of these units is typically 20% that of compression type units. This is approximately equal to the ratio of the cost of electrical energy to natural gas energy. Refer to Section 3.4. Thus there is no cost saving using commercially available natural gas absorption type units and these system refinements were eliminated early in the analysis.

Information recently received on a developmental natural gas fired absorption type heat pump from Energy Concepts Company appears promising. Cost data presented indicates a payback period of 5.1 years for this unit as compared to a payback period of 8.2 years using a conventional lithium bromide commercial unit. Development work is scheduled for completion in July, 1985, after which a commercial prototype demonstration site is planned.

Circulation Pumps

Conventional horizontal centrifugal type, electric driven circulation pumps, in a duplex arrangement (one as standby), were considered for the circulation of the secondary heating medium.

Heating Units

Where lower than normal hot water heating temperatures are used, i.e. where the secondary return water temperature is below 70°C, allowance must be made for the incremental capital cost of additional and/or special types of building space and water heating units necessary. Such an allowance was made for all heating applications used here except the high temperature retrofit use, where return temperatures are above 70°C. Radiant ceiling and floor heating panels suitable for low temperature use, were allowed for heating of new buildings at return temperatures below 70°C (refer to Figures 12 and 13).

SECTION 9.0

DETAILED TECHNICAL AND ECONOMIC ANALYSIS

9.0 DETAILED TECHNICAL AND ECONOMIC ANALYSIS

9.1 DESCRIPTION AND ANALYSIS OF MODELS

A description of the models analysed, the analysis and results of each are summarized below. A schematic diagram of each model is shown on Figures 14 to 17. Results of the analysis are also summarized on Table 9.1.

A large part of the capital cost of the system ($1,100,000 for the low temperature system and $7,200,000 for the high temperature system) is for the supply and disposal wells.

Operation and maintenance costs (over and above power consumption) have been estimated at 2% of capital cost per annum except for capital cost of the well pumps, where 22% of capital cost of well pumps per annum has been allowed for pump replacement every four years. The operation and maintenance cost allowance of 22% for the well pumps is based on discussions with downhole vertical submersible turbine pump manufacturers such as Hughes Centrilift, who advise that normal continuous duty life expectancy on this type of pump in oilfield service applications not unlike conditions expected here, are in the range of 3 to 5 years.

On this basis overall operation and maintenance costs allowed in this study amount to a total of between 4.6% and 5% of capital cost per annum including power consumption. This compares with a calculated average of 2.12% (including power consumption) for 8 of the systems described in Table 1 of the paper "Geothermal District Heating Projects"[18]. Refer to Appendix E.

These figures can also be compared with annual operating and maintenance costs (including fuel and power consumption), as normally allowed by the Government of the Northwest Territories in their analysis of water and sanitation system design alternatives[33], as follows:

- Water treatment plants	12%
- Parking garages	6%
- Water intake pumphouses, water distribution pumphouses, sewage lift stations	5%
- Water storage reservoirs, water supply lines, water and sewer mains	3%

9.2 MODEL 1 - LOW TEMPERATURE BUILDING HEATING WITH HEAT PUMP (Refer to Figure 14)

Description:

This system envisages heating 41,400 m^2 of new apartment buildings consisting of eleven - 30 suite - 3 floor apartment buildings, or other types of new facilities requiring 4,500 kW total peak heating capacity such as a school, office building or recreational facility. One new facility which may be considered for geothermal heating is the recreational complex planned for the Alberta 1986 Winter Games, which may include a swimming pool, an ideal user of geothermal heat.

The system consists of the following:

- 1,500 m deep supply well
- 75 kW constant speed well pump
- 1 km of 150 mm diameter well-to-well buried insulated piping
- 1,500 m deep disposal well
- 390 kW (shaft input) natural gas engine driven heat pump with engine heat recovery exchangers to raise circulation water temperature from 54°C to 73°C by cooling geothermal water from 45°C to 30°C
- 7.5 kW duplex circulation pumps
- 914 m of average 150 mm diameter buried insulated circulation piping to the above buildings

A natural gas engine driven heat pump with jacket water and exhaust gas heat recovery exchangers has been assumed for this model. For purposes of this analysis, it has been assumed that these exchangers recover a total of 50% of the natural gas energy (heat) input to the engine. This heat, amounting to approximately an additional 33% of the geothermal heat input, is utilized in the secondary heating distribution system. Thus this portion of gas energy and it's cost is not included in the heat pump natural gas fuel (net) cost (Item 21 in Table 9.1), and is thus also not included in Items 27 through 30 of Table 9.1 for Model 1.

<u>Analysis:</u>

Estimated Total Capital Cost	$2,978,000
Estimated Total Annual Operating & Maintenance Cost (Capital Cost Repayment not Included)	191,000
Estimated Total Annual Capital, Operation & Maintenance Cost	494,000
Estimated Total Annual Heating Cost Using Natural Gas	156,000

Analysis Results:

Heat pump capital and operating costs are a significant factor in this application. The analysis shows that a geothermal heating system would result in additional costs of $35,000 per year over natural gas heating, not allowing for capital cost repayment and a loss of $338,000 per year with capital cost repayment.

9.3 MODEL 2 - LOW TEMPERATURE GREENHOUSE HEATING

(Refer to Figure 15)

Description:

This system envisages heating a 5,270 m^2 conventional (double plastic pane) greenhouse, requiring 2,900 kW total peak heating capacity.

The system consists of the following:

- 1,500 m deep supply well
- 75 kW constant speed well pump
- 1 km of 150 mm diameter well-to-well buried insulated piping
- 1,500 m deep disposal well
- 1,740 kW plate type heat exchanger to raise circulation water temperature from 25°C to 40°C
- 3.7 kW duplex circulation pumps
- 80 m of average 150 mm diameter insulated circulation piping from the heat exchanger building to the greenhouse

Analysis:

Estimated Total Capital Cost	$2,384,000
Estimated Total Annual Operating & Maintenance Cost (Capital Cost Repayment not Included)	129,000
Estimated Total Annual Capital, Operation & Maintenance Cost	372,000
Estimated Total Annual Heating Cost Using Natural Gas	90,000

Analysis Results:

The analysis shows that a geothermal heating system would result in additional costs of $39,000 per year over natural gas heating, not allowing for capital cost repayment and a loss of $282,000 per year with capital cost repayment.

9.4 MODEL 3 - HIGH TEMPERATURE BUILDING AND GREENHOUSE HEATING (Refer to Figure 16)

Description:

This system envisages firstly heating existing buildings retrofitted for this purpose. These buildings would consist of the following or any combination of existing larger buildings in the study area requiring a total 3,470 kW total peak heating capacity:

St. John's Hospital
Pine Grove School
Parkland High School
Parkland Lodge
A.H. Dakin Elementary School
Jubilee Junior High School

Refer to Figures 8, 9, 10 and 11 for schematics of retrofitting requirements for St. John's Hospital as a typcial example of retrofitting requirements.

Secondly, by "cascading" from the retrofit use, this system would heat a total of 25,300 m^2 of new apartment buildings consisting of seven - 30 suite - 3 floor apartment buildings, or other types of new facilities requiring 3,060 kW total peak heating capacity.

Thirdly, by cascading from the new building use, this system would heat a 9,670 m^2 conventional greenhouse, requiring 5,310 kW total peak heating capacity.

The system consists of the following:

- 3,500 m deep supply well
- 300 kW variable speed well pump
- 1 km of 150 mm diameter well to well buried piping
- 3,500 m deep disposal well
- 7,105 kW plate type heat exchanger to raise circulation water temperature from 25°C to 90°C
- 18.7 kW duplex circulation pumps
- 2,440 m of average 150 mm diameter buried insulated circulation piping to existing retrofitted buildings (90°C to 70.5°C circulation water temperature)
- 914 m of average 150 mm diameter buried insulated circulation (second cascade) piping to the above new buildings (70.5°C to 54°C circulation water temperature)
- 80 m of average 150 mm diameter insulated (third cascade) circulation piping from the above new buildings to the greenhouse (54°C to 25°C circulation water temperature)

Analysis:

Estimated Total Capital Cost (Including $840,000 for Retrofit)	$12,636,000
Estimated Total Annual Operating & Maintenance Cost (Capital Cost Repayment not Included)	409,000
Estimated Total Annual Capital, Operation & Maintenance Cost	1,696,000
Estimated Total Annual Heating Cost Using Natural Gas	438,000

If geothermal heating were applied to the existing retrofitted buildings only without cascading to the other users, the analysis cost figures would be approximately as follows:

Capital Cost	$11,386,000
Annual Operation & Maintenance	368,000
Annual Capital, Operation and Maintenance	1,528,000
Annual Gas Heating Cost	127,000

Analysis Results:

The analysis shows that a geothermal heating system would result in a savings of $29,000 per year as compared to natural gas heating, not allowing for capital cost repayment, and a loss of $1,258,000 per year with capital cost repayment.

Without cascading to the other users, the analysis shows that the geothermal system would result in a loss of $241,000 per year not allowing for capital cost repayment and a loss of $1,401,000 per year with capital cost repayment. Thus a greater loss is indicated with retrofit use only.

9.5 MODEL 4 - HIGH TEMPERATURE GREENHOUSE HEATING (Refer to Figure 17)

Description:

This system envisaged heating a 21,500 m^2 conventional greenhouse requiring 11,800 kW total peak heating capacity.

The system consists of the following:

- 3,500 m deep supply well
- 300 kW variable speed well pump
- 1 km of 150 mm diameter well to well buried piping
- 3,500 m deep disposal well
- 5,800 kW plate type heat exchanger to raise circulation water temperature from 25°C to 90°C.
- 3.7 kW duplex circulation pumps
- 80 m of average 150 mm diameter insulated circulation piping from heat exchanger building to the greenhouse.

Analysis:

Estimated Total Capital Cost	$10,761,000
Estimated Total Annual Operating & Maintenance Cost (Capital Cost Repayment not Included)	352,000
Estimated Total Annual Capital, Operation & Maintenance Cost	1,448,000
Estimated Total Annual Heating Cost Using Natural Gas	366,000

Analysis Results:

The analysis shows that a geothermal heating system would result in a savings of $14,000 per year as compared to natural gas heating, not allowing for capital cost repayment, and a loss of $1,082,000 per year with capital cost repayment.

9.6 SUMMARY OF ANALYSIS

None of the geothermal systems are found to be cost effective in terms of pay-back of capital costs by displacement of natural gas energy use.

Although the capital costs for the low temperature systems (in the range of $2.4 to $3.0 million) are less than for the high temperature systems, the low temperature systems would operate with a net operating loss (not allowing for repayment of capital) of $35,000 per year for the new building heating system and net loss of $39,000 per year for the greenhouse heating system.

The high temperature heating systems would operate with a net operating gain (not allowing for repayment of capital) of $29,000 per year for the building and greenhouse cascading heating system and a net gain of $14,000 per year for the greenhouse heating model, however these annual operating cost savings are very small in comparison with the capital costs for the high temperature systems (in the range of $10.8 to $12.6 million).

TABLE 9.1
EDSON GEOTHERMAL DEMONSTRATION PROJECT
ECONOMIC ANALYSIS OF ALTERNATIVE MODELS
(INCREMENTAL COSTS*)

	ITEM	MODEL 1 LOW TEMPERATURE BUILDING HEATING WITH HEAT PUMP	MODEL 2 LOW TEMPERATURE GREEN HOUSE	MODEL 3 HIGH TEMPERATURE BUILDING & GREEN HOUSE	MODEL 4 HIGH TEMPERATURE GREEN HOUSE
CAPITAL COSTS					
1.	Supply Well, Casing & Head	$ 550,000	$ 550,000	$ 3,600,000	$ 3,600,000
2.	Supply Well, Pump & Controls	300,000	300,000	480,000	480,000
3.	Supply Well, Discharge Piping	15,000	15,000	60,000	60,000
4.	Disposal Well, Casing & Head	550,000	550,000	3,600,000	3,600,000
5.	Well to Well Piping	132,000	132,000	132,000	132,000
6.	Equipment Building	70,000	47,000	55,000	55,000
7.	Plate Heat Exchanger	-	40,000	120,000	120,000
8.	Variable Speed Drive & Controls	-	-	130,000	130,000
9.	Circulating Pump & Controls	20,000	14,000	30,000	14,000
10.	Heat Pump & Controls	300,000	-	-	-
11.	Circulating Piping to Existing Buildings	-	-	339,000	-
12.	Circulating Piping to New Buildings	132,000	-	127,000	-
13.	Circulating Piping to Greenhouse	-	16,000	16,000	16,000
14.	Incremental Heater Unit Costs	314,000	243,000	580,000	402,000
15.	Existing Buildings Retrofit	-	-	840,000	-
16.	Engineering (15% of Items 1 to 15)	357,000	286,000	1,516,000	1,291,000
17.	Contingencies (10% of Items 1 to 15)	238,000	191,000	1,011,000	861,000
18.	TOTALS	$2,978,000	$2,384,000	$12,636,000	$10,761,000

TABLE 9.1 (CONT'D)
EDSON GEOTHERMAL DEMONSTRATION PROJECT
ECONOMIC ANALYSIS OF ALTERNATIVE MODELS
(INCREMENTAL COSTS*)

ITEM	MODEL 1 LOW TEMPERATURE BUILDING HEATING WITH HEAT PUMP	MODEL 2 LOW TEMPERATURE GREEN HOUSE	MODEL 3 HIGH TEMPERATURE BUILDING & GREEN HOUSE	MODEL 4 HIGH TEMPERATURE GREEN HOUSE
ANNUAL OPERATING & OWNING COSTS				
19. Well Pump Power Cost	$ 33,000	$ 25,000	$ 81,000	$ 65,000
20. Circulating Pump Power Cost	3,000	1,000	9,000	1,000
21. Heat Pump Natural Gas Fuel (Net) Cost	42,000	-	-	-
22. Other Operation & Maintenance Cost**	113,000	103,000	319,000	286,000
23. SUB-TOTALS	$ 191,000	$ 129,000	$ 409,000	$ 352,000
24. Capital Amortization Cost (8% - 20 Yrs.)	$ 303,000	$ 243,000	$ 1,287,000	$ 1,096,000
25. TOTALS	$ 494,000	$ 372,000	$ 1,696,000	$ 1,448,000
26. Total Life Cycle Present Value Cost (Capital & O&M) (8% - 20 Yrs.)	$4,853,000	$3,651,000	$16,652,000	$14,217,000
27. Geothermal Energy Utilized KWH/YEAR	10,950,000	6,280,000	30,690,000	25,620,000
28. Value of Geothermal Energy*** Utilized	$ 156,400	$ 89,700	$ 438,400	$ 366,000

TABLE 9.1 (CONT'D)
EDSON GEOTHERMAL DEMONSTRATION PROJECT
ECONOMIC ANALYSIS OF ALTERNATIVE MODELS
(INCREMENTAL COSTS*)

ITEM	MODEL 1 LOW TEMPERATURE BUILDING HEATING WITH HEAT PUMP	MODEL 2 LOW TEMPERATURE GREEN HOUSE	MODEL 3 HIGH TEMPERATURE BUILDING & GREEN HOUSE	MODEL 4 HIGH TEMPERATURE GREEN HOUSE
29. Unit Energy Cost \$/KWH (Item 25 Divided by Item 27)	0.045	0.021	0.013	0.014
30. Annual Utilization Factor****	0.43	0.25	0.42	0.35

1985 ENERGY COSTS FOR COMPARISON:

31. Electrical Energy \$/KWH Input = 0.054
32. Natural Gas Energy \$/KWH Input = 0.010

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*	Incremental Costs:	All capital, operating and maintenance (O&M) costs, in excess of those required to operate conventional (natural gas) heating systems, in 1985 dollars.
**	(Other) O&M Costs:	Allowed for at the rate of 2% of capital and contingency cost per annum except for capital cost of well pumps, where 22% of capital cost per annum is allowed for pump replacement every four years.
***	Value of Geothermal Energy Utilized:	Based on 1985 Natural Gas Energy costs with 70% assumed heat efficiency i.e. Item 28 = Item 27 x Item 32 ÷ 0.70.
****	Annual Utilization Factor:	Ratio of actual geothermal energy delivered to maximum energy available if the system is run at full capacity for the full year referenced to an injection (sink) temperature of 20°C.

SECTION 10.0

CONCLUSIONS AND RECOMMENDATIONS

10.0 CONCLUSIONS AND RECOMMENDATIONS:

10.1 CONCLUSIONS

In summary, it is concluded that the heating of large buildings in Edson with geothermal energy is technically feasible but offers no significant economic advantage at this time. The combination of substantial costs of pumping the geothermal water from significant depths, and relatively low natural gas and high electrical energy costs result in the operational costs being slightly less than equivalent natural gas heating costs in some applications excluding payback of capital. Because of the very high capital cost of geothermal systems due primarily to the cost of the supply and re-injection wells, when payback of capital investment is included, the geothermal system will operate at a substantial annual loss.

The geologic studies identified two prospective producing formations - the Belly River at a depth of 1,500 m producing 45°C water of low salinity and the Beaverhill Lake at a depth of 3,500 m producing 95°C water of extremely high salinity. Because of the nature of the testing done in petroleum exploration wells, data produced on aquifer conditions requires considerable interpretation and cannot be substantiated without the installation of a geothermal test well. The assumptions made with respect to aquifer characteristics - flow rate, drawdown and extent, have a profound effect on the economic viability of using the resource. For a geothermal project to advance further in Edson, a test well is required. An abandoned well in LSD 4-21-53-17W5M may offer a relatively low cost alternative to a new test well and warrants further examination. Because of the active petroleum exploration in and around Edson, there may be future opportunities to use 'dry' exploration wells for testing aquifers.

The study also identified that the capital cost of a geothermal heating system would vary from $2 to $4 million for a low temperature system to $10 to $12 million for a high temperature system. The cost of the doublet supply/disposal wells varied from $1.1 to $7.2 million respectively. Because of the high capital cost of the wells, the use of the geothermal resource must be maximized to optimize the economics of space heating. Maximization of the resource can be achieved by extracting the maximum amount of heat from the geothermal water by cascading the heating fluid in the distribution system to successive lower temperature users; and by using geothermal energy to provide a base load and trimming with natural gas fired furnaces and/or boilers.

Heating systems in buildings in the study area operate on hot water or steam at supply temperatures of 80 to 120°C. These buildings can be retrofitted to accept heat extracted from geothermal water pumped from the ground at 95°C. However, using the geothermal well to provide heat to just these buildings is not cost effective when compared to the capital cost investment. The use of the geothermal resource can be maximized by cascading the hot water from these existing buildings to new facilities designed to accept cooler hot water and finally to a greenhouse facility. Retrofitting existing buildings is not feasible using low temperature geothermal water at 45°C or even boosted to 73°C by a heat pump because temperatures are too low. However, the low temperature water can be used to heat either new buildings designed to accept heating water at 73°C from a heat pump or a greenhouse complex directly without heat pumps. Analysis has shown the use of heat pumps reduces the economic viability of the use of low temperature geothermal energy because of increased capital and operating costs to boost temperature.

The study also indicated that the most cost effective way to operate the geothermal system was to use the system only in the months September through May for normal building use and October through April for greenhouse use, and use the geothermal energy to provide 60% of peak load demand. To meet the peak load demand in excess of the base load, heat would most economically be provided by gas fired boilers. With this combination 95% of the total annual heat load would be provided by geothermal energy.

Because of the indicated unfavourable economics of heating with geothermal compared with natural gas, there are no provincial or federal grant programs in place that can be applied to assist in financing the overall project. However, if the basic supply well-heat exchanger - disposal well system were funded by research grants, there may be other funds available for retrofitting existing buildings through grant programs currently in place that assist in reducing operating costs and displacing fossil fuels.

Ownership of the groundwater is vested in the Crown and usage is regulated under the Water Resources Act by Alberta Environment. Because the geothermal well depth would be greater than 150 m the Energy Resources Conservation Board would also regulate development of the resource under the Oil and Gas Conservatiion Act. Both agencies would have to approve licence applications to drill wells, divert groundwater and re-inject brine.

While the economics of using geothermal energy do not appear to be favourable compared to natural gas, geothermal heating systems appear to be technically sound. There are uncertainties associated with pumping water of such high salinities compared with other systems in operation. There are no geothermal systems operating in Canada on a large scale. There is a need to construct a demonstration facility if the use of geothermal energy is to be advanced. The Edson situation offers some advantages for a demonstration project, specifically active petroleum exploration providing a good data base and the possibility of low cost test wells, and the unique combination of low temperature geothermal energy and gas driven heat pumps.

Considering the high costs of the systems examined, a smaller scale research oriented project using low cost abandoned gas wells would appear to be a logical first step in developing a full scale prototype system.

10.2 RECOMMENDATION

The advancement of geothermal energy technology in Canada will require the installation and testing of full scale prototype systems. A staged advancement of the project in the Edson area would appear to be appropriate:

- Investigate abandoned wells in more detail; determine the feasibility of pump testing a well or wells; and determine the feasibility of using the geothermal energy for a small scale heating system.

- Conduct a pump test on a selected abandoned well.

- Develop a pilot geothermal heating system (probably a single large building).

- Expand system to a full scale prototype (a central multi-building system).

It is recommended that the Government of Canada consider the Edson situation when formulating research plans and priorities and allocating funds for further development of geothermal energy and related technology.

Respectfully submitted,

UMA Engineering Ltd.

DJ Phelps

D. J. Phelps, P.Eng.
PROJECT MANAGER

D. J. PHELPS

PERMIT TO PRACTICE
UMA ENGINEERING LTD.
Signature
Date July 25/85
PERMIT NUMBER: P 329
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

APPENDIX A

STUDY TERMS OF REFERENCE

APPENDIX A

STUDY TERMS OF REFERENCE

I PRELIMINARY ASSESSMENT

This phase will provide a preliminary assessment of the viability of the overall project and involve examination of the following:

Geothermal Potential

- Examination of available petroleum exploration well data for the Edson area to determine depth, water temperatures, production rates, and the extent of aquifers.

- Consideration will be given to using existing abandoned petroleum wells versus the drilling of new wells.

- Current petroleum exploration in the area will be monitored. Should a suitable non-productive well become available, it will be considered for use on the project.

- Define suitable locations and depths of geothermal wells estimating flow characteristics - temperature, potential production rates, solids content and water chemistry.

- Determination of the probable energy output from a single well.

Planning

- Review and recommend on land uses, buildings, and activities that are compatible with each other, with the intent of maximizing the amount of building space that can be developed in the vicinity of the heat source.

- Provide a listing of existing, planned and possible facilities and activities that could be developed within the Town and might best be located in the vicinity of the heat source.

- Review and recommend on any changes or adjustments to existing Town planning bylaws to provide for improved land use to increase the efficiency of a geothermal central heating system.

Heat Load

- Cursory examination of existing and proposed buildings in the study area to estimate present heat loads and load factors and assess the feasibility of retrofitting the present heating systems to accept geothermal heat.

- Prediction of annual fuel cost savings of these buildings.

- Prediction of heat loads and load factors for future proposed structures at the site.

II DETAILED FEASIBILITY STUDY

Low Temperature Model

(Geothermal Water From the Belly River Formation)

In this study phase, the low temperature model developed in the preliminary phase will be expanded and refined as follows:

The overall geothermal system will be optimized by matching the heat load to the energy and therefore flow available from the geothermal source aquifer. The heat load will be expanded by adding buildings and increasing the size of buildings until the use of geothermal energy from a single shallow well is maximized. A water slide/spa will be one of the facilities considered.

Technical refinements such as gas driven heat pumps, gas driven well pumps, and the addition of summer air conditioning will be examined and incorporated where appropriate.

A piping system will be laid out assuming the geothermal supply well is located on the designated site and the re-injection well is located 1 km to the northeast.

The components of the geothermal system such as piping, heat pumps, accumulator tank, etc. will be sized.

Incremental capital costs for the geothermal system will be estimated. Applicable grants will be investigated and applied to the cost estimate.

Operating costs will be estimated and payback period calculated. Royalty and taxation considerations will be included.

Cost comparisons with conventional gas heating systems will be made at present energy costs and at energy costs projected to 1995.

High Temperature Model

(Geothermal Water From the Beaverhill Formation)

This study phase will examine retrofit of present buildings and adding new buildings to a geothermal system operating at temperatures of about 95°C.

Retrofit equipment for each building in the study area will be sized and cost estimated.

The geothermal system will be optimized as outlined in 1.1.

A piping system to present and future buildings as indicated in 1.3 will be laid out.

The components of the geothermal system including wells, accumulator tank(s), etc. will be sized.

Capital and operating costs will be prepared and comparisons made with conventional systems as outlined in 1.5, 1.6 and 1.7.

Greenhouse Model

The combination of greenhouse and cold storage operations will be examined. The system will consist of a single geothermal supply well; accumulator tank; heat pumps/-exchangers; refrigeration units and re-injection well. Three temperatures of geothermal water, 45°C; 75°C; and 95°C drawn from the Belly River; Elkton; and Beaverhill Formations will be considered. The optimum plant size and corresponding incremental capital costs and operating costs will be calculated and comparisons made with conventional heating system.

Regulatory Approvals

Discussions will be held with appropriate provincial and federal government agencies to determine jurisdiction and the approvals process to drill wells, and pump and re-inject geothermal water.

Royalties, if any, and taxation advantages, if any, will be assessed and applied where applicable to the three previously identified models.

APPENDIX B

GEOLOGIC REPORT

THIS REPORT HAS BEEN PREPARED
FOR THE EXCLUSIVE USE OF:

COPY NO: 1

REPORT ON LOW TEMPERATURE GEOTHERMAL POTENTIAL EDSON AREA, ALBERTA

Prepared for

Underwood McLellan Ltd.

March, 1985

SPROULE ASSOCIATES LIMITED

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TABLE OF CONTENTS

INTRODUCTION

This section summarizes the sedimentary subsurface geology of the Edson area as it pertains to possible geothermal water production.

A discussion of low-temperature geothermal resources is included as background to the analysis of specific prospects in the Edson area.

The section is illustrated by one structural cross-section and four maps showing geothermal data.

LOW TEMPERATURE GEOTHERMAL RESOURCES

There is an increase in temperature downwards in the earth's crust beginning at a point a short distance below the surface where seasonal variations in temperature cease to have any effect.

The rate of temperature increase varies not only from geographic area to area but also vertically, depending on rock type and other factors.

In the Edson area the average vertical temperature gradient has been calculated to be about 26.4°C per kilometer with an ambient surface temperature of about 4°C. This is equivalent to about 1.5°F per 100 feet with an average surface temperature of about 39°F.

Sedimentary rocks underlie most of Alberta. These rocks include shales, sandstones, limestones and dolomites as well as a variety of less important rock types.

Sedimentary rocks are more or less porous and permeable.

Porosity refers to the percentage of void space within the rock. For sandstones it is the space between individual sand grains; in limestones and dolomites it may include vugs as well as intergranular space. The effective porosity in shale or shaley sands can be very limited. In sandstones and limestones or dolomites, porosity can vary from very little to 15 percent or more.

Permeability is the ability of a porous rock to transmit fluids between pore spaces. The term hydraulic conductivity is often used in the water well industry. In the oil and gas industry this ability is usually measured in millidarcies. The degree of permeability depends on the size of individual pores and the way in which they are connected. Some sandstones, limestones and dolomites have very good permeability. Others have poor to very poor permeability and shales have effectively no permeability.

All porosity in subsurface rocks is filled with fluid, either gas, oil or water.

The ability of a rock unit to produce water at high rates depends on the porosity and permeability. Porosity must be high enough to ensure the presence of a large reservoir. Permeability must be high enough to allow the water to be transmitted to the well bore. Both the permeability and the porosity have to be widespread so that they provide access to a large body of water to maintain high production rates.

Subsurface water varies greatly in chemical quality. It may range from relatively fresh, with only a few thousand parts per million (p.p.m.) total solids to almost saturated with respect to the dissolved constituents. Very saline water can contain over 300,000 parts per million total solids.

In most subsurface waters the main chemical constituent is sodium chloride (NaCl), although significant amounts of calcium and magnesium may also be present as may other ions.

Generally, the shallower waters are the least saline. Such waters may contain relatively large amounts of carbonate, bicarbonate and sulphate, together with sodium. In the deeper waters the chloride ion predominates with sodium and lesser amounts of calcium and magnesium.

Other chemical constituents may also be present, including hydrogen sulphide gas which can be very dangerous, and dissolved natural gas.

The chemistry of subsurface waters is important because of possible precipitation of salts in a production system, possible corrosive effects and the possible release of gases.

The amount of dissolved material controls the density of the water and affects the production costs.

All produced saline water must be safely disposed of without adversely affecting the environment. In most cases, this means re-injecting the water into the subsurface, usually into the same unit from which it was produced. Relatively fresh waters might not need to be re-injected.

In summary, a geothermal water source must have the following characteristics.

a) It must be deep enough to ensure a sufficiently high temperature,

b) there must be enough porosity and permeability to permit high-volume production over a long period of time,

c) water chemistry must not cause severe problems,

d) there must be a means of disposing of produced water.

It is perhaps surprising that so few subsurface formations meet all of these requirements. One of the main problems is the lack of adequate porosity and permeability in many areas. Even in many units where oil and gas are commercially produced, production of hot water does not appear viable because of the much lower unit value of the hot water. Even a few barrels of oil per day can make a commonly viable operation but production of several thousands of barrels of water per day is required.

APPROACH TO THE PROBLEM

In our investigations of possible sources of geothermal water in the Edson area, we first reviewed the general subsurface geology using data provided by exploratory and development wells drilled by the oil and gas industry. Such wells provide virtually the only source of factual subsurface data.

We considered all of the wells drilled in a nine township block, centred on Edson, for which data have been released through the Energy Resources Conservation Board of Alberta. There are some 235 wells in the area which extends approximately 10 miles in all directions from the Town of Edson. Data for almost all of these wells have been released.

While a large number of these wells were drilled only as deep as the Cardium Formation, or the underlying Blackstone Formation (about 2,000 metres), there are still enough deeper wells to provide a reasonable understanding of the stratigraphic sequence as deep as the Mississippian System (2,750 metres). Below the Mississippian the control is more limited.

Computer printouts of all available data on the wells in the nine township block were purchased from International Petro Data Limited. Microfiche of electrical and radioactivity logs for all wells for which these have been released are available in our files.

The data for each well were reviewed with particular attention being paid to drill stem tests (drill stem tests are a method of assessing the potential of a stratigraphic unit to produce fluid and are also used to determine subsurface pressures).

For each drill stem test which appeared to indicate reliable pressures and which had significant fluid recoveries, we calculated the theoretical water rise in the bore hole, the pressure corrected to a datum at sea level and the piezometric surface (the elevation above sea level to which the pressure should cause the water to rise if given sufficient time).

These calculations were reviewed again and each drill stem test for which there appeared to be adequate information, and which gave indications that the tested interval could be a potential water producer, was selected for further study. For the selected tests, copies of the original pressure charts were purchased together with incremental time and pressure readings and computer projections of these readings as well as other data necessary to attempt to estimate potential production rates.

Methods have been derived for estimating potential production rates from drill stem test data. Unfortunately, such methods are far from precise and seldom do the available data meet all of the requirements of the theoretical calculations. The calculation involves the rate of pressure build-up and the slope of the build-up curve. When the pressure builds very rapidly, the build-up curve becomes flat with zero slope. Division by zero gives a result of infinity which clearly cannot indicate a realistic productive rate, although it does indicate a high rate.

Because the required subsurface measurements are made at considerable depth under adverse conditions the resulting data are not as accurate as would be desired. One frequent problem is the plugging, or partial plugging, of the perforations through which fluid enters the drill pipe during testing. This gives uneven build-up on the pressure charts so that extrapolation is not possible and recoveries may be less than they should be. The frequent use of "water cushions" to maintain control of the well during testing also adversely affects recovery and pressure build-up.

The problems of interpreting reliable flow raterill stem test recoveries to determine whether they were likely to be representative of subsurface conditions.

All available chemical analyses of subsurface water were also reviewed and those that appeared reliable were selected for further study. These were computer calculated as a check and were compared with drill stem test recoveries to determine whether they were likely to be representative of subsurface conditions.

It should be stressed that oil and gas operators naturally seldom test those formations which do not give some indication of the presence of oil or gas. This means that many of the stratigraphic units which have the best potential for water production have been tested much less that those which are potential oil or gas producers.

From the review of the geology and the test data, the units which gave some reasonable indication of potential production were selected for further study.

For those units, available core analyses were summarized and average porosities and permeabilities were calculated. Again, there are very few core analyses for those units which do not give indications of being oil-or-gas-bearing.

The most important data were selected and plotted on maps to a scale of 1:250,000 for each of the stratigraphic units considered to have potential.

The four most important potential water producing zones are discussed later in this report.

REGIONAL GEOLOGICAL SETTING AND STRUCTURE

The Edson area lies on the east flank of the Alberta Basin. Dips in the general area are to the southwest and range from about 10 metres per kilometre in the relatively shallow Belly River Group to about 16 metres per kilometre in the deeper units. Dips are relatively uniform and there is no indication of any major folding or faulting.

The eastern edge of the Foothills Disturbed Belt is some 100 kilometres to the southwest although important thrust faulting in the upper beds begins abut 65 kilometres to the southwest of the Edson area.

In the general area there is major oil production from the Cardium Sand at about 1,900 metres depth. To the west and southwest of Edson, major gas production is obtained from the Elkton Member of the Turner Valley Formation at about 2,600 metres depth. Some oil and gas is also produced from the Cadomin and Gething formations at depths of about 2,500 metres. Most of the traps appear to be stratigraphic rather than structural.

STRATIGRAPHY

The general stratigraphy of the Edson area is shown on Figure 3, a northeast-southwest trending diagrammatic cross-section. The line of section is shown on Figures 4 to 7. The line of section passes a short distance north of the Town of Edson. The projected position of the Town of Edson is shown on the cross-section. It is reasonable to assume that the cross-section will represent the stratigraphic sequence underlying the town.

The sequence immediately below the surface consists of deposits of Recent and Pleistocene age (these are not shown on the cross-section) which consist of surface and glacial deposits.

Underlying the glacial deposits is the Paskapoo Formation of Tertiary age. The Paskapoo consists primarily of sandstone with some interbedded shale and limestone concentrations. Sands of the Paskapoo may form a source of domestic water in the area. The unit extends to a depth of about 500 to 600 metres.

Underlying the Paskapoo is a sequence of Cretaceous age some 2,000 metres thick which consists primarily of shale with beds of sandstone, some coal and minor limestone.

The uppermost Cretaceous unit is the Edmonton Group. This unit was deposited under non-marine conditions and shows the vertical and lateral variations which characterize non-marine rock. It contains a variety of sandstones, with some shale, coal and bentonite beds. It contains porous beds but these are not deep enough to be of geothermal interest.

Underlying the Edmonton Group is the Belly River Group which extends from a depth of about 1,250 metres to 1,500 metres. Like the overlying Edmonton Group, the Belly River Group is predominantly of non-marine origin and consists of sandstone and shale beds with some coal. There are relatively thick sandstone sequences which appear to have good porosity and permeability. Some of the sandstone beds appear to have reasonable continuity but it is not possible to be certain about this.

The Belly River is considered to be an important geothermal prospect and is discussed further in another section of this report.

The Lea Park Shale sequence underlies the Belly River and is in turn underlain by the Colorado Group. The Colorado Group consists largely of marine shale but there are several sandstone bodies which are important for oil and gas production. One of these, the Cardium Formation, is an important oil producing unit in the immediate vicinity of Edson. Production is from a depth of about 1,900 metres. Although a good oil producing zone is some areas, the Cardium Formation produces very little water.

The Viking Sandstone also produces oil and gas in some areas. In the Edson area porosity and permeability are not particularly good and there are not large water recoveries reported.

The Colorado Group is underlain by the Mannville Group which consists of interbedded sandstone and shale. Although some of the Mannville sandstones contain water, there is not evidence of sufficient porosity and permeability to produce large quantities of water.

The Gething Formation and the underlying Cadomin Formation form the base of the Cretaceous sequence. Again, sandstones are present but porosity and permeability are limited. The Gething contains gas locally, and the Cadomin has some oil.

Underlying the Cretaceous is the Fernie Group and the Nordegg Formation of Jurassic age. Some oil and gas occurs in the Nordegg but evidence indicates only limited potential for water production in the area of Edson.

The Jurassic is underlain by a thick sequence of rocks of Paleozoic age extending from a depth of about 2,600 metres to over 3,600 metres. The Paleozoic rocks consist primarily of carbonates (limestone and dolomite) with some shale and anhydrite beds and with significant sandstone beds near the base.

In the Edson area, the upper unit of the Paleozoic is the Elkton Member of the Turner Valley Formation of Mississippian age.

The eastern erosional edge of the Elkton is located close to the Town of Edson. The unit therefore thickens to the west and southwest and is absent to the northeast. The Elkton consists of dolomite and limestone. Porosity varies but locally is good. In some areas it could be an important water producer but at Edson, gas is trapped at the updip edge of the Elkton. Water is present, but the most important amounts of water are located several kilometres to the southwest beneath the gas.

The Elkton is underlain by the Shunda Formation, a limestone which has limited and variable porosity. In the Edson area, Shunda porosity may be in contact with Elkton porosity and form part of the same reservoir.

Underlying the Shunda is the Pekisko Formation, consisting of limestone and dolomite. In some areas the Pekisko is porous and contains oil and/or gas. In the Edson area the evidence does indicate particularly good porosity.

The Banff Formation, which underlies the Pekisko, consists of calcareous shale and argillaceous limestone. It is not usually porous.

The thin Exshaw Shale Formation underlies the Banff Formation and forms the basal unit of the Mississippian System.

The Devonian System underlies the Mississippian. The uppermost unit is the Wabamun Group, consisting of limestone and dolomite. This is underlain by the Winterburn Group which consists of carbonate rocks and which contains good porosity in some areas.

Underlying the Winterburn is the Woodbend Group. Locally, where Leduc reefs are developed, porosity and permeability are good, but in the Edson area, the Leduc is not developed and the generally impermeable Ireton Shale forms the upper part of the Woodbend Group.

The Duvernay Formation at the base of the Woodbend Group consists largely of shale.

The Beaverhill Lake Formation is predominantly limestone which can be very porous and permeable, especially where the reefoid Swan Hills Member is present. There have been large recoveries of very saline water from the unit in the general area of Edson from depths of about 3,600 metres.

The Slave Point, which underlies the Beaverhill Lake, can also be porous and permeable.

The Basal Devonian units, the Watt Mountain and the Gilwood contain porous and permeable sandstone.

The deepest sedimentary rocks for which information is available are sands of Cambrian age at depths of about 3,700 metres. These sands can be very porous and permeable. There is very little information because few wells have been drilled to this depth, but they would appear to have a very good potential to produce water in the Edson area. The thickness of the Cambrian sands is not known but is probably over 50 metres.

The Cambrian sequence is underlain by igneous and metamorphic rocks of Precambrian age which do not have any significant porosity or permeability.

DISCUSSION OF INDIVIDUAL PROSPECTIVE ZONES

Introduction

After a review of the indicated prospects of all units, several sequences were selected as having some degree of potential. These include the following units:

1) Belly River Group - Cretaceous age.
2) Elkton Member of the Turner Valley Formation - Mississippian age.
3) Beaverhill Lake Formation and Swan Hills Member - Devonian age.
4) Upper Cambrian Sands - Cambrian age.

For each unit a map has been prepared showing pertinent data (Figures 4 to 7).

These units are discussed below in descending order. The amount of information available for study generally decreases downward.

Belly River Group (Figure 4)

The Belly River Group is a sand-shale sequence of non-marine origin. In addition to sand and shale, it contains coal seams and bentonite beds. Where exposed at the surface in southeastern Alberta, the unit contains prolific dinosaur remains. Because of its non-marine origin there is a certain lack of lateral continuity of individual beds.

Most of the oil and gas test wells in the Edson area pass through the Belly River Group. Depths to the top of the Belly River Group for the area within three to four miles of Edson are shown on Figure 3.

Since there is a large amount of well control in the immediate vicinity of Edson this map has not been extended to cover the larger area shown on the other maps.

Unfortunately, because the Belly River has not given indications of being an important oil and gas producer in the Edson area, there are relatively few drill stem tests and no core analyses over the interval. The presence of relatively fresh water makes it difficult to make log interpretations.

At the test well in Lsd. 4-21-53-17 W5M, about one mile west of Edson, the Belly River extends from a depth of 1,255 metres to 1,515 metres. Logs are not particularly good but they do indicate a sandstone interval about 15 metres thick at the top, and several thinner sands deeper in the section.

There were no tests or cores of the Belly River in the well. The well was originally drilled to a total depth of 2,761 metres and was completed as an Elkton gas well. The Elkton perforations were cemented and several other higher zones were perforated and tested before the well was officially abandoned.

The perforated and cement-squeezed intervals included 945 metres to 946.5 metres. According to reports available to us, the well was abandoned with 4 1/2 inch casing in place and a cement plug from 228.5 metres to 320 metres. The well was drilled in 1968 and finally plugged in 1977. The abandoned well has become the property of the Alberta Government.

Although it should be stressed that normally, re-entering an abandoned well for testing provides little, if any, cost saving over drilling a new well, in the case where production casing has been run in the hole it may be practical to re-enter the hole at a saving over drilling a new well. It might prove practical to re-enter the 4-21-53-17 W5M hole for testing of the Belly River Formation. The well was originally drilled by Champlin Oil and Refining Ltd. We understand that Gulf Canada Limited now hold the gas rights within the Elkton Member, and that all rights, excluding Elkton natural gas within the SW/4 21-53-17 W5M were purchased at the February 20, 1985 Alberta Crown Land Sale by Atlas Yellowknife Resources Ltd., and Coachwood Resources Ltd. for $1,051.41 per hectare ($421 per acre).

Another well in Lsd. 16-17-53-17 W5M, less than one-half mile to the southwest of the aforementioned 4-21 well encountered the Belly River top at about 1,255 metres and the base at 1,510 metres. This well encountered a sandstone at the top of the Belly River with some 15 metres of net sand. A drill stem test of this sand from 1,260 to 1,277 metres gave gas to surface at a rate too small to measure in 55 minutes and recovered 960 metres of gas-cut fresh water and 60 metres of gassy water-cut mud. The shut-in pressures are very close to stabilized and give interpreted formation pressures of about 10,680 Kpa (1,549 psi). These pressures would give a theoretical water rise of 1,090 metres and a piezometric surface about 750 metres above mean sea level (180 metres below ground surface). The charts do not lend themselves to reasonable calculations of production rates. It does, however, appear that permeability is high and that further testing to establish production rates would be justified.

A second drill stem test of an indicated sand near the base of the Belly River in the same well recovered only drilling mud. This test may not have covered the most favourable part of the Basal sand sequences.

A well in Lsd. 14-21-53 17 W5M, about one mile northwest of Edson, indicates about eight metres of porosity at the top of the Belly River. This well was not tested.

About one mile further to the northwest, a well in Lsd. 9-29-53-17 W5M indicated the presence of some seven metres of sand at a depth of about 1,280 metres at the top of the Belly River. This sand was not tested. A lower, mid-Belly River sand at a depth of about 1,373 metres was tested and the test recovered about 972 metres of fresh water. Relatively high pressures were recorded in this well and, if taken as correct, would indicate the water would rise to the surface given sufficient time. The fact that water did not rise this high may be due to partial plugging of the test tool or it could indicate a limited reservoir. Other sand developments in this well were not tested.

A well about one mile to the northeast, in Lsd. 10-22-53-17 W5M indicates rather limited porosity at the top of the Belly River but the logs lack character and are difficult to interpret, and the porosity may be better than indicated. A Lower Belly River section at about 1,400 metres depth appears to have reasonable porosity.

Overall, the Belly River Group generally appears to have good porous intervals although they are not uniform from well to well. There could be a problem with lack of continuity of porosity. This can be established only by careful testing and pressure measurements.

The Belly River water, where it has been analysed, is relatively fresh, in the order of 3,000 to 5,000 p.p.m. total solids. The main cation is sodium and the main anion is chloride, but there are significant amounts of bicarbonate and, to a lesser extent, sulphate. Typical analyses for Belly River water are appended.

At depths of 1,250 metres temperatures of 35 to 40°C are anticipated. The Lower Belly River, at depths of about 1,500 metres, should have temperatures of about 45 to 50°C.

Elkton Member (Figure 5)

The Elkton Member of the Turner Valley Formation of Mississippian age is an important gas-producing unit in the Edson area. It consists mostly of limestone and dolomite (most of the porosity and permeability is probably in the dolomitic parts of the sequence). Core analyses reports indicate that the formation is fractured locally.

The eastern erosional edge of the Elkton Member passes very close to Edson. The gas is trapped at this updip edge. In the immediate vicinity of Edson the Elkton occurs at a depth of about 2,630 metres.

The gas trap in the Elkton area is underlain by water. For the most part, the major water occurrences are several miles to the west of Edson.

At the well in Lsd. 6-31-53-17 W5M, about five miles northwest of Edson, there is some difficulty in differentiating the Elkton Member from the underlying Shunda Formation. A test of the interval 2,668.8 metres to 2,693 metres recovered about 2,133 metres of salt water. This interval has been variously reported as Elkton or Shunda.

One slightly higher test, 2,655.7 metres to 2,664 metres, obtained a strong gas flow. It is not certain whether the water was recovered from the Elkton or the underlying Shunda. The question does not appear to be particularly important since the porous zones are separated by a few metres at most and may actually be connected a short distance from the well bore.

Although the Elkton gives evidence of being a good potential water producer downdip to the west, we have not considered it to be a prime prospect in the Edson area because it is relatively thin and because of the presence of commercial gas in Edson. We doubt that production and injection of water from immediately beneath the gas would be permitted, at least, not without rigorous controls.

The underlying Shunda porosity locally contains gas and water. The Shunda porosity appears to be intermittent and to be closely associated with the Elkton porosity. We do not believe that it has an important potential.

Elkton and Shunda waters are expected to contain in the order of 80,000 p.p.m. total solids, although locally they may be considerably saltier. The main constituents are sodium and chloride.

At depths of 2,700 metres, tempratures of about 75 to 80°C would be anticipated.

Beaverhill Lake Formation (Including Swan Hills Member) (Figure 6)

There are very few wells in the immediate vicinity of Edson which reach the Beaverhill Lake Formation. One well in Lsd. 10-22-53-17 W5M, only about one mile to the southeast, reached the unit at a depth of 3,506 metres. The Beaverhill Lake was not tested in that well.

Regionally the Beaverhill Lake consists of interbedded fragmental limestone and argillaceous limestone. It may contain good porosity and permeability, especially where the Swan Hills reefoid member is developed. The Swan Hills Member is a very good oil and gas producer in some parts of Alberta.

The few wells in the vicinity of Edson which have tested the Beaverhill Lake have shown a variety of results. A well in Lsd. 6-10-52-16 W5M, some 12 miles to the southeast, recovered 2,500 metres of gas-cut saltwater, 915 metres of water cushion and 6 metres of mud, for a total of 3,420 metres from a depth of 3,627 metres. Pressures indicate that water would rise to 490 metres above sea level or to about 450 metres depth. The fact that water actually rose higher than this is probably because the gas content gave it a lower density than formation water. A calculation using a drawdown to about 1,500 metres indicates a potential of almost 167 cubic metres per hour.

Another well in Lsd. 10-12-4-18 W5M tested the interval 3,560 metres to 3,584 metres and recovered 1,088 metres of gas-cut saltwater and 1,220 metres of water cushion, a total to 2,308 metres. Pressures indicate a piezometric surface of 460 metres above sea level.

Other tests in the general area have had variable results.

Beaverhill Lake water is expected to have salinites between 160,000 and 200,000 p.p.m. with the main constituents being sodium and chloride.

Typical water and pressure analysis of the Beaverhill Lake Formation are appended.

At depths of 3,500 metres, temperatures of 95 to 105°C would be expected.

Locally, the Beaverhill Lake could be a very good water producer but because of the very limited control, there would be a considerable degree of risk in drilling an exploration hole, and because of the depth, drilling would be very expensive.

Cambrian Units (Figure 7)

There is even less control for the sands of the Cambrian than the Beaverhill Lake Formation.

In the well in Lsd. 10-22-53-12 W5M, close to Edson, the unit was reported at 3,651 metres. Only a very short interval (three metres) of the unit was drilled and logs cover only part of this. The logs indicate that part of this was porous. The well was not tested.

A well penetrating this zone 10 miles to the northeast, tested a 10 metre interval of Cambrian and recovered 1,219 metres of water cushion, 140 metres of salt water with a salinity of 160,000 p.p.m. total solids, and 55 metres of drilling mud. A piezometric surface of 241 metres above sea level is indicated.

Temperatures at 3,650 metres should be about 110°C. At the well in Lsd. 10-22-53-12, at a depth of 3,651 metres, a temperature of about 90°C was recorded about 14 hours after circulation ceased, but we would expect the actual temperature to be higher.

Although the Cambrian units have very good prospects, the limited control means that there would be considerable risk in pursuing geothermal prospects within the Cambrian section. The depth to the unit would make the drilling of an exploratory well very expensive.

CONCLUSIONS

There appear to be only four major regional aquifers from which large quantities of geothermal water might confidently be expected to be produced in the Edson area.

The Belly River Group, at depths of 1,250 to 1,500 metres, gives evidence of being able to produce large quantities of water. Because it is a non-marine unit there may be some lack of reservoir continuity, but we expect several different sand bodies to be present and view the potential as very good.

Temperatures are expected to range from 35 to 40°C at 1,250 metres and from 45 to 50°C at 1,500 metres.

The Belly River water salinites are expected to be 3,000 to 5,000 p.p.m. total solids.

The Elkton Member of the Turner Valley Formation has good porosity and permeability to the west and southwest of Edson, but gas is produced at the unit's erosional edge near Edson. The presence of commercial gas and the distance to a water-bearing section downgrades this prospect.

Elkton temperatures are expected to be 75 to 80°C at depths of about 2,700 metres. Salinites are expected to be about 80,000 p.p.m. total solids.

The Beaverhill Lake Formation, including the Swan Hills Member, is a good potential reservoir but the limited control increases the difficulty of making accurate predictions and hence, the risk.

Good water production would be anticipated, but not assured, from depths of about 3,500 metres. Temperatures of 95 to 105°C are predicted with salinites of 160,000 to 200,000 p.p.m. total solids.

The Cambrian Sands also have a very good potential for production but a considerable degree of risk is present. Temperatures of about 110°C would be anticipated at depths of 3,650 metres. Salinities are expected to be over 150,000 p.p.m. total solids.

The depth to the Beaverhill Lake and the Cambrian would make drilling very expensive.

PERMIT TO PRACTICE
SPROULE ASSOCIATES LIMITED
Signature
Date MAR 22 1985
PERMIT NUMBER: P 417
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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140 - 4th Avenue S.W.
Calgary, Alberta
March 25, 1985
MWS/CASB/kwg

**** WATER ANALYSIS ****
BELLY RIVER GROUP

Remarks:

Lsd 2 Sec 6 Twp 54 Rge 18 M5

K.B.: 3174. Ft. 967.4 M.

DST number: 2

Stratigraphic Unit Tested: BLRV

Interval tested:

Top:	4938. Ft. 1505.1 M.	Bottom:	4951. Ft. 1509.1 M.

Elevation of interval tested:

Top:	-1764. Ft. 0.0 M.	Bottom:	-1777. Ft. 0.0 M.

Date of test: OCT 27, 1981

Recovery:
518' FRWTR

CATIONS	ppm	epm	%	ANIONS	ppm	epm	%
Ca	18	0.898	1.29	Cl	1878	52.960	75.60
Mg	0	0.000	0.00	SO4	158	3.290	4.70
Na	1583	68.829	98.71	HCO3	842	13.800	19.70
K	0	0.000	0.00	CO3	0	0.000	0.00
				Br	0	0.000	0.00
SUM	1601	69.727	100.00	SUM	2878	70.050	100.00

Total solids by calculation:	4479
Measured solids after evaporation:	0
Measured solids after ignition:	0

Calculated Density:	1.003
Measured Density:	1.000
pH:	8.10

RATIOS IN TERMS OF EQUIVALENTS

Na/Cl:	1.300	(Na+K)/Cl:	1.300
(Na+Cl)/(Ca+Mg):	76.630		
Cl/SO4:	16.099	SO4/(HCO3+CO3):	0.238
Na/K :	0.000		
Ca/Mg:	0.000	Cl/Br:	0.000

WA5070.032

**** WATER ANALYSIS ****
BEAVERHILL LAKE / SLAVE POINT

Remarks:

Lsd10 Sec32 Twp 54 Rge 16 M5

K.B.: 2920. Ft. 890.0 M.

DST number: 1

Stratigraphic Unit Tested: BHL, SLVP

Interval tested:
Top: 11045. Ft. 3366.5 M.
Bottom: 11120. Ft. 3389.4 M.

Elevation of interval tested:
Top: -8125. Ft. 0.0 M.
Bottom: -8200. Ft. 0.0 M.

Date of test: NOV 21, 1969

Recovery:
2148' SULWTR

CATIONS	ppm	epm	%	ANIONS	ppm	epm	%
Ca	11494	573.551	18.60	Cl	114000	3214.800	99.40
Mg	1555	127.883	4.15	SO4	286	5.955	0.18
Na	54784	2382.008	77.25	HCO3	820	13.440	0.42
K	0	0.000	0.00	CO3	0	0.000	0.00
				Br	0	0.000	0.00
SUM	67833	3083.441	100.00	SUM	115106	3234.194	100.00

Total solids by calculation: 182939
Measured solids after evaporation: 0
Measured solids after ignition: 0

Calculated Density: 1.126
Measured Density: 1.130
pH: 6.20

RATIOS IN TERMS OF EQUIVALENTS

Na/Cl: 0.741
(Na+Cl)/(Ca+Mg): 3.396
Cl/SO4: 539.292
Na/K : 0.000
Ca/Mg: 4.485
(Na+K)/Cl: 0.741
SO4/(HCO3+CO3): 0.443
Cl/Br: 0.000

WA5070.033

**** WATER ANALYSIS ****
BEAVERHILL LAKE / SLAVE POINT

Remarks:

Lsd10 Sec32 Twp 54 Rge 16 M5

K.B.: 2920. Ft. 890.0 M.

DST number: 1

Stratigraphic Unit Tested: BHL,SLVP

Interval tested:
Top: 11045. Ft. 3366.5 M.
Bottom: 11120. Ft. 3389.4 M.

Elevation of interval tested:
Top: -8125. Ft. 0.0 M.
Bottom: -8200. Ft. 0.0 M.

Date of test: NOV 21, 1969

Recovery:
2148' SULWTR.

CATIONS	ppm	epm	%	ANIONS	ppm	epm	%
Ca	15300	763.470	25.18	Cl	107000	3017.399	99.49
Mg	778	63.983	2.11	SO4	306	6.371	0.21
Na	50700	2204.436	72.71	HCO3	556	9.113	0.30
K	0	0.000	0.00	CO3	0	0.000	0.00
				Br	0	0.000	0.00
SUM	66778	3031.888	100.00	SUM	107862	3032.883	100.00

Total solids by calculation: 174640
Measured solids after evaporation: 0
Measured solids after ignition: 0

Calculated Density: 1.121
Measured Density: 1.120
pH: 7.30

RATIOS IN TERMS OF EQUIVALENTS

Na/Cl: 0.731
(Na+Cl)/(Ca+Mg): 2.664
Cl/SO4: 473.621
Na/K : 0.000
Ca/Mg: 11.932
(Na+K)/Cl: 0.731
SO4/(HCO3+CO3): 0.699
Cl/Br: 0.000

WA5070.035

**** WATER ANALYSIS ****
BEAVERHILL LAKE

Remarks:

Lsd 7 Sec28 Twp 54 Rge 17 M5

K.B.: 3031. Ft. 923.8 M.

DST number: 5

Stratigraphic Unit Tested: BHL

Interval tested:
Top: 11340. Ft. 3456.4 M.
Bottom: 11435. Ft. 3485.4 M.

Elevation of interval tested:
Top: -8309. Ft. 0.0 M.
Bottom: -8404. Ft. 0.0 M.

Date of test: NOV 20, 1968

Recovery:
890' SULGCSWTR, 2000' WTRCUSH

CATIONS	ppm	epm	%	ANIONS	ppm	epm	%
Ca	7728	385.627	11.52	Cl	116000	3271.200	97.66
Mg	923	75.908	2.27	SO4	242	5.038	0.15
Na	66395	2886.854	86.22	HCO3	4480	73.427	2.19
K	0	0.000	0.00	CO3	0	0.000	0.00
				Br	0	0.000	0.00
SUM	75046	3348.389	100.00	SUM	120722	3349.666	100.00

Total solids by calculation: 195768
Measured solids after evaporation: 0
Measured solids after ignition: 0

Calculated Density: 1.135
Measured Density: 1.120
pH: 7.70

RATIOS IN TERMS OF EQUIVALENTS

Na/Cl: 0.883
(Na+K)/Cl: 0.883
(Na+Cl)/(Ca+Mg): 6.255
Cl/SO4: 649.249
SO4/(HCO3+CO3): 0.069
Na/K : 0.000
Ca/Mg: 5.080
Cl/Br: 0.000

**** WATER ANALYSIS ****
BEAVERHILL LAKE

WA5070.046

Remarks:

Lsd10 Sec12 Twp 54 Rge 18 M5

K.B.: 3179. Ft. 969.0 M.

DST number: 8

Stratigraphic Unit Tested: BHL

Interval tested:

Top:	11670. Ft. 3557.0 M.	Bottom:	11723. Ft. 3573.2 M.

Elevation of interval tested:

Top:	-8491. Ft. 0.0 M.	Bottom:	-8544. Ft. 0.0 M.

Date of test: NOV 10, 1969

Recovery:
3570' SULGCWTR, 4000' WTRCUSH

CATIONS	ppm	epm	%	ANIONS	ppm	epm	%
Ca	18036	899.996	26.20	Cl	121000	3412.200	99.29
Mg	2432	200.008	5.82	SO4	282	5.871	0.17
Na	53713	2335.441	67.98	HCO3	1120	18.357	0.53
K	0	0.000	0.00	CO3	0	0.000	0.00
				Br	0	0.000	0.00
SUM	74181	3435.445	100.00	SUM	122402	3436.428	100.00

Total solids by calculation:	196583
Measured solids after evaporation:	0
Measured solids after ignition:	0

Calculated Density:	1.136
Measured Density:	1.140
pH:	6.10

RATIOS IN TERMS OF EQUIVALENTS

Na/Cl:	0.684	(Na+K)/Cl:	0.684
(Na+Cl)/(Ca+Mg):	2.123		
Cl/SO4:	581.172	SO4/(HCO3+CO3):	0.320
Na/K :	0.000		
Ca/Mg:	4.500	Cl/Br:	0.000

```
              **** D.S.T. PRESSURE ANALYSIS ****          DP5070.029
                     BELLY RIVER GROUP

Remarks:
DATA B

Lsd 6 Sec14 Twp 53 Rge 18 M5

K.B.:  3198. Ft.   974.8 M.

DST number:    3

Stratigraphic Unit Tested:  BLRV

Interval tested:
  Top:    5190.  Ft.                Bottom:   5220.  Ft.
          1581.9 M.                           1591.1 M.

Elevation of interval tested:
  Top:   -1992.  Ft.                Bottom:  -2022.  Ft.
          -607.2 M.                           -616.3 M.

Date of test:  SEP 20, 1972

Recovery:
4370'SWTR


Times:
 Minutes                      IF:     5  FF:     60  ISI:     60  FSI:     60

Pressures:
 PSI    IHP:   2851 FHP:   2851 IFP:   1030 FFP:   1938 ISIP:   1954 FSIP:   1952
 KPa    IHP:  19656 FHP:  19656 IFP:   7101 FFP:  13362 ISIP:  13472 FSIP:  13458

                Pressure used:       1954   PSI
                                    13472   KPa

                 Density used:        1.00

       Theoretical Water Rise:       4513.  Ft.
                                     1375.5 M.

          Piezometric Surface:       2491.  Ft.
                                      759.2 M.

Corrected Pressure Sea Level:        1078   PSI
                                     7436   KPa
```

```
                    **** D.S.T. PRESSURE ANALYSIS ****         DP5070.041
                             BEAVERHILL LAKE

Remarks:
DATA C

Lsd10 Sec32 Twp 54 Rge 16 M5

K.B.:  2920. Ft.   890.0 M.

DST number:    1

Stratigraphic Unit Tested:  BHL

Interval tested:
  Top:  11045.  Ft.             Bottom:  11120.  Ft.
         3366.5 M.                        3389.4 M.

Elevation of interval tested:
  Top:  -8125.  Ft.             Bottom:  -6200.  Ft.
        -2476.5 M.                       -2499.4 M.

Date of test:  NOV 21, 1969

Recovery:
2148'SULWTR


Times:
 Minutes                     IF:     5  FF:    70  ISI:    30  FSI:   120

Pressures:
 PSI   IHP:   5180 FHP:  4991 IFP:  2015 FFP:  2864 ISIP:  4834 FSIP:  4843
 KPa   IHP:  35714 FHP: 34411 IFP: 13892 FFP: 19746 ISIP: 33329 FSIP: 33391


               Pressure used:      4834    PSI
                                  33329    KPa

                Density used:        1.15

        Theoretical Water Rise:     9708.   Ft.
                                    2958.9  M.

           Piezometric Surface:     1508.   Ft.
                                     459.6  M.

Corrected Pressure Sea Level:        751    PSI
                                    5177    KPa
```

```
                    **** D.S.T. PRESSURE ANALYSIS ****              DP5070.051
                            BEAVERHILL LAKE

Remarks:
DATA C

Lsd 7 Sec28 Twp 54 Rge 17 M5

K.B.:  3031. Ft.   923.8 M.

DST number:    5

Stratigraphic Unit Tested:  BHL

Interval tested:
  Top:  11340.  Ft.                Bottom:  11435.  Ft.
         3456.4 M.                           3485.4 M.

Elevation of interval tested:
  Top:  -8309.  Ft.                Bottom:  -8404.  Ft.
        -2532.6 M.                          -2561.5 M.

Date of test:  NOV 20, 1968

Recovery:
890'SULGCSWTR, 2000'WTRCUSH


Times:
 Minutes                        IF:     3  FF:    60  ISI:    60  FSI:    90

Pressures:
 PSI    IHP:  5431 FHP:  5241 IFP:   419 FFP:  1002 ISIP:  4936 FSIP:  4622
 KPa    IHP: 37445 FHP: 36135 IFP:  2888 FFP:  6908 ISIP: 34032 FSIP: 31867


              Pressure used:     4936   PSI
                                34033   KPa

               Density used:      1.15

      Theoretical Water Rise:    9913.  Ft.
                                 3021.4 M.

         Piezometric Surface:    1509.  Ft.
                                  459.8 M.

Corrected Pressure Sea Level:     751   PSI
                                 5180   KPa
```

```
                  **** D.S.T. PRESSURE ANALYSIS ****              DP5070.064
                             BEAVERHILL LAKE

Remarks:
DATA B

Lsd10 Sec12 Twp 54 Rge 18 M5

K.B.:  3179. Ft.    969.0 M.

DST number:     8

Stratigraphic Unit Tested:  BHL

Interval tested:
  Top:  11680.  Ft.                 Bottom:  11760.  Ft.
         3560.1 M.                            3584.4 M.

Elevation of interval tested:
  Top:  -8501.  Ft.                 Bottom:  -8581.  Ft.
        -2591.1 M.                           -2615.5 M.

Date of test:  NOV 10, 1969

Recovery:
3570'SULGCWTR, 4000'WTRCUSH


Times:
 Minutes                     IF:      5  FF:     75  ISI:     30  FSI:     75

Pressures:
 PSI    IHP:   6213 FHP:   6091 IFP:   2185 FFP:   3834 ISIP:   5025 FSIP:   4872
 KPa    IHP:  42837 FHP:  41995 IFP:  15065 FFP:  26434 ISIP:  34646 FSIP:  33591


               Pressure used:      5025    PSI
                                  34646    KPa

                Density used:        1.15

       Theoretical Water Rise:    10091.   Ft.
                                   3075.9  M.

          Piezometric Surface:     1510.   Ft.
                                    460.4  M.

Corrected Pressure Sea Level:       752    PSI
                                   5185    KPa
```

APPENDIX C

URBAN PLANNING CONSIDERATIONS

APPENDIX C

URBAN PLANNING CONSIDERATIONS

INTRODUCTION

As indicated in the introduction to the project, a large site approximately 50 ha in area has been identified east of 48th Street and north of 10th Avenue that contains some existing large buildings, and is suitable for more. This site could permit the clustering of users of geothermal energy, resulting in economies in the heat delivery system from the geothermal source well. A planning study was undertaken to determine what type, size and location of additional buildings might be suitable for such a site. Following is a review of the study process and results.

Land Use Review

1) Existing public facilities in the Town of Edson are scattered over the built-up area and there is no ideal location for the geothermal heat source to serve these facilities by the central district heating system.

2) Schools are generally in need of more active playfield facilities such as ball diamonds and football fields.

3) The Town is in need of a new arena and indoor swimming pool.

4) Parkland High School and Pine Grove School have only one vehicular access (from 48th Street) and it is desirable to have another vehicular access which is convenient for the residents in the eastern part of the Town.

5) In order to make the geothermal project more effective, it is necessary to centralize future public facilities with large heat consumption.

6) Ideal properties for these future public facilities are identified as the Town owned properties immediately east and west to Parkland High School and Pine Grove School sites.

Proposed Geothermal Well and Surrounding Land Uses

1) The proposed location of the geothermal well and proposed land uses in this vicinity are shown on Figure 2.

2) The shaded areas indicate potential building sites for various future public facilities and the dotted areas indicate the proposed future public outdoor facilities.

3) Building Sites 1 and 2 are suitable for the future institutional purposes such as Auditorium, Library or Health Services whereas Sites 3 and 4 are suitable for the public recreational purposes.

4) The playground associated with the high school is proposed to the north of the building and the playground for the elementary school is proposed to the south of the building.

A new athletic park independent from these schools is proposed to the east of the high school or the Town owned property.

5) The proposed plan illustrates the alignment of new roads through these properties. It is proposed that 16th Avenue be extended further east through the school property then bend to the north through the town owned property. It is also proposed that 16th Street be extended from the 9th Avenue and intersect with the proposed 16th Avenue extension.

Land Use Bylaw

The proposed scheme requires the Land Use Bylaw No. 1430 of the Town of Edson to be amended in the following areas.

1) The area immediately north to the Parkland High School should be reclassified from U.R. to I (industrial)

2) The area immediately east to the high school should be reclassified from RMHS to PR (park and recreation).

3) Those properties west to the two schools should be reclassified from PR to I (industrial).

APPENDIX D

FIGURES 1 - 17

EDSON GEOTHERMAL

FEASIBILITY STUDY

LOCATION PLAN

UMA Engineering Ltd.

figure 1

EDSON GEOTHERMAL
FEASIBILITY STUDY

LEGEND

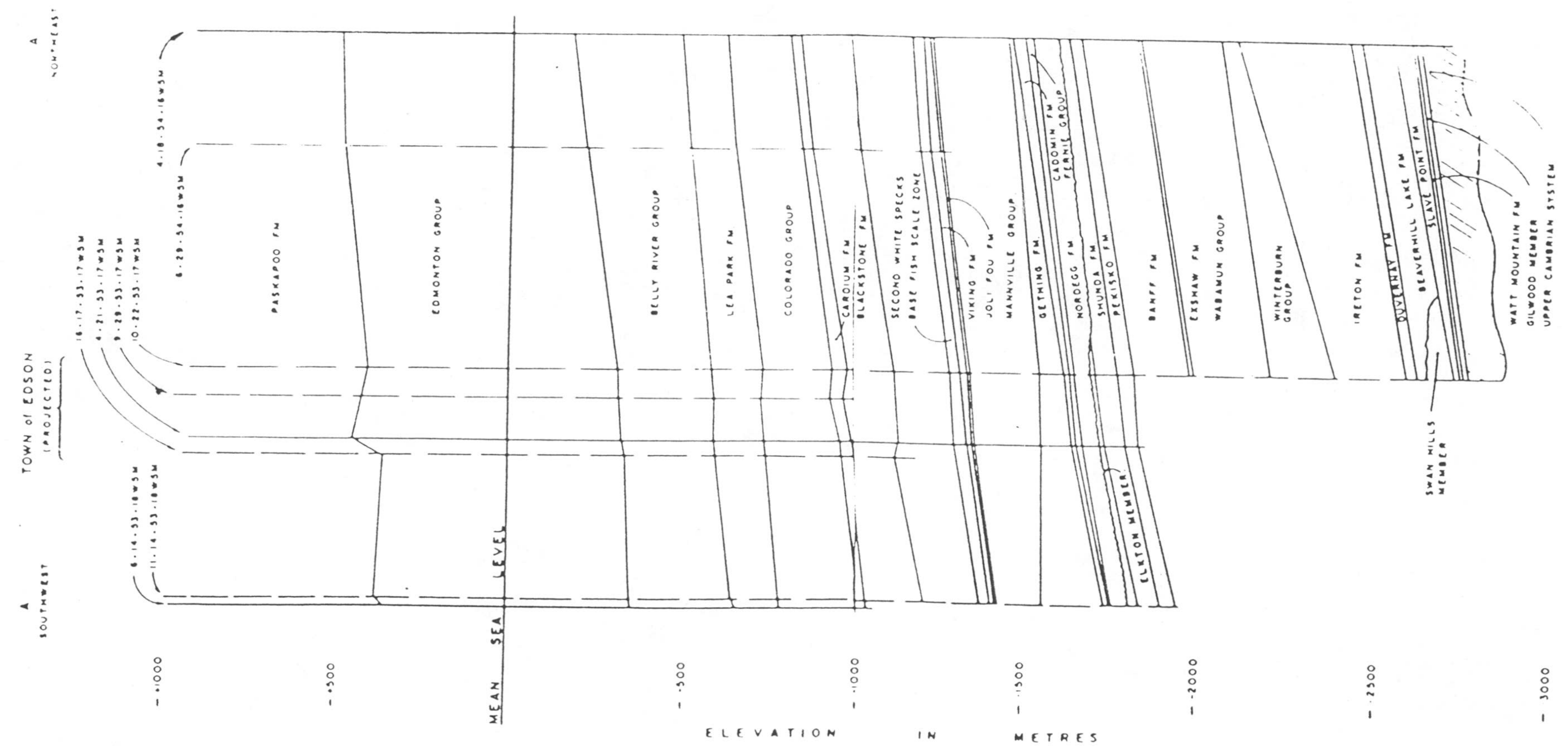
II ..... FUTURE FACILITY

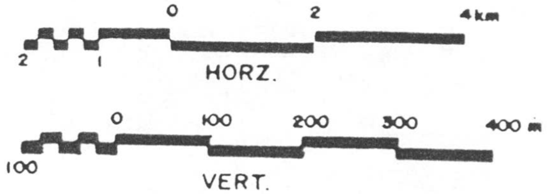
FACILITIES LOCATION PLAN

UMA Engineering Ltd.

figure 2

EDSON GEOTHERMAL
FEASIBILITY STUDY



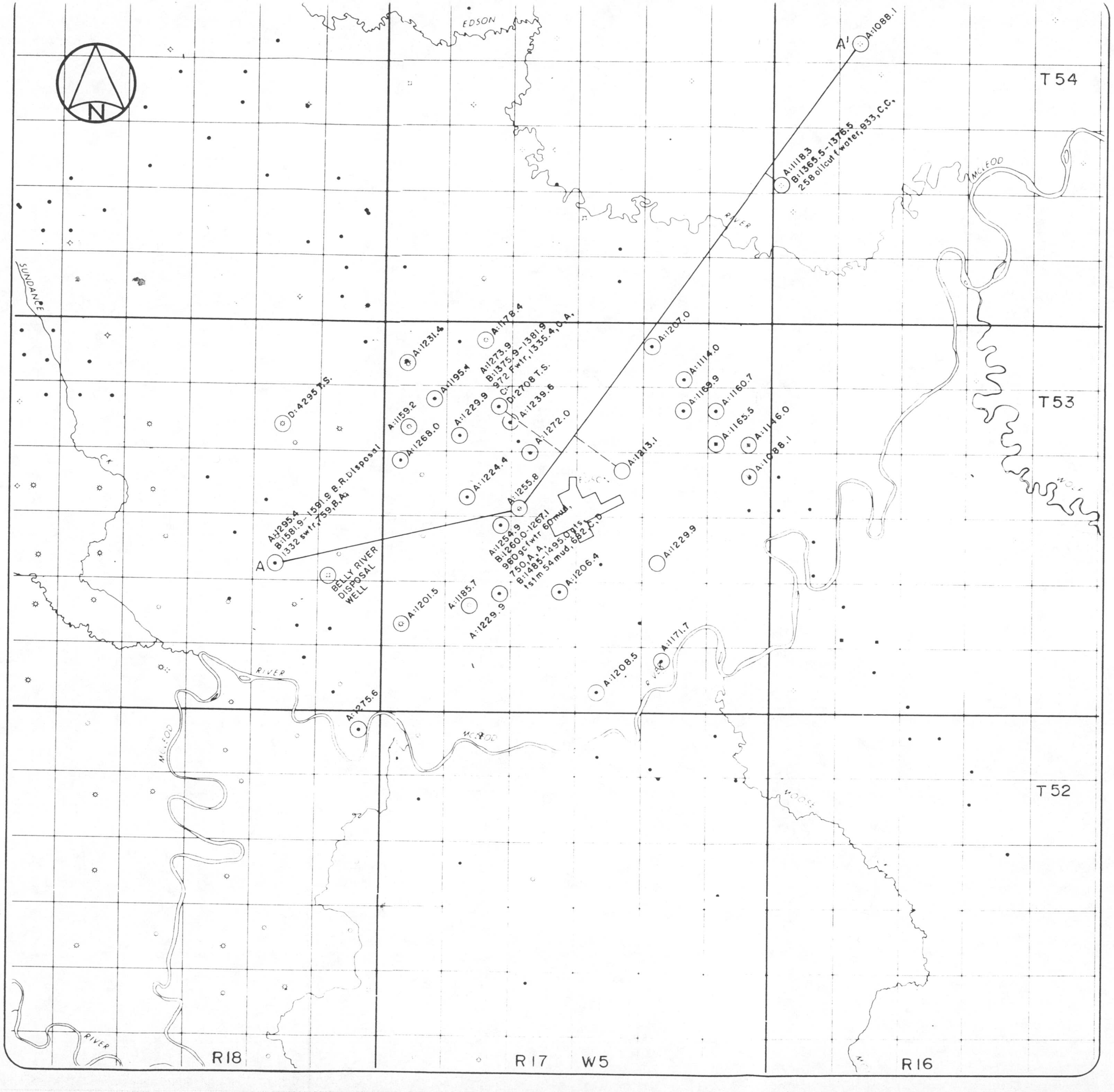


STRUCTURAL GEOLOGY

UMA Engineering Ltd.

figure 3

EDSON GEOTHERMAL
FEASIBILITY STUDY



LEGEND

● ---------- OIL WELL

☼ ---------- GAS WELL

-◇- ---------- ABANDONED WELL

¤ ---------- INJECTION WELL

○ ---------- DATA POINT

A — A' ----- LINE OF CROSS-SECTION

GEOTHERMAL DATA

A: DEPTH TO PROSPECTIVE ZONE (metres)

B: TESTED INTERVAL METRES RECOVERY, PIEZOMETRIC SURFACE, DATA QUALITY (A to B) POTENTIAL (A to B)

C: CORE ANALYSED (metres), WEIGHTED AVER. PERMEABILITY (millidarcies) WEIGHTED AVER. POROSITY (percent)

D: WATER SALINITY PARTS PER MILLION TOTAL SOLIDS.

2 1 0 2 4 Km

GEOTHERMAL DATA MAP
BELLY RIVER GROUP

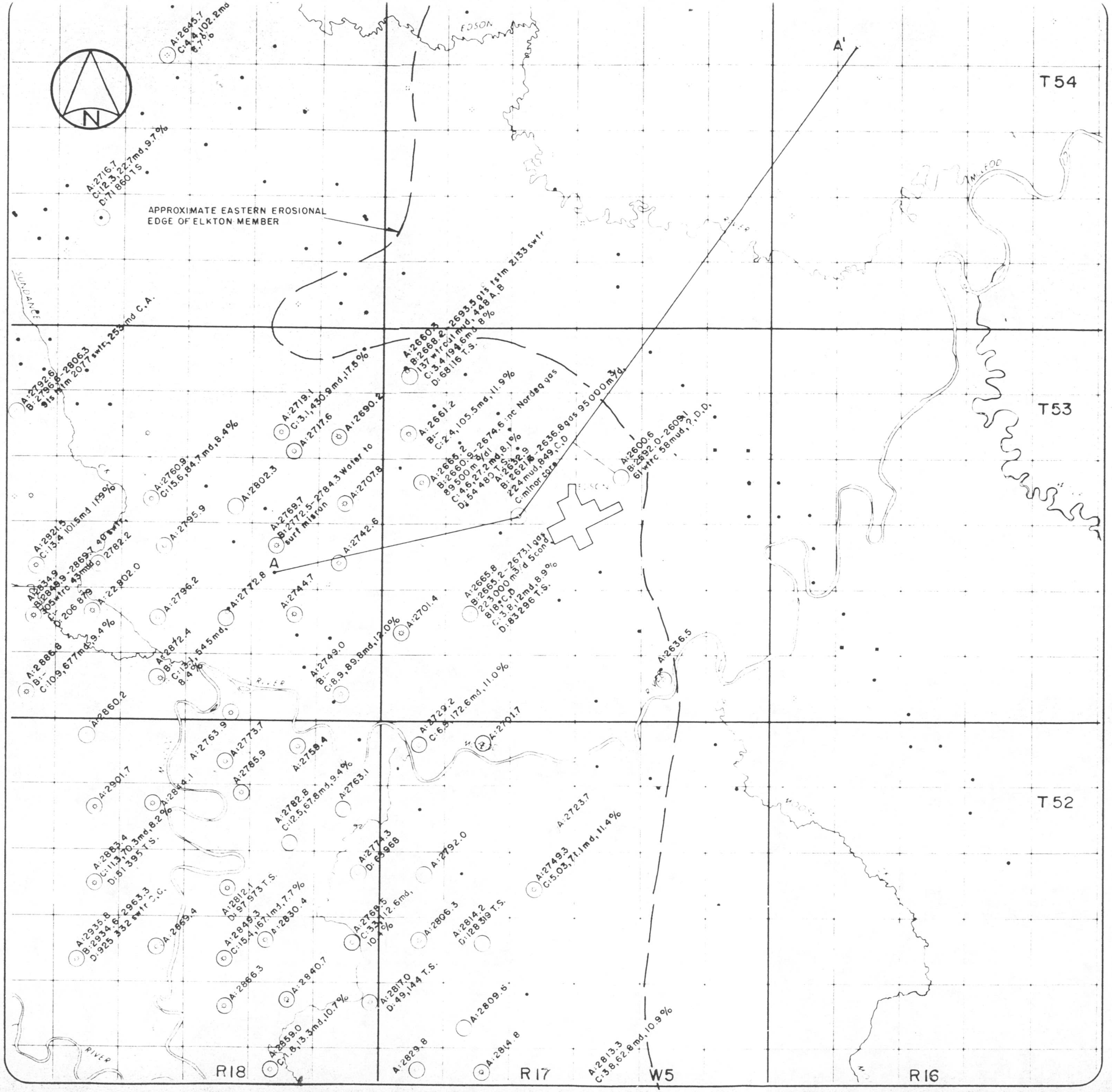
uma

UMA Engineering Ltd.

figure 4

145

EDSON GEOTHERMAL
FEASIBILITY STUDY



LEGEND

● --------- OIL WELL

☼ --------- GAS WELL

⌖ --------- ABANDONED WELL

⌖ --------- INJECTION WELL

○ --------- DATA POINT

A – A' ----- LINE OF CROSS-SECTION

GEOTHERMAL DATA

A: DEPTH TO PROSPECTIVE ZONE (metres)

B: TESTED INTERVAL METRES RECOVERY, PIEZOMETRIC SURFACE, DATA QUALITY (A to B) POTENTIAL (A to B)

C: CORE ANALYSED (metres), WEIGHTED AVER. PERMEABILITY (millidarcies) WEIGHTED AVER. POROSITY (percent)

D: WATER SALINITY PARTS PER MILLION TOTAL SOLIDS.

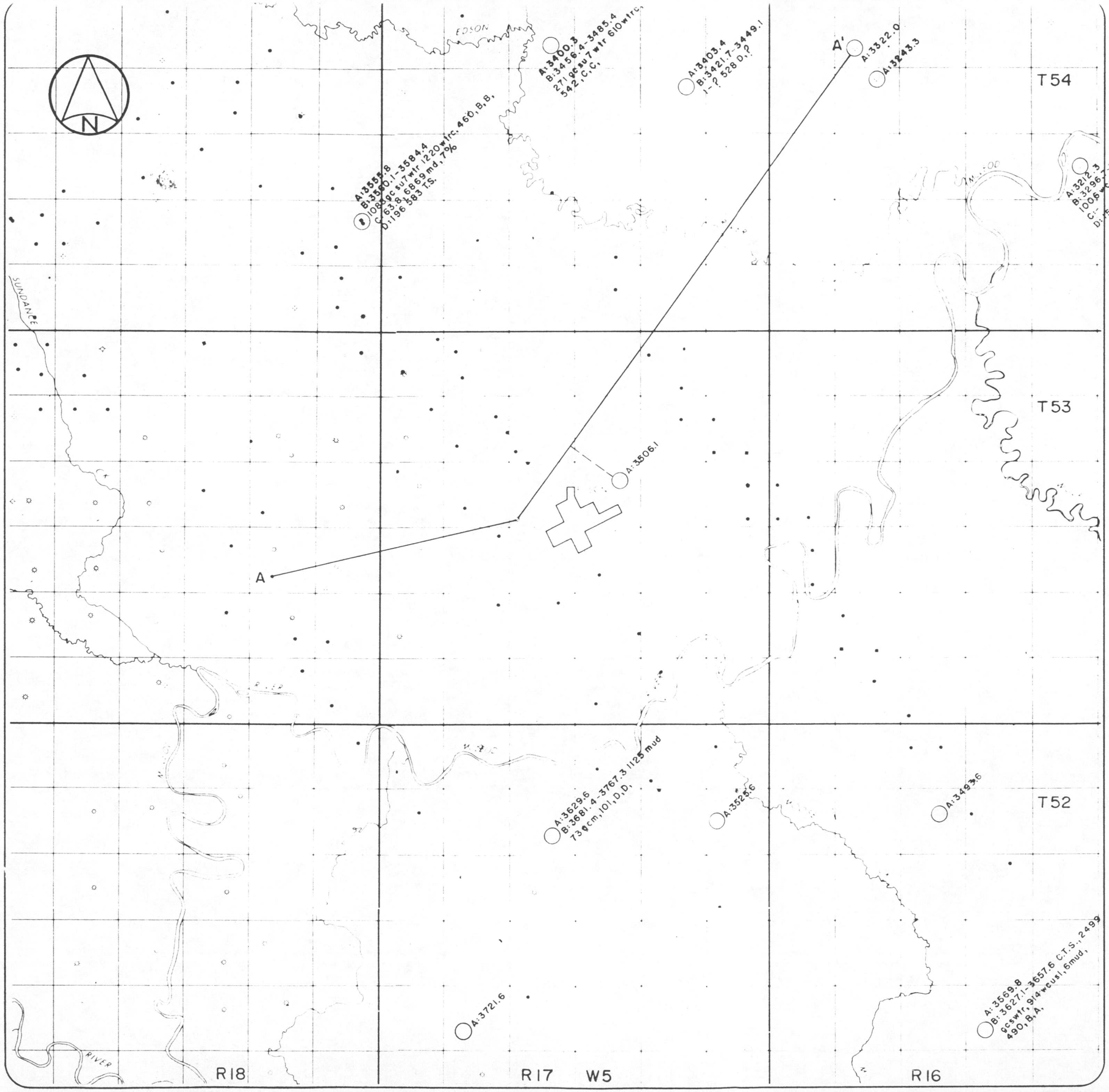
2 1 0 2 4 km

GEOTHERMAL DATA MAP
ELKTON MEMBER

uma

UMA Engineering Ltd.

figure 5



EDSON GEOTHERMAL
FEASIBILITY STUDY

LEGEND

- ● ---------- OIL WELL
- ☼ ---------- GAS WELL
- ⌖ ---------- ABANDONED WELL
- ⌘ ---------- INJECTION WELL
- ○ ---------- DATA POINT
- A – A' ----- LINE OF CROSS-SECTION

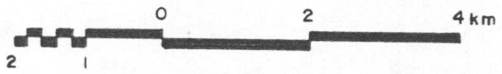
GEOTHERMAL DATA

A: DEPTH TO PROSPECTIVE ZONE (metres)

B: TESTED INTERVAL METRES RECOVERY, PIEZOMETRIC SURFACE, DATA QUALITY (A to B) POTENTIAL (A to B)

C: CORE ANALYSED (metres), WEIGHTED AVER. PERMEABILITY (millidarcies) WEIGHTED AVER. POROSITY (percent)

D: WATER SALINITY PARTS PER MILLION TOTAL SOLIDS.



GEOTHERMAL DATA MAP
BEAVERHILL LAKE
FORMATION
SWAN HILLS MEMBER

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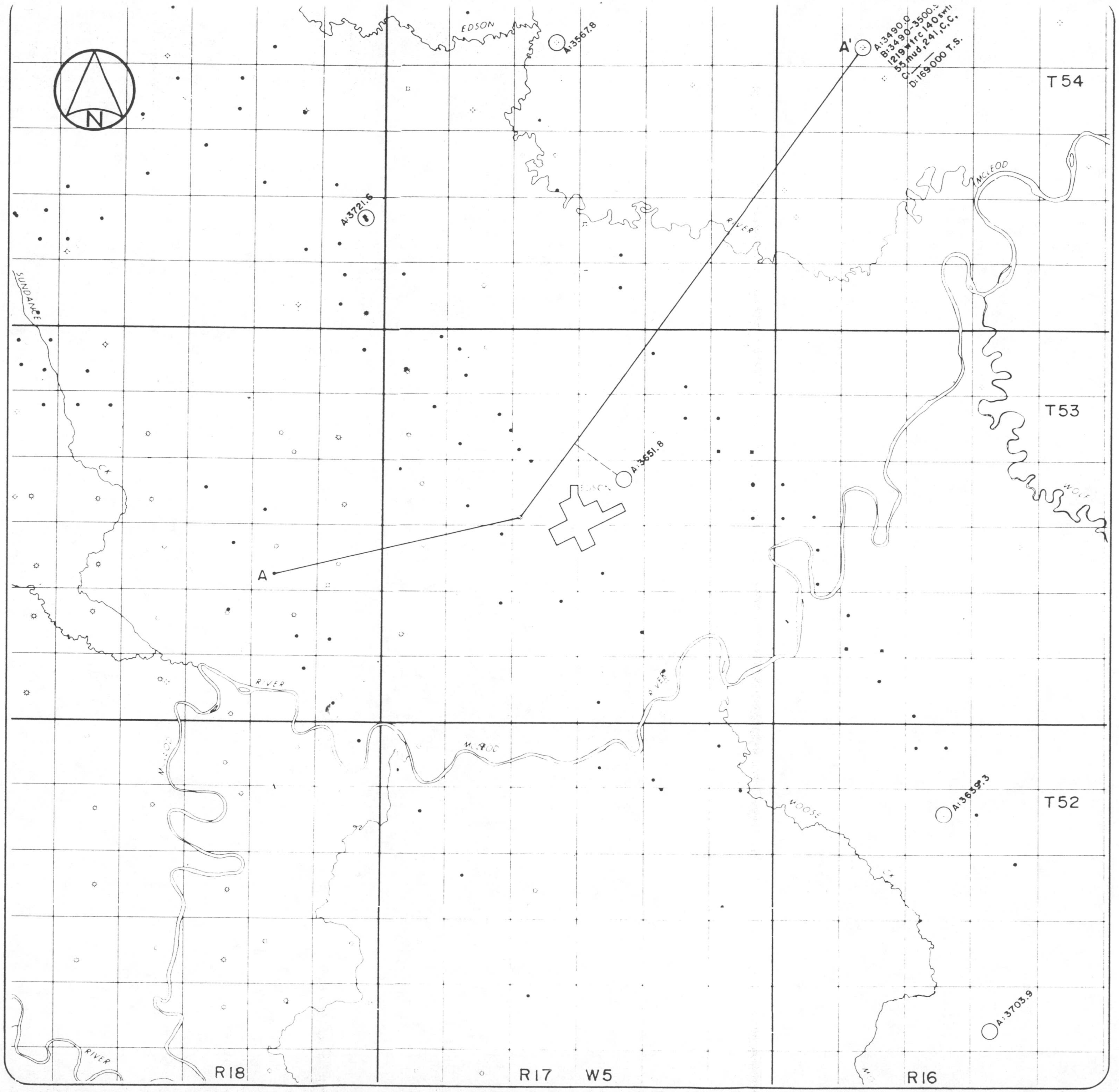
figure 6



EDSON GEOTHERMAL
FEASIBILITY STUDY

LEGEND

● ---------- OIL WELL

☼ ---------- GAS WELL

⌖ ---------- ABANDONED WELL

⌘ ---------- INJECTION WELL

○ ---------- DATA POINT

A – A' ----- LINE OF CROSS-SECTION

GEOTHERMAL DATA

A: DEPTH TO PROSPECTIVE ZONE (metres)

B: TESTED INTERVAL METRES RECOVERY, PIEZOMETRIC SURFACE, DATA QUALITY (A to B) POTENTIAL (A to B)

C: CORE ANALYSED (metres), WEIGHTED AVER. PERMEABILITY (millidarcies) WEIGHTED AVER. POROSITY (percent)

D: WATER SALINITY PARTS PER MILLION TOTAL SOLIDS.

GEOTHERMAL DATA MAP
CAMBRIAN SYSTEM

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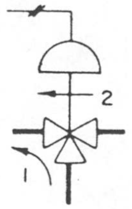
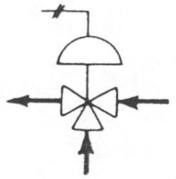
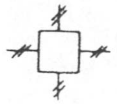
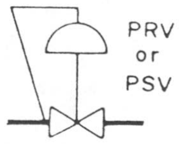
figure 7

	PNEUMATICALLY OPERATED DIVERTER VALVE WITH FLOW PATTERN 1 OR 2. (NUMBERS MAY BE REVERSED)
	PNEUMATICALLY OPERATED MIXING VALVE CONTROL DOWNSTREAM TEMPERATURE.
TC$_1$	TEMPERATURE CONTROLLER, WHEN TEMPERATURE FALLS BELOW SET POINT, CAUSES DIVERTOR VALVES TO CHANGE FROM FLOW PATTERN 1 TO 2.
TC$_2$	TEMPERATURE CONTROLLER, WHEN TEMPERATURE FALLS BELOW SET POINT, OPENS STEAM CONTROL VALVE. (GEOTHERMAL HOT WATER NOT IN USE)
TC$_3$	TEMPERATURE CONTROLLER, MODULATES MIXING VALVE TO MAINTAIN AIR FLOW TEMPERATURE.
TCO	TEMPERATURE CONTROLLER, LOWERS TC$_1$ & TC$_2$ SET POINTS AS OUTSIDE AIR TEMPERATURE RISES
FS	FLOW SENSOR, ON NO FLOW, CAUSES DIVERTER VALVES TO CHANGE FROM FLOW PATTERN 1 TO 2.
	SIGNAL PROCESSOR
T	CONDENSATE TRAP
AFC	AUTOMATIC FLOW CONTROL

CV	CONTROL VALVE
	PRESSURE REDUCING VALVE OR PRESSURE SUSTAINING VALVE
	GATE VALVE
	GLOBE VALVE
	STRAINER
	CHECK VALVE
	PNEUMATIC LINE
------	ELECTRIC SIGNAL LINE
T	ROOM THERMOSTAT
N.C.	NORMALLY CLOSED

EDSON GEOTHERMAL

FEASIBILITY STUDY

NOTE

LEGEND REFERS TO FIGURES 9, 10 & 11.

MECHANICAL LEGEND

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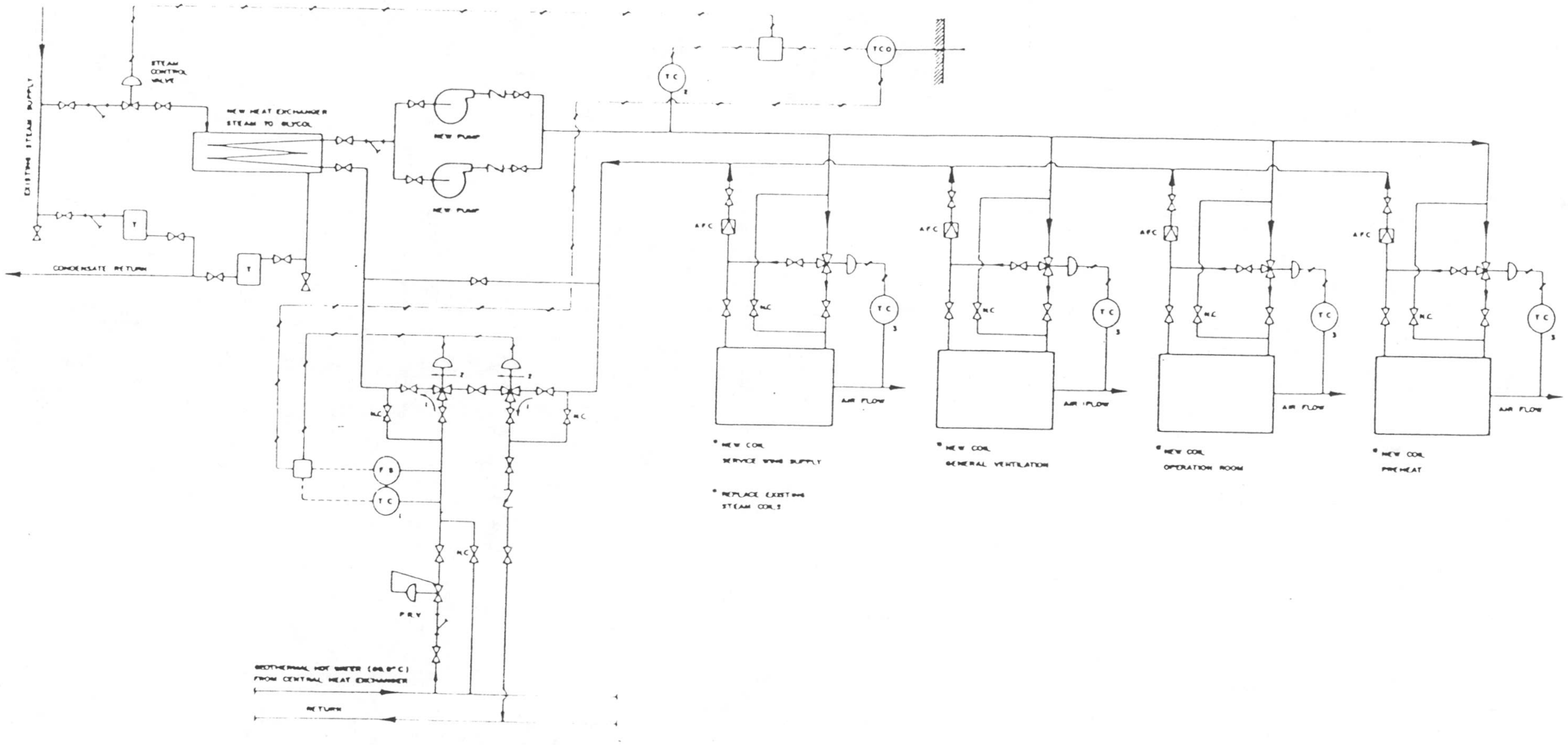
figure 8



EDSON GEOTHERMAL

FEASIBILITY STUDY

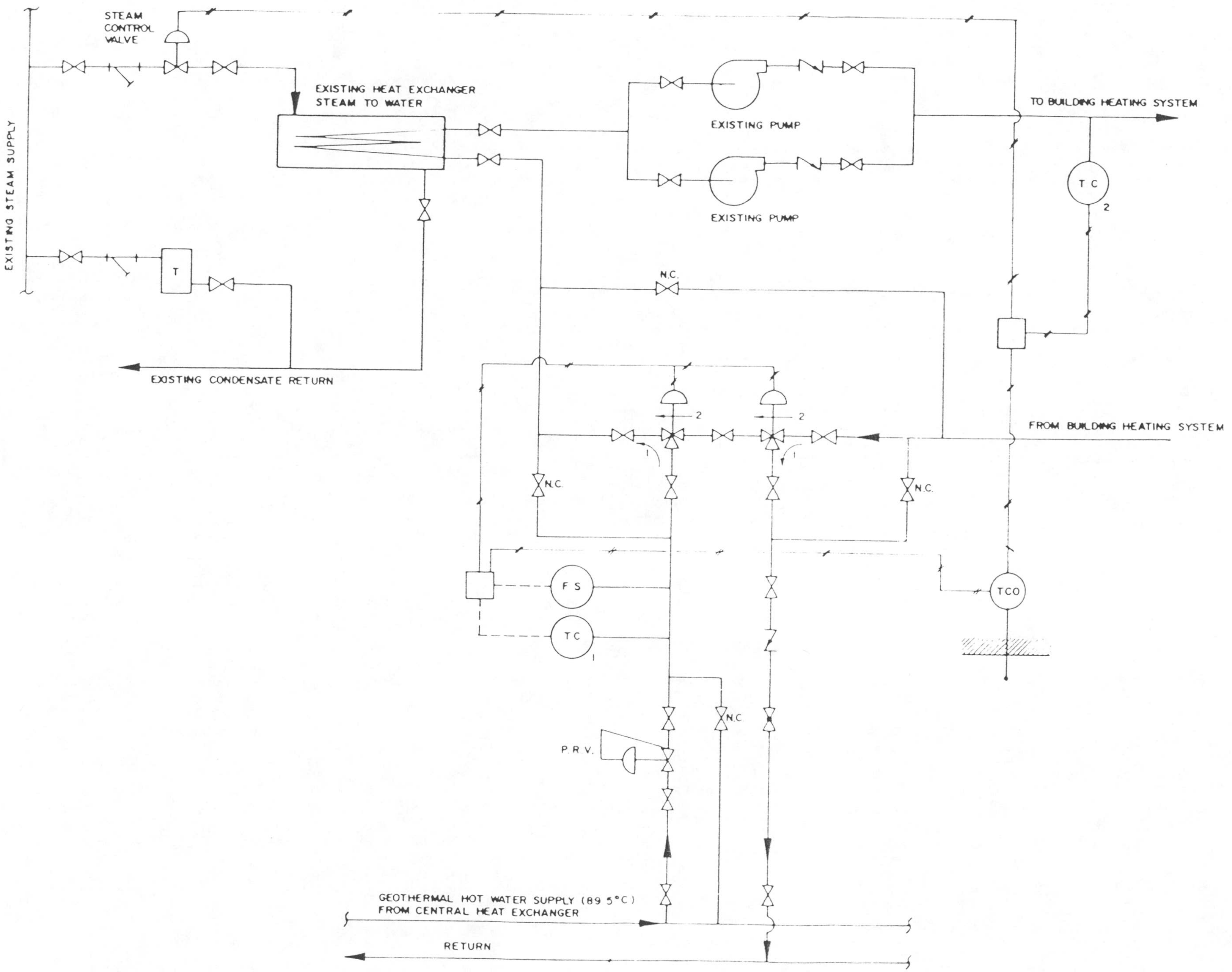
SEE FIGURE 8 FOR LEGEND

ST. JOHNS HOSPITAL

ORIGINAL
BOILER ROOM RETROFIT

UMA Engineering Ltd.

figure 9



EDSON GEOTHERMAL

FEASIBILITY STUDY

SEE FIGURE 8 FOR LEGEND

ST. JOHNS HOSPITAL

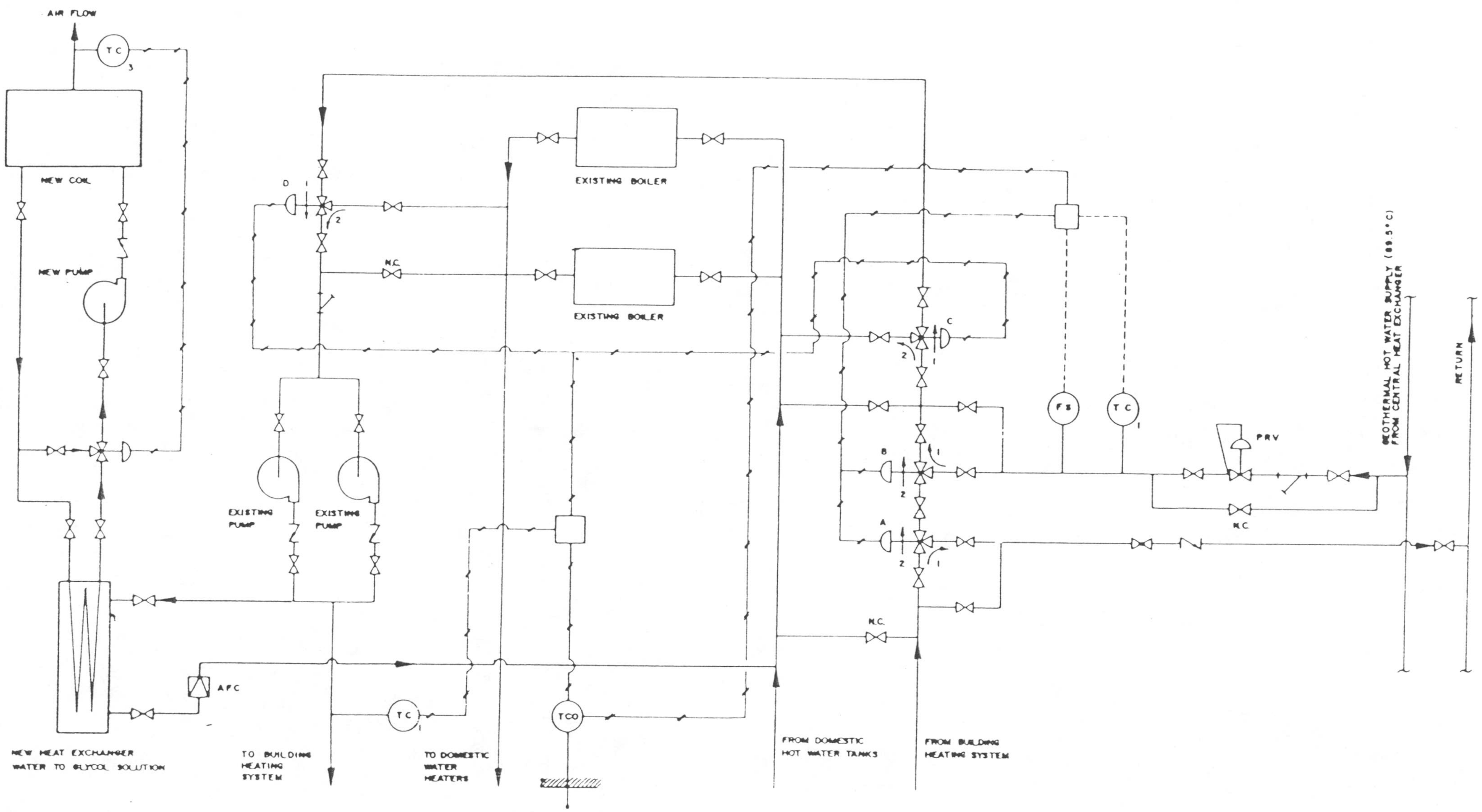
PENTHOUSE AIR HEATING RETROFIT

UMA Engineering Ltd.

figure 10

EDSON GEOTHERMAL
FEASIBILITY STUDY

SEE FIGURE 8 FOR LEGEND



ST. JOHNS HOSPITAL
NURSING HOME

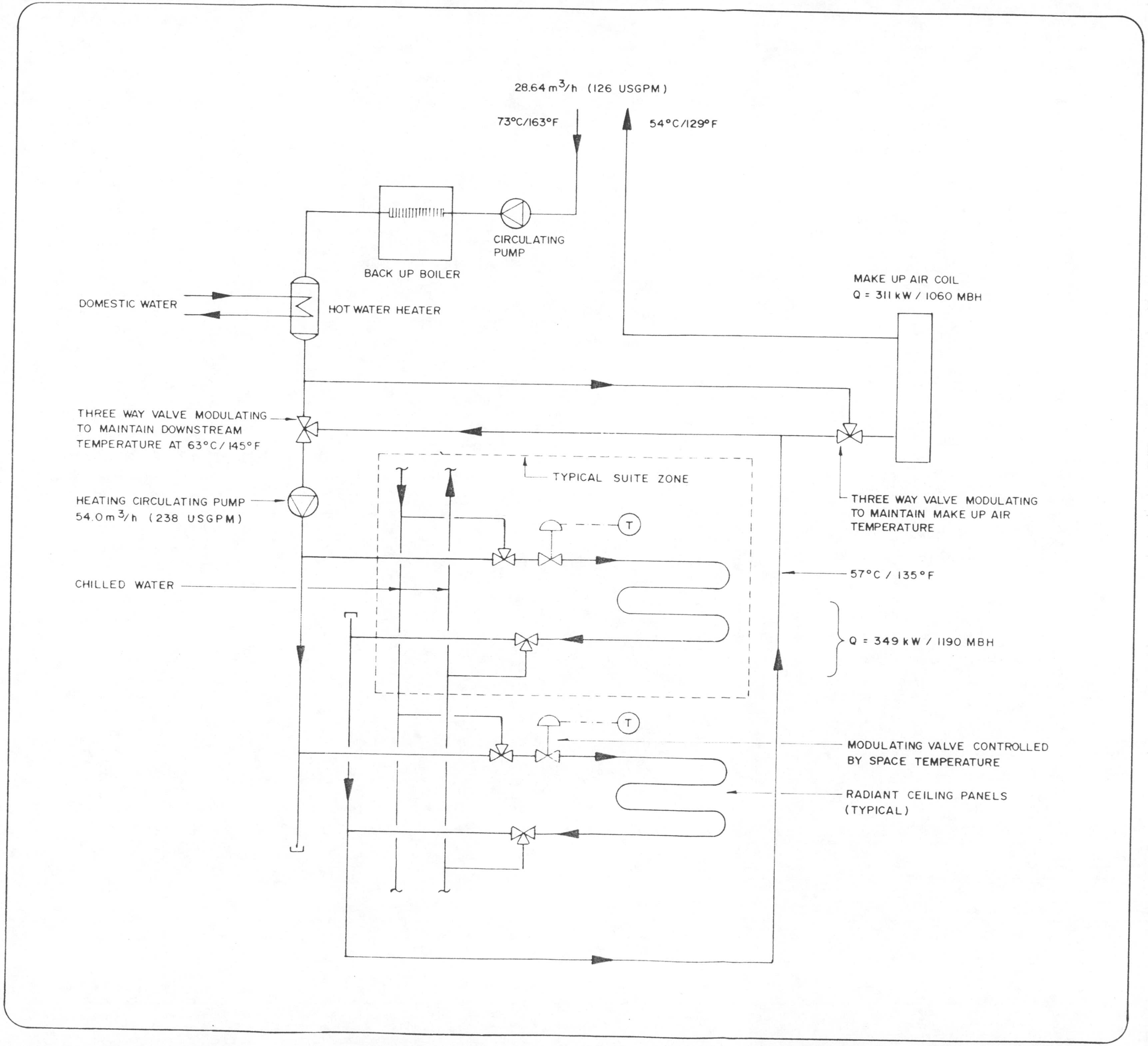
BOILER ROOM RETROFIT

UMA Engineering Ltd.

figure 11

EDSON GEOTHERMAL

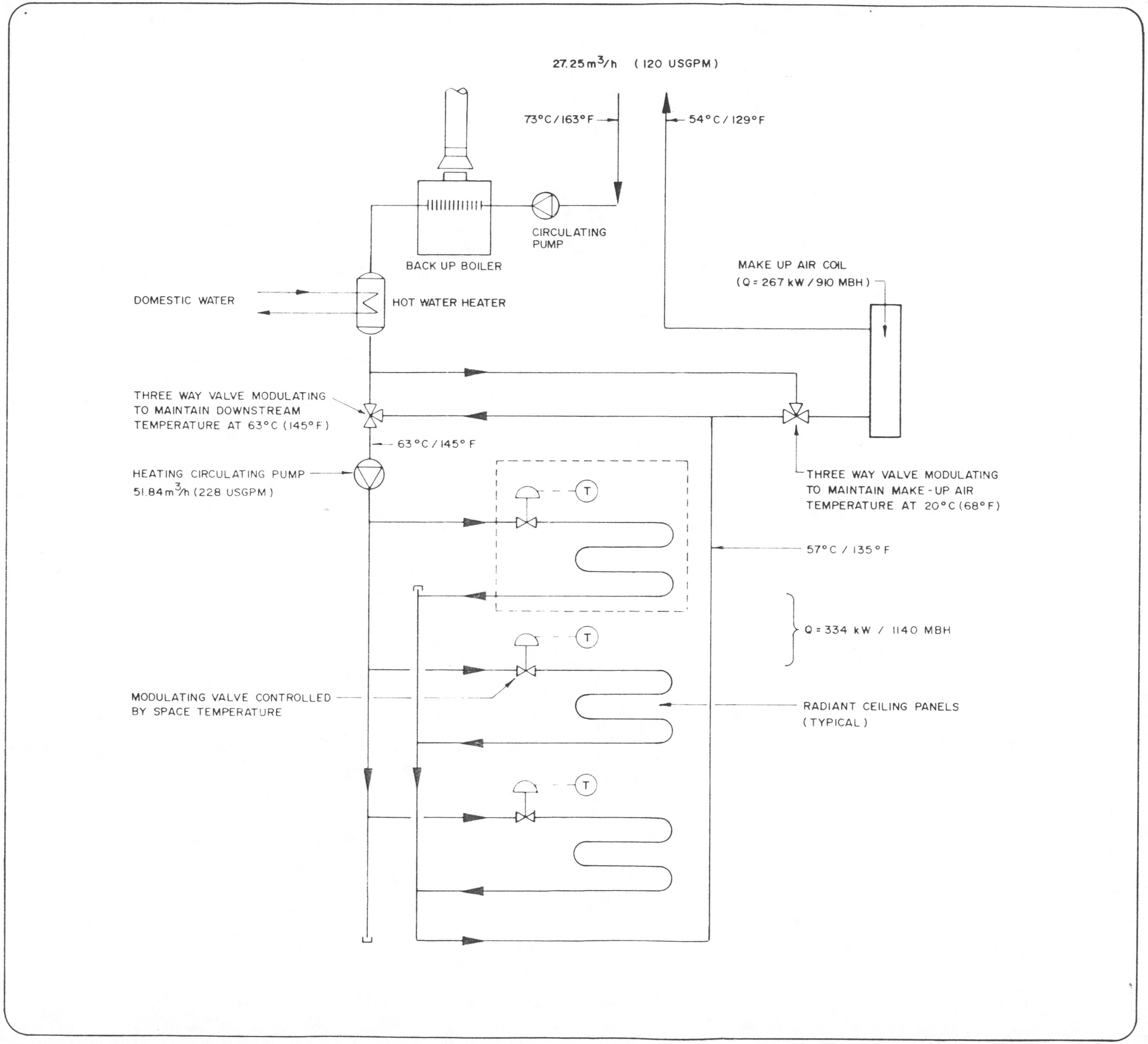
FEASIBILITY STUDY



TYPICAL 3 - FLOOR
OFFICE BUILDING HEATING
(3500 m^2)

UMA Engineering Ltd.

figure 12



EDSON GEOTHERMAL

FEASIBILITY STUDY

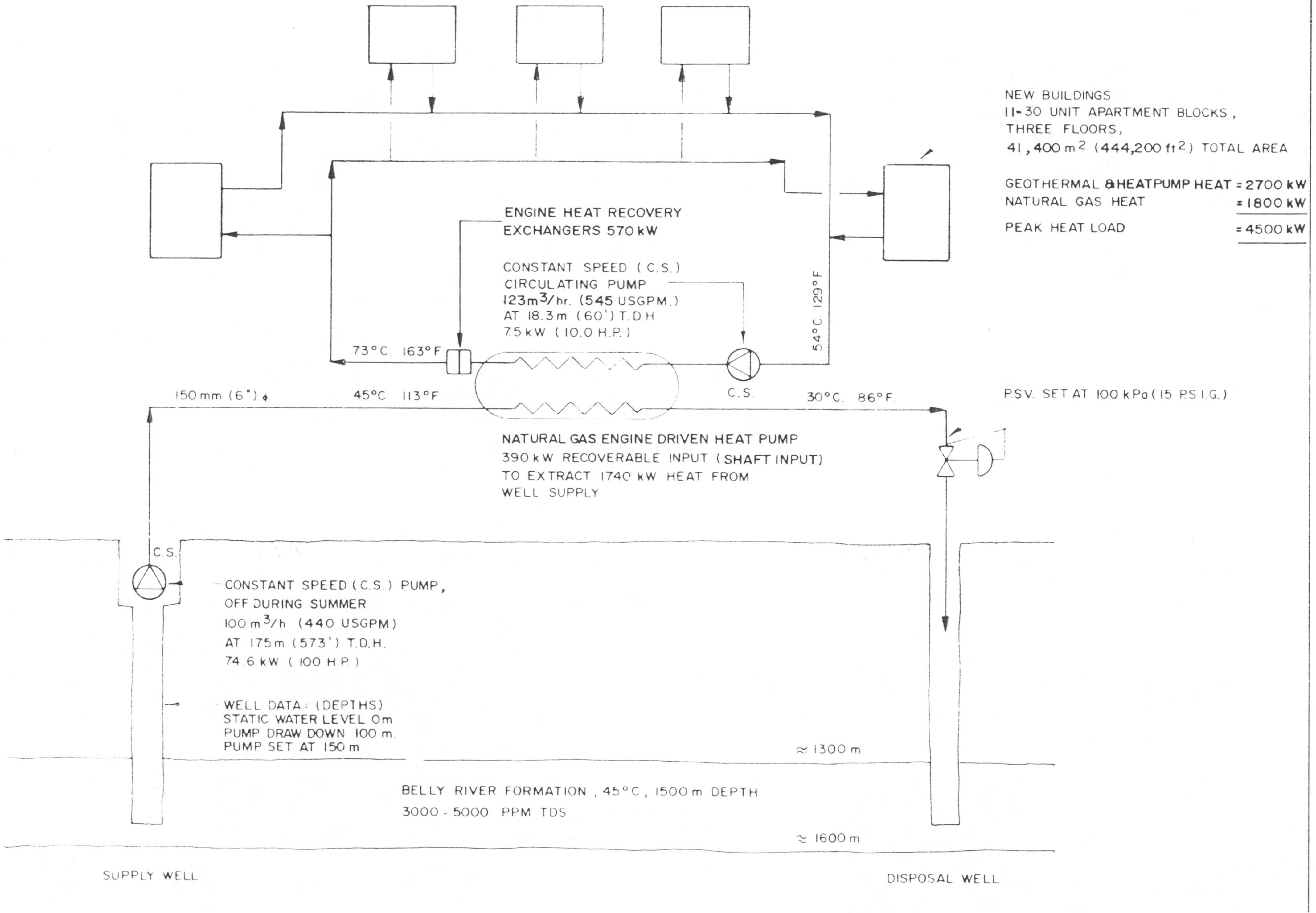
TYPICAL WALKUP
APARTMENT BUILDING
HEATING (75 SUITES)

UMA Engineering Ltd.

figure 13

EDSON GEOTHERMAL

FEASIBILITY STUDY



MODEL I

LOW TEMPERATURE

NEW BUILDING WITH HEAT PUMP

uma

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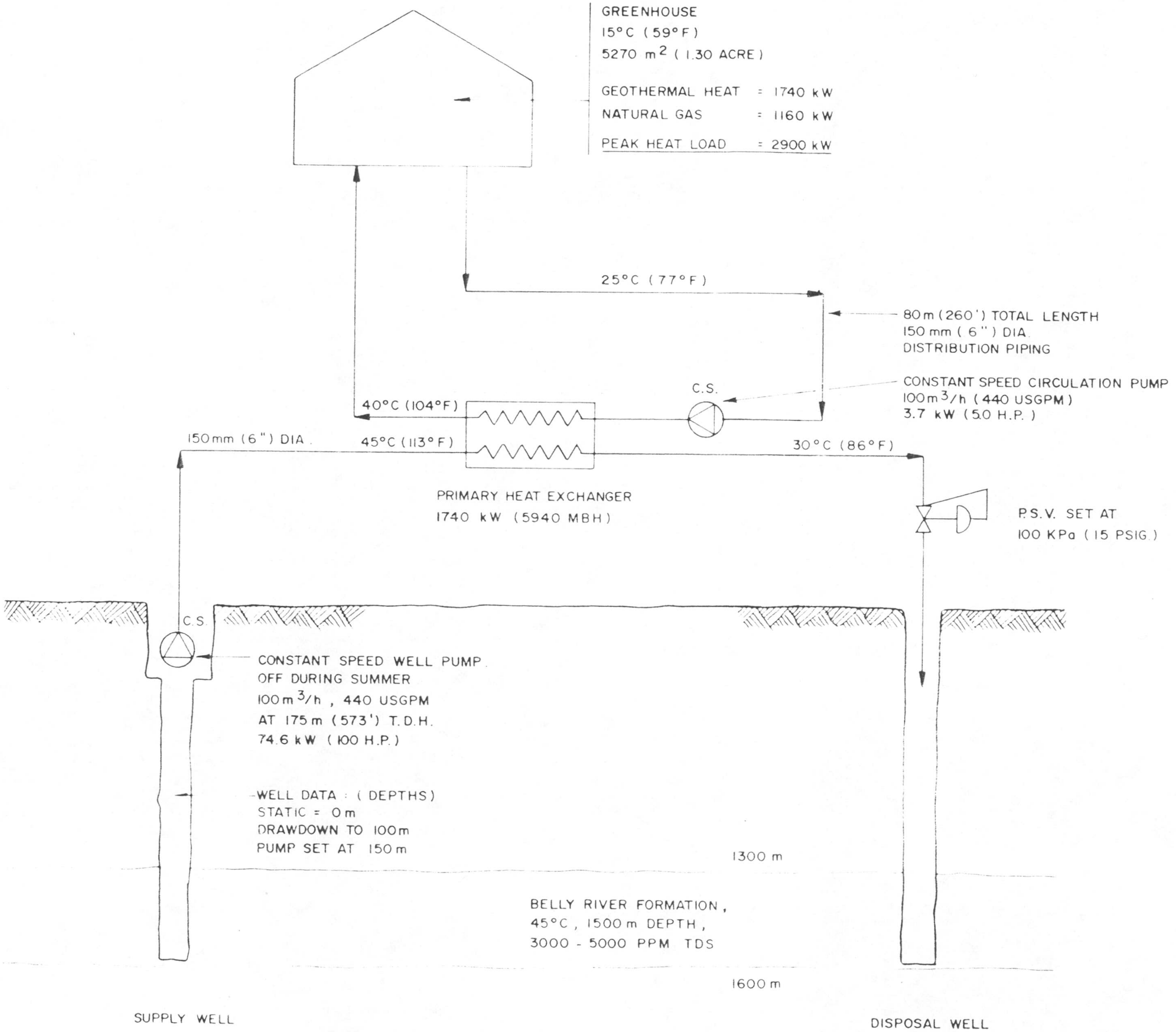
figure 14

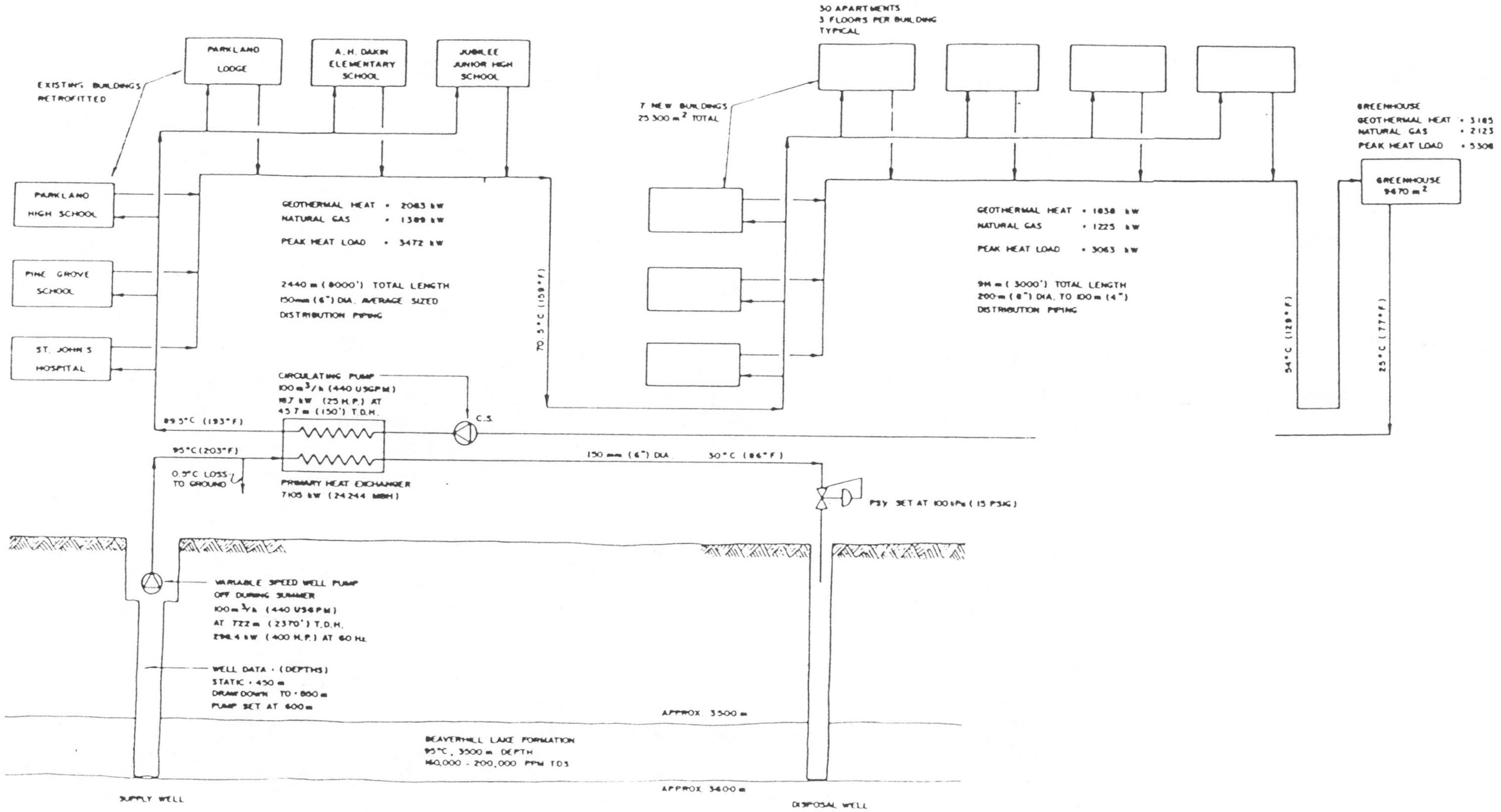


EDSON GEOTHERMAL
FEASIBILITY STUDY

MODEL 2
LOW TEMPERATURE
GREENHOUSE HEATING

UMA Engineering Ltd.

figure 15

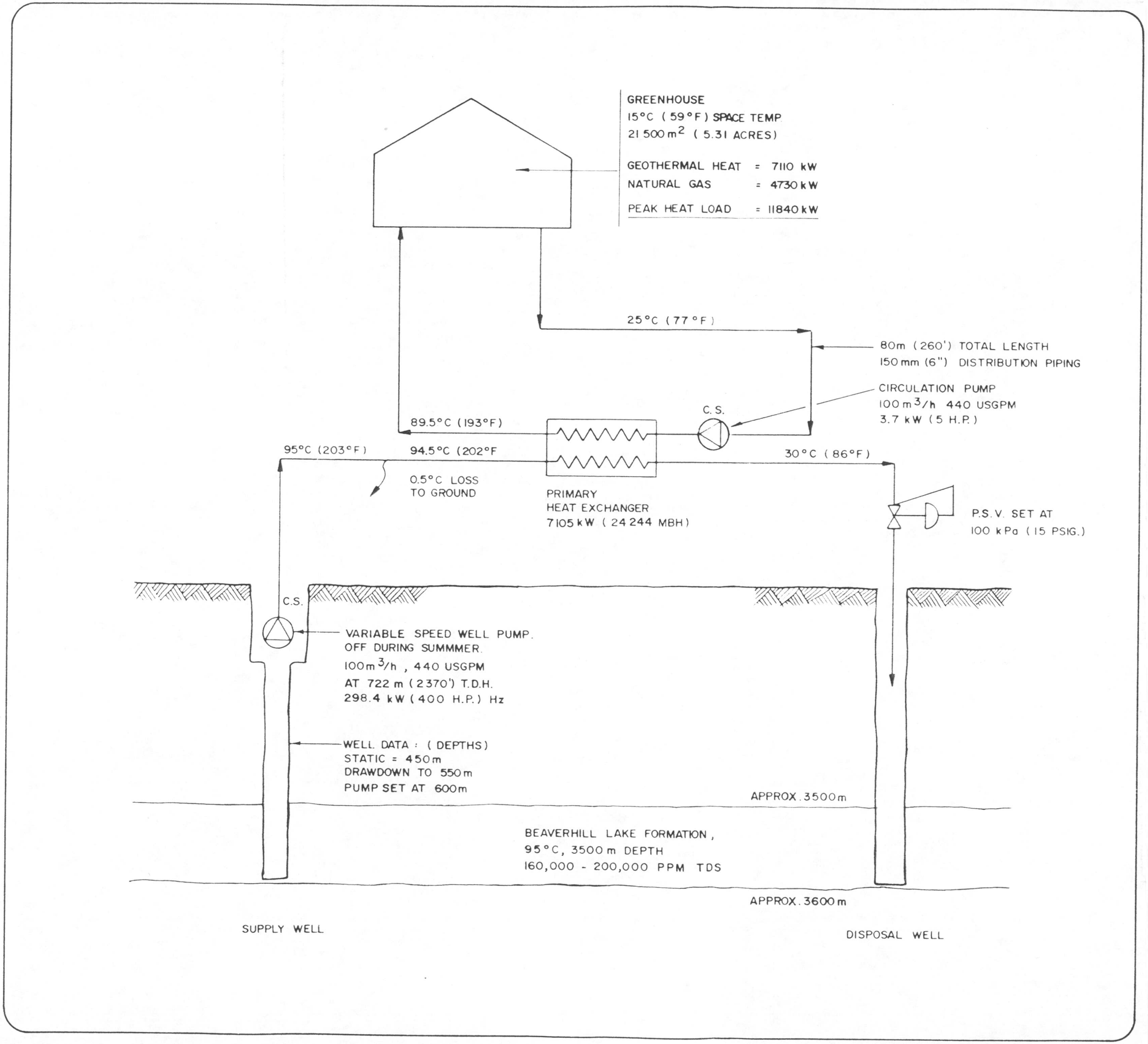


EDSON GEOTHERMAL
FEASIBILITY STUDY

MODEL 3
HIGH TEMPERATURE
EXISTING BUILDINGS
NEW BUILDINGS & GREENHOUSE

UMA Engineering Ltd.

figure 16



EDSON GEOTHERMAL
FEASIBILITY STUDY

MODEL 4
HIGH TEMPERATURE
GREENHOUSE HEATING

uma
UMA Engineering Ltd.

figure 17

APPENDIX E

GEOTHERMAL DISTRICT HEATING PROJECT SUMMARIES

TABLE 1 FROM PAPER BY PAUL J. LINEAU
ENTITLED "GEOTHERMAL DISTRICT HEATING PROJECTS"
FOR DISTRICT HEATING MAGAZINE, JUNE 1984
(UMA REF. NO. 18)

TABLE 1

Geothermal District Heating Project Summaries

District Heating System	Well Depth (feet)	Fluid Temperature (°F)	Flow Rate (gpm)	Peak Thermal Power (MW_t)	Start Up of Operations	Capital Costs (1982$) (thousands)	Annual O&M Costs (1982$) (thousands)	Annual Energy Delivered (10^9 Btu)	Payback Period (years)
Boise, ID	2,010	167-174	600 to 900		1983	7,128	51.7	80.6	10
	800								
	1,893		design capacity						
	1,102		4,000	29.3					
Capitol Mall	3,030	162	750	4.6	1982	1,850		34.5	7
	2,150								
Elko, NV	850	178	400	2.9	1982	1,126	21.6	21.5	9
		30Δt	design cap. 750						
Klamath Falls, OR	350	224	750	6.2	1984	2,801	9.0	51.0	14
	900	213							
Pagosa Springs, CO	275	148	900	3.8	1984	1,364	72.7	28.6	16
	300	131							
Philip, SD	4,266	157	340	1.6	1980	1,209	4.0	9.5	14
San Bernardino, CA	975	138	3,000	15.4	1983	2,750	125.0	127.6	7-10
Susanville, CA	935	170	718	3.2	1982	2,400	57.0	20.7	17
	500+	150	300						
Litchfield Prison	1,500	180	1,000	4.4	1983	2,172	30.0	60.0	9
	1,400	160	1,500 capability						

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