AN EVALUATION OF MOUND FORMATION BY THE BRÄCKE MOUNDER IN INTERIOR BRITISH COLUMBIA

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ABSTRACT

The Bräcke mounder was evaluated on a site that had been full-tree logged in the sub-boreal spruce zone of British Columbia. On average, 70% of mounding attempts (1230 mounds per ha) consisted of inverted organic material capped by ≥1 cm of mineral soil or ≥5 cm of well decomposed FH material. Of the successfully capped mounds, 22% had cap depths that exceeded 6 cm. Site factors (e.g., slash, stumps, etc.) had an adverse effect on 77% of all mounding attempts, either by preventing the formation of inverted organic material or by reducing cap volume. Large-diameter slash adversely affected 35% of all mounding attempts; stumps were the second most common problem, affecting 15% of the attempts. Mounds with a cap area of more than 1200 cm^2 were produced significantly more often during downhill travel than during uphill travel. "Cap grading" by the mounder's spades was evident on 64% of all attempts and was associated with failure of the spade to clear the mound cap while in a raised or retracted position. Recent modifications to the Bräcke mounder have been directed at increasing mound size and decreasing the incidence of cap grading.

RÉSUMÉ

On a fait l'essai de la butteuse Bräcke dans un terrain exploité par arbres entiers de la zone à épinettes subboréale en Colombie-Britannique. En moyenne, dans 70 % des essais (1 230 buttes par ha) les buttes étaient constituées de matière organique retournée couverte d'une couche de sol minéral de 1 cm ou plus ou d'une couche de matière bien décomposée venant des sous-horizons FH de 5 cm ou plus. L'épaisseur de la couverture dépassait 6 cm sur 22 % des buttes bien couvertes. Les facteurs du terrain (par exemple les déchets de coupe, les souches, etc.) ont nui dans 77 % des essais, soit parce qu'ils nuisaient au retournement de la matière organique, soit parce que le volume de couverture était réduit. Les déchets de coupe de grand diamètre ont nui dans 35 % des essais; ensuite, les souches ont constitué le problème majeur, leur présence ayant nui dans 15 % des essais. Il était plus fréquent, et ce dans une mesure significative, que la couverture s'étale sur plus de 1 200 cm^2 lorsque la machine descendait les pentes que lorsqu'elle les remontait. Dans 64 % des essais, la couverture a été aplatie, un phénomène s'expliquant par le fait que le disque ne s'éloignait pas assez de la butte en position d'élévation ou de retrait. On a récemment modifié la butteuse en cherchant le moyen de faire en sorte que les buttes soient plus grosses et moins aplaties.

ACKNOWLEDGMENTS

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INTRODUCTION

In the Sub-boreal Spruce zone (Krajina 1959), Interior Subalpine section (Rowe 1972), of the north central interior of British Columbia the positive effects of mounding site preparation on the establishment of white spruce (**Picea glauca** [Moench] Voss) are well documented (McMinn 1982, 1983, 1985 and footnote 1). McMinn found that constraints on early outplant performance on these sites include: low soil temperature beneath surface organic matter; low air temperature and low light intensity beneath dense, rapidly invading vegetation; excessive soil moisture; poor soil aeration; poor root penetration through compact, fine-textured subsurface soil; and low nutrient availability. Results from McMinn[1] and from other studies have shown that mounds that consist of inverted surface organic matter (LFH) together with some underlying mineral soil can increase soil temperature in the rooting zone, reduce competing vegetation, increase the nitrogen content of seedling needles, and increase seedling growth (Berg et al. 1981, Laiho and Kinnunen[2], Edlund and Jönsson[3]). Although mounding can be beneficial in many situations, mounds consisting of an organic substrate with a mineral soil cap can dry out quickly during periods of drought, and consequently, seedling moisture stress and mortality are increased (Söderström et al. 1978, Sutton 1984). This situation is more severe for mineral mounds on an organic than on a mineral substrate.

The Bräcke mounder is a towed implement developed in Sweden to collect mineral soil and release it on the scarified patch or the upside-down turf from each patch (Bäckström 1981). Introduced to Canada in 1983, the unit was first used operationally in central British Columbia by the Ministry of Forests [and Lands] (Brewis 1984) (Fig. 1).

In June of 1983, an operational trial of the Bräcke mounder was conducted in British Columbia by staff of the Great Lakes Forestry Centre (GLFC) in cooperation with staff of the Pacific Forestry Centre (PFC) and the British Columbia Ministry of Forests (BCMOF). The primary objective of the evaluation was to assess the quality of mounds made by the Bräcke mounder on slopes.

Location and Site Description

The study area was approximately 60 km north of Prince George near the village of Bear Lake (Fig. 2), in the BCMOF Prince George Forest Region. The soils are generally humo-ferric podzols with some gray luvisols, which have developed on glacial tills. Prior to harvesting, the stand was predominantly

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[1] McMinn, R.G. 1985. Site preparation by inverted mounding improves the performance of planted white spruce. Gov't of Can., Can. For. Serv., Victoria, B.C. PFRC File Rep. 06/32/10. 8 p.

[2] Laiho, O. and Kinnunen, K. Mounding as a soil preparation method in Finland. Pap. presented at IUFRO Symp. on Equipment/Silviculture Interface in Stand Establishment, Research and Operations. Jasper, Can. (unpubl.).

[3] Edlund, L. and Jönsson, F. Swedish experience with ten years of mounding site preparation. Pap. presented at IUFRO S1.05-12 North For. Silvic. and Manage. Grande Prairie-Dawson Creek, Can. (unpubl.).

Figure 1. General view of Bräcke mounder in operation near Bear Lake.

white spruce with a minor component of lodgepole pine (**Pinus contorta** Dougl. var. **latifolia** Engelm.). The area was full-tree logged during the winter of 1979, and moderate-to-high slash loadings resulted. The bulk of slash remaining on the site consisted of large-diameter, overmature or unmerchantable tree species.

Implement and Prime Mover

The Bräcke mounder is an adaptation of the standard two-row Bräcke cultivator (Smith et al. 1985), with the additional feature of a hydraulically operated spade behind each mattock wheel (Fig. 3). Additional specifications are listed in Appendix A.

The production of a mound is a two-stage process. In the first stage, a scalp and inverted surface material are created by the mattock teeth; the inverted surface material comprises L, F and H soil horizons that were overturned by the mattock wheel of the Bräcke (see Appendix B for possible variations in this process). In the second stage, the spade, activated by the mattock wheel, digs into the scalp and brings up subsurface material onto the shoulder and/or the inverted surface material (Fig. 4). Hydraulic power to operate the spades and lift the mattocks for maneuvering and for road travel is supplied by a self-contained diesel power plant mounted on the Bräcke frame and operated with a radio remote control (Fig. 5).

The Bräcke mounder was towed by a 134-kW Caterpillar D7E crawler tractor fitted with 63-cm-wide track pads, and was attached to the tractor with a quick-disconnect "Bräcke"-type hitch (Fig. 6) (Brewis 1984). A V-type plow with a central lifting prong was mounted on the front of the tractor's C-frame (Fig. 7).

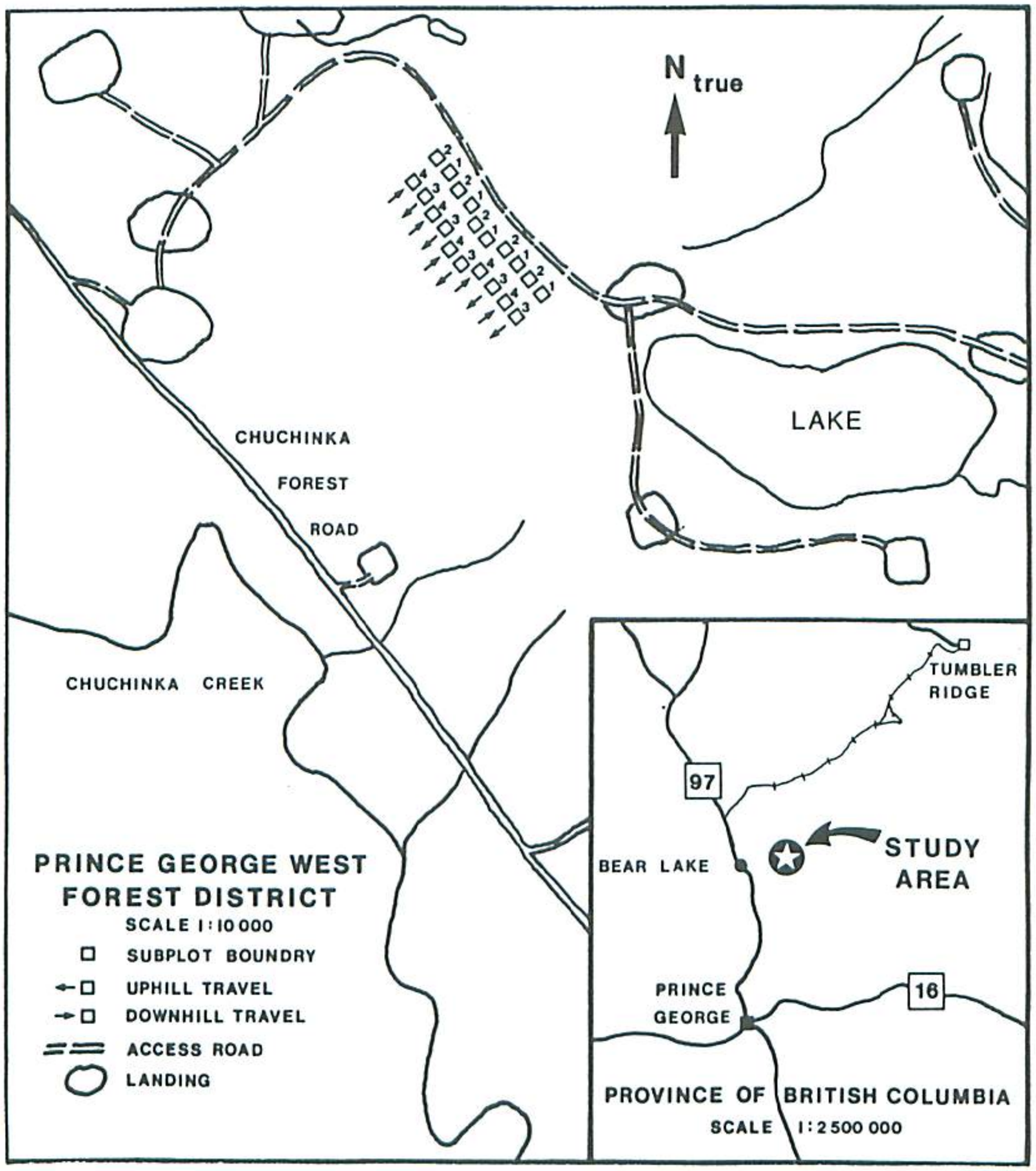

Figure 2. General location of study area and of the ten 20- x 20-m subplots near Bear Lake.

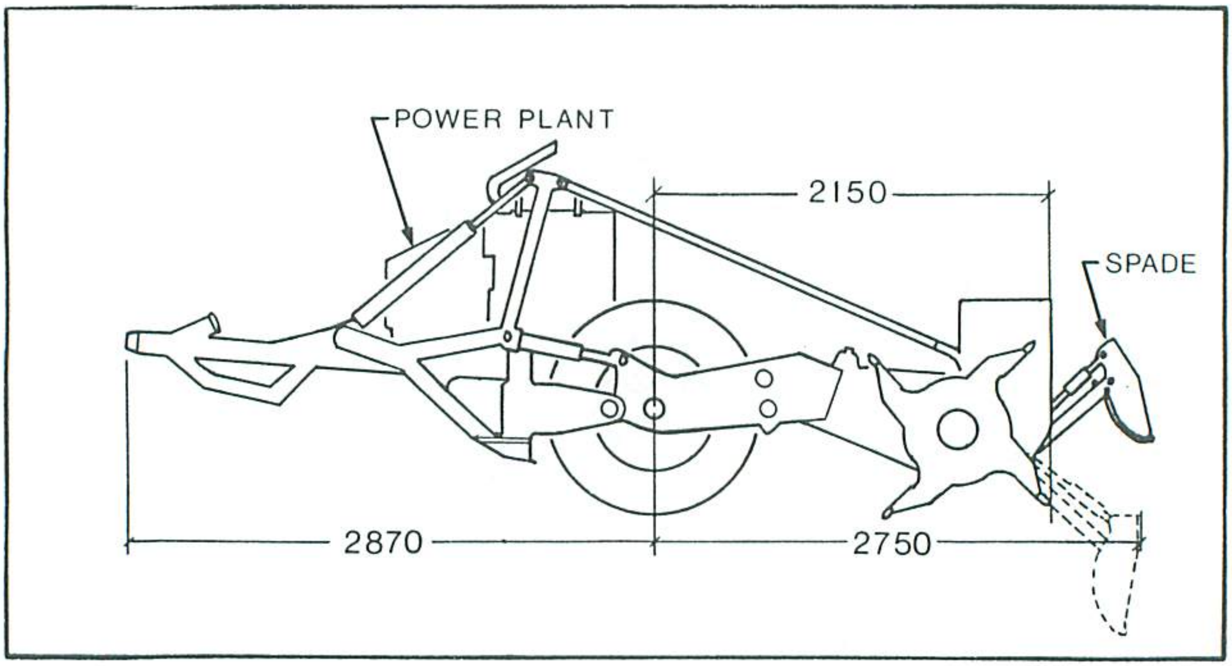

Figure 3. Spade position and overall dimensions (mm) of the Bräcke mounder (after Wickström 1981).

Figure 4. View of mounded mineral soil over the inverted organic horizons produced by the Bräcke mounder.

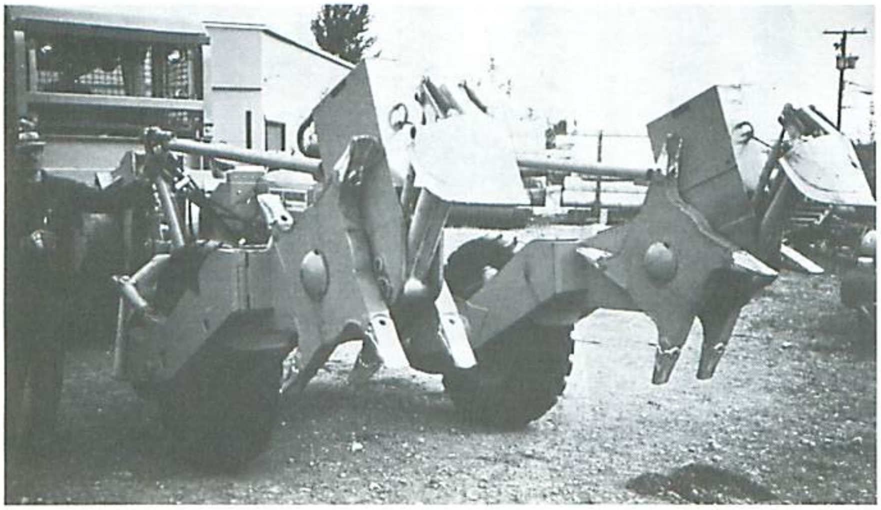

Figure 5. Bräcke mounder in a raised position for road travel.

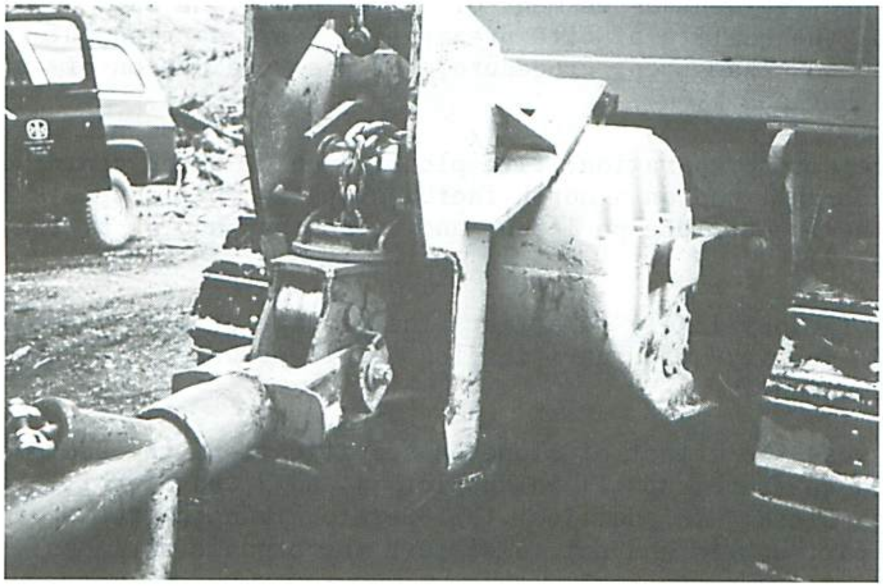

Figure 6. Quick-disconnect "Bräcke" hitch mounted on the winch of the Caterpillar D7E tractor.

Figure 7. V-plow mounted on the front of the C-frame of the Caterpillar D7E tractor used at Bear Lake.

METHODS

The pretreatment assessment of site conditions and a post-treatment assessment of the quality of site preparation were carried out in accordance with a standard assessment procedure for the evaluation of silvicultural equipment (Sutherland 1986).

Before site preparation, five plots, each of which contained four subplots, were established on a north-facing slope so that subplots 1 and 2 were located at the lower slope position and subplots 3 and 4 at the upper slope position (Fig. 2).

Site factors likely to affect the passage of the implements and the quantity and quality of scarification achieved were evaluated in a pretreatment assessment.

To assess the effect of slope on scarification, the equipment operator was instructed to travel uphill in subplots 1 and 3 and downhill in subplots 2 and 4 in each block. In addition, the operator was instructed to use the V-plow only to part debris and not to disturb the organic horizons.

Post-treatment assessment consisted of a tally of all mounding attempts within subplots. For each mounding attempt the following characteristics were recorded: whether the inverted surface material was capped with either mineral soil or well decomposed organic material, the dimensions of the cap, the degree of spade penetration into the scalp and grading (shearing off the top layer) of the mound, and the reasons for less than satisfactory mounding and/or spade penetration (see Appendix B). Mound grading occurs when the Bräcke spade fails to clear the mineral or organic cap just deposited on the Bräcke scalp and instead pulls the material ahead; this results in reduced cap depth or, in some cases, total removal of the cap.

RESULTS AND DISCUSSION

Pretreatment Assessment

The depth of mineral soil on the trial site exceeded 30 cm; soils ranged in texture from silty loam on the lower and mid-slope positions to coarse sandy loam on the upper slopes. Subsurface stoniness was recorded in 93% of the soil depth soundings (Table 1). However, stones were generally <8 cm in diameter and of little consequence to equipment function. Duff depths varied from an average of 9 cm on the better-drained, coarse-textured soils of the upper slope to 20 cm on the poorly drained lower slope. Ground roughness averaged class 2, which is intermediate in difficulty for equipment operation (Anon. 1969); in this system, class 1 represents very even ground, whereas class 5 is very rough ground.

Table 1. Assessments of duff depth, soil stoniness, ground roughness class and vegetative cover for the study site. (Mineral soil depth exceeds 30 cm in all cases.)

Slope position and direction of travel	Duff[a] Avg depth (cm)	Duff[a] Range (cm)	Stoniness[b] (%)	Ground roughness class[c]	Ground cover by minor vegetation[d] (%, by area)
Top	9	5-18	94	2	4
Bottom	20	5-41	93	2	4
Uphill travel	12	7-24	93	2	4
Downhill travel	16	4-41	93	2	3

[a] consists of fermentation (F) and humus (H) layer only
[b] The proportion of quadrats in which the presence of surface or subsurface stones (up to a depth of 30 cm) is detected with the soil probe. Stoniness was assessed at the same time and location as mineral soil depth.
[c] see Sutherland (1986)
[d] principal species was fireweed (**Epilobium angustifolium**)

Minor vegetation covered only 3-4% of the ground. There was no fresh or residual tree cover.

Slash cover was evenly distributed across the trial area; the number of pieces of slash, their average diameter, and their depth were similar for all slope positions and directions of travel (Table 2). Small-diameter (<5 m) slash was scarce and larger-diameter blowdowns of poplar (**Populus** sp.) or coniferous species existed in small numbers as scattered individuals. Volumes of slash >5 cm in diameter were high, with averages between 115 and 136 m^3/ha. Of all 2-m line intersects, 57% had no slash >5 cm in diameter (Fig. 8).

Table 2. Assessment of slash on the study site.

Slope position and direction of travel	No. of pieces per 2 m of linear tally		Avg diameter >5 cm (cm)	Avg depth (cm)	Avg volume (m^3/ha)			Species[a]	
	1-5 cm	>5 cm			1-5 cm	>5 cm	Total	Conifer (%)	Hardwood (%)
Top	2.9	.65	17.4	9.9	5.9	118.1	123.0	99	1
Bottom	2.4	.53	19.1	8.5	5.0	130.6	135.6	99	1
Uphill travel	2.4	.56	19.9	8.2	5.0	136.3	141.3	99	1
Downhill travel	2.8	.61	17.8	10.1	5.8	114.8	120.6	99	1

[a] proportion of 2- x 2-m quadrats with a majority of either coniferous or hardwood slash

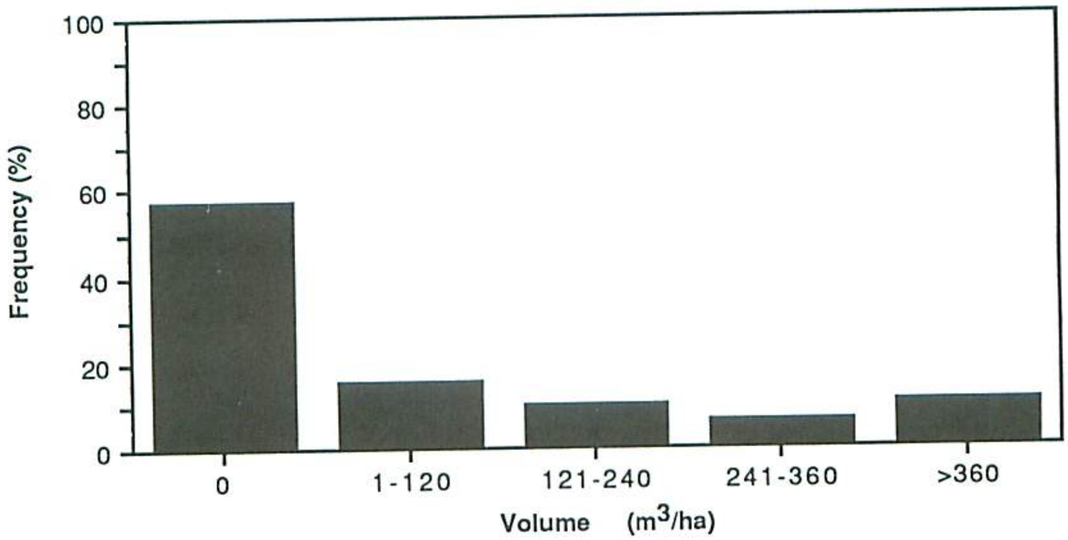

Figure 8. Frequency distribution for volume of slash >5 cm in diameter.

Average stump frequency varied with both slope position and direction of travel (Table 3). Despite this, average height and diameter were similar for all slope positions and directions of travel, ranging from 43 to 51 cm and 35 to 41 cm, respectively. Even though stump frequency, which averaged from 313 to 438/ha, was relatively low, large-diameter spruce stumps can hinder the operation of scarification equipment because of their characteristic shallow dendritic rooting habit.

All slope readings exceeded 11% (Table 4). Approximately 60% of slope readings ranged between 16 and 25%.

Table 3. Stump assessment.

Slope position and direction of travel	Average			Species		
	Frequency (no./ha)	Height (cm)	Diameter (cm)	White spruce (%)	Sub-alpine fir[b] (%)	Other (%)
Top	418(132)[a]	51.3(7.5)	39.7(5.2)	57	20	23
Bottom	348(120)	42.9(5.7)	35.3(6.7)	68	24	8
Uphill travel	313(125)	46.1(8.3)	35.2(7.9)	60	25	15
Downhill travel	438(125)	48.3(6.1)	40.9(4.9)	63	29	9

[a] Values in parentheses are confidence intervals at the 10% level of significance.

[b] **Abies lasiocarpa** (Hook) Nutt.

Table 4. Slope assessment.[a]

Direction of travel	No. of segments sampled	Slope				
		11-15%	16-20%	21-25%	26-30%	(%)
Uphill	16	31.2	25.0	37.5	6.3	100
Downhill	20	25.0	40.0	20.0	15.0	100

[a] Values in the table represent the percentage of 20-m-long passes of the scarifier that fall within four classes of slope.

Post-treatment Assessment

On average, 70% of mounding attempts (i.e., 1230 attempts per ha) consisted of inverted organic material capped by either mineral soil or well decomposed FH material (Fig. 9). The goal was to obtain 1400 acceptable planting spots/ha (Brewis 1984). The inability of the prime mover to negotiate the slope conditions in the test plots resulted in erratic uphill travel and, as a result, poor control of spacing.

Of all mound attempts made while travelling uphill, 67% were capped; the comparable figure for downhill travel was 73% (Table 5). In comparison with uphill travel, downhill travel produced significantly ($P < 0.01$ by Pearson's Chi-squared test) more (42%) completely capped mounds with a cap area ≥ 1200 cm^2 and the lowest proportion (12%) of capped mounds with a cap area <1200 cm^2. The comparable percentages for uphill travel were 26% and 22%, respectively. The number of complete capped mounds ≥ 1200 cm^2 did not differ significantly between the top and bottom slope positions when the mounder was travelling downhill. However, the mounder, when travelling uphill, produced significantly ($P = 0.03$) more capped mounds at the top than at the bottom of the slope.

It was clear that mound-making ability was adversely affected during uphill travel. A partial explanation for this result lies in the operating technique used. When the prime mover had insufficient traction to advance uphill while pulling the Bräcke, the unit was released by means of the quick-disconnect hitch. The prime mover would then advance up the hill a short distance, pause to winch in the mounder, then repeat the process. During winching, when the Bräcke tongue was not fixed in position, the Bräcke tended to pivot from side to side around points of resistance. This resulted in an uneven travel speed for each wheel and mattock assembly, which occasionally disrupted the synchronization of the spade and the mattock; for example, a spade may stop momentarily and deposit the capping material before reaching the inverted material. By the time the mounder reached the upper slope the unit was close-coupled to the prime mover and normal operation was resumed. This may explain why more mounds occurred in the category with capping area >1200 cm^2 in the top of slope position during uphill travel.

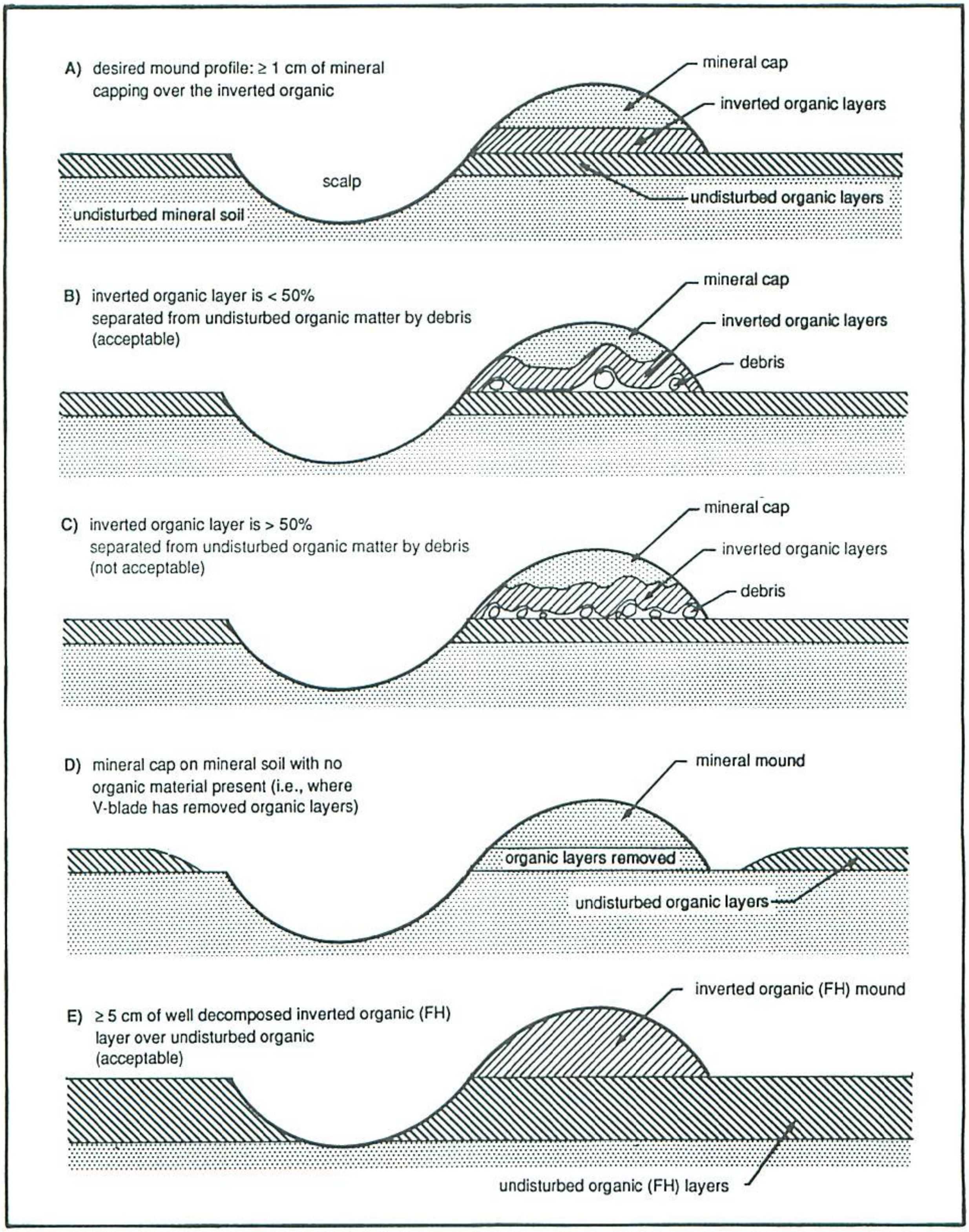

Figure 9. Mound profiles

Table 5. Mounding attempts.

Slope position and direction of travel	Total attempts			Capped[a]: Cap area 1200 cm^2 complete[b]		Capped[a]: Cap area 1200 cm^2 incomplete[c]		Capped[a]: Cap area <1200 cm^2		Capped[a]: Total capped mounds		Uncapped	
	No.	No./ha	(%)	No./ha	(%)	No./ha	C+D(%)	No./ha	(%)	No./ha	(%)	No./ha	(%)
Top	675	1877	100	717	38	367	6 + 14	297	16	1381	74	495	26
Bottom	589	1638	100	523	32	281	4 + 13	286	18	1090	67	548	33
Total	1264												
Uphill travel	541	1690	100	450	26	303	5 + 13	378	22	1131	67	559	33
Downhill travel	723	1808	100	755	42	340	6 + 13	222	12	1318	73	490	27
Total	1264												
Overall avg attempts		1753						Overall avg capped mounds		1230	70%		

[a] Inverted organic material with capping material consisting of either mineral soil ≥1 cm or well decomposed FH material ≥5 cm deep over the inverted organic matter. Includes all mound profiles in Figure 9.

[b] Length and width measured along the interface of mineral or FH cap at a level ≥1 cm above the inverted organic. Includes mound profiles C and D in Figure 9.

[c] Includes only mound profiles C (inverted organic layer is >50% separated from undisturbed organic by debris) and D (mineral cap on mineral soil with no organic material present). See Figure 9.

Slope can also affect mounding through the effects of gravity on the capping process. The capping material was projected farther when the scarifier was moving downslope than when movement was on flat ground or uphill; as a result, cap depth was often reduced. Greater speed when the scarifier was moving downslope increased this effect.

Site factors such as surface and subsurface obstacles or prior disturbance can hinder the operation of site-preparation equipment. To provide a clear path ahead of the Bräcke mounder, a V-blade slash parter was added to the front of the prime mover. Despite this, 77% of all Bräcke mounder attempts were adversely affected (i.e., either inverted organic matter not formed or cap volume reduced) by site factors. Obstacles, specifically pieces of slash >5 cm in diameter, were the most common problem; large slash affected 35% of all attempts adversely, followed by stumps >25 cm in diameter, at 15%, litter at 9% and ground roughness at 8% (Fig. 10). Subsurface, large-diameter downed and decayed conifer boles often exceeded the penetration capabilities of the Bräcke mounder. The influence of site factors on the mounding process did not differ significantly between uphill and downhill travel.

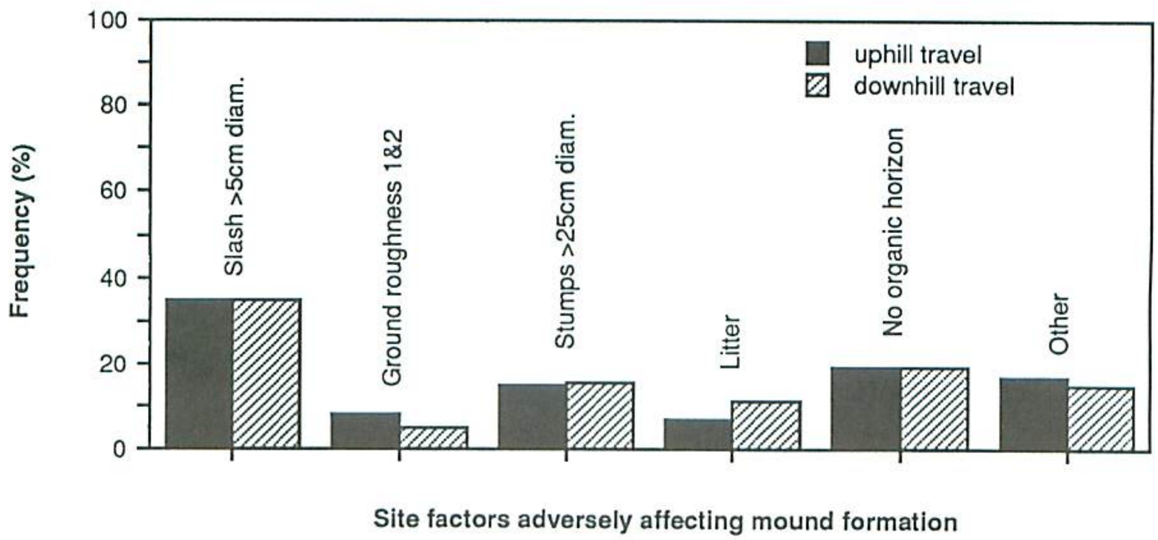

Figure 10. Site factors that adversely affected mound formation, by direction of travel.

The effectiveness of slash-clearing or slash-parting equipment depends on several factors, such as the design configuration of the implement, the skill and motivation of the operator, and the severity of operating conditions. The tractor operator in this trial was instructed to remove slash with the V-blade but not to disturb the underlying F and H horizons (Brewis 1984). The size of the V-blade hampered operator visibility ahead of the tractor and prompted constant raising and lowering of the unit in an attempt not to disturb the F and H horizons. As a result, slash was missed when the blade was too high; conversely, the organic layers were gouged when the blade was too low, as is evidenced by the mounds made directly on mineral soil with no organic layers present (approximately 13% of the total in Table 5; see mound profile D in Figure 9).

The degree of spade penetration determines how much mineral soil can be brought up and deposited on the inverted organic material. An average of 72% of the mounding attempts that were assessed exhibited full spade penetration, whereas 11% had less than full penetration because of subsurface tree roots and a further 16% had less than full penetration because of surface debris (Fig. 11). Spade penetration did not differ significantly between downhill and uphill directions of travel or between upper and lower slope positions.

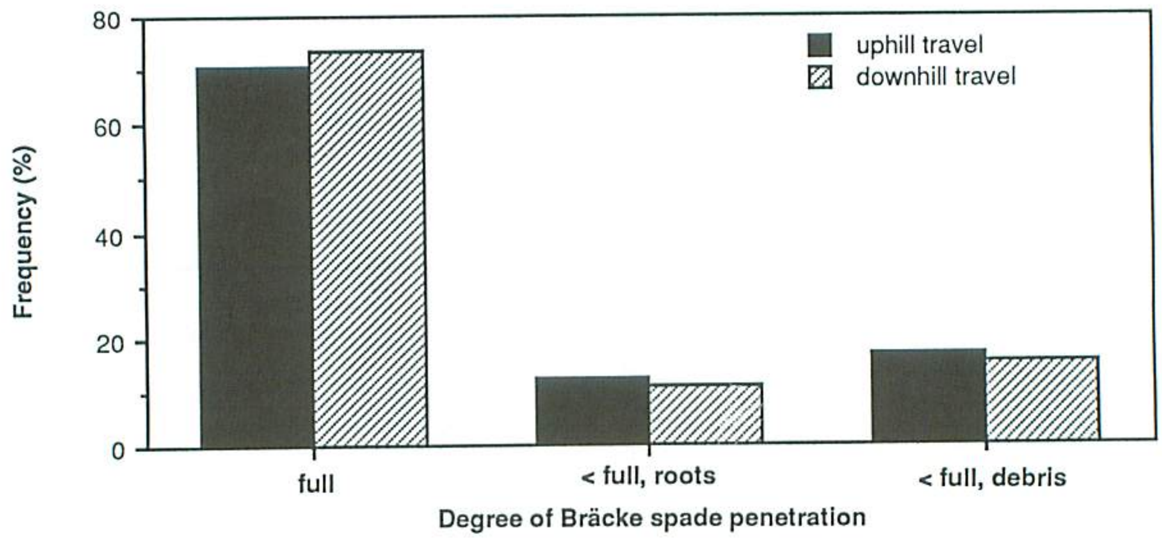

Figure 11. Degree of spade penetration and causes of less than full penetration, by direction of travel.

On average, 64% of mounding attempts resulted in grading of the cap material by the Bräcke spades. Field and filmed observations suggest that compression of the organic layer by the Bräcke wheels reduced the ground clearance of the unit and the ability of the mounding spade to clear the capped mound even when the spade was in the retracted or raised position. The proportion of attempts in which grading occurred was significantly ($P = 0.01$) higher during downhill travel (75%) than during uphill travel (49%) (Fig. 12). As discussed previously, graded material was projected downhill in a fashion similar to that of capping material as a result of increased travel speeds. The distribution of graded and non-graded categories also differed significantly ($P = 0.01$) between slope positions. Grading of the cap occurred more frequently on the upper slope, where there was a higher proportion of capped mounds. Over all, grading was most common during downhill travel and at the upper slope position.

To date, several other trials of the Bräcke mounder have been conducted, both in British Columbia and in other regions of Canada (Zroback 1985, Parolin[4], Leblanc and Smith 1989). On moist, fertile, fine-textured soils in British Columbia, McMinn (see footnote 1) found that white spruce seedlings

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[4] Parolin, R.W. 1986. Upper-halfway trials of Bräcke mounder. Industr. For. Serv. Ltd., Prince George, B.C. 15 p. (unpubl.).

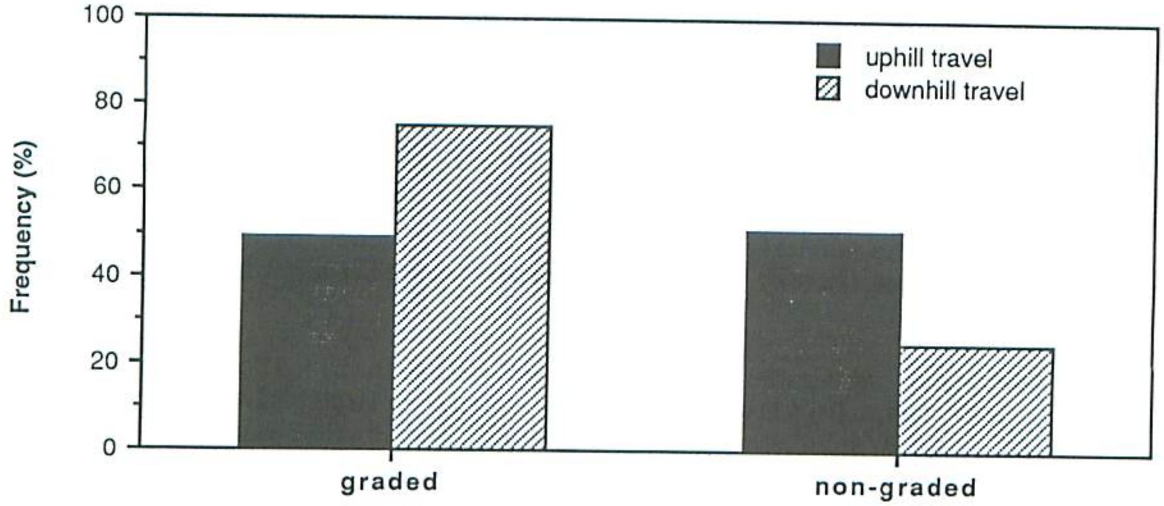

Figure 12. Cap grading by the Bräcke's spade, by direction of travel.

planted in inverted mounds grew better in mounds with 12 cm of mineral soil capping than in mounds with 6 or 2 cm of mineral soil capping. Only 22% of all capped mounds in the Bear Lake trial had capping depths >6 cm. From the initial trials in 1983, and as a result of continued monitoring by BCMOF and PFC, it was concluded that insufficient mineral soil was being placed on top of the inverted organic matter by the Bräcke mounder. Consequently, a contract was let in 1985 to modify and test the Bräcke mounder in an effort to increase mineral soil capping (Zroback 1985). Results of these trials led to the adoption of a three-tine mattock wheel (Fig. 3) (rather than the standard four-tine wheel) to produce larger mounds. The spade mechanism was modified to decrease the incidence of cap grading. In an evaluation conducted in 1986 on several sites in the interior of British Columbia the modified version of the Bräcke mounder produced 70-80% acceptable mounds (Hedin 1987). A slash divider was not used and two-thirds of the locations had been brush bladed previously. Hedin concluded that preparing mounds with >10 cm of mineral soil capping was dependent on and limited by the characteristics of the site (i.e., slash, stumps, excessive litter, roots and decomposing wood).

SUMMARY

Of all mounding attempts assessed, 70% (1230 attempts/ha) consisted of inverted organic material capped by either mineral soil or well decomposed FH material. Of these, 22% had mounds with capping depths that exceeded 6 cm. Site factors had an adverse effect on 77% of all attempts; obstacles such as slash pieces >5 cm in diameter (which accounted for 35% of all attempts) and stumps >25 cm in diameter (which accounted for 15%) were the most common adverse factors. The influence of site factors on the mounding process did not differ significantly between uphill and downhill travel.

Both slope position and direction of travel affected mound formation. A significantly higher proportion of capped mounds with a cap area ≥1200 cm^2

was produced during downhill operation than during uphill operation; similarly, the upper slope position had significantly more capped mounds than did the lower slope position. The influence of position, however, was not as strong as that of the direction of travel. The best results from the Bräcke mounder were obtained when the unit was close-coupled to the prime mover, a factor worth consideration when one is laying out operating patterns in rolling topography in which prime mover traction is limited.

Cap grading was associated with lack of clearance of the mound cap by the raised or retracted spade, and was recorded more frequently during downhill than uphill travel.

The Bear Lake assessment represents a preliminary look at the Bräcke mounder under one set of site conditions. This trial coincided with the introduction of the Bräcke mounder to Canada, and both operating time and experience of field staff were limited. The effectiveness of the mounder is highly dependent on the suitability and condition of the prime mover, on the experience and motivation of the operator and on physical site factors. Further studies of the biological efficacy of mounding are needed to assess the capabilities of the Bräcke mounder. Careful selection of the prime mover and/or slash parting device is essential for optimum performance of the Bräcke mounder.

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APPENDIX A: TECHNICAL DATA FOR THE BRÄCKE MOUNDER

Engine:

Deutz - air cooled	
Model/cylinders	FL 511/2 cyl
Max. power	19.5 kW (26 hp)
R.P.M.	2000
Displacement	1600 cm^3 (98 $in.^3$)
Fuel tank capacity	20 L (4.4 imp gal)
Fuel consumption	2-3 L/hr (.4-.7 imp gal/hr)

Electric system:

generator	12 volt 33 amp A.C.
battery	60 amp hr
fuse	one 16-amp/two 8-amp

Hydraulic system:

Pump	gear type
Oil cooler	tube type
Reservoir	80 L (17.6 imp gal)
Hydraulic oil type	SHS 32

Remote control:

radio	27.180-27.210 Hz

General particulars:

Weight	4500 kg
Length	5.85 m
Width	2.53 m
Ground clearance	0.80 m
Tire size	30.00 x 60.0 cm, 16-ply
Mattock wheels	2 wheels with 4 pairs of tines per wheel
Tine & tooth width	11 cm & 15 cm
length	24 cm & 67 cm
Drive sprocket	17 teeth/sprocket
Option	15- and 19-toothed sprockets for changing patch length
Hitch	Bräcke type

Manufacturer:

Robur Maskin AB
Gransgatan 42
S-840 60 Brac
SWEDEN

Distributors:

KBM Forestry Consult. Inc.
360 Mooney St.
Thunder Bay, Ontario
P7B 5R4

Woodlands Services Inc.
Box 257
Moose Lake, Minn. 55167
USA

KBM Forestry Consult. Inc.
Box 5462
Rome, Georgia 30162
USA

FORABI Inc.
221 rue Bolduc
Amos, Quebec
J9T 3M4

APPENDIX B: POST-TREATMENT ASSESSMENT CRITERIA FOR MOUNDING ATTEMPTS

Each mounding attempt was assessed by means of the following criteria:

1) Mound profile (see Fig. 9).

2) Length and width of the mound cap measured to the nearest 10 cm along the interface between the mineral cap or between the well decomposed inverted organic cap and the inverted organic matter at a position of $\geq$1 cm above the inverted organic matter. A mound cap less than 1200 cm^2 in size was not considered complete.

3) Mound attempt graded by the Bräcke spade: yes or no.

4) Spade penetration was either full, or less than full as a result of stones, dense or compacted soil, roots, debris or ground roughness.

5) Primary reasons for less than satisfactory mounding and, if evident, secondary reasons. Categories of reason:

   a) interference with the mounding process by site factors:

      - slash diameter in the ranges 1-5, 6-15, 16-25, or >25 cm
      - stone (mean dimension) 7 cm, 7-30 cm, boulder (>30 cm), or bedrock
      - ground roughness classes 1-7
      - stump (diameter at face) in the ranges 1-5, 6-15, 16-25, 26-35, or >35 cm

   Note: "Stump" is recorded as the cause of a poor mound when associated roots are the precise cause.
      - minor vegetation, brush, residual trees
      - excessive "litter"

   b) "cap" not on the inverted organic matter

   c) mound damaged, destroyed or otherwise made unusable by effects of adjacent and subsequent machine passages

   d) no organic horizon because of skid trail

   e) no organic horizon because of the effect of V-blade, slash parting or tractor passage

   f) "cap" graded

   g) no apparent reason