ISSN 0706-9413

Pacific Forest Research Centre

ENERGY FROM FOREST BIOMASS ON VANCOUVER ISLAND

PAUL H. JONES & ASSOCIATES LIMITED, VANCOUVER, B.C.

Energy ENFOR from the Forest

Énergie ENFOR de la Forêt

VICTORIA, B.C.
BC-X-197, JULY, 1979

TABLE OF CONTENTS

ABSTRACT

A study was performed on Vancouver Island to determine the availability and cost of forest biomass for energy production. Total annual availability of logging slash, red alder and material from precommercial thinnings is 195 million cubic feet. Cost of removal ranged from a high of $73.50/cunit to a low of $25.10/cunit. Within the economic road hauling distance of 30-40 miles, 4 generation sites were identified: Port McNeill/Beaver Cove, Campbell River/Menzies Bay, Lake Cowichan and Port Alberni. Wood costs at these locations would give a fuel cost of about 20 mills/KWH.

RESUME

Une étude a été effectuée sur l'île Vancouver pour déterminer la disponibilité et la coût de la biomasse forestière en vue de la production d'énergie. La disponibilité totale annuelle de rémanents de coupe, d'Aulne rouge et de matériel provenant d'éclaircies commercialisables est de 195 millions de pieds cubes. Les coûts de déblaiement ont varié de $73.50 à $25.10 le cunit. A l'intérieur de la distance de débardage de 30 à 40 milles, quatre stations génératrices ont été identifie'es; ce sont: Port McNeill/Beaver Cove, Campbell River/Menzies Bay, Lac Cowichan et Port Alberni. Les costs de bois à ces endroits pourraient générer un coût d'environ 20 mills/kWh pour le combustible.

FOREWORD

ENFOR is the bilingual acronym for the Canadian Forestry Service's ENergy from the FORest (ENergie de la FORet) program of research and development aimed at securing the knowledge and technical competence to facilitate, in the medium to long term, a greatly increased contribution from forest biomass to our nation's primary energy production. This program is part of a much larger Federal Government initiative to promote the development and use of renewable energy as a means of reducing our dependence on petroleum and other non-renewable energy sources.

ENFOR projects are selected from among proposals submitted by private and public research organizations according to scientific and technical merit, in the light of program objectives and priorities. Regardless of proposal source, projects are carried out primarily by contract. For further information on the ENFOR program, contact...

ENFOR Secretariat
Canadian Forestry Service
Department of the Environment
Ottawa, Ontario
K1A 0E7

... or the director of the establishment issuing the report.

This report, based on ENFOR project P-25, was produced under contract (DSS File No. OSB78-00120) by Paul H. Jones and Associates, Ltd., Vancouver, B.C. The conclusions of this report are the sole responsibility of the author, and may not correspond to the policies or views of the Government of Canada, its departments or agencies.

The report has been reviewed by a number of persons, who were generally satisfied with its content. However, two substantive questions arise, which are detailed as follows:

1. The manner in which the logging residues were sampled may lead to an overestimate of volume. The basic approach taken by the consultant is applicable if the transects are taken in random directions. However, the transects were, in fact, taken perpendicular to the general orientation of the slash, thus invalidating the statistical tests for accuracy and precision.

2. The logging costs outlined in Schedule 1 of Chapter 7 appear on examination to be somewhat low.

In the estimate, 74 Ccf of logs and debris are yarded in a shift and the average cost of yarding logs and debris is $21.60 per cunit. This cost is employed as the cost of yarding debris and no account is made of the increased cost incurred in the reduction of log yarding productivity that will result if debris is yarded in addition to logs. The concept of the estimate is erroneous and it would apply only if the entire stand were to be utilized for energy.

Average productivity of a high lead yarder in average conditions (volume of 80 to 100 cunits per acre, terrain even, landings without undue space restriction) is approximately 75 cunits per shift. If the yarder had to yard debris in addition to logs, productivity would depend on the ratio of debris to logs. In average conditions, it would be reasonable to expect productivity to be reduced to approximately 55 cunits of logs and debris per shift. It is assumed that 10 cunits of debris and 45 cunits of logs would be yarded. In practice, there would be great variations in the proportion of debris. Decadent cedar, hemlock stands would produce a greater proportion of debris and terrain would be an important factor in all stand types.

Yarding debris in addition to logs would require an additional choker man compared to yarding logs. The'yarder costs noted in the report are reasonable and this estimate adapts the costs as follows:

Yarder operation costs in logs
$1,395 per shift

Yarder operation costs in logs and debris
$1,580 per shift

If the "average" stand was yarded and only logs were extracted, costs are $\frac{\$1580}{55}$ cunits = $28.72 per cunit.

Incremental costs of yarding debris are:

$$\$28.72 + \frac{(28.72 - 18.60)}{10} \times 45$$
$$= \$28.72 + 45.54$$
$$= \$74.26 \text{ per cunit of debris.}$$

Schedule 1 appears to employ a long-boom-type loader for loading yarder debris and debris which it can reach along right-of-ways. The material reached on the right-of-way would not have a yarding cost and it would tend to reduce the average cost of debris on the truck. Total cost of debris on the truck would approximate $85.00 per cunit, including supervision and administration.

Schedule 2 notes that a similar size of yarder would be required for logging debris. Yarding distances are generally less than 800 feet and, owing to the lower weight of debris pieces, a mini spar could be employed and yarding costs could be reduced from $58.10 to approximately $42.00 per cunit,

PAUL H. JONES & ASSOCIATES LIMITED
FOREST INDUSTRY DEVELOPMENT CONSULTANTS
270 — 2025 WEST 42nd AVENUE • VANCOUVER, B.C., CANADA V6M 2B5 • TEL. (604) 263.9119
CABLE: JONFOR

March 15, 1979

Dr. G. H. Manning
Department of the Environment
Canadian Forestry Service
Pacific Forest Research Centre
506 West Burnside Road
Victoria, B.C.
V8Z 1M5

Dear Dr. Manning:

I am pleased to present herewith our final report, in twenty copies, entitled ENERGY FROM FOREST BIOMASS ON VANCOUVER ISLAND as per our contract OSB 78-00120.

The principal finding is that forest biomass appears to have the potential of providing the Island with electrical energy, in at least four locations, at fuel costs which are similar to those of coal. While we have a high degree of confidence in our estimates of physical residues and other wood availabilities <u>we must caution you with regard to our estimate of the costs of assembling and delivering this unhomogeneous material to potential power generation sites, because none is being collected and delivered presently. and because its availability would immediately: Lead to questions with regard to its use as either the raw material for products or fuel</u>.

Yours very truly,

PAUL H. JONES & ASSOCIATES LIMITED

Paul H. Jones
President

SUMMARY OF MAJOR FINDINGS

1. Total annual availability of wood residues from logging and precommercial thinnings and from red alder stands on Vancouver Island amounts to about 195 million cubic feet, comprised of 92 percent logging residue, 5 percent alder and 3 percent precommercial thinnings. By the year 2000, available volumes could decline to about 140 million as a result of changes in utilization levels and the shift of logging away from mature old-growth stands to second-growth stands.

2. The costs of removing logging debris at the time of primary logging - as opposed to returning to logging sites after logging - and of felling and logging pure stands of alder are estimated to be $43.10 per cunit and $25.10 per cunit, respectively.

3. The above logging costs combined with relatively short hauls of some 30 to 40 miles to four potential electrical energy conversion sites on Vancouver Island suggest that forest biomass could be converted to energy at a fuel cost of about 20 mills per kwh, which compares favourably with fuel costs of coal.

4. The four sites where forest biomass might be converted to electrical energy are in the vicinity of:

   Port McNeill/Beaver Cove
   Campbell River/Menzies Bay
   Lake Cowichan
   Port Alberni

5. Installations built at these locations could have a total capacity of 210 MW, with plant sizes varying from 35 to 72 MW.

6. The four plants identified above would use about 45 percent of the logging debris created annually, and a part of the annual potential harvest of alder, provided estimated costs of extraction, transport and processing of residues and alder are correct.

1. STUDY OBJECTIVES AND SCOPE

Early in 1978, the Pacific Forest Research Centre of the Canadian Forestry Service invited proposals from interested parties for an assessment of the volumes and locations of forest biomass which might be available in the future from forest areas on Vancouver Island for purposes of electrical energy generation.

Concern was growing on the Island over the longer term needs for energy. Several agencies, including B.C. Hydro and the B.C. Energy Commission, were examining the costs of thermal generation using coal and natural gas against the alternative of bringing hydro power from the mainland. Part of the expected future demand for power was the forest companies, which themselves create forest residues as a product of their logging activities.

Paul H. Jones & Associates Limited was selected to make the assessment on behalf of the Canadian Forestry Service, with specific terms of reference to examine the supply and economic feasibility of using logging residues, alder stands and residues from precommercial thinnings for electrical energy generation on the Island.

The basic requirements for the study were that it be carried out using surveys of appropriate statistical design to assemble reliable data on volumes of forest biomass which might be transported in either solid or fibre form to three conversion sites for energy generation. Costs of extracting, processing, transporting and generating energy using forest biomass were to be compared with more conventional forms of energy.

2. PERSPECTIVE AND BACKGROUND

This is one of a number of studies being carried out concurrently across Canada, funded by Environment Canada, which look at the energy generation possibilities of forest biomass, a renewable resource. Earlier Canadian Government studies have looked at the extent to which sawmill and plywood mill residues are used for energy and their future potential (Neill and Gunter Ltd. 1978).

Some of the most rigorous investigations into energy generation from forest biomass, and the associated surveys of forest residues, have been carried out in the U.S. Pacific Northwest. That region has developed most of its hydro resources and, with limited conventional forms of energy, it has been forced to look toward forest residues (mill residues being almost fully utilized) to meet a growing proportion of its future energy needs. During 1978, a Bioconversion Workshop was held in Portland, in October, and the Comptroller General's office released a report to Congress entitled, "Region at the Cross-roads – The Pacific Northwest Searches for New Sources of Electrical Energy." This latter document observes:

> The conversion of waste biomass materials–principally wood residues from lumber and papermills--into electricity or electricity replacements already plays an important role in the region. Recent developments indicate that a near-term expansion of that role may be likely.
>
> In 1974 wood residues accounted for about 13 percent of industrial energy consumption in the region and about 5 percent of the total energy consumed. Wood residues are used by regional forest products companies to meet many of their needs for process heat and electricity. Several northwest municipalities purchase surplus electricity from such operations.

A list of energy from wood biomass studies and papers dealing with wood residue survey methods is included in the Bibliography. Many of the studies have been carried out by the US. Forest Service.

In British Columbia, the British Columbia Hydro and Power Authority's projected increase in energy demand, or load growth for the Island, is 5.6 percent annually (British Columbia Hydro and Power Authority 1978). This compares with forecasts for the U.S. Pacific Northwest, which range from 0.47 percent to 4.5 percent per year for the next 25 years (United States, Comptroller General 1978). The B.C. Energy Commission's projection of 2.5 percent for all of British Columbia (British Columbia Energy Commission 1978) is significantly below that of B.C. Hydro. Each has different expectations of family formation, industrial development and overall economic growth. The B.C. Energy Commission states:

> In recent years in Canada, total energy requirements forecasts have been revised downwards in all jurisdictions, as higher energy prices, conservation measures, lower rates of increase in population and other factors have contributed to a much slower rate of increase. in both per capita and total requirements. With the possible exceptions of Alberta and Saskatchewan, forecasted annual average growth rates in the vicinity of 2.0 to 3.0 percent per year are now common in all provinces.

Vancouver Island's economy is dominated by the forestry sector. The six large pulp and paper mills on the Island and 21 large sawmills[1] are at the same time the major industry and the major users of power on the Island. Annual paper and paperboard production is about 1 million tons, while pulp output is some 1.2 million tons. In addition, Island sawmills produce about 1,600 million feet of lumber per year. The forest products companies use in excess of 3 million barrels of heavy fuel oil per year and about 820,000 units of hog fuel. They generate some 65 MW of power for their own use, most of it from hog fuel. Fifty percent of B.C. Hydro's electrical energy sales on Vancouver Island are made to nine large forest industry buyers of power. World requirements for pulp and paper, to which these mills respond, are growing at a rate of some 3 to 4 percent per year.

The forest area of Vancouver Island is about 6,512 thousand acres (2,635 thousand hectares), or 82 percent of the land area of the Island. The annual allowable cut or sustained yield capacity of the Island forests is in excess of 600 million cubic feet (17 million cubic meters) according to the B.C. Forest Service. Many of the more productive forests on the Island are under long-term tenure to forest companies through Tree Farm Licences. In addition to the Tree Farm Licences there are large areas of Crown land dedicated to timber production under the Public Sustained Yield Unit scheme. This latter form of tenure attracts both large and small companies into uncommitted areas for timber. The Esquimalt and Nanaimo Railway Belt lands on Vancouver Island, covering some 1.9 million acres, are still largely in private hands (see Appendix A).

By the mid 1980s, it is likely that a new thermomechanical pulp/newsprint mill will be in operation on Vancouver Island. It is also likely that capacity expansions will have been completed or underway at most existing mills and that total consumption of hog fuel could have doubled while heavy fuel purchases might have declined to something less than 2 million barrels. At that time Coast supplies of hog fuel will be under severe pressure, as is the case today in the U.S. Pacific Northwest, an area which is on the threshold of using logging

[1] Each producing in excess of 25 million board feet per annum.

residues for generation of power.

Logging residues are a product of logging. However, the amount of residues left in the woods depends on market conditions, the species being logged, the amount of rock in the area, the biogeoclimatic zone, the amount of decay in the original stand, the distance from the log dump and the vigilance of the B.C. Forest Service. The amount of residue lying on the ground after logging varies, not only from place to place but from time to time. For instance, a strong cedar market might lead to less cedar in the debris. A high incidence of rot in hemlock and balsam, as in overmature stands, would naturally lead to heavy accumulations of large logs of these species at the landings. A poor pulp market might result in above normal accumulations of small hemlock and balsam logs in the woods.

As supplies of surplus hog fuel diminish, attention can be expected to focus on logging residues. Similarly, as markets for B.C. lumber, pulp and paper expand, there will be a corresponding increase in the use of biomass for both product and for fuel.

Vancouver Island's logging and precommercial thinning residues, as well as alder stands, are an obvious and promising source of electrical energy for Island communities. The role these renewable sources of energy might be expected to play in the future is examined in the following chapters.

3. LOGGING RESIDUES

In September 1978, two field parties of Paul H. Jones *81* Associates Limited carried out a survey of Vancouver Island logging residues as a part of this Biomass Study in order to determine the nature, volume and location of residues which might be used for energy generation on the Island. For purposes of the study, logging residues were considered to be sound, partially rotten and rotten woody materials over 2 feet in length and over 3 inches in diameter, lying on or near the ground after logging operations had ceased. Roots, stumps and standing trees were excluded from the inventory. Field talliesdistinguished sound from rotten material. Sound volumes as shown in this report include some material with incipient decay but exclude material with advanced decay where the advanced decay represents more than 50 percent of the piece tallied. All sound logging debris volumes shown represent material which might be used for lumber, pulp chips or fuel. Very little material was found that qualified as saw timber. The vast bulk of the residues was comprised of pieces which had been broken in the felling or yarding operation. Some of the material tallied represented trees that had fallen naturally prior to the logging operations and were therefore not a part of the standing volume when loggingoperations commenced.

Description of Residue Survey Methods

Logging residues on recently logged areas of Vancouver Island were measured, using the rapid and easy-to-use line intersect (or line transect) method introduced in New Zealand (Warren and Olsen 1964) and now widely adopted, especially in the energy short U.S. Pacific Northwest, during the past 10 years. The technique is described in James K. Brown's "Handbook for Inventorying Downed Woody Material" (1974). The method involves counting downed woody pieces that intersect vertical sampling planes and measuring the diameters of intersected pieces if they are over a chosen minimum diameter.

The Vancouver Island residue survey was designed in such a way that the results might be compared with B.C. Forest Service and forest company data as well as with U.S. Pacific Northwest Studies. LANDSAT photos were used to identify active logging areas, using appropriate colour separations. 'Some 430 recent openings were identified, marked on a map and numbered. The average size of openings was established from B.C. Forest Service and industry experience and the product of the number of openings times the average size (130 acres) was found to compare favourably with the actual B.C. Forest Service reported area logged on Vancouver Island; i.e., some 55,638 acres.[2]

The next step was a random selection of openings, without regard to tenure, by Ranger District, followed by the actual field enumeration of logging debris, using the line intersect method in the randomly chosen logging openings. To minimize errors in the results, most transects were run at right angles to the direction of yarding because there is a tendency of pieces to be directionally oriented in the logging debris.

Plots of 200 feet were used along a con-

[2] See Table 2.

tinuous transect, with pieces tallied by species in inch diameter classes from 3 to 6 inches, 2 inch classes from 6.1 inches to 10 inches, and actual diameters and lengths over 10 inches, according to sound and rotten categories.

A total of 704 plots, each 200 feet in length, were tallied in 42 openings from the north end of Vancouver Island to the outskirts of Victoria in the south.[3] In most openings 20 200-foot plots were measured. Where there was considerable uniformity in the volumes, sizes and number of pieces being tallied, a lesser number of plots was taken. Where an opening was obviously more than 2 years old, which occurred three times, the nearest new opening (1977 or 1978 logging) was substituted. Two west coast openings, which were inaccessible, in terms of time and expense, were switched for two accessible west coast locations.

Logging Residue Volume Results

Average sound volumes per acre of logging residues per opening on Vancouver Island varied, in the 42 openings, from 828 cubic feet on a low site Douglas-fir area near Duncan to 8,792 cubic feet on a high site rocky red cedar area near Tofino, for material 3 inches and over. The average volume per acre for all 42 openings was 3,174 cubic feet of sound wood.[4] The average volume of sound and rotten wood per acre was some 18 percent higher at 3,742 cubic feet.

The average degree of precision attained per Ranger District in the survey in terms of volumes per acre was + 18.2 percent at the 95 percent confidence level. This result is similar to that obtained by Howard & Ward in "Measurement of Logging Residue - Alternative Application of the Line Intersect Method" (1972). The degree of precision achieved for total volume of residues on Vancouver Island, based on the study sample, was computed to be ± 10 percent of the actual volume at the 95 percent probability level. Naturally, at the local level, the precision can be expected to be somewhat less, especially where large differences occur within specific areas such as Ranger Districts. For B.C. Forest Service residue surveys, see Appendix B.

The total sound volumes of residues by Ranger District presented in Table 2 are a simple product of average volumes per acre as obtained in the field surveys, times the area logged. Port McNeill, Tofino and Gold River were the three Ranger Districts with the highest total volume of logging residues in 1977. This result differed from the ranking of Ranger Districts in terms of total areas logged, of which the leading three were Port Alberni, Port McNeill and Gold River.

Significantly, the highest volumes of residues per acre and in total tend to exist, as may be expected, in areas fairly remote from centres of population and thus from centres of the highest energy consumption.

Logging Landing Residues

The line intersect method used to obtain the above estimates of logging debris is an inappropriate system to sample the sometimes large volumes of wood that accumulate, especially in the high-lead cable yarding system, at logging landings or at dry land sorting areas. The method is inappropriate because landing accumulations of debris are spot rather than area volumes, which require a system of spot rather than area sampling.

The B.C. Forest Service unrecovered wood survey of landings for 1977 provided an estimate of 724,000 cubic feet on 404 landings on the Island or approximately 1,800 cubic feet per landings. Our own studies suggested there were some 2,400 landings (on some 300 openings each with 2,600 cubic feet of sound or nearly sound material per landing, yielding an estimate of landing volumes for Vancouver

---

3 **Only one** out of **the 42 openingsfell in a second growth logging area.**

4 **The basic formula used to obtain volume per acre results as derived by Van Wagner,** is:

$$V = \frac{\pi^2 \Sigma d^2}{8L} \cdot \frac{43,560}{144}$$

where:

V = **Volume per acre in cu. ft.**

d = **diameter** of **residue at point** of **intersection in inches**

L = **length** of **sample line in feet**

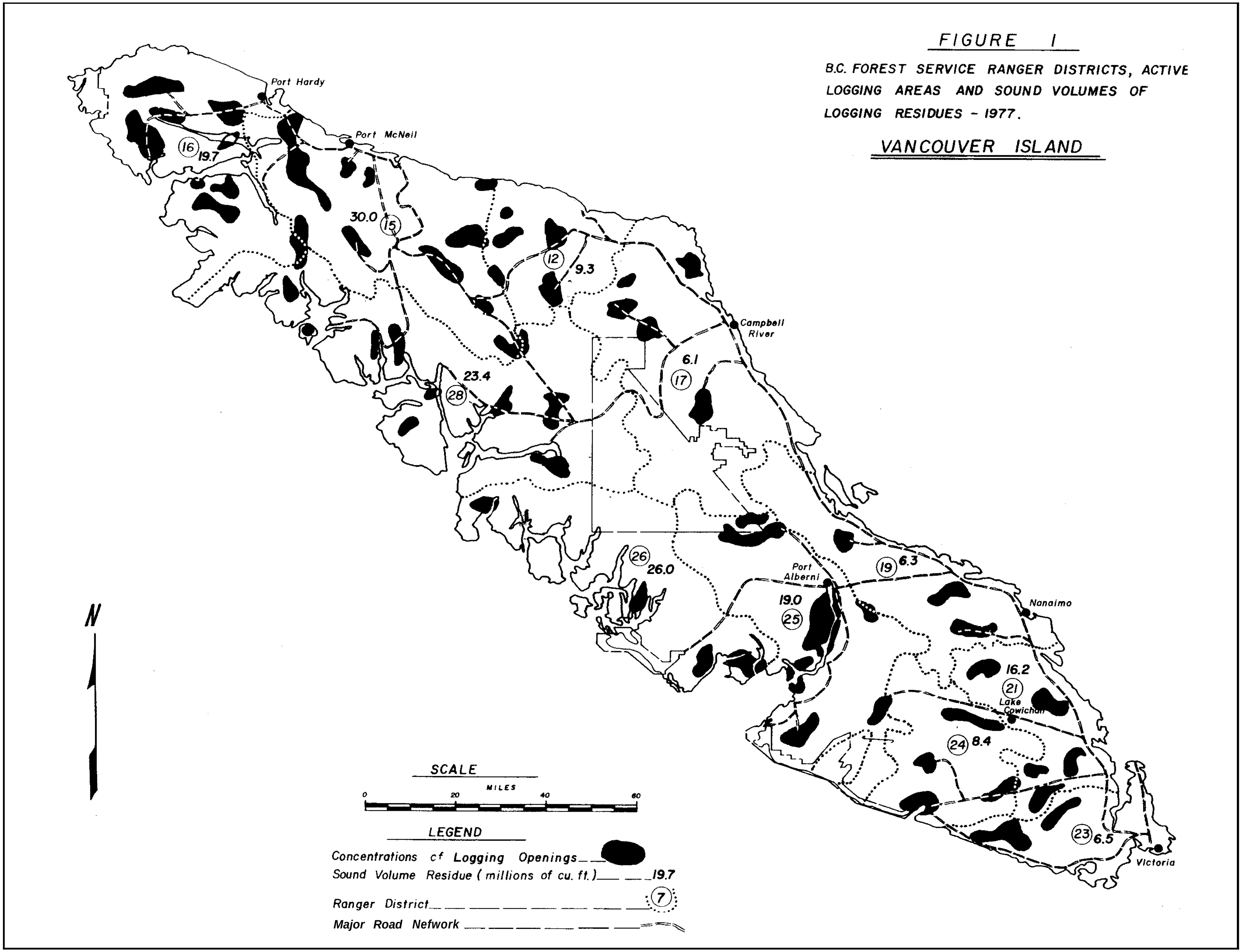


FIGURE 1

B.C. FOREST SERVICE RANGER DISTRICTS, ACTIVE LOGGING AREAS AND SOUND VOLUMES OF LOGGING RESIDUES - 1977.

VANCOUVER ISLAND

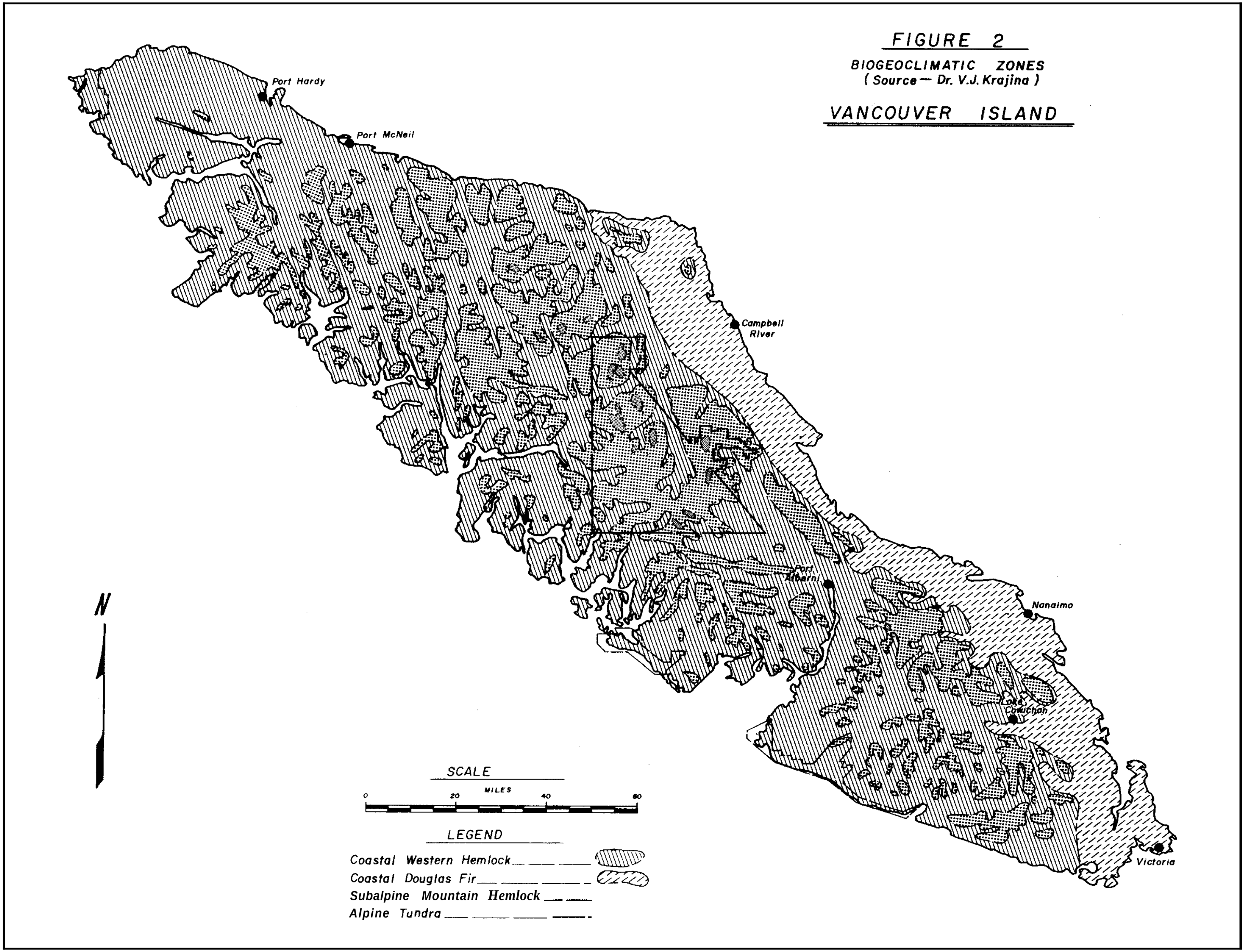


FIGURE 2

BIOGEOCLIMATIC ZONES
(Source — Dr. V.J. Krajina)

VANCOUVER ISLAND

Table **1**

Vancouver Island Logging Residues **1977**

Sound Volumes **Per** Acre in Cubic Feet

Opening No.	Name	Ranger District No.	Ranger District Name	Biogeo-Climatic Zone[1]	Sound Volumes Per Acre[2] Over 3"	Over 4"	Over 10"
1	Mocjack River	16	Port Hardy	CWH	5968	5854	5009
2	William Lake	16	Port Hardy	CWH	3138	3024	2276
3	Nahwitti Lake	16	Port Hardy	CWH	3683	3556	2594
4	Coal Harbour	16	Port Hardy	CWH	3289	3211	2382
5	Neurotsus Inlet	16	Port Hardy	AMH	1631	1540	701
6	Kilpala River	15	Port McNeill	CWH	7429	7132	4918
7	Nimpkish Lake East	15	Port McNeill	CWH	2745	2704	1701
8	Bonanza Lake North	15	Port McNeill	AMH	1465	1366	765
9	Bonanza Lake South	15	Port McNeill	CWH	5742	5664	3506
10	Nimpkish Lake **S.**	15	Port McNeill	CWH	2337	2255	1012
11	Nimpkish-Woss	15	Port McNeill	CWH	4791	4612	3150
12	Zeballos Pass Wolf Lake	15	Port McNeill	CWH	2673	2598	1769
13	Espinoza Inlet	28	Gold River	CWH	1975	1895	1285
14	Zeballos Lake	28	Gold River	CWH	1559	1470	457
15	Woss. Lokwa Creek	15	Port McNeill	CWH	4112	4056	3238
16	Tlupana River Pass	28	Gold River	AMH	5339	5238	3741
17	Gold River Upawa	28	Gold River	CWH	3491	3361	2080
18	Montague Creek	12	Sayward	CWH	2761	2671	1900
19	White River	12	Sayward	AMH	2215	2154	1641
20	Stewart Main	12	Sayward	AMH	2986	2871	2297
21	Cold Lake	17	Campbell River	AMH	2083	2027	1280
22	Salmon Main	17	Campbell River	CDF	3095	2815	1838
23	Oyster River	17	Campbell River	CDF	1028	951	276
24	Elsie Lake	25	Port Alberni	CWH	1298	1223	487
25	Taylor River W. Sproat Lake	25	Port Alberni	AMH	3569	3357	2374
26	S. Sproat Lake	25	Port Alberni	CWH	2314	2258	1146
27	Cous Ck. Alberni West	25	Port Alberni	CWH	1242	1199	627
28	Lizard Main	25	Port Aiberni	CWH	1277	1204	779

Table 1 (cont'd)

Opening No.	Name	Ranger District No.	Ranger District Name	Biogeo-Climatic Zone[1]	Sound Volumes Per Acre[2] Over 3"	Over 4"	Over 10"
29	Sarita	25	Port Alberni	CWH	3874	3744	2687
30	Kennedy Lake North	26	Tofino	CWH	8087	7998	6734
31	Kennedy Lake South	26	Tofino	CWH	8792	8634	6666
32	Toquart Bay	26	Tofino	CWH	2988	2950	1800
34	Cowichan Lake N.	19	Parksville	CWH	1856	1795	1186
35	Cowichan Lake N.	21	Duncan	CWH	2715	2636	1533
36a	Holt Creek	21	Duncan	CDF	828	761	178
36b	Wild Deer Creek	21	Duncan	CDF	1100	954	54
37	West Fleet Main	21	Duncan	CWH	6579	6448	4870
38	Valentine Sooke	23	Langford	CWH	3094	3030	2066
39	West Jordan River	23	Langford	AMH	2801	2739	1623
40	Mount Todd	24	Lake Cowichan	CWH	1512	1457	640
41	Cowichan Lake S.	24	Lake Cowichan	CWH	1478	1404	579
42	Caycuse-Cowichan Lake S.	24	Lake Cowichan	AMH	2387	2320	1512
	Totals				133,326	129,136	87,357
	Average Volume Per Acre - cu. ft.				3174.4	3074.7	2079.9

[1] Biogeoclimatic Zones. V. Krajina
CWH Coastal Western Hemlock
CDF Coastal Douglas-fir
AMH Alpine Mountain Hemlock

[2] Excluding volumes at landings.
For a comparison of B.C. and U.S. Pacific Northwest logging residue volumes per acre see Appendix C.

Island of 6,240,000 cubic feet.[5] The material at landings differs slightly in character from open slash debris in that piece sizes are somewhat larger, the degree of incipient decay is also marginally higher and a high proportion of the wood accumulations includes logs with splits and spiral grain.

4. ALDER AVAILABILITIES

Hardwood stands occur at lower elevations on all parts of Vancouver Island. The heaviest concentrations occur on the low elevation areas that have been logged in the past. Since the heaviest

Table 2

Sound Volumes of Logging Residues on Vancouver Island (Excluding volumes at Landings) for Material 3" and up

Ranger District	1977 Acreage logged[1]	Avg vol residues[2] Cu ft per acre	Total[2] volume Mill cu ft
12 Sayward	3,511	2,654	9.3
15 Port McNeill	7,774	3,912	30.0
16 Port Hardy	5,550	3,542	19.7
17 Campbell River	2,968	2,069	6.1
19 Parksville	3,382	1,856	6.3
21 Duncan	5,671	2,856	16.2
23 Langford	2,214	2,948	6.5
24 Lake Cowichan	4,687	1,792	8.4
25 Port Alberni	8,384	2,262	19.0
26 Tofino	3,925	6,622	26.0
28 Gold River	7,572	3,091	23.4
Total Vancouver Island	55,638		170.9

[1] B.C. Forest Service

[2] Study Findings

[5] Appendix C shows a comparison of our own Study findings with those of the B.C. Forest Service of open slash residue volumes of approximately 3,000 to 1,000 cubic feet per acre respectively, because of the difference in sizes and types of debris included in each survey. At landings, however, our definition of residues mostly in the form of loge with checks, splits and incipient decay conforms quite closely with that of the B.C. Forest Service, and hence the observed differences are not as great; i.e., 2600 cu ft:1800 cu ft.

logging has taken place along the east coast of the Island, from Victoria to Kelsey Bay, the most extensive stands of hardwoods occur in this region, For purposes of this study, the east coast and areas easily adjacent to it include the low elevation lands between Victoria and Port Renfrew on the lower west coast and the lands near the community of Port Alberni.

Broad leafed maple is considered along with alder as it is commonly mixed in with alder, usually as a minor component of the stand. Maple is similar to alder as a fuel; therefore, the analysis has assumed that mixed alder-maple stands will be cleanly harvested and treated, from the point of view of fibre yields, as if they were pure alder stands.

About 40 percent of the forested area of Vancouver Island can be considered to be in this east coast area. This is an area of about 2,400,000 acres. Approximately 800,000 acres are covered by mature stands, leaving approximately 1,600,000 acres occupied by second-growth softwood and hardwood stands.

The available information on the area and location of east coast hardwood stands is sketchy at best. The most complete survey available is the Forest Survey Report of the 1970 Unit Survey of the Crown Portion **of** the E and N Belt, which covered 143,857 acres. According to this survey, 9.56 percent of the immature area was occupied by immature hardwood stands and 9.19 percent was covered by mixed hardwood-conifer stands.

These areas of Crown second-growth timber occupy land that was logged in earlier years (96 percent of the area was logged prior to 1950). Accordingly, the proportion of higher sites, now occupied by alder stands, will probably be greater than on lower sites and higher elevation lands that have been logged more recently. From the above, it is considered that hardwood stands (includingthe hardwood component of mixed hardwood-softwood stands) comprise approximately 12 percent of the second-growth area on the east coast of the Island. It is assumed also that 144,000 acres are occupied by the hardwood component of mixed stands (33 percent hardwoods x 144,000 acres = 48,000 acres). The total area of 192,000 acres represents **12** percent of the second-growth area of 800,000 acres.

An excellent road network extends throughout most *of* the area covered by' hardwoods on the east coast of the Island. The topography is generally favourable. Seasonal difficulties may exist in wet weather on some bottomland areas, and the small size and scattered occurrence of some stands could cause extraction problems but, on the whole, the hardwood forest can be harvested at reasonable cost.

The major constraint to utilizing hardwood stands on Vancouver Island is the varied ownership of lands occupied by the resource. Much of the area is in small private ownership, with the remainder fairly evenly divided between the large forest companies and the B.C. Forest Service. Small holdings covered with hardwoods are being subdivided into smaller parcels, causing them to be withdrawn from the forest land base. However, these lands should not be completely disregarded because clearing operations generate substantial volumes of wood, and some subdivided lands will remain in hardwood cover, available for future use.

Hardwood stands vary considerably in terms of age, site, stocking and in size and quality of trees. Much of the area of hardwood types consists of poor quality, low volume stands. Also, as has been noted, some hardwoods are mixed with coniferous stands. For convenience, stands might be classified into four broad categories, as follows:

High site pure stands
Medium site pure stands
Low site pure stands
Mixed coniferous-hardwood stands

The heavy volume alder stands which produce logs of sawlog size are limited primarily to rich bottomland soils and to some flats, benches and gentle slopes where moisture conditions are favourable.

The stands, which occupy low to medium sites, generally produce logs of lower quality which are too small for sawlogs. The stands often are not fully stocked, creating open grown, branchy trees, and volumes per acre are much lower than on good sites. Frequently these stands have captured the site immediately after logging, inhibiting coniferous growth and creating a serious forest management problem. The potential commercial use of these stands (if they can be utilized at all) will be primarily for fuel or pulp.

Alder, which grows in mixtures with conifers, varies in size and quality with the site. High quality alder trees, of good form, grow in mixtures with conifers on good sites, their form apparently being improved as the result of competition with the conifers.

Hardwood Market Prospects

Up to the present time there has been a very limited market on the **B.C.** coast for alder for lumber, pulp or fuel. Interestingly enough, there was a more active market for hardwood sawlogs 30 to 40 years ago, when several furniture and specialty hardwood mills operated on the Lower Mainland.

The present market for sawlogs is very weak, with only two or three small mills buying logs on the entire coast. The export market for hardwood logs also is very limited. The market for hardwood pulp chips, too, is practically non-existent, so that residues from lumber manufacture and from small trees and tops left in logging cannot be utilized except for fuel.

There is practically no market for maple sawlogs. Twenty to 30 years ago maple logs were as strongly in demand as alder logs, but in recent years the demand has declined greatly, not only in British Columbia but also in Washington and Oregon.

Even with a strong market for sawlogs, the level of utilization of hardwoods is very poor. Hardwood mills usually accept only logs that are 10 inches in diameter and larger, and of good grade. Accordingly, sawlog harvesting is confined primarily to older, high site stands, and even in these stands 50 to 60 percent of the volume, consisting of tops, small trees and sub-grade logs, is left in the woods as residue. Logging becomes a "high grading" operation.

The future market outlook for alder or maple sawlogs on the coast, according to people in the hardwood business, is bleak. They point to the static and declining nature of the business during the past few decades, and they note that British Columbia is "at the end of the line" and hence must pay high shipping costs to the major southern California market. Mills in Washington and Oregon have a great advantage in serving this market. Strong competition from eastern hardwoods and tropical hardwoods adds to the problems of the industry.

The future market for hardwood pulp chips also appears to be in doubt, chiefly because the supply of softwood mill residues and logging waste appears to be sufficient to meet mill requirements for a long time. If hardwood pulp chips can be exported in the future, the possibility of improved utilization may be increased.

Surprisingly, the strongest demand for alder and maple on the coast today is for fuel. It is a very small market but an active, viable one. The delivered price of alder firewood in Vancouver ranges from $60 to $70 per cord, which is approximately $85 to $100 per cunit of solid wood. In comparison, the price of second-growth fir sawlogs is about $100 per cunit.

The comparison must be treated with caution, because much firewood is produced as a comparatively low cost byproduct of land clearing operations, usually located in very accessible areas. There is a high labour cost in cutting and splitting wood for domestic use.

If future markets for hardwood sawlogs and pulp logs appear to be weak, any possibility of using alder for fuel in large volume would assume great importance. If facilities existed for utilizing the entire tree, the following opportunities would be created.

1. Large scale production would create operating efficiencies. We are advised, for example that Weyerhaeuser Timber Company is having alder pulp logs delivered to its mill at Cosmopolis, Washington for $63 per cunit. These logs are being produced by clear cutting the stand under close utilization limits.

2. Existing stands could be logged over a comparatively short period of time, resulting in accelerated harvesting of present growing stock and setting the stage for future yields in "energy plantations" under short rotation forestry.

3. As an alternative to number 2 above, existing stands could be harvested on the same basis but then converted to softwood stands instead of energy plantations. The average cost of converting hardwood stands to coniferous stands, where the hardwoods must be destroyed instead of utilized, is about $150 per acre. If the planting cost is $50 per acre, the savings created by clean logging would be about $100 per acre.

Increased Hardwood Yields

The comparative advantage of growing hardwoods on short rotations or long rotations, or of growing softwoods to replace hardwoods, depends upon the nature of the stands and upon economic conditions in the future.

The option of growing hardwood fuel in energy plantations depends largely upon the future price of fuel and upon the costs of growing and harvesting short rotation stands. It is likely that the factors of volume per acre yields and average tree sizes will have a large effect on costs and returns. The importance of these factors is demonstrated in Table 3.

It is obvious that if the entire stand (including trees down to 1 inch in diameter) is utilized for fibre production, the highest yields will be achieved on 10- or 21-year rotations. According to Table 3, for example, the mean annual increment on fully stocked medium sites is 142 cubic feet per acre on a 20-year rotation as compared with 104 cubic feet on a 50-year rotation.

Dr. J. Harry G. Smith of the University of British Columbia has drawn attention to the possibility of growing alder stands for high fibre yields on short rotations, In this report to the Productivity Committee of the B.C. Forest Service (1978), Dr. Smith provides sample plot information covering a wide range of ages and sites. According to his report, mean annual increments per acre at 10 years of age range from 84 to 277 cubic feet and at 22 years, from 81 to 344 cubic feet. The number of trees per acre ranges from 1,885 to 6,901 at 10 years and from 281 to 2,450 at 22 years. There is a wide variation owing to site, stocking and sampling error, but the figures indicate that surprisingly large yields can be achieved in young alder stands.

While the objective of maximum fibre production is important, it is necessary to consider also the economic factors of costs and return. From both logging and utilization standpoints there are great differences between young stands and older stands. For example, the 20-year-old stand contains 560 trees per acre with an average volume per tree of 5.08 cubic feet. In comparison, the 50-year-old stand contains only 140 trees with a much greater volume per tree of 32.5 cubic feet.

Table 3

Yields Per Acre, Trees Per Acre and
Average Tree Sizes for Medium Site Alder Stands[1]

Age of Stand Years	Yield per Acre Cubic Feet[2]	Mean Annual Increment Cubic Feet Per Acre	Number of Trees Per Acre	Average Volume Per Tree Cubic Feet
10	1,520	152	1,600	0.95
20	2,850	142	560	5.08
30	3,950	132	305	12.95
40	4,675	117	205	22.80
50	5,200	104	160	32.50
60	5,600	93	140	40.00

Notes

1 **From "Normal Yield Tables for Red Alder" (B.C. Forest Service, 1938)**

2 **Trees 1 inch d.b.h. and larger**

The 20-year-old stand has 2,850 cubic feet per acre compared with 5,200 cubic feet in the 50-year-old stand.

Vancouver Island Hardwood Potentials

The estimates of hardwood production that follow assume a 30-year rotation to harvest existing pure alder stands and a 60-year period for hardwoods that grow in mixtures with softwoods because it is assumed that the hardwoods must be logged at the same time as the softwoods on a 60-year rotation.

The estimated area of hardwood stands on the east coast of Vancouver Island is approximately 192,000 acres (including the hardwood component of mixed stands). If 17,000 acres are deducted from this area to allow for withdrawals for subdivision and development purposes, 175,000 acres are assumed to be available for harvest. An analysis of the proposed harvest from this area is set out in Table 4.

The annual harvest will yield approximately 14 million cubic feet over the next 30 years, during which time all existing pure hardwood stands will be logged along with about half of the hardwood component of mixed stands. The plan assumes that 90 percent utilization of total stand volumes will be achieved.

Approximately one-third of the volume of

Table 4

Analysis of Proposed Harvest of Hardwood Stands
on the East Coast of Vancouver Island

Type of Hardwood Stands	Area in Type (Acres)	Period of Harvesting Present Stands (Years)	Area Harvested Per Year (Acres)	Volume Per Acre Harvested (Cu ft)[1]	Total Annual Volume Harvested (McF)
High site pure stands	40,000	30	1,333	4,245 [2]	5,659
Medium site pure stands	55,000	30	1,833	2,936 [3]	5,382
Poor site pure stands	35,000	30	1,166	1,890 [4]	2,204
Hardwood components of[5] mixed stands	45,000	60	750	1,000	750
Total	175,000		5,082		13,995

Notes:

(1) The yields are taken from "Normal Yield Tables for Red Alder" (B.C. Forest Service, **1938**). All yields are reduced first by a factor for stocking, and then by 10 percent for waste, as per the notes below.

(2) Because of the existence of some older age classes on the better sites logged in earlier years, the average age of stands to be logged is estimated to be **40** years. Yield at **40** years is **5,550** cubic feet x **85** percent for stocking x **90** percent utilization factor = **4,245** cubic feet per acre.

(3) Average age of stands to be logged is estimated to be **35** years. Yield at **35** years is **4,350** cubic feet x **75** percent for stocking x 90 percent utilization factor = **2,936** cubic feet per acre.

(4) Average age of stands to be logged is estimated to be **35** years. Yield at **35** years is **3,230** cubic feet x **65** percent **for** stocking x **90** percent utilization factor = 1,890 cubic feet per acre.

(5) It is assumed that the hardwood component of mixed stands will be logged at the same time as the softwoods; namely, on a 60-year average rotation. It is assumed also that the harvest in mixed stands will be the Same as on medium sites.

the pure high site stands and the hardwood component of mixed stands will be sawlog material (about 2.6 million cubic feet per year). In comparison, the total reported harvest of hardwoods (mostly sawlogs) in the Vancouver Forest District in 1977 was 672 thousand cubic feet.

If the demand for sawlogs should increase, the sawmill industry would be aided by the high utilization program because of efficiencies achieved by logging the entire stand, instead of "highgrading" under present practice. The sawlogs would be bucked or sorted at the landing or mill, thus reducing cost, improving grade and eliminating waste, which would "go to the boiler".

The area of pure hardwood stands logged annually under the plan would be 5,082 acres. These lands could either be re-established in hardwoods for continuous production of fuel or converted into coniferous stands. If the entire 130,000 acres of pure hardwood types are converted into short rotation energy plantations which have an average annual fibre yield of 130 cubic feet per acre, hardwood production will be sustained into the future at a rate of 16.9 million cubic feet per annum.

On the other hand, if the lands are converted into coniferous stands, and if the savings in site rehabilitation costs owing to clean logging are $100 per acre, the annual savings on the 5,082 acres logged will be $508,200 as compared with conventional site preparation costs.

It has been assumed that the sites occupied by the hardwood component of mixed stands (45,000 acres) will be converted into coniferous stands after logging takes place.

5. PRECOMMERCIAL THINNINGS

The area of forest land on Vancouver Island which has been given juvenile spacing treatment (or precommercially thinned) has increased greatly during the past few years. The area treated has increased from some 3,800 acres in 1975 to approximately 14,000 acres in 1978. The area which will be treated in the future is expected to reach 15,000 acres per year for the next several years. Most of the recent thinning programs have been carried out in Douglas-fir plantations in the Douglas-fir biogeoclimatic zone of the east coast of Vancouver Island by the B.C. Forest Service.

The ideal age for thinnings is when the trees are 10 to 15 feet tall and 10 to 15 years old. Many stands between 20 and 35 years of age are being thinned at the present time, in order to take care of the backlog of older stands which require treatment.

In thinning operations being carried out today, between 500 and **4,000** trees are felled per acre. The great variation in number of trees felled relates to the large differences in stand ages, site and stocking. Some experimental treatments have been made, using chemicals.

The following statistics describe the number, size and volume of trees felled in typical immature spacing operations on Vancouver Island.

	13-year-old stand	18-year-old stand
Site index (Base 100)	115	115
Initial number of stems per acre	1,928	8,869
Residual stems per acre	378	379
Number of stems per acre felled	1,550	1,490
Average d.b.h. of stems felled	1.30 inches	2.15 inches
Average gross vol per tree felled	0.064 cu ft	0.26 cu ft
Gross volume per acre felled	99 cu ft	387 cu ft

Source: B.C. Forest Service

The average volumes per tree and the average volumes per acre remaining are extremely low. Under present conditions, removal of the felled materials is marginal or uneconomic, depending upon age, site and species. Some 35-year-old Douglas-fir thinnings on good sites might be economic, provided damage constraints are not too stringent and terrain is favourable.

As an example, the smallest logs being marketed on the coast today are "chip-and-saw" logs for sawmill use. The purchasers of these **logs** will accept logs down to a 5-inch minimum top diameter, with a high proportion of logs between 6 and 9 inches in diameter. The average volume per piece in typical booms varies from 14 to 25 cubic feet, with a strong preference given to the larger logs. The smallest log accepted is 5 inches in diameter and 30 feet long, containing about 7 cubic feet. This "smallest log" is 23 times as large as the 0.3 cubic foot average tree in the precommercial thinning example cited above.

Furthermore, "chipand-saw" logs are usually produced in clear cutting operations which yield many times the volumes per acre of wood ascompared with the precommercial thinning operations, and which are much less costly to log.

The problems of small piece size and low volume per acre in precommercial thinning operations are compounded by the difficult nature of the harvesting operations. The trees to be removed are tangled together between the remaining irregularly spaced crop trees in such a way that skidding is a difficult and costly operation. The removal of the great number of small limbs also serves to increase costs. Taking out whole trees from among the crop trees, without damage, for instant conversion of the whole tree to chips or hog fuel on the spot is clearly not possible in stands over 20 to 25 years.

The heaviest volumes of wood from precommercial thinnings are being created in the Sayward Forest. At the present time, about 7,500 acres are being treated per year, much of the area in 20- to 35-year-old plantations. Some of the operations in these older stands are producing comparatively large volumes of wood per acre, with larger than average piece sizes.

A typical stand being treated in the Sayward Forest is 24 years old and contains 800 trees per acre, with 570 trees per acre being removed, leaving a crop stand of 230 trees per acre. The average d.b.h. of the crop trees is 5.5 inches with an average volume of 4.57 cubic feet per tree, or 1,051 cubic feet per acre.

The average volume per tree of the 570 trees being felled is 1.58 cubic feet, or 1,224 cubic feet per acre, In spite of the larger piece size and volume per acre (as compared with younger stands), it is considered that these residues cannot be economically extracted. It might be possible to use some of the larger felled trees that lie close to roads but, on the whole, this potential source of wood must be disregarded, because of the potential damage to the residual stand and because of costs.

This study assumes that the volume of residues which are potentially available from precommercial thinnings on Vancouver Island is about 6 million cubic feet, based on annual thinnings on 15,000 acres, and an average recoverable volume of residues per acre of 400 cubic feet.

6. TOTAL WOOD BIOMASS AVAILABILITIES

Table 5, which follows, is a summary of potential wood availabilities from logging areas, alder stands and precommercial thinning (or spacing) operations on Vancouver Island, without regard to the costs of extraction, the subject of Chapter 7. The table shows that nearly 200 million cubic feet (2 million cunits or 5.7 million cubic meters) of wood biomass is available annually on Vancouver Island for energy generation purposes. This volume of wood is sufficient to generate 480 megawatts of power.

The reason greater use is not being made of forest residues and alder stands today is largely historical. However, there are strong technical and economic forces at play that prevent Vancouver Island's forest biomass from finding a ready use today. The reason the wood is not being used at present for energy or for products, is presumably because the costs of extraction and delivery to points of use are too high to make it a profitable undertaking for public or private interests. The building of thermal generating plants on Vancouver Island would, of course, create a new market for logging residues. At the same time, the availability of this new fibre on the market - much of which is suitable also as raw material for lumber and pulp - would alder existing chip and hog fuel balances on the Island. The actual volumes of forest biomass which might find a market in thermal generating plants (as distinct from power facilities at existing forest industry complexes) is considered in the following chapters.

7. COSTS AND METHODS OF BIOMASS ASSEMBLY

The unit cost of recovering logging debris, or precommercial thinnings, or of felling and removing alder from scattered locations on Vancouver Island can be expected to exceed the average unit costs of initial or first-pass logging of large uniform logs from mature stands, even though the initial

Table 5

Summary of Wood Availability
on Vancouver Island for Energy Generation
1980 - 2000

		Millions of Cubic Feet				
		Logging Openings[1]			PC	
RD	Ranger District	Debris	Landings	Alder	Thinnings	Total
12	Sayward	**9**	–	**1**	**3**	**13**
15	Port McNeill	**30**	**1**	–	–	**31**
16	Port Hardy	**20**	**1**	**1**	–	**22**
17	Campbell River	**7**	–	**2**	**1**	**10**
19	Parksville	**6**	–	**2**	**1**	**9**
21	Duncan	**16**	**1**	**2**	**1**	**20**
23	Langford	**7**	–	**1**	–	**8**
24	Lake Cowichan	8	–	**3**	–	**11**
25	Port Alberni	**19**	**1**	–	–	**20**
26	Tofino	**26**	**1**	–	–	**27**
28	Gold River	**23**	**1**	–	–	**24**
1980 Potential		**171**	**6**	**12**	**6**	**195**
1990 Estimates		**146**	**5**	**10**	**8**	**169**
2000 Estimates		**124**	**4**	**8**	**3**	**139**

Source: Study Findings

1. The volumes of residues from logging are expected to decline, despite higher annual allowable cuts and larger harvests, on the assumption that utilization standards will improve and that there will be an increase in the proportion of second growth cutting, where less breakage and defect can be expected

logging has to pay for the road system needed to gain access to the timber, Little research has been done into the actual costs of salvaging logging debris or of determining the effects on logging costs per unit of output for changing standing volumes or average piece sizes. The relatively high prices of cedar prevailing at present make cedar salvaging economical, at least from some locations where its volume end quality is high enough to warrant salvaging. Otherwise, there is little or no salvaging of any kind being carried out on Vancouver Island for any purpose. This alone suggests that salvaging, at least for products, is currently uneconomical.

The removal of material felled during pre-commercial thinning operations has been attempted on a small scale on Vancouver Island, but most of the attempts have been abandoned because of the danger of damaging the remaining crop trees and because the yields of logs and other material of saleable quality are too low to be profitable to the operator. Even in Douglas-fir stands of 35 years, the removal of thinnings is a marginal operation, despite the relatively high prevailing prices for chip-and-saw material.

Alder stands on Vancouver Island provide small quantities of domestic fuelwood to residents of Island communities and insignificant quantities for consumption on the Mainland. Individuals obtain permits from the B.C. Forest Service or operating companies to remove limited volumes for personal use. Commercial cutting of alder for sale in Island or Mainland communities for fuel, generally in split cords, appears to be limited by the general lack of good alder stands in Crown ownership and the nuisance value the supervising of contracts would pose to the Forest Service. Some alder is being felled by certain companies - B.C. Forest Products Limited is one - for purposes of stand conversion. In such cases, little or no use is made of the alder.

In the almost complete absence of general data, let alone local, up-to-date information, and because there are no known operations where residues are being extracted, or alder stands felled and yarded to landings, it has been necessary to construct cost estimates for such operations on Vancouver Island, using different systems and methods of logging and yarding. The estimates presented here represent late 1978 on-truck costs, which include capital, operating and servicing costs of equipment, depreciation, administration, supervision and labour costs (at going IWA wage rates), a payroll burden of 30 percent and crew transport to and from the work location (see Appendix D).

Excluded are costs of building roads to gain access to alder stands, and board and lodging for work crews.

The daily machine operating expenses used in arriving at yarding and loading costs are based on 100 operating days per year. A load average of 500 cubic feet has been assumed for dual axle trucks with residue boxes similar to refuse disposal trucks. Load averages could be doubled by using "pup" trailers.

The grapple yarding system for salvaging logging debris was considered, but was excluded as this system demands high volume production which could not be achieved with salvage material.

Since most logging on Vancouver Island is now carried on at higher elevations where snow conditions limit logging to 8 months of the year, logging residues should be collected during the spring, summer and fall, where removal is done following logging; i.e., second pass logging. On the other hand, alder logging and removal of material from precommercial thinning areas, if the latter is feasible, should be carried out during the winter months, as most of these operations are at lower and intermediate elevations.

Logging Cost Estimates

As indicated above, the following cost estimates have been constructed on the basis of average piece size, data taken from the field surveys and extrapolations of actual earlier records of salvage operations carried out on Vancouver Island.

Extraction Cost Summary

The on-truck costs of extracting logging residues, precommercial thinnings, and of felling and extracting alder, in summary, as taken from the foregoing cost estimates, are presented in Table 6.

Table *6*

On-Truck Cost Summary **Wood** Biomass
Dollars Per Cunit

	Logging Residues		Alder Stands		PCT Residues
	Single Pass	2nd Pass	Skidder	High Lead	
Yarding	$21.60	$58.10	$17.40	$27.15	$71.75
Loading	16.50	11.25	5.60	5.60	11.25
Supervision & Administration	5.00	4.15	2.10	2.10	4.15
On-Truck	$43.10	$73.50	$24.10	$34.85	$87.15

Schedule 1

Single pass yarding of logging residues

Phase	Cost/Ccf
Yarding	$ 21.60
Loading	16.50
Supervision and Administration	5.00
On Truck	$ 43.10

Statistics

Yarding	- Volume/piece	33 cf
	- Pieceslshift	225
	- Volume/shift	74 Ccf
	- Cycles/shift	75
	- Pieces/cycle	3
	- Cost/day	$1,580.00
	- Codpiece	$ 7.00
Loading	- Volume/shift	50 Ccf
	- Loadslshift	10
	- Volume/load	5 Ccf
	- Pieceslshift	625
	- Cost/day	$ 825.00
	- Codpiece	$ 1.30

1. All debris is yarded in conjunction with primary logging and left to be loaded out at a later date.
2. Daily yarder expense is higher, owing to increased use of lines, rigging, fuel and one more worker.
3. Piece volume is the average of primary logs and debris pieces.
4. Yarding productivity is averaged as in item 3.
5. Loading productivity is less and daily cost higher, owing to the loader reaching out 100 feet to bring some of the debris to roadside for loading.

Schedule **2**

Second pass yarding and loading

Phase	Cost/Ccf
Yarding	$ 58.10
Loading	11.25
Supervision and Administration	4.15
On Truck	$ 73.50

Statistics

Yarding	- Volume/piece	8 cf
	- Pieces/shift	300
	- Volume/shift	24 Ccf
	- Cycles/shift	75
	- Pieces/cycle	4
	- Cost/day	$1,395.00
	- Codpiece	$ 4.65
Loading	- Volume/shift	60 Ccf
	- Loads/shift	12
	- Volume/load	5 Ccf
	- Pieces/shift	750
	. Cost/day	$675.00
	- Cost/piece	$ 0.90

1. Second pass salvage logging will require a similar type yarder as that used in primary yarding, due to cover the same distance; e.g., 800 feet.

2. The difference in productivity between yarder and loader is due to the loader having the landing and roadside debris to load as well as the yarder production.

Schedule 3

Alder Stands - Rubber Tired Skidders

Phase	cost/Ccf
Yarding	$ 17.40
Loading	5.60
Supervision and Administration	2.10
On Truck	$ 25.10

Statistics

Yarding	- Volume/piece	20 cf
	- Pieces/shift	150
	- Volume/shift	30 Ccf
	- Cycles/shift	30
	- Pieces/cycle	5
	- Cost/day	$525.00
	- Codpiece	$ 3.50
Loading	- Volume/shift	120 Ccf
	- Loads/shift	24
	- Volume/load	5 Ccf
	- Pieces/shift	600
	- Cost/day	$675.00
	- Codpiece	$ 1.10

1. Rubber ir d skidders are used where soil nd moistur nditions permit.
2. Piece average includes limbs.
3. Loading productivity is based on production from four skidders.
4. Labour cost includes felling.

Schedule 4

Hi-lead System for logging Alder Stands

Phase	Cost/Ccf
Yarding	$ 27.15
Loading	5.60
Supervision and Administration	2.10
On Truck	$ 34.85

Statistics

Yarding	- Volume/piece	20 cf
	- Pieces/shift	150
	- Volume/shift	30 Ccf
	- Cycles/shift	75
	- Pieces/cycle	[illegible]
	- Cost/day	$815.00
	- Cost/piece	$ 5.40
Loading	- as in B.I	

1. This alternative to be used where excessive moisture in the soil precludes the use of rubber tired' skidders.

2. A Mini-Alp type cable system has been used as in precommercial thinning.

3. Labour cost includes felling.

Schedule 5

Precommercial Thinning - Salvage of Felled Material

Phase	cost/Ccf
Yard and Forward	$ 71.75
Loading	11.25
Supervision and Administration	4.15
On Truck	$ 87.15

Statistics

Yarding	- Volume/piece	5 cf
	- Pieces/shift	300
	- Volume/shift	15 Ccf
	- Cycles/shift	50
	- Pieces/cycle	6
	- Cost/day	$815.00
	- Codpiece	$ 2.70
Forwarding	- Pieces/shift	600
	- Volume/shift	30 Ccf
	- Cycles/shift	30
	- Pieces/cycle	20
	- Cost/day	$525.00
	- Cost/piece	$ 0.85
Loading	- Volume/shift	60 Ccf
	- Loads/shift	12
	- Volume/load	5 Ccf
	- Pieces/shift	1200
	- Cost/day	$675.00
	- Cost/piece	$ 0.55

1. A Mini-Alp type cable system is proposed for thinningsfrom young timber stands.
2. Ten-footwidth yarding corridors, allowed by the B.C. Ministry of Forests, necessitates the use of rubber tired skidders to forward yarded thinnings to roadside for loading.
3. One skidder will serve two yarders.
4. One loader to service four yarders.
5. Labour cost includesfelling.

Single-pass logging of residues (see Schedule 1) from logging openings, where both slash (logging debris) and residue accumulations at landings are taken out at the time of primary logging, and alder logging, using rubber tired skidders (see Schedule 3), appear to be the two cheapest means of extracting wood biomass on Vancouver Island. The most expensive extraction costs are for precommercial thinnings, even for material with an average piece size of 5 cubic feet, thus implying a stand age of more than 30 years.

8.0 TRANSPORTAT ION AND PROCESSING

8.1 Introduction

Transportation of forest biomass from the landing to a thermal generating facility presents special problems. Current transportation systems deal with a similar situation except that current systems are moving the best material; i.e., logs which are reasonably uniform and have a high volume per piece. Forest biomass transport, on the other hand, requires moving a wide variety of material with a low volume per piece. Moving forest biomass, consequently, is anticipated to be more costly than log transport.

The purpose of this section is to provide a preliminary estimate of transportation costs for forest biomass. A subsequent chapter will determine the economics of scale in termal generating plants and indicate, in a preliminary way, the relationship between the length of haul and plant size for Vancouver Island. No recovery of forest biomass for energy purposes presently occurs on Vancouver Island. No accepted transport system for moving forest biomass exists; as a consequence, the first task is to consider alternative transportation systems and select a system or systems for the cost analysis.

8.2 Transport Systems

The basic transportation infrastructure and networks - logging roads, main haul roads, railways and water routes - are in place on Vancouver Island and the flow of forest biomass from landing to thermal generation site can be expected to show a similar pattern to the current log flows. Transporting forest biomass will have to rely heavily on the existing log hauling systems and, specifically, the basic network of logging roads. Two basic log transportation systems are currently used on Vancouver Island.

(i) In the more remote coast areas, logs are hauled by off-highway logging trucks relatively short distances (approx 10 miles) and dumped directly into the water. Subsequently, the logs are sorted in the water and forwarded to the appropriate conversion facility.

(ii) In the major watersheds (e.g., the Nimpkish Valley), the logs are hauled much longer distances (approx. 40 miles) from the landing to a dry-land sort yard. In turn, the logs are forwarded by water or road to the appropriate conversion facility. The landing- to dry-land-sort-yard portion of the haul can be by off-highway logging trucks on private roads, on-highway logging trucks on public highway, railway, water tow, or some combination; each operator appears to have a unique transportation system dictated by terrain, existing equipment, etc.

In order to utilize forest biomass, material must be reduced in size prior to being introduced to a power boiler at a thermal generating plant. This reduction could be performed at any point in 'the transport system from the landing to the thermal plant. Possible locations for reducing the forest biomass would include the landing, an intermediate point, such as a log dump or dry land sort yard, and the thermal generation site.

Any number of transport systems can be hypothesized for the movement of biomass from landing to thermal generation site. However, this study is preliminary in nature and only a three 'generic' system will be considered and some preliminary cost estimates presented. The three systems considered are:

Truck haul of biomass from the landing to the plant site.

Truck haul from the landing to a tidewater dump area. Biomass hogged at the dump and forwarded by barge to the thermal generation facility.

Biomass hogged at the landing and hog fuel forwarded by truck from the landing to the plant site.

The technical feasibility of each system will be discussed and cost estimates developed for the systems that are deemed feasible. No forest biomass transport systems operate on Vancouver Island and cost estimates will, of necessity, be estimated by comparing these systems with the existing log hauling costs and adjusting certain factors. The preliminary nature of this work should be clearly understood; that is, the transportation systems considered are simply adaptations ~~of~~ existing systems applied to the movement of forest biomass and the cost estimates should be viewed as preliminary order-of-magnitude estimates.

a) Truck Haul to Conversion Facilities

This biomass transport system is similar to the present log haul system within major watershed areas. The main change is that the equipment for biomass hauling will be different. Specifically, the equipment is as follows:

Truck and Box - Instead of a log truck, a straight truck with a heavy duty steel box on **it** is suggested. This configuration would be similar to the system used in the construction industry for removing rubble from construction sites. The box size is assumed to be the maximum allowable (roughly 8' x 8' x 25'); a loading of 5 cunits per box has been assumed in the yarding and loading work, A trailer carrying an identical box is also assumed.

Operation -The empty box(es) would be unloaded at the landing and full box(es) would be winched on to the truck (and trailer). At the conversion site, the box(es) would be dumped hydraulically. **A** truck and trailer would likely be able to operate to the landing; however, an alternate scheme would have a single unit hauling from the landing to the main haul road, where boxes would be assembled for forwarding by truck and trailer to the conversion site.[6] Traction on the steep slopes up to the landings is a problem and the truck and trailer combination would have to be designed to have sufficient weight on the driving wheels to get to the landings. For calculation purposes, a loading weight of 10 cunits per combination is assumed in the cost estimate of this system.

b) Off-Highway **to** Tidewater Assembly Area

For those isolated forest operations on the west coast of Vancouver Island, logging biomass would require a system that would have a truck haul from the landing to an assembly area on tidewater. Owing to the piece size, **it** would not be feasible to put the biomass in the water for forwarding to the thermal generation site. The biomass would have to be hogged at the assembly area and forwarded to the conversion site by barge. The equipment is as follows:

Truck and Box - Similar in concept to the truck and box discussed in a) above.

Hogging & barging - A hog mill (or chipper), capable of handling a wide variety of materials, would have to be installed at the assembly area. Material handling equipment - front end loaders, grapples, conveyors, etc., would be required to feed the reduction unit and convey the fuel away. A barge loading system would **also** be needed.

Operation - A drop off system for the box at the landing and hydraulic unloading at the assembly area is envisioned to allow good turn around time for the truck haul. Given the through-put rate for the hog mill and the per diem barge charges, direct barge loading from the hog mill does not seem reasonable. Hog fuel would be stockpiled at the assembly yard, with barge load from the stockpile. Clearly, collecting and transporting biomass from isolated cutting areas on the west coast would be a complex operation.

c) Reduction at the Landing with Truck Haul to the Conversion Facility

The **system** would have a portable hog or chip mill at the landing; biomass would be fed to the

6. The B.C. Department of Highway limitations on truck and trailer configurations is 65% feet overall length, 8% feet wide, 13% feet high with gross weight of 100,000 to 105,000 lbs (depends on axle spacing). The biomass haul truck configuration would most likely meet the standard.

mill and loaded directly into a chip truck.[7] This operation would be similar to whole tree chipping operations as carried out in eastern Canada (McIntosh and Johnson 1975, Folkeman 1977). Technically, this system seems unsuitable, or at least less efficient, than the system outlined in a) above and, consequently, no cost estimate will be developed. The technical problems include:

- insufficient space at the landings for the equipment;
- reduced hauling efficiency, owing to loading times;
- insufficient weight on the driving wheels of the truck tractor and, consequently, insufficient traction on the drive wheels to allow the tractor and trailer to get up to the landings;
- the density of hog fuel (solid wood per unit of volume) in a chip truck does not appear to be greater than residue pieces in a box;[8] hence, hogging at the landing offers little scope for improving the truck loadings.

8.3 System Costs

a) General Consideration

The transport systems fdr forest biomass discussed in Section 8.2 do not exist in practice today but are conceptual systems. As a result, no direct operating cost information is available for these systems. The procedure that has been used in this study for estimating transport costs is to begin with the current *costs* for log hauls and to develop a means of modifying these costs to represent the conceptual system.

All the major logging companies with operations on Vancouver Island were contacted and questioned about their log haul transportation systems, general mode of operation, average length of haul by logging division and hauling costs, These discussions indicated that a diversity of transport systems and costs exists and that generalizing log haul costs is a difficult task.

All crown timber is subject to a provincial stumpage payment; the British Columbia Forest Service calculates the stumpage payment to the Province. The timber appraisal system, in theory, develops an average cost for timber harvesting. On the coast, the difference between the value of the logs in the Vancouver log market and the harvesting costs is the stumpage due to the Crown. The timber harvesting costs in the appraisal system are developed by looking at each component of the harvesting process and working up an "average" cost for each component. Haulage costs are one component of the timber appraisal system. The logging companies complain that the timber appraisal haulage costs, as calculated by the B.C. Forest Service, are less than their actual costs. Some of these complaints arise because:

(i) there are unique geographical or operational characteristics at particular operations;

(ii) some companies are not able to load trucks to the B.C. Forest Service standard;

iii) the companies feel that the capital cost allowances (depreciation and working capital) are not adequate.

The general opinion, however, is that the haulage costs in the timber appraisal system are not too far off the mark. Consequently, the haulage cost calculation of the timber appraisal system has been used in the study as the basic cost information for estimating the costs of biomass transport systems. The relevant sheets from the B.C. Forest Service timber appraisal manual (1978) are reproduced as Appendix D.

b) Truck Haul **Costs**

Table 7 presents estimates of the cost of

7. The Forest Engineering Research Institute of Canada (FERIC) has a research program in progress on converting the dry land sort yard residues into pulp chips and/or hog fuel. The results of this research will be *of* interest as the systems developed may **be** applicable to forest residue operations.

8. The truck and tandem unit system has an estimated load of 10 cunits of wood residue, a 40-foot open-top chip van has a capacity of 9.6 cunits of wood residue.

Table 7. Estimate of Forest Biomass Hauling Costs

One-way Trip Distance	costs					Costs per Cunit		
	Trips per Day[1]	Daily Fixed costs[2]	Operators' Wages[3]	Running Costs[3]	Total per day	Low[4]	High[5]	Average[6]
5	7.71	79.17	115.08	43.95	238.20	3.09	6.18	4.60
10	5.40	79.17	115.08	61.56	255.81	4.74	9.48	7.10
15	4.70	79.17	115.08	80.37	274.62	5.84	12.57	9.20
20	4.15	79.17	115.08	94.62	288.87	6.96	14.22	10.60
25	3.72	79.17	115.08	106.02	300.27	8.07	15.32	11.70
30	3.38	79.17	115.08	115.60	309.86	9.17	16.44	12.80
35	3.09	79.17	115.08	123.29	317.54	10.28	17.55	13.90
40	2.84	79.17	115.08	129.50	323.75	11.39	18.65	15.00
45	2.63	79.1;	115.08	134.92	329.17	12.52	19.76	16.10
50	2.45	79.17'	115.08	139.65	333.90	13.63	20.87	17.20
60	2.16	79.17	115.08	147.74	341.99	15.83	23.11	19.50
70	1.93	79.17	115.08	154.01	348.26	18.04	25.31	21.70

NOTES

1 Trip time calculated on the following basis - loading time 20 minutes, unloading time 10 minutes, 5 miles (one-way) of logging road with average speed of 15 mph, additional miles on main haul road at 40 mph; time available per day 9.0 hours (i.e., delay time per day 5 hours).

2 From D.G. Smith and P.P. Tse, Logging Trucks: Comparison of Productivity and costs, FERIC, Technical Report No. TR-18, November 1977, p. 25.

3 See Appendix A, On-Highway Hauling.

4 Based on truck loading of 10 cunits. Assumes truck with residue box and trailer with box from landing to thermal plant.

5 Based on a truck loading of 5 cunits for the first 10 miles and 10 cunits for any additional miles; is., trucks with a residue box would operate from the landing to an assembly area and trucks with trailers would operate from the assembly area to the thermal plant.

6 Average (to the nearest $.10) of the low and high estimates.

truck hauling forest residues.[9] The trucking hauling costs are developed from timber appraisal hauling costs, with some modifications. The daily fixed costs have been increased as a response to the industry criticisms regarding the capital cost allowances; information from a FERIC report (Smith and Tse 1977) was used. By using the appraisal haul costs, the assumption is that although the truck and the equipment configuration will be different for biomass hauling, the truck costs (fixed daily, operators' wages, and running costs) will be roughly the same as a logging truck.

In calculating the cost per cunit, specific assumptions as to the truck loading have been made. The "low" cost per cunit estimate in Table 7 assumes a 10 cunit loading and represents a system where a truck and box with a trailer and identical box would operate directly from the landing to the thermal plant. The "high" cost estimate assumes that tandem trucks would not be able to operate direct to the landing but that an intermediate assembly yard would be required. Trucks with a single box would operate from the landing to the assembly yard and a tandem unit would operate from the assembly yard to the thermal plant. The "average" cost per cunit is a simple average of the low and high estimates and can be thought of as a situation where half the biomass available at the thermal plant can be hauled directly from the landing by a tandem unit and half comes from more difficult terrain where intermediate assembly is necessary. The "average" cost per unit estimate is used for the site specific analysis in Chapter 10.

c) Off-Highway to Tidewater Assembly Area: Barge to Thermal Plant

Many areas on the west coast of Vancouver Island are currently logged, using a system where off-highway logging trucks haul the logs from the landing to a tidewater log dump. The logs are dumped in the water, sorted, and towed or barged to the appropriate conversion facility. Transportation of forest biomass from these areas would be a difficult and complex operation. Biomass would be truck hauled to a tidewater assembly area, hogged, and barged to the thermal plant. Table 8 provides a preliminary estimate of the costs of the system. If 10 miles is a reasonable average for the off-highway miles involved, the total transport and handling cost for isolated west coast forest biomass is estimated at:

	Cost per Cunit for	
Barge one-way distance	25,000 cunit assembly yard	100,000 cunit assembly yard
150	21.00	17.50
250	23.50	20.00
350	26.00	22.50

For a barge haul system, a minimum of perhaps four barges would be required in order to realize the economies of scale assumed in Table 8.

9.0 THERMAL GENERATION COSTS

9.1 Thermal Generation Plant Costs

Thermal electric generation is the only application[10] covered by this study. Information on cost of thermal generation facilities using wood wastes is limited. Many of the studies quoted in the literature are either dated or are site specific to the point that it may not be prudent to generalize (i.e., SNC Consultants Ltd. 1976). From a technical point of view, existing equipment is available for the construction of a plant of approximately 50 MW capacity. Large hog fuel boilers as currently installed in some pulp mills produce roughly 450,000 lb of steam per hour, the amount of steam required for a 50 MW plant. Larger plant sizes are speculative at this time.

One study which treats the costs of thermal generation in detail and provides estimates for a range of plant sizes is the Mitre Corporation (1977) study on biomass farms.[11] The Mitre study estimates

9. No road costs have been included in the haul cost; the assumption is that logging pays all the road costs and that biomass recovery gets the use of the roads at no cost.

10. Cogeneration is the other application on Vancouver Island that might be interesting.

11. Also, as reported in Morris Wayman Limited, Wood-Fire Electricity Generation in Eastern Ontario, prepared for the Royal Commission on Electric Power Planning, July 1978, the background Mitre work on production cost appears in D. Salo, System Description and Engineering Costs for Solar Related Technologies: Volume IX, Fuels from Biomass, Publication No. MTR-7485, May, 1977.

Table 8. Estimated Forest Biomass Transport Costs from West Coast to Thermal Plant

Off-Highway Truck Haul to Tidewater[1]

One-way Trip Distance	Trips per Day	Costs: Daily fixed costs	Costs: Operators' Wages	Costs: Repairs, Maintenance & Overhauls	Costs: Running costs	Costs: Total per Day	Costs per cunit
5	7.71	26.20	118.68	186	80.96	411.84	5.34
10	4.91	26.20	118.68	186	103.11	433.99	8.84

Tidewater Assembly Yard Costs[2]

Annual Throughput	25,000 cunits	100,000 cunits
Annualized Capital Costs	$100,000	$200,000
Operating Costs	$ 75,000	$150,000
Total Costs	$175,000	$350,000
Cost per Cunit	$7.00	$3.50

Barging Costs[3]

One-way Distance	Barge costs	Yarding Costs	Line Haul Tug Costs	Total costs	costs per Cunit
150	1680	600	2850	5130	5.13
250	2160	600	4750	7510	7.51
350	2640	600	6650	9890	9.89

NOTES

1 The off-highway truck hauls are the timber appraisal haul costs (Appendix A). Assumptions used in the calculation are 200 shifts per year, trips per day based on a loading time of 20 minutes, average speed of 15 mph and 10 minutes to unload, truck loading is assumed to be 10 cunits.

2 Assembly Yard Costs are speculative. The equipment required includes a hog mill, grapple yarder, conveyors from the hog mill to storage, and a wharf and barge loading system. Operating costs include equipment operating costs and labour.

3 The barge costs are based on discussions with a tug and barge operator. Assumptions are: Barges would be new equipment with a cost of $480/barge-day. Loading per barge would be 1000 cunits per barge, yarding costs estimated at 6 hours at $100 hour. Line haul tug costs based on a tandem tow, $3800 per day for the tug and an average speed of 8.3 mph including a bad weather allowance.

costs for plant capacities of 55 MW, 100 MW and 220 MW. A thermal plant cost estimate specific to British Columbia is contained in the H.A. Simons report for the British Columbia Wood-Waste Energy Coordinating Committee (1978). The H.A. Simons study estimates the capital and operating costs for a 47.6 MW thermal generating facility located at Quesnel. Table 9 summarizes the pertinent characteristics from both studies for the 50 MW unit size. Table 10 presents the cost estimates from both studies. A direct comparison of the two studies is not possible as the assumptions are not compatible.[12] The two estimates indicate, however, that the range of costs for thermal electric generation for a 50 MW facility is 20 mills/kwh t 5 mills/kwh. The Mitre study also suggests that for increasing plant size substantial economies of scale exist.

9.1 Tradeoff Between Plant Size and Transport Haul Distance

The Mitre study, as per Table 10, indicates an average reduction in generating costs of 6.5 mills/kwh for a 110 MW plant as compared with a 55 MW plant. Assuming that these economies of scale exist, a utility company could afford to pay up to the equivalent of 6.5 mills/kwh in transport costs to assemble an additional 685 tons (dry) per day of forest biomass at a single site. Based on 685 tons (dry) per day or 548 cunits per day of fuel for a 110 MW plant operating at an 80 percent load factor, the utility company could afford hauling costs of up to $25.05 per cunit of biomass (green basis).[13] For Vancouver Island, it appears that an additional 548 cunits per day or 200,000 cunits per year of

Table 9

Characterization of Two Wood-Fired Thermal Generating Plants

Characteristics	Mitre	H.A. Simons
Average feed requirement	685 ODT/day	787 ODT/day
Load factor	80%	80%
Wood heating value (dry)	8500 Btu/lb (dry)	8600 Btu/lb (dry)
Moisture content of wood	50%	45%
Steam temperature	1000° F	825° F
Steam pressure	1000 psig	900 psig
Boiler efficiency	70.8%	67.5%
Plant heat rate	10,950 BtulKwh	14,800 Btu/Kwh
outputs		
Steam production	425,000 lb/hr	442,000 lb/hr
Power output	55 MW	47.59 MW

SOURCE: Mitre, op. cit.; and H.A. Simons, op. cit.

12. There are a lot of problems in comparing the two studies; e.g., the Mitre study is in $1976 U.S.; Simon's is $1977 Cdn.; the heat rates are vastly different, suggesting that the Mitre Corporation estimate involves an advanced power cycle; the annualization of capital costs differs between the studies, etc.

13. Note that if an additional 1644 cunit per day (green) of biomass could be collected in one location (i.e., 220 MW plant), the equivalent of 11.1 mills/kwh or $28.52 per cunit could be paid by a utility company.

Table 10

Thermal Plant *Cost* Estimates

	H.A. Simons	Mitre		
Plant Size				
Feed capacity ODT/day	787	850	1700	3400
Power output MW	47.6	55	110	220
Capital costs ($$10^6$)	33.1	55.0	74.7	107.4
Capital Costs ($/Kwh) of capacity	695	1000	679	488
Annual Operating costs ($$10^6$)	1.64	3.60	5.56	8.22
Generation Costs (mills/Kwh) at 80% capacity factor	16.8	24.3	17.8	13.2

SOURCE: Mitre, op. cit.; and H.A. Simons, op. cit.

biomass can be assembled at a single site for an additional transport cost of $25.00 per cunit.

In the next section, four Vancouver Island sites are identified, with biomass at average haul of 30 miles that would roughly fuel a 50 MW plant. Section 8.3 indicates that the truck haul costs for a 30 mile haul are $12.80 per cunit. For an additional $25.00 per cunit, i.e., for $37.80 per cunit, very lengthy truck hauls would be possible. For $37.80 per cunit, a large haul of 350 miles - virtually the length of Vancouver Island - is possible. Provided the Mitre study estimates of the economies of scale in thermal generation are correct, the conclusion is that the savings in fixed plant costs are sufficient to allow the assembly of forest biomass for larger size plants.

10.0 THERMAL PLANT SELECTION

10.1 Site Selection

The Ranger Districts on Vancouver Island were reviewed with respect to the forest biomass available and the existing logging operations. Table 11 summarizes the basic information. The thermal plant site selection process involved a number of steps and utilized the basic information in Table 11 plus information solicited directly from the logging operations. The steps were:

(i) The forest companies with major logging operations on Vancouver Island were contacted and information on their logging operations -volumes, transportation systems, and average haul distance - was collected,

(ii) From the transportation cost analysis (Section 8.3) and the thermal generation plant cost analysis (Section 9.1), the most interesting biomass supply sufficient for a 50 MW plant available within a 30 - to 40-mile truck haul was ascertained. Four sites met these general criterion - Port McNeill/Beaver Cove, Campbell River/Menzies Bay, Lake Cowichan and Port Alberni.

(iii) For the four sites above, the volumes of forest biomass and average length of haul were estimated.

Table 11 summarizes the information for the four sites. The average haul distance is similar for all four sites, i.e., 25 to 30 miles, and results in a similar total fuel cost - roughly $2.60 per MM Btu or 20 mills per kwh generated. The Port McNeill/Beaver Cove site is the most interesting site in that roughly 300,000 cunits per year of forest biomass, sufficient fuel for

Table 11. Costs of Forest Biomass as Fuel for Thermal Electric Generation

	Annual Forest Biomass Available Mill. cu ft	Length Of Haul Miles	Energy: Btu Available[1] 10^{12} Btu/yr	Energy: Electric Energy Output[1] 10^{6} Kwh/yr	Energy: Plant Capacity MW	Fuel Costs: Yarding & Loading Cost[3] $/MMBtu	Fuel Costs: Hauling cost $/MMBtu	Fuel Costs: Total Fuel Cost[4] $/MMBtu	Fuel Costs: Total Fuel Cost[4] mills/Kwh
Pt. McNeill/ Beaver Cove	30.8	30	6.55	504	72.0	20.3	0.60	2.63	20.21
Campbell River/ Menzies Bay	15.4	25	3.27	252	35.9	2.03	0.55	2.58	19.9
Lake Cowichan	24.6	30	5.23	402	57.5	20.3	0.60	2.63	20.21
Port Alberni	19.0	25	4.04	311	44.4	2.03	0.55	2.58	19.9
Total	89.8		19.09	1469	209.8				

NOTES:

1. 8500 Btu/pound (dry) of residues and a heat rate of 13,000 Btu/Kwh is assumed.

2. An 80 percent load factor, i.e. 7000 hours per year is assumed.

3. The single pass yarding and loading cost of $43.10 per cunit is used in this calculation.

4. The total fuel cost includes the costs of first pass yarding, loading, and hauling forest residues to the thermal plant. No road building or maintenance costs are included; the costs of preparing and storing the residues at the thermal plant are not included. It is assumed here that no stumpage or royalty charges will be levied on salvaged materials.

a 72 MW plant, could be generated with a 30-mile average haul. If the biomass from the Campbell River/ Menzies Bay area were moved to Port McNeill/Beaver Cove, a barge haul of approximately 100 miles, the development of a thermal plant with a capacity in excess of 100 MW would be possible.

10.2 Siting and Site Characteristics

No original work was done on the availability of land and water at specific sites in the four general locations selected. However, B.C. Hydro did an exhaustive site identification and ranking study for Vancouver Island in 1975. The study examined the entire Island for sites suitable for large scale (1200 MW) coal-fired thermal generation sites. The site selection and evaluation procedure was a progressive screening process, whereby sites were evaluated using environmental and technical parameters which were more rigorous at each stage. At the initial site selection level, only two basic criterion were applied - roughly 400 acres of fairly level land and proximity to an adequate water supply for once-through cooling or for make-up to a cooling tower or a cooling pond. A total of 168 sites were identified with these characteristics. The 168 sites were subjected to a screening process where the following questions were posed:

(i) Is there a problem with transmission from the site?

(ii) Is there a fuel access (water or rail) problem?

(iii) Is there a highway access problem?

(iv) Are there environmental problems?

(v) Is there a land use problem?

Those sites which were assessed as having two or more problem areas were dropped from the inventory; this preliminary screening eliminated 105 sites, leaving 63 with no problem areas or only one problem area.

The 63 sites were widely distributed over Vancouver Island and the four general locations identified for wood residue thermal generation each had two sites of the 63 identified.

Siting a wood fired thermal plant would not seem to be a problem. The land and water requirements for a 100 MW wood-fired plant would be a small fraction of the qualities required for a 1200 MW plant[14] and it is likely that sites suitable for a wood fired thermal plant exist in addition to those identified in the B.C. Hydro inventory.

The existing transmission grid for Vancouver Island is shown in Figure 3. The four general locations have reasonable access to this grid.

11.0 SUMMARY AND CONCLUSIONS

Logging activities on Vancouver Island generate an annual volume of between 155 and 190 million cubic feet of sound logging debris (over 3" in diameter). Combined with potential yields from red alder stands and residues from precommercial thinning operations, up to 200 million cubic feet per year of forest biomass is available for conversion into electrical energy on the Island.

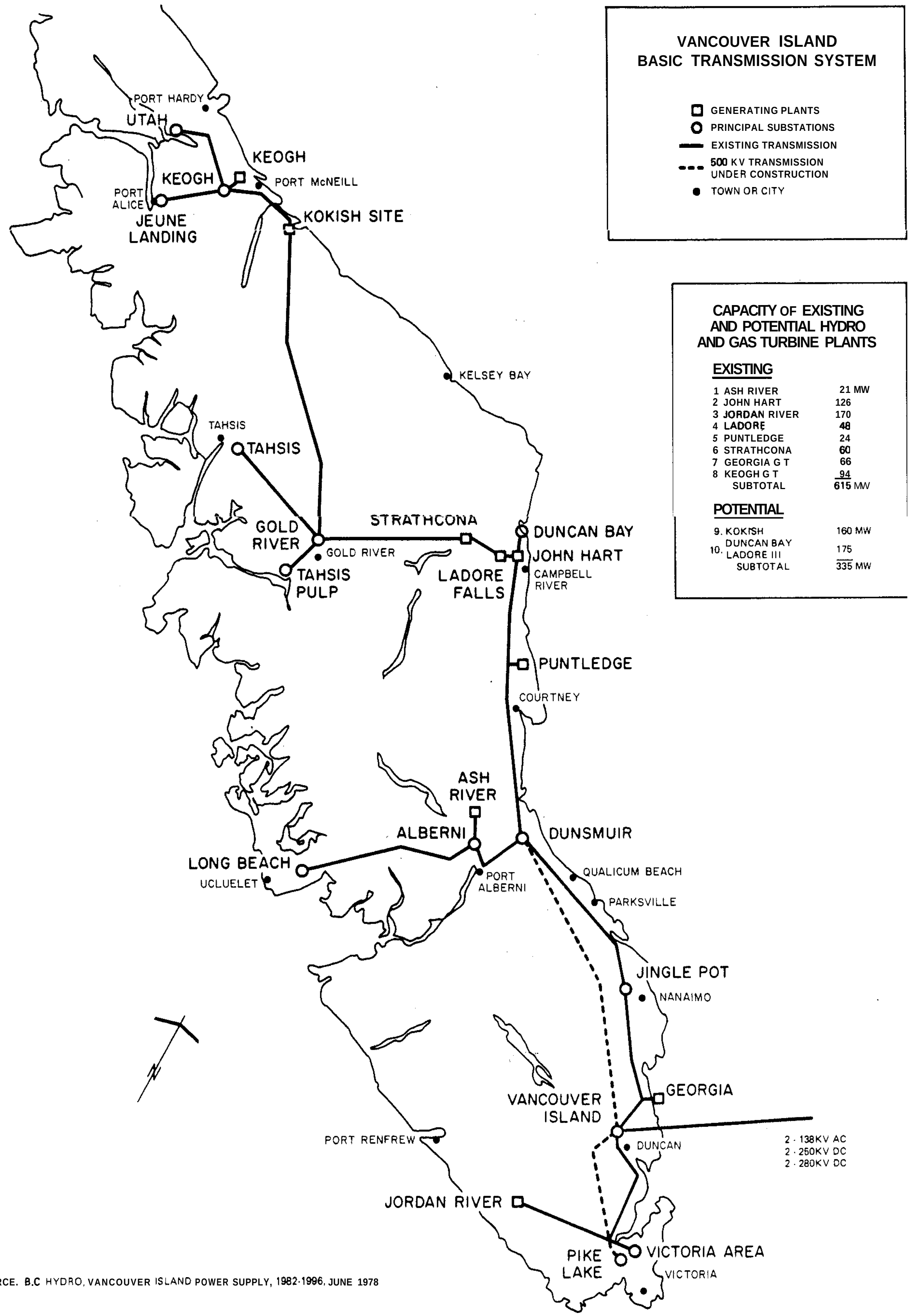
The average volumes of residues remaining after logging on Vancouver Island are only marginally higher per acre than volumes left after logging in comparable mature and overmature stands of U.S. National Forest timber in Washington and Oregon. Logging residues have a relatively short pickup period of about 1 year, between logging and replanting. Their availability is subject, in addition, to road washouts and slash burning as well as insects and disease.

Logging residues presently remain in the woods after logging because the costs of their removal exceed the value of their conversion into products - or into energy,

The energy-short U.S. Pacific Northwest is on the threshold of using logging residues as a source of power now that forest industry mill residues are almost fully utilized. British Columbia's mill residues, on the other hand, have not reached this stage.

Recent investigations into energy sources for Vancouver Island's short term requirements, at least half of which are to meet the needs of the forest industry, appear to have overlooked the opportunities

14. B.C. Hydro feels a 20-acre site would be sufficient for the proposed Quesnel thermal plant, The 20 acres would allow for a doubling of the Quesnel plant to roughly 100 MW and 2 weeks of on-site fuel storage.



CAPACITY OF EXISTING AND POTENTIAL HYDRO AND GAS TURBINE PLANTS

EXISTING	
1 ASH RIVER	21 MW
2 JOHN HART	126
3 JORDAN RIVER	170
4 LADORE	48
5 PUNTLEDGE	24
6 STRATHCONA	60
7 GEORGIA G T	66
8 KEOGH G T	94
SUBTOTAL	615 MW
POTENTIAL	
9. KOKISH	160 MW
10. DUNCAN BAY LADORE III	175
SUBTOTAL	335 MW

SOURCE. B.C HYDRO, VANCOUVER ISLAND POWER SUPPLY, 1982-1996, JUNE 1978 of using forest biomass, a renewable source of energy.

By removing residues at the time of primary logging (first pass logging), the costs of accumulation and delivery can be as low as $43.00 per hundred cubic feet, with a resulting fuel cost for electrical energy generation of approximately 20 mills/kwh.

Logging residues, together with alder, could be used to generate power at four sites on Vancouver Island for a fuel cost approaching that of coal.

The four sites which lend themselves to supporting mills in the 35 to **72** MW capacity range are located in the Port McNeill/Beaver Cove area, the Campbell River/Menzies Bay area, Lake Cowichan and Port Alberni. These sites would use some 45 percent of the current annual potential wood biomass availabilities identified in this report.

Future availabilities of forest biomass are likely to decline from present levels of some 200 million cubic feet to **140** million cubic feet **by** the end of the century, as a result of a number of factors. These include: a) more stringent utilization requirements on the part of the B.C. Forest Ministry; b) increased use by the forest industry itself, as a result of market demands, of more residues for product; c) the shift toward second-growth logging (which leaves far less debris), and d) continuing energy shortages, despite an expected increase in the actual annual level of cut on the Island.

Forest biomass on Vancouver Island appears to offer real prospects of meeting a major part of the Island's short term power needs. In fact, the forest industry itself has the opportunity of expanding its own power and process steam output using forest residues.

BIBLIOGRAPHY

British Columbia Energy Commission, 1978, British Columbia energy supply and requirements forecast, 1978-1992; summary report, Nov.

British Columbia Forest Service, 1938, Normal yield tables for red alder.

British Columbia Hydro and Power Authority, 1978, Vancouver Island power supply, 1982-1996, June.

British Columbia Hydro and Power Authority, 1975, Vancouver Island thermal generating plant site selection inventory.

Brown, James K., 1974, Handbook for inventorying downed woody material, USDA Forest Service General Technical Report INT-16.

Folkeman, M.P., 1977, Whole-tree chipping with the Morbark Model 22 Chiparvester, FERIC Technical note no. TN-16.

Howard, James O., 1973, Logging residue: volume and characteristics, USDA Forest Service Resource Bulletin PNW-44.

McIntosh, J.A. and L.W. Johnson, 1975, "Chipping in the bush", Canadian Forest Industries, Oct.

Mitre Corporation, 1977, Silvicultural biomass farms, v.I. Summary; v.5. Conversion processes and costs, MITRE-TR 7347.

Morris Wayman Limited, 1978, Wood-fired electricity generation in Eastern Ontario, prepared for the Ontario Royal Commission on Electric Power Planning, July.

Neill and Gunter Limited, 1978, A study of the potential for residue/energy systems in Eastern Canada utilizing wood residues, prepared for Environment Canada.

H.A. Simons (International) Ltd., 1978, Hog-fuel co-generation study: Quesnel, British Columbia, prepared for the British Columbia Wood-Waste Energy Coordinating Committee, May.

Smith, D.G. and P.P. Tse, 1977, Loggingtrucks: comparison of productivity and costs, FERIC Technical Report no. TR-18.

Smith, J. Harry G., 1978, Foundation and strategies for modelling wood fibre and energy yields from red alder, a report to the Productivity Committee of the B.C. Forest Service, March.

SNC Consultants Ltd., 1976, Hearst wood wastes energy study, prepared for the Town of Hearst Lumberman's Association, Ontario Ministry of Energy, Ontario Ministry of the Environment.

United States. Comptroller General, 1978, Region at the crossroads - the Pacific Northwest searches for new sources of electric energy; report to the Congress.

Warren, W.G. and P.F. Olsen, 1964, "A line intersect technique for assessing logging waste", Forest Science, v. 10, no. 3, p. 167-276.

OTHER REFERENCE MATERIALS

Adams, Thomas C., 1976, Economic availability of logging residue in the Douglas-fir Region, USDA Forest Service Resource Bulletin PNW-64.

Adams, Thomas C. and R.C. Smith, 1976, Review of the logging residue problem and its reduction through marketing practices, USDA Forest Service General Technical Report PNW-48.

Bare, B.B. and B.F. Anholt, 1976, Selecting forest residue treatment alternatives using goal programming, USDA Forest Service General Technical Report PNW-43.

Bare, B.B. et al, 1976, A simulation-based approach for evaluating logging residue handling systems, USDA Forest Service General Technical Report PNW-45.

Biology of aider, proceedings of a symposium held at Northwest Scientific Association Fortieth Annual Meeting, Pullman, Washington, USDA Forest Service, 1968.

British Columbia Energy Commission, 1978, British Columbia energy supply and requirements forecast, 1978-1992; technical report, Sept.

British Columbia Wood Waste Energy Coordinating Committee, Hog fuel availability in British Columbia, prepared by Reid, Collins and Associates, May.

British Columbia Wood Waste Energy Coordinating Committee, 1978, Hog fuel availability study - South Coastal Region of B.C., prepared by Reid, Collins and Associates, Sept.

Canada, Energy, Mines and Resources, 1978, Tree power: an assessment of the energy potential of forest biomass in Canada, Report ER 78-1.

Canadian Forestry Service, Pacific Forest Research Centre, 1974, Marketing British Columbia hardwoods in North America, Mimeo.

Chambers, Charles J., 1974, Empirical yield tables for predominantly alder stands in Western Washington, DNR Report no. 31.

Conder, S.E., 1975, "Transportation costs in Oregon of wood and bark residues" Wood residues as an energy source, Forest Products Research Society, Madison, Wisc., Proceedings no. P-75-13.

Currier, R.A. et al, 1978, Potential energy uses for diseased and beetle-killed timber and forest residues in the Blue Mountain Area of Oregon, DOE Report no. RLD/2227/T33-1, Sept.

Dell, John D. and F.R. Ward, 1971, Logging residues on Douglas-fir clearcuts - weights and volumes, USDA Forest Service Research Paper PNW-115.

Diggle, Paul K. and R.B. Addison, 1977, Management opportunities on the Sayward Forest, British Columbia Forest Service, Special Studies Division.

Evans, R.S., 1974, Energy plantations: should we grow. trees for power plant fuel, Environment Canada VP-x-129.

Evans, R.S., 1977, Energy self-sufficiency prospects for the British Columbia forest products industry, Fisheries and Environment Canada Information Report, VP-X-166.

Garner, G.J., 1978, Study of a contractor hauling system, FERIC Technical Report no. TR-24.

Granthan, John B. et al, 1974, Energy and raw material potentials of wood residue in the Pacific Coast States - A summary of a preliminary feasibility investigation, USDA Forest Service General Technical Report PNW-18.

Granthan, John B., 1974, Status of timber utilization of the Pacific Coast, USDA Forest Service General Technical Report PNW-29.

Hamilton, Thomas E et al, 1975, Per-acre pricing - its effect on logging residue, USDA Forest Service Research Paper PNW-192.

Howard, James O. and F.R. Ward, 1972, Measurement of logging residue - alternative applications of the line intersect method, USDA Forest Service Research Note.

Howard, James O., 1976, A technique for predicting logging residue volumes in the Douglas-fir Region, USDA Forest Service Research Paper PNW-235.

Increased energy from biomass: 1985 possibilities and problems, working papers for planners. Recommendations and proceedings from Pacific Northwest Bioconversion Workshop, Oa., 1978.

Johnson, L.R., 1978, "Forest residue delivery". presented to the Pacific Northwest Bioconversion Workshop, Portland, Ore.

Koss, William et al, 1977, Residue, roundwood and the Washington pulp industry, DNR Report no. 35.

Manning, G.H., 1975, British Columbia's neglected hardwood resource, Canadian Forestry Service Pacific Forest Research Centre Report BC-X-118.

Martin, A. Jeff, A user's guide to the REST system for summarizing logging residue information, Northeastern Forest Experiment Station, n d .

Martin, Brian, 1978, "Government policies to be scrutinized", British Columbia Lumberman, Jan.

Maxwell, Wayne G. and F.R. Ward, 1976, Photo series for quantifying forest residues in the: Coastal Douglas fir-hemlock type/Coastal Douglas fir-hardwood type, USDA Forest Service Technical Report PNW-51.

McConnell, J.M., 1976, "Back-pressure turbines warrant a larger role in energy conservation", Pulp and Paper, Nov.

New England Federal Regional Council Energy Resource Development Task Force Wood Utilization Work Group, 1977, The potential of wood as an energy resource in New England.

Peat, Marwick and Partners, 1977, Analysis of wood costs in the North American forest products industries, prepared for ITC.

Randall, Robert M., 1977, Financial consequences of commercial thinning regimes in young-growth Douglas-fir, USDA Forest Service Research Note.

Reukema, Donald L. and D. Bruce, 1977, Effects of thinning on yield of Douglas-fir; concepts and some estimates obtained by simulation, USDA Forest Service Technical Report PNW-58.

Ruth, Robert H. and A.S. Harris, 1975, Forest residues in hemlock-spruce forests of the Pacific Northwest and Alaska, USDA Forest Service General Technical Report PNW-39.

Ryan, Kevin C. and S.G. Pickhard, 1978, Physical properties of woody fuels in the Blue Mountains of Oregon and Washington, USDA Forest Service Research Note.

Siegal, G.R., **1975,** "Wood residuaas a fuel in the commercial productions of electricity", Wood residues as an energy source, Forest Products Research Society, Madison, Wisc., Proceedings no. **P-75-13.**

Smith, Nicholas J., **1977,** Red alder as a potential source of energy, paper presented to the Alder Utilizetion and Management Conference, Ocean Shores, Washington.

Staples, R. et al, **1978,** Watts from wafers, prepared for the Ontario Royal Commission on Electric Power Planning, March.

U.S. Dept. of Agriculture. Forest Service, **1962,** Red alder, its management and utilization, Miscellaneous publ. no. **881.**

APPENDICES

APPENDIX A

Table A I

1977 Acreages Logged by Ranger District, Management Unit and Tenure - Vancouver Island

Ranger District	Management Unit	Tenure	Acreage Logged: Close Utilization	Optional Utilization	Unknown* Utilization	Total
12	Quadra	Private**		90		90
Savward	T.F.L.	T.S.L. (within T.F.L. 7)	66			66
	T.F.L.	T.F.L. 7		1,062		1,062
	T.F.L.	T.F.L. 25	156			156
	T.F.L.	T.F.L. 39		2,137		2,137
	Total T.F.L.		222	3,199		3,421
	Grand Total		222	3,289		3,511
15	Nootka	T.S.H. L.		424		424
Port McNeill	Nootka	Timber Lic.	192			192
	Total Nootka		192	424		616
	T.F.L.	(Lot 240-Nimpkish within T.F.L. 37)		151		151
	T.F.L.	T.F.L. 2		1,036		1,036
	T.F.L.	T.F.L. 25	748			748
	T.F.L.	T.F.L. 37		3,638		3,638
	T.F.L.	T.F.L. 39		1,585		1,585
	Total T.F.L.		748	6,410		7,158
	Grant Total		940	6,834		7,774
16	Kingcome	T.S.H. L.	467	566		1,033
Port Hardy	Kingcome	T.S. L.	75			75
	Total Kingcome		542	566		1,108
	T.F.L.	T.F.L. 6	4,442			4,442
	Grant Total		4.984	666		5,550

* Most unknown utilization logging lies within private lands. Acreages logged within these lands have been obtained mainly from the individual Ranger Districts, and are mostly approximate acreages. In many cases there is no specific utilization standard on private lands, but the average utilization would fall somewhere between C.U. and Optional. Therefore, about half the unknown utilization could be assumed to be C.U. and the other half Optional or, alternatively, the printout average volume per acre for all logging could be used to multiply by these acreages to obtain a total volume.

** Acreages listed as private, in all cases in this table, do not truly form part of the Management unit as such, but since they are within the boundaries of the specific Management unit mentioned, form part of the unit total.

Ranger District	Management Unit	Tenure	Acreage Logged: Close Utilization	Optional Utilization	Unknown Utilization	Total
17 Campbell River	Quadra	T.S.H. L.	202	792		994
	Quadra	T.S. L.	79	330		409
	Quadra	Timber License		134		134
	Total Quadra		281	1,256		1,537
	E & N	Tax Tree Farm	8			8
	E & N	Private			463	463
	Total E & N		8		463	471
	Park	Strathcona Park			181	181
	T. F. L.	T.F.L. 7		779		779
	Grand Total		289	2,035	644	2,968
19 Parksville	E & N	T.S.L. (in island plantation	161			161
	E & N	Tax Tree Farm			1,013	1,013
	E & N	Farm Woodlot			10	10
	E & N	Hydro ROW (Crown)			178	178
	E & N	Private (includes 344 Hydro ROW)			2,020	2,020
	Grand Total E & N		161		3,221	3,382
21 Duncan	E & N	T.S.L. (in island plantation)	306			306
	E & N	Tax. Tree Farm		3,363		3,363
	E & N	Farm Woodlot		2		2
	E & N	Private			2,000	2,000
	Grand Total E & N		306	3,365	2,000	5,671
23 Landford	Nootka	T.S. L.			61	61
	Nootka	Timber License		170		170
	Total Nootka			170	61	231
	E & N	Tax. Tree Farm			50	50
	E & N	Private		1,200		1,200
	Total E & N			1,200	50	1,250
	T.F.L.	T.F.L. 25	733			733
	Grant Total		733	1,370	111	2,214

Ranger District	Management Unit	Tenure	Acreage Logged: Close Utilization	Optional Utilization	Unknown Utilization	Total
24 Lake Cowichan	Nootka	T.S. L.	258			258
	E & N	T.S.L. (within island plantation)	36			36
	E & N	Private	___		1,260	1,260
	Total E & N		36		1,260	1,296
	T.F.L.	Timber License (revertingto T.F.L. 22 on completion)	513			513
	T.F.L.	T.F.L. 22	1,855			1,855
	T. F. L.	T.F.L. 27	252			252
	Total T.F. L.		2,620			2,620
	Grand Total		3,427		1,260	4,687
25 Port Alberni	Nootka	T.S.H.L.	189			189
	Nootka	T.S. L.	23			23
	Nootka	Timber License	___	132		132
	Total Nootka		212	132		344
	E & N	Timber License		215		215
	E & N	License to Cut	38			38
	E & N	Private	37	528		565
	Total E & N		75	743		818
	Park	Strathcona Park	410			410
	T.F.L.	T.F.L. 20		745		745
	T.F.L.	T.F.L. 21		6,067		6,067
	Total T.F.L.			6,812		6,812
	Grant Total		697	7,687		8,384
26 Tofino	Nootka	T.S.H.L.		120		120
	Nootka	Timber License		532		532
	Nootka	Right of Way		20		20
	Nootka	Private		___	150 (IU)	150
	Total Nootka			672	150	822
	T. F. L.	T.F.L. 20		2,453		2,453
	T.F.L.	T.F.L. 22	650	___		650
	Total T.F.L.		650	2,453		3,103
	Grant Total		650	3,125	150	3,925

Ranger District	Management Unit	Tenure	Acreage Logged			
			Close Utilization	Optional Utilization	Unknown utilization	Total
28	Nootka	T.S.H. L.	1,753	450		2,203
Gold River	Nootka	T.S.L.	404			404
	Nootka	Timber License	1,041	270		1,311
	Nootka	Private			265 (IU)	265
	Total Nootka		3,198	720	265	4,183
	T.F.L.	T.F.L. 19	3,159			3,159
	T.F.L.	T. F. L. 22	230			230
	Total T.F.L.		3,389			3,389
	Grand Total		6,587	720	265	7,572

Table A2

Tree Farm License Acreage Logged and Recoverable and Non-recoverable (Firmwood Rejects) Waste Volumes Per Acre for Tree Farm Licenses in which Waste Surveys Volumes have been Supplied by the Licensee and which were not Compiled by the Ministry of Forests

T.F.L.		Volume per acre in cubic feet			
T.F.L.	Acreage Logged	Recoverable Optional Volume (within Optional Specifications Only),	Recoverable Close Utilization Volumes	Non-Recoverable Close Utilization Volumes	Total Close Utilization Volumes
6	4,442	N/A	777	89	866
7	1,841	435	1,063	64	1,127
19	3,159	N/A	692	5	697
20	3,198	1,047	1,984	52	2,036
21	6,067	232	868	26	894
27	252	N/A	608	3	611
25	1,637	N/A	912	138	1,050
39	3,722	295	943	26	969

Table A3

Vancouver Island Logging - 1977

Ranger District No.	• Name	Log removals* 1000 cu ft	Area logged Acres	Avg vol of logs removed in cu ft /acre
12	Sayward	35,376	3,511	10,076
15	Port McNeill	72,565	7,774	9,334
16	Port Hardy	56,885	5,550	10,249
17	Campbell River	25,759	2,968	8,679
19	Parksville	50,441	3,382	14,914
21	Duncan	45,891	5,671	8,092
23	Langford	33,384	2,214	15,079
24	Lake Cowichan	62,704	4,687	13,378
25	Port Alberni	66,147	8,384	7,890
26	Tofino	41,324	3,925	10,528
28	Gold River	75,740	7,572	10,003
Totals		566,216	55,638	10,177

• **Logs scaled**

Source: B.C. Forest Service Records

APPENDIX B

1977 B.C. FOREST SERVICE UNRECOVERED WOOD SURVEY - VANCOUVER ISLAND CALCULATION OF STANDARD ERROR OF PER ACRE VOLUME ESTIMATE

The B.C. Forest Service unrecovered wood survey printout provides information by individual opening (logging setting or landing) on the volume of "waste" left on the ground following logging activities during 1977. Each opening is clearly identified by management unit, sub-unit, timber mark, landing or road number, ranger district and year logged. Within each opening, one-tenth acre plots are randomly located to give a sampling intensity of approximately one percent by area (i.e., one 1/10-acre plot to every 10 acres). Within each plot, individual pieces of unrecovered wood to a 6-inch top diameter are identified by species, kind of waste (B.C.F.S. classification), top diameter, butt diameter, length and volume in cubic feet. Waste volume per acre is found by simply calculating the average waste volume per plot and multiplying by 10. Summaries provided in the printout give average volume per acre in cubic feet by opening, broken down by species, waste class and kind of waste.

To demonstrate the statistical precision of the volume per acre estimates, the survey for **T.F.L.** 37 was taken as an example. In T.F.L. 37 there are 35 individual openings (excluding landings) with a total area of 2,077 acres (an average of 59 acres per opening) on which are located 205 individual sample plots. For 16 openings (HH11 to A100), the mean volume per acre, standard error and coefficient of variation (standard error as a percentage of the mean) were calculated. These are summarised in Table B1. Coefficients of variation ranged from 4 to 74 percent. The volume of unrecovered wood frequently varies greatly over a single opening and this is reflected in the very high standard errors exhibited by many of the volume estimates. It would be fair to say that unrecoverable volume estimates on a per opening basis are imprecise and could only be improved by increasing the sampling intensity. If, however, all sample plots are grouped together and the mean volume per acre for all 16 openings calculated simultaneously, the statistical precision of this mean volume estimate is greatly improved, having a coefficient of variation of only 7 percent. If the mean volume per acre estimate was extended to include all 35 openings and 205 sample plots, it is likely that the standard error would be reduced further.

Table B1

Open Slash **T.F.L.-37 RD-15 Yr Logged - 1977**

Opening	No. of Plots (1/10 ac)	Area	Mean Volume Per Acre	Standard Error	Coefficient of Variation
		acres	cu ft	cu ft	%
HH11	14	136	1110.6	233.5	21
MC9	5	47	682.8	145.4	21
HR77	6	51	1276.5	244.5	19
H72B	1	10	633.0	—	—
HTIO	2	18	2111.5	1554.2	74
HT4	3	24	1677.0	598.0	36
H70	8	76	1215.7	260.7	21
HG33	3	30	1401.0	768.6	55
KT51	5	50	1470.6	107.4	7
AW2W	2	14	415.5	15.6	4
Y3WF	2	18	605.0	154.5	26
K73	2	18	1071.5	517.0	48
M28	6	56	1100.9	204.9	19
TO5W	2	23	1392.5	168.0	12
H931	2	13	1321.0	636.9	48
A100	15	147	1115.2	198.0	18
TOTAL	78	731 (16 openings)	1162.5	85.9	7

Table B2a

Study Findings - Average Volumes of
Sound Logging Residues by Ranger District

Volumes per Acre in Cubic Feet
(3" and over in diameter)

Ranger District No.	Ranger District Name	Avg Vol/Acre
12	Sayward	2,654
15	Port McNeill	3,912
16	Port Hardy	3,542
17	Campbell River	2,069
19	Parksville	1,856
21	Duncan	2,856
23	Langford	2,948
24	Lake Cowichan	1,792
25	Port Alberni	2,262
26	Tofino .	6,622
28	Gold River	3,091

Table B2b

Study Findings - Logging Residues by
Biogeoclimatic Zone

(For material 3" and over in diameter)

Biogeoclimatic Zone	Basis No. of Plots	Avg Vol/Acre cu ft
Coastal Douglas-Fir	6	2,591
Coastal Western Hemlock	24	3,538
Alpine Mountain Hemlock	12	2,756
Totals	42	3,179

APPENDIX C

COMPARATIVE B.C. AND U.S. PACIFIC NORTHWEST SOUND LOGGING RESIDUES SURVEY RESULTS

B.C. Forest Service 1977 Logging
Vancouver Forest District

Close utilization volumes - all tenures	735 cu ft/ac
Optional utilization volumes - all tenures	1,067 cu ft/ac

Paul H. Jones & Associates Limited Study 3" t

Vancouver Island only - all tenures	3,174 cu ft/ac
Washington State Dept. of Natural Resources	2,763 cu ftlac

U.S. Forest Service (Howard 1973)

National Forests, Washington & Oregon	3,127 cu ft/ac
Other public forests in Washington & Oregon	1,327 cu ft/ac

and from same study

Age of Stand	Avg Gross Volume	Avg Defect of Residue
Under 101	1,236	12
101 - 200	1,948	18
201 - 300	3,915	26
301 +	5,812	31

Olympic Peninsula - Cedar Residue over 4"	18,604 cu ft/ac
Alaska - All species (19 clearcut units)	1,329 cu ft/ac

STUDY SAMPLE CALCULATIONS
FOR PORT McNEILL RANGER DISTRICT
FOR OPENINGS 6, 7, 8, 9, 10, 11, 12 & 15

Opening	Plot	Cu ft/ Acre
6	1	4,307
	2	6,130
	3	6,580
	4	7,313
	5	16,408
	6	7,626
	7	17,893
	8	4,669
	9	3,489
	10	5,951
7	1	1,108
	2	2,245
	3	5,831
	4	3,971
	5	3,442
	6	7,104
	7	4,410
	8	1,203
	9	2,451
	10	2,812
	11	1,541
	12	1,132
	13	1,140
	14	4,733
	15	930
8	1	1,982
	2	2,624
	3	1,569
	4	785
	5	1,784
	6	1,271
	7	1,263
	8	522
	9	1,433
9	1	5,988
	2	6,630
	3	4,960
	4	5,917,
	5	7,255
9	6	6,412
	7	8,403
	8	5,967
	9	7,367
	10	5,462
	11	3,866
	12	4,618
	13	2,551
	14	4,352
	15	4,412
10	1	2,551
	2	2,450
	3	1,528
	4	3,846
	5	1,836
	6	2,769
	7	1,571
	8	2,409
	9	3,773
	10	771
	11	1,191
	12	2,051
	13	2,790
	14	2,905
	15	1,627
	16	2,504
	17	2,489
11	1	9,800
	2	5,135
	3	1,823
	4	7,494
	5	2,935
	6	2,640
	7	2,599
	8	1,390
	9	4,846
	10	8,360
	11	5,227
	12	5,189
	13	5,932
12	1	1,594
	2	2,515
	3	1,780
	4	948
	5	5,173
	6	1,209
	7	4,958
	8	1,125
	9	2,549
	10	2,344
15	1	9,047
	2	3,499
	3	4,157
	4	8,907
	5	3,558
	6	8,322
	7	8,472
	8	8,210
	9	4,034
	10	1,149
	11	3,415
	12	4,191
	13	467
	14	4,973
	15	113
	16	4,971
	17	1,248
	18	2,969
	19	2,426
	10	256
TOTAL		432,772

Study Sample Calculations (cont'd)

Hence Arithmetic Mean

= Σ (Ed^2 x 1,866) IN

where N = number of plots

= 432,8361109

= 3,971 cu ft/acre

Net assumed mean = 4,000

			x	f	fx	$x^2 \times 10^6$	$fx2 \times 10^6$
0	–	2,000	–2,000	32	–64,000	4	128
2,001	–	4,000		31			
4,001	–	6,000	+2,000	26	+52,000	4	104
6,001	–	8,000	+4,000	10	+40,000	16	160
8,001	–	10,000	+6,000	8	+48,000	36	288
10,001	–	12,000	+8,000				
12,001	–	14,000	+10,000				
14,001	–	16,000	+12,000	1	+12,000	144	144
16,001	–	18,000	+14,000	1	+12,000	196	196
				109	+100,000		1,020

Stand Dev. = + 2,931

C.V. = .74

Z. Degree of Prec. = 13.9%

using $Z = \sqrt{\frac{(C.V.)^2 (t)^2}{N}}$

where **Z** = degree of precision

t = "Students' " **t** value at 95% confidence level

N = number of sample units

C.V. = coefficient of variation for each sample

NOTE: 1.866 is the constant from the volume formula on Page 8.

APPENDIX D HAULING COST CALCULATION[1]

Hauling - On-highway

A. Function - Truck haul to dump or dryland sorting area.

B. Cost Components -

1. Licences, Permits and Insurance
2. Depreciation - as determined by 1977 truck survey
   Truck and trailer 15% of purchase price
   Scales 5 years straight line no residual.
3. Operator's wages plus benefits and running costs.

C. Phase Allowance

1. Daily fixed costs

SHIFTS/YEAR	DAILY COST ALLOWANCE
200	51.27
190	53.96
180	52.14
170	55.21
160	58.66

2. Qperators'wages 9.5 hours. 115.08
   - overtime rate $16.84
3. Running cost = Round trip haul distance x trips per day x .57/mile
4. TOTAL COST PER DAY
5. Number of loads hauled x average load in cunits
   (Load sizes HB types 4.1 m^3 F. types 4.2 m^3)
6. Haul cost/m^3 (4 ÷ 5)

D. Comments

1. This method is based on the results of our 1977 truck review.
2. It is assumed that trucks carry weigh scales in order to transport the maximum within the limits of D.O.T. regulations; hence, the average loads sizes stated above.
3. To determine haul times:
   (a) Ascertain the normal number of trips hauled per day out of an area and the total time involved;
   (b) Check with the weigh station for time "in" and "out";
   (c) If the above data are not available:
      (i) Determine normal speed throughout route by pickup;
      (ii) Calculate delays per trip
         (a) Loading – Heelboom 1 minute/log for the average load count
             – Frontend loader .5 minute/log for the average load count
             – maximum 40 minutes.
         (b) Unloading or dumping. . . . . 10 minutes.
         (c) Divide the total trip time into 9.1 hours or 546 minutes to acquire the number of loads and parts of loads that can be hauled within the average time available each shift (96 percent of 9.5 hours – normal availability is 96 percent)

[1] **From B.C. Forest Service Timber Appraisal Manual 1978**

Hauling - Off Highway

A. Function - Truck haul from all planned logging settings to the dump at tidewater or dry land sorting area. The average distance to be weighted by volumes hauled from each cutting permit or block.

B. Cost Components

1. Depreciation
2. Operator's Wages
3. Repairs and Overhaul Costs
4. Running costs per mile,

C. Phase Allowance

1. Daily Fixed Costs

(a) Annual Depreciation $4,927
Modified for 94 percent availability $5,241

SHIFTS/YEAR	RATE/SHIFT
220	$ 23.82
210	24.96
200	26.20
190	27.58
180	29.12
170	30.83
160	32.76
150	34.94
140	37.44
130	40.32
120	43.68
110	47.65
100	52.41

(b) Operator's Wages
Rate $9.23 x 10.25 hours x 1.2545 = $118.68/shift

(c) Repairs, Maintenance, Overhauls - Supplies and Labour $186/shift

2. Running Costs per mile. $1.05/mile (0.65/km)

3. Average load size. .... 24.6 cunits (8.7 m3)

D. 1. All units were depreciated at 15 percent of their purchase price to arrive at a total annual figure for the units sampled. In turn, this figure was amortized over the total number of trucks.

2. It was discovered in our review that the normal truck day approximates 9.5 hours, during which the units sampled average an availability of 94 percent. The Range was 87 - 98 percent.

3. There was a wide range of running costs and of size of loads transported; the maximum exceeding the minimum by 46 percent.

4. Determine the number of trips and parts of trips that can be accomplished within the 9 hour day (the 9.5 hour day has been reduced by an availability of 94 percent).

Delay times are to be calculated as follows:

(i) Loading - number of logs per 8.7 m^3 load times 0.8 minutes per log.
(ii) Unloading or dumping 10 minutes.

Derivation of Hauling Cost - on Highway

A. FIXED COSTS

		9 months	12 months
1. Licence - Truck and Trailer		851	$1,135
2. Insurance	Truck	1,214	1,698
	Trailer	480	640
3. Depreciation - Truck and Trailer			5,975
	Scales		535
	TOTAL		6,5 10
	Modified for 96% availability		6,781

4. Daily fixed costs

Annual Number of shifts	160	180	200
Annual Cost	9386	9386	10254
Shift Cost	58.66	52.14	$51.27

B. OPERATOR'S WAGES & FRINGE BENEFITS

1. Assuming an average 9.5 hours per day

$8.95 x 10.25 hours x 1.2545 = **$115.08**
Overtime rate $8.95 x 1.5 x 1.2545 = 16.84

C. RUNNING COSTS PER MILE.. .... .57

The above rate per mile was determined from a November-December, 1977 truck survey.

Logging Cost Basis

Logging costs were calculated on the basis of the formula used by the Truck Loggers Association of B.C. A copy of the Association's 1978 schedule of rental rates follows. For logging, the proportion of labour costs to total costs are normally much higher than in construction. Depending upon the amount of "travel and overtime", labour costs normally represent (including payroll burden) 62 to 65 percent of total logging costs.

The following factors were considered in arriving at logging costs:

Fixed	Variable
Volumes per acre	Logging system
Average piece size	Labour rates
Range in size of pieces	Distance of yarding
Climate	Size of machine
Number of normal work days per year	Material flow
	Slope
	Uphill or downhill yarding

LOGGING COSTS AND SYSTEMS

The Truck Loggers Association Suggested Rental Rates - All Found Rates with Operators

(Effective June 15, 1978)

NOTES

1. All rates are in $/hour, except as stated.

2. Rates are calculated using the standard formula expressed in most equipment and operating guides.

3. The purchase cost of equipment is based on current costs for a machine equipped for normal coastal operations and includes such items as tilt cylinders, extreme service packages, heavy duty rubber, winch and R.O.P.S. protection.

4. The rates are for the rental of the basic machine under average conditions. Special conditions such as replacement of wire rope and chokers where they are in continued use, provision of transportation for the operator, supply of fuel tanks, provision of extra attachments such as integral arch or rippers on site supervision and room and board for the operator must be negotiated since, in some cases, they can amount to as much as **$13.20** per hour.

5. Rates for additional labour should be charged at payroll cost plus 100 percent.

6. The basic rate applied to operations with good road access.

7. Zone A - Up coast areas with poor access, including parts of Kingcome P.S.Y.U. and Nootka area, plus Estevan district and mainland Quadra district.

   Zone B - Isolated parts of Dean and Rivers P.S.Y.U.'s and Queen Charlottes, etc.

MACHINE TYPE		BASIC RATE $	ZONE A $	ZONE B $
Crawler Tractor				
D-5		50.50	54.00	57.75
D-6D		57.50	61.50	65.75
D-7G		69.50	74.25	79.50
D-8K		88.50	94.75	101.25
D-9H		115.25	123.25	132.00
Crawler Loader				
955L	2-¼ yd	44.25	47.25	50.75
977L	3-¼ yd	57.75	61.75	66.00
983	4-½ yd	79.50	85.00	91.00
Rubber Tired Loaders - Bucket or Forks				
950	2-½ yd	45.00	48.25	51.50
966C	3-½ yd	55.00	58.75	63.00
980C	4-½ yd	73.00	78.00	83.50
988B	6 yd	98.00	104.75	112.25

MACHINE TYPE	BASIC RATE $	ZONE A $	ZONE B $
Hydraulic Excavators			
Cat 225	61.00	65.25	69.75
Cat 235	98.75	105.75	113.00
Cat 245	139.50	149.25	159.75
Grade Shovels - excluding Padman			
1-¼ yd	66.75	71.50	76.50
1-¾ yd - 2 yd	81.75	87.50	93.50
Gravel Trucks			
Diesel 12 yd Off-Highway	2.90/yd hr	3.00/yd hr	3.15/yd hr
12 yd Off-Highway Rock	3.10/yd hr	3.20/yd hr	3.35/yd hr
Graders			
12G	45.00	48.15	51.52
14G	56.00	59.92	64.11
16G	68.50	73.30	78.43
Rubber Tired Skidders			
Cat 518 (120 H.P.)	36.75	39.32	42.07
Cat 528 (175 H.P.)	51.00	54.57	58.39
Rock Equipment			
150 cfm Compressor			
1 Jackhammer - 1 Driller	31.00	33.25	35.50
325 cfm Compressor			
2 Driller - 2 Jackhammers	50.25	53.75	57.50
450 cfm Compressor			
Airtrac - 1 Driller	57.25	61.25	65.50
600 cfm Compressor			
Airtrac - 2 Man	79.25	84.75	90.75
Mini Drill, Tank Mounted			
- 2 Men	74.00	79.25	84.75
600 cfm Tank Drill			
- 2 Men	92.50	99.00	106.00
Lowbeds			
Truck & Trailer, 25 ton	39.75 on highway		
Truck & Trailer, 35 ton	43.75 on highway		
Truck & Trailer, 50 ton	49.00 on highway		

MACHINE TYPE	BASIC RATE $	ZONE A $	ZONE B $
Logging Trucks, 10 hr/day + fuel			
12 ft Bunks	41.00	43.87	46.94
15 ft Bunks	54.00	57.78	61.82

Yarder & Loader

Monthly rental of 5% of present machine value, exclusive of: . . . . .
hours, labour, repairs, maintenance and operating costs.

EQUIVALENT MACHINE MODELS

Crawler Tractor

Cat	Fiat Allis	International	Komatsu	Terex
D5	---	---	D-53A-16	---
D6D	HD 11-B	TD 15C	D-65A- 6	---
-	---	---	D-65E- 6	---
D7G	HD 16-B	TD20E	D-85A-12	82-20
-	---	---	D-85E-12	---
-	---	---	---	82-30B
D8K	HD 21-B	TD25C	D-155A	---
D9H	---	---	D-355A-3	82-50B

Crawler Loader

Cat	Fiat Allis	International	Komatsu
955L	FL10B	175C	D-57S
977L	12G-B	250C	D-75S-3

Rubber Tired Loaders

Cat	Fiat Allis	International	Michigan	Terex	Trojan
950	645-B	H65C	75B	72-31	2000
-	---	--	---	72-41	--
966C	745-B	H80B	---	72-51	2500
-	745H-B	H90E	125B	---	3000
980C	---	H100C	175B	---	4000
988B	945-B	--	275B	---	6000
-	---	560	---	72-71	--

Graders

Cat	Fiat Allis	Wabco	Champion	Galion	A & W
12G	150-C	666B	D600	T500L	5-301
14G	200-c	777B	D686	T600SB	5-501
16G	---	888B	D760	---	--

Skidders

Cat	Clark	Tree Farmer	Timberjack
518	667	C6	360
528	668B	C8	550

METHOD USED TO CALCULATE EQUIPMENT RATES

General

Purchase price is current list price from supplier for machine equipped for construction including Provincial tax; e.g., a D8K is assumed to have double tilt angle blade, extreme service package hydraulic winch, etc., but no provision for extra winch of other custom modifications.

Depreciation

Straight line to no residual

Crawler Tractors	- 10,000 hours	
Loaders	- 10,000 hours)	on purchase price
Graders	- 12,000 hours)	less tires
Excavators	- 10,000 hours	

Interest & Insurance

Insurance	- $1.30/$100 of Investment
Interest	- 15% simple interest

Field & Lube Costs

Consumption from Caterpillar handbook, using the following prices;

Diesel	$0.73 per gal
Lube & Hydraulic Oil	$3.19 per gal
Grease	$0.82 per pound

Repairs & Labour

Arbitrary decision to use compromise between Caterpillar and Terex handbooks.

Crawler Tractors	- 80% of depreciation
Drill Equipment	- 70% of depreciation
Wheeled Equipment	- 55% of depreciation
Hydraulic Excavators	- 60% of depreciation for Cat 225
	- 70% of depreciation for Cat 235,245

Tires

Assume 3000 hours on loaders, 4500 hours on graders. 80% replacement cost for recaps.

Operating Labour

Current I.W.A. wage rates (COLA included), plus 30% payroll loading.

Overhead

10% on total to allow for office, accounting, advertising, etc.

Profit

10% of total

Operating Season

1,500 hours on all crawler and construction equipment.
2,000 hours on loaders in sorting yard.

EXAMPLE CALCULATIONS

D8K	- Purchase Price	$221,807	June 1978
Operating season, 1,500 hours/yr			
	- depreciation	$ 22.18/hr	
	- insurance	$ 1.92	
	- interest	$ 11.83	
	Total Owning Cost	$ 35.93	
Operating costs			
	- fuel and lube	$ 6.77	
	- repairs	17.74	
	Operating costs	$ 24.51	
Total O & O		$ 60.44	
	- operating wages	$ 12.71	
	- overhead	$ 7.32	
	- profit	$ 8.05	
	Total	$ 88.52	

WAGE SUPPLEMENT NO. 1

		EFFECTIVE		
		June 15/77	June 15/78	Jan 1/79
Yarding & Loading Crew				
Tension Skidder Hook & Rig	R.W.	10.07	10.57	10.62
Steel Spar Hooktender	R.W.	9.79	10.29	10.34
Mobile Grapple Yarder Hooktender	R.W.	9.51	10.01	10.06
Tension Skidder Hooktender	R.W.	9.23	9.73	9.78
Slackline Rigging Slinger	R.W.	8.95	9.45	9.50
Rigging Slinger	R.W.	8.73	9.23	9.28
Rubber Tired Skidder Hooker		8.51	9.01	9.06
Cat Hooktender		8.51	9.01	9.06
Landing Bucker		9.79	10.29	10.34
Landingman		8.51	9.01	9.06
Second Loader -Widening Rt. of Way		8.51	9.01	9.06
Second Loader		8.16	8.66	8.71
Chaser		8.16	8.66	8.71
Chokerman		8.06	8.56	8.61
Radio Whistle (other than R.W. categories)		Occupational Rate + 15%¢ /hour		
Machine Operators				
Mobile Grapple Yarder Operator		9.79	10.29	10.34
Grapple Operator - Widening Rt. of Way		9.79	10.29	10.34
Grapple Operator (Loading 2 or more sides)		9.79	10.29	10.34
Grapple Operator (Loading one side)		9.23	9.73	9.78
Tension Skidder Operator		9.23	9.73	9.78
Steel Spar Operator (Grapple Yarding)		9.23	9.73	9.78
Slackline Steel Spar Operator		9.23	9.73	9.78
Front End Log Loader & Unloader		9.23	9.73	9.78
Steel Spar Operator		8.95	9.45	9.50
Log Dump Operator Weighmaster		8.95	9.45	9.50
Rubber Tired Skidder Operator (Grapple)		8.73	9.23	9.28
Rubber Tired Skidder Operator		8.51	9.01	9.06
Cat Arch Operator		8.51	9.01	9.06
Log Dump Operator		8.51	9.01	9.06
Boom Crew				
Head Boomman		8.95	9.45	9.50
Second Boomman		8.51	9.01	9.06
Boatman		8.51	9.01	9.06
Boomman		8.16	8.66	8.71
Falling & Bucking				
Falling & Bucking - 6% hour day		113.52	117.52	117.92
Falling & Bucking - Call Time & Travel Time		14.19	14.69	14.74
Woods Scaler		8.73	9.23	9.28

	EFFECTIVE June 15/77	June 15/78	Jan 1/79
Road Construction			
Shovel Operator - Grade	9.23	9.73	9.78
Bulldozer Operator - Grade	9.23	9.73	9.78
Rock Driller - Tractor, Tank or Air Track	8.95	9.45	9.50
Grade Operator	8.73	9.23	9.28
Front End Loader Operator	8.73	9.23	9.28
Bulldozer - Utility	8.73	9.23	9.28
Shovel Operator - Ballast	8.51	9.01	9.06
Powderman	8.41	8.91	8.96
Driller's Assistant	8.06	8.56	8.61
Padmen, Pitmen, Swampers	8.06	8.56	8.61
Roadman	7.86	8.36	8.41
* Drillers & Powderman - With Ticket	Occupational Rate + 20C		
Trucks			
Log Truck Driver - Off Highway	9.23	9.73	9.78
* – Preload	– Truck Rate + 10¢ /hour		
– Pup Trailers	– Truck Rate + 25 C /hour		
Highway Log Truck Driver	8.95	9.45	9.50
Gravel Truck Driver	8.51	9.01	9.06
Crew Bus Driver	8.06	8.56	8.61
Cookhouse & Bunkhouse			
Cook (Room & Board +)	8.95	9.45	9.50
Second Cook (Room & Board +)	8.41	8.91	8.96
Baker (Room & Board +)	8.41	8.91	8.96
Lunchman	7.86	8.36	8.41
Kitchen Mechanic	7.86	8.36	8.41
Flunkey	7.76	8.26	8.31
Dishwasher	7.76	8.26	8.31
Bullcook	7.76	8.26	8.31
* Head Cook with Ticket	Rate + 21C /hour		
Shop Crew			
Mechanic (with certificate)	10.07	10.57	10.62
Mechanic	9.86	10.36	10.41
Machinist (with certificate)	9.96%	10.46%	10.51%
Machinist	9.75%	10.25%	10.30%
Blacksmith (with certificate)	9.96%	10.46%	10.51%
Blacksmith	9.75%	10.25%	10.30%
Welder (with certificate)	9.96%	10.46%	10.51%
Welder	9.75%	10.25%	10.30%
Carpenter (with certificate)	9.96%	10.46%	10.51%
Carpenter	9.75%	10.25%	10.30%
Tire Repairman (with certificate)	9.86	10.36	10.41
Tire Repairman	9.65	10.15	10.20
Power Saw Mechanic (with certificate)	9.86	10.36	10.41

		EFFECTIVE	
	June 15/77	June 15/78	Jan 1/79
Shop Crew - Cont'd . . . ,			
Power Saw Mechanic	9.65	10.15	10.20
Improvers	8.54%	9.04%	9.09%
Helpers	8.19%	8.69%	8.74%
*Chargehand - Occupational Rate + 22	per hour		
Miscellaneous			
First Aid Attendants - Class AA	8.73	9.23	9.28
- Class A	8.51	9.01	9.06
- Class B	8.41	8.91	8.96
- Class C	8.26	8.76	8.81
First Aid Attendant------- Occupational Rate +			
- AA Ticket		Rate + 60¢ /hr	
- A Ticket		Rate t 50C /hr	
- B Ticket		Rate + 40¢ /hr	
- C Ticket		Rate t 30¢ /hr	

PROVIDED THAT ANYONE RECEIVING OVER THE ABOVE ESTABLISHED RATES SHALL CONTINUE TO RECEIVE THE HIGHER RATE THROUGHOUT THE TERM OF HIS EMPLOYMENT.

****

E. & O.E.

APPENDIX E

ELECTRIC ENERGY SITUATION - VANCOUVER ISLAND

B.C. Hydro and Power Authority recently **(1978)** reviewed the electric energy supply situation for Vancouver Island. The relevant electric load forecast information and existing power supply information from B.C. Hydro is presented in Table **E-I.** Vancouver Island requires additional electric energy supply capacity in the near future. Based on the information in Table **E-I,** the Island requires additional capacity by **1983** and additional electric energy by **1985.**[1]

The B.C. Hydro report reviews the different generation alternatives available for increasing electric energy supply on Vancouver Island. Table E-2 presents cost estimates for thermal generation based on coal as the fuel. Vancouver Island coal generation costs at **28** to **30** mills/kwh are a suitable alternative with which to compare wood residue thermal generation. **It** should also be noted that B.C. Hydro in their report favour Mainland generation with a new double circuit **500** KV DC transmission to any of the coal alternatives shown in Table **E-2.**

1. **The load forecast shown in Table E-1 amounts to an average annual growth rate *of* 5 Percent. In the consultant's view, this is an optimistic growth rate; regardless of the growth rate; however, Vancouver Island will need additional capacity by the mid 1980s.**

Table E l

Vancouver Island Electric Energy Situation

Year[1]	Vancouver Island Electrical Load Forecast: Electric Energy Requirements	Vancouver Island Electrical Load Forecast: Peak Load
	10^6 kwh	MW
1977/78	6,390	1,120
1978/79	6,955	1,155
1979180	7,410	1,230
1980/81	7,775	1,295
1981/82	8,120	1,365
1982183	8,610	1,450
1983/84	9,050	1,535
1984/85	9,520	1,625
1985186	10,000	1,720
1986187	10,525	1,820
1987188	11,050	1,925
1988189	11,600	2,030
1989190	12,180	2,140
1990/91	12,790	2,260

Existing Vancouver Island.Power Supply

Type	Firm Energy	Effective Capacity
	10^6kwh/yr	MW
Hydro Plants	1830	455
Gas Turbines	280	160
Mainland Interconnections	7680	1076
Total Installed Supply	9790	1691
Required Reserve	270	231
Total Dependable Supply	9520	1460

[1] **B.C. Hydro's year is from April 1 to March 31.**

Table E-2: Vancouver Island Thermal Generation Costs

Coal Thermal Plant[1] on Vancouver Island Fueled by:	Capacity cost $/kw	Fixed Interest Amortization and Operating Costs mills/kwh	Variable Operating and Maintenance Costs	Fuel costs	Total costs
Kootenay coal	715	**13.3**	0.5	**14.3**	28.1
Hat Creek coal	715	**13.3**	0.5	18.1	**31.9**
Comox coal	824	**15.3**	0.5	12.5	28.3

Source: B.C. Hydro and Power Authority, Vancouver Island Power Supply, 1982-1996, June 1978; and Canadian Resourcecon.

[1] 600 MW plants at 80% load factor.

APPENDIX F - DEFINITIONS

Cunit — 100 cubic feet of solid wood; moisture content is approximately 50 percent and a. cunit weighs approximately 5000 pounds.

Tons (wet) - The wet weight of wood residue may be made up of roughly half wood and half water. In this report, the conversion fact for wet (or green) round material is 50 pounds per cubic foot of wood and bark. Hence, one cunit contains 2.5 tons (wet) of wood and bark.

Tons (dry) - also known as ODT (over dry tons). The bone dry weight of wood and bark is a basic unit of measuring wood residue of varying densities and moisture Content. A conversion factor of **25** pounds per cubic foot (bone dry) is used in this report. One cunit contains **1.25** tons (dry) of wood and bark.

Unit — The unit is a volumetric measure of hog fuel, 200 cubic feet of bulk volume. In this study, a unit is considered equivalent to 0.8 cunits of solid wood and bark with a wet weight of 4000 pounds and a dry weight of **2000** pounds,

Environment Canada Environnement Canada
Forestry Service Service des Forêts

Environment Canada
Canadian Forestry Service
Pacific Forest Research Centre
Victoria, B.C. V8Z 1M5
BC-X-197, July, 1979