Provincial Soil Disturbance Summary: 1989 - 1990 Results

Prepared for:

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by

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INTRODUCTION

This report summarizes the results of post-harvest soil disturbance surveys conducted throughout British Columbia in 1989 and 1990. Survey results are presented in a series of tables and figures accompanied by a point form description of important relationships. Due to the large number of surveys with incomplete site descriptions, more rigorous quantitative analysis was not undertaken. Due to missing data for some attributes, the sample sizes reported in the tables may differ slightly in some cases. The baseline data have been compiled in an electronic database that accompanies this report.

The cutblocks summarized were derived from a number of projects with varying objectives, that were initiated at the regional level. In some projects, cutblocks assumed to represent "best" or "worst" case conditions were selected, while in others, random site selection was used. Although the cutblocks that form the database were not obtained solely from random sampling, the normal distribution of results would strongly suggest that the database is representative of current harvesting practice. **In this report "detrimental disturbance" refers to the sum of skidding and landing disturbance, as this term is currently defined in the Ministry of Forests Interim Harvesting Guidelines.**

HIGHLIGHTS

1. On a provincial basis, **detrimental disturbance averaged 4.6% on the 13 cable harvested blocks surveyed, and 16.7% on the 242 blocks harvested using ground systems. For the "best" sites harvested using ground systems** (i.e. the 25% of sites with the lowest disturbance levels), **detrimental disturbance averaged 5.9%,** with landing disturbance of 2.8%, and skidding disturbance of 3.1%. All of these sites were random skidded. **The worst 25% of sites averaged 29.8% detrimental disturbance,** with landing disturbance of 4.4% and 25.4% skidding disturbance.
2. **Site that were random skidded had lower average detrimental disturbance levels** (17.6%) than sites with constructed skidroads (22.7%). **Steeper sites had higher disturbance levels,** irrespective of the season of harvest or skidding system. Disturbance was slightly lower on winter skidded versus summer skidded cutblocks, but further sampling is required to verify this trend.
3. **Landing area was greater on random skidded cutblocks (3.9%) than contour skidded blocks (2.8%),** but was only marginally different on steeper slopes. Due to the fact that all contour skidded cutblocks were located in the Nelson Forest Region, this interpretation may be confounded with differences in regional operating standards, or licensee performance.
4. There was a poor correlation between Overall Hazard rating and detrimental disturbance levels. This suggests that current operating practices are not being adapted to site specific hazard ratings.
5. **The survey design should be modified to use 22 transects, 60 meters in length, with a 1 meter sampling interval.** On large cutblocks use 1 additional 60 meter transect for each additional 5 hectares greater than 50, to a maximum of 30 transects per survey.
6. The reliability and detail of the comparisons discussed above could be significantly improved if site descriptions for the survey areas were included in the information package provided for construction

[1] Frontline Forest Research, Nelson, B.C.

of the provincial summary. This additional data should be added to the existing database, and a more complete analysis made in a future project.

SURVEY RESULTS

Site Characteristics by Region

- Sample distribution by forest region is summarized in Figure 1.
- Surveyed cutblocks were larger, on average, in the Cariboo, Prince George and Prince Rupert regions than in the Nelson or Kamloops regions (Table 1).
- Slopes were steeper in the Nelson and Kamloops regions than in Cariboo and Prince George (Table 1). The data provided by the Prince Rupert region did not include slope steepness.
- Nelson was the only region where contour skidded cutblocks were sampled.

Detrimental Disturbance Levels

- On a provincial basis, detrimental disturbance averaged 4.6% on the 13 cable harvested blocks surveyed, and 16.7% on the 242 blocks harvested using ground systems (Table 2).
- **Slope steepness and skidding system were the factors most correlated with the level of detrimental disturbance.**
- Differences in disturbance levels among regions were primarily attributable to differences in site characteristics and harvesting systems for the sites sampled (Tables 1 and 2).

Disturbance by Slope Steepness, Skidding System and Season of Logging

- Higher levels of disturbance were noted on sites in the 30 - 45% slope class than on less steeply sloping sites, regardless of skidding system or Overall Hazard Class (Figures 2 and 3, Tables 3 and 4).
- Detrimental disturbance on random skidded blocks (17.6%) was lower than on contour skidded blocks (22.7%). The lowest disturbance (14.7%) was observed on blocks where the skidding system was unknown (Table 4 and Figure 2).
- Some differences between summer and winter logging are evident, but the general trend is difficult to interpret due to the small sample size in specific classification cells, and the large number of sites with unknown harvest season (Table 4, note levels in the > 30% slope class).

Disturbance by Site Sensitivity

- There was a poor correlation between Overall Site Sensitivity and detrimental disturbance levels (Figure 4 and Table 3).
- On Moderate and Low hazards, approximately 2/3 of the sites harvested using ground systems were below the 19% limit for allowable detrimental disturbance. On High hazard sites, only 1/4 of ground harvested sites were below the allowable limit of 9%.

Landings

- **Landing area was greater on random skidded cutblocks (3.9%) than contour skidded blocks (2.8%)**, but was only marginally different on steeper slopes (Table 5). Due to the fact that all contour skidded cutblocks were located in the Nelson Forest Region, the difference attributed to skidding system may be confounded with differences in regional operating standards, or licensee performance.

- Average landing area was highest in the Kamloops (4.2%) and Prince Rupert (4.3%) regions, and lowest in Nelson (3.0%, Table 1). Skidding system was not reported in Kamloops and Prince George, therefore it is difficult to determine if these levels are a result of regional differences in operating practices, or skidding system differences.
- **Regional differences in landing area** (%) are evident in a comparison of similar site types in the Nelson and Prince George Forest Regions (Table 6). Average landing area was 0.6% - 2.4% lower on random skidded sites in Nelson than in Prince George, depending on slope class. Due to missing site attributes from other regions, it is not possible to determine regional differences over the entire province.
- Average individual landing size (in hectares) was substantially higher in the Prince George (.44 ha) and Prince Rupert (.53 ha) regions than in the Nelson (.29 ha) or Kamloops (.34 ha) regions.

Skidding disturbance

- Overall trends in skidding disturbance are similar to those described for detrimental disturbance (Table 7).

Spur Road Disturbance

- Spur road disturbance was higher on randomly skidded cutblocks (2.7%) than on contour skidded blocks (1.5%, Table 8). Differences in spur road disturbance levels may be confounded by differences the overall transportation network associated with each skidding system. Lower levels of spur road disturbance would be expected on sites where a main haul road was present.

Detrimental Disturbance on the "Best" and "Worst" Sites

- Detrimental disturbance on the "best" sites harvested using ground based systems (i.e. the 25% of sites with the lowest disturbance levels), averaged 5.9%, including skidding disturbance of 3.1% and landing disturbance of 2.8% (Table 9). All of these sites were random skidded. Both skidroad and landing area were substantially lower on the best sites than all other categories.
- The worst 25% of sites averaged 29.8% detrimental disturbance, including 25.4% skidding disturbance.and landing disturbance of 4.4%. Fifteen of the 30 contour skidded sites surveyed were in the "worst" category (Table 9 and Figure 6).

Survey Variability

- The average co-efficient of variation for the 54 sites where confidence interval data were reported, was 121%. Sample size requirements for 30 meter transects as a function of the absolute 90% confidence interval half-width are shown in Figure 7. To achieve a survey precision of $\pm$ 4% (in absolute terms), 67 transects are required (see Recommendations).

Electronic Database

- An electronic database of survey data accompanies this written report. The database is duplicated in 2 formats: a Lotus 1-2-3 worksheet, and a DBASE III database. Description of the database variables is given in Table 10.

RECOMMENDATIONS

1. A data form and consistent reporting format should be developed and implemented for future surveys.
2. More consistent training of surveyors is essential. Key issues to be addressed are: site stratification, measurement of landings, recognition of Heavy Skidtrail (HST) disturbance.
3. The survey method should be modified to use 20 - 24 transects 60 meters in length, with a point interval of 1 meter. Alternatively, the existing system of 30 meter transects with a 2 meter point interval could be used with a sample size of 60 - 70 transects. On large cutblocks use 1 additional 60 meter transect, or 2 additional 30 meter transects for each additional 5 hectares greater than 50. Use a maximum of 30 transecst 60 m in length. Surveys in the 1991 field season should be closely monitored to verify that the desired level of precision is attained.
4. The existing survey data should be updated to include the missing site description information (in particular, slope class and skidding system). The updated dataset should be analyzed in conjunction with 1991 sampling results.
5. **Change the basic approach to description of soil compaction by using a 2 code rating.** This change is strongly recommended, at least on an interim basis, until the reliability of visually assessing compaction can be established by further research. The first code would describe soil displacement (e.g. HST, SR, OT etc.). The second code would indicate the presence or absence of compaction.
6. Detrimental disturbance from ground skidding on sites in the 30 - 45% slope class should be closely monitored in the 1991 field season. Steeper slopes were consistently correlated with higher detrimental disturbance. On sites that have only constructed skidroads, consider using the traverse method for surveys. This will allow for calculation of average skidroad spacing.

Table 1 Descriptive statistics for selected site attributes by forest region.*

	Region	Sample Size	Mean	Standard Deviation	Minimum	Maximum
Block Size (ha)	Cariboo	17	55.1	22.1	27.1	96.0
	Kamloops	21	21.3	17.8	5.5	73.9
	Nelson	66	24.2	16.4	3.8	80.0
	Prince George	103	85.0	60.5	9.0	428.0
	Prince Rupert	33	47.7	32.4	5.9	147.0
	ALL	**240**	**55.4**	**50.9**	**3.8**	**428.0**
Slope (%)	Cariboo	21	20.2	16.7	3.0	60.0
	Kamloops	21	29.2	13.5	7.0	51.0
	Nelson	66	28.6	13.0	0.0	63.0
	Prince George	68	15.8	12.5	0.0	60.0
	Prince Rupert	0	-	-	-	-
	ALL	**176**	**22.7**	**14.6**	**0.0**	**63.0**
Landing Area (%)	Cariboo	24	3.5	2.9	0.0	12.6
	Kamloops	21	4.2	2.0	0.0	9.3
	Nelson	66	3.0	2.3	0.0	14.0
	Prince George	117	3.9	1.8	0.0	9.7
	Prince Rupert	35	4.3	3.2	0.0	16.8
	ALL	**263**	**3.7**	**2.3**	**0.0**	**16.8**
Number of Landings per Cutblock	Cariboo	8	2.7	5.1	0.0	14.0
	Kamloops	21	2.4	1.4	0.0	7.0
	Nelson	52	2.6	1.7	0.0	8.0
	Prince George	74	6.4	4.0	0.0	17.0
	Prince Rupert	35	4.1	2.9	0.0	10.0
	ALL	**190**	**4.4**	**3.6**	**0.0**	**17.0**
Landing Size (%)	Cariboo	3	3.3	5.0	0.2	9.1
	Kamloops	20	2.2	1.3	0.5	5.6
	Nelson	48	1.6	2.1	0.2	14.0
	Prince George	73	0.9	1.1	0.0	6.6
	Prince Rupert	29	1.3	1.0	0.3	4.8
	ALL	**173**	**1.4**	**1.6**	**0.0**	**14.0**

* Attribute sample size varies because each forest region provided different data packages for summarization

TABLE 2: Mean Disturbance by Harvesting System, Season, and Forest Region

		DETRIMENTAL DISTURBANCE (%)																	
System:	**CABLE**	**GROUND**																	
Specific Pattern:	Cable	Random					Constructed					Mixed	Road Side	Ground Unknown					**ALL**
Season:	**ALL**	S	W	W&S	?	**ALL**	S	W	W&S	?	**ALL**	**ALL**	**ALL**	S	W	W&S	?	**ALL**	**ALL**
REGION																			
Cariboo	**3.1**	-	-	-	-	-	-	-	-	-	-	-	**13.1**	14.4	10.7	12.0	17.6	**14.0**	**13.8**
	[1]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[4]	[5]	[4]	[2]	[4]	[15]	[19]
Kamloops	**4.5**	-	-	-	-	-	-	-	-	-	-	-	-	15.4	16.5	-	-	**16.1**	**16.1**
	[4]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[6]	[11]	[0]	[0]	[17]	[17]
Nelson	**4.7**	17.0	19.9	10.6	20.8	**17.2**	24.8	19.5	32.8	19.3	**22.7**	**22.3**	-	22.1	14.4	6.4	23.8	**18.4**	**20.5**
	[3]	[7]	[4]	[2]	[1]	[14]	[16]	[7]	[1]	[6]	[30]	[5]	[0]	[7]	[5]	[1]	[1]	[14]	[63]
Prince George	**5.0**	20.4	16.9	12.9	36.7	**17.7**	-	-	-	-	-	**20.0**	-	15.9	15.9	17.0	12.3	**14.7**	**16.4**
	[5]	[13]	[40]	[5]	[1]	[59]	[0]	[0]	[0]	[0]	[0]	[1]	[0]	[6]	[22]	[3]	[17]	[48]	[108]
Prince Rupert	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.9	**12.9**	**12.9**
	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[35]	[35]	[35]
ALL	**4.6**	19.2	17.2	12.3	28.7	**17.6**	24.8	19.5	32.8	19.3	**22.7**	**21.9**	**13.1**	17.3	15.4	13.6	13.3	**14.7**	**16.7**
	[12]	[20]	[44]	[7]	[2]	[73]	[16]	[7]	[1]	[6]	[30]	[6]	[4]	[24]	[42]	[6]	[57]	[129]	[242]

* bracketed numbers are the sample size for the class.

Table 3 Detrimental disturbance (%) by slope class and Overall Hazard rating, for ground systems.

	Detrimental Disturbance (%)					
	Hazard Class					
Slope Class	Low	Moderate	High	Very High	Unknown	ALL
Unknown	-	15.6	12.9	15.2	23.5	**16.3**
	-	[51]	[15]	[2]	[13]	[81]
<30%	14.3	15.3	16.2	13.3	17.5	**15.5**
	[17]	[56]	[21]	[1]	[11]	[106]
30-45%	-	19.0	18.3	-	22.4	**18.9**
	-	[32]	[13]	-	[1]	[81]
46-60%	-	27.0	-	-	-	**27.0**
	-	[5]	-	-	-	[5]
>60%	-	-	32.8	-	-	**32.8**
	-	-	[1]	-	-	[1]
ALL	**14.3**	**16.6**	**16.1**	**14.6**	**20.8**	**16.8**
	[17]	[144]	[50]	[3]	[25]	[239]

* bracketed numbers are the sample size for the class.

TABLE 4 Detrimental disturbance by slope class, harvesting pattern, and season for ground system

Slope Class	Detrimental Disturbance (%)																
	Random					Constructed					Road Side	Ground Unknown					ALL
	?	S	W	W&S	ALL	?	S	W	W&S	ALL	ALL	?	S	W	W&S	ALL	ALL
Unknown	36.7	32.2	17.1	.	**22.1**	-	-	-	-	-	-	13.6	20	15	21.8	**14.8**	**16.2**
	[1]	[4]	[11]	[0]	[16]	-	-	-	-	-	-	[38]	[5]	[20]	[2]	[66]	[82]
<30	20.8	17	15.1	12.3	**15.3**	16.9	26.3	12.6	-	**20.4**	**13.1**	12.2	15.7	15.1	7.4	**14.1**	**15.5**
	[1]	[12]	[29]	[7]	[49]	[4]	[5]	[2]	-	[11]	[4]	[14]	[10]	[15]	[1]	[40]	[108]
30-45	-	13	23.1	-	**17.3**	22.4	23.4	23.7	-	**23.4**	-	13.9	17.2	17	13.6	**16**	**18.9**
	-	[4]	[3]	-	[7]	[1]	[10]	[4]	-	[15]	-	[5]	[8]	[7]	[2]	[22]	[46]
46-60	-	-	59.3	-	**59.3**	25.5	30.7	16.5	-	**24.2**	-	-	-	-	3.1	**3.1**	**27**
	-	-	[1]	-	[1]	[1]	[1]	[1]	-	[3]	-	-	-	-	[1]	[1]	[5]
>60	-	-	-	-	-	-	-	-	32.8	**32.8**	-	-	-	-	-	-	**32.8**
	-	-	-	-	-	-	-	-	[1]	[1]	-	-	-	-	-	-	[1]
ALL	28.7	19.2	17.2	12.3	**17.6**	19.3	24.8	19.5	32.8	**22.7**	**13.1**	13.3	17.3	15.4	13.6	**14.7**	**16.7**
	[2]	[20]	[44]	[7]	[73]	[6]	[16]	[7]	[1]	[30]	[4]	[57]	[23]	[42]	[6]	[129]	[242]

* bracketed numbers are the sample size for the class.

Table 5 Landing area (%) by slope class and harvesting system.*

Slope Class	CABLE	GROUND				
	Cable	Random Skid	Constructed Skidroad	Roadside	Unknown Ground	ALL GROUND
Unknown	0.0	4.4	-	-	4.3	**4.3**
	[1]	[16]	-	-	[65]	[81]
<30%	2.6	3.8	3.1	1.1	3.8	**3.6**
	[3]	[49]	[11]	[4]	[39]	[103]
30-45%	1.6	4.2	2.9	-	3.6	**3.5**
	[2]	[7]	[15]	-	[22]	[44]
46-60%	4.0	0.0	1.0	-	3.1	**1.2**
	[7]	[1]	[3]	-	[1]	[5]
>60%	-	-	1.9	-	-	**1.9**
	-	-	[1]	-	-	[1]
ALL	**3.0**	**3.9**	**2.8**	**1.1**	**4.0**	**3.8**
	[13]	[73]	[30]	[4]	[127]	[234]

* bracketed numbers indicate sample size for the classification cell.

Table 6 Landing disturbance in the Nelson and Prince George forest regions

	Landing Disturbance (%)		
	Nelson		Prince George
Slope Class	Random	Constructed Skidroad	Random
<30%	3.3	3.1	3.9
	[38]	[11]	[49]
30-45%	2.8	2.9	5.2
	[4]	[15]	[7]
ALL	**3.3**	**3.0**	**4.1**
	[42]	[26]	[56]

* bracketed numbers indicate sample size for the classification cell.

Table 7 Skidroad disturbance by slope class and harvesting system.

Slope Class	CABLE	GROUND				
	Cable	Random Skid	Constructed Skidroad	Roadside	Unknown Ground	ALL GROUND
Unknown	8.8	17.6	-	-	10.7	**12.0**
	[1]	[16]	-	-	[65]	[81]
<30%	0.6	11.5	17.3	12.0	10.5	**12.0**
	[3]	[49]	[11]	[4]	[40]	[103]
30-45%	2.0	13.2	20.5	-	12.4	**15.3**
	[2]	[7]	[15]	-	[22]	[44]
46-60%	0.9	59.3	23.3	-	-	**32.3**
	[7]	[1]	[3]	-	-	[4]
>60%	-	-	30.9	-	-	**30.9**
	-	-	[1]	-	-	[1]
ALL	**1.6**	**13.7**	**19.9**	**12.0**	**10.9**	**12.9**
	[13]	[73]	[30]	[4]	[127]	[234]

* bracketed numbers indicate sample size for the classification cell.

Table 8 Spur road disturbance by slope class and harvesting system.

Slope Class	CABLE	GROUND				
	Cable	Random Skid	Constructed Skidroad	Roadside	Unknown Ground	ALL GROUND
Unknown	0	2.6	-	-	2.5	**2.5**
	[1]	[16]	-	-	[64]	[80]
<30%	4.4	2.8	1.8	2.7	2.8	**2.7**
	[3]	[49]	[11]	[4]	[40]	[103]
30-45%	0	2.2	1.2		3.2	**2.3**
	[2]	[7]	[15]	-	[21]	[43]
46-60%	4	2.6	1.3		5	**2.3**
	[7]	[1]	[3]	-	[1]	[5]
>60%	-	-	2.4	-	-	**2.4**
	-	-	[1]	-	-	[1]
ALL	**3.2**	**2.7**	**1.5**	**2.7**	**2.7**	**2.6**
	[13]	[73]	[30]	[4]	[126]	[233]

* bracketed numbers indicate sample size for the classification cell.

Table 9 Attributes of best and worst sites harvested using ground systems (ranked by quartiles of detrimental disturbance)

	Mean			
	Best 25%	2nd Best 25%	2nd Worst 25%	Worst 25%
Area (ha)	62.8	59.9	66.0	43.2
	[51]	[55]	[52]	[57]
Slope (%)	19.7	16.5	23.7	26.8
	[37]	[34]	[39]	[42]
Detrimental Disturbance (%)	5.9	12.1	18.5	29.8
	[58]	[59]	[58]	[59]
Skidroad Disturbance	3.1	8.4	14.4	25.4
	[58]	[59]	[58]	[59]
Landing Area (%)	2.7	3.8	4.1	4.4
	[58]	[59]	[58]	[59]
Spur Road Disturbance (%)	2.8	2.5	2.7	2.3
	[57]	[59]	[57]	[58]
Number of Landings	4.1	4.5	5.5	3.6
	[43]	[42]	[42]	[45]

* bracketed numbers are the sample size for the class.

Table 10 Description of database variables.

Variable Name	Description
KEY	Unique number attached to each site
SURVEYOR	name of the survey contractor
FUNDING	Company or agency funding the survey
YRSURVEY	Year that the survey was carried out
REGION	Forest Region in which the survey was carried out
FD	Forest District in which the survey was carried out
COMPANY	Company or agency responsible for harvesting
LICENCE	Form and number of forest tenure
CP	Cutting permit number
BLK	Cutblock number
OPENING	BCGS opening number
STRATUM	Stratum, if cutblock was stratified for sampling
BLKAREA	Area of stratum in hectares
SLOPE	% slope of stratum
HZCOMP	Compaction hazard rating
HZDISP	Displacement hazard rating
HZEROS	Erosion hazard rating
HZMW	Mass wasting hazard rating
HZOVER	Overall hazard rating
N	Number of sample points in Grid Point Interecept survey
SRAV	Average level of skidroad disturbance, in percent
SRCI	Confidence interval for SRAV, in percent
SRSD	Standard deviation for SRAV, as the number of points
OT2AV	Sum of average percent non-degrading Other Type (OT) disturbance and average percent non-degrading Light Skid-Trail (LST)disturbance
OTAV	Average percent of non-degrading Other Type disturbance
OTCI	Other Type disturbance confidence interval, in percent
OTSD	Other Type disturbance standard deviation, as the number of points
LSTAV	Average disturbance level for non-degrading Light Skid Trail type disturbance
UNAV	Average percent of undisturbed area
UNCI	Undisturbed area confidence interval, in percent
UNSD	Undisturbed area standard deviation, as the number of points
LL	Landing area, in percent, calculated by dividing total landing area, in ha., by the total block area, in ha., and multiplying by 100.
LLCI	Landing area confidence interval, calculated when the area of each individual landing was known
LLNO	Number of landings
LLMETH	Landing area measurement method, TRAV=traverse method, LW=length by width method
FGAV	Average disturbance, in percent, resulting from fireguards
FGCI	Fireguard confidence interval, in percent
FGSD	Fireguard standard deviation, as the number of points

Table 10 Description of database variables (continued).

Variable Name	Description
HRAV	Disturbance level, in percent, resulting from haul roads constructed within cutblocks that end within that cutblock and will not continue on to any other area.
HRCI	Haul road confidence interval, in percent
MACHINE	Type of machinery used in harvesting operations.
PATTERN	Method of harvesting,i.e.,RAN=random skidding,SR=contour skidroads, ROAD=roadside,COM=random and contour skidding, CAB=cable yarding, MIX=cable and ground skidding,U=unknown
SEASON	Season in which block was harvested,i.e., W=winter,S=spring , summer, or fall, W/S=all seasons
YRHARV	Year in which block was harvested
DISTTYPE	Source of disturbance, i.e., H=all disturbance results from harvesting activities, MSP=disturbance results from both harvesting and MSP activities,not included in summaries
COMMENTS	General comments

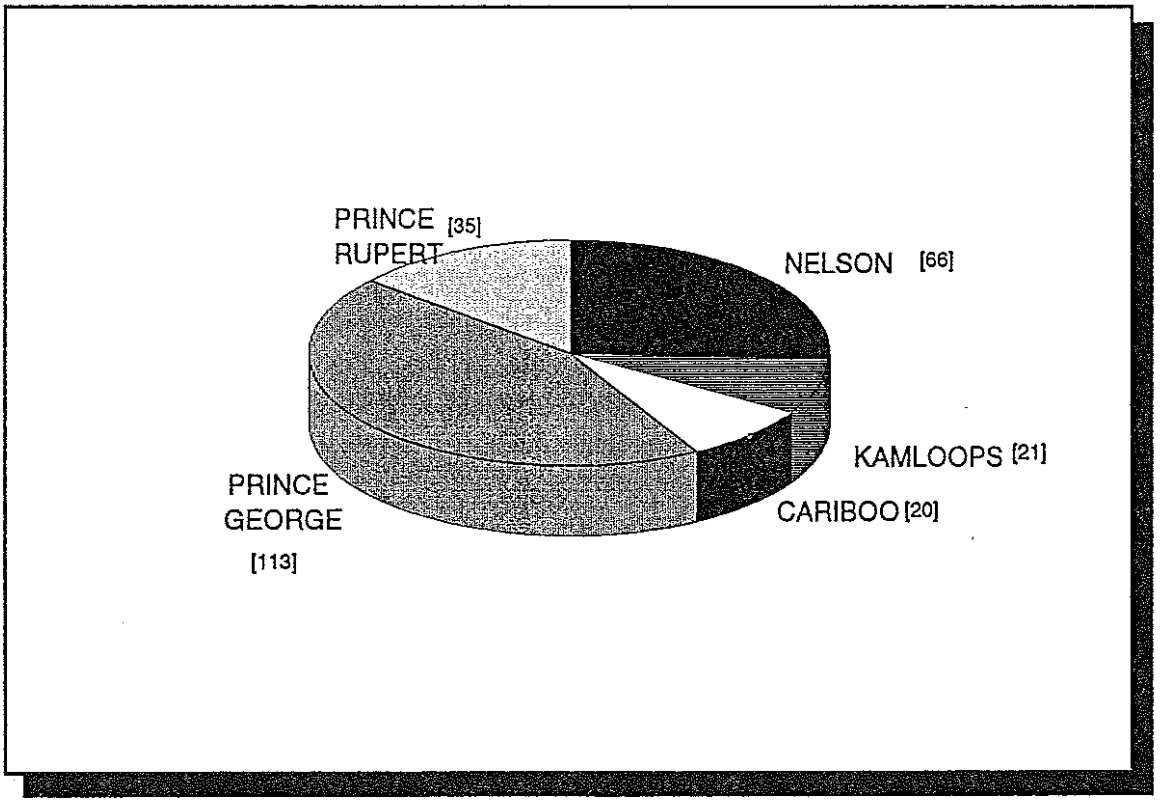

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Figure 1 Sample size by forest region.

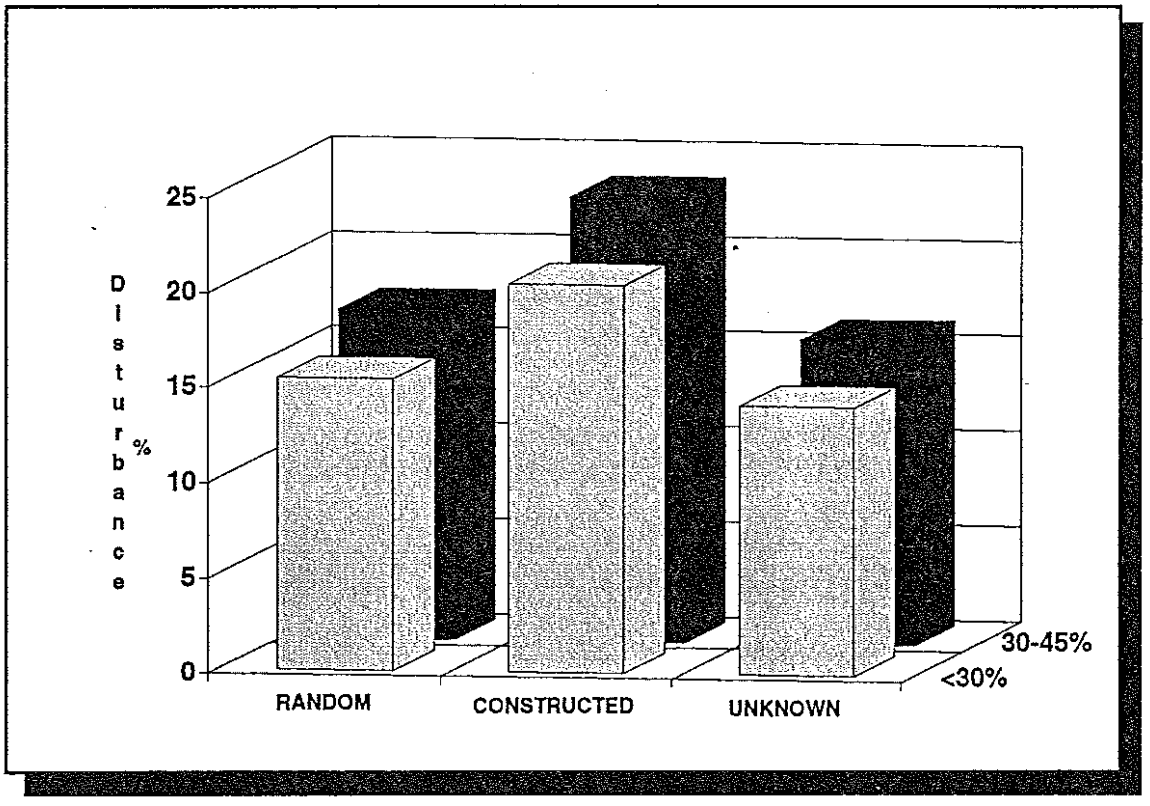

Figure 2 Detrimental disturbance by slope class and skidding system. Disturbance levels are consistently higher on steeper sites (shown by the dark bars).

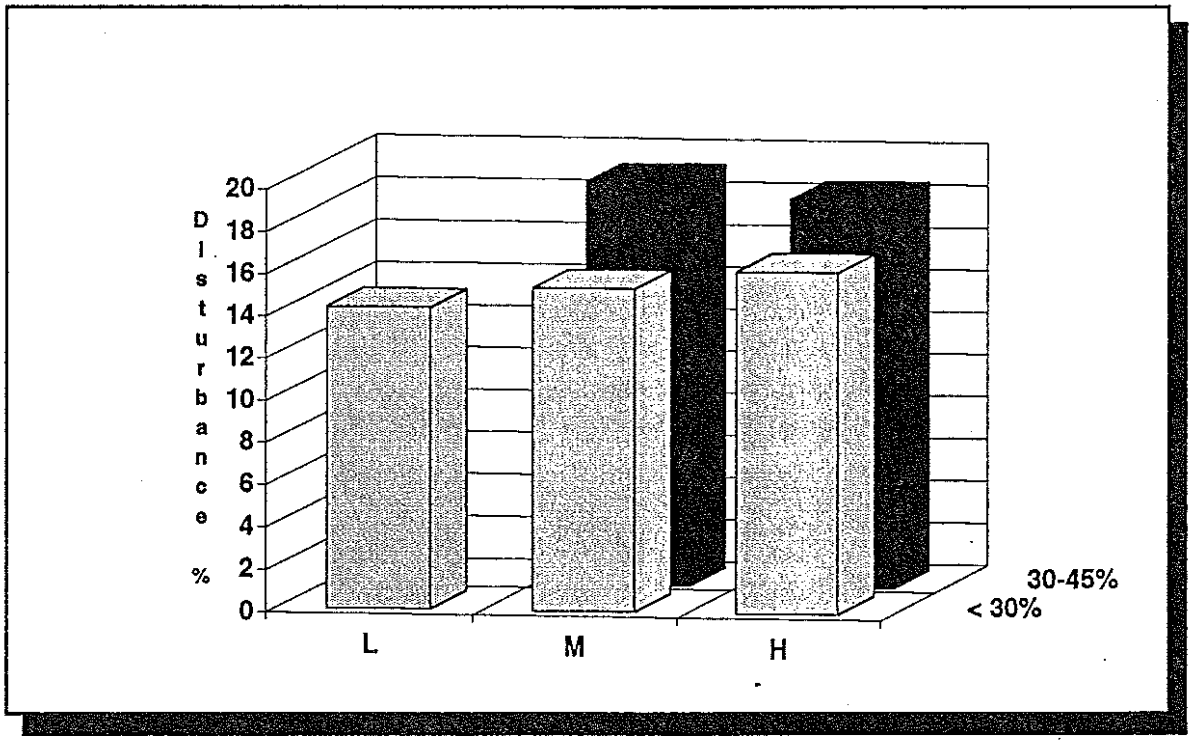

Figure 3 Detrimental disturbance by slope class and Overall Hazard class. Disturbance levels are consistently higher on steeper sites (shown by the dark bars).

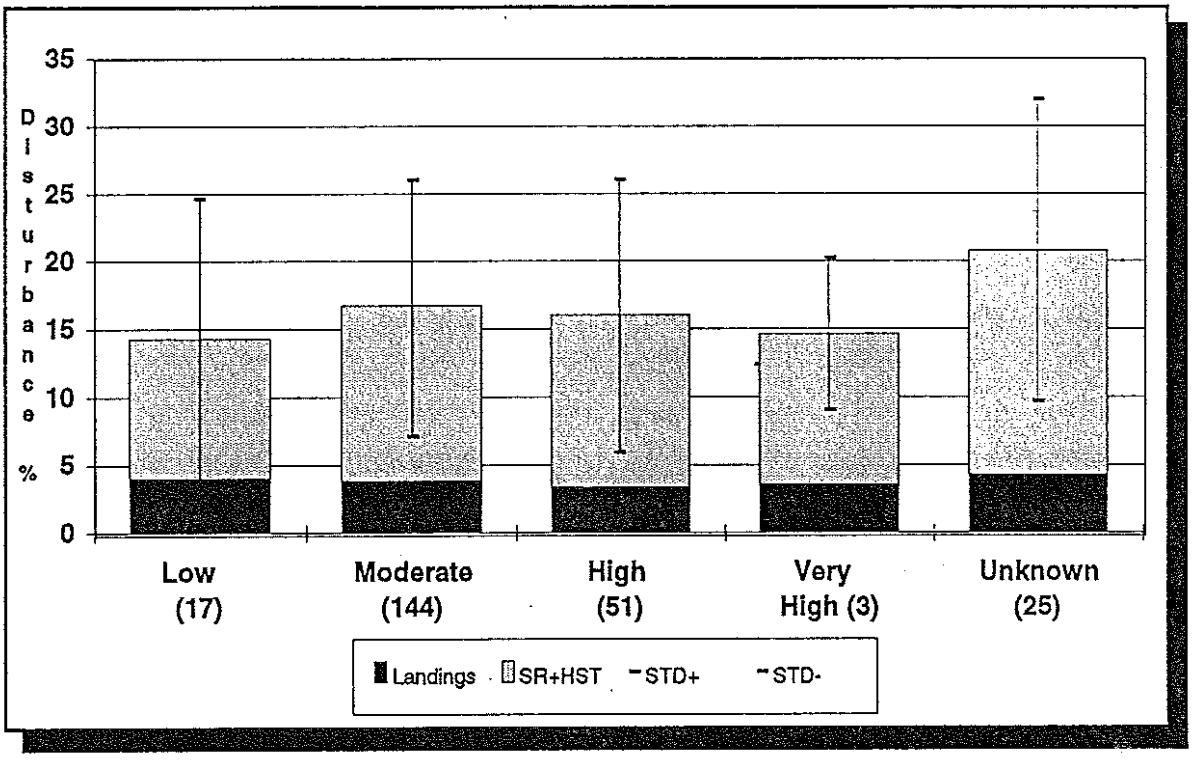

Figure 4 Detrimental disturbance by Overall Hazard class. The dark portion of the bar shows the percentage landing area, the light portion shows skidroad disturbance. The vertical lines show the range of ± 1 standard deviation (i.e. 2/3 of the sites sampled fall in this range). Bracketed numbers show the sample size.

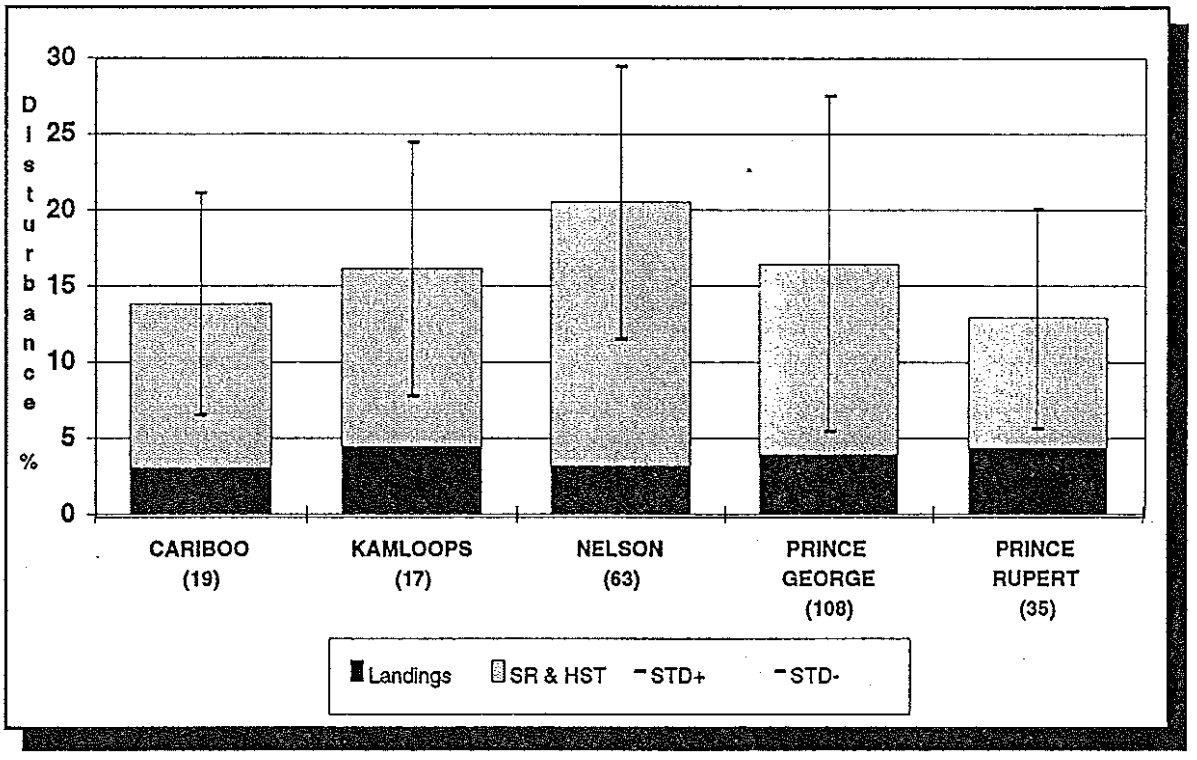

Figure 5 Detrimental disturbance by forest region. The solid portion of the bar shows the percentage landing area by region. The vertical lines show the range of ± 1 standard deviation (i.e. 2/3 of the sites sampled fall in this range). Bracketed numbers show the sample size.

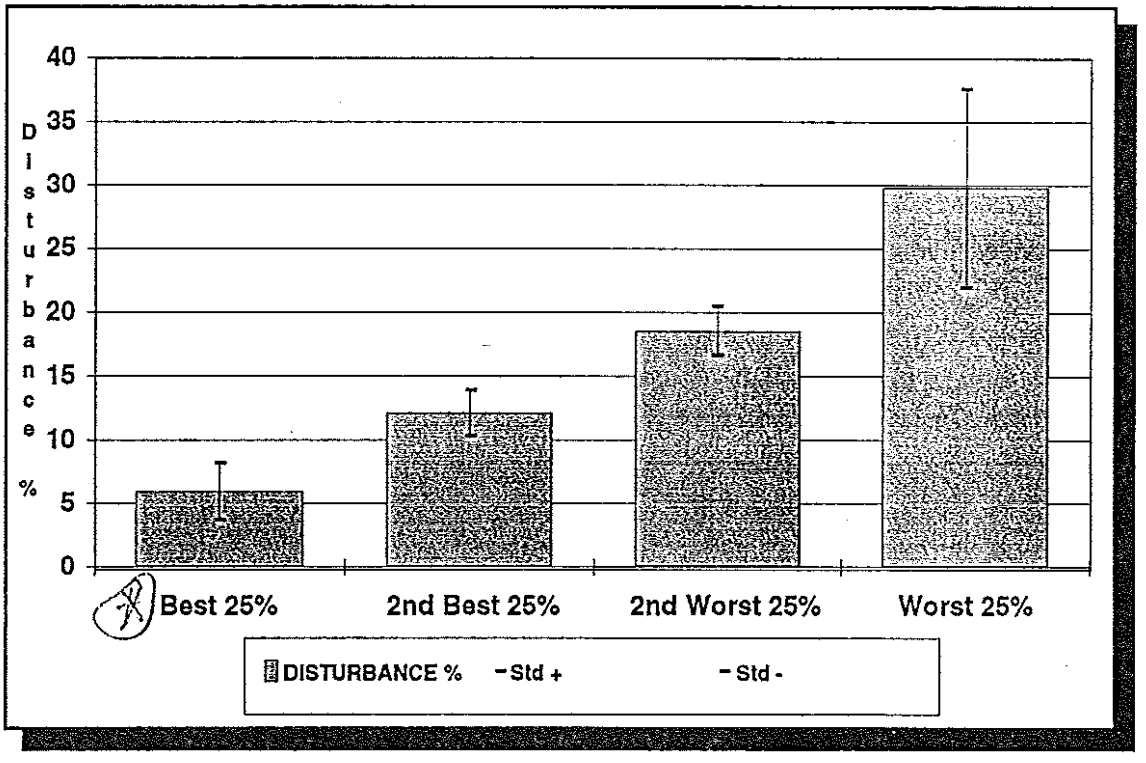

Figure 6 Detrimental disturbance ranked by quartiles from best to worst.

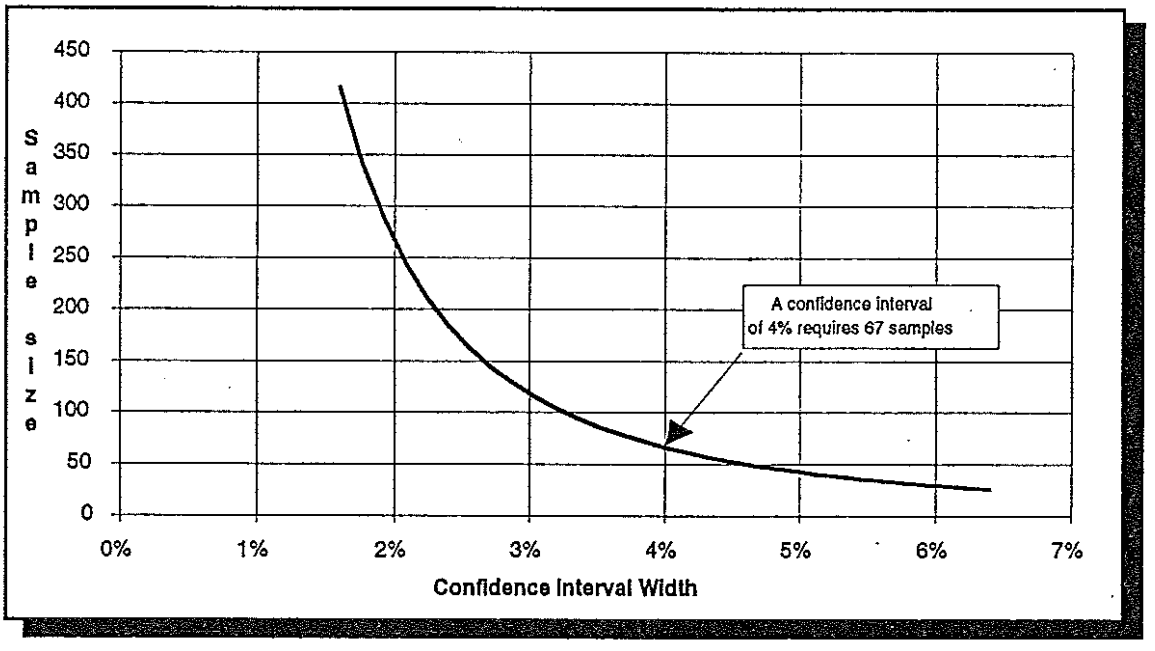

Figure 7 Number of samples required to obtain a specific confidence interval width using 30 meter transects with a 2 meter point interval.