Research Report

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Visual Resource Management in British Columbia: Part II

Partial cutting in the frontcountry: A win-win solution for short-term timber availability and aesthetics?

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Abstract

This paper explores the potential of alternative harvesting practices (including partial cutting) to meet Visual Quality Objectives (VQOs), while providing short-term timber volumes substantially higher than is currently possible with clearcutting under the existing visual resource management (VRM) system in British Columbia. In general, public preferences decrease as visible landscape alteration increases. This has led to the impression that VQOs are a major constraint on timber supply in visually sensitive areas. However, various studies of the relationship between aesthetics and timber availability indicate that the amount of timber removed may have less influence on public preferences than the pattern and distribution of cutting. In British Columbia, the prescriptive approach to VQOs as an automatic constraint on timber supply can ignore substantial opportunities to meet these objectives with increased timber harvesting through partial cutting techniques and better landscape design. Based on B.C. Ministry of Forests perception studies, hypothetical relationships between short-term timber availability and VQO intensity at the landscape level suggest that using partial cutting in areas with more restrictive VQOs could offer at least equivalent or increased timber availability relative to conventional clearcutting. In the Arrow Forest District, initial analyses suggest that the impact of VQOs on timber availability could theoretically be reduced by as much as 10.3% if partial cutting is used in visually sensitive frontcountry situations—without sacrificing aesthetics. However, a thorough study of the advantages, disadvantages, and feasibility of these techniques is needed.

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Introduction

Selected North American case studies and the visual resource management (VRM) system in British Columbia were reviewed in Part I of this article (Picard and Sheppard 2001). This second paper further explores the potential for alternative planning procedures and timber harvesting practices such as partial cutting to meet visual objectives in visually sensitive areas, while permitting timber extraction at levels substantially higher than is possible with clearcutting under current procedures. Emphasis is placed on approaches to partial cutting and improved landscape design. What is the potential of these tools to make British Columbia's substantial second-growth timber reserves in sensitive frontcountry locations more accessible for harvesting, while maintaining acceptable visual quality?

Visual quality objectives are valuable as an effective and defensible performance standard, both in the frontcountry and increasingly in backcountry recreation and ecotourism settings.

We examine the theoretical relationships between timber availability[1] and aesthetics for both clearcutting and partial cutting, drawing primarily on recent B.C. Ministry of Forests research findings (B.C. Ministry of Forests 1996, 1997a, 1998a). These theoretical relationships are developed specifically for the landscape-unit level[2] and are then examined in the context of available data on timber supply[3] and Visual Quality Objectives (VQOs) in the Arrow Forest District in the West Kootenays. The potential linkages to other resource goals, such as biodiversity and water quality, as well as implications for VRM procedures and forest decision making are discussed. Our discussion recognizes, but does not attempt to address in detail, other important considerations with partial cutting, such as physical access constraints, harvesting costs, and effects on post-harvest growth and yield.

Relationships Between Timber Availability and Visual Quality Objectives

The policy and procedures relevant to visual resource management in British Columbia, as described in Part I of this series, provide the framework for a theoretical quantification of the effects of visual quality objectives on timber availability. The procedures used by the B.C. Ministry of Forests for timber supply analysis typically assume the use of clearcutting as the dominant harvesting practice. However, recent research on public perceptions of partial cutting relative to the extent of timber removal (B.C. Ministry of Forests 1997a), as described in Part I of this series (Picard and Sheppard 2001), enables quantitative comparisons of effects of alternative timber harvesting practices on timber availability under VQOs.

Theoretical relationships between timber availability and visual quality were derived from B.C. Ministry of Forests figures (B.C. Ministry of Forests 1998a; see also Picard and Sheppard 2001), which in turn were based on public perception studies (B.C. Ministry of Forests 1996, 1997a). In these studies, representatives of the public ranked photographs showing different levels of landscape alteration or denudation from timber harvesting (clearcuts and partial cuts), based on their visual quality. Scenes used represented a range of stand types, slope and landform conditions, and harvesting designs. The examples of partial cutting were selected to represent "uniform distribution of residual trees" (B.C. Ministry of Forests 1997a:2) (i.e., partial cutting with no discernible pattern, such as strip cuts or patch cuts).

1 The expression "timber availability" is used in this paper in the context of current or near-term timber availability. Availability also incorporates both the biophysical and the legislative availability of timber. Availability, as used in the model described below, does not take into account forest growth rates, which should be included if longer-term timber supply is being considered.

2 Landscape units are planning areas delineated on the basis of topographic or geographic features. Typically they cover a watershed or series of watersheds, and range in size from 5000 to 100 000 ha (B.C. Ministry of Forests 2001a). They typically cover larger areas than Visual Sensitivity Units (see definition in footnote #5).

3 The B.C. Ministry of Forests defines timber supply as being the available timber categorized by species, end use, and relative value (B.C. Ministry of Forests 2001a). However, in this paper we define "timber supply" to indicate an assessment of future timber supplies over long planning horizons (more than 200 years) by using timber supply models (growth models) for different scenarios identified in the planning process, and for a given area.

FIGURE 1. Examples of a partial cut (left) and a typical square clearcut (right) as seen with snow on the ground (winter condition).

The B.C. Ministry of Forests perception studies suggest that people react more adversely to a specific harvest volume when it is clearcut rather than partially cut. The studies found that partial-cut areas with a high proportion of stems removed tended to be rated as higher in visual quality than clearcuts with similar or even lower volumes removed. The participants' responses were significantly correlated with the VQOs (levels of landscape alteration) resulting from the harvests. The implication is that VQOs may be met with higher basal area removals if partial cutting is used rather than clearcutting. The results obtained were used by the Ministry of Forests to factor in the effect of visual resource management in Timber Supply Reviews (TSR) by establishing expected norms for "percent denudation" (for clearcuts) and basal area removal (for partial cuts). This provided guidelines for harvesting that met given VQOs (see B.C. Ministry of Forests 1998a). Participants were shown few examples with either very low or very high volume removals (preservation and maximum modification VQOs) in the partial-cutting study, which casts some doubt on the reliability of these results at these extreme levels of basal area removal. Further testing of perceptual responses in this range is required.

The apparent timber volume advantage of partial cutting where VQOs exist seems to rest primarily with the screening effect of residual trees. Except for the steeper slopes and at the highest viewing angles, it takes a relatively small number of residual trees to filter and block open views of disturbed ground, or to soften or eliminate abrupt cutblock edges (Figure 1) and maintain the appearance of a continuing forest canopy. This makes the amount of landscape alteration very hard to detect or measure; partial cutting, at least in those forms that avoid rectilinear strips or patches, is simply much less noticeable to the public, and also less distinguishable from natural vegetation patterns.

By extension, the lack of visibility of the "cutblock" frees partial cutting from the limitations of "percent alteration" and adjacency. Theoretically, the majority of a hillside or visual landscape unit could be partially cut without necessarily reducing the level of visual quality.

Table 1 shows the percent denudation allowable when clearcutting is used to meet VQOs and the percent basal area allowable for partial cutting. Timber available is defined as what could be harvested at any one time while meeting a given VQO, taking into account previously harvested areas that have not yet achieved visually effective green-up (VEG)[4] (B.C. Ministry of Forests 1994b). Thus, for example, according to the B.C. Ministry of Forests (1998a) timber availability projections, a VQO of partial retention is typically met with 5.1–15%

[4] Visually effective green-up is usually expressed in tree height and varies depending on slope, distance, stand attributes, etc. As an example, a VEG of 5 m was used in the first Timber Supply Review for the Arrow Forest District (B.C. Ministry of Forests 1994a). Partial cutting is not subject to VEG or to the adjacency constraints when 60% of the basal area (or less) is harvested (B.C. Ministry of Forests 1995a).

TABLE 1. Visual quality objectives associated with different levels of timber removal under clearcutting and partial cutting (derived from B.C. Ministry of Forests [1998a])

	Clearcutting		Partial Cutting
	Percent denudation for clearcutting[a]	Percent denudation for clearcutting with a 2:1 green-operable to green-inoperable ratio	Percent basal area available for partial cutting[b]
Visual quality objectives			
Preservation	0–1	0–1.5	—[c]
Retention	1.1–5	1.6–7.5	5–45
Partial retention	5.1–15	7.6–22.5	65–70
Modification	15.1–25	22.6–37.5	95
Maximum modification	25.1–40	37.6–60	—[c]
No VQO	100[d]	100	100[d]

[a] Assumed to be roughly equivalent to the percentage basal area available (B.C. Ministry of Forests 1998a). Figures provided by the B.C. Ministry of Forests use percent planimetric denudation allowed for clearcutting under any given VQO and were converted to percent basal area available in a 1:1 ratio for the purpose of this paper. This assumption was made to compare available basal area under both partial cutting and clearcutting. This ratio is likely to vary substantially within a landscape because of variations in stand density, growth rate, age class, and site index. Further research is under way to find better comparisons between timber supplies available under clearcutting versus partial cutting for any given VQO.

[b] The basal area available for partial cutting represents the basal area that could be harvested and still retain at least a 70% probability of meeting the established VQO (B.C. Ministry of Forests 1998a). The probability cut-off of 70% or better (which contributes to the discontinuities observable in the range of percentage basal area removal in this table's last column) comes from a recommendation for timber supply analyses (B.C. Ministry of Forests 1998a). No extrapolation was made to fill these gaps since the Ministry document did not provide guidance on how to direct such extrapolation.

[c] No value is available for the preservation and maximum modification VQOs because of the small sample used for these VQOs in the perception study (B.C. Ministry of Forests 1997a) on which these figures are based.

[d] Theoretical assumption of available timber under no VQOs and with no other legislative constraints.

denudation (measured in plan) of a Visual Sensitivity Unit[5] (often a discrete hillside; see Figure 2a), other factors being equal. By contrast, the B.C. Ministry of Forests figures indicate that with certain partial-cutting practices the same VQO can be met[6] with a basal area removal of 65–70%. This could potentially extend over much of the Visual Sensitivity Unit (Figure 2b).

In practice, the actual percent denudation suggested to meet a particular VQO with clearcutting is a higher percentage of the "green-operable" area (Figure 2c), since considerable portions of the Visual Sensitivity Unit often fall into the "inoperable" category. This ratio of green-operable to green-inoperable is generally estimated at 2:1 on average across the province (J. Marc, Senior Visual Resources Specialist, B.C. Ministry of Forests, pers. comm., 1999) and could allow for one and one-half times as much denudation of available stands (when clearcutting is used). For comparative purposes, Table 1 includes estimates using a 2:1 green-operable to green-inoperable ratio. However, this table shows that partial cutting approaches still yield greater timber availability under the most commonly applied VQOs (retention, partial retention, and modification), assuming that percent denudation is roughly equivalent to basal area removal at the landscape-unit level.

Modelling Timber Availability Under Visual Quality Objectives at the Landscape-unit Level

In an area subject to a given visual quality objective, the percentages presented above could be used in an attempt to quantify the potential differences in timber availability that may result from a shift in harvesting techniques (from clearcutting to certain types of partial cutting). However, a literature review showed that no commonly

[5] A Visual Sensitivity Unit (VSU) is a distinct topographical unit as viewed from one or more viewpoints, and is based on homogeneity of landform and of biophysical elements comprised in a scene (B.C. Ministry of Forests 1997b).

[6] With a probability of 70% or greater (B.C. Ministry of Forests 1998a).

used measures exist to express the cumulative intensity of VQOs *at the landscape-unit level*. Thus, it is difficult to compare the effect of different VQO combinations on timber availability between landscape units. In this

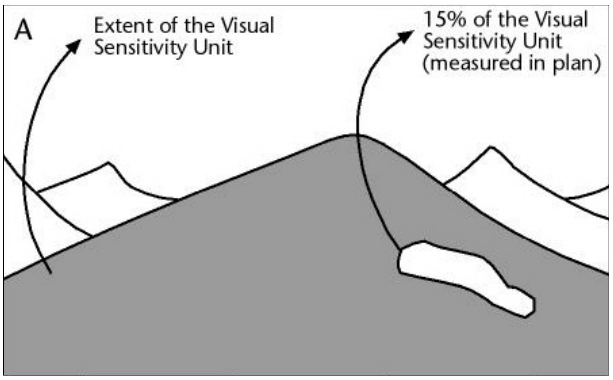


FIGURE 2A. Percent denudation guideline for partial retention with clearcutting.

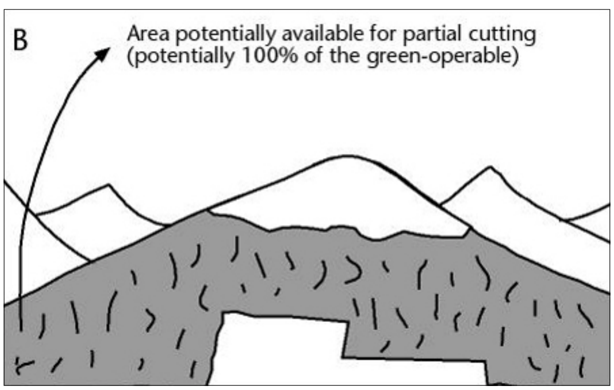


FIGURE 2B. Partial cutting for partial retention.

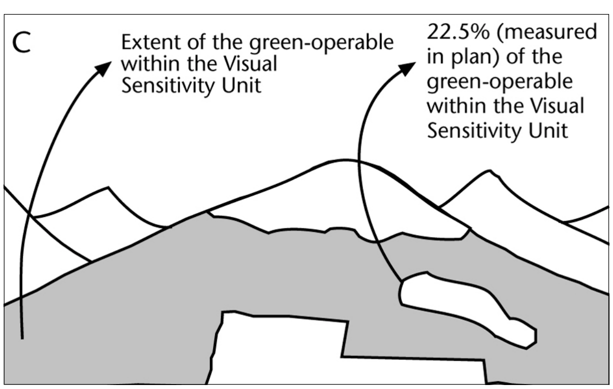


FIGURE 2C. Percent denudation for clearcutting within "green-operable" areas for partial retention.

paper we therefore advance the concept of a "VQO intensity index" for use in timber availability modelling at the landscape-unit level. We assign a value from 0 to 1 to each VQO, which expresses the intensity or restrictiveness of VQOs (see Table 2, column 3). For a particular landscape unit, this value is multiplied by the area under each given VQO (percent of total area as seen in plan view). The result is used as a measure of the individual contribution of the VQO polygon to the total VQO intensity applied to the landscape unit. For a given landscape unit, the sum of these "VQO-by-area" multiplications provides an overall VQO intensity index that expresses the restrictiveness of the objectives over an area composed of many visual sensitivity units with different VQOs. This index can then be used to rank all possible combinations of VQOs (or "no VQOs") applied to a landscape, from 0 to 100% (where 100 represents 100% of the area under a preservation VQO, and 0 represents 100% of the area without VQOs).

An associated indicator of timber availability can also be derived at the landscape-unit level. Percent denudation or percent basal area allowed for removal under the harvesting system used (clearcut or partial cut) is multiplied by the area (as a percentage of the total area) under each VQO. Similar to the VQO intensity index, a resulting "timber availability score" (with a similar scale from 0 to 100%, 0 being the lowest once again) can be summed from the individual available timber levels from each VQO (for a given harvest system). This score represents the percentage of available standing timber in the landscape unit, assuming it is all operable and mature and that VQOs are the only limiting factor. It represents only the timber theoretically available at the time of the first pass through attainment of visually effective green-up.

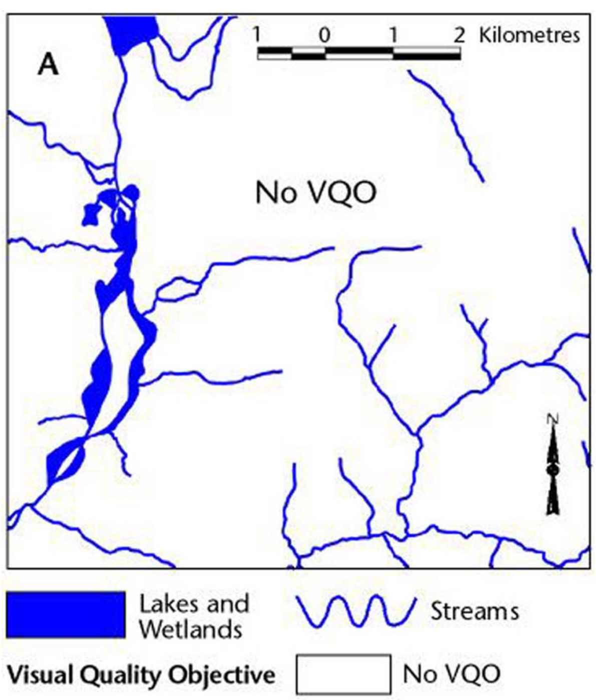
Examples of VQO intensity index and timber availability score are presented in Figure 3, where Figure 3A and 3B provide two extreme examples with one VQO per landscape unit (considering "no VQO" as a visual prescription), and Figure 3C provides an example of multiple VQOs in a landscape unit (as is often the case). These examples, in conjunction with the calculations provided in Table 2, illustrate the method used for computing the VQO intensity index and the timber availability scores presented in this paper. Values used for the available timber for clearcut and partial-cut systems are the averages of the B.C. Ministry of Forests' (1998a) values presented in Table 1.

Once the VQO intensity index and timber availability score are calculated, assessments can be made of

TABLE 2. Example of VQO intensity index and associated timber availability scores under a clearcut system in a hypothetical landscape unit with a particular combination of VQOs

	Column 2 Percent area under each VQO	*Column 3* VQO intensity value	*Column 4* VQO intensity index contributions (%) (col. 2 x col. 3)	*Column 5* Average percent basal area available for harvest[a]	*Column 6* Timber availability score (col. 2 x col. 5)	*Column 7* Timber availability score (2:1 green-operable to green-inoperable ratio)
Visual quality objectives						
Preservation		1.0	0.0	0.0	0.0	0.0
Retention	25.0	0.8	20.0	3.0	0.8	1.2
Partial retention	10.0	0.6	6.0	10.0	1.0	1.5
Modification	2.0	0.4	0.8	20.0	0.4	0.6
Maximum modification		0.2	0.0	32.5	0.0	0.0
No VQO	63.0	0.0	0.0	100.0	63.0	63.0
Total	***100%***	—	***26.8%***	—	***65.2%***	***66.3%***

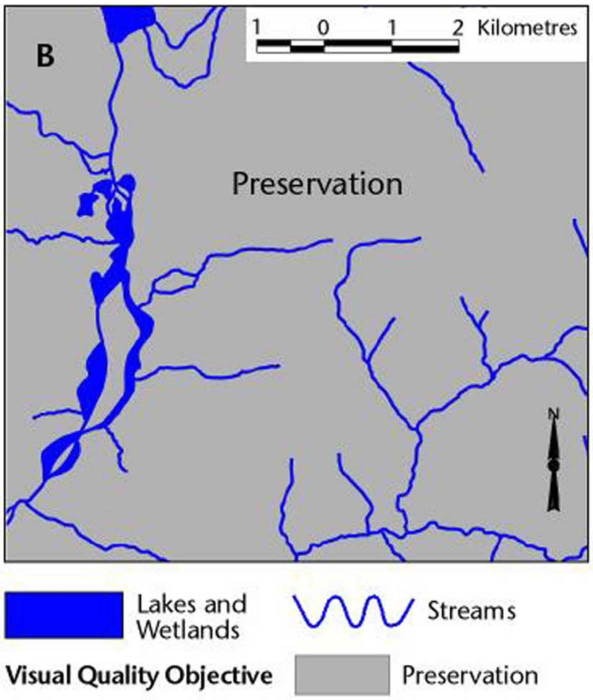
[a] Values in column 5 are averages adapted from a B.C. Ministry of Forests publication (1998a), with the assumption that percent denudation equals percent basal area removal.



"No VQO" (entire landscape unit):

- 100% of area at 0 VQO intensity value = 0% VQO intensity index.
- 100% of area at 100% timber availability score (TAS) = 100% timber availability index.

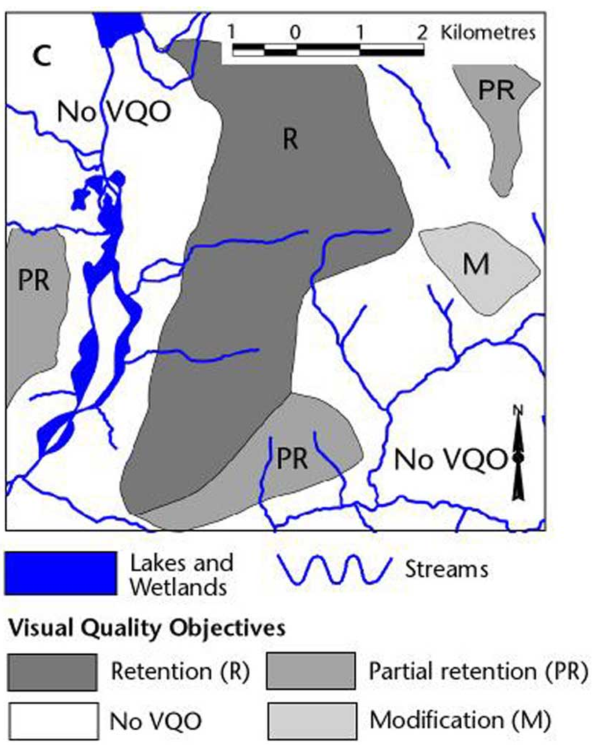
FIGURE 3A. Example of calculations for a hypothetical (square) landscape unit with one visual prescription. VQO intensity index = 0% and timber availability index = 100%.



Preservation VQO (entire landscape unit):

- 100% of area at 1 VQO intensity value = 100% VQO intensity index.
- 100% of area at 0% timber availability score (TAS) = 0% timber availability index.

FIGURE 3B. Example of calculations for a hypothetical (square) landscape unit with one visual prescription. VQO intensity index = 100% and timber availability index = 0%.



	%
R: 25% of area at 0.8 VQO intensity value =	20.0
PR: 10% of area at 0.6 VQO intensity value =	6.0
M: 2% of area at 0.4 VQO intensity value =	0.8
No VQO: 63% of area at 0 VQO intensity value =	0.0
Total VQO intensity index for the unit =	***26.8***
R: 25% of area at 3% timber availability score =	0.8
PR: 10% of area at 10% timber availability score =	1.0
M: 2% of area at 20% timber availability score =	0.4
No VQO: 63% of area at 100% timber availability score =	63.0
Total timber availability index for the unit =	***65.2***

FIGURE 3C. Example of calculations for a hypothetical (square) landscape unit with multiple visual prescriptions. VQO intensity index = 26.8% and timber availability index = 65.2% (when clearcutting is used). (See Table 2 for detailed calculations.)

TABLE 3. Example of VQO intensity index and associated timber availability scores under a partial cutting system in the same hypothetical landscape unit as Table 2

	Column 2 Percent area under each VQO	*Column 3* VQO intensity value	*Column 4* VQO intensity index contributions (%) (col. 2 x col. 3)	*Column 5* Average percent basal area available for harvest[a]	*Column 6* Timber availability score (col. 2 x col. 5)
Visual quality objectives					
Preservation		1.0	0.0	NA	0.0
Retention	25.0	0.8	20.0	25.0	6.25
Partial retention	10.0	0.6	6.0	67.5	6.75
Modification	2.0	0.4	0.8	95.0	1.9
Maximum modification		0.2	0.0	NA	0.0
No VQO	63.0	0.0	0.0	100.0	63.0
Total	***100%***	—	***26.8%***	—	***77.9%***

[a] Values in column 5 are averages adapted from a B.C. Ministry of Forests publication (1998a), with the assumption that percent denudation equals percent basal area removal.

available timber under a constant VQO intensity index (but using different harvesting approaches) or of the combinations of visual prescriptions that could be achieved with a given timber availability score. Two hypothetical examples are provided in Tables 2 and 3, one using clearcutting and the other using partial cutting (based on the landscape unit shown in Figure 3C). A comparison of the tables reveals the difference in timber availability for an identical set of VQOs. In this situation, theoretical available timber increases by 12.7% (from 65.2% to 77.9%) by using a partial-cut system instead of a clearcut system. When a green-operable to green-inoperable ratio of 2:1 is taken into consideration, the partial cutting option still yields a timber availability increase of 11.6% (from 66.3% to 77.9%).

Figure 4 shows the theoretical relationship between VQO intensity and short-term timber availability. This figure illustrates the simple situation of one VQO covering an entire landscape unit (as in Figure 3A and 3B). For a given VQO, significant increases in timber availability are observed with a shift towards partial cutting.

Building from Figure 4, the rationale is extended to establish theoretical relationships between timber availability and different VQO combinations to determine the timber available (until VEG is reached) for *any given combination* of VQOs. Using this simple model, the full range of VQO intensity indices and associated timber availability scores for different combinations of VQOs were computed and plotted (Figure 5)[7].

Figure 5 demonstrates the difference in timber availability attributed to the harvesting system used. For example:

- In areas with a VQO intensity of 80% (equivalent to the entire area being under a retention VQO), timber availability can vary from 3% (with clearcutting) to 33.75% (with partial cutting): an 1125% increase.
- In areas with a VQO intensity of 60% (equivalent to the entire area being under a partial retention VQO), timber availability can vary from 10% (with clearcutting) to 67.5% (with partial cutting): a 675% increase.
- In areas with a VQO intensity of 40% (equivalent to the entire area being under a modification VQO), timber availability can vary from 20% (with clearcutting) to 95% (with partial cutting): a 475% increase.

For a given VQO intensity, the resulting timber availability can vary significantly according to the

[7] Figure generated by computing timber availability and VQO scores for any given combination of VQOs and on any given proportion of the land base (by varying the area under each VQO in column 2 of Tables 2 and 3).

particular combination of VQOs, and great variance is observed in VQO intensity for a given timber availability.

Theoretically then, the greatest short-term timber availability for any given set of VQOs occurs when partial cutting is considered. Similarly, for any given timber availability, highest visual quality is achieved when using partial cutting. Both circumstances assume the avoidance of percent alteration or denudation limits (i.e., cutblock limitations) with partial cutting. These findings stress the potential importance of partial cutting in visually sensitive areas, as well as the possibility of increasing either the available timber or the visual quality of given landscapes by using different harvesting techniques. This should be expected, given the relatively low percentages of denudation available for harvest under VQOs with clearcutting and the high percentages of basal area apparently available with partial cutting as suggested by the B.C. Ministry of Forests (1998a) data.

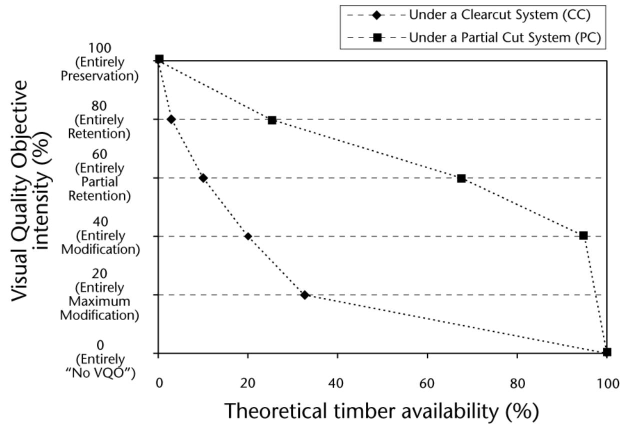


FIGURE 4. Theoretical short-term timber availabilities for landscape units with a single VQO, under both clearcutting and partial cutting regimes. For a given VQO, significant availability increases are observed with a shift towards partial cutting (source: B.C. Ministry of Forests 1998a).

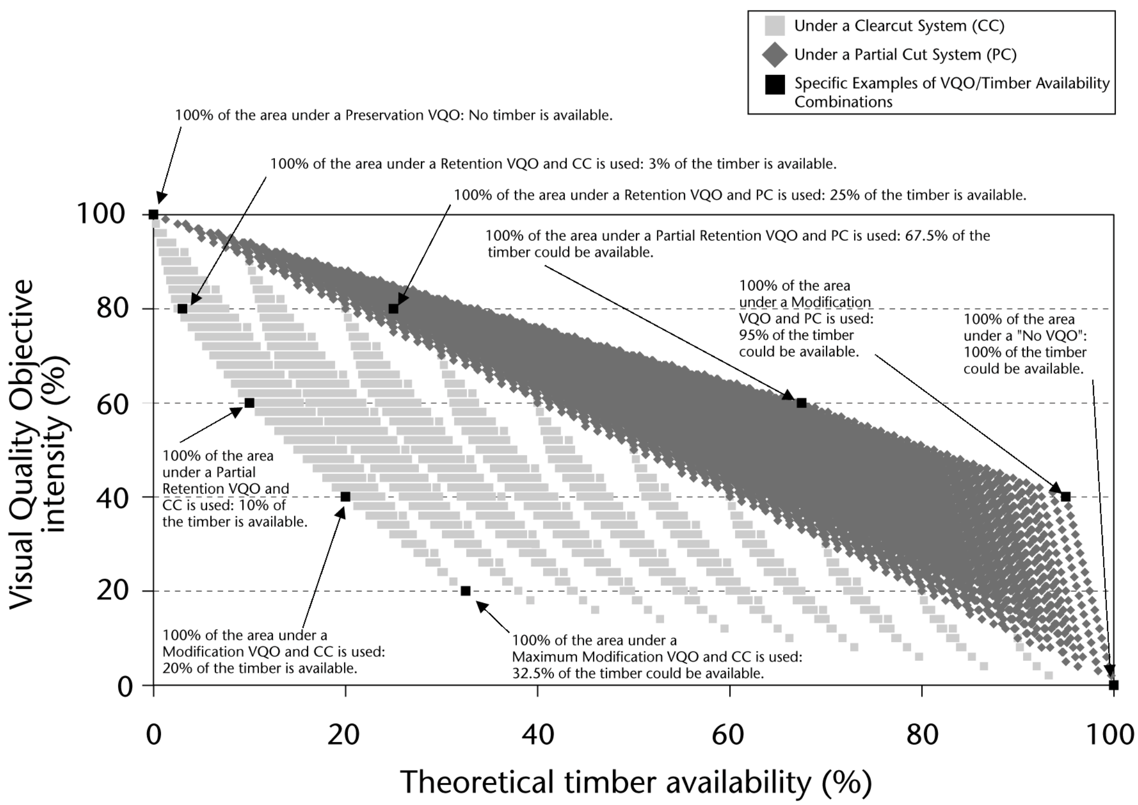


FIGURE 5. Theoretical short-term VQO-timber availability relationships for both clearcutting and partial cutting based on the full range of possible combinations of VQOs at the landscape-unit level.

The following major caveats require consideration before attempting to apply these hypothetical findings to the real world of forest management.

- We have assumed that the recommended percent denudation values provided by B.C. Ministry of Forests (1998a) are equivalent to percent basal area available (i.e., a ratio of approximately 1:1). In other words, clearcutting "X" percent of a landscape would result in "X" percent of basal area removal for that same landscape. This assumption is only true if the basal area is constant over the landscape, which would most likely not be the case. Basal area is a stand-level attribute, while percent denudation is a landscape-level attribute. The high variability of basal area over the landscape may also reduce the validity of using basal area averages. However, despite this weakness, our theoretical approach can still reveal trends in the visual resource management–timber availability relationship.

  Assuming that basal area is not evenly distributed (as is likely in most situations), and that the areas harvested correspond to those with higher basal area concentration, clearcutting the allowed percent denudation would result in higher basal area removals (for any given VQO) than those assumed in Table 1. This would result in a reduced timber availability gap between clearcutting and partial cutting under VQOs. On the other hand, if the percent denudation allowed under clearcutting is applied over landscape areas with lower than average basal area (harvesting of the stands with low basal area), then the timber availability difference between clearcutting and partial cutting would increase, since a given percent landscape denudation would yield lower basal area removal. However, the first scenario is more likely since the general harvesting strategy consists of cutting the oldest stands first (and therefore those stands with higher basal area).
- The theoretical relationships developed here do not take into account any practical limit on the extent of partial cut harvesting operations. Unlike clearcutting, extensive partial cutting over an entire landscape, may theoretically meet VQOs, although a physical limit inevitably exists to individual harvesting blocks and the rate at which a finite pool of labour and equipment can harvest the entire forest landscape. Whether partial cutting over entire landscapes in the province would meet VQOs has yet to be established: the limited samples used in perception testing did not contain such large-scale harvesting blocks. However, preliminary analysis of certain case studies using innovative partial-cutting techniques over entire hillsides (e.g., Timfor's operation at Knight Inlet) shows that visual quality may be maintained while allowing significantly more timber to be removed (Sheppard and Picard 2000). The extensive use of partial cutting, landscape design, and alternative management approaches used in the Knight Inlet operation resulted in the provisional granting of Forest Stewardship Council (FSC) certification, in addition to yielding increased timber availability (Sheppard and Picard 2000).
- The rotation length, growth rates under partially shaded conditions, species regenerated, and the sustainable rate of cutting achieved under partial cutting regimes may also reduce the initial volume advantage of partial cutting over clearcutting under VQOs in the long term.
- Adjacency, which does not apply to partial cutting under the Forest Practices Code (B.C. Ministry of Forests 2001c), could yield even higher differences in timber availability when a shift towards partial cutting is undertaken. Using a clearcutting system, approximately one-third of any area could apparently be harvested at any one time under current adjacency rules (assuming no VQOs are applied). This would effectively limit the maximum achievable volume through clearcutting (33% at any one time) and reduce the timber availability score obtained in Figure 3c. However, when low levels of basal area are retained (40% or less), adjacency may also apply to partial cutting, which could potentially reduce some partial cutting gains.

  However, if the percent alteration to percent denudation ratio (1:2) is inaccurate at any given location, volumes permitted with clearcutting may greatly exceed or underestimate the level of cut recommended to meet the given VQO, depending on actual landscape conditions. To obtain a more accurate figure for the potential "boosting" effect of green-operable to green-inoperable ratios for clearcutting, we could apply a 2:1 ratio to the example shown in Figure 3c. Surprisingly, it emerges that the green-operable to green-inoperable ratio shows *no significant result in this case*. This is because in areas with no VQOs, the timber availability is already considered to be 100%, while in areas subject to VQOs, the volumes allowed (under clearcutting) are so constrained that the gains are very modest. In fact, multiplying the available timber under a clearcut system by a factor of 1.5 (to account for a green-operable to green-inoperable ratios of 2:1) only increases the clearcut availability by 1.1% (up to 66.3%; see Table 2 for detailed calculations).

- Other overlapping constraints (see Part I of this series), other resource values, and policies (e.g., water quality, biodiversity requirements) may limit the areas available for harvesting, and the resultant available timber. Assuming that partial cutting is subject to the same restrictions from other resources values as clearcutting, this would further reduce the apparent "partial cutting gain" over clearcutting under VQOs, particularly in visual landscape units with higher VQO intensities where clearcutting is the most tightly constrained [see specific discussion as applied to the Arrow Timber Supply Area below].
- Various factors related to feasibility and cost viability may combine to limit or even exclude the possibility of partial cutting (e.g., silvicultural and productivity requirements, risk of windthrow, disease, worker safety, operational costs [as discussed in Part I], and difficulty of harvesting in steeper terrain) (Nyland 1996).
- The spatial extent of visual sensitivity units within which the percent alteration or percent denudation is calculated can be critical—5% of a large hillside or valley can permit large openings, whereas 10% of a small unit may restrict harvests to patch cuts with a different set of cost to volume ratios.

Other *less obvious factors* may reduce the potential gains of partial cutting over clearcutting under VQOs. Planning and permitting procedures, which are geared for clearcutting, combined with the relative lack of experience with partial cutting in industry and government, may add to the "red tape" in approving partial cutting operations. Also, the apparent relative losses in volume with clearcutting under VQOs may be reduced in practice by application of the maximum percent denudation levels recommended in B.C. Ministry of Forests (1998a) procedures, rather than using average levels (as used in Table 1 and applied to generate Figures 4 and 5). The application of skillful forest design, as advocated in B.C. Ministry of Forests training manuals (B.C. Ministry of Forests 1994c), may also allow the removal of higher volumes with clearcutting or mixed harvesting systems, while still attaining VQOs. The relationships shown in Figure 5 may also exaggerate the advantages of partial cutting at higher volume removals, since we have very little information on public judgements of visual quality at these levels. Industry may also be concerned that reduced growth rates under partial cutting may lead to reduced annual allowable cut (AAC) allocations.

However, where alternative harvesting techniques with at least some kind of partial cutting are feasible, and within the range of low to moderately high basal area removals, a strong possibility exists that VQOs may cease to act as major constraints on timber supply and availability relative to other resource constraints. Therefore, the relaxation of VQOs may not be required in frontcountry areas with substantial timber resources.

Applications to the Arrow Timber Supply Area

To apply these theoretical relationships and findings on visual resource management versus timber availability in the Arrow Timber Supply Area (TSA), we used the Timber Supply Review 1 (TSR1) as a data source (see B.C. Ministry of Forests 1994a). Although recently revised, we believe it still provides an instructive illustration of the VQO–timber availability relationship in the Arrow Forest District. In addition, an initial review of Timber Supply Review 2 (TSR2) (B.C. Ministry of Forests 2000) suggests that the results obtained would remain similar. Note that the Arrow Forest District has no established VQOs, only Known Scenic Areas with recommended Visual Quality Classes (VQCs) (D. Fitchett, Recreation/Range Officer, Arrow Forest District, B.C. Ministry of Forests, pers. comm., 1999). However, VQOs of retention and partial retention were modelled in TSR1 (B.C. Ministry of Forests 1994a), and we use those here to illustrate the visual resource management–timber availability relationship in the Arrow TSA.

The Arrow Forest District covers approximately 1 388 000 ha within the Nelson Forest Region in the West Kootenays of British Columbia. Within this area, the Arrow TSA covers 754 000 ha (B.C. Ministry of Forests 1999a). It consists of several major valleys occupied by the Arrow Lakes, Slocan Lake, and the Slocan, Kootenay, Salmo, and Columbia rivers. The area is characterized by several biogeoclimatic zones (B.C. Ministry of Forests 1998c) and contains a rich diversity of forest types.

While both the frontcountry and, more recently, the backcountry have a history of extensive logging, the most visible areas seen from major highways and communities within the Slocan Valley and parts of the Columbia River Valley appear relatively natural and undisturbed by logging. Forest licensees in the district have expressed concerns over the dwindling availability of merchantable timber (Arrow Forest License Group 1999) as many of the less visible backcountry areas have been heavily logged and are now constrained by FPC limitations. Some of the local communities have also strongly voiced their opposition to logging. The district, therefore, provides a classic example of the visual resource management versus timber availability issue, both in terms of the problems faced and potential solutions available.

In the TSR1, the B.C. Ministry of Forests divided the harvesting land base into five management zones to account for various resource constraints and its management emphasis based on wildlife habitat, water quality and quantity, and landscape aesthetics (B.C. Ministry of Forests 1994a).

Figure 6 illustrates the distribution of the management zones over the timber harvesting land base. Approximately 18.8% of the timber harvesting land base is managed under restrictive VQOs: 1.5% is managed for retention and 17.3% is managed to meet partial retention[8]. The VQO map for the Arrow Forest District (Figure 7) shows that the most restrictive VQOs are contained on the valley sides surrounding the Arrow Lakes, Slocan Lake, Trout Lake, and their smaller tributary watersheds closest to main highways and communities. As an example, the Lemon Landscape Unit (39 700 ha) in the Slocan Valley has a timber harvesting land base of 15 700 ha and 7700 ha in visually sensitive areas (Nelson and Wells 2000). If the two layers (VQOs and timber harvesting land base) are overlapped spatially, 35% of the landscape unit's timber harvesting land base (and potentially merchantable or mature timber) is under some of the most restrictive VQOs (mostly retention and partial retention).

Linking the land allocation figures for VQOs shown in Figure 6 with the available timber values provided by the B.C. Ministry of Forests (1998a) (see Table 1) yields the theoretical values shown in Table 4. On average, 25% and 67.5% of the basal area could be available for harvest under retention and partial retention VQOs, respectively (using partial cutting). Using clearcutting, 3% and 10% of the visual sensitivity unit (and, by extension, of the potential basal area) could be available for harvest under retention and partial retention VQOs, respectively. We obtained approximate values of

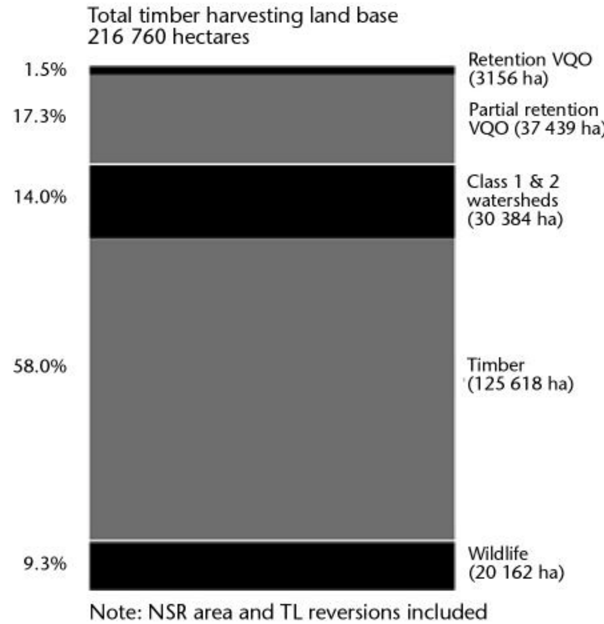


FIGURE 6. Management zones defined for the timber harvesting land base, Arrow TSA (B.C. Ministry of Forests 1994a).

potential timber availability for both retention and partial retention VQOs using the same rationale (see Figure 3 calculations), and for clearcutting and partial cutting (see columns 3 and 5, Table 4). These values approximate the hypothetical impact of such VQOs on timber availability for both clearcutting and partial cutting (see columns 4 and 5 in Table 4) in the Arrow TSA.

These hypothetical calculations show that shifting from clearcutting to partial cutting theoretically reduces the impact of VQOs on overall timber availability by as much as 10.27% (from 1.78% to 12.05% availability) (see Table 4 for more detailed calculations). This represents approximately 55 000 m^3 (or about 1222 truck loads assuming 45m^3 per highway truck load) of timber out of the current AAC[9] of 550 000 m^3. This hypothetical 10% increase comes from the use of partial cutting *only* in areas subject to VQOs. At the landscape-unit level, availability increases obtained could be significantly higher (as seen in Figure 5). Clearly, many caveats should be applied before any realistic numbers can be accepted; research is already under way in the Arrow TSA to quantify the predicted effect of such a

[8] In fact, more than 18.8% of the timber harvesting land base is managed for visual quality, but the retention and partial retention VQOs are the most binding constraints on this amount of the land base.
[9] The AAC for the Arrow TSA was revised to 550 000 m^3 on January 24th, 2001 from the previous 619 000 m^3 (B.C. Ministry of Forests 2001b).

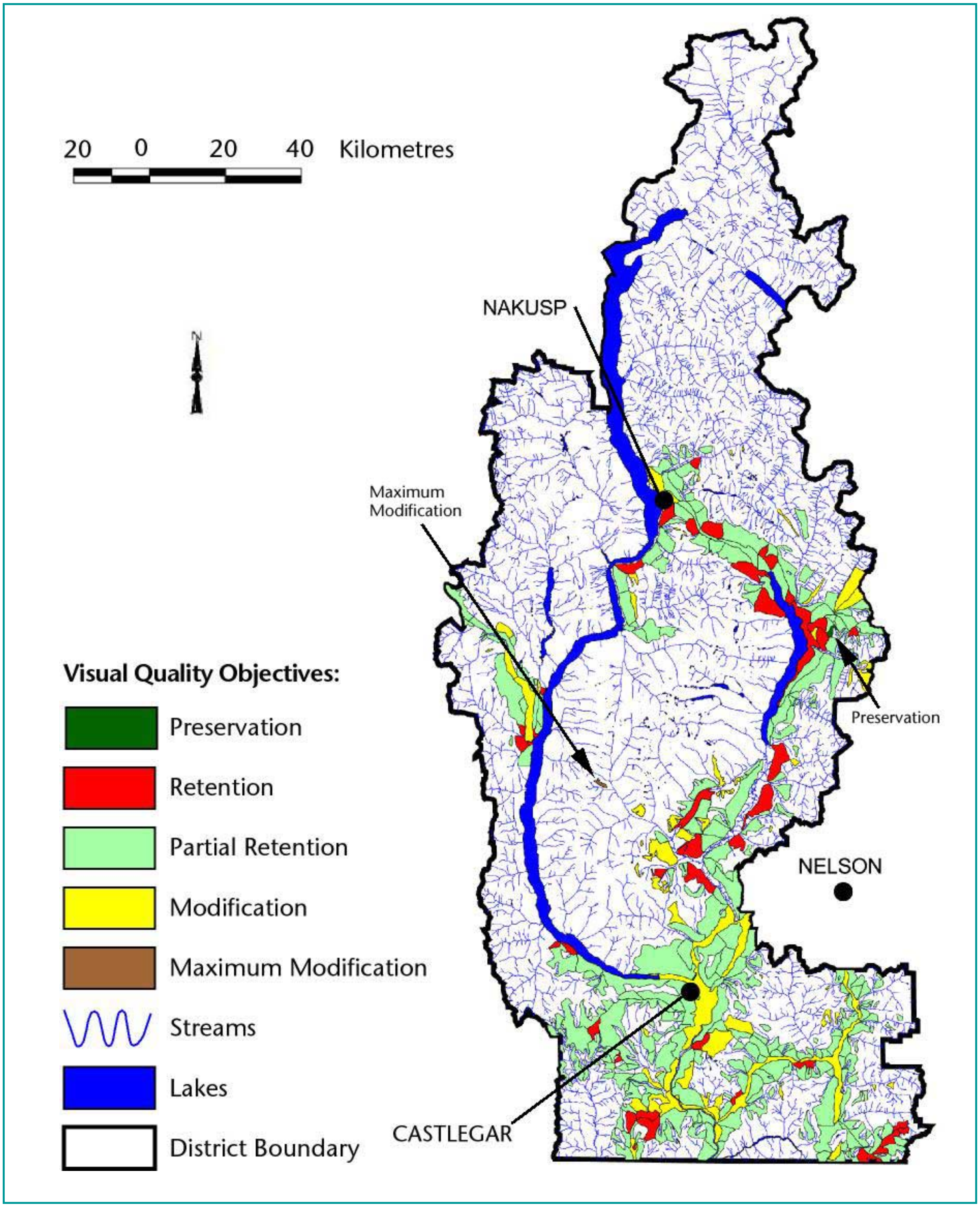


FIGURE 7. Arrow Forest District VQO map (B.C. Ministry of Forests 1991).

TABLE 4. Theoretical differences in timber availability between clearcut and partial cut harvesting systems for the Arrow Timber Supply Area. Adapted from B.C. Ministry of Forests (1994a and 1998a)

Column 1 VQO applied for management zones 1 and 2	*Column 2* Proportion of timber harvesting land base (%)	*Column 3* Timber availability score[a] using clearcutting	*Column 4* Timber availability score[a] using clearcutting and a 2:1 green-operable to green-inoperable ratio	*Column 5* Timber availability score[a] using partial cutting
Retention	1.5	0.045	0.068	0.375
Partial retention	17.3	1.730	2.595	11.678
Total:	**18.80 % of the TSA under VQOs**	**1.78% of the area under VQOs is available at any one time**	**2.66% of the area under VQOs is available at any one time**	**12.05% of the area under VQOs is available at any one time**

[a] These scores are based on the average percent basal area available for harvest as shown in Tables 2 and 3. Values in column 5 are averages adapted from a B.C. Ministry of Forests publication (1998a), with the assumption that percent denudation equals percent basal area removal.

shift in harvesting practices. Nevertheless, the potential scale of the difference in timber supply and availability suggests the topic is worthy of serious attention.

In addition to harvesting technique, the "active practice" of visual landscape design may allow more harvesting when clearcutting is used (estimated by the B.C. Ministry of Forests [1998a] at up to 5% denudation for retention and up to 15% denudation for partial retention). If these figures are correct and based on TSR1 assumptions[10], this could translate into a 0.9% increase in total timber availability in the Arrow Forest District. For comparative purposes, a green-operable to green-inoperable ratio of 2:1 was considered (see Table 4 for detailed calculations) and timber availability (when clearcutting is used) is still only 2.66% (compared to 12.05% when partial cutting is used). Even when the maximum figures for the percent denudation ranges are considered (for clearcutting only) along with this 2:1 ratio, timber availability is still three times less with clearcutting than with partial cutting (4% vs. 12%). These results are particularly relevant since the difference between the AAC and the timber availability level is often quite small (B.C. Ministry of Forests 1999b; Arrow Forest License Group 1999), leading to the inability of licensees in actually "finding" the timber on the ground to meet their AAC requirements. However, more research is required before such figures can be verified for the Arrow TSA.

Discussion

Available evidence suggests that for any given set of VQOs in a given landscape (or on a given visible slope, if considered in perspective view) under current FPC direction, the greatest timber availability occurs when partial cutting is used (see Figure 5). Similarly, for potentially any given timber availability, highest visual quality is achieved when using partial cutting. In addition, linking landscape design with silviculture may increase both timber yields and visual scenery (McDonald and Litton 1998), or at least, it may help to mitigate the impact of visual resource management on timber supplies and vice-versa.

However, caution should be used in applying these preliminary hypothetical relationships to actual forest management scenarios. These figures are based primarily on two studies (B.C. Ministry of Forests 1996 and 1997a), but are generally supported by other broader perceptual research findings (e.g., Berris and Bekker 1989; Bradley 1996; Paquet and Belanger 1997; Clay 1998) as well as considerable practical experience within the B.C. Ministry of Forests. While our assumptions and calculations should be tested and validated, the subject is clearly worthy of considerable further research to replicate, corroborate, and perhaps expand the B.C. Ministry of Forests' results. Further work, such as the ongoing Innovative Forest Practices Agreement (IFPA)

[10] Three percent denudation was used for the retention VQO, allowing a potential 2% gain (up to 5%) from the practice of visual landscape design (B.C. Ministry of Forests 1994a). For the partial retention VQO, 5% denudation was used for slopes above 50% and 15% denudation was used for slopes below 50% (for an average of 10% denudation), which also leaves room for a 5% potential increase through the use of visual landscape design (B.C. Ministry of Forests 1994a).

studies in the Arrow Forest District (Arrow Forest License Group 1999), is required to apply such findings quantitatively to the complexities of real world situations.

In particular, the notions of which partial cutting techniques conform to these relationships should be examined in depth. Although the B.C. Ministry of Forests perception studies used a range of partial cut and clearcut techniques, different visual effects can occur with different harvesting techniques for a given volume removal (see Part I of this series, Picard and Sheppard 2001). In addition, we assumed that partial cutting could be undertaken virtually everywhere. This issue, however, is still under debate between silviculture foresters and licensees (Industrial Forestry Services Ltd. and B.C. Ministry of Forests 1998; Timberline Forest Inventory Consultants Ltd. and Greg Rowe 1999). Partial cutting may not be feasible everywhere; we made this assumption to show the theoretical potential for gains in timber availability through a shift from clearcutting to partial cutting.

Our findings highlight a number of possible implications for forest districts such as the Arrow. Given the community interest in alternative harvesting practices and the availability of B.C. Ministry of Forests data favouring partial cutting in visually sensitive areas, it is surprising that the draft TSR2 (B.C. Ministry of Forests 1999c) assumes an increased use of clearcutting from 53.1% to 64.7% of total harvested in the Arrow TSA.

Other FPC regulations, and biodiversity and forest cover constraints for community watersheds, could significantly reduce or eliminate the influence of VQOs on timber supply and availability (B.C. Ministry of Forests 1995b), if these other values were more constraining on the cut. The constraints included in the FPC regulations will be modelled in the ongoing IFPA studies (Arrow Forest License Group 1999) to determine whether TSR1 and TSR2 determinations of AAC are accurate in their calculation of visual resource management constraints. Unless the different constraints occur in different areas, overlapping forest cover constraints (for managing water quality, wildlife habitat, etc.) may reduce the effect of visual resource management on timber availability. An example is the maximum equivalent clearcut area (ECA) value allowed for each of the six watershed classes in the Arrow TSA (B.C. Ministry of Forests 1994a). The ECA allowed varies from 15% (for Class 1 and 2) to 40% (Class 6). In TSR1, cut-offs for ECA contribution (when a stand reaches hydrological green-up) are set at 7 m (stand height) for Watershed Classes 1 and 2 and at 9 m for all other classes (B.C. Ministry of Forests 1994a). Since the VEG height used for the Arrow TSA in TSR1 is 5 m (B.C. Ministry of Forests 1994a), the ECA requirement for Class 1 and 2 watersheds would most likely meet a VQO of partial retention. Similarly, Watershed Classes 3–6 have an ECA of 25% (Class 3), 30% (Class 4 and 5), and 40% (Class 6). These classes could potentially meet a VQO of maximum modification (according to B.C. Ministry of Forests figures [1998a]) within their respective watersheds where clearcutting is used[11]. Class 3 watersheds may even meet a modification VQO. Consequently, watershed management may contribute to additional visual resource management through forest cover constraints. Therefore, the overall or net effect of VQOs on timber availability at the landscape level will have to account for the "contributions" of forest cover constraints involved with managing other non-timber resources and the degree of spatial overlap. It is not clear, however, to what extent partial cutting practices would reduce the risks of, and therefore limitations on, logging in sensitive watersheds.

Simple techniques, such as the VQO intensity index, should be tested further at the landscape level and higher to substantiate the assumptions used and applied. This will allow comparison between landscape units and aggregation of the relative levels of VQO constraint. These techniques should also be of value in strategic planning and in spatially explicit allocations of AAC, and could be useful if area-based tenures are used more widely in the future.

For regions like the Arrow Forest District, available strategies to gain access to limited timber supplies, while simultaneously maintaining visual quality in the frontcountry, would include the following.

- Maintain the currently recommended VQCs in Known Scenic Areas, along with the current procedures for percent alteration limits for clearcutting, but whenever possible, use certain partial cutting approaches to maintain visual quality.
- Maintain the currently recommended VQCs, but remove percent denudation as the effective performance standard, and use better landscape design to allow greater flexibility (e.g., through larger irregular

[11] Depending on the ECA contribution of specific partial cut systems, even more restrictive VQOs may be met for a given ECA.

openings, feathering, etc.). To be effective, this would require more training and more landscape architects and landscape foresters than are currently available.

- Relax VQOs and use a public education program, alternative planning processes, and perhaps an ecological aesthetics movement, as advanced by Gobster (1995), to convince the public that certain currently unpopular practices may be ecologically desirable, particularly when traded off against backcountry or old-growth preservation. The success of this latter strategy may depend on increased community involvement and ownership of the design and decision-making process.

If visual qualities in the backcountry were more proactively managed to recognize tourism opportunities and public pressure, while limiting the impacts on timber availability, the need for such strategies would increase. Allowing some timber flow from the frontcountry, while using visually acceptable harvesting techniques and landscape design, may provide an effective trade-off and permit recognition of visual quality in the backcountry. Frontcountry areas, often harvested at the turn of the century, may offer more volume, higher site index, and shorter hauls, while the backcountry or higher-elevation areas may in some cases have less volume, lower site index, and longer hauls. Such a shift in location of timber harvesting to more visible areas, rather than less visible areas, will require a major effort on the part of industry to exhibit "visible stewardship" of these much-loved frontcountry places (Sheppard 2000).

Conclusions

Despite the potential for partial cutting to accommodate significant amounts of timber harvesting in visually sensitive areas, many concerns should be addressed before such actions are implemented and a win:win situation realized. Some of these concerns include: forest health implications, possibly reduced growth rates, increased costs in planning time and field layout, longer approval processes, potentially increased risks for forest workers, and windthrow. Definitive studies evaluating alternative harvesting strategies are required to document the likely effectiveness of partial cutting in visually sensitive areas. Such research should include: modelling growth and yield linked to partial cutting, and assessing cost effects, long-term supply impacts of partial cutting, approval delays (if any), and rotation length. At the same time, pinpointing the public's perceived visual thresholds for partial cutting activities, monitoring costs, tracking constraint overlaps, and testing different designed harvesting patterns should be carefully analyzed.

Meanwhile, the percent denudation measures currently used under a clearcut system with VQOs are useful in predicting timber supply impacts, but may be overlimiting in some cases at the forest design or cutblock planning levels. We believe these measures should not be used uniformly as a rigid timber supply constraint in practice or as the dominant visual design determinant. Instead, increased landscape design resources and training are necessary to deliver the more flexible solutions promised by the B.C. Ministry of Forests (1998b)—without loss of visual quality. Visual quality objectives are valuable as an effective and defensible performance standard, both in the frontcountry and increasingly in backcountry recreation and ecotourism settings. The VQO intensity index advanced in this paper may prove useful in assessing the influence of VQOs on timber availability at the landscape-unit level. Further work should explore inconsistencies in the methods used to estimate these impacts; that is, inconsistencies between the TSR/AAC modelling process, official visual resource management policies, spatially explicit modelling exercises, and actual implementation on the ground.

Further studies, such as those under way in the Arrow Forest District, may contribute some of these answers and provide possible solutions associated with relationships between timber supplies, timber availability, and aesthetics.

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