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Contents

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Skid-trail construction and rehabilitation techniques using small excavators

Abstract

During both summer and winter seasons, the Forest Engineering Research Institute of Canada (FERIC) sampled representative examples of skid-trail construction and rehabilitation using small excavators in southeastern British Columbia. The study documented the operating techniques and identified factors affecting productivities and costs of trail construction and rehabilitation over a range of moderate and steep slopes.

Keywords

Harvesting systems, Soil disturbance, Skid trails, Rehabilitation, Interior British Columbia, Steep slopes, Ground based harvesting.

Introduction

Protecting forest soil during harvesting operations is an important aspect of forest management. Forest managers can select from a wide array of harvesting strategies to minimize soil impacts, for example, substituting lower-impact harvesting machines or systems in place of conventional ground-based systems. In southeastern British Columbia, soil disturbance by conventional systems utilizing crawler tractors and rubber-tired skidders has been a concern on steep slopes since the 1970s. As a result, more specialized cable-yarding and alternative ground-based systems (Thibodeau 2002) have been adopted. At the same time, refining less costly conventional systems to operate on moderate (30–55%) slopes with reduced site impacts (Kockx and Krag 1993; Krag and Webb 1987; Krag et al. 1991) remains an issue with the forest industry. For skid-trail building, reduction in the size of crawler tractors has reduced the width of skid trails and the amount of soil disturbance (Kockx and Krag 1993; McMorland 1980). As an alternative to crawler tractors, small hydraulic excavators have gained wide acceptance for use in skid-trail building and rehabilitation.

The goal of rehabilitation is to restore subsurface drainage, replace topsoil, and distribute woody debris to prevent surface erosion and to provide shade and an improved microclimate for seedlings and other vegetation. Excavators place rather than push materials (Lewis et al. 1991). Users of small excavators believe they have better control than with crawler tractors when removing stumps and windfalls and placing excavated soil, resulting in shallower cuts and narrow trails (Krag et al. 1991). The British Columbia Forest Practices Code (FPC) recommends that skid trails are constructed with an excavator, so excavated soil material can be placed in a position where it can be retrieved for recontouring the slope (BCMOF and BC Environment 2001). Excavators can segregate nutrient-rich surface mineral soil from less favourable material, and retrieve surface soil and organic material during trail rehabilitation. This rehabilitation process returns the site to productive condition and allows ground-based harvesting on these steeper slopes.

Tembec Inc. (formerly Crestbrook Forest Industries Ltd.) has been using small excavators since 1987 for skid trail construction. However, the relationship between productivity of the equipment and site factors had not been clearly defined. Tembec and FERIC's other members requested more information on the use of this technique. This report describes the trail construction and rehabilitation techniques using excavators, and the relationships between site factors, machine productivities, and costs. The studies were conducted during both summer and winter seasons at Tembec's five divisions in south-eastern B.C.

Objectives

The study had the following objectives:

- Document the operating techniques and identify stand and site factors affecting the productivity of small excavators used to build and rehabilitate skid trails on moderate to steep slopes.
- Determine productivities and costs of skid-trail construction and rehabilitation.

Study sites

Over 60 field days of data in summer and winter seasons were collected as representative examples of ongoing trail building and rehabilitation at Tembec's five operations (Table 1). The goal was to sample construction and rehabilitation activities for a variety of site and operating conditions. The cutblocks were located in the Dry Cool subzone of either the Engelmann Spruce-Subalpine Fir or Montane Spruce biogeoclimatic zones (Braumandl et al. 1992). Slopes ranged from 30 to 70% with most blocks situated at mid to upper-slope positions. Soils were primarily silt loams that varied in coarse fragment content and subsoil condition.

Study methods

Data were collected over a series of timed segments of trail being built or rehabilitated. The beginning and end of a segment was determined by a change in cutbank height that was readily identified by the FERIC researcher. The elapsed time for the excavator to complete each segment was recorded. Cross-sectional profiles were measured along each segment at intervals of approximately 15 m. Cutbank height was measured vertically from running surface to the cut edge of the organic layer; trail width or width of prism was measured horizontally from edge of cutbank to lower edge of sidecast material;

Table 1. Length of skid trail monitored, by activity and season

Division	Construction		Rehabilitation		Total by division (m)
	Summer (m)	Winter (m)	Summer (m)	Winter (m)	
Sparwood	820	-	2 888	-	3 708
Elko	2 133	-	3 666	-	5 799
Cranbrook	1 072	3477	-	2 110	6 659
Canal Flats	395	448	-	566	1 409
Parson	-	819	-	267	1086
Total	4 420	4 744	6 554	2 943	
Total by activity	9 164		9 497		
Grand total		18 661			

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and slope of the terrain was measured from above the cut to below the fill slope (Figure 1). Finally, trail grade was measured between cross-sectional profile locations.

Productive time was recorded across each segment to the nearest minute. Only productive activities—excavating or grading of trail material, push falling and positioning felled trees, or handling woody debris associated with the trail—were included. Regression analysis was used to examine relationships between productivity and cutbank height, and ground slope.

Detailed notes of operating technique were logged for each operator, including descriptions of site or stand conditions. Some of this information was obtained during conversations with the operators.

Equipment and treatments

Five different excavators were observed (Table 2). Standard digging buckets with hydraulic thumbs were used on all machines.

Summer skid-trail construction and rehabilitation

Skid trail construction with an excavator is a two-stage process. Trees along several metres of pre-flagged right-of-way are push-felled ahead, preferably upslope, using the excavator bucket and thumb. Trees are uprooted and placed temporarily off the cleared path. After several trees are push-felled, the second stage involves constructing the trail by cutting into the slope and depositing the fill on the down-slope side (i.e., cut and fill) (Figure 2). The aim of trail construction is to separate productive surface soil and organic material from less productive subsoil, so that during trail rehabilitation, both layers can be retrieved and deposited in the original order. To accomplish this, the forest floor and surface woody material are first pushed or graded downslope to form the base of the fill (Figure 3). If large woody debris is abundant, it can be placed against lower trees to support the fill and reduce the quantity of cut and fill required. Next, the most productive, darker-coloured surface soil layers are deposited against the organic material and tamped in place in a continuous layer. Last, the less productive, lighter-coloured subsoils

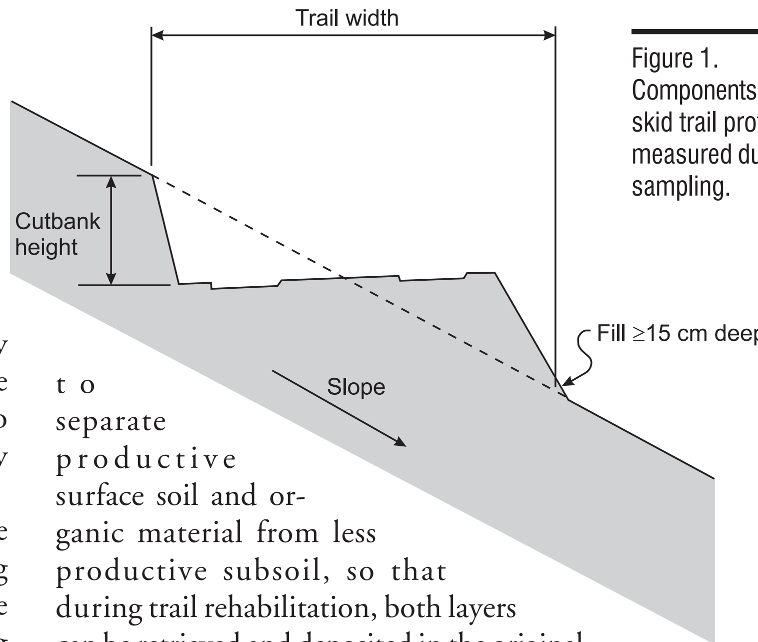


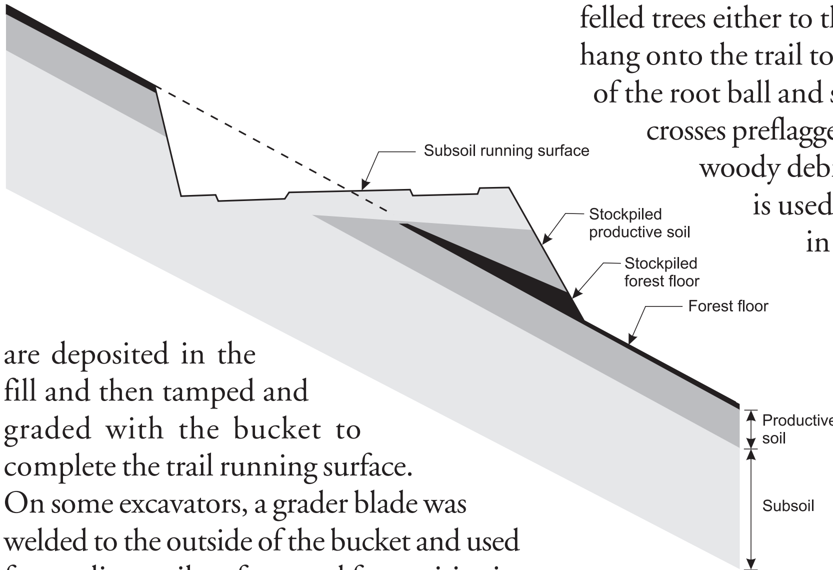
Figure 1. Components of skid trail profile, measured during sampling.

Figure 2. Trail constructed using cut and fill techniques.

Table 2. Selected features of the hydraulic excavators observed in this study

Equipment	Weight (kg)	Width (m)	Attachments
Linkbelt 2700	15 980	2.59	standard bucket with hydraulic thumb (76 cm wide)
Komatsu PC200LC-6	21 300	3.08	standard bucket with hydraulic thumb (width n.a.)
Caterpillar 320BL	28 610	3.08	standard bucket with hydraulic thumb (80 cm wide)
MD Yutani 140	12 400	2.69	standard bucket with hydraulic thumb (107 cm wide)
Hyundi 130 LCM	13 200	2.60	standard bucket with hydraulic thumb (width n.a.)

Figure 3. Summer trail profile.



are deposited in the fill and then tamped and graded with the bucket to complete the trail running surface. On some excavators, a grader blade was welded to the outside of the bucket and used for grading trail surfaces and for positioning push-felled trees (Figure 4). At the end of the trail the excavator backs out, pulling the felled trees either to the trail edge or to overhang onto the trail to facilitate later removal of the root ball and skidding. Where a trail crosses preflagged drainage ways, coarse woody debris or surplus steel pipe is used as a drainage structure in the trail subsurface.

Figure 4. Grader blade added to bucket (see arrow).

Figure 5. Decompaction of trail surface.

Figure 6. Rehabilitated trail recontoured into slope.

Skid trail rehabilitation consists of decompacting the running surface to restore subsurface drainage patterns, and retrieving sidecast fill material into the original contour. The excavator first removes woody debris from the trail surface to prevent it from being buried when the soil is retrieved. Starting at the end of a trail, the excavator decompacts several metres of the inner track of the trail to a depth ranging from 30 to 50 cm (Figure 5). The outer track is decompacted with the second bucket pass, to a greater depth than the inner track so as to ensure downslope drainage. Where subsurface water flow is evident, cross ditches are excavated to ensure stability of the reclaimed trail. In a reverse order from trail building, lighter-coloured subsoil is reclaimed first and deposited against the cutslope. Next, surface soil and organic material located at the base of the fillslope are retrieved and spread over the subsurface soil to achieve a slope matching the original contour (Figure 6). Surface organic soil is difficult to separate from subsoil as organic material is unconsolidated and is easily mixed with subsoil during handling with toothed excavator buckets.

As a final step, woody debris is unearthed, and stumps and slash within reach are distributed across the finished surface to help prevent surface erosion, to blend in with the surrounding harvested block, and to provide a more suitable microclimate for seedling regeneration. Large woody debris is positioned at an angle to the contour to avoid either blocking surface water drainage or piping water directly downslope. Angled waterbars are excavated approximately every 50 to 75 m, or as required by trail grade, to break up surface water flows. Where there is no or very little road cut, the practice is to decompact the trail and distribute woody debris. Previously prepared drainage structures are removed and replaced with cross ditches to restore natural drainage patterns, and cross ditches are reconstructed at natural draws.

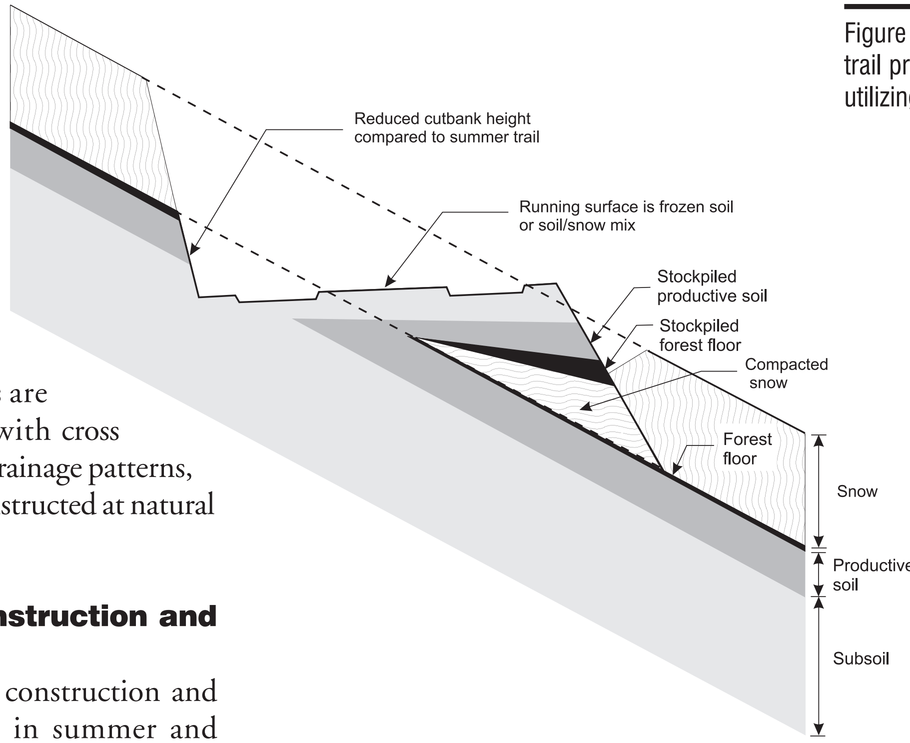


Figure 7. Winter trail profile utilizing snow.

Winter skid-trail construction and rehabilitation

The process for trail construction and rehabilitation is similar in summer and winter, with the following modifications in winter. The overlying snow on a trail right-of-way is utilized along with the soil to build or support the skid trail. Snow may be mixed with soil during trail construction and allowed to freeze. More commonly, if the snow is compactable, it is piled and tamped in a downslope direction to support soil fill piled adjacent to it (Figure 7). Once constructed, freezing temperatures improve the load carrying ability of the finished trail.

Winter-built trails using snow often have shallower cuts than summer-built trails. As a result, trail rehabilitation is usually conducted prior to snow melt to avoid having to rebuild the trail for access.

Snow is a better trail building substrate when temperatures are warmer and the snow is compactable. During construction, non-compactable snow can be mixed with cutbank soil, creating material that can freeze into a good trail structure. Frozen conditions during skidding can protect soil from compaction on the trails and reduce the depth of decompaction required. When the snow is mixed with soil, a greater volume of material must be retrieved during rehabilitation to offset settling after snowmelt.

Results and discussion

Productivity

Figures 8 and 9 present productivity per productive machine hour (PMH) by cutbank height and slope, respectively, for summer and winter trail construction and rehabilitation. Table 3 provides the productivity equations. When interpreting the trend lines in Figures 8 and 9, the user should be aware that the lines should not be extended beyond the maximum and minimum values provided for cutbank height and slope under the stated sample range in Table 3.

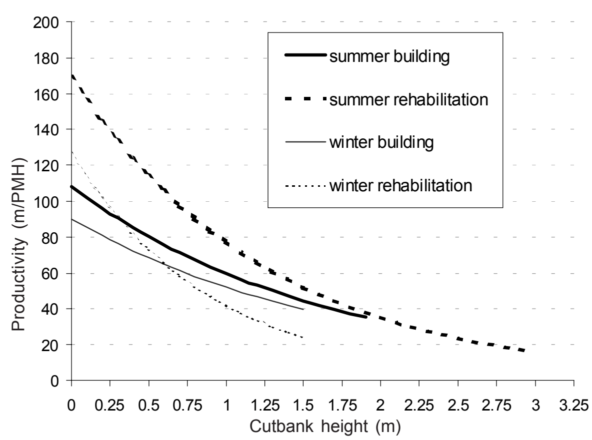


Figure 8. Productivity of summer and winter skid-trail construction and rehabilitation, by cutbank height.

Table 3. Productivity equations for trail construction and rehabilitation

Parameter	Equation: Productivity (m/PMH) =	r^2	Standard error of the estimate	Number of observations	Sample range
Summer trail construction					
Cutbank height (m)	$108.03 \cdot e^{-0.5898 \cdot \text{cutbank height}}$	41%	0.33	55	0–1.9 m
Slope (%)	$111.24 \cdot e^{-0.0117 \cdot \text{slope}}$	26%	0.37	55	4–75%
Summer trail rehabilitation					
Cutbank height (m)	$168.94 \cdot e^{-0.7812 \cdot \text{cutbank height}}$	78%	0.22	86	0–3.0 m
Slope (%)	$231.95 \cdot e^{-0.0274 \cdot \text{slope}}$	72%	0.24	86	15–75%
Winter trail construction					
Cutbank height (m)	$90.22 \cdot e^{-0.5508 \cdot \text{cutbank height}}$	33%	0.30	49	0–1.5 m
Slope (%)	$95.92 \cdot e^{-0.0118 \cdot \text{slope}}$	29%	0.31	49	0–66%
Winter trail rehabilitation					
Cutbank height (m)	$126.34 \cdot e^{-1.0946 \cdot \text{cutbank height}}$	46%	0.44	29	0–1.5 m
Slope (%)	$125.78 \cdot e^{-0.0198 \cdot \text{slope}}$	24%	0.52	29	2–65%

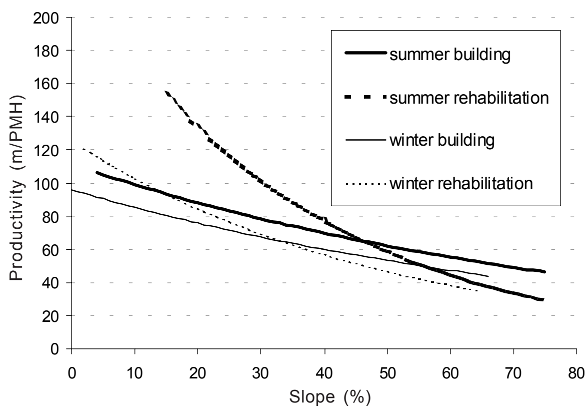


Figure 9. Productivity of summer and winter skid-trail construction and rehabilitation, by slope.

Figure 10. Decompaction of frozen trail surface.

Higher productivity for summer compared to winter operations are evident for both trail building and rehabilitation. Summer conditions offer better visibility of the ground, better traction, and safer working conditions, and the technique is less complex than in the winter. As slope increases, the seasonal differences in productivity decrease, with summer and winter rehabilitation productivities near equal at the steepest slopes (Figure 9). Although productive activities were not timed separately in this study, as slope increased, excavation of cut or fill was observed as having a greater impact on overall productivity. As a result, seasonal factors such as snow removal or decompaction of frozen trails had less influence on overall productivity.

For slopes below 40%, the greater productivity for summer rehabilitation compared to winter is most noticeable (Figure 9). Snow cover and especially drifted snow on the trail reduces ground visibility, which slows productivity. As well, decompaction of the trail running surface can take more time if soils are frozen at depth. The road surface is pulled up in large chunks and then shattered with the bucket (Figure 10).

Caution is advised when interpreting the differences in productivity between summer and winter rehabilitation. The relationship between productivity and slope was stronger for summer (r^2 = 72%) than it was for winter (r^2 = 24%). In addition, the number of observations in the study was considerably lower for winter than it was for summer rehabilitation (Table 3).

Productivity values derived from the equations in Table 3 are based on productive machine hour and do not include non-

Example:

The cost per metre of skid trail built or rehabilitated can be calculated using the equation in Table 3. To calculate the cost \$/m of summer trail construction on a 35% slope, using a 70 kW excavator, and assuming a shift level utilization of 70%:

$$\text{Productivity (m/SMH)} = \text{Productivity (m/PMH)} \bullet \text{Utilization (\%)}$$

$$\text{Cost (\$/m)} = \frac{\text{Total ownership and cost of excavator (\$/SMH)}}{\text{Productivity (m/SMH)}}$$

Assume total ownership and operating cost of a 70 kW excavator = \$92/SMH. From Table 3
Productivity (m/PMH) = $111.24 \bullet e^{-0.0117 \bullet 35\%} = 73.86$ m/PMH
Productivity (m/SMH) = 73.86 m/PMH • 70% = 51.70 m/SMH

$$\text{Cost of trail building} = \frac{\$92/\text{SMH}}{51.70 \text{ m/SMH}} = \$1.78/\text{m of trail}$$

productive activities that occur over a shift. Delays for equipment repairs, servicing and other components of trail work—e.g., walking the equipment within a trail system and building or deactivating drainage structures—must be included to arrive at productivity per scheduled machine hour (SMH). Productivity is adjusted or reduced from PMH to SMH to reflect the degree of utilization expected over a shift (see example above).

Analysis of data for trail grade did not show a significant relationship with productivity, consistent with the operators' indications that grades up to 25% did not affect productivity. In most cases, trail grades in this study did not exceed 20% (Table 4).

For trail construction, trail width increased as slope and cutbank height increased (Table 4). Trails were built narrower in the winter than in the summer, primarily because snow was used as building and support substrate.

Table 4. Average trail width and grade in summer and winter by slope

	Summer trail construction			Winter trail construction		
Slope class (%)	Trail length sampled (m)	Width [a] (m)	Grade [a] (%)	Trail length sampled (m)	Width [a] (m)	Grade [a] (%)
0–30	1896	4.0 (2.6–5.4)	10 (1–27)	1 612	3.0 (0–4.5)	9 (0–25)
31–40	710	4.2 (3.8–4.8)	17 (2–31)	1 190	4.4 (3.2–5.4)	11 (3–26)
41–50	604	4.9 (4.1–5.3)	25 (6–42)	402	4.7 (4.1–5.0)	19 (14–31)
51–60	1 057	5.6 (4.5–7.3)	20 (3–38)	1 256	4.7 (4.2–5.8)	19 (14–31)
>60	153	5.3 (5.1–5.6)	29 (15–42)	284	4.9 (4.3–5.7)	17 (4–36)

[a] Range of sample values in brackets.

Wheeled skidders have a higher centre of gravity and travel at higher speeds, reducing their stability compared to small crawler tractors. Trails were built for both types of skidders and therefore were wider than necessary for small crawlers. Citing unpublished FERIC data, Krag et al. (1991) reported that for trails built by a Caterpillar D4 or equivalent machine, skid trail width averaged 5.0 +/- 0.4 m over a range of slopes of 20 to 50%. In this study using excavators, average summer-built skid trail width varied from 4.0 m on slopes of 0–30%, 4.2 m on slopes of 31–40%, and 4.9 m on slopes of 41–50% (Table 4).

Equipment size class and the width of standard bucket varied (Table 2), but no differences were identified with respect to suitability for trail building and rehabilitation. In one instance, the operator commented that the Yutani 140 (lightest machine among the five within the study) did not have sufficient hydraulic power to easily handle push-falling of larger trees.

Other observations

The skill and experience of an equipment operator doing skid-trail construction or rehabilitation work have considerable influence on machine productivity. The operators observed in this study had a clear understanding of the objectives of trail building and rehabilitation, and most had several years of experience (some more than ten). These activities were conducted in a smooth, seamless manner with little wasted effort or inefficiencies. Generally, the operators began with experience in the use of an excavator, and then trained on-the-job to develop the skills needed for the skid-trail construction and rehabilitation tasks. Operators are involved in both steps, and therefore have a clear understanding of the consequences of poor construction technique. To assist in the training of operators, a video entitled "Skid trail rehabilitation" (Curran 1997) and two pocket-sized field cards are available for training and illustrate the objectives of skid trail construction and rehabilitation.

Figure 11. Extensions for hooking trees (see arrows).

Variations in forest stand, terrain, seasonal operating conditions, and technique influenced productivity and utilization as follows.

Trail construction

- Stand age and composition can have a large impact on productivity. The larger the tree, the more productive time is required to push-fall and position it, and the higher the likelihood of tree hang-up. When Douglas-fir and western larch >20 cm in diameter are push felled, productivity slows as the trees are tall, well rooted and difficult to direct. When trees hang-up on other standing trees, they must be alternately pushed and pulled by the excavator to complete felling. With larger Douglas-fir and larch (>40 cm), excavation of the roots is required, and the tree may be rocked back and forth until push-falling is completed. As a means of improving falling efficiency, in some cases, small extensions were welded to the side of the bucket and thumb to serve as hooks for pulling trees (Figure 11).
- Snags within felling distance of a trail are push-felled to fulfill Worker's Compensation Board of B.C. guidelines for faller safety. This task can be quite time consuming in decadent stands with large numbers of dead trees or in stands with mortality from mountain pine beetle. As well, large diameter, downed woody material can slow productivity when clearing right-of-way. One

operator interchanged the standard bucket with an articulated grapple clam attachment when push-falling pockets of beetle-killed pine. Although the grapple clam was better suited to push-falling and positioning trees in these circumstances, it is not as productive as the bucket for soil excavation.

- Stopping to look for trail markings can reduce machine productivity. In some blocks with well developed understories, the operator could not see trail flagging clearly from the cab, and numerous stops were required to verify trail location on foot. Inadequate flagging of trees during trail layout was cited as one problem while in other situations bears had removed some flagging. Dust generated by the excavator in dry conditions and snow flurries during the winter were also cited as causes of poor visibility of trail flagging. More prominent or frequent marking or placing trail marking just prior to trail building would reduce delays caused by poor visibility.
- Winter conditions slow productivity because the ground cannot be seen easily and freezing conditions lead to reduced traction and greater caution by operators. Heavy snow loads add weight to leaning trees, making directional falling more difficult and leading to more hang-ups during push-falling. In winter, trees push-felled downslope from the trail should be pulled up and aligned along the edge of the trail. If this is not done, the frozen running surface can be damaged when trees are skidded up and over the edge. Extra time is spent shaking the root balls of larger felled trees to retain frozen soil on the trail and reduce the weight of the roots. With frozen soil adhering to roots, the safety risk of a root ball rolling downslope is increased.

Although not observed, excess soil moisture and bedrock outcrops can negatively affect the productivity of trail building.

Trail rehabilitation

- Decompaction of the trail surface involved one of two techniques: decompacting while backing up and facing the same direction as pullback, or reaching behind (swing 180°) and decompacting for several metres before reversing again to do pullback. Reaching behind to decompact the trail surface required more time but some operators felt this ensured that decompaction was continuous along the entire trail length. However, this technique required the excavator to travel over the newly decompacted surface. On trails with deep cuts (>1 m), turning to rehabilitate can be difficult and unsafe due to restricted tail swing.
- Complex terrain dominated by ridge and gully topography requires winding skid trails. During skidding, considerable sweeping or grading of trail material into gullies occurs, widening fill slopes at these locations. Productivity of rehabilitation is reduced as fill material is pulled back from longer distances at these locations.
- At steep trail grades above 25%, productivity is reduced when the excavator uses the reverse travel technique. Maneuverability is reduced at these grades, and there are safety concerns over fill slope stability, particularly when the trail is no longer insloped. On occasion, frozen trail surfaces are “roughened up” with the bucket to improve traction. Productivity is further affected by reduced visibility and extra load placed on turn-table hydraulics when swinging a loaded bucket uphill. Trail grades should not approach levels that compromise performance or safety of operations.
- During decompaction in the winter, deep frost penetration requires more digging force and the large frozen plates of soil require shattering by the bucket in order to recontoured the slope. Drifted snow on trails requires clearing with the bucket prior to decompaction. One operator switched to a larger ditch cleaning bucket for this task.

Safety of operations

As with other aspects of mechanized logging in steep terrain, safe operating practices are important during skid-trail construction and rehabilitation. The following section describes safety concerns and how these were addressed in the monitored operations.

- Excavator cabs are protected from penetration by broken tree stems resulting from push falling.
- Skid trails are constructed wide enough to provide a stable running surface for wheeled skidders.
- Because trails are graded during skidding, outsloping of the running surface can result. This poses a hazard for equipment and load stability. During trail construction, the trail surface is insloped to compensate for this and to allow for settling.
- The tail swing of the excavator can interfere with high cutslopes and risk machine stability. Utilizing small excavators with reduced tail swing or increasing trail width helps to decrease this risk.
- Equipment operators often work alone during skid trail building and, to a greater degree, during rehabilitation. In their cabs, they are in radio contact at all times with others in the vicinity. However, during stops for maintenance and repairs, rest breaks, moving personal vehicles, or checking trail markings, operators can be away from radio contact. Checking for trail markings can pose a particular hazard for operator safety as the operator may walk a considerable distance away from the machine. Having a regular call-in procedure for the operator reduces the hazard of working alone.
- Winter operations are more hazardous and require greater caution than in the summer due to icy conditions, snow cover, and reduced daylight working hours. Snow obscures visibility of the ground and can reduce traction of the excavators. Snow loads can make trees more prone to breakage during push-falling. Drifted snow can increase outsloping of the trail surface which can be particularly hazardous for an excavator. The excavator can slip sideways on steel tracks during rehabilitation when the trail surface is frozen. Actions can be taken to reduce these risks. Ice cleats are welded to track grousers to improve traction, and drifted snow is removed from the trail surface prior to rehabilitation. Good lighting is necessary when working in darkness.

Conclusions and implementation

Small excavators in the range of 15 000–22 000 kg were the most common size class used in this study of skid-trail construction and rehabilitation. These machines appeared well suited to operating in dense forest stands and on moderate slopes where the goal is to construct and rehabilitate narrow trails within a confined space. However, excavators require sufficient power and weight for adequate control of larger trees when push-falling. Minor add-on features to standard excavator buckets and hydraulic thumbs can improve the control of larger trees during push-falling.

Productivity was most strongly correlated with cutbank height and slope for summer trail rehabilitation. Excavation of cut and fill materials and push-falling were large components of overall productive time. As slope increased, so did the amount of cut and fill. For push-falling, as tree size increased, more time was required to directionally fall trees and avoid hang-ups.

Productivities for both trail building and rehabilitation decreased in the winter due to reduced ground visibility from snow, less operating time in daylight, and frozen ground that reduces traction and slows trail decompaction. The difference in productivity between summer and winter rehabilitation was most pronounced for trail rehabilitation at slopes below 40%. Operating safely in the winter required more caution that generally reduced overall productivity. The addition of ice cleats to track grousers and the removal of excess drifted snow from trails increased machine stability.

Productive surface soils deposited at the base of fillslopes during trail construction were successfully retrieved during rehabilitation. However, the unconsolidated nature of this soil, combined with excavators using toothed buckets, resulted in some unavoidable mixing of surface and underlying soils. It is important to minimize the mixing of soil layers when dealing with unfavourable (e.g., calcareous) subsoil.

Highly prominent and more frequent trail marking, and applying trail marking just prior to trail building, would prevent delays resulting from machine stoppages to check trail location and reduce the safety risk for operators who depend on close radio contact when working alone.

Skid-trail construction and rehabilitation using excavators is a well-refined component of timber harvesting at Tembec Inc. First initiated at the company's operations in 1987, some equipment operators observed in this study have over 10 years experience and demonstrated a clear understanding of good trail construction techniques that facilitates trail rehabilitation and the maintenance of soil and site productivity.

References

Braumandl, T.F.; Curran, M.P. (compilers and editors). 1992. A field guide for site identification and interpretation for the Nelson Forest Region. B.C. Ministry of Forests, Victoria, B.C. 311 pp.

British Columbia Ministry of Forests (BCMOF); BC Environment. 2001. Forest Practices Code of British Columbia: Soil conservation guidebook. 2nd edition. Victoria, B.C. 24 pp.

Curran, M.P. 1997. Skid trail rehabilitation video, BC Ministry of Forests, Research Program, Nelson Forest Region, Nelson, B.C. 53 minutes.

Kockx G.P.; Krag R.K.1993. Trial of ground-skidding methods on steep slopes in the east Kootenays, British Columbia: Productivities and impacts. FERIC, Vancouver. Special Report SR-89. 20 pp.

Krag, R.K.; Webb, S.R. 1987. Cariboo Lake logging trials: a study of three harvesting systems on steep slopes in the central interior of British Columbia. FERIC, Vancouver. Technical Report TR-76. 48 pp.

Krag, R.K.; Mansell, J.; Watt, W.J. 1991. Planning and operational strategies for reducing soil disturbance on steep slopes in the Cariboo Forest Region, British Columbia. FERIC, Vancouver. Technical Report TR-103. 26 pp.

Lewis, T; Timber Harvesting Subcommittee. 1991. Developing timber harvesting prescriptions to minimize site degradation. B.C. Ministry of Forests, Forest Science Research Branch, Victoria, B.C. Land management report no. 62. 4 pp.

McMorland, B.A. 1980. Skidding with small crawler-tractors. FERIC, Vancouver. Technical Report TR-37. 89 pp.

Thibodeau, E.D. 2002. An alternative ground-skidding method for reducing soil disturbance on steep slopes. FERIC, Vancouver. Advantage Report Vol. 3, No. 1. 12 pp.

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