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Implementing new forest management principles in coastal British Columbia: case study 3

Contents

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Abstract

Ecosystem-based management is centred on an ecological approach that considers a wide range of resources 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 is the third in the series, and discusses the clearcut and dispersed retention compartments of a cutblock in a second-growth stand on northern Vancouver Island.

Keywords

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

Introduction

To conserve biological diversity and ecosystem functions in managed forests, forest companies in British Columbia began implementing new forest management systems in the 1990s (Hopwood 1991). In 1998, MacMillan Bloedel Limited (now Weyerhaeuser Company Limited, BC Coastal Timberlands) adopted its Forest Project (now the Coast Forest Strategy), a strategic initiative to address public and customer concerns over old-growth conservation and clearcutting. The goal of the Forest Project was to sustain ecological values and assure economic viability. A key component of this project was implementation of variable retention (VR)—an approach to silvicultural systems and forest harvesting in which structural elements of the existing stand are retained throughout a harvested area for at least the next rotation to achieve specific management objectives. This approach utilizes a wide spectrum of retention with varying amounts, types, and spatial patterns of living and dead trees (Weyerhaeuser 2003).

In VR, portions of the original forest are retained in groups of various sizes or as single trees. Some portions are permanently retained, while others may be scheduled for later harvest when new trees growing after the first harvesting pass reach certain minimum requirements or other criteria are met. Various levels of retention can be used with different types, amounts, and patterns of leave trees, depending upon the objectives (Weyerhaeuser 2003). Franklin et al. (1997) identified the following as being the main goals of VR:

- maintain “lifeboats” for species and processes immediately after logging and before forest cover is reestablished
- enrich reestablished stands with structural features that would otherwise be absent (leave a legacy)
- enhance connectivity in the managed landscape

The primary silvicultural system used for implementing VR is the retention system. This system has two variants—group and dispersed retention—which may be used in the same cutblock. The retention system can also be combined with conventional silvicultural systems to define the cutting and regeneration strategies.

To provide its members with information on the operational challenges of implementing new forest management principles such as VR, FERIC is conducting case studies to document the application of new forest management systems at the cutblock level in a variety of site and stand conditions, retention levels, and harvesting systems. This report, the third in the series, describes a trial conducted in a second-growth stand on northern Vancouver Island, in collaboration with Weyerhaeuser.

The study sites presented in this report are components of a complex cutblock established for a multifaceted investigation of VR. The cutblock consists of five compartments: a clearcut, three retention compartments with different retention patterns (large- and medium-sized patches, and dispersed retention), and a control with no treatment applied. This report describes the harvesting operations and presents the results for the clearcut and dispersed retention compartments. The two patch-cut treatments, which are scheduled for harvest in late 2004, will be described in a future report.

Objectives

The goal of this study was to assess the economic and operational feasibilities of the harvesting methods used, in the context of VR. 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.
- Assess site and residual stand conditions after harvesting.

Site and stand description

The study site is located approximately 5 km southwest of Port McNeill, B.C., adjacent to the Cluxewe River. The cutblock is situated on Crown land within Tree Farm License 39. Ecologically, the area is within the submontane very wet maritime Coastal Western Hemlock variant (CWHvm1) (Green and Klinka 1994). A map showing the entire cutblock is presented in Figure 1. This study describes Compartments A (clearcut) and E (dispersed retention).

In the clearcut compartment, site topography is even with an average slope of 10%, but a few areas contain gradients up to 35%. In the dispersed retention compartment, site topography is rolling with an average slope of 35%. The southeastern corner of this compartment is characterized by steeper slopes of up to 50%. The entire cutblock is covered by fine-textured soils with a thin organic layer. The silviculture prescription identified the following soil hazard ratings: high for compaction, and moderate for surface erosion and soil displacement. All streams identified within the two compartments are Class 6, except for Stream A which is Class 4.[1]

The main site and stand characteristics are presented in Table 1. In both compartments, the stand consisted primarily of western hemlock with minor elements of amabilis fir, Sitka spruce, and western red cedar.

[1] The Fish-stream Identification Guidebook of the Forest Practices Code of BC (BC Ministry of Forests and BC Environment 1998) describes Class 4 (S4) streams as fish streams with an average slope gradient of less than 20% and less than 1.5 m wide. Class 6 (S6) streams are non-fish streams with an average slope gradient of more than 20%.

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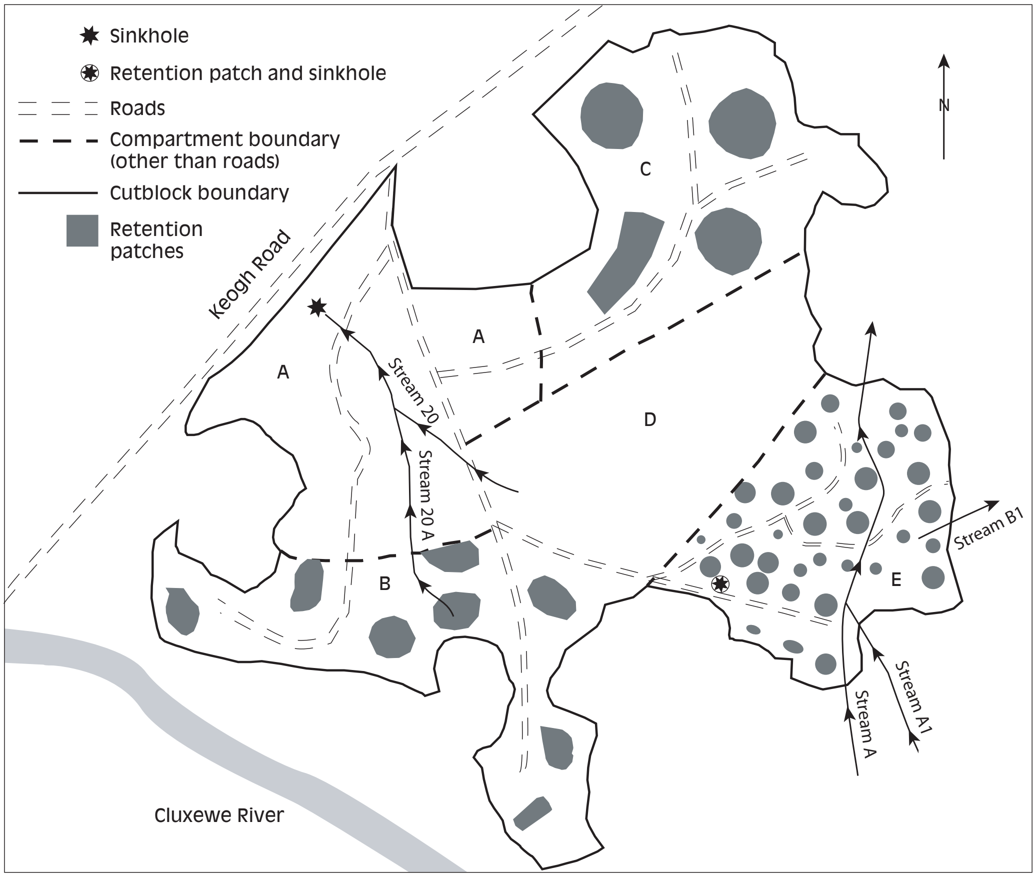

Figure 1. Map of entire cutblock.

Table 1. Site and stand description

	Compartment A (clearcut)	Compartment E (dispersed retention)
Site characteristics		
Slope (%)		
Range	0–35	0–50
Average	10	35
Compartment area (ha)		
Retention patches	-	2.1
Road right-of-way	2.6	2.2
Harvest area	18.1	11.8
Total	20.7	16.1
Max. forwarding distance (m)	150	165
Stand characteristics [a]		
Species composition (by volume)	85% western hemlock, 8% amabilis fir, 5% Sitka spruce, 2% western red cedar	85% western hemlock, 8% amabilis fir, 5% Sitka spruce, 2% western red cedar
Net merchantable volume (m^3/ha)	691	703
Stand density (merchantable stems/ha)	1 217	1 105
Average net merchantable volume (m^3/tree)	0.57	0.64
Average dbh of live and dead potential trees (cm)	27.7	28.5
Average tree height (m)	33.2	33.6

[a] Based on cruise data supplied by Weyerhaeuser.

Silviculture prescription

Through the Coast Forest Strategy, Weyerhaeuser has phased in VR over the last five years in all of its coastal operations in British Columbia. The system uses stand and landscape strategies to achieve stewardship objectives for old-growth and habitat conservation. Bunnell et al. (1999) stated that the change in forest management system resulted in two broad yet interrelated objectives for the new system:

- Ensure that the forest management strategy retains future options, sustains healthy ecosystems, maintains economic opportunities, and sustains biological diversity.
- Forest managers and planners can learn from these actions and refine them.

The study block described in this report will be assessed by Weyerhaeuser under the monitoring and adaptive management program that is an integral part of the company's Coast Forest Strategy. Growth and yield, regeneration, forest organisms, habitat attributes, forest health, windthrow, and costs for a range of VR treatment options will be monitored over time. This block is partitioned into five treatment units including clearcut, uncut (control), and three retention areas: large groups (0.8–1.2 ha); small groups (0.2–0.5 ha); and dispersed (single tree to very small groups up to 0.1 ha). All retention treatments retain 15% of compartment area as standing trees (Figure 1). The key question that the company addresses in this block is "what is the effect of the amount and pattern of retention on the above attributes?"

In the dispersed retention compartment, 35 groups, or clumps, ranging from 150 m^2 to 1 020 m^2 in area were retained. One of the retention clumps contained a sinkhole. Also, 12 individual trees were retained on the eastern side of the compartment. The retention clumps were selected based on the specific site and stand conditions of this compartment, and on operational criteria related to the harvesting process. The silviculture prescription specified that trees left standing in clumps or as individual trees will be a source of habitat, structure, and diversity within the regenerating stand, and will provide a legacy of the harvested stand. Retention patches were delineated with yellow rope to ensure visibility during and following the falling phase.

Figure 2. Feller-buncher working in the clearcut compartment.

Class 6 streams in the study site were mostly ephemeral with narrow and shallow channels, low stream banks, and low debris transport potentials. Falling and yarding away from these streams was not a requirement, and no stream cleaning was planned. For the Class 4 stream (Stream A), the silviculture prescription specified that the harvesting operation had to protect the existing fisheries resources. Falling and yarding away from this channel was required, stream crossings were not permitted, and any harvesting debris that entered Stream A had to be removed after harvesting. Other general recommendations were to avoid slash and debris accumulations in sinkholes and streams that enter sinkholes, and to avoid falling trees into VR patches unless safety hazards required it.

Harvesting system and equipment

In the clearcut compartment, falling was done using a Tree King 1127T feller-buncher equipped with a RotoSaw V 2229B head (Figure 2).

Felled trees were loader-forwarded to the roadside by a John Deere 892E LC hydraulic log loader. The loader-forwarder moved the logs in swaths in an up-and-down pattern (McNeel and Andersson 1993). The logs were extracted to within one pass of roadside, except where this was not feasible due to steep slopes. In a relatively small area adjacent to Stream 20A (Figure 1), the ground conditions were unsuitable to loader-forwarding, so felled trees were grapple yarded with a

Cypress 7280 swing yarder and a mobile backspar. Roadside processing was performed with a Waratah HTH624 head mounted on a Hitachi Forester EX450 LC carrier. The processor processed all the logs extracted to the roadside and also performed the last pass for the loader-forwarded wood. Loading was performed by a Hitachi Forester EX450 LC hydraulic loader. For most shifts, a second loader was also on site.

In the dispersed retention compartment, a Waratah HTH624 processor mounted on a Caterpillar 325 carrier felled and processed the trees around the leave patches, and laid them on the ground in piles of varying sizes (Figure 3). Owing to the soft ground and steep slopes in some parts of this compartment, the feller-processor could not harvest all of the unit, and approximately 28% of the volume had to be manually felled. No topping or limbing was performed on manually felled trees. Loader-forwarding was done using a John Deere 892E LC hydraulic log loader. Roadside processing of manually felled trees and loading was performed by the same machines used in the clearcut compartment.

In both compartments where the bearing capacity of the terrain was relatively low and in minor seepage areas, the harvest machines travelled on a puncheon of branches and wood residue.

Logs were hauled by company off-highway trucks 4 km to the Port McNeill sortyard.

Study methods

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

Figure 3. Logs piled by the feller-processor in the dispersed retention compartment.

Results and discussion

Clearcut compartment

The total volume extracted from the clearcut compartment was 14 981 m^3, consisting of 13 191 m^3 removed from the harvest area and 1 790 m^3 of right-of-way volume. Machine productivities and costs are presented in Table 2.

The feller-buncher achieved a productivity of 79.0 m^3 per productive machine hour (PMH) at a cost of \$2.79/m^3. The operator thought that the soft ground and butt flares of trees had a negative effect on machine productivity. Owing to the low bearing capacity of the ground, the machine got stuck twice during the operation, and the loader-forwarder working in the other compartment travelled to pull it out. In three wet spots located near Stream 20A, the feller-buncher could not work and 60–70 trees were manually felled later. The time for this activity was not recorded. However, the machine has good ground clearance and self-levelling capabilities, and it negotiated most of the compartment. Also, the ability to retract the saw helped the machine to move in steep areas as the operator could use the grab-arms of the cutting head to grip stumps or standing trees, pulling the machine up slopes. The feller-buncher had a relatively low utilization (75%) because of mechanical and electrical problems, and because the operator had to do a reconnaissance of the area. In the vicinity of a sinkhole in this compartment, and in wet and steep spots, the operator interrupted his work to walk the area and adequately plan his next moves. The operator also spent some

Table 2. Harvesting productivity and cost - clearcut

	Shifts (no.)	Average shift length (h)	Scheduled machine hours (SMH)	Productive machine hours (PMH)	Utilization (%)	Volume harvested (m^3)	Productivity (m^3/SMH)	Productivity (m^3/PMH)	Cost ($/SMH)	Cost ($/$m^3$)
Falling	24	9.3	223	167	75	13 191	59.2	79.0	165.28	2.79
Extraction										
Loader- forwarder [a]	36	8.8	315	262	83	12 391	39.3	47.3	130.20	3.31
Grapple yarder [b]	4	7.9	32	21	66	800	25.0	38.1	363.76	14.55
Processing	37	8.9	329	279	85	13 191	40.1	47.3	146.97	3.67
Loading	23	8.0	184	162	88	13 191	71.7	81.4	194.46	2.71
Total	-	-	-	-	-	-	-	-	-	13.16 [c]

[a] Non-productive time for the loader-forwarder included building trails for the backspar and processor, and piling slash.
[b] Grapple-yarded volume was estimated. The cost also includes the mobile backspar.
[c] For extraction, the cost was weighted according to the volume extracted by each machine, resulting in a cost of $3.99/$m^3$.

time to identify the boundary between compartments.

Loader-forwarding was also influenced by site characteristics, and the machine had difficulties negotiating wet and especially steep areas (Figure 4). In this study, the loader-forwarder achieved a productivity of 47.3 m^3/PMH at a cost of $3.31/$m^3$. The machine was also used in this compartment for building trails for the backspar and processor, and for piling slash.

Grapple yarding was a minor component of the harvesting system, and the machine was on site for only four days to extract the logs from the wet area. The productivity of the grapple yarder was 38.1 m^3/PMH at a cost of $14.55/$m^3$. The machine experienced several mechanical problems which resulted in low utilization.

The processor had a productivity of 47.3 m^3/PMH at a cost of $3.67/$m^3$. The machine processed the logs and also performed the last pass to the roadside for most of the loader-forwarded trees. The operator stopped a few times during each shift to check log lengths.

Figure 4. Loader-forwarder negotiating a steep slope in the clearcut compartment.

Loading was not affected by the prescription applied in this compartment. The loader achieved a productivity of 81.4 m^3/PMH and the cost of loading was $2.71/$m^3$. The total cost of the falling and extraction phases (weighted for loader-forwarding and grapple yarding) was $13.16/$m^3$.

Woody debris was abundant on site, and construction of puncheon on soft and wet terrain was easily performed. However, as most of the area was travelled by two machines, some site disturbance was visible in soft areas.

Dispersed retention compartment

The total volume extracted from the dispersed retention compartment was 9 832 m^3, consisting of 8 292 m^3 in the harvest area, and 1 540 m^3 of right-of-way wood. Machine productivities and costs are presented in Table 3.

The feller-processor had a productivity of 37.4 m^3/PMH at a cost of $3.95/$m^3$. Retention patches and the presence of wet and steep areas affected machine productivity. The feller-processor often had difficulty negotiating steep slopes and laying trees or processed logs on the ground. The operator sometimes grabbed old stumps from the original harvest to help the machine climb steep slopes. Log lengths were checked a few times during each shift by the machine operator and company scalers. Productivity for manual falling, without

Table 3. Harvesting productivity and cost - dispersed retention

	Shifts (no.)	Average shift length (h)	Scheduled machine hours (SMH)	Productive machine hours (PMH)	Utilization (%)	Volume harvested (m^3)	Productivity (m^3/SMH)	Productivity (m^3/PMH)	Cost ($/SMH)	Cost ($/$m^3$)
Falling										
Feller-processor	21	9.1	192	160	83	5 980	31.1	37.4	122.93	3.95 [a]
Manual falling [b]	12	6.5	78	63	81	2 312	29.6	36.7	54.70	1.85 [a]
Loader-forwarding [c]	28	8.9	249	221	89	8 292	33.3	37.4	130.20	3.91
Processing	7	8.3	58	54	93	2 312	39.9	42.8	146.97	3.69 [d]
Loading	13	7.6	99	86	87	8 292	83.8	96.4	194.46	2.32
Total	-	-	-	-	-	-	-	-	-	10.62

[a] For falling, the cost was weighted by the volume felled by each method, resulting in a cost of \$3.36/m^3.
[b] Falling only, no topping or limbing. Utilization was determined based on time cards and limited observations in the field. Manual falling wages are based on the IWA Coast Master Agreement for 2003 and include 38% wage benefit loading. Saw allowance is based on a per-shift rate of \$57.26.
[c] Non-productive time includes 5 hours spent to pull out the feller-buncher from wet areas in the clearcut compartment (2 incidents).
[d] The unit cost of processing was computed based only on processed wood; when computed for the total volume of the harvest area the cost is \$1.03/m^3.

topping or limbing, was 36.7 m^3/PMH (192.4 m^3/6.5-h shift) at a cost of \$1.85/m^3. The presence of the residual clumps and the relatively long distances between trees to be felled did not affect this phase.

The productivity of the loader-forwarder was affected by the way the processed logs were positioned. The loader-forwarder operator commented that processed logs were not aligned with the direction of extraction and this created the need for additional log swinging. Full trees manually felled on top of processed logs made the operation more difficult, as they had to be separated and forwarded to roadside in distinct piles. Retention patches made log swinging more difficult, especially for full trees. In this study, the loader-forwarder achieved a productivity of 37.4 m^3/PMH at a cost of \$3.91/m^3. Woody debris was abundant on site, and construction of puncheon on soft and wet terrain was easily performed. The machine attempted to rehabilitate its trails with the grapple when the work in an area was finished. Figure 5 illustrates the area after harvesting was complete.

The processor had a productivity of 42.8 m^3/PMH at a cost of \$3.69/m^3. Loading was not affected by the prescription applied in this cutblock, and the cost of this phase was \$2.32/m^3. The total cost of the falling and extraction phases was \$10.62/m^3. Field layout took an additional 10 person-days of work, compared to a clearcut, to select and delineate the retention patches. The incremental cost of field layout[2] was \$0.29/m^3.

At the end of harvesting, soil disturbance was observed on steep and wet areas, which were travelled by both the feller-processor and loader-forwarder. A total of 27 trees sustained visible damage, either through bark removal or shallow gouging. These were single trees or trees on the margins of the retention patches. Damage to residual trees occurred when they were hit by other trees during falling, or by logs or the loader-forwarder during extraction. No blowdown was observed in the retention compartment a few months after logging was completed.

A cost comparison between the two compartments in this study shows the

[2] Engineering costs are based on 10 person-days for an engineering crewman IV. The wages are based on the IWA Coast Master Agreement for 2003 and include 38% wage benefit loading.

Figure 5. View of the residual stand in the dispersed retention compartment.

counter-intuitive result that the harvesting cost in the clearcut is higher than in the retention area. This outcome was heavily influenced by the relatively low utilization of the machines used in the clearcut compartment, especially for the feller-buncher and the grapple yarder. As well, the loader-forwarder had a lower utilization in this compartment as it was used for building backspar trails and piling slash. The harvesting costs in the dispersed retention compartment were reduced because a relatively large portion of the harvest area was manually felled. An indirect comparison conducted on a phase-by-phase basis for similar studies (Clark 2001; Phillips 2001) suggests that costs achieved in the retention area for this study are higher than for a clearcut performed in similar conditions.

Summary and conclusions

In the clearcut compartment, trees were mechanically felled with a feller-buncher, and extracted to the roadside by a loader-forwarder. Trees in a small area of the compartment were grapple yarded because of wet soil conditions. Productivities were 79.0 m^3/PMH for mechanical falling, 47.3 m^3/PMH for loader-forwarding, and 38.1 m^3/PMH for grapple yarding. The total cost of the harvesting phases was \$13.16/m^3 (on the truck). A more complete interpretation of results in the clearcut compartment will be possible after the completion of all retention compartments in the cutblock.

In the dispersed retention compartment, most trees were felled and processed by a feller-processor. As site conditions did not allow the machine to reach all the trees to be felled, 28% of the volume was manually felled. Processed logs and manually-felled full trees were extracted to the roadside by a loader-forwarder. Roadside processing was necessary for the full trees. Productivities were 37.4 m^3/PMH for mechanical falling and processing, 36.7 m^3/PMH for manual falling (192.4 m^3/6.5-h shift), and 37.4 m^3/PMH for loader-forwarding. The total cost of the harvesting phases was \$10.62/m^3 (on the truck). Field layout took an extra 10 person-days, compared to a clearcut, and added a cost of \$0.29/m^3. The difference in cost between the two compartments was attributed mostly to the lower utilization rates of machines in the clearcut area. For the retention compartment analyzed in this study, an indirect comparison with other studies suggests that the combination of prescription and site conditions increased the cost of the operation compared to a clearcut prescription.

The silviculture prescriptions described in this study are different from those presented in the previous studies in this series (Pavel 2004a, b). In the first two case studies, the silviculture prescriptions emphasized primarily emulation of natural disturbance processes. In this study, prescriptions applied focus on quantifying the impact of different retention patterns.

Implementation

Planning and layout of logging cutblocks using VR to meet multiple objectives is a complex task. Objectives may include emulating natural disturbance patterns and maintaining 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 stands within various natural disturbance types are presented in the Biodiversity Guidebook of the Forest Practices Code of BC (BC Ministry of Forests and BC Environment 1995) and other publications (Bunnell et al. 1999; Weyerhaeuser 1999; Harvey et al. 2003; Beese et al. 2003; Coast Information Team 2004). Some principles to be considered in the planning and layout phase are:

- 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.

- Retention of patches seems to be more effective for maintaining a full range of habitat elements than retention of individual trees and snags. Early results suggest that a mix of aggregated and dispersed retention may be the most favourable for a variety of species. Enlarged openings favour conifer growth and certain wildlife species.
- Tree removal should not be based only on economic criteria ("high-grading"). Planners and engineers should have very clear guidelines to aid in selecting the trees to be retained for the benefit of biodiversity and wildlife.
- The planned harvesting system should minimize damage to reserve trees to ensure that the leave trees provide the long-term benefits intended.
- Safety, especially for manual fallers, must be considered at all times. Selection of residual trees should be done by layout personnel in collaboration with the falling supervisor and experienced manual fallers.

Based on the findings of this study, the following factors should be considered to increase the overall efficiency and success of the harvesting operation:

- The season of harvesting is important. In this study, if harvesting was conducted in the dry season it is likely that some operational efficiencies could have been realized. In the clearcut compartment, for example, the feller-buncher could have been more efficient, and the grapple yarder would not have been necessary, thus reducing the costs. In the dispersed retention compartment, the feller-processor could probably have cut all of the trees. However, selection of a different season is usually not an option in coastal British Columbia—in the dry season, forest companies harvest in cutblocks situated at higher elevations and in more difficult terrain conditions.
- When the harvesting system uses loader-forwarding and processing (as in the clearcut compartment), leaving the trees one pass away from the road reduces the cost and increases the efficiency of the operation. The processor can move the logs to roadside without reducing its productivity.
- Informing all machine operators about the entire harvesting process can reduce the costs considerably. In the dispersed retention compartment, if processed logs were better aligned, the loader-forwarder could have achieved higher productivities.
- 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 puncheon made of wood residue seemed to be effective. Also, a loader-forwarder can perform limited site rehabilitation with the grapple.
- Good delineation of retention patches is an important component of the system. In the dispersed retention compartment, utilization of thick yellow rope, rather than ribbon, proved to be a good method. The rope was visible during harvesting (especially important during falling), and for most patches it stayed in place until the end of the operation.

Other recommendations for implementation of harvesting and silvicultural systems under ecosystem-based management are contained in the previous two reports in this series (Pavel 2004a, b). As the retention system is in its early stages of application, it is important that the experience gained at each site be used to refine prescriptions and techniques for future cutblocks. The concept of adaptive management (i.e., refining future prescriptions based on existing experience) is important as the forest industry learns to implement these new techniques (Bunnell et al. 2003; Bunnell and Dunsworth 2004).

FERIC will monitor the remaining two retention prescriptions in this cutblock. It also continues to monitor other harvesting trials implementing new forest management principles to present its members with current information on the prescriptions, operating practices, and harvesting productivities and costs of these new approaches.

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Appendix I

Machine costs ($/SMH)

	Swing yarder with grapple (80 000 kg) (3-man crew)	Mobile backspar (used)	Feller buncher with high speed saw (35–40 tonne)	Processor [d] (25–30 tonne)
OWNERSHIP COSTS				
Total purchase price (P) $	1 450 000	30 000	650 000	670 000
Expected life (Y) y	12	5	6	6
Expected life (H) h	17 280	7 200	10 800	15 000
Scheduled hours/year (h)=(H/Y) h	1 440	1 440	1 800	2 500
Salvage value as % of P (s) %	30	0	25	25
Interest rate (Int) %	6.0	6.0	6.0	6.0
Insurance rate (Ins) %	3.0	3.0	3.0	3.0
Salvage value (S)=((P•s)/100) $	435 000	0	162 500	167 500
Average investment (AVI)=((P+S)/2) $	942 500	15 000	406 250	418 750
Loss in resale value ((P-S)/H) $/h	58.74	4.17	45.14	33.50
Interest ((Int•AVI)/h) $/h	39.27	0.63	13.54	10.05
Insurance ((Ins•AVI)/h) $/h	19.64	0.31	6.77	5.02
Total ownership costs (OW) $/h	117.65	5.11	65.45	48.57
OPERATING COSTS				
Wire rope (wc) $	32 000	0	0	0
Wire rope life (wh) h	1 440	0	0	0
Rigging & radio (rc) $	12 500	0	0	0
Rigging & radio life (rh) h	5 760	0	0	0
Fuel consumption (F) L/h	50.0	10.0	30.0	25.0
Fuel (fc) [a] $/L	0.53	0.53	0.53	0.53
Lube & oil as % of fuel (fp) %	10	10	10	10
Track & undercarriage replacement (Tc) $	65 000	0	35 000	20 000
Track & undercarriage life [b] (Th) h	8 640	0	5 400	7 500
Annual operating supplies (Oc) $	10 000	0	0	0
Annual repair & maintenance (Rp) $	90 000	5 000	72 000	50 000
Shift length (sl) h	8.0	8.0	9.0	9.0
Wages [c] $/h				
Operator	26.80	0.00	26.84	25.48
Labourer No. 1	26.10	0.00	0.00	0.00
Labourer No. 2	23.16	0.00	0.00	0.00
Total wages (W) $/h	76.06	0.00	26.84	25.48
Wage benefit loading (WBL) %	38	0	38	38
Wire rope (wc/wh) $/h	22.22	0.00	0.00	0.00
Rigging & radio (rc/rh) $/h	2.17	0.00	0.00	0.00
Fuel (F•fc) $/h	26.50	5.30	15.90	13.25
Lube & oil ((fp/100)•(F•fc)) $/h	2.65	0.53	1.59	1.33
Track & undercarriage $/h	3.76	0.00	3.24	2.67
Operating supplies (Oc/h) $/h	6.94	0.00	0.00	0.00
Repair & maintenance (Rp/h) $/h	62.50	3.47	40.00	20.00
Wages & benefits (W•(1+WBL/100)) $/h	104.96	0.00	37.04	35.16
Prorated overtime (((1.5•W-W)•(sl-8)•(1+WBL/100))/sl) $/h	0.00	0.00	2.06	1.95
Total operating costs (OP) $/h	231.70	9.30	99.83	74.36
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/h	349.35	14.41	165.28	122.93

[a] Diesel fuel unit price as per a quote from Freight Carriers Association of Canada for June 2003.
[b] Assumes tracks on swing yarder are only replaced once over the life of the machine.
[c] Wage rates are as per 2002 rates outlined in the IWA Coast or Southern Interior Master Agreement; dependant on applicable labour categories.
[d] Both processors include harvesting heads.

Appendix I - continued

	Processor [d] (45–50 tonne)	Hydraulic loader (30–35 tonne)	Hydraulic loader (45–50 tonne)
OWNERSHIP COSTS			
Total purchase price (P)	800 000	455 000	625 000
Expected life (Y) y	6	6	6
Expected life (H) h	15 000	10 800	10 800
Scheduled hours/year (h)=(H/Y) h	2 500	1 800	1 800
Salvage value as % of P (s) %	25	25	25
Interest rate (Int) %	6.0	6.0	6.0
Insurance rate (Ins) %	3.0	3.0	3.0
Salvage value (S)=((P•s)/100) $	200 000	113 750	156 250
Average investment (AVI)=((P+S)/2) $	500 000	284 375	390 625
Loss in resale value ((P-S)/H) $/h	40.00	31.60	43.40
Interest ((Int•AVI)/h) $/h	12.00	9.48	13.02
Insurance ((Ins•AVI)/h) $/h	6.00	4.74	6.51
Total ownership costs (OW) $/h	58.00	45.82	62.93
OPERATING COSTS			
Fuel consumption (F) L/h	30.0	30.0	30.0
Fuel (fc) [a] $/L	0.53	0.53	0.53
Lube & oil as % of fuel (fp) %	10	10	10
Track & undercarriage replacement (Tc) $	48 500	32 000	48 500
Track & undercarriage life [b] (Th) h	5 400	5 400	5 400
Annual repair & maintenance (Rp) $	75 000	52 000	75 000
Shift length (sl) h	9.0	8.0	8.0
Wages [c] $/h			
Operator	25.39	25.39	25.39
Labourer No. 1	0.00	0.00	23.80
Total wages (W) $/h	25.39	25.39	49.19
Wage benefit loading (WBL) %	38	38	38
Fuel (F•fc) $/h	15.90	15.90	15.90
Lube & oil ((fp/100)•(F•fc)) $/h	1.59	1.59	1.59
Track & undercarriage $/h	4.49	2.96	4.49
Repair & maintenance (Rp/h) $/h	30.00	28.89	41.67
Wages & benefits (W•(1+WBL/100)) $/h	35.04	35.04	67.88
Prorated overtime (((1.5•W-W)•(sl-8)•(1+WBL/100))/sl) $/h	1.95	0.00	0.00
Total operating costs (OP) $/h	88.97	84.38	131.53
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/h	146.97	130.20	194.46

[a] Diesel fuel unit price as per a quote from Freight Carriers Association of Canada for June 2003.
[b] Assumes tracks on swing yarder are only replaced once over the life of the machine.
[c] Wage rates are as per 2002 rates outlined in the IWA Coast or Southern Interior Master Agreement; dependant on applicable labour categories.
[d] Both processors include harvesting heads.