GEOLOGICAL SURVEY OF CANADA

OPEN FILE 2502

Geothermal feasibility study for the use of hot water near Riondel, British Columbia

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GEOTHERMAL FEASIBILITY STUDY FOR THE USE OF HOT WATER NEAR RIONDEL, B.C.

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Abstract

This study assesses the economic viability of using hot water from the old Riondel Mine for direct heating applications in Riondel. Since the water is supersaturated with carbon dioxide, there are technical problems with producing it as a continuous source of heat. This problem and possible solutions are examined in order to supply heat to three different loads. The heating of existing buildings by this source is found to be uneconomical, as is the heating of a new resort spa. The tourism value to the spa of the geothermal waters would have to justify the cost of the well and delivery system. Although the heating costs of a commercial green house and a fish hatchery were investigated, the market studies to decide on the overall economic feasibility of such operations were beyond the scope of the study.

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SUMMARY

Thermal water intersected in the lower workings of the now-abandoned Bluebell Mine is a potential source of geothermal energy. Slightly acidic thermal water charged with CO_2 gas was encountered within the Badshot Formation limestone during mining operations becoming overwhelming on the 9A level of the Kootenay Chief Zone.

The study assesses the potential to utilize thermal water for direct heating applications in Riondel community facilities and in new facilities including a resort spa, commercial greenhouse operation and fish hatchery. Thermal water would be pumped to surface from a well, cased to isolate the thermal water from cooler groundwater.

Production rates from the Main Thermal Zone in the vicinity of the lower Kootenay Chief mine workings of up to 150 litres/sec are achievable. Thermal water at 37.8°C could be produced by drilling a production well, inclined at 45°, from the Old Mill Site on the west shore of Riondel Peninsula at a cost of $312,000 or by completing a production well within the No. 1 Shaft at a cost of $266,000. These well costs represent the minimum amount of money required to demonstrate the viability of the resource.

Other viable well sites on Cominco property on Riondel Peninsula involve a degree of exploration risk because the thermal occurrences in the mine to the north of the Main Thermal Zone are not well documented. Potential well sites located adjacent to the Cominco property to the east of the mine would be technically difficult or impossible to drill because of the length of hole and shallow angle required in incompetent "footwall" rock.

Solutions are necessary to overcome problems anticipated with CO_2 gas exsolution and calcium carbonate precipitation from the thermal water which caused pumps to cavitate and discharge lines to plug during former mining operations. The standing water level under static conditions in the proposed production well is projected to be 82 metres below lake level, requiring the well to be pumped to bring the water to surface.

Pump cavitation can be eliminated by setting a submersible pump below the level at which the gas is held in solution by the water column in the well. During mining, such a water column could not be maintained because the mine had to be kept open down to 8-level. CO_2 gas may partially exsolve in the well bore and it can be separated at the well head.

It is proposed that calcium carbonate scale be controlled by introducing organic polymer antiscalants by means of stainless steel tubing from surface to the well casing below the pump intake. Successful control procedures for calcium carbonate scale must be developed by further pilot testing.

Thermal water delivery costs including production well, well pump, scale treatment, CO_2 removal, piping to local application site and disposal are estimated to be $365,000 for Site A (Old Mill Site) and $326,200 for Site B (Bluebell Mill Site). These sites are both suitable for resort spa and fish hatchery installations. Site B would also be suitable for a greenhouse complex. To service existing community buildings including the Recreation centre and Community Centres, a $100,000 pipeline system would be required.

An evaluation of the existing community buildings including the Community Centre, Recreation Centre, Galena Bay Restaurant, Bluebell Manor senior citizen's home, general store and individual residences indicates the energy savings utilizing geothermal heating do not justify the pipeline installation costs or heating system conversion costs at each building.

Riondel thermal water energy applications in a resort spa, greenhouse complex, and fish hatchery were analyzed. In each case, it is probable that an initial development of any one of the potential applications would have to be economically justified on a stand alone basis. Thermal water requirements, capital costs, operating costs and energy savings for geothermal heating installations versus all electric installations are compared as follows:

COST SUMMARY FOR NEW APPLICATIONS (all 1991 dollars)

	Resort/Spa	Greenhouse (60% of heat demand)	Fish Hatchery
Thermal Water Delivery (Site B)			
Capital Cost	$ 326,000	$ 326,000	$ 326,000
Annual Pump Energy	20,000	17,400	30,000
Annual Operating Cost (Chemicals, Maintenance)	15,000	14,600	20,800
Site Costs			
Capital cost difference (geothermal over electric)	64,960	143,000	77,690
Annual Operating cost:			
Geothermal	18,650	14,622	13,050
Electric	34,800	132,280	386,120
Total Capital Cost Difference	390,960	469,000	403,690
Total Annual Operating Cost:			
Geothermal	53,650	46,622	63,850
Electric	34,800	132,280	386,120
Total Annual Energy Cost Savings	$ (18,850)	$ 85,658	$ 322,270

The resort spa comprised of 115 m^2 open air pool, whirlpool, resort centre, 50 seat restaurant and 20 unit hotel, has a net energy cost savings on site utilizing geothermal, however, with the additional delivery cost of the thermal water, it would incur a net loss. The cost for the well and delivery system must therefore be justified by the tourism market value derived from the use of the thermal water in the spa.

The heating cost savings for a 4,000 m^2 commercial greenhouse or a fish hatchery/spawning facility with 6,000,000 eggs annual capacity are significant for geothermal versus electric heating comparing identical facilities. Market studies for each business and cash flow projections from commercial operations are beyond the scope of the current study.

One hundred percent of the capital and operating costs for thermal water supply has been applied to each individual application. If the well costs were applied between more than one application or user, the overall cost savings for heating would increase dramatically. This would require sharing the resource (eg. greenhouse using spent water from spa) and co-operation amongst a small number of developers with one business partially dependent upon the success of the other.

1.0 INTRODUCTION

1.1 Terms of Reference

Thermal water intersected by Cominco Mining and Smelting Company in the lower working levels of the Bluebell Mine is a potential source of geothermal energy. The mine, located on the east shore of Kootenay Lake at Riondel BC was closed in 1971 and is now flooded.

The Geological Survey of Canada contracted Fairbank Engineering Ltd. to conduct an engineering study to determine the production potential of the thermal waters, methods and costs of heat production, uses for geothermal energy at Riondel, associated economics and benefits, and other potential locations of similar geothermal resources in the area.

Fairbank Engineering Ltd. was assisted in the study by subconsultants Concept Engineering Limited for heating systems engineering and Fairbank Architects for development of design criteria using local experience.

1.2 Sources of Information, Acknowledgements

Information and data crucial to the work was obtained through numerous sources. Dr. Trevor Lewis of the Pacific Geoscience Centre identified the requirements for the work and, in his capacity as the scientific authority, helpfully guided the study through to completion.

Cominco Exploration in Vancouver made available their complete file on the Bluebell Mine which contributed invaluable information on the mine workings, local geology and thermal fluids. In particular, the freely given assistance of Grant Gibson, Tenure Manager, and Fred Collisson was helpful and much appreciated.

A site examination of Riondel and the surrounding region was made during March 1-2, 1991 to compile a building inventory, inspect potential development sites and assess local conditions. The Regional District of Central Kootenay at Nelson, BC provided maps, land ownership and planning information. We are indebted to Colin Turner, Chairman of the Riondel

Commission of Management, and Stuart Bennett of Cominco for assistance on site and for providing access to various facilities in Riondel. Ray Nelson, P.Eng. and Frank Shannon, retired Bluebell Mine Manager and Chief Geologist, respectively, provided personal insights regarding the configuration of underground workings and the problems associated with handling the thermal fluid, based on their first hand practical experience.

In addition, the Geological Survey of Canada, the British Columbia Ministry of Mines and Petroleum Resources, the Ministry of Crown Lands, the Ministry of the Environment, the Ministry of Tourism and the Ministry of Agriculture and Fisheries were contacted for information and regulations pertaining to utilization of thermal water at Riondel.

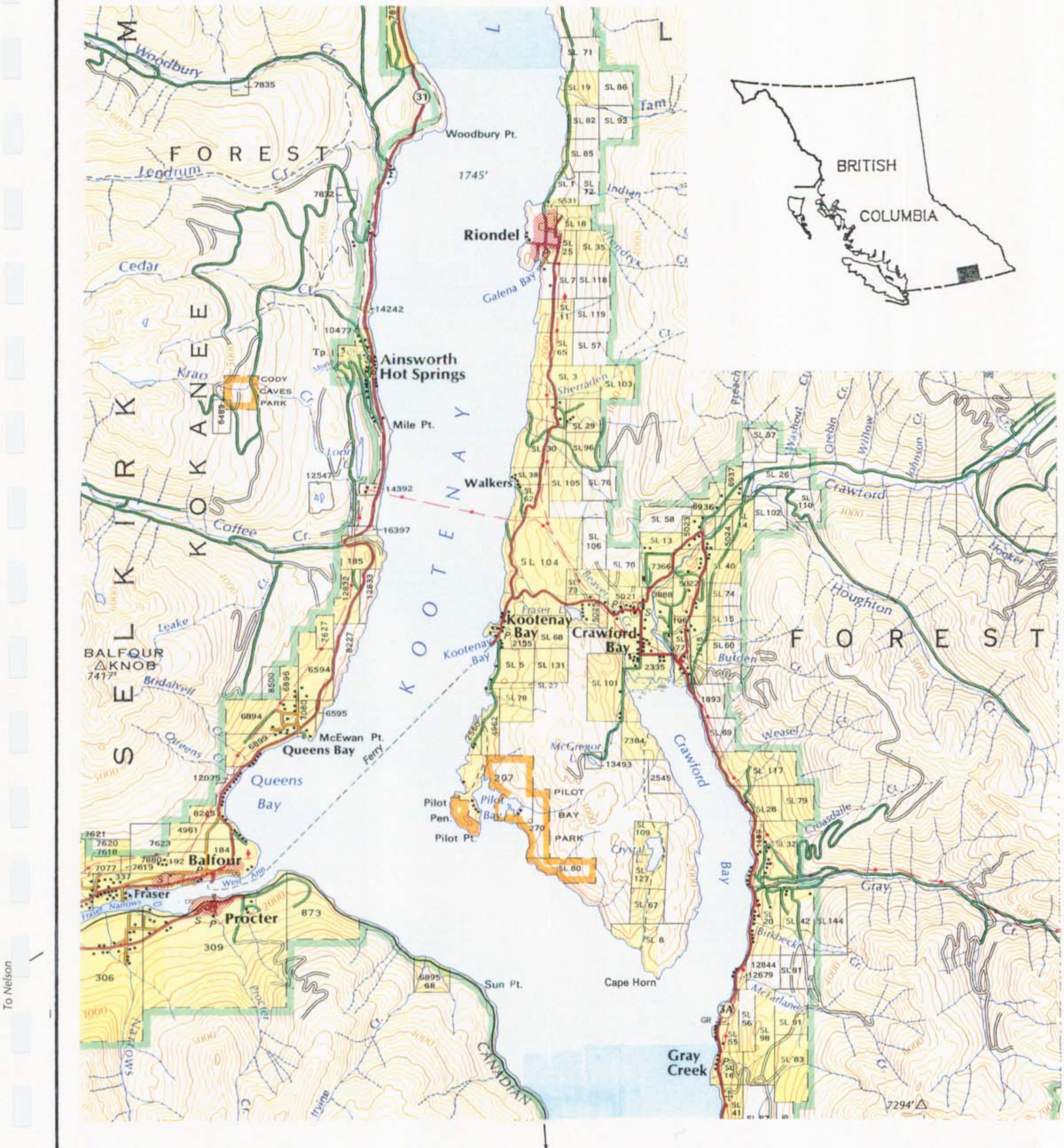
1.3 Community Background

Riondel is an unincorporated village located on the Riondel Peninsula along the east shore of Kootenay Lake in southern British Columbia (Figure 1). It is the former site of the Bluebell Lead-Zinc Mine discovered in 1895 and most recently operated by Cominco from 1952 - 1971. Since the mine closed, the economy of Riondel has been based on tourism and retirement recreation. The community has a population of 310 persons, 60% of whom are retirees greater than sixty years of age (1986 census).

Access is via a paved highway to Riondel from Kootenay Bay. From Kootenay Bay, Highway 3A south leads to Creston and west via the Kootenay Lake Ferry to Balfour and Nelson. The road north of Riondel is not a through route.

The main village is located in the open low saddle forming the isthmus of the peninsula. Most of the housing stock and community facilities were built in the 50's and 60's during the life of the mine. Approximately 160 single family, individually owned residences on private lots, a senior citizens villa, community centre, curling club, medical clinic, parks, three churches, a restaurant and general store form the core of the village (Figure 2). Other recreational facilities include a marina, park and campground at North Bay and a golf course on the south side of town.

Figure 3, showing the land ownership, was produced following a detailed

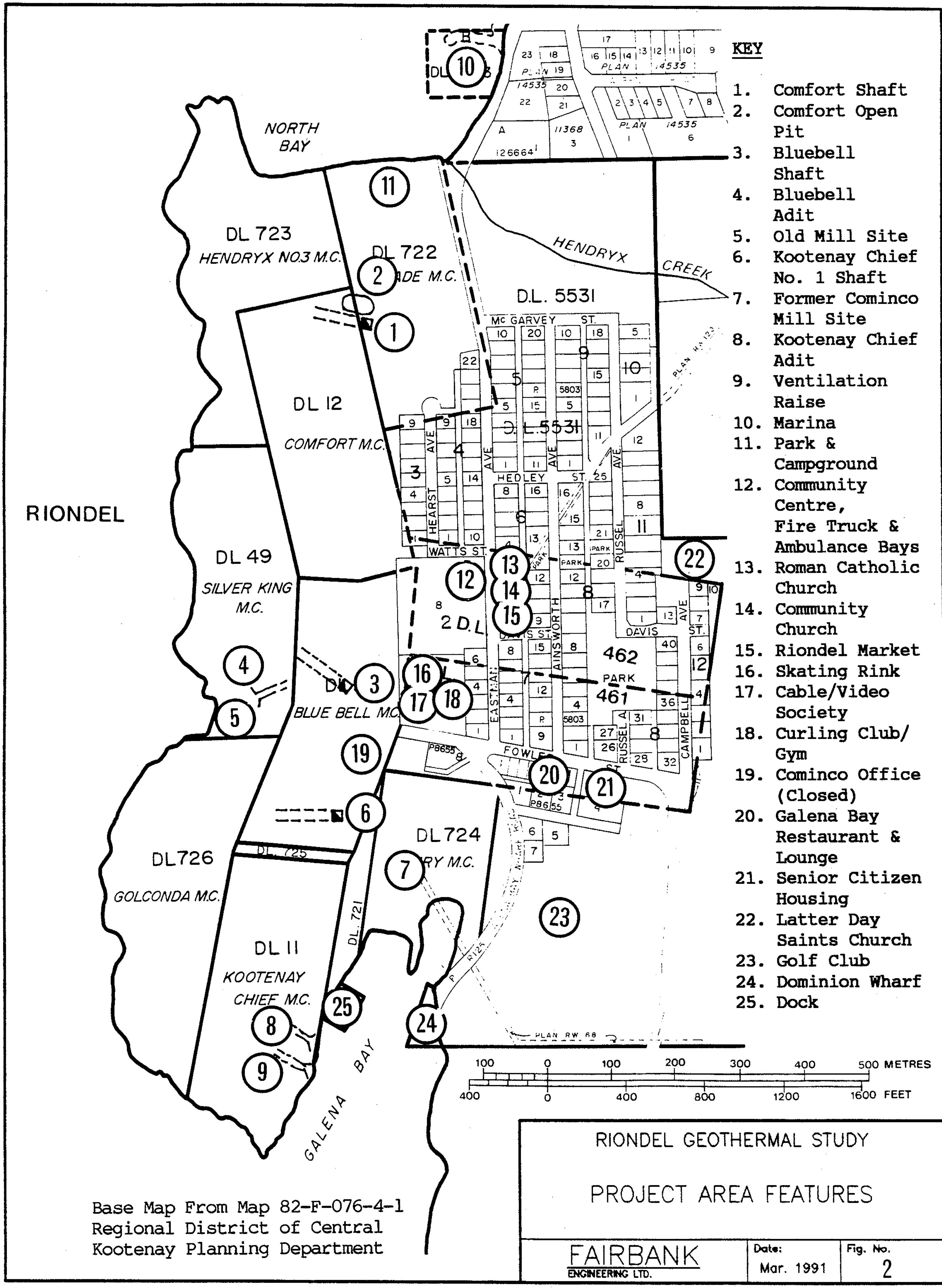


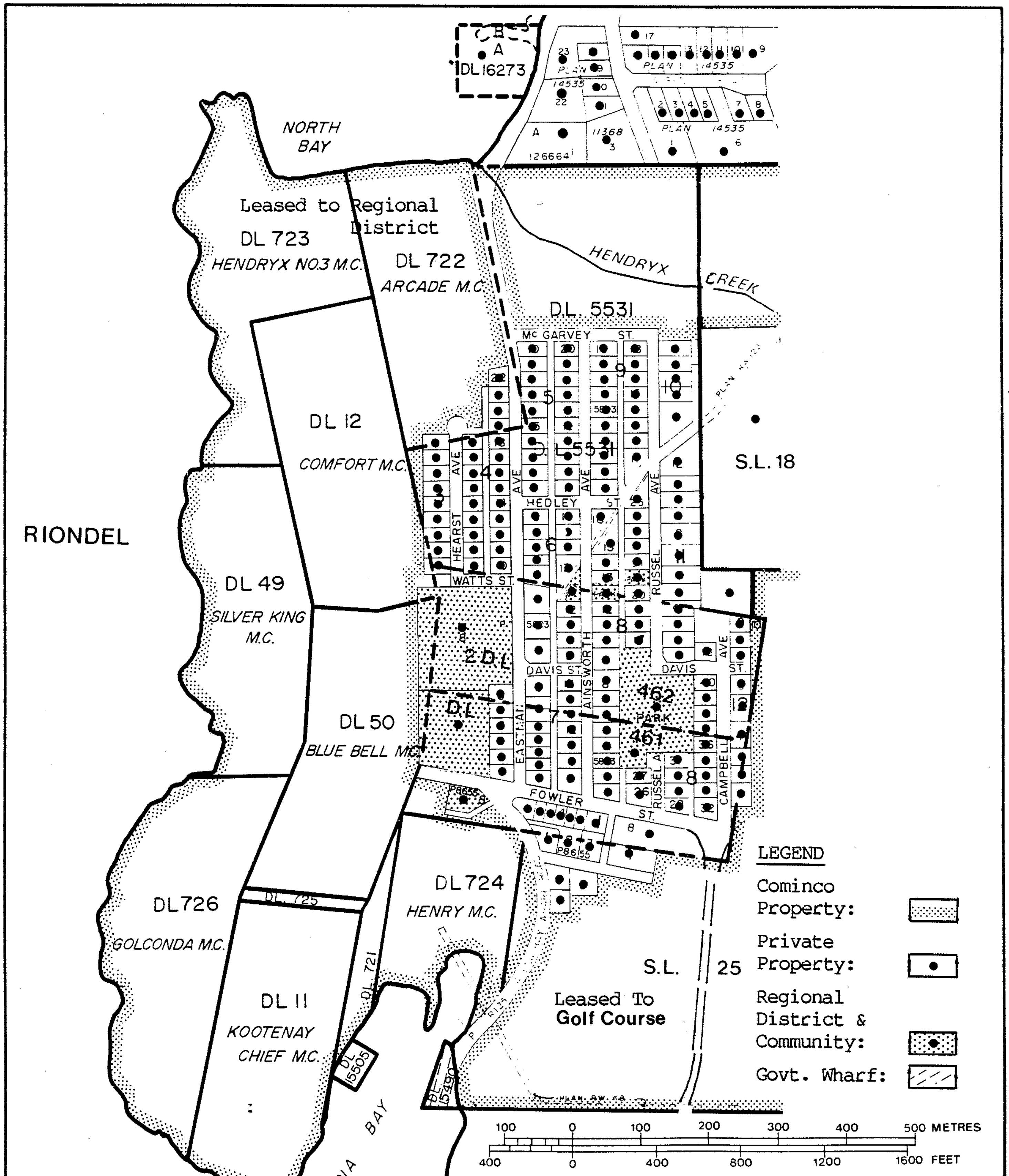
Base Map From Map 82F/NE 2nd Status Edition
B.C. Department of Lands, Forests and Water
Resources, Surveys and Mapping Branch, 1973

Scale of Kilometres

0 2 4 6

RIONDEL GEOTHERMAL STUDY		
LOCATION MAP		
FAIRBANK ENGINEERING LTD.	Date: Mar. 1991	Fig. No. 1


KEY
1. Comfort Shaft
2. Comfort Open Pit
3. Bluebell Shaft
4. Bluebell Adit
5. Old Mill Site
6. Kootenay Chief No. 1 Shaft
7. Former Cominco Mill Site
8. Kootenay Chief Adit
9. Ventilation Raise
10. Marina
11. Park & Campground
12. Community Centre, Fire Truck & Ambulance Bays
13. Roman Catholic Church
14. Community Church
15. Riondel Market
16. Skating Rink
17. Cable/Video Society
18. Curling Club/ Gym
19. Cominco Office (Closed)
20. Galena Bay Restaurant & Lounge
21. Senior Citizen Housing
22. Latter Day Saints Church
23. Golf Club
24. Dominion Wharf
25. Dock
RIONDEL
NORTH BAY
DL 723
HENDRYX NO.3 M.C.
DL 722
DL 12
COMFORT M.C.
DL 49
SILVER KING M.C.
BLUE BELL M.C.
DL726
GOLCONDA M.C.
DL 725
DL 11
KOOTENAY CHIEF M.C.
DL 721
DL 724
D.L. 5531
HENDRYX CREEK
MC GARVEY ST.
HEDLEY ST.
WATTS ST.
DAVIS ST.
FOWLER ST.
HEARST AVE
EASTMAN AVE
AINSWORTH AVE
RUSSEL AVE
CAMPBELL AVE
PARK
462
461
GALENA BAY
100 0 100 200 300 400 500 METRES
400 0 400 800 1200 1600 FEET
Base Map From Map 82-F-076-4-1
Regional District of Central
Kootenay Planning Department
RIONDEL GEOTHERMAL STUDY
PROJECT AREA FEATURES
FAIRBANK ENGINEERING LTD.
Date: Mar. 1991
Fig. No. 2



RIONDEL GEOTHERMAL STUDY

LAND OWNERSHIP

FAIRBANK ENGINEERING LTD.

Date: Mar. 1991

Fig. No. 3

review of the property plans and tax rolls obtained from the BC Assessment Authority. Cominco is the largest land owner through its holdings of crown granted mineral claims which include surface rights to almost all of the Riondel Peninsula. Cominco's Crown granted claims conferring rights to both minerals and surface do not extend beyond those shown on Figure 3. The small lots are mostly individually owned. To the north and south of Riondel, most of the surveyed lots along the road and shoreline are privately owned.

Cominco sold the community centre, curling club, medical clinic and certain parks, street lighting system, water supply system, fire fighting equipment and ambulance equipment to the Regional District of Central Kootenay in 1972 for a nominal sum. These facilities are administered by the Riondel Commission of Management appointed by the Board of the Regional District.

Tourism and recreation in the region is oriented around Kootenay Lake and outdoor activity (refer to Figure 1). Integrated marina facilities are located at Balfour and at Woodbury Creek across the lake from Riondel. Golf courses, resorts and summer cottages are located at Balfour and Crawford Bay. Ainsworth Hot Springs is a popular day excursion regional resort.

The community expressed an interest in studying the potential to use thermal mine waters at a public meeting organized by Dr. Trevor Lewis of the Geological Survey of Canada, held on October 21, 1990. New industry, capable of coexisting with the existing recreational values, would expand the local economy and allow the community to maintain and increase the amenities available to its citizens.

1.4 Thermal Water Experience at Bluebell Mine

The Bluebell Mine produced 274,000 tons of zinc, 258,000 tons of lead, 2,150 tons of copper and 7,130,000 ounces of silver from 5.3 million tons of ore before closing in 1971 (Hoy, 1980). Ore was mined from three main tabular replacement zones within the Badshot Limestone striking north-south along the Riondel Peninsula and dipping 35 degrees west under Kootenay Lake.

The southern most zone, called the Kootenay Chief Ore Zone, was the largest producer and was developed deeper than any of the other ore zones. In August

1956, the deepening of the No.1 Shaft at the Kootenay Chief (#6 on Figure 2) inclined at -35 degrees, encountered a 90 litres/sec (1,200 g.p.m.) flow of 21°C (70°F) warm water at 1650 kPa (240 psi) in a channel 15 metres below the 8-level at elevation 292 metres or 260 metres below ground (Bloomer PT., 1958). All attempts over an eighteen month period at grouting ahead of the shaft failed because of mud adhering to the walls of cavities and the percolating effect of CO_2 gas in the thermal water on liquid grout. Pumping proved futile and the thermal flow was blocked off by installing a concrete plug in the shaft 8 metres below 8-level.

A vertical shaft was sunk from 8-level into footwall argillites to the 9A level (elevation 212 m) in an attempt to get below the Main Thermal Zone and drain it. Upon completing the shaft to the 9A level, a crosscut was constructed westward to the ore limestone and three horizontal exploratory holes were drilled from the face. Heavy thermal water was present over the explored strike length of 120 metres, extending throughout the entire thickness of the limestone unit and out into both the hanging wall and footwall rocks.

Interestingly, the flat hole drilled west penetrated lake bottom sediments 190 metres horizontally from the mine workings. Results show that Kootenay Lake occupies a deep, steep-sided valley infilled with a thick layer of mud forming the lake bottom. The valley wall is steeper than the dip of the Badshot limestone which is probably truncated by the erosion surface at greater depths.

The extent of thermal activity and the temperature increased significantly between the 8- and 9A-level. Based on the much more widespread thermal activity on the 9A-level, it was anticipated that the various zones encountered on the 8-level would be much stronger at depth and that several of the zones coalesced into one large zone (Donald, J.B., 1963). Estimates of thermal flows to be pumped from level 9A in the Kootenay Chief ore zone ranged up to 1000 litres/sec (13,500 g.p.m.) and possibly much higher.

The 9A level was abandoned in September 1963 with 150 metres (500 ft) of tunnel development having been accomplished. Abandonment entailed closing the 9A-level door to impede influx of hot water while exploration was completed on 8-level. 8-level was put through the north to connect the three main ore zones along the length of the peninsula, and mining continued to late 1971.

High volumes of thermal water and dissolved CO_2 gas had to be pumped from the mine during operations. Rapid precipitation of $CaMgCO_3$ caused scale build up on discharge lines and CO_2 gas caused pumping problems so that the gas had to be released into underground sumps and vented (Nelson, 1991 pers comm). Scaling problems led to the installation of four 12-inch diameter discharge lines from the mine. Methods used to inhibit scale build up included a mechanical reamer, hydrochloric acid treatment and sodium tripolyphosphate treatment (best). In an attempt to seal the thermal flow, 110,000 bags of cement were pumped into the thermal conduits at high pressures in a massive grouting program with only limited affect.

The mine was closed in early 1972. A Cominco study, conducted prior to allowing the mine to flood, was done to determine the feasibility of isolating hot water inflows on 8 level and leading them to surface. Flows of 190 litres/sec (2,500 g.p.m.) at 32°C (90°F), with static head in the thermal zones sufficient to drive water to 70 metres below lake surface at 533 metres (1,750 feet) elevation, were projected. Because of the substantial expenses associated with bulkhead construction, pumping installations and time delays, the proposal was not considered feasible (Bluebell Operation Shutdown Report, 1972).

The mine was allowed to flood during January through March 1972 (Bluebell Operations Shutdown Report, 1972). CO_2 gas pushed out ahead of the rising water filled the Comfort pit and overflowed into an adjacent low swamp. When the mine filled and static equilibrium was reached, CO_2 emission ceased.

The ore horizon crops out immediately west of the village running north-south the length of the peninsula. Mine buildings and structures have been removed and mine openings (Figure 2) have been protected by steel grates, doors or concrete bulkheads or by caving.

2.0 RESOURCE EVALUATION

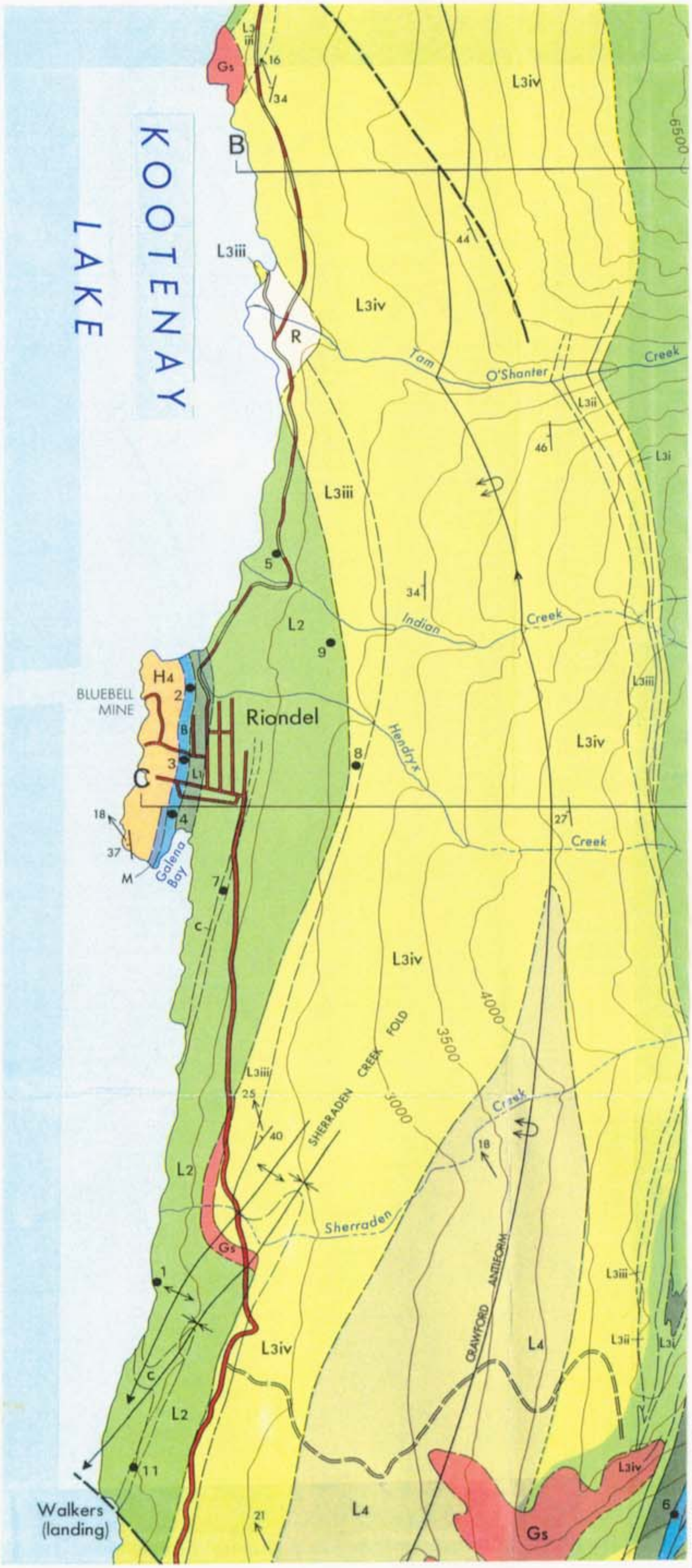
The regional geology has been described by Hoy (1980) in Bulletin #73, published by the B.C. Department of Energy, Mines and Petroleum Resources. Local geology of the Riondel Peninsula, Bluebell mine geology, and thermal occurrences, are detailed in Cominco internal memorandums, authored by B.E. Hurdle, J.B. MacDonald, N.M. Anderson, W.T. Irvine, D.S. Campbell, F.T. Shannon and P.T. Bloomer between 1958 and 1963 (see reference list). The data outlined in the following section was derived from these sources.

2.1 Regional Geology

Regional geology is shown on Figures 4 and 5, after mapping by Hoy (1980). Stratigraphy is described by Hoy as follows: "The youngest rocks within the map area, Unit L4, are exposed in the core of a fold , the Crawford Antiform, on the west slope of Bell Mountain. Hamill Group rocks are exposed in its west limb on Riondel Peninsula and in its east limb in the Bluebell Mountain area..."

"Rocks on Riondel Peninsula comprise a north-trending and west-dipping succession of Lower Cambrian quartzites, pelitic schists, calcareous schists, and marble. The succession is inverted; the older rocks of the Hamill Group outcrop along the western shoreline of Riondel Peninsula and overlie successively younger rocks of the Mohican Formation, the Badshot marble which hosts the sulphide mineralization, and schists of the Index Formation."

"The upper part of the Hamill Group (Unit H4) consists of at least 200 metres of fine-grained, dark grey biotite-quartz schist and quartzite. Pelitic micaceous schist layers comprise at least half the Upper Hamill succession on Riondel Peninsula, and thin white quartzite layers are common. Calcareous schist, pelitic schist, quartzite, and marble characterize the stratigraphically overlying Mohican Formation. On Riondel Peninsula the Mohican is represented by a basal limestone (the Upper Limestone) and overlying micaceous schist. The Badshot Formation is a 30 to 50-metre-thick white calcite marble. Accessory minerals include tremolite, phlogopite, and graphite. It is stratigraphically overlain by calcareous and pelitic schist and gneiss of the Index Formation (Unit L1). These rocks are the youngest



SCALE ~ KILOMETRES

0 1 2 3

CONTOUR INTERVAL 500 FEET

LEGEND

QUATERNARY

R	PLEISTOCENE AND RECENT ALLUVIAL DEPOSITS

JURASSIC–CRETACEOUS (?)

GRANITIC ROCKS

Gp	'POST–TECTONIC' QUARTZ MONZONITE
Gs	'SYNTECTONIC' QUARTZ MONZONITE, PEGMATITE; GS1: MIXED ZONE OF INTRUSIVE, PEGMATITE, AND METASEDIMENTS

MIDDLE CAMBRIAN

LARDEAU GROUP

L	UNDIFFERENTIATED

INDEX FORMATION

L_4	BIOTITE – QUARTZ – FELDSPAR ± GARNET GNEISS; MINOR AMPHIBOLITE
L_3	iv. CALC – SILICATE GNEISS WITH AMPHIBOLITE, SCHIST, AND MARBLE LAYER; MAY INCLUDE UNITS L3i, L3ii, AND L3iii iii. CALCITE MARBLE WITH CALC–SILICATE, AMPHIBOLE, AND SCHIST LAYERS ii. AMPHIBOLITE i. MICACEOUS QUARTZITE
L_2	HORNBLENDE GNEISS, AMPHIBOLITE: c = CALCITE MARBLE
L_1	BIOTITE – MUSCOVITE SCHIST AND GNEISS

LOWER CAMBRIAN

BADSHOT FORMATION

B	CALCITE MARBLE, DOLOMITE

MOHICAN FORMATION

M	CALCAREOUS SCHIST, QUARTZITE, MARBLE

HAMILL GROUP

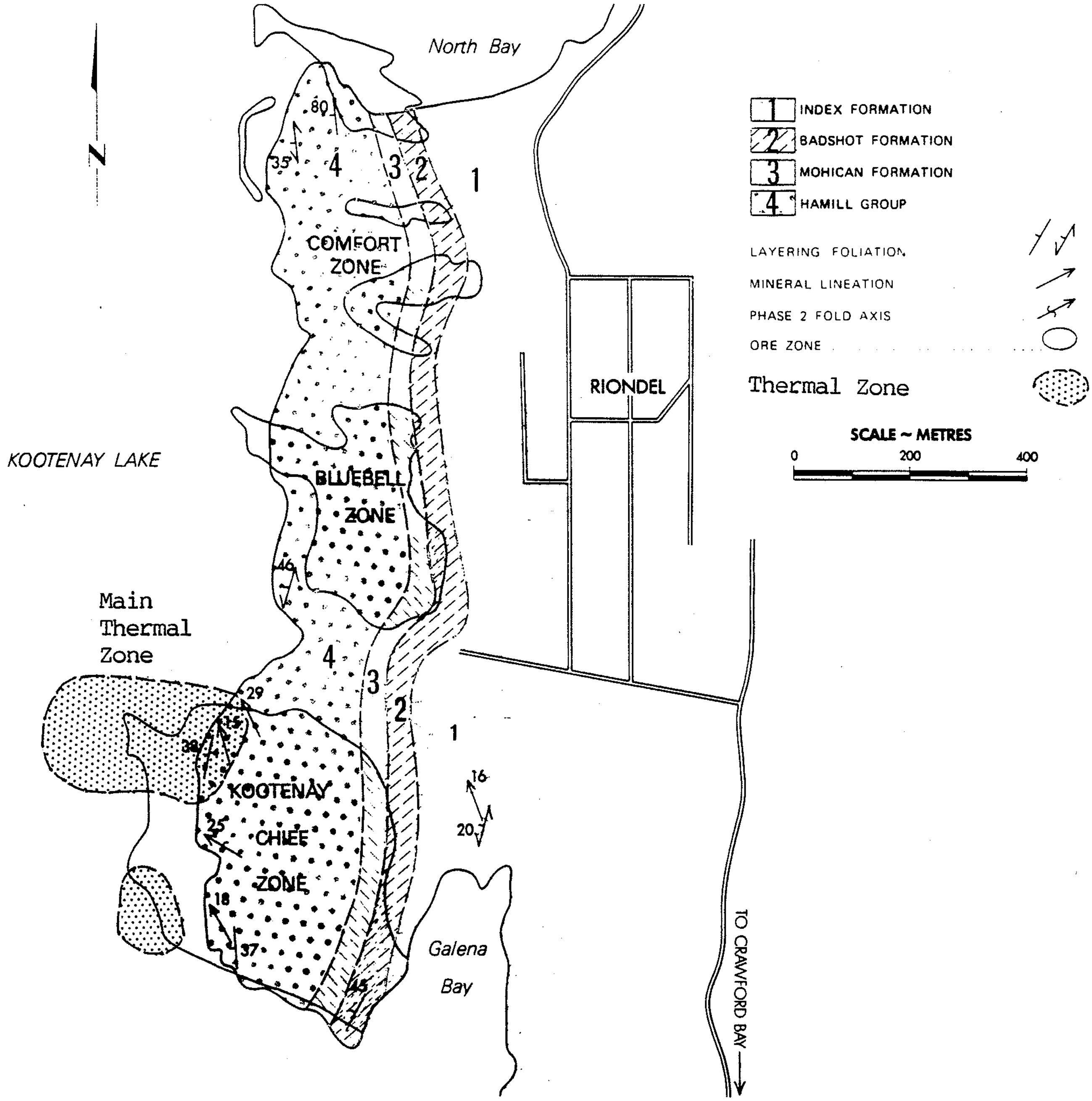
H	UNDIFFERENTIATED
H_4	DARK QUARTZITE, QUARTZ–RICH SCHIST
H_3	WHITE QUARTZITE: q = MASSIVE WHITE QUARTZITE WHICH MAY IN PART BE UNIT H3
H_2	MUSCOVITE–BIOTITE–CHLORITE SCHIST, QUARTZITE, SILTSTONE

After Hoy - 1980

RIONDEL GEOTHERMAL STUDY

REGIONAL GEOLOGY

FAIRBANK ENGINEERING LTD.	Date: Mar. 1991	Fig. No. 4



Modified After Hoy, 1980

RIONDEL GEOTHERMAL STUDY

GEOLOGY AND THERMAL ZONES
RIONDEL PENINSULA

FAIRBANK ENGINEERING LTD.	Date: Mar. 1991	Fig. No. 5

metasedimentary rocks on Riondel Peninsula, and comprise the footwall of the Badshot-hosted sulphide ore."

Granitic pegmatite dykes and sills are common throughout the mine area. The most noticeable is a laterally extensive pegmatite sill, 1 to 3 metres thick, that occurs in the top 10 metres of the Badshot Formation (Ransom, 1977). Lamprophyre dykes, a few centimetres to a metre in thickness, cut both the metasedimentary rocks and the pegmatites (Irvine, 1957). The dykes are porphyritic, containing phenocrysts of plagioclase (labradorite to andesine), olivine, pyroxene, hornblende, and biotite which have been largely replaced by calcite, epidote, chlorite, and magnetite (Ohmoto and Rye, 1970)."

2.2 Geology and Hydrogeology - Bluebell Mine

The Bluebell ore deposit is comprised of three main ore zones (Comfort, Bluebell and Kootenay Chief), with ore shoots spaced at intervals within the Badshot Formation limestone and separated by barren rock (Figure 5). Ore zones are localized at the intersection of limestone with steep cross fractures that trend northwestward and dip 85° north.

Hanging wall rocks are competent Mohican Formation quartzites while the footwall rocks are very broken, fractured and faulted argillites of the Index Formation. The sequence is overturned, strikes north-south and dips 35° west.

A major north trending fault extending the length of the mine is described in the footwall rocks immediately below the Badshot limestone. The fault is identified below 2-level at Comfort, cutting limestone on 5-level at Bluebell and below 8-level at the Kootenay Chief. Below the ore limestone in the Bluebell, the first 2.5 metres of footwall rock is hard, quartzitic, unaltered and competent. Immediately below this horizon is an 18-inch section of thick muddy gouge, and ground below the gouge (fault-zone) is always bad. In the area of the No.1 Shaft, the footwall is 1.8 metres of strong argillaceous quartzite followed by 9 metres of graphitic, broken, gougy, argillaceous schist, constituting very poor ground.

Acidic thermal water charged with CO_2 gas, was encountered in the Kootenay

Chief mine within the Badshot limestone of the Kootenay Chief Zone at the locations shown on Figure 5. At least five other thermal water flows occur to the north in the 1.6 km developed length of the mine, however, these are not well documented.

While sinking the No.1 Shaft at the Kootenay Chief Zone, a major 21°C (70°F) thermal water flow was intersected between 6 - 25 metres below 8-level which caused advance on the shaft to be halted. Using flow measurements at various pressures, the flow was calculated at 140 litres/sec (1,800 g.p.m.) at zero pressure at 8-level (Irving, 1958).

Upon reaching the 9A-level, thermal activity became much more widespread and estimates of water flow range from 450 litres/sec to 1,000 litres/sec (6,000 - 13,500 g.p.m.). On 8-level, thermal activity was confined to narrow, well defined areas, while on the 9A-level, the fracturing and thermal activity is widespread throughout the limestone and also extends into the footwall and hanging wall rocks. Grouting in three holes on 9A-level (over 20,000 bags) was extensive, however, grouting in one hole would have little effect on another and, in many cases, little effect on the zone grouted. Grouting of holes on 9A-level often gave grout returns on 8-level. Unrestricted flow on 9-level had no effect on flows at 8-level.

Higher in the mine, the Main Thermal Zone flowed 26 litres/sec (347 g.p.m.) on 3-level, 54 litres/sec (709 g.p.m.) on 5-level, 84 litres/sec (1,109 g.p.m.) on 6-level and 120 litres/sec (1,572 g.p.m.) on 8-level indicating a linear increase of flow with depth. No flows were encountered above 3-level.

The thermal water conduits generally follow the rake of fracture systems but in detail are apt to be irregular interconnected caverns. It is probable that the thermal waters ascended through broken and faulted footwall rock.

Table 1: Mine Level Elevations and Thermal Features

Mine Level	Elevation Above Sea Level	Thermal System Feature
No.1 Shaft Collar	552 m (1810 ft)	
	533 m (1750 ft)	Lake
2-level	475 m (1558 ft)	
	451 m (1480 ft)	Projected thermal water static level
3-level	429 m (1408 ft)	First thermal water intersections
5-level	383 m (1258 ft)	Top of South Thermal Zone
6-level	338 m (1108 ft)	
8-level	292 m (958 ft)	
No.1 Shaft Plug	286 m (938 ft)	
No.1 Shaft Bottom	277 m (908 ft)	
9A level	212 m (697 ft)	Widespread thermal water (Main Zone)
	286 m - 138 m (938 ft - 453 ft)	Thermal Target Zone

It is proposed by Irving (1858, 1962), and supported by the current study, that the thermal water migrates from great depths upward along open faults and fractures in the footwall rocks, and intersects the footwall fault and Badshot Limestone at some point below the mine workings. The acidic waters react with the limestone, creating mud-filled cavities, open channel ways along fracture intersections, and CO_2 gas. Drill holes across the downward projection of the No.1 Shaft indicated a series of open spaces in the limestone, varying from small cracks to cavities 5 metres across.

North and south of Riondel Peninsula, the trace of the Bluebell Formation hosting thermal fluids is west of the shore of the lake (Figure 4). The potential target zone is under water and inaccessible.

Evidence for the thermal water migrating upward through structures in the footwall is indirect, it is based on the premise that the water would be neutralized if it migrated long distances in the limestone.

2.3 Distribution of Resource

Controls on the localization of thermal water are lithology and structure. The known thermal flows are hosted within the westward dipping Badshot Formation limestone on Riondel Peninsula.

Based on the distribution of known thermal systems, host Badshot limestone and the footwall fault, the regional target area for developing geothermal water by drilling is everywhere west of the surface trace of the Badshot limestone as shown on Figure 5. The Main Thermal Zone is the best drilling target because thermal production is virtually assured. Elsewhere on the peninsula, geothermal targets are prospective and subject to exploration risk. The Badshot Formation dips 35° west and is approximately 40 metres (130 feet) thick.

The target depth for 35 - 40°C geothermal fluid production on Riondel Peninsula is at 200 m elevation, or 330 m below lake level, therefore the primary target zones are west of the shore of Kootenay Lake. Vertical drilling on the peninsula has only a limited chance for success.

The Badshot Formation is repeated in the east side of the Crawford Antiform (Figure 4) and can be traced southward to Crawford Bay. There is a spring reported in the vicinity of Crawford Creek (Souther, 1976), in the Crawford Bay area; however, it has a low temperature (31°C), low flow rate (0.2 litres/sec, 3 g.p.m.), and low mineral content (65 ppm total dissolved solids). The spring is not indicative of subterranean mineral water suitable for large scale development.

2.4 Thermal Fluid Characteristics

2.4.1 Temperature

Temperature of the thermal water flow into the bottom of the No. 1 shaft (elevation 277 m) is 21°C (70°F). Temperatures reported by Cominco from the 9A level (elevation 212 m) range from 23° - 40°C (75 - 104°F), showing an increase in temperature compared to higher levels. For the purpose of this study, it has been considered that 38°C (100°F) water will be produced from a well penetrating the 9A level (refer to Section 3.1).

2.4.2 Pressure

Warm water flows on 3-level at elevation 430 metres had a static water head of about 21 m. As the mine developed to lower levels, the thermal head pressure increased by an amount equivalent to standing water. Shut in pressure of water intersected in 9A level ranged from 2200 - 2700 kPa (320 - 400 psi). It is therefore anticipated that the system pressure is sufficient to drive the thermal water to elevation 451 metres or 82 metres below lake level.

The projected static level of the thermal system is from measured pressures in underground drill holes. The standing thermal water level in wells has never been observed because the mine water was constantly being pumped out. The thermal system appears, from reported mine measurement data, to be underpressured rather than being equivalent to local groundwater pressure. It is possible that recorded pressures are lower than actual system pressure due to lateral system leakage into the mine workings. Since a requirement for well pumping in future thermal water production systems is a potential problem, the system pressure is important; however, it can only be determined with certainty by drilling a test well. For the purposes of the current study, worst case conditions with the thermal water standing in the well at 80 m below lake level under static conditions will be assumed.

2.4.3 Water Chemistry

Only a few complete chemical analyses are in the record. Representative analyses are given below, with one sample from Ainsworth Hot Springs for comparison.

Table 2: Thermal Water Chemistry
Bluebell Mine (from Shannon)

	Kootenay Chief Area				**North Comfort Area**	**Ainsworth Hot Springs**
	525'Lev.	875'Lev.	925'Lev.	1,125'Lev.	Comfort 825'Lev.	
Temp	80°F	70°F	90°F	104°F	86°F	112°F
	Analyses in parts per million					
TDS	3,300	2,500	4,700	3,340	3,870	800
SiO_2	110	60			175	140
Ca	430	410				
SO_4	280	190			214	55
Mg	280	160			190	7.5
Cl	80	50	106	178	70	45
B	.1	0.3				
F	2.0	1.6				
Al_2O_3	7	6				
Cu	.1	< .1			< .01	< .01
Pb	<2	<2			< .1	< .1
Zn	2	14			.02	.01
P_2O_5	5	5				
Fe	<1	<1			2.1	0.8
Na	440	290			440	215
Mn					< .05	< .05
Sr					5	1.2
K					60	20
pH			7.2	7.4		

Bluebell thermal water is slightly acidic. The ascending acidic water reacts with and dissolves the limestone host forming cavities and CO_2 gas. When pressure is released, CO_2 gas dissolves from the thermal water causing safety hazards and pumping problems. The water has a strong tendency to precipitate calcium carbonate deposits on discharge pipes and pump equipment which, during mining operations, was partially controlled using a sodium tripolyphosphate inhibitor.

In comparing the Ainsworth Hot Springs analysis with the Comfort 825' Level analysis, immediately to the left of Ainsworth analysis in Table 2, J.F. Harris, Cominco senior research geologist, stated: "Notable features are the very low concentrations of heavy metals. The most striking differences between the samples are in the contents of the alkalis, alkaline earths, and the combined anions, notably Mg, Na, K, SO_4. The Bluebell water is considerably more saline than the Ainsworth sample, and the difference in compositional ratios such as Ca/Mg and SO_4/Cl_3 seem at first sight to argue against derivation by differing dilution from a common source" (Shannon, undated).

2.5 Configuration and Condition of the Mine Workings

Extensive workings including shafts, ventilation raises, drifts, and stopes occur in the plane of the Badshot Formation at each of the three mineralized zones. Stopes follow ore shoots raking in the limestone unit on a trend line of 300°.

The mine is developed on 6 main levels running generally north-south at 45 metres (150 ft) vertical separation with the deepest working level being 8-level at 292 metres (958 feet) elevation or 240 metres (790 feet) below lake level. A vertical shaft was put down from 8 level a further 80 metres (261 feet) to the 9A level and a crosscut was completed west to the ore host limestone.

The Comfort, Bluebell and Kootenay Chief Zones are separated by 180 - 360 metres (600 - 1200 feet) of barren, relatively competent rock. All of the zones are connected by drifts on the 2-, 3-, 5- and 8-level and the No.1 Shaft at the Kootenay Chief was used as the main vertical access route. Shafts at the Comfort and Bluebell Zones provided secondary access.

To control thermal water flowing into the bottom of the Kootenay Chief mine, water doors, bulkheads and pumping stations were installed. Two bulkheads isolate parts of the thermal system and thus are important to this study. Upon abandonment of the 9A-level, a water control door in the crosscut leading to the thermal zone was shut, isolating the thermal zone on the 9A-level behind the door. A bulkhead was installed 6 metres below 8-level in the No.1 Shaft to isolate the high volume thermal flow encountered in the bottom of the shaft. The concrete bulkhead was 2.5 metres (8 feet) thick and contained two 60 cm (24 inch) diameter steel casings to accommodate two 60 HP Flygt submersible pumps. The pumps were removed when operations ceased and one-inch thick steel covers bolted to the casing flanges.

According to the Bluebell Operations Shutdown Report (August, 1972), all shaft rails, guides and timber were left in place. It would be reasonable to expect that flooded mine water would protect the timber, as was found to be the case when the Bluebell Shaft was dewatered prior to Cominco production.

Any future requirement for dewatering the mine could be carried out simply by installing a submersible pump(s) on a dolly and lowering it into the No. 1 Shaft with the water table. Similarly, heat pump, heat exchange or well casing equipment could be lowered into the No.1 Shaft.

2.6 Energy Resource Base, Achievable Production Rates

From a Cominco internal report of May 21, 1963, by M.N. Anderson, mine superintendent, the encountered thermal water influx quantities and, hence, estimated de-watering pump rates are:

- from No.1 Shaft Thermal Zone, 197.87 litres/sec,
- expected thermal water flow at mine level 9A (212 metres elevation)

  196.9 litres/sec from "No.1 Shaft" Thermal Zone
  181.7 litres/sec from "Main" Thermal Zone
  378.6 litres/sec combined

Water Temperatures:

- 40°C (104°F) maximum temperature encountered (increasing with depth),
- calculation base for this study: 37.8°C (100°F).

Hydraulic Head Considerations:

- Thermal water first encountered 114 metres (375 feet) below top of No.1 Shaft (elevation 552 metres), at static head pressure of 21 metres.
- Calculated "zero thermal head" horizon, 552 - 114 + 21 = 459 metres, Average level of Kootenay Lake = 533 metres.
- Hence, "zero thermal head" horizon = 74 metres below lake level.
- Thermal heads measured at subsequent deeper mine working levels yielded similar "zero thermal head" horizon (ref. Cominco reports).

Available Energy Considerations:

- Conservatively, 150 litres/sec at 37.8°C (100°F) available from either the "Main" thermal zone or the "No.1 Shaft" thermal zone.
- Considering heat extraction from well water via heat exchangers or hydronic air coils, to a final temperature of 32.2°C (90°F), ie. 5.6°C (10°F) temperature differential: 3,500 kW minus pumping energy of approximately 250 HP x 0.75 = 190 kW,
- Net available energy = 3,500 - 190 = 3,300 kW (for each thermal zone).
- Additional heat extraction from 32.2°C "spent" thermal well water will further increase the available energy extraction potential (see Section 3.3.3, Heat Pumps). If all spent 32.2°C thermal water was to be used for space heating via heat pumps, the available energy potential would effectively be tripled, ie. approximately 10,000 kW per thermal zone.

3.0 HEAT EXTRACTION

3.1 Recommended Heat Extraction - Production Well with Fluid Disposal to Mine

A production well to isolate and bring the thermal fluid to surface for direct utilization and heat extraction, with the spent fluid to be returned to the mine workings, has been selected as the optimum heat production method. Compared to other methods considered (Section 3.3), the recommended scheme has the following advantages:

1. Extracts the maximum amount of heat possible.
2. Sustainable over a long period with no resource depletion or temperature degradation expected.
3. Least maintenance problems because equipment components are at or near the surface.
4. Solves environmental concerns associated with disposal of warm saline water.

The capital investment required to supply 30 litres/sec of 37.8°C thermal water to potential new development sites will be between $320,000 - $362,000. Operating costs, principally for pump energy and scale treatment are $39,500 per year (1991 dollars) at full production. Maintenance of the equipment would be required on a twice annual basis and would be budgeted at $7,500. These cost figures are further amplified in the following sections.

Table 3: Summary of Heat Extraction Cost For 30 Litres/Sec Thermal Water

		Capital Cost	Operating Cost
1.	Production Well:		
	Site A	$312,000	
	Site B	266,500	
2.	Well Pump	20,100	29,000
3.	Scale Treatment	6,500	10,500
4.	CO_2 Separation	12,400	
5.	Primary Heat Exchange	40,000	
6.	Distribution System:		
	Site A	14,000	
	Site B	20,500	
	Community Facilities (Incl. Booster Pump)	101,000	
Total For Development At Site A:		$365,000	$39,500
Total For Development At Site B:		326,000	39,500

Notes:

A. Site A or B are one or the other, not both.

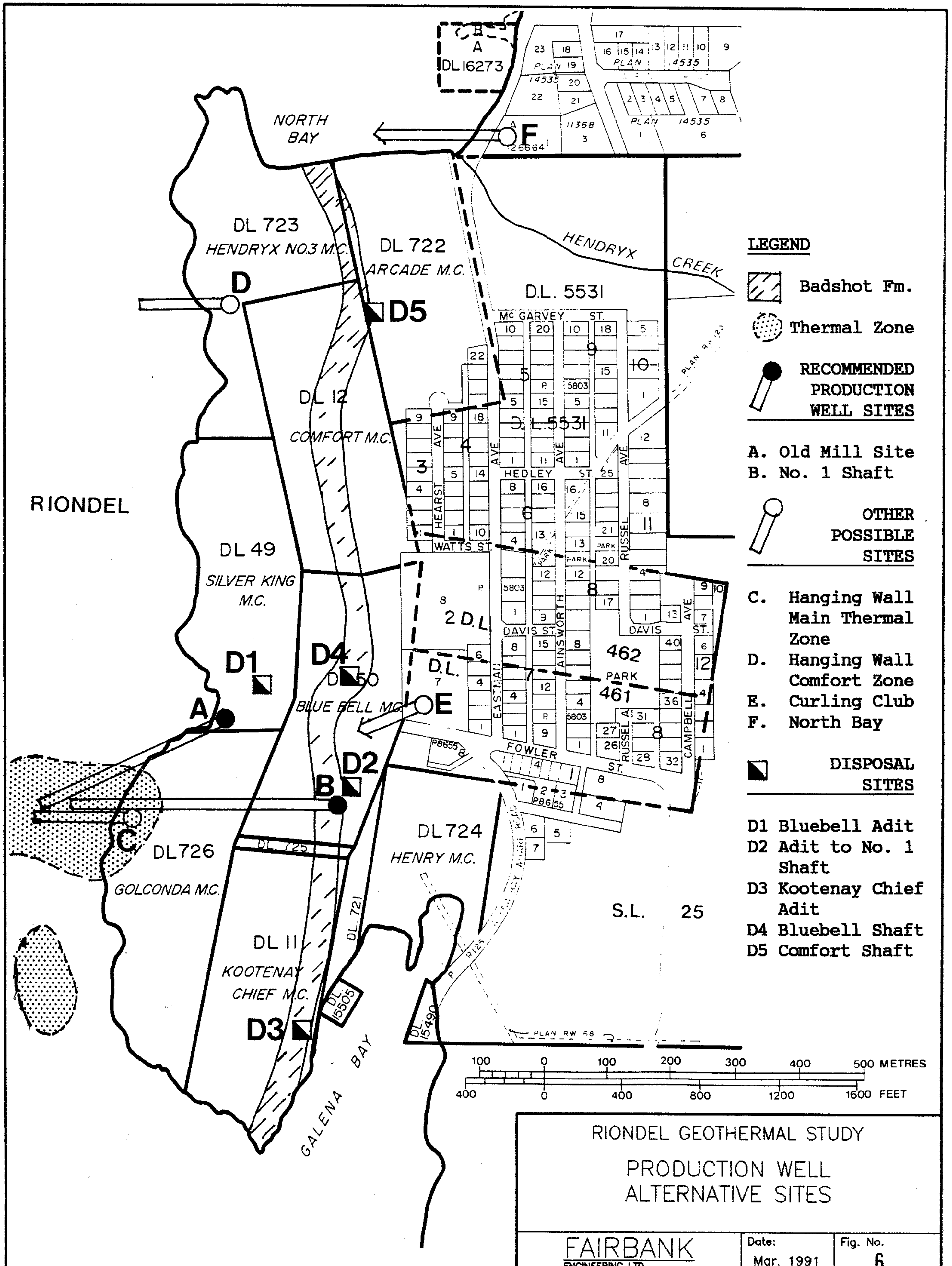
B. Primary heat exchanger used only if found necessary after pilot tests and not used in spa.

3.1.1 Main Thermal Zone Production Well Alternatives

The Main Thermal Zone is the primary target for the production of geothermal fluids because it has the least exploration risk associated with development.

Two production well alternatives are technically viable and have been costed as part of the study.

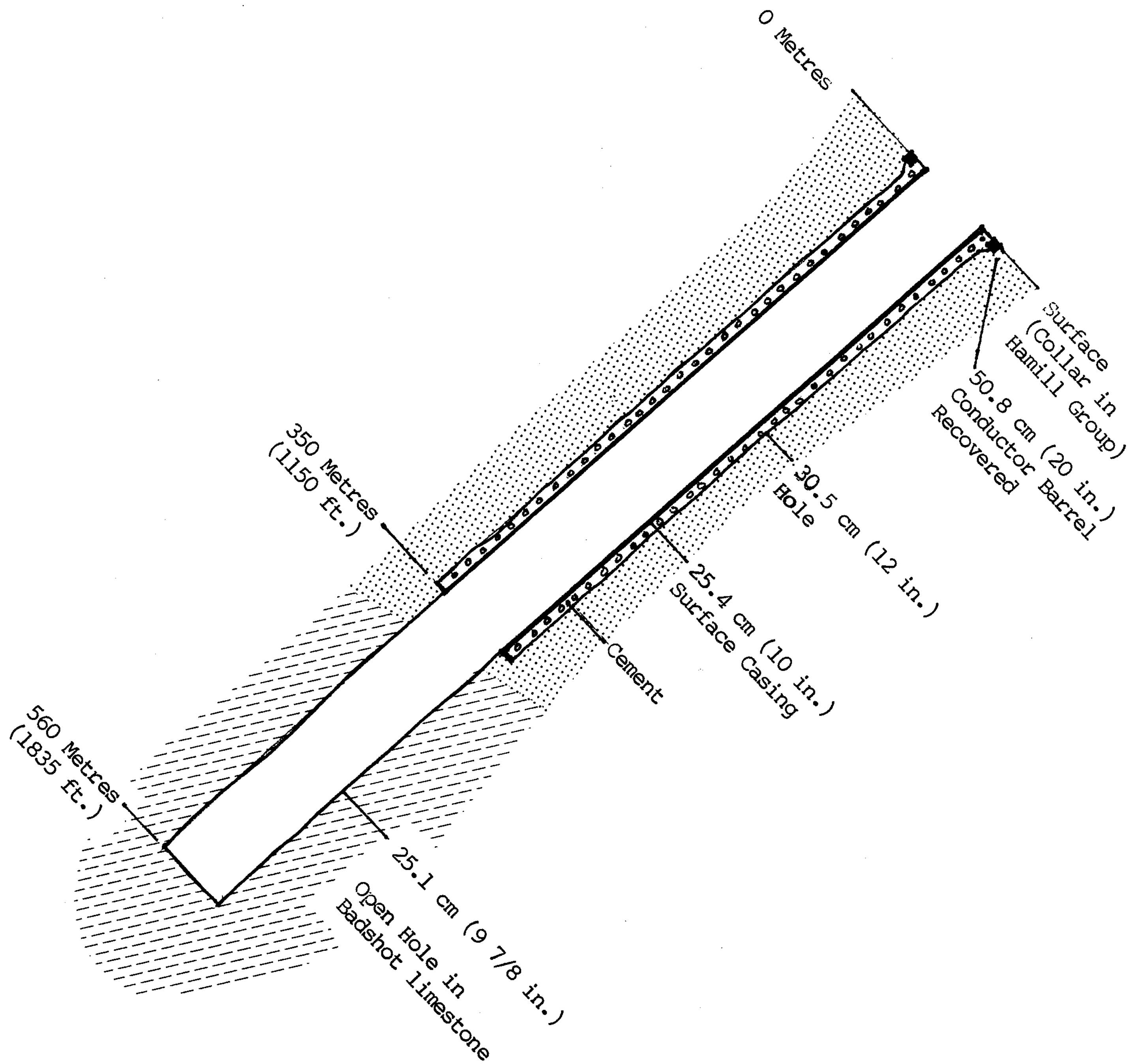
Alternative 1 is a new well drilled in bedrock from the Old Mill Site on the west shore of Riondel Peninsula (Site A, Figure 6). The site shown in Photos 3 and 4, Appendix A, is close to potential application sites (Section 4).



RIONDEL GEOTHERMAL STUDY

PRODUCTION WELL ALTERNATIVE SITES

FAIRBANK ENGINEERING LTD. | Date: Mar. 1991 | Fig. No. 6



RIONDEL GEOTHERMAL STUDY

PRODUCTION WELL PROFILE

FAIRBANK ENGINEERING LTD.	Date: Mar. 1991	Fig. No. 7

The well would be collared in competent hanging wall rocks and the thermal zone could be reached with little danger of accidentally drilling into mine openings. Pumping requirements and associated problems with calcium carbonate precipitation and gas would be minimized with the well head at as low an elevation as possible. Because the site is in an embayment in the bedrock surface, problems associated with drilling parallel to the steep rock face would be reduced with the increased distance allowed between the well bore and the bedrock surface (compared to Alternative Site C of Figure 6, for example).

A 45° slant hole drilled on an azimuth of 240° to a measured depth along the well bore of 560 metres (1,835 feet) (Figure 7), would successfully intersect the Main Thermal Zone in the immediate vicinity of the 9A level 25 cm (10 inch) surface casing is required to house the pump and should be cemented in a 30 cm (12 inch) hole, to a measured depth of 350 metres.

Alternative 2 is to install casing down the No. 1 shaft to directly access the Main Thermal Zone. Shaft timbers and guide rails are still in place in the shaft. 30 cm (12 inch) casing would be guided on dollys to meet the cement plug installed in the bottom of the shaft. A reamer and milling tool would be utilized to open a hole in the cement plug to 38 cm (15 inches). An additional 150 m of drilling would be done beyond the bottom of the No. 1 shaft to intersect higher temperature thermal water as required. Upon completion, casing would be pulled back to the level of the plug and cemented through the plug interval to isolate the production zone. The completed well length would be 620 m, with casing to 450 m or the level of the No. 1 shaft plug. The production interval would include the open shaft below the plug and 150 m of drill hole below the bottom of the shaft.

Although there are cost advantages associated with not having to drill the upper portion of the production well, this scheme has the disadvantage of having to lift the thermal fluid an extra 30 metres above lake level by pumping to bring the thermal water to surface.

A cost estimate for alternative production wells is given in Table 4 below:

Table 4: Production Well Cost Estimates

		(1) 560 Metre Well @ 45°C 25 cm Surface Casing to 350 m	(2) 620 m Well in No. 1 Shaft 30 cm Surface Casing to 450 m
Intangible:			
1.	Location Prep.	$ 10,000	$ 15,000
2.	Mob/Demob	8,400	8,400
3.	Contractor	(32 days) 134,400	(22 days) 92,400
4.	Fuel and Fluids	16,400	9,400
5.	Bits, Tools	13,500	9,000
6.	Supplies & Misc.	7,500	12,500
7.	Cement & Services	12,600	8,500
8.	Directional Tools & Service	15,000	5,000
9.	Completion Tests	5,000	5,000
10.	Supervision	16,000	11,000
11.	Engineering	32,000	26,000
Tangibles:			
12.	Well Casing	28,700	51,800
13.	Well Head	12,500	12,500
		$ 312,000	$ 266,500

3.1.2 Other Well Site Alternatives

Other well site alternatives are shown on Figure 6 in order to give some flexibility in securing application sites. In general, distribution lines should be kept as short as possible to reduce pipe costs, temperature losses, and maintenance hassles. There are serious trade-offs associated with all sites alternatives to Sites A and B.

Site C, located on the west shore of Riondel Peninsula immediately above and east of the Main Thermal Zone, would require the shortest drill hole to reach the target; however, the collar would be about 70 feet above lake level because of the steep rocky shoreline (Photo 5, Appendix A). The hole would be parallel to the bedrock surface and there would be a danger of the hole breaking out into the lake bottom sediments.

Site D, at the north end of the peninsula, would attempt to intersect thermal water in the vicinity of the Comfort Zone. Although thermal water is reported to have been intersected in this area, data is scarce. Topography is subdued so that the hole could be positioned to penetrate a target horizon with minimal trouble. As at location A, the well would be collared in competent hanging wall quartzite and could be engineered to intersect Badshot limestone at the prescribed depth. However, the chances of successfully developing thermal water are considered to be less than at the Main Thermal Zone.

Sites E and F are suggested as the best well sites available on land not controlled by Cominco (see Section 5 for land issues). In both cases, drilling would be technically very difficult because the hole would be nearly parallel to layering and foliation in broken, incompetent footwall argillites. To get close to known thermal occurrences, these sites would require that the holes be drilled at a very shallow angle to the west.

3.1.3 Well Pump

As single source energy supply, the geothermal well pump is to be sized for the total required flow quantities to all application sites under consideration.

In accordance with calculated heating requirements listed in Part 4.0 of this report, the following quantities of 37.8°C (100°F) water must be supplied:

New Resort/Spa/Pool	340 USgpm	=	21 litres/sec
New Fish Hatchery	400 USgpm	=	25 litres/sec
New Greenhouse	550 USgpm	=	35 litres/sec
Existing Community Centre	65 USgpm	=	4 litres/sec
Existing Curling Club	65 USgpm	=	4 litres/sec
	1,720 USgpm	=	108 litres/sec

Preferred well sites "A" and "B" (Figure 6) are nominally located 9 metres (30 feet) above the level of Kootenay Lake (average elevation 530 metres (1,750 feet). In addition, the anticipated "zero thermal head" horizon of the well (see section 2.7.1) is approximately 76 metres (250 feet) below lake level. Therefore, the minimum lift capacity of the well pump is 76 metres +

9 metres + dynamic pipe line losses + safety factor = approximately 105 metres (350 feet) (design head).

In accordance with published "Performance Curves" by various manufacturers of submersible, multi-stage turbine pumps (eg. "Flygt", "Us", "Berkeley"), suitable for mine dewatering and geothermal well applications, a 20 cm (8") diameter, 75 HP (nominal) pump would be required to produce 30 litres/sec at 105 metres total head. In selecting a flow of 30 litres/sec, it is assumed that only one new development application would proceed or that additional applications would be in series or "cascaded".

Based on price quotations from various suppliers and standard installation cost analyses, the installed cost (March 1991) for the pump and associated piping, fittings, check valve, electrical wiring, controls, accessories, labour, freight, taxes and contingencies is estimated to be $20,100, complete to well head. Annual pump energy cost is $29,000.

3.1.4 Scale Treatment

Chemical treatment of the thermal water will be necessary to prevent calcium carbonate scaling in pipes, pumps and other thermal fluid bearing system components.

Phosphate compound type chemical treatment, as used in the past by Cominco, is cumbersome and associated with adverse environmental side effects (ie. heavy algae growth etc.). Phosphate treated water is not useable in swimming pools and spas.

Scale prevention water treatment via synthetic organic polymers is a technique developed in the past five years and the preferred solution. These compounds function by crystal distortion, dispersion and modification mechanisms. Organic polymers become absorbed into growing $CaCO_3$ crystals and the resultant net negative charge results in mutual particle repulsion (Vaska and Kellogg, 1989). Very low dosages, to give concentrations of 5 ppm, are used so that the antiscalant can be used in pool water, according to suppliers. 85 - 98 percent scale reduction efficacies are achieved.

Introduction of chemicals below the pump is achieved by means of a 0.6 cm diameter stainless steel tubing to the well casing. Dosing and metering equipment will be located at the well head. Capital costs are estimated to be $6,500 for the installed equipment and tubing. Chemicals based on treatment of 30 litres/sec at 5 ppm dosage will cost $9,000/yr, plus 10%, plus 7% G.S.T., or a total of $10,500/yr.

In addition to synthetic organic polymer water treatment, some chemical de-scaling process with acidic chemical compounds must be considered on a regular basis, eg. once a year. Such chemical de-scaling would require shut-down of any swimming pool or spa facility for the full treatment period and shorter time shut-down for the remainder of the system.

3.1.5 CO_2 Separation

Heavy carbon dioxide gas concentrations were encountered whenever thermal source water was subjected to atmospheric pressure conditions. Information on the volume of CO_2 gas that was vented from the mine is lacking. CO_2 caused pump cavitation problems in the Cominco water pumping operations and presents a safety hazard when it is allowed to collect in confined spaces. Although it is not poisonous, it displaces air in sumps or basins and may cause suffocation.

Further testing is required to determine the pressure conditions for which CO_2 remains in solution, so as to determine optimum down-hole setting depth for minimization of CO_2 cavitation of pump impellers (ie. establish minimum required "Net Positive Pump Suction Head").

Controlled CO_2 separation from thermal water will be completed at the well head via vortex separators. Such devices are pressure vessel type pipeline components which are normally employed to separate air flow water in closed hydronic piping systems. Water enters tangentially, creating a flow vortex inside the vessel, which separates gases from the water towards the vortex centre. Released gas is extracted at the top of the device.

If required, additional CO_2 separation will be by means of an insulated settling tank or chamber situated in the piping system downstream of the vortex separators. 98 percent CO_2 removal can be achieved by these combined separators.

CO_2 is discharged to the atmosphere from the top of a vent stack with blower ventilators provided.

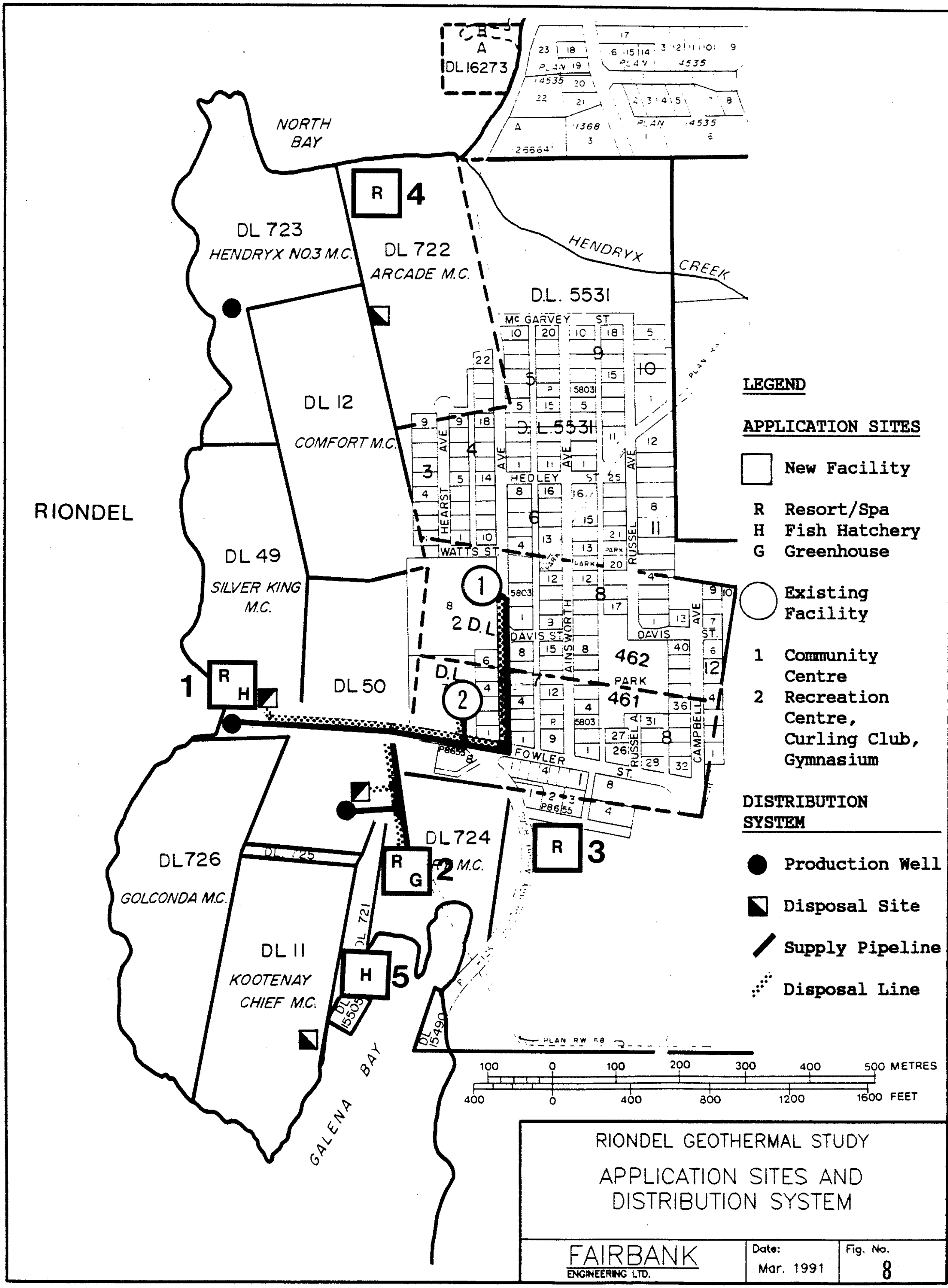
Since data on CO_2 emission volumes from the well water are not available at the present time, only rough installation cost estimates can be provided.

Vortex Separator (Installed)	$ 3,200
Settling Chamber	2,500
Piping, Fittings, Accessories	2,300
Electrical Wiring & Controls	1,200
Equipment Bases	1,500
15% Contingencies	1,100
7% GST	600
Total	$ 12,400

3.1.6 Primary Heat Exchange

If the thermal well water proves acidic and, thus, corrosive to copper piping materials such as employed in hydronic system components (eg. air coils), or if long pipelines are susceptible to carbonate scaling, isolation of the hot water distribution system to application sites from the raw well water via heat exchanger would be required. This heat exchanger, preferably located near the thermal well, is to be of cleanable "plate type" configuration and of stainless steel construction. In the case of a primary heat exchanger being used, CO_2 gas separation is not necessary. CO_2 ventilation must be considered at fluid disposal sites.

In addition to the heat exchanger, a circulation pump (or pumps) will be required for the closed loop distribution system, which contains treated water and glycol mix for freeze-up prevention. The cost of a bank of stainless steel plate-type heat exchangers capable of handling the required 30 litres/sec flow capacity, with 35°C discharge temperatures on the clean



RIONDEL GEOTHERMAL STUDY

APPLICATION SITES AND DISTRIBUTION SYSTEM side, is approximately $40,000.

3.1.7 Distribution Piping System

Figure 8 shows proposed locations of preferred well site(s), existing mine openings for fluid disposal, potential new facility sites, existing buildings being considered for geothermal heating, and pipeline routes.

Due to the low harvest temperatures from the well head, thermal water distribution piping material can be polybutylene or similarly inexpensive plastic of equal properties. All supply piping from well head to the application sites would be insulated with polyurethane insulation, complete with jacketing, which can be applied in the field prior to installation. Alternatively, polybutylene piping may be purchased pre-insulated, reducing on-site labour costs. Unless the cooled discharge water from a particular application site is to be used again for secondary heat extraction (eg. heat-pump systems), the return piping to the final discharge site at the nearest existing mine adit is to be uninsulated.

The recommended standard burial depth for distribution system piping along roadways is 1.2 m (4 feet), with insulated supply pipe and separate return flow pipe installed in the same trench.

Referring to Figure 6, the discharge for preferred well location "A" is at location "D1" (Bluebell Adit). Similarly, for well site "B", the preferred discharge location is "D2" (No.1 Shaft). Given the geographic placement of the various potential application sites, piping distances for either well location option are essentially equal (Figure 8).

Averaging pipe size, the installed costs of the distribution piping include $15 per metre for polybutylene pipe (supply and return in same trench), $22 per metre for polyurethane pipe insulation and jacketing, $100 per metre for excavation, installation of pipes and backfilling, for an approximate total of $137 per metre. Repaving of disturbed roadway sections will add $20 per metre to the installed cost (total $157 per metre).

Pipeline lengths for new facilities at either of Site 1 or 2 (Figure 8), from nearby production wells, are 100 and 150 metres, respectively. Distribution lines to the community and recreation centres from the production well area (via Fowler Street and Eastman Avenue) would be 650 metres total, with 50 metres under paved roads.

The estimated installed cost for distribution piping is $14,000 - $20,500 for new facilities at Site 1 and Site 2, respectively, and $90,000 for service to the existing buildings.

A booster pump will be required to overcome the dynamic head of the distribution piping system to reach Riondel. Hydraulic system analysis indicates the requirement of a 40 to 50 HP booster pump, preferably located near the well head. Utilizing the proximity of electrical services and equipment support base structures at the well head, the installation costs for the booster pump can be minimized. The approximate installation cost for the booster pump and associated piping, fittings, valves, gauges, accessories, electrical is estimated at $12,000 to $15,000 (freight, labour, taxes and contingencies included).

It is recommended to provide a stand-by booster pump of equal size and capacity, with suitable automatic switch-over controls. This stand-by pump would cut-in and maintain water flow through the distribution system in case of failure of the operating booster pump.

3.1.8 Fluid Disposal

Return water from the geothermal system is to be discharged into the nearest existing mine shaft. All piping must be adequately supported along its entire length. The open discharge pipe end is to be anchored to the mine shaft wall to counteract reaction forces of the discharging water volumes.

Disposal of "spent" (cooled) geothermal fluid to the mine system will alleviate any possible environmental concerns arising from the discharge of well water on the surface or into the lake. No water level changes in the mine are anticipated as water extracted via the well pump(s) from the thermal zones hydraulically communicates with the water body contained within the existing flooded mine and is being replaced back at the discharge end of the geothermal heat harvest system.

Pipe cost is $10 per metre. Disposal pipeline costs have been incorporated into distribution system costs in Section 3.1.7.

3.2 Alternative Heat Extraction Systems

3.2.1 Thermal Water Pump from the Mine

In order to produce thermal water by pumping water directly from the mine, the water level in the mine would have to be pumped until it reached a point below the "zero head" elevation of the thermal system. Pumping could be achieved by setting a pump on a dolly lowered in stages down the No. 1 Shaft as the water level dropped. Thermal water would recharge the mine water and produced water would be mixed thermal water and groundwater at perhaps 15-25°C. Normal groundwater is 8-10°C. Energy from water at 20°C can be extracted by heat pumps. Spent water would presumably be disposed of by discharging into Kootenay Lake.

The scenario outlined above is similar to an existing geothermal heating application at Springhill, Nova Scotia. At Springhill, 18-21°C water is pumped from coal mine stopes at 3 litres/sec (40 g.p.m.). Heat exchangers are utilized to extract energy from the thermal water, with a temperature drop of 6°C on the return side. The energy is used to heat a 7,500 m^2 (80,000 ft^2) industrial facility owned by ROPAK CANAM Ltd. located directly above the resource. The heating system installation cost $150,000 in 1989. Further expansion is planned.

3.2.2 Downhole or Mine Heat Exchange

Due to the requirements for cleaning and maintenance, downhole heat exchangers, located some 300 metres or more below lake level, are not considered viable. In addition, the temperature of water in the mine, under static conditions, is unknown but probably is not greater than 15°C. High initial capital costs make downhole heat exchangers not viable alternatives for the proposed thermal water harvest rates.

3.2.3 Heat Pumps

Water-to-air heat pump units, employing state-of-the-art refrigeration and heat exchanger (condenser) technology, represent a reliable and cost effective alternative to standard hydronic air coils or water-to-water heat exchangers, especially at lower entering water temperatures from low thermal systems. Specially constructed units, commonly referred to as "ground source" or Geo-Thermal heat pumps, are capable of economic heat extraction for space heating from water entering at temperatures as low as 7°C (45°F). Heat pumps are also capable of providing economical space cooling from water entering at temperatures as high as 43.3°C (110°F) - Data published by "Friedrich Climate Master", LSB Industries, Utica, New York, USA.

High-efficiency water-to-air heat pumps (such as those manufactured by "Friedrich Climate Master", "Carrier" and others) are designed to operate at entering water temperatures ranging between 16°C (60°F) and 38°C (100°F), with "Energy Efficiency Ratios" to 11.9 for cooling and "Coefficients of Performance" (COP's) to 3.8 and above for heating. For reference, the following is a list of typical performance data for a standard "Friedrich" Model No. 814 - 027 water-to-air heat pump unit:

entering water	21.11°C = 70°F
leaving water	17.22°C = 63°F
water flow rate	0.14 litres/sec = 2.18 USgpm
heat of absorption	21,800 BTU/litres = 6.387 kW
heating capacity	29,500 BTU/litres = 8.643 kW
total kW input	2.27 kW
Coefficient of Performance (COP)	3.808
air flow (average)	850 cfm = 401.2 litres/sec

The above performance data are representative of the required operating characteristics for a typical, residence in Riondel, BC, using either "spent" (cooled) water from the proposed deep thermal well or, alternatively, low-grade water pumped from the mine.

As an option, heat pump units may be equipped with a refrigerant-to-water "de-superheater" heat exchanger (coaxial coil type) for pre-heat of domestic water at negligible energy costs. Such heat exchanger coils are either factory-mounted in the units or can be field-installed externally.

4.0 ENERGY APPLICATIONS - COMMUNITY BUILDINGS

It would not be economic to heat any of the existing community facilities with geothermal energy because of excessive retrofit and pipeline costs relative to energy savings. Details are outlined in the following sections.

4.1 Community Centre

The Community Centre is located at the southwest corner of Eastman Avenue and Watts Street (Figure 2; Appendix A, Photo 14). Built as a seven classroom school, the building was turned over to the Community after the construction of the Crawford Bay School. On the main floor, the building's current usage is the: Library, Assembly Hall, Senior Citizen's Lounge, Daycare and Youth Activities Room. The fire and ambulance vehicle storage and fire fighters office/lounge is located on the lower floor.

The original construction dates back to the early 1950's, with subsequent additions estimated in 1953, 1957 and 1960. The building's current site coverage is 1,115 m^2, (12,000 ft^2), with a gross floor area of 1,384 m^2 (14,000 ft^2), due to the partial basement of 269 m^2 (2,900 ft^2).

The wood frame structure has minimal insulation and includes large areas of single pane glazing, estimated at 75% of the east and 45% of the west exterior elevations.

The current heating system includes a ceiling suspended propane unit heater in the Assembly Hall (gymnasium) and an oil fired furnace with an air duct system for the remainder of the structure. The annual propane consumption is 450 litres, at an annual cost of $13,600.00. The annual oil consumption is 10,426 litres, at an annual cost of $5,440.00 in 1990. Allowances should be made for oil cost increases and the 7% Federal Goods and Services Tax (G.S.T.).

Application of geothermal heating would include retro-fitting the existing oil furnace system with hydronic heating air coils fed with 38°C well water from pipes connected to the proposed main distribution piping system trunk on Eastman Avenue. Similarly, the gymnasium would be retro-fitted with a new hydronic unit heater, ceiling suspended beside the existing propane-fired unit heater.

In order to minimize hydronic coil sizes and, at the same time, reduce infiltration heat losses to this aged structure, the existing furnace system would be retro-fitted with outside air intake ductwork and new hydronic heating coils, capable of providing pressurization of up to one air change per hour for the building (approximately 2,150 cfm). Additional new hydronic heating coils would be added to the return air duct system.

For economic reasons, the new hydronic system components would be selected to provide approximately 55% of the total required heating design load, thus providing approximately 81% of the annual heat demand. The existing furnace system and unit heater would provide the additional heating capacity required at lower outdoor temperatures.

In addition, a cleanable plate-type heat exchanger for domestic water pre-heat is proposed upstream of the existing water heaters. This heat exchanger would be capable of providing up to 50% of the domestic water heating requirements on a yearly basis.

The estimated in-house retrofit costs would be approximately $45,400, + 20% contingencies + 7% G.S.T. = $58,300., including unit heater, coils, heat exchanger, auxiliary pump, piping, valves, insulation, ductwork, controls, electrical, labour, freight and taxes (1991 costs).

The retro-fitted system would require 4.1 litres/sec (65 USgpm) of 37.8°C (100°F) geothermal water supply, resulting in anticipated direct annual energy cost savings of $5,059 for space heating + $253 domestic water heating = total $5,312 (including 5% energy cost increases January 1991 and 7% G.S.T.).

4.2 Recreation Centre and Curling Rink

The Recreation Centre and Curling Rink Building is located on the west end of Fowler Street, facing north (Figure 2; Appendix A, Photo 15). The original gymnasium structure was constructed in the early 1950's and contains a two storey ancillary space. Subsequently, a two sheet curling rink was built adjoining the gymnasium. All the above ground structure is wood frame construction with minimal insulation values. The current site coverage is 870 m^2 (8,365 ft^2), with a 75 m^2 (807 ft^2) mezzanine, the gross area is 945 m^2 (10,172 ft^2).

The current heating systems consist of a ceiling suspended propane heater in the gymnasium, supplemented by electrical heat in the curling rink and ancillary spaces. The annual propane consumption in 1,830 litres at a cost of $552.00. The annual electrical consumption is 61,400 kilowatts at a cost of $3,062.00. It is assumed that the greatest demand for electrical power is attributed to the ice production plant. The January, 1991 rate increase for electricity is 12%, including 7% G.S.T..

Retro-fitting the building for geothermal heating would include the installation of a new hydronic unit heater in the gymnasium beside the existing propane heater, and new hydronic fan coil units for the mezzanine and lower floor (less curling ice sheet area), complete with new distribution ductwork. All existing electric heaters are to remain. All new hydronic units are to be fed with 37.8° (100°F) geothermal water via insulated pipes connected to the main distribution piping system on Fowler Street. For economic reasons, the new systems would be designed to provide 63% of the total space heat load requirements, thus providing approximately 90% of the annual heat demand.

For domestic water pre-heat, a cleanable plate-type heat exchanger installed upstream of the existing water heaters is recommended. This heat exchanger would provide up to 50% of the total annual domestic water heating requirements.

The estimated in-house retro-fit costs would be approximately $25,700 + 20% contingencies + 7% G.S.T. = $33,000, including unit heater, fan coil units, ductwork, piping, valves, auxiliary pump, domestic water heat exchanger, controls, electrical, labour, freight and taxes (1991 costs).

The retro-fitted system would require a maximum of 4.1 litres/sec geothermal water supply, resulting in anticipated direct annual cost savings of $2,215 for space heating plus $288 for domestic water heat (total $2,503), including 5% energy cost increase of January 1991 and 7% G.S.T..

If water-to-air heatpumps are used instead of the proposed new hydronic unit heater and fan coil units, the estimated total in-house retro-fit costs would increase slightly to approximately $26,200 + 20% contingencies + 7% G.S.T. = $33,640. The resulting annual cost savings for space heating would be approximately $1,980, however, with the added benefit that the system can provide summer cooling.

4.3 Galena Bay Restaurant

The Galena Bay Restaurant and Pub is located on the southwest corner of Fowler Street and Ainsworth Avenue (Figure 2, Appendix A, Photo 16). The building's original wood frame construction dates back to the 1940's. With several additions, the building has a current site coverage and gross area of 186 m^2 (2,000 ft^2). Insulation values in the exterior building envelope are minimal.

The current ducted heating system includes two oil fired furnaces with 122,000 and 112,000 BTU output.

Both forced-air furnace systems are adaptable for geothermal heating by installing hydronic heating coils in the return air duct system. These coils would be fed with 37.8°C (100°F) geothermal well water via insulated pipes connected to the main distribution system which would have to be extended along Fowler Street to the east from Eastman Avenue. In all likelihood, the air handling blowers and motors of both furnaces would have to be upgraded to handle the increased airflow requirements.

The retro-fit costs, including coils, ductwork alterations, piping, valves, insulation, controls, electrical and labour are estimated at $4,700 + 20% contingencies + 7% G.S.T. = $6,035 total. Sizing the coils for 63% of the furnace output capacities would result in annual energy cost savings of up to 90%. Actual annual energy cost records were not available from the restaurant for analysis purposes, neither are details of the domestic hot water system available. However, the installation of a domestic water pre-heat exchanger would provide savings up to 50% of annual energy costs.

4.4 Senior Citizen's Housing

Bluebell Manor, located on the southwest corner of Fowler Street and Russell Avenue (Figure 2; Appendix A, Photo 17), was constructed of wood frame components in 1987, with a single storey site coverage of 367 m^2 (3,950 ft^2).

The five suites and common areas are independently heated by electric baseboard and unit heaters to a total of 80 kilowatt design load. The total annual electrical consumption from June 1989 to May 1980 was 50,980 kilowatts at a cost of $2,605.00. The January, 1991 rate increase is 5% plus 7% G.S.T. for an equivalent annual cost of $2,918.00. A proportion of the consumption should be allocated to the electric domestic hot water, ranges, lighting and general power.

The annual electrical energy consumption costs for the common area are an average 29% of the total, or approximately $846 (1991 adjusted costs), common area space heating and domestic water heating costs being a fraction thereof (ie. estimated maximum $400 per year).

Due to the nature of the existing heating system, being mostly electric baseboard heater, and the low annual energy consumption costs for heating, the relatively high capital costs required for geothermal heating of this building would not be economical.

4.5 General Store

The Riondel Market is located on the northeast corner of Eastman Avenue and Davis Street and operates as a General Store, Liquor Store and Post Office (Figure 2; Appendix A, Photo 18). The single storey wood frame structure is approximately 20 years old and has a site coverage and gross floor area of 112 m^2 (1,200 ft^2).

The building is heated by three ceiling-suspended 5 kilowatt electric unit heaters. The total annual electrical consumption was 45,470 kilowatts at a cost of $2,547.00. The January 1991 rate increase is 5% plus 7% G.S.T. for an equivalent annual cost of $2,853.00. A proportion of the consumption should be allocated to the electric domestic hot water, lighting, refrigeration and general power.

Taking into account heat expelled from air cooled refrigeration condensers of store fixtures, the annual energy consumption for space heating is estimated as 15,915 kW hrs or approximately 35% of the total annual electrical energy consumption. This translates into annual heating costs of $998 (1991 costs).

Geothermal heating adaption for the store would include the installation of two ceiling-suspended hydronic unit heaters, complete with insulated water piping, 37.8°C (100°F) thermal well water feed, connected to the geothermal distribution pipe lines on Eastman Avenue. The existing electric unit heaters are to be retained for back-up. The estimated installation costs for the two unit heaters, associated piping, valves, insulation, electrical, labour, freight and taxes, are $5,900, plus 15% contingencies + 7% G.S.T. = $7,260 total. Due to the estimated low domestic hot water consumption, the installation of a heat exchanger would be considered uneconomical.

4.6 Residences

Within the immediate community of 10 hectares (24.7 acres) there are approximately 160 single family residences which vary in age from 50 years to recent new construction (Appendix A, Photos 22, 23). It is estimated that 75% of the residences are over 40 years old, with 75% of single storey and 25% of two storey construction. Building areas vary between 70 m^2 (750 ft^2) and 140 m^2 (1,500 ft^2) with an average area of 100 m^2 (1,076 ft^2). The total area of all residences is approximately 16,000 m^2 (172,230 ft^2).

We have estimated that 50% of the residences are heated with electricity and the other 50% are heated by propane or oil fire furnaces.

Only residences with forced-air heating systems are adaptable to geothermal heating with relative ease. A typical retro-fit installation would consist of a hydronic heating coil fitted into the return air ductwork upstream of an existing furnace, insulated supply and return water piping 37.8°C (100°F) thermal water connected to the geothermal distribution piping in the street, valving, controls and control wiring. For an average residence with a floor area of 100 m^2 (1,076 ft^2), the installation costs are estimated as $2,840 + 10% contingencies plus 7% G.S.T. = $3,343 total.

Domestic water tank heaters are usually installed near the furnace, hence, the installation of heat exchangers for domestic water pre-heating via geothermal fluid becomes quite economical. Typically, the cost for a small stainless steel heat exchanger plus piping and installation is estimated as $680 + 10% contingencies plus 7% G.S.T. = $800 total.

Alternatively, for residences without forced-air heating systems or when comfort cooling is desired, the installation of water-to-air-heat pumps should be considered. Such heat pump units may be installed in central closets, with minimal ductwork requirements, or free-standing (eg. terminal units with decorative cabinetry). The geothermal fluid piped through the heat pumps is used as heat absorption/refection medium for both heating and cooling modes of operation.

4.7 Other Structures

Within the community of Riondel, the following wood framed structures are also present: 84 m^2 (900 ft^2) Medical Clinic (Appendix A, Photo 21), with electric baseboard heating; a community cable/video building of 19 m^2 (205 ft^2), with an electric unit heater; and two churches (Appendix A, Photo 19), both of 93 m^2 (1,000 ft^2). The heating systems of the churches are unknown.

Decisions regarding the adaptability to geothermal heating for these buildings and business premises can only be made per analysis on an individual basis. Economic considerations (installation costs, energy cost savings, borrowing costs, amortization periods, etc.) and proximity to the geothermal distribution piping system will dictate the viability of geothermal retrofit.

4.8 Community Plan

During the operation of the Bluebell Mine, the housing stock and community buildings were built up to meet the needs of the Riondel residents. Upon the closure of the mine in 1972, there was a high vacancy rate for housing, with the community facilities exceeding the needs of the town's remaining residents. The current inventory of residences and community facilities comfortably meet the requirements of this retirement oriented community of 300 inhabitants.

Because of limited funding available with no industrial base, there is no official community plan per se. Polled residences have stated that the general population is receptive to further "outside" development which does not impact the environment.

The Regional District of Central Kootenay has undertaken a feasibility study to upgrade the Riondel water supply system. The water source of Indian and Hendrix Creeks have a reliable base flow and acceptable water quality for the current user demand. There is a current need to provide a new storage tank with a proposed disinfection facility at an estimated 1990 cost of $363,000.

The Regional District has also commissioned a feasibility study for the upgrading of the surface drainage system for the community of Riondel. This report states a need for a new drainage system to safely route the runoff water through the community. The cost of providing a totally new drainage system is considered prohibitively expensive, to an 1990 estimate of $465,000.

5.0 ENERGY APPLICATIONS - NEW FACILITIES

New recreational/industrial facilities consuming larger amounts of energy than the existing community buildings are needed in order to economically amortize the high initial capital cost associated with geothermal resource development at Riondel. Destination resort, commercial greenhouse, and fish hatchery installations are considered in the following sections. All costs are in March, 1991 dollars with GST included.

Potential development sites are located on Figure 8. Sites 1 and 2 are the best all around sites for the facilities indicated, Site 3 is suggested as a potential resort site located off Cominco controlled land and Sites 4 and 5 are second priority sites.

Selection criteria in order of importance include:

1) proximity to preferred supply wells;
2) adequate level area for facility;
3) access;
4) topography, visual appeal, sun exposure, views;
5) proximity to lake.

Photos of each site are in Appendix A.

Site 1: Photos 3, 4
Site 2: Photos 6, 7, 8, 9, 10
Site 3: N/A
Site 4: Photos 1, 2
Site 5: Photos 9, 11

5.1 Resort Spa

5.1.1 Outline Specifications

The tourism area within which Riondel is situated is defined by the east side of the south arm of Kootenay Lake extending from Creston in the south, to Riondel in the north. The area caters to outdoor family recreation. The existing south arm tourist development is comprised of eight commercial facilities providing numerous private campsites, 10 motels, one Provincial campsite and two golf courses.

The Regional District of East Kootenay states that there is a strong preference for small resort developments as opposed to large complexes and identifies the Crawford Bay (Figure 1) area as a focus of attention for future developments. Crawford Bay's current attraction is the 18 hole golf course, with numerous privately owned summer homes built around the golf course complex. Kokanee Springs Golf Course has plans for a 1st phase, 30 unit lodging development in 1991-92. Riondel, being 15 kilometres north of Crawford Bay, is considered within this market area.

Directly across from Riondel on the west shores of Kootenay Lake is Ainsworth Hotsprings. This resort consists of a main open pool of approximately 100 m^2, water caves, 43 hotel rooms and 85 seat restaurant.

The Regional District specifies a resort lodge bearing from 20 to 100 rooms as best suited to meet the needs of the tourism development opportunities.

The proposed resort/spa for Riondel would provide a 115 m^2 (1,240 ft^2) open air main pool with a water volume of 18,700 litres, and a whirlpool with an area of 18.6 m^2 (200 ft^2) and a water volume of 18,600 litres. The building would include two change rooms, two shower rooms, office/control area, mechanical room and ancillary spaces, to a total enclosed area of 280 m^2 (3,000 ft^2).

The following plumbing fixtures would be required: five showers (two female, two male and one staff), four water closets (two female, one male and one staff), one male urinal, and three lavatories (one female, one male and one staff).

To maintain a destination status, the proposed resort would also contain a 50 seat restaurant of 180 m^2 (1,938 ft^2) and a 20 unit hotel complex of 1,020 m^2 11,000 ft^2). The hotel would provide 21 washrooms, complete with one lavatory, one water closet and one combination shower/bath tub.

The described resort/spa would be best suited for a 1.5 to 2.0 hectares (3.7 to 5 acres) site.

5.1.2 Energy Analysis Considerations

In general terms, the geothermal water will provide a high percentage of the heat energy required for the proposed resort spa complex. Specifically, direct use of geothermal water is proposed for both pools, ventilation make-up air heating via hydronic air coils and domestic water pre-heating via plate-type heat exchangers at all buildings on site, i.e. the resort centre building (bath house), restaurant, and 20 unit hotel complex. "Spent" (i.e. cooled) water is subsequently pumped through piping systems within the buildings to water-to-air heat pump units, which provide all required space heating and cooling. Discharged water from the resort complex is returned (pumped, as required) to the distribution system return main for down stream applications or disposal in the mine.

Outdoor climatic data relating to National Building Code (1980) Design Criteria were chosen as published for Nelson, BC, the nearest reporting weather station:

Winter:	1% Design Temperature (January)	-24°C
	2.5% Design Temperature	-20°C
Summer:	Dry Bulb Temperature	31°C
	Wet Bulb Temperature	19°C
Degree Days below 18°C		3734

Minimum water circulation rate requirements for flow-through swimming pools are such as to achieve a turn-over period of six hours (B.C. Health Code). For whirlpools, the maximum allowable turn-over period is one hour, and preferably one-half hour for therapeutic pools. Code requirements translate into water flow quantities of 8.6 litres/sec for the swimming pool, and 10.3 litres/sec for the therapeutic whirlpool.

For 10.3 litres/sec of 37.8°C (100°F) thermal water entering the outdoor whirlpool (18.6 m^2 = 200 ft^2 surface), the calculated heat loss due to evaporation at minus 24°C (minus 11.2°F) design ambient temperature and 10 km/hr (6.3 miles/hr) wind velocity at the pool surface, plus transient heat losses through the pool bottom and side walls, is approximately 47.6 kW (162,300 BTU/hr), with a safety factor of 20% included. The calculated outflow water temperature from the whirlpool at these conditions is 36.7°C (98°F), with an evaporation loss of approximately 55.8 kg/hr (123 lbs/hr) from the pool surface to atmosphere (Note: method of analysis and data per ASHRAE handbooks and related publications).

Similarly, for the outdoor swimming pool (115 m^2 = 1,238 ft^2 surface), with 8.6 litres/sec of 37.8°C of (100°F) thermal water entering, the calculated total heat loss is approximately 192 kW (656,000 BTU/hr) at -24°C (-11.2°F) ambient temperature and 10 km/hr wind conditions. The outflow water temperature from the swimming pool at these conditions is calculated at 31.7°C (89°F) (10% safety), with an evaporation loss of approximately 251.7 kg/hr (555 lbs/hr) from the pool surface to atmosphere.

Alternatively, if the outflow from the whirlpool, i.e. 10.3 litres/sec of 36.7°C water, is to be used as the supply to the swimming pool, Health Code permitting, the resulting turnover for the swimming pool is 5.02 hours. The calculated heat loss (192.2 kW = 656,000 BTU/hr), evaporation rate (251.7 kg/hr = 555 lbs/hr) and exiting water temperature (31.7°C = 89°F) are identical to those calculated for water entering conditions of 8.6 litres/sec at 37.8°C.

Using either the outflow from the whirlpool at 36.7°C minimum, or 37.8°C temperature water directly from the geothermal supply, piped to hydronic coils for make-up air heating and plate-type heat exchangers for domestic water pre-heating, the following water flow quantities are required (estimate):

Resort Centre Building:	Make-up Air	1.2 litres/sec
	Domestic Water	1.6 litres/sec
	Total	2.8 litres/sec
50 Seat Restaurant:	Make-up Air	2.8 litres/sec
	Domestic Water	1.6 litres/sec
	Total	4.4 litres/sec
20 Unit Hotel Complex:	Make-up Air	1.4 litres/sec
	Domestic Water	1.8 litres/sec
	Total	3.2 litres/sec
	Total All Bldgs =	10.4 litres/sec

Adding the flow requirements for the whirlpool (10.3 litres/sec), plus building make-up air heat and domestic water pre-heat (10.4 litres/sec), plus a contingency allowance for pool evaporation losses, the overall direct thermal water flow requirement for the proposed resort spa complex is approximately 21.4 litres/sec (maximum).

If the whirlpool outflow (10.3 litres/sec approximately equals the building requirements of 10.4 litres/sec) of 36.7°C water is piped to the buildings and the swimming pool is fed directly with 8.6 litres/sec of 37.8°C geothermal source water, the total thermal water supply is 10.4 litres/sec, plus 8.6 litres/sec, plus contingency allowance for evaporation, or approximately 19.9 litres/sec (minimum).

"Spent" (i.e. cooled) water, at a minimum estimated temperature of 30°C (86°F), is piped to heat pump units for space heating and cooling in the buildings and through piping embedded in concrete floor slabs for floor heating of shower areas, change rooms and washrooms. Similarly, in-slab heating of pool decks for freeze-up protection may also be considered. As a final stage of utilization, "spent" water may be used for recreational water slides.

5.1.3 Proposed System and Heating Components

Incoming water for the pools may have to be filtered and chlorinated as required by the local Health Authorities. Additional chemical treatment such as pH adjustment, etc., may also have to be considered. All equipment to meet these requirements, i.e. pool filters, chlorinators and chemical feed pumps, are standard items and are readily available from pool equipment suppliers.

Delivery pumps for each pool will be typically in the 3 HP to 5 HP range for the estimated flow quantities of maximum 10.4 litres/sec (165 USgpm). Similarly, harvesting of pool water from surge tanks for distribution to buildings and auxiliary systems (eg. pool deck heating) will require total pump capacities in the range of 6 HP to 12 HP. Additional pump capacities would be required for water slides.

Heat loss and heat gain estimates for the proposed buildings and resulting heat pump capacity estimates indicate that "spent" water flow quantities, discharged from ventilation make-up heat exchangers within each building, are sufficient for all water-to-air heat pump water flow requirements. The following is a listing of capacity requirements for the three major buildings comprising the resort/spa complex.

Resort Centre Building:

Estimated heat pump system capacity:	28 to 35 kW
Average water flow required to heat pumps:	1.26 litres/sec
Discharge from make up air coils and heat exchange:	2.84 litres/sec

50 Seat Restaurant:

Estimated heat pump system capacity:	28 to 35 kW
Average water flow required to heat pumps:	1.26 litres/sec
Discharge from make up air coils and heat exchange:	4.42 litres/sec

20 Unit Hotel Complex:

Estimated heat pump system capacity:	98 to 106 kW
Avg/min water flow required to heat pumps:	3.09 litres/sec
Discharge from make up air coils and heat exchange:	3.16 litres/sec

An approximate balance of water flow requirements for each building exists with the result that the hydronic piping systems can be configured simply. Additional distribution pumps would not be required. Insulation for piping would only be required on supply lines to hydronic air coils and domestic water heat exchangers. Piping for heat pumps need not be insulated.

"Spent" water return piping from all systems is routed to an equalization tank, from where a booster pump disposes of the efflux water to the main return piping system for disposal in the flooded mine. Preliminary estimates indicate the booster pump size will be in the 10 HP range.

Aside from the proposed geothermal system, standard domestic water tank heaters downstream of cleanable plate-type heat exchangers, air handling systems for ventilation make-up air and ductwork for central heat pumps (not required for unitary console heat pumps) must be provided in all buildings. These items, however, would have to be provided in a conventional heating system and are not unique to the geothermal heating application.

5.1.4 Capital Costs

Based on pricing for equipment in consultation with suppliers, installation contingencies and labour, the following cost estimates are intended to provide a comparison for the geothermal system versus heating, ventilating, air conditioning (HVAC) and domestic water heating systems.

Whirlpool & Swimming Pool:

Supply pumps, sand filters (4 of), chlorinators, piping and fittings for both pools, accessories, installation and labour, are approximately $14,700, plus 15% contingencies, plus 7% G.S.T., or $18,090 total. These items would be required regardless of geothermal application. Stand-by items such as pumps and/or pool boilers are recommended, but are not included in the installation cost estimates.

Surge Tanks, On-Site Distribution and Return Discharge:

Insulated surge tank at pool outflow, supply water distribution pump(s), insulated supply piping, non-insulated return piping from buildings, collection tank, discharge booster pump and discharge piping (non-insulated) to main distribution return pipe connection, are approximately $21,400, plus 15% contingencies, plus 7% G.S.T., or $26,330 total, installed. These capital costs are only applicable for the geothermal recovery system.

Resort Centre Building:

The geothermal heating/cooling system installation costs, including cleanable plate-type heat exchanger for domestic water pre-heat, ventilation make-up air heating fan coil air handler, in-house insulated thermal water supply piping to heat exchanger and coil, terminal type water-to-air heat pumps (office, reception areas, etc.), central system heat pumps, distribution ductwork, non-insulated piping to heat pumps and in-house return piping to building discharge connection, are approximately $26,300, plus 20% contingencies, plus 7% G.S.T., or $33,770 total.

Conventional all-electric heating/cooling system installation costs, including ventilation make-up air heating unit, baseboard heaters, through-wall air conditioners (office, reception, etc.) central furnaces and distribution ductwork, are approximately $16,100, plus 20% contingencies, plus 7% G.S.T., or $20,670 total.

50 Seat Restaurant:

The geothermal heating/cooling system installation costs, including cleanable plate-type heat exchanger for domestic water pre-heat, ventilation make-up air heating fan coil airhandler, in-house insulated thermal water supply piping to heat exchanger and coil, central system water-to-air heat pumps, distribution ductwork, non-insulated piping to heat pumps and in-house return piping to building discharge connection are approximately $37,500, plus 15% contingencies, plus 7% G.S.T., or $46,140 total.

Conventional all-electric heating/cooling installation costs, including ventilation make-up air unit, central heating and air conditioning roof-top units and distribution ductwork, are approximately $32,400, plus 15% contingencies, plus 7% G.S.T., or $39,870 total.

20 Unit Hotel Complex:

The estimated installation costs for the geothermal heating/cooling system installation, including cleanable plate-type heat exchanger for domestic water pre-heat, hallway pressurization unit(s) with hydronic heating coil(s), in-house insulated thermal water supply piping to coil(s) and heat exchanger, water-to-air terminal heat pump units (guest rooms, office, etc.), central system heat pumps (lobby, common areas), distribution ductwork, non-insulated piping to heat pumps and in-house return piping to building discharge connection, are approximately $71,000, plus 20% contingencies, plus 7% G.S.T., or $91,160 total.

For a resort hotel, the least expensive all-electric heating/cooling system, consisting of baseboard heaters and through-wall air conditioners for the guest rooms, is undesirable because of poor quality. Hence, for a good quality, medium price range option, the estimated installation costs for a standard all-electric heating/cooling system installation, complete with hallway pressurization make-up air unit(s), terminal type heat/cool units (under windows in guest rooms, offices, etc.) heat/cool rooftop units (lobby, common areas) and distribution ductwork, are approximately $56,000, plus 20% contingencies, plus 7% G.S.T., or $71,900 total.

Excluding the pools, the differences of estimated capital costs for geothermal and conventional all-electric systems (space heating and domestic water heating) can be summarized as follows:

	Geothermal	Electric
Resort Centre Building	$ 33,770	$ 20,670
50 Seat Restaurant	46,140	39,870
20 Unit Hotel Complex	91,160	71,900
Thermal Water Distribution system	26,330	N/A
Total:	$197,400	$132,440

5.1.5 Operating Costs and Energy Cost Savings

Based on design outdoor weather conditions (Nelson, BC), building heat loss analysis and recommended domestic hot water usage estimates for the proposed resort complex, as well as January, 1991 electrical energy costs (including 7% G.S.T.), the approximate yearly heating system energy consumption costs are:

	Geothermal	Electric
Resort Centre Building	$ 2,550	$ 8,300
50 Seat Restaurant	3,400	11,900
20 Unit Hotel Complex	4,800	14,600
On-Site Thermal Water Distribution System	7,900	N/A
Total:	$ 18,650	$ 34,800

The annual total energy cost savings for domestic water and space heating, using geothermal water, are estimated to be $16,150 (1991 costs). Additional capital costs of $64,960 are incurred with the geothermal system compared to conventional system.

Not included in the operating cost estimates and energy cost savings analysis are general lighting, building exhausts, pool heating, pool pumps and proportioned annual costs for the geothermal well and main distribution system pumps.

A resort developer may have to bear all of the well costs since it is unlikely that potential new applications would go ahead at once. In this case, a $326,000 (Site A) - $365,000 (Site B) capital expenditure (1991 dollars) would be required for a supply well, well pump, primary wellhead equipment and pipeline.

Well pump energy for running a 50 HP well pump continuously to supply 21.4 litres/sec would add operating costs of $20,000. Delivery system operating costs would be $7,500 for chemical inhibitors and $7,500 for scheduled maintenance twice a year.

It is clear that energy savings at the resort/spa installation do not in themselves justify the high capital, operating and maintenance costs of the well. High thermal water supply costs must be justified by the tourist market value of the mineral water that is a primary ingredient of a spa. Note that it would be prohibitively expensive to artificially heat groundwater or surface water with electricity year round. Given that a spa is to be constructed to meet a tourist market demand, then the figures show that it would be economical to heat the facility by utilizing the residual geothermal energy.

5.2 Greenhouses

5.2.1 Outline Specifications

Discussions with the Ministry of Agriculture and Fisheries indicate that there is a need for commercial greenhouses within the southeast portion of British Columbia to service the Calgary, Alberta and Spokane, Washington markets. There are existing greenhouses within the Kootenay Lake region which service the "transplant" industry for hobby farms and residential gardens. Currently, the viability of commercial greenhouses is weakened by the lack of a marketing and transportation infrastructure and the high cost of heating.

The geothermal resource at Riondel has the possibility of making a commercial greenhouse facility feasible. For the purpose of this study, a viable greenhouse would have an area of 4,000 m^2 (43,000 ft^2) and an air volume of 14,000 m^3, kept at an average temperature of 20°C (68°F) with a minimum night time temperature of 16°C (61°F).

The greenhouse complex is comprised of standardized quonset type modules grouped by joining individual modules at the eaves. An economical configuration for the proposed size of operation would be nine (9) modules each of 7 m (24 ft) wide by 60 m (200 ft) long nominal dimensions, for a total of 4,013 m^2 (43,200 ft^2) floor area, such quonset modules are approximately 4 m (13 ft) high at peak level. Each module would be fitted with a separate heating and ventilation system (i.e. one independent system per module).

The typical greenhouse modular structure is covered in two layers of polyethylene plastic. A pressurized air space is created between the layers of plastic to maintain a heat loss equal to that of conventional double glazing. Heat for the greenhouse is evenly distributed at low level to give the optimum benefit for plant root development.

A commercial greenhouse planting season would commence in March to produce June transplants for cabbage, tomatoes, broccoli, cauliflower and cucumbers. Seeding of these crops would be planted in two week intervals to carry the transplant crop season from mid-May to mid-July. Specific crops such as tomatoes and cucumbers would be taken to their full maturity for marketing in September and October. Off season production would be supplemented by specialty crops such as lilies, poinsettias and Christmas cactus.

The greenhouse complex would require an ancillary building of approximately 100 m^2 (1,075 ft^2) for sorting, office, washroom, seed storage and fertilizer storage areas.

A level site of approximately two hectares (five acres) would be required for the commercial greenhouse operation.

5.2.2 Proposed Heating System

For geothermal application, the heating and ventilation system would include a fan coil unit at one end of each module, complete with return/outside air mixing plenum, motorized outside air intake louvres, blower and hot water heating coil, one summer exhaust fan and one winter exhaust fan (both at the end wall opposite the fan-coil unit), hydronic blower type unit heaters suspended near the ceiling and/or finned-tube piping type heaters near the floor along the perimeter. For ideal growing conditions polybutylene piping, carrying "spent" return water from hydronic heating coils, installed at the bottom of planting trenches, to maintain approximately 20°C near the root level of plants, is recommended. Similarly, return water polybutylene piping, installed in-ground near the perimeter foundations, is recommended to provide an effective thermal break at the building edges.

Supply air distribution from the fan-coil unit in each greenhouse module is proposed via fabric tubing duct, ceiling-suspended along the centre of the module. Holes punched along both sides of this tube duct provide air passage openings along the whole duct length, resulting in an even-supply air distribution. Air jet streams, discharged from the tube duct disturb the normally stratified and warmer upper air layers near the top of the structure reducing the conduction heat losses. Further conduction heat loss reductions are achieved by blowing discharge air from the winter exhaust fan into the air space created by the two layers of plastic, which form the outer skin of the greenhouse module. Replacement outside air (make-up air), in amounts equal to the winter exhaust quantity plus an additional small amount for building pressurization, is introduced and heated via the fan-coil unit.

The geothermal heating system for the proposed 100 m^2 (1,075 sq. ft.) ancillary building would include ceiling suspended hydronic unit heaters and/or fan-coil type blower units and distribution ductwork.

Building codes permitting, all hydronic piping may be plastic (polybutylene), with supply piping insulated and sheathed. All hydronic coils and heaters must be supplied with hot thermal water. Alternatively, in areas where cooling is desirable, water-to-air heat pumps can be installed, complete with distribution ductwork, as required. Such heat pumps may be fed with "spent" return water from the greenhouses, thus reducing the overall demand quantities of thermal water for the greenhouse complex.

In addition to geothermal space heating, domestic water pre-heat and irrigation water tempering via cleanable plate-type heat exchangers is recommended. "Spent" thermal return water from heat exchangers may be utilized for heat pumps.

The proposed geothermal water distribution system for the complex would include insulated and sheathed supply piping from the geothermal main system connection to all greenhouse modules and the ancillary building, one or more system supply pumps (15 to 20 HP total approximately), non-insulated return piping to main system disposal connection and a return flow booster pump, (approximately 50% HP of supply pump total).

5.2.3 Energy Analysis

For the proposed greenhouse complex, configured of nine (9) quonset type modules each 7 m x 60 m x 4 m high with double glazed end walls and double-sheathed roof and sides of polyethylene plastic, the conduction heat losses for 18°C average indoor temperature and outdoor conditions of -20°C (2.5% January), 3734 degree days below 18° are:

Module end walls, roof, sides:	363,020 BTU/hr =	106.4 kW
Ventilation make-up air heating: (for 0.75 air changes/hr)	53,880 BTU/hr =	15.5 kW
Subtotal per Module:	415,900 BTU/hr =	121.9 kW
Total for 9 Modules:	3,743,100 BTU/hr =	1097.1 kW
Heat Loss per Floor Area:	86.65 $BTU/hr/ft^2$ =	0.273 kW/m^2

The conduction heat loss estimates per module include perimeter floor edge losses, hence the overall totals represent the worst case of nine (9) free-standing greenhouse modules.

It is recommended that a stand-by boiler system be provided, as back-up in case of geothermal system shut-down due to pump failure or for maintenance. Stand-by boilers (electric, oil or propane), and associated boiler circulation pumps, would utilize the geothermal water distribution piping system and hydronic heating components.

The back-up boiler system scenario allows two geothermal system options to be considered. Firstly, the geothermal system and all its components are selected to provide 100% of the heating load. Secondly, the geothermal system and components provide a portion of the required heating capacity, with the back-up boilers providing the additional capacity for the relatively few colder days per year.

Table 5 outlines the relationship between design heat demand (2.5% January) for various outdoor temperatures on a yearly basis (data for Nelson, BC).

Table 5: Annual Heat Demand at Various Outdoor Temperatures

OUTDOOR TEMPERATURE	% DESIGN HEAT LOAD	% BACK-UP HEAT REQ'D	DEGREE DAYS BELOW 18°C	% ANNUAL HEAT DEMAND
-20°C	100 %	0 %	3,734	100 %
-15°C	86.8%	13.2%	3,715	99.5%
-10°C	73.7%	26.3%	3,658	98.0%
-5°C	60.5%	39.5%	3,581	95.9%
0°C	47.4%	52.6%	3,374	90.4%
5°C	34.2%	65.8%	2,861	76.6%
10°C	21.2%	78.9%	2,012	53.9%

Table 5 indicates that, if the geothermal system is designed for -20°C outdoor temperatures, it would provide 100% of the heating requirements of the building. Similarly, a geothermal system designed to handle heating requirements down to 0°C, would only have to be sized at 47.4% capacity of the full load system and would be sufficient to handle all heat demands for 90.4% of the year, using only 47.2% of the geothermal water flow quantities required for the full load system. Below 0°C, a back-up system sized to at least 52.6% of full load capacity is required to provide additional heating for 9.6% of the year.

It should be noted that, according to weather data, for 2.5% of the total time period during which temperature records were accumulated in the area, outdoor temperatures below -20°C were encountered. Similarly, for 1% of the time, temperatures below -24°C were recorded. For greenhouses, where indoor temperatures must be maintained above 16°C, it is recommended that heating systems should be designed so as to handle all heating requirements down to the 1% level minimum outdoor temperatures (i.e. -24°C, Nelson, BC).

Taking into consideration the calculated total greenhouse heating loads and adding the space heating loads for the ancillary building, plus requirements for the irrigation water and domestic water heat exchangers, for a geothermal heating system capable of providing 100% of the design heat loads, a total volume flow of approximately 53.6 litres/sec of 37.8°C thermal water is required for the overall greenhouse complex. Alternatively, for a geothermal heating system designed for 60.5% of full load capacity, being capable of providing all heating requirements down to -5°C (i.e. 95.9% of yearly heating demand) and adding requirements for space heating of the ancillary building and the heat exchangers, the total thermal water (37.8°C) flow requirements are reduced to 35.0 litres/sec, approximately.

5.2.4 Capital Costs

Based on the estimated energy analysis data, budget pricing for equipment and materials, established in consultation with suppliers, and standard estimated procedures for installation contingencies and labour, the following cost estimates are intended to provide a comparison base for the proposed geothermal system alternates versus conventional space heating systems, as well as domestic and irrigation water heating systems.

Heating and ventilation system components such as boilers, distribution piping to greenhouse modules, greenhouse ventilators and fan-jet systems with heating coils, heating system piping within greenhouse enclosures and hydronic system pumps, are not considered for this capital cost comparison as these items are also used for the geothermal system (eg. stand-by boiler system back-up).

The largest hydronic heating coils which would be compatible with the proposed fan-jet system are capable of providing approximately 60% of the total estimated greenhouse heat load with 37.8°C thermal water entering. Hence, for the 100% capacity geothermal heating system, the additional 40% heating system capacity is to be provided with ceiling-suspended hydronic unit heaters (blower type), evenly spaced along the length of each greenhouse module.

The estimated total geothermal system costs for the 60% capacity greenhouse system, including below ground supply piping (insulated and sheathed) from geothermal main to boiler house, geothermal water supply pump, hydronic greenhouse heating coils (less credit for standard system coils), ductwork to house larger coils, cost difference for larger geothermal vs. standard distribution pipe size, irrigation water and domestic water heat exchangers, unit heaters, fan coil unit, ductwork, water-to-air heat pump (office) and geothermal piping for ancillary building, "spent" geothermal water return booster pump and below ground return piping to disposal main connection, are approximately $116,000, plus 15% contingencies, plus 7% G.S.T., or $143,000 total.

Similarly, for the 100% capacity greenhouse system, complete with additional hydronic unit heater, the overall installation costs are approximately $158,400, plus 15% contingencies, plus 7% G.S.T., or $195,000 total.

5.2.5 Operating Costs and Energy Cost Savings

Considering the estimated heat losses for the proposed greenhouse, the annual heating costs for an all-electric system would be approximately $128,750 (1991 electrical rates, including 7% G.S.T.), or $32.08/m^2.

For comparison, a 4,460 m^2 (48,000 ft^2) greenhouse complex in Langley, BC, of modular construction similar to the one proposed for Riondel, BC, experienced 1990 total heating costs of $64,705, or $14.51/m^2, using natural gas fired heating equipment. Assuming 70% average efficiency of gas heating systems and translating the 1990 costs for natural gas ($4.81 per giga joule) into 1991 electrical rates ($0.055 per kW hr, including 7% G.S.T.), the equivalent electrical heating costs for the Langley complex would be $119,415, or $26.77/m^2. It should be noted that design weather data for Langley, BC are -10°C (January, 2.5%), 3,117 degree hours, versus Nelson, BC at -20°C (January 2.5%), 3,734 degree days.

The estimated annual energy consumption costs for space heating, domestic and irrigation water heating for the proposed greenhouse complex are (1991 costs):

	Geothermal	All-Electric
Greenhouse, 100% capacity system:	$ Nil	$ 128,750
Greenhouse, 60% capacity system	5,280	128,750
Ancillary Building, domestic and irrigation water heating (18°C):	1,136	3,530
On-site thermal water distribution pumps @ 90% motor efficiency:	8,206	Nil
Total:	$14,622	$132,280

Not included in the operating cost analysis are general items, such as electrical lighting, exhaust systems, air distribution blower motors and proportioned operating costs for the geothermal well pump and main distribution system pumps.

Potential energy savings at the greenhouse application site are substantial. A greenhouse facility would have to justify the capital and operating cost of a production well and delivery system on its own unless it was planned in conjunction with the spa or fish hatchery. In the stand alone case, production capital cost would be $326,000 (Site B), pump energy cost would be $17,400/year (75 HP pump running 58% of the year). Additional operating costs would be $7,100/year for chemical scale treatment and $7,500/year for scheduled maintenance for a total of $32,000/year. Hence, the overall increased capital cost for geothermal over all electric would be $465,000, with yearly operating/maintenance costs of $46,600 to effect an annual energy cost savings of $85,700 (all 1991 dollars).

5.3 Fish Hatchery

5.3.1 Outline Specifications

The fish hatchery considered for the purposes of this study consists of a hatchery/spawning facility of 195 m^2 (2,100 ft^2) and a processing building of 195 m^2 (2,100 ft^2). The hatchery and spawning facility would have holding tanks of approximately 84,000 litres of continuously flowing water giving a capacity to produce 6,000,000 eggs annually. The hatchery/spawning facility and processing building's room temperature should be maintained at approximately 16°C (61°F).

Exterior rearing ponds, exposed to the outdoor elements, each of approximately 4.5 x 6.0 x 1.5 metres deep, or 40,000 litres, are proposed. Twenty-five rearing ponds with a total volume of 1,000,000 litres of flow through water would produce approximately 453,000 kilograms (100,000 lbs) of fish annually.

The flow through water for the hatchery/spawning facility and rearing ponds would be pumped from the lake at a rate of 38 litres/sec at a constant temperature between 7-9°C. The most suitable water temperature for fish breeding is 12°C (53.6°F) and may range between 10-14°C (50-57°F) without affecting the quality of the fish or increasing disease potential.

Fish hatcheries are a natural match with geothermal energy because of the large volumes of water required under reliable and controlled conditions at temperatures slightly above natural groundwater or surface runoff water temperatures. According to the British Columbia Trout Farm Association, however, the current market for trout fry and fingerlings trout from 225 grams - 245 grams (8 - 15 oz) is saturated, with the production in British Columbia, Idaho and Washington producing more marketable fish than the demand. Nevertheless, the scenario of a geothermal trout hatchery, which could be a government facility for enhancement of wild stocks for recreation fishing or a commercial facility supplying fingerlings for food production, is developed to demonstrate the economic potential of this application.

The required site area for the fish hatchery is approximately 1.5 hectares (3.7 acres).

5.3.2 Geothermal System Components and Capital Costs

The geothermal system for the fish hatchery complex would provide for the heating of 38 litres/sec of lake water via cleanable plate-type heat exchangers, plus space heating and ventilation make-up air heating of the processing building, as well as domestic water preheating via heat pumps.

The proposed process water heating system would consist of a bank of plate-type heat exchangers (one heat exchanger unit for stand-by), through which geothermal water at 37.8°C is pumped on one side and lake water (7°C to 9°C entering, 12°C to 14°C leaving) on the other side. The geothermal part of the system would be comprised of below ground polybutylene supply piping (insulated and sheathed) from the main thermal supply to the hatchery pump house, supply pump(s), insulated piping to the heat exchanger bank, return piping (non-insulated), return booster pump and below ground return piping for disposal of "spent" geothermal water in the flooded mine. The estimated installation cost for this part of the geothermal system is approximately $48,500, plus 15% contingencies, plus 7% G.S.T., or $59,600 total.

Space heating of the processing building would be achieved via water-to-air heat pumps, using "spent" geothermal water at approximately 30°C temperature returned from the lake water heat exchangers. A small pump would be required to deliver water to the heat pumps. Ventilation make-up air heating would be achieved via a fan-coil unit which is fed with 37.8°C thermal water. In addition, a small cleanable plate-type heat exchanger would provide domestic water pre-heating in the processing building. This heat exchanger is also fed with 37.8°C thermal water and would provide approximately 40% of the domestic water heat requirements. Insulated supply piping from the main geothermal water supply pump (pump house) to the make-up air heating coil and the domestic water heat exchanger would be required, with non-insulated piping returning "spent" thermal water to the main return booster pump. The estimated installation costs for this in-house part of the geothermal system serving the processing building is approximately $14,700, plus 15% contingencies, plus 7% G.S.T., or $18,090 total.

5.3.3 Operating Costs and Cost Savings

Based on constant lake water temperatures of 7°C to 9°C to the fish hatchery (year round), design outdoor weather data for Nelson, BC (re. processing building), estimated domestic hot water consumption and January, 1991 electrical energy costs (including 7% G.S.T.), the approximate annual consumption costs for water and space heating are:

	Geothermal	All-Electric
Lake water heating for tanks:	$ Nil	$ 380,620
Processing Building space heat and domestic water heating:	1,070	5,500
On-site thermal water pumping (at 90% pump efficiency):	11,980	N/A
Total:	13,050	386,120

Not included in the operating cost estimates and energy cost saving analysis are lake water pumping through heat exchangers to hatchery/breeding tanks, general lighting, building exhausts and proportioned annual operating costs for the geothermal well pump and main distribution system pumps.

In the stand alone case for the fish hatchery, thermal water supply capital cost would be $326,000, well pump energy costs would be $30,000 to supply 38 litres/sec, chemical scale treatment would be $13,300 and maintenance costs would be $7,500.

Total stand alone capital costs are $403,690, yearly operating and maintenance costs are $50,800 resulting in a potential energy savings for geothermal and conventional electric heating of $373,070.

6.0 INSTITUTIONAL AND LAND ISSUES

6.1 Resource Ownership and Development

Ownership and jurisdiction over groundwater and geothermal resources resides with the provincial Crown. Tenure or development rights for low temperature geothermal cannot be obtained under any existing provincial legislation. The Geothermal Resources Act (1982) provides for exploration permits and leases of geothermal resources, however, the Act excludes from the definition of geothermal resources "water that has a temperature less than 80°C at a point where it reaches the surface."

Thermal water at less than 80°C would thus be considered groundwater, which in British Columbia is specifically excluded from the Water Act.

Because of the considerable expense attached to initial well drilling, tenure to the resource is important to developers as a means of investment protection and resource conservation control. In order for low temperature thermal resources to be developed efficiently, it is necessary to settle a number of jurisdictional and ownership concerns and to establish a uniform legal framework (Acres and Nevin Sadlier-Brown Goodbrand, 1984).

A geothermal development well can be drilled without obtaining permits or specific resource development rights. Guidelines for waterwell construction, well completion, and well testing are outlined in "Guidelines for Minimum Standards in Water Well Construction, Province of British Columbia" by the Water Management Branch (1982). These guidelines should be followed in order to avoid unnecessary problems with regulatory agencies given the ill defined jurisdictional boundaries and to ensure safe operations.

Where groundwater is developed for community use, its utilization will be controlled under the Water Utility and Utilities Commission Acts and a Certificate of Public Convenience and Necessity would be required. This would not be the case for private energy extraction schemes such as the spa, greenhouse and fish hatchery applications but might be required by the owner of low-temperature geothermal rights distributing thermal water to customers.

6.2 Access

Production well locations with the greatest potential to tap thermal water are located on land currently owned by Cominco (Figure 3). Suitable development sites occur both in the Cominco property and on private land adjacent to Cominco. Cominco holds both their surface and mineral rights through title to crown granted mineral claims. Although Cominco does not have thermal rights, development that blocks access to the minerals would not be allowed. Therefore to gain access to the resource, either a purchase, purchase option or surface access lease is required from Cominco. Any option to purchase or leasing agreement would address concerns of both parties regarding liabilities and responsibility for public safety, environmental cleanup and reclamation expenses resulting from either the new geothermal operations (eg. CO_2 gas production) or the old mining operations (subsidence hazards, tailings dumps).

In a purchase agreement, all liabilities would presumably be the responsibility of the purchaser. Cominco considers that the mineable reserves are exhausted and has indicated (Grant, pers comm) that it would sell the land as a complete package totalling about 128.1 hectares (316.3 acres). The property includes several locations suitable for resort/spa, commercial greenhouse and fish hatchery developments.

7.0 CONCLUSIONS

The major conclusions of the study are:

1) Production rates under pump of 150 litres/sec of 35-40°C water are achievable from the main thermal zone.

2) A production well drilled from the Old Mill Site or constructed within the No. 1 Shaft, would be assured of tapping the Main Thermal Zone.

3) Other production well sites are available on Riondel Peninsula but these would incur exploration risk. Drill sites on land not owned by Cominco would necessarily be collared in incompetent footwall rocks and would be technically difficult or impossible to complete.

4) No viable exploration targets are present outside of the Riondel Peninsula.

5) Returning "spent" thermal fluid to the abandoned mine is the most economical way to dispose of large volumes of produced water and mitigate any adverse impacts associated with disposal on surface or to Kootenay Lake.

6) Initial "front end" cost for a production well is estimated to be \$266,000 - \$352,000 for the old Mill Site and No.1 Shaft site respectively. Total capital cost for thermal water delivery, including the production well, well pump, CO_2 removal and calcium carbonate treatment systems, and piping, is \$326,200 - \$365,000.

7) A solution to CO_2 removal and calcium carbonate scale formation in pipes is proposed and costed. Further pilot tests are required to demonstrate the utility of organic polymer scale inhibitors.

8) Existing buildings within Riondel are not cost effective for geothermal heating applications.

9) Resort spa development economics depend on the tourist market value compared to development costs incorporating thermal water supply costs. Geothermal heating costs savings for a resort/spa are significant when the thermal water supply costs are discounted.

10) Energy cost savings for commercial greenhouse or fish hatchery operations justify the capital cost of installing geothermal heating systems.

11) Costs for thermal water supply and hypothetical examples of geothermal heating generated by this study provide a framework for more detailed analysis of specific future developments.

12) Cominco is the largest owner of surface rights at Riondel with 128.1 hectares (316.3 acres). Excellent development sites are present on Cominco land and on adjacent private land on Riondel Peninsula. Viable production well sites occur only on the Cominco Property.

13) Purchase of Cominco land or a surface lease covering the production well location and pipeline will be required for development of the Main Thermal Zone water.

14) Thermal water ownership is vested in the provincial Crown, however, there are no provisions for exclusive rights to thermal water at temperatures less than 80°C.

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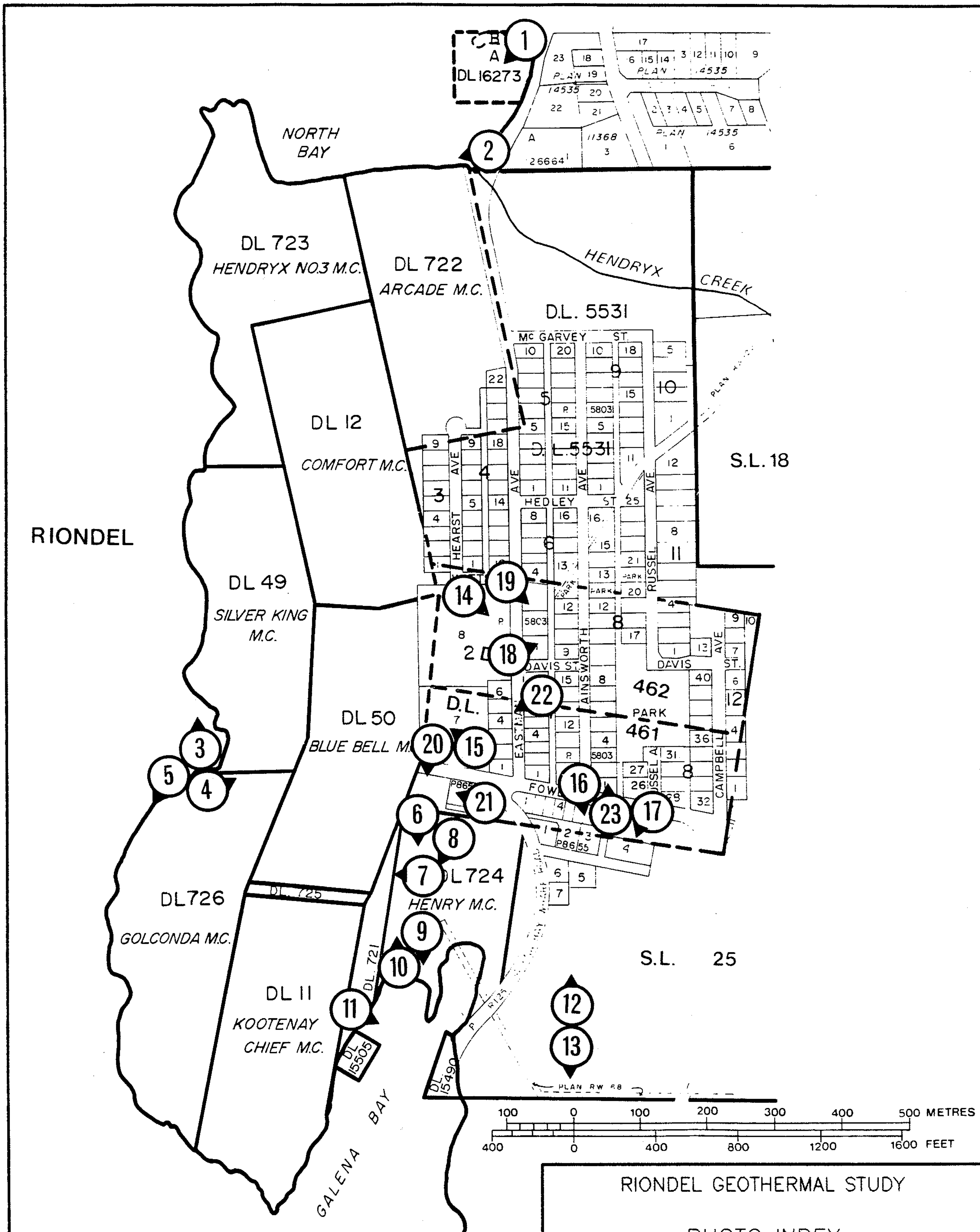
APPENDIX A

PHOTO INDEX



RIONDEL GEOTHERMAL STUDY

PHOTO INDEX

FAIRBANK ENGINEERING LTD.	Date: Mar. 1991	Fig. No.

Photo 1. North Bay Park with marina in foreground.

Photo 2. North Bay Park (view looking west).

Photo 6. Kootenay Chief Zone (view looking south). Manway to No. 1 Shaft is at right center. Flat area is former site of Bluebell Mill.

Photo 7. Collar of No. 1 Shaft. Hoist system and structure are removed, opening protected by steel grate and doors.

Photo 8. View looking south to Galena Bay over abandoned Bluebell Mill site. Potential site for resort, greenhouse facility or fish hatchery.

Photo 9. Galena Bay view looking south. Note deep water wharf.

Photo 10. Bluebell Mill foundation.

Photo 11. View to east across Galena Bay to government wharf.

Photo 12. Riondel Golf Course Clubhouse.

Photo 13. Riondel Golf Course.

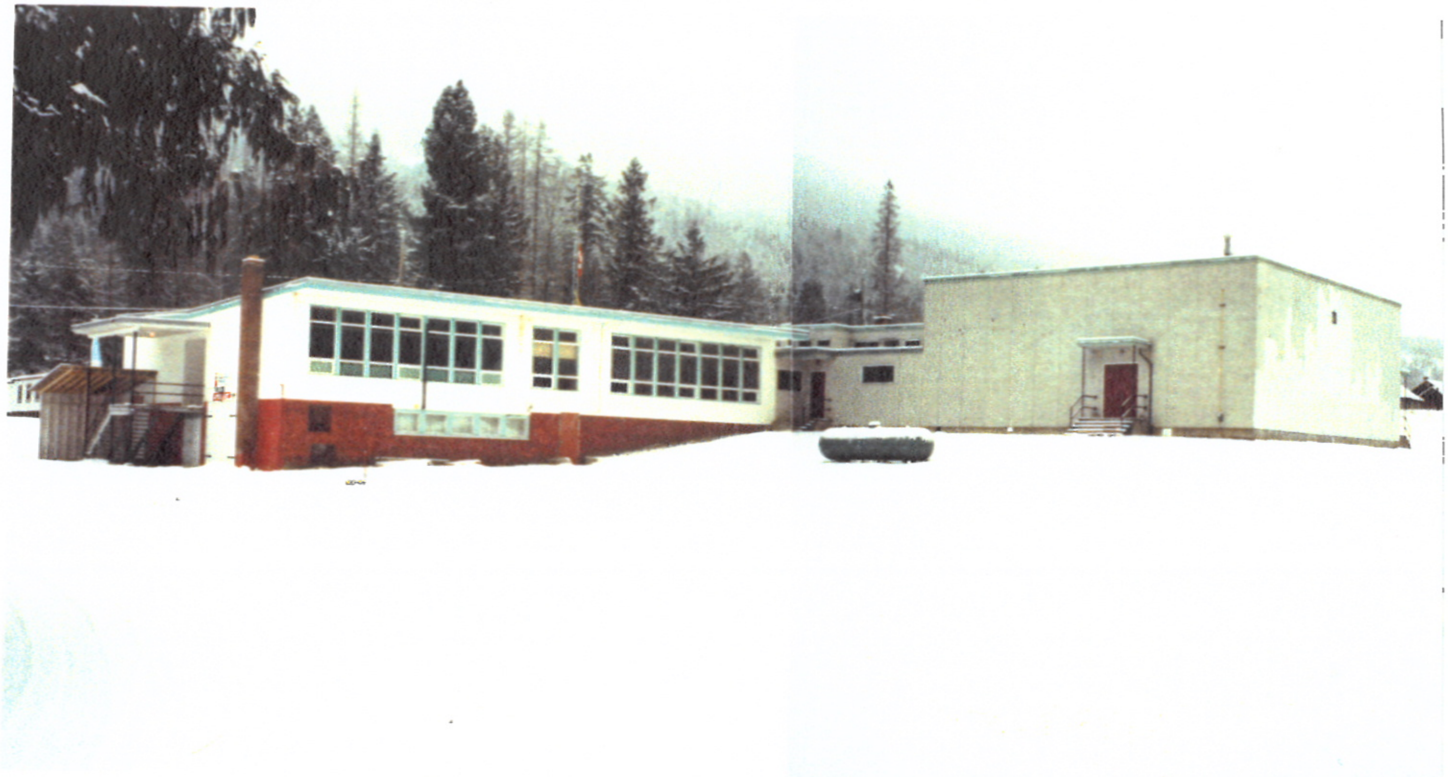


Photo 14a. Community Centre looking southeast - Eastman Avenue. Ambulance and fire pumper truck and muster stations are in basement bays on left end of the building. Community hall to right.

Photo 14b. Community Centre hall used for dances, plays, banquets, etc.

Photo 14c. Community Centre daycare.

Photo 14d. Community Centre pool and meeting room with kitchen facilities.

Photo 14e. Pumper Truck Bay. North end lower level of Community Centre.

Photo 14f. Ambulance Bay-north end lower level of Community Centre.

Photo 14g. Firehall Lounge - Community Centre.

Photo 14h. Firehall Muster Station - Community Centre.

Photo 15a. Recreation Centre - Fowler Street. Curling Club and Gymnasium.

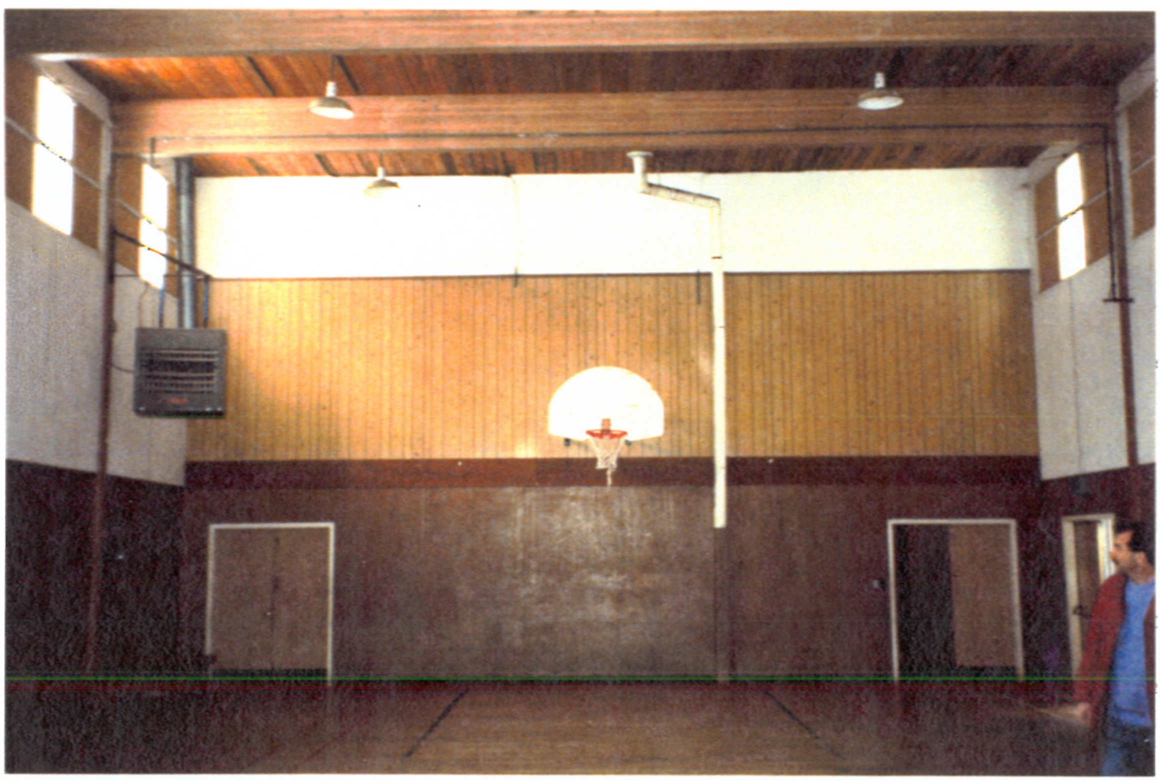


Photo 15b. Gymnasium showing propane unit heater suspended from ceiling.

Photo 16. Galena Bay Restaurant and Lounge - Fowler Street.

Photo 17. Bluebell Manor (senior citizens residence) - Fowler Street.

Photo 18. Riondel Market - Eastman Avenue and Davis Street.

Photo 19. Roman Catholic Church (Community Church in background) - Eastman Avenue.

Photo 20. Cominco Mine Office (closed) - Fowler Street.

Photo 21. Medical Clinic.

Photo 22. Residences, looking south along Eastman Avenue between Davis and Fowler Streets.

Photo 23. Modern era residence - Fowler Street and Ainsworth Avenue.

APPENDIX B

BUILDING INVENTORY

INDEX NUMBER	: 1
BUILDING NAME	: Bluebell Manor
LOCATION	: South west corner of Fowler Street and Russell Avenue
USAGE	: Senior Citizen's Housing
AGE	: 4 years
STOREYS	: Single storey, with crawl space
SITE COVERAGE	: 367 m^2 (3,950 ft^2)
GROSS AREA	: 367 m^2 (3,950 ft^2)
CONSTRUCTION	: Wood frame construction
HEATING SYSTEM	: Electric baseboard with 400 amp service and 80 kW design load
REMARKS	: Wall insulated with RSI 3.5 (R20) fibreglass batts. Ceilings insulated with RSI 7.0 (R40) cellulose.

Total annual electrical consumption (June 1989 - May 1990) was 50980 kW at cost of $2605.

January 1991 rate increase is 5% plus 7% GST for an equivalent annual cost of $2918.

A proportion of the consumption should be allocated to the electrical domestic hot water, ranges, lighting and general power.

The building has six meters for five residential units and common space. The common space consumption is 29% of the remaining five units.

INDEX NUMBER	: 2
BUILDING NAME	: Galena Bay Restaurant and Pub
LOCATION	: South west corner of Fowler Street and Ainsworth Avenue
USAGE	: Restaurant and Pub
AGE	: 30+ years
STOREYS	: Single storey
SITE COVERAGE	: 186 m^2 (2,000 ft^2)
GROSS AREA	: 186 m^2 (2,000 ft^2)
CONSTRUCTION	: Wood frame construction
HEATING SYSTEM	: Two oil furnaces, with 122,000 and 112,000 BTU output
REMARKS	: Building envelope insulation values considered minimal

INDEX NUMBER	: 3
BUILDING NAME	: Medical Clinic
LOCATION	: South side of Fowler Street, west of Eastman Avenue
USAGE	: Medical Clinic
AGE	: 30+ years
STOREYS	: Single storey
SITE COVERAGE	: 84 m^2 (900 ft^2)
GROSS AREA	: 84 m^2 (900 ft^2)
CONSTRUCTION	: Wood frame construction
HEATING SYSTEM	: Electric base board heating
REMARKS	: The Medical Clinic's original usage was the Community Fire Hall. The roofing and exterior siding were upgraded approximately 15 years ago.

Building envelope insulation values are considered minimal.

Total annual electrical consumption (June 1989 - May 1990) was 18,894 kW at a cost of $1175.00. January 1991 rate increase is 5% plus 7% GST for an equivalent annual cost of $1316.00. A proportion of the consumption should be allocated to the electrical domestic hot water, lighting and general power.

INDEX NUMBER	:	4
BUILDING NAME	:	Mining Office
LOCATION	:	West end of Fowler Street, south side
USAGE	:	Abandoned
AGE	:	40+ years
STOREYS	:	Two storeys
SITE COVERAGE	:	143 m^2 (1,526 ft^2)
GROSS AREA	:	286 m^2 (3,052 ft^2)
CONSTRUCTION	:	Wood frame construction
HEATING SYSTEM	:	Unknown
REMARKS	:	The mining office has been abandoned since the closure of the mine in 1972.

INDEX NUMBER : 5

BUILDING NAME : Riondel Community Cable/Video

LOCATION : West end of Fowler Street, north side

USAGE : Control Building

AGE : 10 years

STOREYS : Single storey

SITE COVERAGE : 19 m^2 (205 ft^2)

GROSS AREA : 19 m^2 (205 ft^2)

CONSTRUCTION : Wood frame construction

HEATING SYSTEM: Electric unit heater

REMARKS : For the two month period between December 1, 1990 and January 28, 1991, 1,540 Kilowatts were used.

Total annual electrical consumption (June 1989 - May 1990) was 10,930 kW at a cost of $773.00. January 1991 rate increase is 5% plus 7% GST, for an equivalent annual cost of $866.00.

INDEX NUMBER	: 6
BUILDING NAME	: Recreation Centre
LOCATION	: North west corner of Eastman Avenue and Fowler Street
USAGE	: Gymnasium and Curling
AGE	: 40 years
STOREYS	: Single storey, plus mezzanine
SITE COVERAGE	: 870 m^2 (8,365 ft^2)
GROSS AREA	: 945 m^2 (10,172 ft^2)
CONSTRUCTION	: Wood frame construction
HEATING SYSTEM	: Ceiling suspended propane unit heating the gymnasium. Curling rink - unknown.
REMARKS	: Mezzanine area of 75 m^2 (807 ft^2) has one stair access, with an exterior metal fire exit planned to be attached in the near future. Until the fire exiting is upgraded, the mezzanine is unusable.

The curling rink includes a 56 m^2 (600 ft^2) addition, erected within the last 10 years.

Building envelope insulation values are considered minimal.

INDEX NUMBER : 7

BUILDING NAME : Community Centre

LOCATION : South west corner of Eastman Avenue and Watts Street

USAGE : Main Floor: Library, Dance Hall, Library, Senior Citizen's Lounge, Day Care and Youth Activities room.
Lower Floor: Fire and Ambulance Vehicle Storage and the fighter's Office/Lounge.

AGE : 40 years

STOREYS : single storey, with crawl space and partial basement of 269 m^2

SITE COVERAGE : 1,115 m^2 (12,000 ft^2)

GROSS AREA : 1,384 m^2 (14,900 ft^2)

CONSTRUCTION : Wood frame construction

HEATING SYSTEM: Oil furnace with air duct system. Ceiling suspended propane unit heater in dance hall (gymnasium).

REMARKS : The Community Centre's original usage was a seven classroom Elementary School with gymnasium.

The original single classroom school underwent substantial additions in 1953, 1957 and 1960.

Building envelope insulation values are considered minimal.

Annual propane consumption is 450 litres at a cost of $136.00 (tank was recharged, once in April 1990 at 1,800 litres, since its original installation in 1986).

Annual oil consumption is 10,426 litres at a cost of $5440.00.

Allowances should be added for unit cost increases and GST.

INDEX NUMBER : 8

BUILDING NAME : Riondel Market

LOCATION : North east corner of Eastman Avenue and Davis Street

USAGE : General Store, Liquor Store and Post Office

AGE : 20 years

STOREYS : single storey

SITE COVERAGE : 112 m^2 (1,200 ft^2)

GROSS AREA : 112 m^2 (1,200 ft^2)

CONSTRUCTION : Wood frame construction

HEATING SYSTEM: Three 5 kW electric unit heaters, ceiling suspended

REMARKS : Total annual electrical consumption (June 1989 - May 1990) was 45,470 kW at cost of $2547.00. January 1991 rate increase is 5% plus 7% GST for an equivalent annual cost of $2853.00. A proportion of the consumption should be allocated to the electrical domestic hot water, lighting, refrigeration and general power.

INDEX NUMBER	:	9
BUILDING NAME	:	Community Church
LOCATION	:	Eastman Avenue, at mid-block east side between Watts and Davis Streets
USAGE	:	Church
AGE	:	20 years
STOREYS	:	Single storey
SITE COVERAGE	:	93 m^2 (1,000 ft^2)
GROSS AREA	:	93 m^2 (1,000 ft^2)
CONSTRUCTION	:	Wood frame construction
HEATING SYSTEM	:	Unknown
REMARKS	:	

INDEX NUMBER : 10

BUILDING NAME : Roman Catholic Church

LOCATION : South east corner of Eastman Avenue and Watts Street

USAGE : Church

AGE : 20 years

STOREYS : Single storey

SITE COVERAGE : 93 m^2 (1,000 ft^2)

GROSS AREA : 93 m^2 (1,000 ft^2)

CONSTRUCTION : Wood frame construction

HEATING SYSTEM: Unknown

REMARKS :

INDEX NUMBER	: 11
BUILDING NAME	: 162 Residences
LOCATION	: Within the community proper, in an area of 10 hectares (24.7 acres)
USAGE	: Single family
AGE	: Vary between 50 years to current, with approximately 75% at an age of 40+ years
STOREYS	: 75% single storey, 25% two storey
SITE COVERAGE	: Vary between 140 m^2 (1,500 ft^2) to 70 m^2 (750 ft^2) with an average area of 102 m^2 (1,100 ft^2)
GROSS AREA	: 162 units x 102 m^2 = 16,524 m^2 (177,870 ft^2)
CONSTRUCTION	: Wood frame construction
HEATING SYSTEM	: 50% propane/oil, 50% electric
REMARKS	: