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Contents

Implementing new forest management principles in coastal British Columbia: case study 1

Abstract

Ecosystem-based management is centred on an ecological approach that blends social, physical, economic, and biological needs and values to assure productive, healthy ecosystems. The Forest Engineering Research Institute of Canada (FERIC) is conducting a series of case studies in coastal British Columbia of applications of new forestry principles that incorporate ecosystem-based management, in a variety of site and stand conditions, retention levels, and harvesting systems. This report documents the first in the series, and discusses ground-based and cable harvesting in a second-growth stand on northern Vancouver Island with individual tree and group retention.

Keywords

Ecosystem-based management, Harvesting, Forest management, Productivity, Costs, Coastal British Columbia.

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Introduction

In the 1990s, a consensus began to emerge among foresters and ecologists that the best approach for conserving biological diversity and ecosystem function in managed forests was to emulate the disturbance processes that drive forest succession and dynamics in natural, unmanaged forests (Hopwood 1991; Swanson et al. 1997; Haeussler and Kneeshaw 2003). This approach was summarized into forest management principles that attempt to manage ecosystems as whole integrated systems. These principles consider timber as well as a wide range of other resources and values, including wildlife, watershed, fish, biodiversity, aesthetics, spiritual, recreation, and non-timber products. Although individual forest companies use different terminology to describe the theoretical and/or practical side of this new approach, "ecosystem-based management" is a generally accepted and widely used term for the new paradigm in forest management.

Given the newness of this approach and the limited experience in applying it to the diverse situations in nature, foresters lack the empirical knowledge needed to implement it with confidence. To provide its members with information and to aid in its implementation, FERIC is conducting case studies of applications of these new forestry principles in coastal British Columbia.

This report describes a study that was conducted in cooperation with Canadian Forest Products Ltd. (Canfor), Englewood Division on northern Vancouver Island. Canfor defines ecosystem-based management as a management system that recognizes and incorporates the natural variability of an ecosystem and attempts to emulate these responses with man-made disturbances while managing forests for a range of values (Deal 2000). This study is the first in a series documenting the application of the new forestry principles in a variety of site and stand conditions, retention levels, and harvesting systems. This trial addresses the application of ecosystem-based management at the block level.

Objectives

The primary goal of this study was to assess the economic and operational feasibility of the harvesting methods used, in the context of ecosystem-based management. FERIC's objectives were to:

- Determine overall productivities and costs for all phases of the operation.
- Assess the impact of the retention level and pattern of dispersion of leave trees on the harvesting phases, and recommend improvements where appropriate.
- Conduct a visual assessment of the site and residual stand at the end of the operation.

This report also presents some principles for implementation of ecosystem-based management, and general comments from a broader forest management perspective.

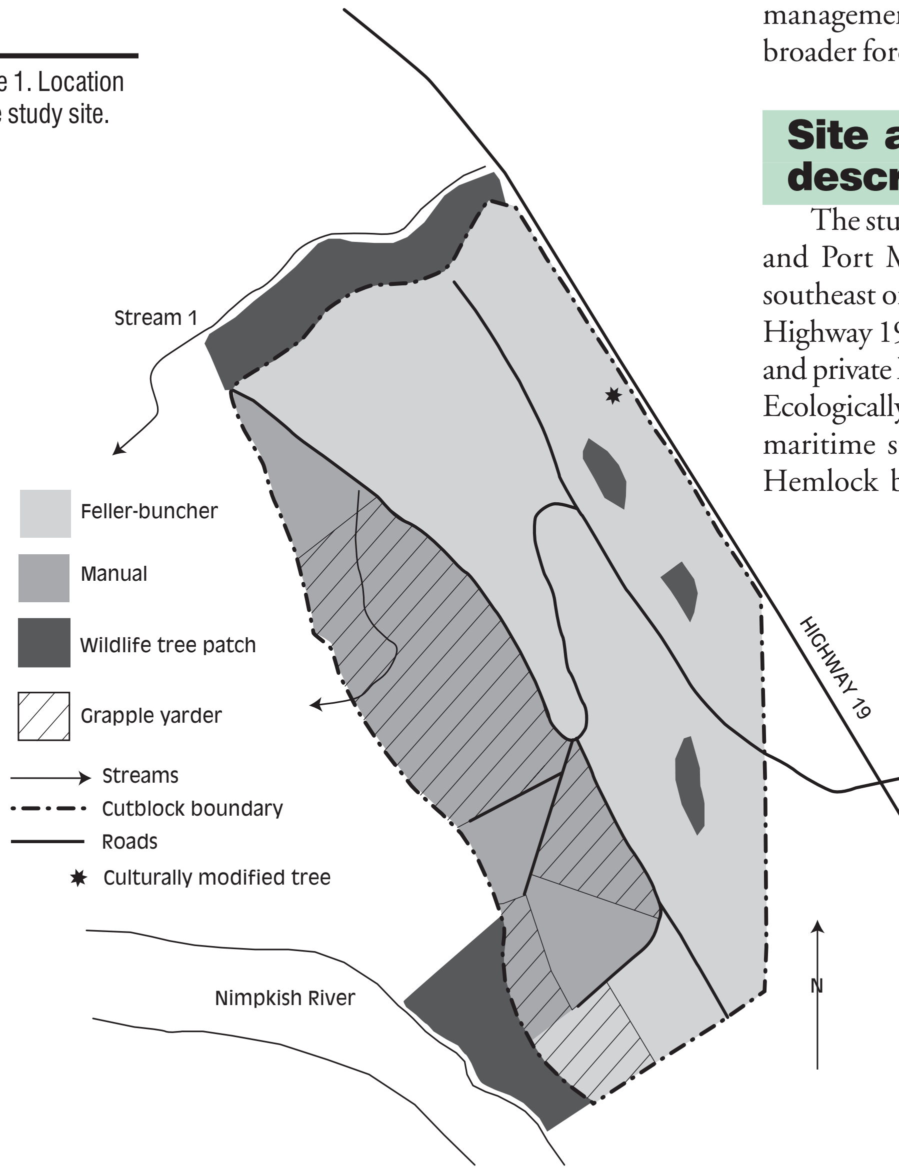

Figure 1. Location of the study site.

Site and stand descriptions

The study site was located between Woss and Port McNeill, approximately 1.5 km southeast of Nimpkish Lake and adjacent to Highway 19. The block included both crown and private land within Tree Farm Licence 37. Ecologically, the area was within the very dry maritime subzone of the Coastal Western Hemlock biogeoclimatic zone (CWHxm) (Green and Klinka 1994). Site topography was generally rolling; however, small areas of steeper slopes occurred over the entire block. The area was covered by fine-textured soils (loam–silt loam) with a thin organic layer. The logging map of the cutblock is presented in Figure 1, and the main site and stand characteristics are presented in Table 1.

The stand was 74 years old and was naturally established in 1928 following initial harvesting. It consisted primarily of Douglas-fir

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(*Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*) and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), with minor elements of western red cedar (*Thuja plicata* Donn), western white pine (*Pinus monticola* Dougl. ex D. Don), and red alder (*Alnus rubra* Bong.). The stand was thinned from below in 1991.[1]

Silviculture prescription

Canfor's Environment Policy commits the company to "practice forest management that recognizes ecological processes and diversity and supports integrated use of the forest" (Deal 2000). Canfor's coastal implementation plan for ecosystem-based management addresses natural disturbance processes, spatial and temporal landscape level biodiversity, stand-level biodiversity, species-specific management, timber sustainability, and restoration. Based on the Ecosystem Management Units (EMU) established by the company, the study site falls within the Enhanced Forestry Zone–Fire Adapted Ecosystem. This EMU requires 50% forest influence, 2–5 single trees per hectare, and a minimum of 14% of the harvest area to remain in wildlife tree patches (WTP). Also, an area equivalent to 15% of the WTP target must be retained inside the block, as either WTP or internal patches, not contiguous with the falling boundary. The silvicultural system applied in the block was the retention system.

Retention consisted of 115 individual trees distributed over the harvest area, and five WTP with a total area of 4.9 ha. Two of the WTP (with a total area of 4.3 ha) were adjacent to the harvest area, and three of the WTP (with a total area of 0.6 ha) were located within the harvest area (Figure 1). The silviculture prescription specified that the purpose of all WTP is to provide a representative sample of the original stand for the benefit of stand-level biodiversity, as well as to protect the water quality and fisheries resources of the Nimpkish River and Stream 1 (Figure 1). The specific purposes of the three internal WTP were to contribute to Canfor's ecosystem management targets, and to provide additional stand-level biodiversity and forest influence. The individual trees were retained to meet Canfor's ecosystem management targets. The retained trees were of species that were less prone to windthrow, and they had no visible signs of hemlock dwarf mistletoe infection. The purpose of leaving individual trees was to mimic the natural disturbance processes typical of this biogeoclimatic variant. Fire is the natural disturbance type in this area, and it would naturally leave live single trees after disturbance.

Leave trees were selected by overlaying a geometric grid over the block, and by

Table 1. Site and stand description

Site characteristics	
Elevation range (m)	50–100
Slope (%)	
Range	0–30
Average	10
Block area (ha)	
WTP[a] (4.3 ha external and 0.6 ha internal)	4.9
Road right-of-way	3.5
Harvest area	31.7
Total area under prescription	40.1
Maximum extraction distance (m)	
Loader-forwarding	120
Grapple yarding	180
Stand characteristics	
Species composition	60% Douglas-fir 40% western hemlock
Net merchantable volume (m^3/ha)[b]	504
Stand density (merchantable stems/ha)	350
Average net merchantable volume (m^3/tree)	1.44
Average dbh of live trees (cm)	39
Average tree height (m)	38.4

[a] Wildlife tree patches.
[b] Based on cruise of Crown area.

[1] During the thinning, about 360 m^3/ha were removed. Volume was concentrated primarily on smaller-diameter co-dominant hemlock. Harvesting was done using a small tracked skidder.

considering the operational and safety constraints on a tree-by-tree basis. The majority of leave trees were Douglas-fir, with a few hemlock and white pine. During logging, when a leave tree was badly damaged or had to be felled, an equivalent replacement tree in the same vicinity had to be retained. Also, where falling and extraction were not affected, non-merchantable cedar was retained throughout the entire block. On the northeast side of the block, along the highway, all non-merchantable trees were left as a visual buffer. One culturally modified tree was identified in the block, and was marked and protected.

The silviculture prescription identified the following soil hazard ratings: high for compaction, moderate for soil displacement, and moderate for surface erosion. A non–fish bearing stream of Class 6 (S6) was identified within the block boundaries (Figure 1). Cross-stream falling and yarding were permitted and no debris management was required.

Figure 2. Madill 4800 loader forwarding logs to the roadside.

Figure 3. Madill 124 swing yarder with grapple working in the block.

Harvesting system and equipment

Douglas-fir poles were selectively harvested late in 2001 and early in 2002 to recover the high-value products before the regularly scheduled harvest. Trees were hand-felled, topped, and delimbed at the stump, skidded to the roadside with a line skidder, and hauled by self-loading trucks.

During the main harvest, a Caterpillar FB 300B feller-buncher felled most of the block until mechanical problems occurred. More than one-third of the area was hand-felled by company fallers (Figure 1). As well, eleven oversized trees exceeded the maximum diameter for the machine of 55 cm, and were left for subsequent hand falling. A Madill 4800 loader-forwarder (Figure 2) worked in an up-and-down pattern (McNeel and Andersson 1993), moving wood from the backline to roadside in swaths. As the bearing capacity of the terrain was relatively low, the loader-forwarder travelled frequently on a rubber mat made of used tires. The oversized trees were hand-felled after the loader-forwarder had completed moving the mechanically felled wood to roadside. Therefore, an additional forwarding pass over the areas involved was necessary.

In part of the block, soils were too wet to use the loader-forwarder, and the wood was yarded with a Madill 124 swing yarder equipped with a grapple (Figure 3). A Hitachi 400 EX excavator was used as a mobile backspar. Machine scheduling required the yarder to continue in the block after harvesting the sensitive area, and the yarder also worked in areas initially planned for the loader-forwarder (Figure 1). Yarding road changes involved moving both the yarder and backspar, and averaged 15 minutes. The loader-forwarder cleared the log deck in front of the yarder when necessary. Because the two machines worked near each other, the loader-forwarder did not have long walks when assisting the yarder.

Trees were processed with a Denharco boom-stroke processor mounted on a

Caterpillar 322C carrier. This machine was double-shifted. Loading was mainly performed by a John Deere 992 log loader. The loader-forwarder loaded trucks for one day until the log loader arrived. Logs were hauled by company off-highway trucks 5 km to the nearest reload station, where they were loaded on railway cars and transported to the Beaver Cove sortyard.

Study methods

Shift-level data were collected using Servis recorders, FERIC's daily report forms, and operator time cards. Data were summarized to develop machine and phase productivity and cost. Volumes were obtained from company records. Machine costs were based on FERIC's standard costing methodology (Appendix I) and did not reflect the actual cost of the equipment or operation. FERIC also conducted detailed timing to gain insight into various phases of the logging process and for a subsequent comparison with other study sites. Stand and site evaluations at the end of the harvesting operation were conducted by visual assessment.

Results and discussion

The total volume extracted from the block was 19 345 m^3, consisting of 12 260 m^3 in the harvest area, 1 925 m^3 of right-of-ways, and 5 160 m^3 of poles. The residual stand (not including the two external WTP) consisted of the three internal WTP, and 111 mature trees and 118 unmerchantable cedar scattered over the area. A general view of the residual stand is presented in Figure 4. Machine productivities and costs are presented in Table 2.

Engineering took an extra 4.5 person-days of work, compared to a clearcut, to select

Figure 4. View of the residual stand.

Table 2. Summary of productivity and cost data

Phase	Shifts (no.)	Average shift length (h)	Scheduled machine hours (SMH)	Productive machine hours (PMH)	Utilization (%)	Volume harvested (m^3)	Productivity (m^3/PMH)	Cost ($/SMH)	Cost ($/m^3)
Falling									
Hand falling [a]	31	6.5	200	174	87	5 200	29.9	n.a.	2.38
Feller-buncher	17	9.8	167	145	87	7 060	48.7	152.50	3.61
Extraction									
Loader-forwarder [b]	21	8.3	174	158	91	8 620	54.6	173.70	3.93
Swing yarder	14	8.4	117	93	79	3 640	39.1	335.51	10.78
Processing [c]	41	9.6	395	353	89	14 185	40.2	107.94	3.01
Loading [d]	23	9.1	209	171	82	14 185	83.0	155.60	2.30
Total	-	-	-	-	-	-	-	-	14.36 [e]

[a] Hand falling volume was estimated based on daily time cards, considering a uniform spread over the area. Utilization was based on field observations and data from a similar study (Andersson and Warren 1996).
[b] The loader-forwarder spent 2.5 shifts building backspar trails and clearing the deck for the yarder.
[c] The processor was double-shifted, except for weekends and holidays. The actual number of days worked in the block was 25. Volume includes right-of-way wood.
[d] Loading time also includes one shift when the operation was performed by the loader-forwarder. Volume includes right-of-way wood.
[e] For falling and extraction, the cost was weighted with the volume harvested by each method.

and mark the leave trees. The incremental cost of engineering was \$0.13/m^3 (engineering costs were applied to the total volume of the block, including right-of-ways and poles). As leave trees were dispersed at relatively large distances, they did not pose major problems for hand fallers. Falling conditions were very good. The productivity of this phase was 169 m^3/shift (6.5 hours), and the cost was \$2.38/m^3. The feller-buncher did not encounter problems in negotiating the terrain, and the machine achieved a productivity of 48.7 m^3 per productive machine hour (PMH). However, the presence of residual trees created occasional difficulty to the operator when bunching stems with butts facing the road. The machine did not have a self-levelling cab, and the subsequent discomfort for the operator on the steeper slopes in this block likely affected productivity. The cost of mechanical falling was \$3.61/m^3.

The loader-forwarder had occasional problems negotiating localized steep slopes. In these cases, the operator used the grapple to help stabilize the machine or push it uphill. Repositioning the rubber mat required additional movements, but little impact on machine productivity was evident. Misaligned or non-bunched wood also affected machine productivity. In general, the operator attempted to align trees with butts facing the road during the first pass at the backline. However, sometimes the presence of residual trees made it impossible, and stem alignment was left for a subsequent pass. This had some impact on productivity, as the machine moved few stems in the pass to align some stems.

Loader-forwarding is a relatively simple logging method, but the factors affecting it are variable (Fisher 1986; McNeel and Andersson 1993). Machine productivity is influenced by the following factors:

- site conditions such as slope and soil bearing capacity
- piece size
- number of passes, principally a function of extraction distance and boom length
- working pattern
- falling pattern (i.e., layout of felled logs or stems)
- whether the machine uses any methods to protect the soil, such as a rubber mat or a puncheon (unmerchantable logs and other debris placed under the machine to reduce soil disturbance and ground pressure impact)
- residual trees
- operator experience

Although the conditions were sometimes difficult, the loader-forwarder had a productivity of 54.6 m^3/PMH in this study, which was comparable to that achieved by a similar machine in a clearcut (Pavel 1998). The main factor contributing to this high productivity was the operator's experience and versatility. The cost of loader-forwarding was \$3.93/m^3.

The yarder achieved a productivity of 39.1 m^3/PMH, which was also similar to the productivity achieved by the same machine in clearcut areas (Boswell 2003). The cost of grapple yarding was \$10.78/m^3. Site conditions were generally favourable for yarding, providing good deflection and visibility, and the crew was skilled and efficient. Productivity was affected by residual trees located in the cable-yarded area. Also, yarder utilization was relatively low, as the machine had to be repositioned frequently.

Processing was occasionally affected by residual trees at the roadside. The operators commented that these reduced their ability to swing logs and place them in the most efficient locations. Loading was not affected by the prescription applied in this block. The costs of processing and loading were \$3.01/m^3 and \$2.30/m^3, respectively. The total cost of the extraction phases was \$14.36/m^3.

No soil damage was visible at the end of the operation. The impact of tracked machines on forest soil is questioned in some geographic areas. Studies performed in the same region (northern Vancouver Island) by Douglas and Courtin (2001) showed that regeneration performed more poorly on loader-forwarder tracks due to soil compaction, but on areas adjacent to the tracks, nutrient mobilization occurred and was beneficial to the regeneration. Some mature trees sustained visible damage, either through bark removal or shallow gouging. Of the 111 residual trees, 41 trees (37%) were damaged. Unmerchantable cedar was damaged more easily than other species because of its thin bark—58 trees (49%) of the 118 sustained severe bark removal, deep gouging, and broken tops. Damage to residual trees occurred as they were hit by logs and machines, especially during the loader-forwarding and yarding phases. Unusually strong winds in the summer of 2002 blew down five of the mature trees in the residual stand.

Conclusions

Trees in the block were felled using a combination of hand and mechanical falling, extracted to the roadside by loader-forwarding and grapple yarding, and then mechanically processed. The loader-forwarder and yarder achieved productivities of 54.6 and 39.1 m^3/PMH, respectively. For both the loader-forwarding and yarding phases, productivities and costs were similar to those calculated for similar machines in relatively similar site and stand conditions in clearcut operations. The cost of harvesting was \$14.36 /m^3 (on the truck). Engineering the block took 4.5 extra days (compared to a clearcut) and added a cost of \$0.13/m^3.

To meet visual objectives, ecosystem-based management prescribes leaving trees dispersed across the block. Often, isolated trees are blown down by wind within a couple of years after harvesting, and the visual objectives may not be met. Subsequent removal of these trees increases the cost of the system and the likelihood of soil compaction. However, in the block studied, only five trees have blown down since harvesting and their removal was not considered necessary.

Implementation

Forest management planning based on natural disturbance and forest dynamics is a complex task both at the landscape and logging block level (Crow and Gustafson 1997; Harvey et al. 2003). The layout phase aims at implementing the key components of ecosystem-based management: emulation of natural disturbance patterns, and preservation (or even increase) of biodiversity. Existing stand structures and patterns following natural disturbances provide good models. However, as Mitchell and Beese (2002) state, it is neither practical nor desirable to emulate the full range of disturbances encountered in these stands (e.g., true emulation of windthrow or flooding is not desired). Simplification of natural structures and patterns may be necessary to improve the efficiency of management, balance the supply of products or features, or meet other societal objectives. Recommendations for emulating natural disturbance patterns in various natural disturbance types of stands are presented in the Biodiversity guidebook, of the Forest Practices Code of BC (BC Ministry of Forests and BC Environment 1995). The same guidebook includes recommendations with respect to achieving certain biodiversity goals, e.g., retention levels in different conditions, both at the landscape and stand level, and retention of wildlife trees.

Bunnell et al. (1999) also identified some principles for application of ecosystem-based management:

- Based on the wide range of structural features to which various plants and animals are adapted, it is critical that the same practices not be implemented everywhere.
- Major forest habitat elements to be maintained are cavity sites, downed wood, shrubs, deciduous broadleaved trees, riparian areas, and early and late seral stages. These elements are the most relevant to maintaining vertebrate richness, which are considered major indicators of quality of the ecosystem.

- Retention of patches seems to be more effective than retention of individual trees and snags. It appears that enlarged openings and a mix of aggregated and dispersed retention is the most favourable.
- Retention of some larger dead trees is important, but there is no simple diameter limit.

Other principles to be considered in the planning and layout phase are:

- In the process of selecting leave trees, planners should avoid the pitfalls of "high-grading". Criteria used for retention of these trees should be clearly distinguished from removal based solely on economic criteria (Mitchell and Beese 2002).
- To ensure that reserve trees provide the long-term benefits intended, their damage should be avoided through careful design of yarding patterns (Mitchell and Beese 2002).
- Safety, especially for hand fallers, must be considered at all times (BC Ministry of Forests 1997). Residual stands usually consist of individual trees, WTP, and riparian management areas, making safety a complicated issue. For this reason, selection of residual trees should be done by engineers in collaboration with the falling supervisor (bull bucker) and experienced manual fallers. The ability of the faller to substitute trees is also critical.

In the harvesting phase, the following conditions will increase the overall efficiency and success of the operation:

- When log extraction is conducted with ground-based systems, provisions must be made for minimizing ground disturbance, especially on soil with low bearing capacity. In this study, utilization of a rubber mat seemed to be effective. Also, a loader-forwarder can perform limited site rehabilitation with the grapple.
- When using mechanized falling, it is important to plan for trees larger than the machine's capability, and have hand fallers available. If hand falling of oversized trees occurs after forwarding, another entry of the machine is necessary, but this increases costs and has potential negative impacts on the site.
- For cable systems, utilization of a mobile backspar greatly reduces the time for changing roads and moving lines past residual trees, and increases productivity.
- Good machine scheduling is an essential component of the harvesting system. In this study, if the feller-buncher and loader-forwarder were used according to the initial schedule, the harvesting cost would be lower.

As ecosystem-based management is in its early stages of application, it is important that each block be considered an experiment, and this experience be used to refine prescriptions and techniques for future blocks. The concepts of adaptive forest management and monitoring are very important as the forest industry learns to implement these new techniques. FERIC continues to study other ecosystem-based management trials to present to its members the prescriptions, operating practices, and productivity and cost results.

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Appendix I

Machine costs ($/SMH)

	Madill 124 swing yarder with grapple (3-man crew)	Hitachi 492 backspar (used)	Feller buncher with disc saw (30–35 tonne) [a]	Processor (25–30 tonne) [a]	Hydraulic loader (45–50 tonne) [a]	Hydraulic loader (55–60 tonne) [a]
OWNERSHIP COSTS						
Total purchase price (P) $	1 250 000	30 000	550 000	460 000	625 000	745 000
Expected life (Y) y	12	5	6	6	6	6
Expected life (H) h	17 280	7 200	10 800	15 000	10 800	10 800
Scheduled hours/year (h)=(H/Y) h	1 440	1 440	1 800	2 500	1 800	1 800
Salvage value as % of P (s) %	30	0	25	25	25	25
Interest rate (Int) %	6.0	6.0	6.0	6.0	6.0	6.0
Insurance rate (Ins) %	3.0	3.0	3.0	3.0	3.0	3.0
Salvage value (S)=((P•s)/100) $	375 000	0	137 500	115 000	156 250	186 250
Average investment (AVI)=((P+S)/2) $	812 500	15 000	343 750	287 500	390 625	465 625
Loss in resale value ((P-S)/H) $/h	50.64	4.17	38.19	23.00	43.40	51.74
Interest ((Int•AVI)/h) $/h	33.85	0.63	11.46	6.90	13.02	15.52
Insurance ((Ins•AVI)/h) $/h	16.93	0.31	5.73	3.45	6.51	7.76
Total ownership costs (OW) $/h	101.42	5.10	55.38	33.35	62.93	75.02
OPERATING COSTS						
Wire rope (wc) $	31 600	0	0	0	0	0
Wire rope life (wh) h	1 440	0	0	0	0	0
Rigging & radio (rc) $	12 500	0	0	0	0	0
Rigging & radio life (rh) h	5 760	0	0	0	0	0
Fuel consumption (F) L/h	36.0	10.0	30.0	25.0	30.0	30.0
Fuel (fc) [b] $/L	0.53	0.53	0.53	0.53	0.53	0.53
Lube & oil as % of fuel (fp) %	10	10	10	10	10	10
Tire replacement (tc) $						
Track & undercarriage replacement (Tc) $	63 000	0	30 000	20 000	40 500	48 500
Track & undercarriage life [c] (Th) h	8 640	0	5 400	7500	5 400	5 400
Annual operating supplies (Oc) $	10 000	0	0	0	0	0
Annual repair & maintenance (Rp) $	85 000	5 000	65 000	50 000	62 000	75 000
Shift length (sl) h	8.0	8.0	10.0	10.0	9.0	8.0
Wages [d] $/h						
Operator	26.80	0.00	26.84	25.48	25.39	25.39
Labourer No. 1	26.10	0.00	0.00	0.00	0.00	0.00
Labourer No. 2	23.16	0.00	0.00	0.00	0.00	0.00
Total wages (W) $/h	76.06	0.00	26.84	25.48	25.39	25.39
Wage benefit loading (WBL) %	38	0	38	38	38	38
Wire rope (wc/wh) $/h	21.94	0.00	0.00	0.00	0.00	0.00
Rigging & radio (rc/rh) $/h	2.17	0.00	0.00	0.00	0.00	0.00
Fuel (F•fc) $/h	19.08	5.30	15.90	13.25	15.90	15.90
Lube & oil ((fp/100)•(F•fc)) $/h	1.91	0.53	1.59	1.33	1.59	1.59
Track & undercarriage (Tc/H) $/h	3.65	0.00	2.78	1.33	3.75	4.49
Operating supplies (Oc/h) $/h	6.94	0.00	0.00	0.00	0.00	0.00
Repair & maintenance (Rp/h) $/h	59.03	3.47	36.11	20.00	34.44	41.67
Wages & benefits (W•(1+WBL/100)) $/h	104.96	0.00	37.04	35.16	35.04	35.04
Prorated overtime (((1.5•W-W)•(sl-8) •(1+WBL/100))/sl) $/h	0.00	0.00	3.70	3.52	1.95	0.00
Total operating costs (OP) $/h	219.68	9.30	97.12	74.59	92.67	98.69
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/h	321.10	14.41	152.50	107.94	155.60	173.70

[a] Costs for feller-buncher, processor, and the two loaders were calculated using generic machines for each type and for each class size.
[b] Diesel fuel unit price as per a quote from Freight Carriers Association of Canada for June 2003.
[c] Assumes tracks are only replaced once over the life of the machine
[d] Wage rates as per 2002 rates outlined in the IWA Coast or Southern Interior Master Agreement; dependant on applicable labour categories.