Harvesting Systems and Equipment in British Columbia

BRITISH COLUMBIA Ministry of Forests
Forest Practices Branch

FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
FERIC
INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

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PART 1: EQUIPMENT SELECTION

EQUIPMENT DESCRIPTIONS

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The handbook does not attempt to define a single "best" system for any site. Instead, it presumes that readers need to be aware of the key factors that influence the probability of achieving success with any given combination of equipment and site characteristics. Readers will then use their own judgement to evaluate the merits of the various options. The information in the handbook should be considered only as part of an overall process for equipment selection which will vary from company to company.

EQUIPMENT DESCRIPTIONS

The various types of harvesting equipment are described in two sets of graphics. The first set summarizes the costs and characteristics of various equipment types in a tabular format using a High-Medium-Low rating system. By scanning the "characteristics" tables, the reader can quickly determine whether a particular type of equipment is suitable to various site conditions and operating environments.

The second set identifies the key factors that affect the likelihood of conducting successful operations with various equipment types. By following through these charts, the reader can quickly identify those site characteristics that imply high risk with any given type of equipment.

Neither set of graphics attempts to identify the "correct" equipment for a particular site because there are usually too many variables for there to be just one feasible solution. Instead, these graphics can help to focus the reader's attention on those equipment types that have the lowest risk and the highest probability of achieving success.

After reading this section, the reader may wish to consult Part 2 of the handbook for more detailed information about specific equipment types.

What Equipment To Consider?

The tables and charts presented later in this section have been developed assuming that all equipment types are available to be used on any given site, and that a selection process will eliminate the less suitable types. Given the full range of equipment to choose from, cost is often the first selection criteria. However, cost is not the only consideration, and depending on the circumstances, may not even be the primary consideration. For example, a cutblock with sensitive soils may require specialized equipment for harvesting to proceed at all, and costs become a secondary consideration.

The planner must carefully consider all available options for harvesting systems, and a starting point is to consider the range of equipment costs. Relative cost ranges of various equipment types are shown in Table 1.

Costs can be considered in various ways, including unit production costs, ownership costs, and total costs. Unit production costs include the machine's operating and maintenance costs coupled with an estimate of productivity. Ownership costs include the machine's purchase price, plus interest on capital and other fixed costs such as insurance. Total costs represent the total cost of owning, operating, and repairing the equipment over its lifespan. Low initial costs may not necessarily result in the lowest total costs over the equipment because of high maintenance costs or low productivity.

Costs can also vary widely depending on operating conditions and techniques. For example, Table 1 lists loader-forwarders in the low-cost category for unit production costs, which is accurate for easy terrain with large timber, but is inaccurate for rough terrain or small timber. The unit production costs for Table 1 are applicable under ideal conditions.

Total costs are important to consider, but also difficult to quantify because of different operating conditions and techniques, and widely varying maintenance regimes. Total costs are omitted from Table 1 because of their even wider variability than unit production costs and capital costs.

Unit production costs and ownership costs should be considered separately because they are not always related. For example, helicopters have both high unit production costs and high ownership costs, while clambunk skidders have high ownership costs but low unit production costs. Furthermore, different companies place different emphasis on unit production and ownership costs.

In the long term, all options from Table 1 should be considered, but in the short term only those machine types that are available need be considered.

Table 1. *Relative cost ranges for primary transport equipment under ideal conditions*

Cost range	Unit production costs	Ownership costs
Low cost	Wheeled skidder Loader-forwarder Cherry picker/Super snorkel Grapple yarder	Wheeled skidder Horse Small-scale equipment
Medium cost	Crawler skidder Clambunk skidder Forwarder Horse Small-scale equipment Highlead Small single-span skyline	Crawler skidder Flex-track skidder Highlead Small single-span skyline Multi-span skyline
High cost	Flex-track skidder Large single-span skyline Multi-span skyline Medium-lift helicopter	Clambunk skidder Forwarder Cherry picker/Super snorkel Loader-forwarder Grapple yarder Large single-span skyline Medium-lift helicopter
Very high cost	Heavy-lift helicopter	Heavy-lift helicopter

Equipment Characteristics Summarized by Phase

After using ownership costs or unit production costs to rank the various types of available equipment, the next step is to use equipment characteristics to match equipment to operating conditions. To help with this process, this section presents tables for each harvesting phase that summarize the major features of different equipment types. Four tables are presented: primary transport in Table 2, falling in Table 3, processing in Table 4, and loading in Table 5.

The rows in each table list the important characteristics that can be used to match equipment to operating conditions. The various types of equipment that can be used for each phase are listed in columns across the tables, and the entries in the tables contain a variety of information. In some cases, a High-Medium-Low system is used to rank the various equipment according to each characteristic. In other cases, the tables list actual values such as maximum yarding or skidding distances or maximum slope limits for ground-based equipment. Lastly, "+" or "-" symbols are used to indicate whether a particular feature will enhance or detract from the various characteristics.

In keeping with the objectives of this handbook, the terms "high, medium, and low" are left undefined in the tables. Defining these terms would tend towards a "cookbook" approach for determining the single "correct" answer, which the handbook tries to avoid. Instead, the tables should be used only to rank equipment types *relative to one another*. For example, the required operator skill level for skidders is listed as low, implying only that less skill is required to operate skidders than clambunks, forwarders, or other machines. This list does not say that skidder operators are unskilled. On the contrary, skidder operators require a significant amount of skill and training, especially considering the consequences if the machines are operated in an unsafe or environmentally risky fashion. However, the mechanical simplicity of skidders as compared with forwarders and the reduced manual dexterity as compared with yarding cranes places skidders in the "low" operator skill category.

Using the list of equipment ranked by cost, the reader should determine whether each type of equipment remains a candidate for consideration. As stated previously, costs may not be the primary consideration, and the list of candidate equipment could be ranked by different criteria. Items such as skidding distance, tree size, slope, and susceptibility to high soil moisture will help to eliminate types that are unsuitable for the anticipated site conditions. Other items such as safety hazards, daily productivity, ability to work independently, and capital investment will help to determine whether the equipment will fit within the corporate organizational structure.

After completing the rankings from these tables, the reader should move on to the next section — determining various risk levels.

Risk-level Assessment

Risk levels

Acceptable results by a specific equipment type cannot be guaranteed on a given site because too many variables are involved — prescription, operator skill and attitude, weather, business objectives, and quality of site description. Instead, an element of uncertainty or risk is implied, especially when operating techniques are considered. For example, wheeled skidders can be operated safely on gentle slopes, but become unstable on steep slopes especially if turning is required. To increase the safety factor, skidders can be operated straight down the slope or from excavated trails. However,

Table 2. *Characteristics of primary transport equipment*

Characteristics of primary transport equipment	Ground												Cable						Aerial	
	Wheeled skidder - line	Wheeled skidder - grapple	Crawler skidder - line	Crawler skidder - grapple	Flex-track skidder - line	Flex-track skidder - grapple	Clambunk	Forwarder	Loader-forwarder	Cherry picker/Super snorkel	Horse	Small scale	Highlead	Swing yarder - grapple	Swing yarder - dropline	Small single-span skyline	Large single-span skyline	Multi-span skyline	Heavy-lift helicopter	Medium-lift helicopter
PERSONNEL																				
Safety hazards	H	M	H	M	H	M	L	L	L	L	H	H	H	M	H	M	H	H	H	
Crew size	M	L	M	L	M	L	L	L	L	L	L	L	M-H	L	M	M	H	M	H	M
Operator skill level required	L		L		M		M	M	M	H	M	L	M	H		M	H	H	VH	
Level of supervision required	M		M		M		L-M	M	M-H	L	M	L	M	M		M	H	H	VH	
LAYOUT																				
Layout skill level	L		L		M		M	M	M	L	L	L	M	M		M	H	H	M	
Typical distance to cutblock boundary (m)	200	200	200	150	200	200	300	300	120	50	80	150	200	150	300	200	400	500	1500	
Long-distance operating range (m)	300	250	250	200	300	250	800	800	200	50	100	200	300	200	400	250	700	800	2000	
Road density	M		M		M		L	L	H	n/a	H	H	M	H	M	M	L	L	L	
Requires landings	Y	N	Y	N	Y	N	N	N	N	n/a	N	N	Y	N		Y		Y	Y *	
Suitability to partial cut	M	L	M	L	M	L	L	H	M	L	H	H	L	L	H	H	L	H	M	
SITE																				
Low-risk favourable slope limits (%)	35		35		35		35	35	35	n/a	25	n/a	n/a						n/a	
High-risk favourable slope limits (%)	40		50		60		55	35	35	n/a	25	n/a	n/a						n/a	
Adverse slope limits (%)	10		15		20		10	15	20	n/a	5	5	n/a						n/a	
Preferred direction	downhill									up	downhill		up	dn	uphill				downhill	
Soil strength required	H		H		M		M	M	M	n/a	H	L-M	L						n/a	
Ability to avoid causing soil disturbance	L-M		L-M		L-M		M	M	M-H	n/a	H	H	M	M		M	H	H	H	
Suitability for small trees	H		H		H		H	H	M	M	H	H	M	L	M	M	L	M	L	M
Suitability for large trees	H		H		H		H	H	H	H	L	L	H						load limit	
Adaptability to low volumes/ha	H		H		H		M	H	M	M	H	H	M	L-M	M	M	L	M	L	M
WEATHER RESTRICTIONS																				
Susceptibility to high soil moisture	H		H		H		M-H	M	M-H	n/a	H	M	L-M	L		L		L	L	
Susceptibility to poor visibility (fog)	L		L		L		L	L	L	L	L	L	M	H	M	M	H	M	H	
Susceptibility to high winds	L		L		L		L	L	L	L	L	L	M						H	
Restricted by deep snow	M		L		L		L	L	M	L	H	M	H	M	H	H		H	H	
Ablility to work at night	L	H	L	H	L	H	H	H	M	M	L	L	L	M	L	L	L	L	n/a	
CORPORATE																				
Ability to work independently of loader	L	H	L	H	L	H	H	H	H	H	H	H	L	H		M	L	L	L	
Capital investment	L	M	M	M-H	M	M-H	H	H	H	H	L	L	M	H		M	H	M	VH	H
Hourly productivity	M	M-H	L	M	M		H	M	H	H	L	L	M	H		M		L	VH	H
Unit production cost range	L-M		M		M-H		L	M	L	L	M-H	M	M	L	M	M	H	H	VH	H

* Helicopters can transport logs either to landings or to water drop-zones.

Table 3. *Characteristics of falling equipment*

Characteristics of falling equipment	Rating*								Modifications**									
	Type					Carrier			Head			Features						
	Hand-falling	Feller-buncher	Feller-director	Single-grip feller-processor	Double-grip feller-processor	Tracked, boom-type	Wheeled, boom-type	Wheeled, drive-to-tree	High-speed disc	Low-speed disc	Director/chainsaw	Leveling cab	Zero-clearance tailswing	Accumulator	Large-range side-tilt	Rigid head-to-boom attachment	High stability at long reach	Overhead visibility
PERSONNEL																		
Safety hazards	H	L	L	L	L	L-M	L	M	+			+			+		-	-
Operator skill level required	H	M	M	H	H	M	M	L-M	+			-		+		-		
SYSTEM																		
Ability to avoid causing soil disturbance	H	M	M	H	H	type limit		L-M				-			+		+	
Suitability for partial cutting in open stand	H	H	M	H	H	M	H	L			+	+	+		+	+	+	+
Suitability for partial cutting in dense stand	L	H	L	M	M	M	M	L				+	++	+	+	++	++	++
Suitability for choker extraction	H	H	H	L	L	type limit***								+				
Suitability for grapple skidder extraction	L	H	M	L	L	type limit								+	+	+	+	
Suitability for grapple yarder extraction	H	H	M	L	L	type limit								+	+	+	+	
Suitability for forwarder extraction	L	L	L	H	H	type limit												
Ability to sort	L	M	L	H	M-H	type limit		M						+	+	+	+	
SITE																		
Maximum slope (%)	n/a	carrier limit				60	30	20				++			+		+	
Immunity to obstacles	H	M	M	M	M	H	M	L	-								+	
Ability to work in dense underbrush	L	H	M	L	L	H	H	L	+		--							
Suitability for small trees	M	H	M	H	L	M-H	M-H	H	+	-	+			++				
Suitability for large trees	H	M	H	L	H	M	L-M	M-H	-	+	-	+			+		+	
Suitability for windfall	L-M	M	M	H	H	M	L-M	L	-	+	+	+			++			
WEATHER RESTRICTIONS																		
Ability to work during high winds	L	M	L	M	M	M	M	M			-							
Ability to work under deep snow conditions	L	H	H	L	M	H	M	L	+	+	-							
Ability to work at night	L	H	H	H	H													
CORPORATE																		
Capital investment	L	H	M	H	H	H	H	M			-	+	+	+	+		+	+
Daily productivity	L	H	M	M	H	H	M	M	+			+		+			+	+
Unit production costs	variable					H	H	L				-		-			-	-

* Rating: Low to High for this characteristic.

** Modification: + indicates that adding this feature will increase the characteristic, - indicates decrease, blank is neutral.

*** Type limit: governed by the type, rather than by the carrier.

Table 4. *Characteristics of processing equipment*

Characteristics of processing equipment	Delimbers/Processors						Other			
	Hand-bucking	Small dangle-head processor	Large dangle-head processor	Small-stroke delimber	Large-stroke delimber	Pull-through delimber	Chain-flail delimber/debarker	Chipper	Hogger	Slasher
SYSTEM										
Safety hazards	H	L		L		L	H	M	M	L
Suitability to landings	H	H		H		H	H	H	H	H
Suitability to roadside	L-M	M	H	H		L	L	L-M	L	M-H
SITE										
Suitability for small trees	L-M	H	M	H	M	H	H	H	n/a	H
Suitability for large trees	H	L	H	M	H	H	M	L	n/a	L
Maximum tree diameter (cm)	n/a	50	80	50	70	n/a	n/a	40		n/a
CAPABILITY										
Delimbing	+	+		+		+	+	-	-	-
Topping	+	+		+		-	-	-	-	+
Log measuring	+	+		+		-	-	-	-	+
Butt-rot removal	+	+		+		-	-	-	-	+
Midstem-rot removal	+	+		+		-	-	-	-	-
Can work without support equipment	-	+		+		-	-	-	-	+
Extraction from log deck	n/a	L	M-H	M	H	n/a	n/a	n/a	n/a	M
Sorting	n/a	M		M	H	n/a	n/a	n/a	n/a	M
CORPORATE										
Capital investment	L	H		H		L	M	H	H	M
Daily productivity	M	H		H		M	H	H	H	H

Table 5. *Characteristics of loading equipment*

Characteristics of loading equipment	Type					Carrier	
	Front-end loader	Hydraulic	Butt 'n top	Line loader	Self-loading log truck	Wheeled carrier	Tracked carrier
PERSONNEL							
Safety hazards	L	L	L	M	M		
Operator skill level required	L	L	M	H	L		
CAPABILITY							
Suitability for small logs	H	M	H	M	H		
Suitablility for large logs	H	H	L-M	H	L-M		
Ability to reach below grade	L	M-H	M	H	M		
Maximum reaching distance (m)	5	15	15	30+	10		
Able to load from side of truck	H	M	H	M	H		
Able to load from front of truck	n/a	H	L	H	n/a		
Able to load from rear of truck	n/a	H	L	H	n/a		
Cherry-picking, primary transport	L	H	L	H	L	-	
LAYOUT							
Space requirements while loading	H	L	M	M	L	+	-
Suitability for landings	H	H	L	H	H		
Suitability for roadside	L	H	H	H	H	-	+
Suitability to load from several sites concurrently	H	M	L	L-M	H	+	-
Required level of travel surface preparation	M	L	L	H	n/a	+	
CORPORATE							
Capital investment	L	M-H	H	H	L		+

excavated trails may have an impact on soil erosion, water quality, or the amount of site disturbance. Similarly, flotation mats can allow excavators to work on soft ground, but may slow machine travel and reduce productivity.

Most importantly, each machine type is suitable to a range of conditions as defined by its basic features. When operating the machine within its appropriate range, the risk of exceeding operational and environmental limits is minimized, but operating outside the range will increase the risk of generating unacceptable results. Even the most benign harvesting system can produce unacceptable results if used inappropriately, and seemingly unsuitable equipment can be made suitable by incorporating appropriate techniques.

Under this concept, selecting the appropriate equipment for each site becomes a matter of matching features to risk. The planner must understand the basic features of the equipment, the range of operating techniques, the influence of site conditions and the external requirements that might be imposed, and how these four factors are related to one another by risk levels. Combinations of equipment and conditions with low risk levels should be considered rather than those with higher risk levels. The use of higher risk combinations may be appropriate under certain operating conditions or to achieve specific goals, but such a selection should be made only with a full understanding of all the potential risks and benefits.

This handbook uses a system of risk evaluation, and Table 6 defines various risk levels on a scale from 1 to 6. These risk levels are not absolute; instead they indicate the relative amount of risk of operating the machine under varying site and objective conditions. A low risk level indicates a good chance of successful operations, while a high number indicates a high risk of failure.

Some high risk activities are constrained by environmental considerations (e.g., high likelihood of soil degradation by wheeled skidders on moist, fine-textured soils), while others are constrained by operational considerations such as productivity (e.g., poor performance of large highlead systems with small trees). In either case, the risk level is shown as a single value, and the underlying cause is not indicated in the charts. The descriptions in Part 2 of the handbook will provide additional detail and explanation regarding the cause of the high risk level.

The high-risk levels as defined in Table 6 and used in the charts that follow are quite definite, whereas the lower levels should be considered more as general guidelines. For

Table 6. *Risk-level descriptions*

Risk Level	Description
1	Minimal risk, best operating conditions.
2	Generally acceptable; normal operating conditions. Unusual circumstances may increase risk.
3	Acceptable under many conditions, but exercise caution.
4	Risky; good reasons or special operating techniques required to operate under these conditions.
5	Highly risky; exceptional circumstances required to operate under these conditions. Special planning and operating techniques will be required.
6	Not recommended.

example, Chart 13 for multi-span skylines lists only four possible outcomes, three of which are risk level 5 or 6, and one of which is risk level 1. This should be interpreted as saying "Three factors rule out multi-span systems. In the absence of these factors, the system is feasible." In contrast, Chart 15 for large skylines lists more factors, some of which have mid-level risks. These mid-level risks indicate that the equipment and site are compatible, but caution should be exercised.

Risk factors that apply to all harvesting systems are shown in Table 7. These factors should be considered, and used to modify the risk factors shown in the individual charts.

Key factors

The following charts list the key factors to consider when determining the suitability of each machine type for operating on a particular site. Only the most important factors have been listed — clearly, other factors must be considered when choosing equipment, and the reader should refer to Part 2 of the handbook for additional information. This is especially critical for the low- and mid-level risks — whereas the high-level risks are more definite.

The charts are presented as flowcharts starting from the upper-left corner of each chart. The various factors are shown in diamond-shaped boxes, and the risk levels are shown in small rectangular boxes. Choose one of the paths leading from each decision box as determined by the site conditions. The most critical factors are listed first, and may constitute a simple go/no-go decision. For example, using wheeled skidders on fine-textured soils with high moisture content is not recommended. The factors further down in the chart typically have more feasible outcomes — follow the path that most closely

Table 7. *Risk factors applicable to all harvesting equipment*

Factor	Comment
Operator experience, attitude, and history	Risk is decreased with an experienced operator who has worked successfully under similar conditions in the past, and has demonstrated a desire to do a proper job.
Contractor experience, attitude, and history	Risk is decreased with an experienced contractor who has worked successfully under similar conditions in the past, and has demonstrated a desire to do a proper job. Effective communications between the planners and the workers and adequate supervision decrease the risk of a mishap caused by misunderstood instructions.
Weather	Inclement weather, especially excessive rainfall, increases the risk. The risk of causing soil disturbance increases with higher soil moisture content. Maintaining a flexible schedule, with the ability to work on different areas as required by weather conditions, reduces the risk.
Sensitive zones	Working in the vicinity of riparian zones, or other sensitive zones, increases the risk. Operators should always take extra care when working in sensitive zones.
Tree size	Risk is minimized when the tree size is matched to machine size. Trees that are too small decrease productivity and increase costs, while trees that are too large can overwork the machine, causing mechanical failure or environmental damage.
Timber quality	Risk is increased with poor-quality timber because of reduced values. Poor-quality timber requires as much, or more, time for processing, yet returns a smaller profit.

describes the site characteristic. Proceed through the chart until you arrive at a risk-level box.

In some cases, a first-mentioned factor on the chart may result in a high, but non-limiting, risk level (e.g., in Chart 15, non-clearcuts are ranked as risk level 4). On the same chart, another factor may be ranked with a higher risk level (e.g., poor deflection is ranked as risk level 6). This result should not be interpreted as saying that poor deflection in a non-clearcut will result in risk level 4. Obviously, the higher risk level will prevail.

Comments at the bottom of each chart list additional factors that apply for all types of sites, and should be considered in assessing the risk level. Table 7 lists risk factors that should be considered for all types of equipment. Finally, the contractor and operator may employ special operating techniques that can modify the risk levels.