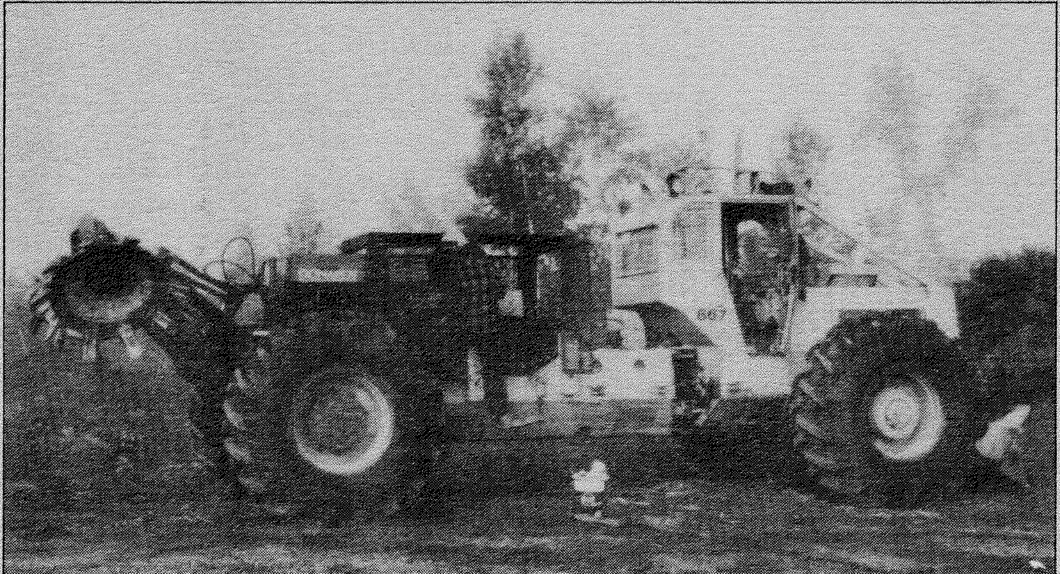
FERIC FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

Technical Report No. TR-54

October 1982

Evaluation of the Donaren 180D Powered Disc Trencher

Mark Ryans



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PREFACE

FERIC's evaluations are designed to assist future users in appraising the current status and prospective value of specific equipment. This report describes a field study of the technical and operating characteristics of the Donaren 180D disc trencher. This study is the first from the Eastern Division in the field of mechanization of silviculture. Biological studies are outside FERIC's mandate within the program of mechanization of silviculture. The effectiveness of a treatment will be measured against the prescription provided by the co-operating forester, industry or government. Longer term biological evaluations may be included in co-operative studies with other agencies.

The machine was the subject of a short-term study. Short-term evaluations describe potential productivity under measured, but limited, operating and environmental conditions. Since both the range of conditions and the period of observation were limited, this study cannot be expected to predict long-term productivity and performance under all circumstances. The results presented in this report should be considered only as a guide to realistic expectations of machine performance.

At the time of writing this report, a SLAP (Shift Level Availability and Productivity) study was planned to be undertaken to measure long-term mechanical availability and productivity and thereby determine cost per machine hour and cost of treatment.

Details of study procedures and analysis, plus results of limited interest, have been omitted for sake of brevity. Further details of the study will be supplied upon request.

All quantitative data throughout the report are given in "SI" (Systême International d'Unités) units. A table for conversion to Imperial units is provided in Appendix E.

Grateful appreciation for help and cooperation during the study is extended to Messrs. Richard Landry and Mike Carson of Les Industries James Maclaren Inc., and to George LeRoux of Les Équipement Équisyl International Inc. (At the time of the study, Mr. LeRoux was working for Canadian Forestry Equipment, Saint Eustache, Qué.)

Technical assistance was provided by FERIC employees D. MacGregor, R. Levesque and E. Vajda.

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SUMMARY

Since the introduction of the first disc trencher to Canada in the early 1970's, there has been a widespread interest in disc trenchers across the country. Over the past few years, a number of disc trenchers have been developed by Scandinavian manufacturers with hydraulic features to expand the use of the disc trencher technique and the range of sites that can be treated. Cylinders can manipulate the working positions of the discs and add downpressure. On a number of models hydraulic motors have been added to power the discs. To date, few of these new models have been tested in Canada.

The Donaren 180D has both hydraulically controlled arms and powered discs. There are three working positions of the arms: raised for transport, scarifying with hydraulic downpressure and, scarifying in float position where the discs are working under their own weight plus that of the arms. Lateral control cylinders can adjust the distance between the two discs. All the hydraulic functions are controlled from the cab of the skidder. As with mechanical trenchers, it can be mounted on a forwarder or skidder of 90-115 kW. However, an additional 35 kW is required to run the hydraulics of the Donaren.

A short-term study was conducted in August 1981 on the operations of Les Industries James Maclaren Inc., north of Mont Laurier, Qué. FERIC undertook the study to determine if there are advantages over conventional disc trenchers and, to evaluate its productivity and effectiveness of scarification.

The Donaren was mounted on a Clark 667 grapple skidder (104 kW) with a modified Clark forwarder rear chassis. The extra length was required to mount the auxiliary engine (41 kW), hydraulics for the Donaren, and reservoirs for fuel and hydraulic oil.

The 20-hectare site was on the middle to lower slopes of a former mixed stand of balsam fir, spruce, white birch and white pine. The stand was harvested using a treelength to roadside system two years prior to treatment. White birch and dead balsam fir remained after logging. There was a heavy layer of raspberry and young trees. The well-drained sandy loam soil was boulder and stone-free. The terrain was uneven with slopes ranging from 0 to 30%.

Productivity averaged 1.05 'net' hectares per productive machine hour despite moderately difficult site conditions, small treatment blocks less than 10 hectares, an inexperienced operator, and frequent delays caused primarily by overheating of the skidders torque converter. Travel speed while scarifying averaged 4.4 km/hr. Delays comprised an average of 21 percent of the productive time.

The 'gross' Mineral Soil Exposure averaged 15% while the 'net' Mineral Soil Exposure was 76%. There were 1968 plantable spots per hectare in an assessment of planting spots created solely by the scarifier and on a 2-metre spacing along the furrow.

Although comparative trials on the same site or different sites in other regions were not carried out, the Donaren demonstrated a number of operational advantages over conventional, mechanical disc trenchers. Briefly these include:

- faster and safer travel between sites and while manoeuvering in the cutover due to the hydraulic raising of the discs and the direct mounting,
- simple changing of operating downpressure on the discs to deal with various site conditions,
- shocks from striking obstacles are dampened by the hydraulic system via an accumulator circuit rather than by the discs, hitch and prime mover resulting in a smoother ride and less damage to the machine. As well, there is a quicker return of the discs to the soil,
- disc spacing is easily changed for various silvicultural prescriptions.

In terms of scarifier effectiveness, the Donaren also showed a number of advantages. These include:

- higher inherent exposure of mineral soil in both 'net' and 'gross' terms,
- effective penetration of slash and transmission of slash away from furrow,
- consistently wider but shallower furrow.

The main disadvantages of the Donaren are its higher capital cost, higher horsepower required to run hydraulics, and the need for modifications to standard prime movers.

INTRODUCTION

Disc trenchers, under the trade name TTS, were first developed by the Finnish Work Efficienty Association (Työtehoseura) in the 1960's. Conventional models are strictly mechanical, consisting of two passive discs on a triangular box frame. The toothed and concave discs produce two continuous furrows of exposed mineral soil with a ridge of humus, mineral soil and slash along the outer edge. During the 1970's, a number of disc trenchers were developed by manufacturers in Scandinavia to increase the efficiency and the range of sites that can be treated using this method. Appelroth (1976) states that disc plowing comprised 16% of the total machine site prepared area in Sweden and 41% in Finland in 1973. It was projected that by 1980 these figures would increase to 27% in Sweden and 66% in Finland.

The TTS-35 was introduced into Canada during the early 1970's. Since then their use has spread to almost every province in the country. However, few of the models offering hydraulic features have been used in Canada to date.

The Donaren 180D in this study was the first unit used in Canada. Wickstrom (1981) reports that there have been 102 units of the Donaren series produced by 1981. This total includes models with hydraulic downpressure and those that have both hydraulic downpressure and driven discs.

The Donaren is manufactured by Nordfor Teknik AB of Vikmanshyttan, Sweden. At the present time, Les Équipement Équisyl International Inc. of Pointe-Aux-Trembles, Québec has the Canadian distribution rights. In March 1981, the price for the Donaren 180D unit was C$58,900.00 (f.o.b. Pointe-Aux-Trembles).

This report describes a three-week study of the Donaren 180D made during an operational trial by Les Industries James Maclaren Inc. in their concession north of Mont Laurier, Québec. The study was undertaken to assess the productivity and performance of the scarifier, and to determine any advantages the Donaren 180D may offer over other presently available disc trenchers.

MACHINE DESCRIPTION

The scarifying machine consists of three major components (see Fig. 1):

- the Donaren 180D disc trencher;
- an auxiliary power unit to run hydraulics of the disc trencher;
- the prime mover, composed of a Clark 667C grapple skidder front chassis and modified Clark forwarder rear chassis.

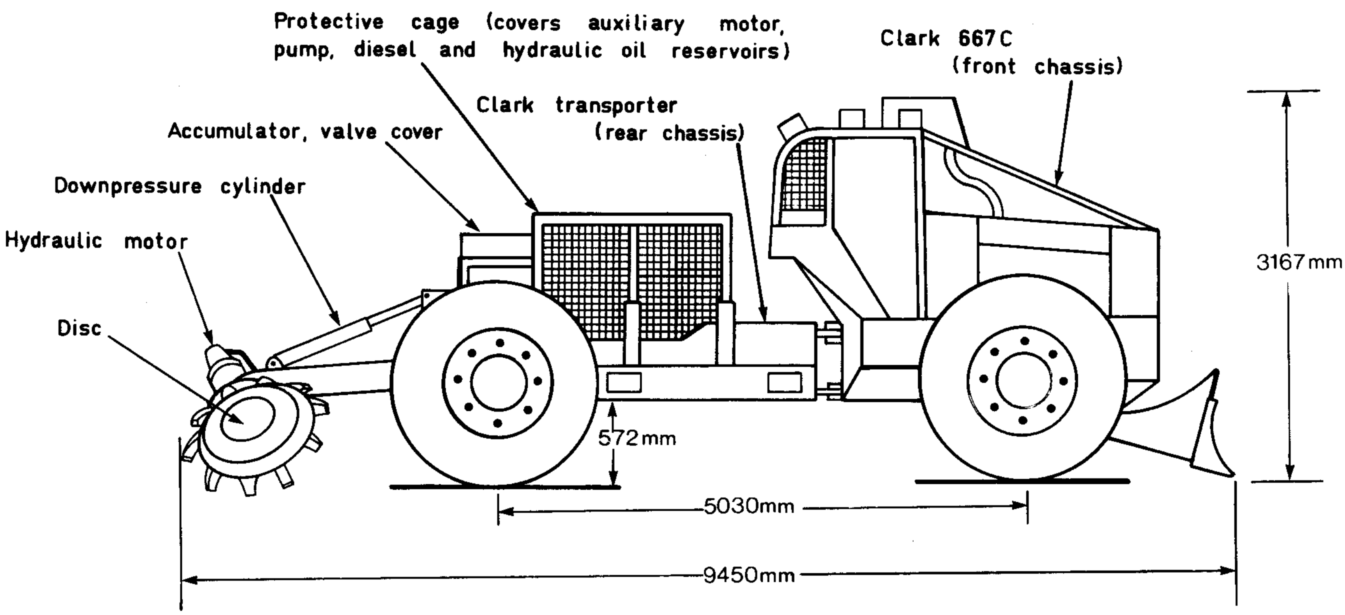

Figure 1. Major features of the scarifying machine in the study.

Donaren 180D

The Donaren 180D is a disc trencher designed to create two continuous furrows. The main features which differentiate it from conventional mechanical disc trenchers are:

- directly-mounted onto the prime mover;
- continuously variable downpressure on discs provided by hydraulic cylinders;
- the scarifying discs are hydraulically driven;
- the spacing between furrows is adjustable and controlled by hydraulic cylinders.

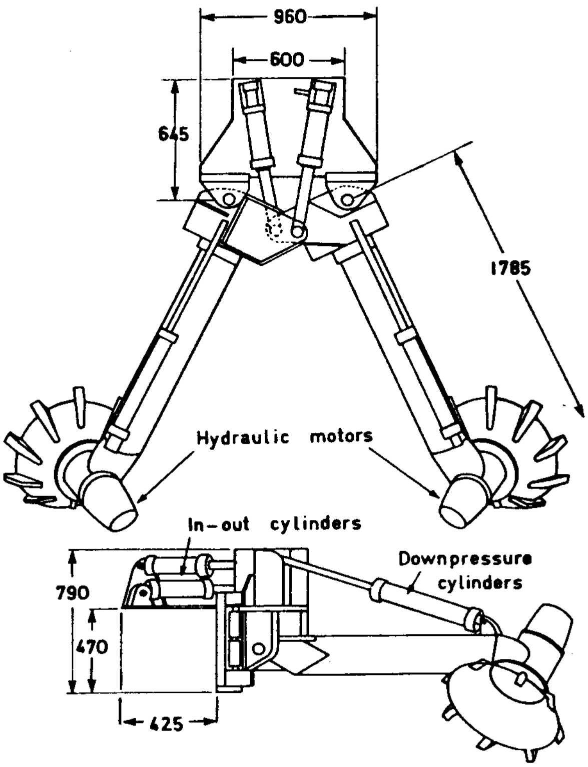

Figure 2. The Donaren 180D Disc Trencher. Dimensions are in millimetres.

The trenching discs are mounted on two separately articulated arms. The arms have three operating positions:

- continuously adjustable load pressure from 0 to 40 bars;
- 0-pressure float position where the discs operate solely under their own weight;
- and the raised transport position used when manoeuvering, cleaning discs of debris and long distance transport.

The maximum and minimum furrow spacing can be varied from 1.0 to 2.75 metres. The desired widths for a particular operation are set by welding stops on the mounting plate to restrict the lateral movement of the arms.

Each disc is powered by a hydraulic motor and planetary gear drive (Fig. 3B). The rotation speed can range from 15 to 30 rpm but it is set at one speed prior to operation. The discs rotate in the same direction as the wheels.

On each disc there are ten 150mm-long teeth. As shown in Figure 3D, the teeth are easily removed and are similar to the teeth on the bucket of an excavator.

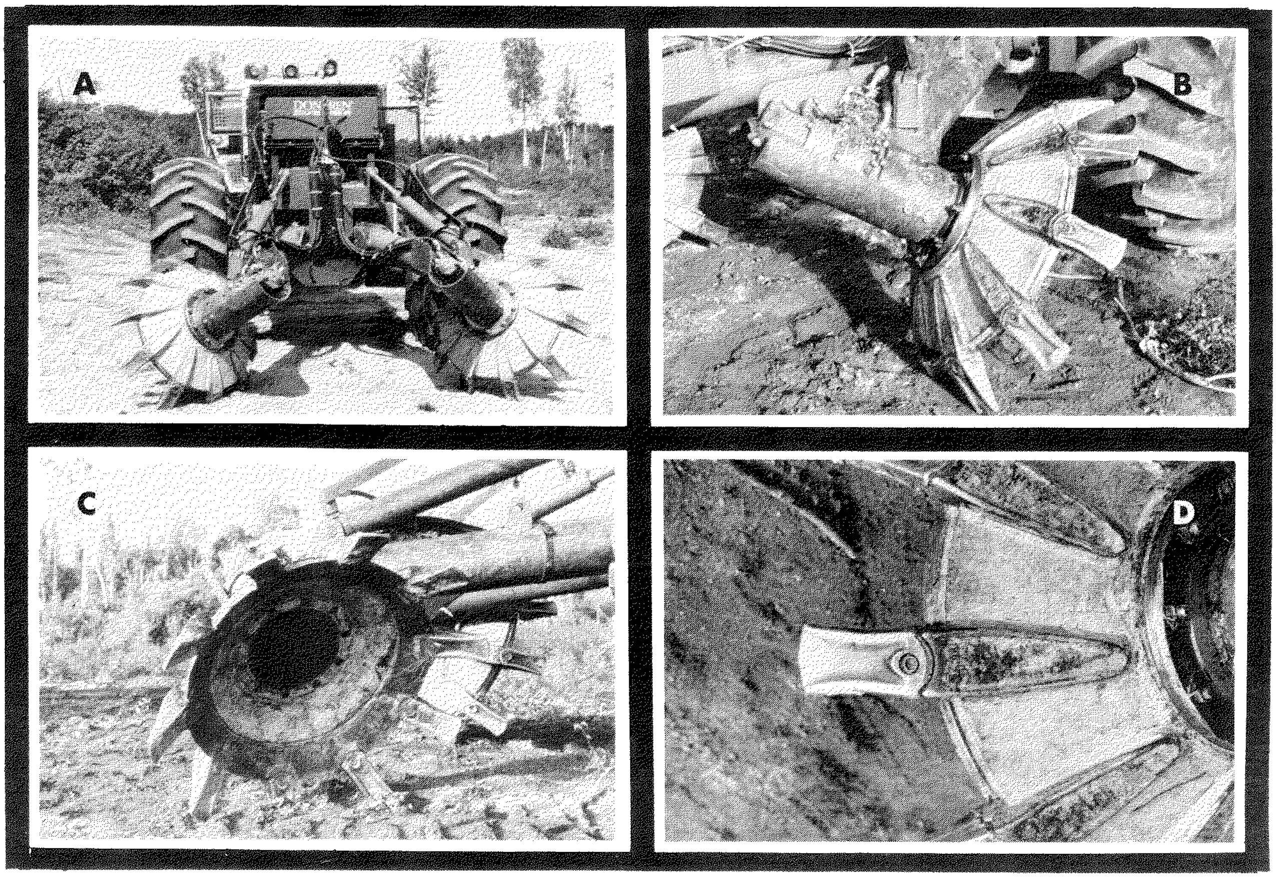

Figure 3. Main features of the Donaren 180D Disc Trencher:
A. Rear view of Donaren 180D disc trencher.
B. Hydraulic motor.
C. View of inner surface of the concave discs and teeth.
D. Closeup of removable teeth showing locking pin.

Automatic vertical and lateral control of the arms through the hydraulic cylinders is activated by pushing a button on the control panel mounted in the cab (Fig. 4). The selection of working position and downpressure on the discs are done at the same panel. A foot switch turns the rotation of the discs on or off.

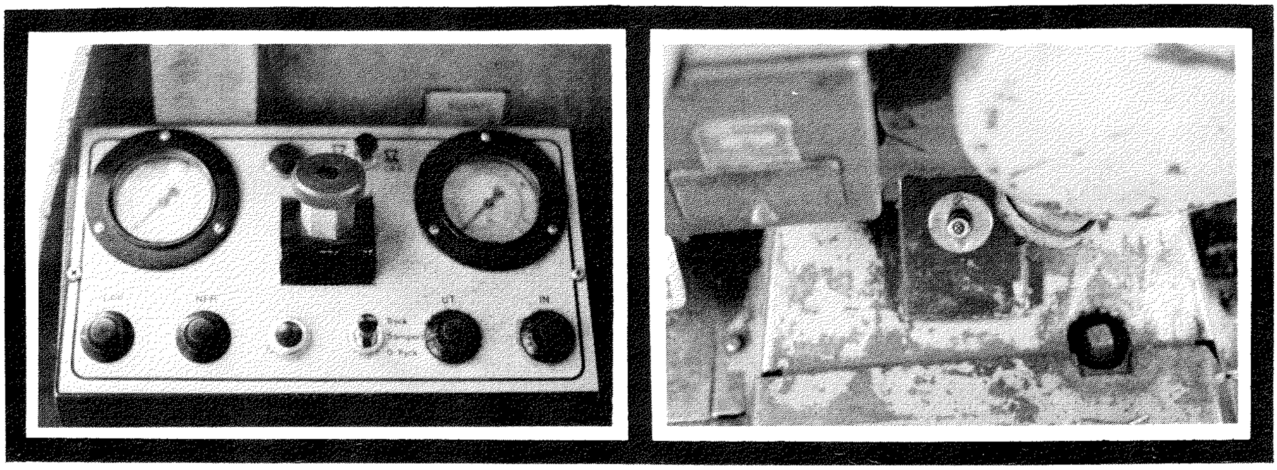

Figure 4. Operator controls mounted in cab.
Left photo: Main Control Panel. The two pairs of buttons control vertical and lateral movement of arms. Downpressure is selected by turning large centre knob and is indicated on dial. The small lower switch has three positions to select working position.
Right photo: Floor switch to control rotation of discs.

An accumulator circuit takes the shocks of hitting an obstruction. It also allows the discs to follow the contours of the ground and ride over obstacles independently of each other.

Prime Mover

A 3-year old Clark 667C grapple skidder was used as the prime mover. A longer Clark forwarder chassis was used on the rear to replace the grapple chassis and carry the auxiliary power unit. The Clark 667C was equipped with a 104 kW Cummins diesel engine, a Clark 3-speed powershift transmission with torque converter, and 30.5 x 32 tires without chains.

The total weight for the Clark-Donaren 180D scarifying unit was 16 150 kg. The addition of the longer rear chassis increased the wheelbase from the 3260 millimetres of the conventional Clark 667C grapple to 5030 mm. The diameter of the turning circle was measured at 17.7 m (outside rear tire).

Auxiliary Power Unit

Power to the hydraulics of the Donaren 180D was supplied by a fixed displacement pump run by a 41-kW Deutz air-cooled diesel engine. A protective cage housed the auxiliary power unit, fuel tanks for the engine and skidder, and the hydraulic oil reservoir for the powered disc trencher. Figure 5 shows the Donaren 180D and auxiliary power unit prior to the addition of the screen.

Technical data on the three components of the scarifying machine are given in Appendix A.

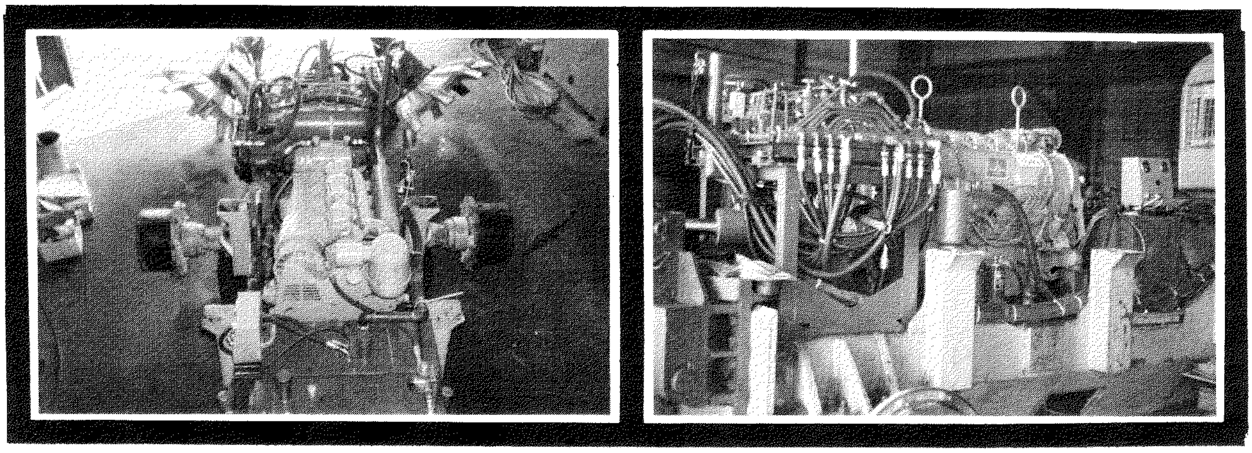

Figure 5. Donaren and auxiliary power unit prior to the mounting of the protective screen.
Left photo: Note the accumulator to the rear of the Deutz engine, and the fuel and oil reservoirs in the foreground.
Right photo: One of the short lateral control cylinders and mounting plate are visible on the left.
(Photos courtesy of Les Industries James Maclaren Inc.)

OPERATION

Site

The site was located approximately 40 kilometres northeast of Mont Laurier, Québec near Lac Franchère on the concession of Les Industries James Maclaren Inc.

The general area has an irregular topography, dominated by strongly rolling upland terrain. The treated site lay in the lower to middle slopes, where prior to logging the stand was mixed, containing black spruce*, balsam fir and white birch. Large white pine and white spruce occurred as scattered individuals. A more tolerant hardwood stand of yellow birch, sugar maple and red maple dominates the upper slopes, but these areas are not readily treatable due to the steep slopes and heavy residual stand. These stands are common in the Algonquin-Pontiac Section of the Great Lakes-St. Lawrence Forest Region (Rowe 1974).

Figure 6. Left: View of Block 1 prior to scarification. Note dense raspberry cover.
Right: Donaren 180D working on Block 1 among white birch residuals.

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* Scientific names for the tree species given in the report can be found in Appendix B.

The soil was a deep, loamy fine sand with a Humic Podzol profile. It was practically boulder-free and stone-free to a depth of 30 centimetres. The site is a class 2.2.2 according to the C.P.P.A. terrain classification system (Mellgren 1980). However, some short slopes in the area had between 20 and 30% grades.

The site was logged two years prior to scarification in two phases. Conventional cut and skid removed softwood treelengths to roadside. In a subsequent operation, quality hardwoods were removed in treelengths for sawlogs and peelers. The residual stand was therefore comprised of poor quality and undersized trees, of primarily white birch. Dead balsam fir also occurred due to an earlier devastation by the spruce budworm.

Figure 7. Block 2 after scarification looking across the furrows. Photo taken the following spring before leaf flushing of the raspberry.

The slash was moderate in loading and coverage (Fig. 7). Large white pine tops lay sparsely scattered over the area. Herbaceous and ground cover vegetation was light due to an extremely dense cover of one-metre high raspberry.

Purpose and Method of Treatment

The purpose of the site preparation was to create suitable planting microsites by scarification. Seedlings were to be planted the following spring at a 1.8 m x 1.8 m spacing.

During the study, the company was renting the Donaren 180D. They have purchased the machine since the study. The Donaren was run operationally on a one 8-hr shift per day and 5 days per week basis. The operation consisted of one operator and one supervisor who was also responsible for laying out the areas to be treated and follow up inspection. Daily service and minor repairs were performed by the operator and supervisor. Major repairs were done by the company field mechanics in the bush or at a main garage.

The operator had less than two weeks experience on the machine at the time of the study. He had no previous site preparation experience but was an experienced skidder operator. This was also the first time that the company was involved with any form of site preparation.

The maximum distance between the discs was set at 1.8 metres. The disc rotation was measured at 25 rpm. The working position was kept at the 0-pressure float position and various rotation speeds were not tried during the FERIC study.

Operating Pattern and Sequence

The operating pattern of working in patches or 'lands' was used primarily although some run-by-run passes were made. Furrows were run as perpendicular to the road as possible, which meant that manoeuvering on the road followed every other pass.

Moving or 'walking' between sites was done by raising and bringing the discs together and driving the machine to the next area. A lowbed trailer was used to move the machine from one division to the next or to bring the machine to camp for any major repairs (Fig. 8).

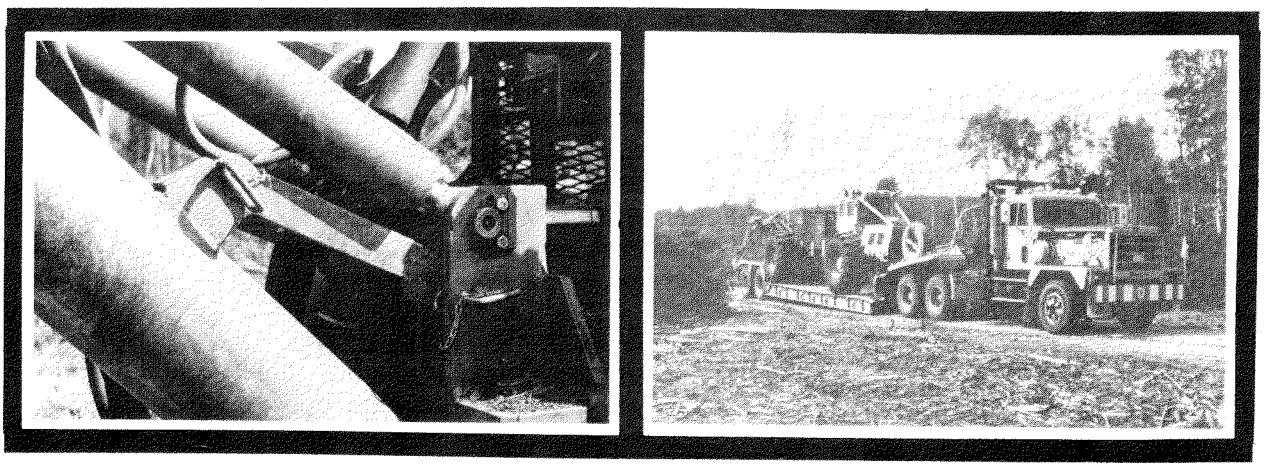

Figure 8. Safety locking pin (left) and scarifier on float ready for long distance transport (right).

The operating sequence of the Donaren 180D is similar to other scarifiers except for the push-button controls. Definition of time elements are given in Appendix C.

The operator drives the machine to the edge of the road to begin scarification. After lowering the discs, he drives forward scarifying the soil until the end of the pass or until he reaches an obstacle. Upon reaching an obstacle such as a large white pine stump, clump of residuals or a wet spot, the discs are raised and the machine driven around the obstacle to a point were the discs are lowered and the scarification continues. The discs are cleaned during a pass by simply raising the scarifying arms and letting the debris fall off as the discs rotate.

At the end of a pass, the discs are raised and the machine driven, either along the edge of the cutover or along the road, to the starting point of the next pass.

The discs are kept rotating during the entire sequence. However, the disc rotation was stopped during some delays, such as cooling down the engine.

Figure 9. Operating positions of discs.
Left: Donaren scarifying with discs lowered.
Right: Manoeuvering in site between passes with discs raised.

ASSESSMENTS

Prior to scarification, the site conditions which may affect the passage of the machine and the subsequent quality of the scarification were assessed. The plots were located in three main blocks in the study area. Further information on the preassessment procedure used can be found in Riley (1975). Slash measurements under this procedure were made using the line-intersect method as described by Van Wagner (1968).

Continuous time studies were carried out to evaluate the productivity, performance and operational problems of the Donaren 180D. Measurements of fuel consumption and noise exposure were also taken at this time.

Post-treatment assessments were done to evaluate the quality of scarification. The method used was similar to the procedure used by the Ontario Ministry of Natural Resources as outlined in Anon. (1979). Assessments of mineral soil exposure and plantable spots included those areas or spots prepared by the scarifier only. Planting spots, tallied on a suitable or unsuitable basis, were appraised every two metres along the furrow in the plot with the starting point being the location perpendicular to the centre stake of the plot. The planting location, chosen by the company, was on the outer slope of the furrow at the edge of the exposed mineral soil and the overturned humus. This location can be seen in Figure 12. The basis for this decision was that the seedling is farthest removed from undisturbed competing vegetation, and there is a close proximity to a supply of nutrients in the humus.

Post-treatment assessment also included a measure of average travel speed for a pass. The length of approximately every fourth pass was measured in each block. Travel time for each furrow was obtained in the time study with the furrow also being numbered at this time. A survey of slopes was also done after scarification to determine the maximum slope that the Donaren could effectively scarify while travelling up the slope. A closed traverse was run around each scarified block to obtain an accurate figure on 'net' area.

RESULTS

Pre-Treatment Assessments

The results from the pre-treatment assessments are given in Tables 1 through 6.

Table 1. Residuals and brush assessments.

Location	Residuals (d.b.h. greater than 10 cm)					Brush (d.b.h. <10 cm, height >1 metre)		
	Balsam Fir Density (no/ha)	White Birch Density (no/ha)	Total Density (no/ha)	Avg. Diam. (cm)	Diam. Range (cm)	Density (no/ha)	Avg. Height (m)	Height Range (m)
Block 1	75	30	105	18.1	10-28	2817	1.3	1.0-2.0
Block 2	140	15	155	16.8	10-38	1800	1.5	1.0-3.0
Block 3	68	37	105	20.0	10-40	700	1.3	1.1-2.0
Overall[a]	88	30	122	18.1	10-40	1772	1.4	1.0-3.0

[a] Weighted averages where appropriate.

Table 2. Woody plant assessment.

Woody Plants (less than 1 metre)

Location	Tree Species			Raspberry			Other Woody Plants
	Density (no/ha)	Stocking[b] (%)	Avg. HT (m)	Stocking[b] (%)	Coverage (%)	Avg. HT (m)	Stocking[b] (%)
Block 1	12 450	86	.53	84	53	1.0	62
Block 2	10 150	80	.57	82	67	1.0	20
Block 3	11 425	68	.42	97	57	1.1	44
Overall[a]	11342	78	.50	88	59	1.03	42

[a] Weighted averages where appropriate.

[b] Stocking based on 4 m^2 quadrats.

Table 1 indicates the amount of residuals and brush found on the blocks and on the overall scarified area in the study. The residuals averaged 122 stems per hectare on the overall area. The density of white birch was highest in Block 3. In general, the balsam fir residuals were dead and brittle while the white birch were still living. Brush was moderate in Blocks 1 and 2, and light in Block 3.

All three blocks were densely stocked with woody plants. The density of tree species (less than 1 metre in height) averaged 11 342 stems per hectare overall. Raspberry was very dense in all blocks and averaged 1 metre in height. As a result of the dense raspberry growth, the ground cover of herbaceous plants was light to nonexistant. Pin cherry, white birch and mountain maple comprised the major hardwood component in both the brush and woody plant layers. A list of tree species can be found in Appendix B.

Stumps (Table 3) were light to moderate in frequency but there were a number of large spruce and white pine stumps scattered in all three blocks. Balsam fir and spruce comprised over 90 percent of the stumps.

Slash volume ranged from 15.0 to 244 m^3/ha and averaged 146.2 m^3/ha for pieces 7 cm and greater (Table 4). The slash was two years old in all the blocks.

Table 3. Stump assessment.

Location	Density (no/ha)	Avg. Height (cm)	Height Range (cm)	Avg. Diam. (cm)	Diam. Range (cm)	Percent of Density (%)	
Block 1	625	41	20-90	28	10-60	Balsam Fir	30
						Spruce	58
						White Pine	12
Block 2	600	32	20-90	18	8-36	Balsam Fir	79
						Spruce	21
Block 3	350	29	8-52	24	12-46	Balsam Fir	58
						Spruce	36
						White Birch	3
						White Pine	3
Overall[a]	525	35	8-90	23	8-60	Balsam Fir	55
						Spruce	39
						White Birch	1
						White Pine	5

[a] Weighted averages where appropriate.

Table 4. Slash assessment.

Location	Pieces per 40 m of lineal tally (<7 cm diam.)	For pieces greater than 7 cm in diameter: # pieces per 40 m lineal tally	Avg. Diam. (cm)	Diam. Range (cm)	Volume (m^3/ha)	Volume Range (m^3/ha)	Height (cm)	Coverage (%)
Block 1	82.2	22.8	15.6	8-44	202.7	180-244	18	20
Block 2	81.6	23.6	12.5	8-32	123.9	88-145	25	26
Block 3	109.5	19.4	13.8	8-34	129.0	15-238	21	23
Overall[a]	95.7	21.3	13.9	8-44	146.2	15-244	21	23

[a] Weighted averages where appropriate.

In general, the blocks were rolling. Block 1 was generally flat to rolling and contained no slopes that were a deterent to machine travel while scarifying. A long gully in Block 2 had slopes reaching up to 30%. Block 3 was flat, as indicated in Table 5, with the exception of one small ridge. However, there was a steep area at the far end of Block 3, where the machine often had to manoeuver.

Table 5. Slope assessment.

Location	Level (±2% slope) (% of lineal tally)	Avg. Upslope (%)	Max. Upslope (%)	Avg. Downslope (%)	Max. Downslope (%)
Block 1	40	6	13	5	5
Block 2	70	11	11	6	7
Block 3	80	4	5	3	3
Overall[a]	68	7	13	4	7

[a] Weighted averages where appropriate.

Table 6. Soil and terrain assessment.

Location	Depth to Mineral (cm)	Soil Texture	Soil Depth (cm)	Soil Moisture	Ground[b] Condition	Ground[b] Roughness Class
Block 1	6.4 (4-9)	loamy sand	>30	dry-fresh	2	3 (1,2)
Block 2	6.2 (5-8)	loamy sand	>30	dry-fresh	2	2 (1)
Block 3	5.4 (4-7)	loamy sand	>30	dry-fresh	2	1 (2)
Overall[a]	6.0 (4-9)	loamy sand	>30	dry-fresh	2	2 (1,3)

[a] Weighted averages where appropriate.

[b] According to the Swedish terrain classification system. The classes in brackets indicate extreme class or classes that covered at least 10 percent of the area.

The depth of the L-F-H layer averaged 6.0 cm and the mineral soil was a loamy fine sand exceeding 30 cm in depth (Table 6). The combination of a dry to fresh soil moisture regime and a loamy sand texture produced a ground condition class 2, which is an intermediate between average and very good conditions according to the terrain classification for Swedish forestry (Anon. 1969). Ground roughness (Anon. 1969) ranged from class 1 to 3 and averaged class 2. Class 2 is an intermediate between a somewhat uneven surface and very smooth surface. There were no boulders found on the area and the soil was stone free.

Time Studies

The results of the continuous time studies are presented in Table 7. Definition of time elements are given in Appendix C.

Table 7. Summary of time elements.

Time Element	Observed Productive Time (%)			
	Block 1	Block 2	Block 3	Overall
Scarify	51.2	48.6	48.9	49.7
Manoeuver	28.6	24.6	26.0	26.6
Move During Pass	1.8	4.8	1.7	2.4
(subtotal)	(81.6)	(78.0)	(76.6)	(78.7)
Delay*	18.4	22.0	23.4	21.3
Total Time	100	100	100	100

* Delay only includes those between 0.05 min and 15 min. Delays less than 0.05 min were included in the element in which they occurred, while those over 15 min were not considered productive time and thus excluded from the sample.

There were no major differences in time breakdown between the blocks. The time spent scarifying made up 49.7 percent of the productive machine hours (PMH). Manoeuvering between passes comprised 26.6 percent. The element "Moving around obstacle" describes the time during a pass when the machine moves around residuals, stumps or upslope while the discs are raised. It averaged 2.4% overall and was greatest in Block 2 because of a larger number of steep slopes. The time spent self-cleaning the disks by raising them is included in the element "Scarify" as it usually took less than 15 centiminutes. The operator raised the disks (for cleaning only) every 248 cmin during the time scarifying for Block 1, 173 cmin for Block 2 and 422 cmin for Block 3.

Table 8. Breakdown of delays.

Delay Classification	Percent of Total Delay Time			
	Block 1	Block 2	Block 3	Overall
Personal delay	7.6	1.3	21.4	12.2
Supervision	8.2	9.1	3.8	6.6
Delay due to prime mover:				
- Breakdown	16.3	-	5.6	8.0
- Cooldown	47.8	42.3	53.9	48.8
Stuck or movement impeded by obstacle	16.3	12.7	9.0	12.2
Clean disks:				
- brush	2.7	14.5	0.4	4.7
- choker	-	7.3	3.4	3.3
Clean road of debris	1.1	6.4	0.4	1.9
Remove debris from muffler	-	6.4	2.1	2.3
All Delays	100	100	100	100
Percent of Total Time	18.4	22.0	23.4	21.3

Delays comprised an average of 21.3 percent of the productive time. A breakdown of the delay time is presented in Table 8. Mechanical delays due to the prime mover were the major source of lost time. Cooldown occurred frequently due to high temperatures of a defective torque converter. There were no repairs made on the Donaren during the study. "Stuck or movement impeded by an obstacle" occurred when the machine drove over a stump or residual tree and the forward progress was stopped. "Clean disks" involves clearing the brush by hand that has wrapped around the disks (see Fig. 13). On two occasions, a choker had been wrapped around the disks.

Table 9. Productivity summary.

	Block 1	Block 2	Block 3	Overall
Productive Machine Hours (PMH)	7.41	4.31	7.33	19.05
'Net' Area (ha)	8.57	3.65	7.83	20.05
Productivity (ha/PMH)	1.16	0.85	1.07	1.05
Productivity with Delay Time Removed (ha/h)	1.41	1.28	1.40	1.34
Avg. Scarifying Speed (km/h)	4.5	3.5	4.6	4.4
Avg. Pass Length (m)	151	158	128	141
Avg. Time per Pass (cmin) 'Scarify' only	178	222	151	173
Avg. Time per Turn (cmin) 'Manoeuver' only	100	114	80	94

Productivity per productive machine hour (PMH) varied between the three blocks and averaged 1.05 hectares per PMH. Travel speeds while scarifying ranged from an average high of 4.6 km/hr on Block 3 to 3.5 km/hr on Block 2. The scarifying speed ranged from a low of 1.9 to a high of 8.1 km/hr for the area overall and averaged 4.4 km/hr. The length of the average pass was 151, 158 and 128 metres for Blocks 1, 2 and 3 respectively. The Donaren was therefore scarifying in first gear during the study.

Fuel consumption data were available for 12 hectares of the 20 hectares in the study. Consumption was 6.1 litres/ha for the Deutz auxiliary engine and 17.8 litres/ha for the engine in the skidder, making a total of 23.9 litres/ha. Data supplied by La Compagnie James Maclaren Ltée and based on 67.5 engine hours was 6.5 L/h for the Deutz and 14.5 L/h for the Cummins to make a combined total of 21.0 litres per engine hour.

In an assessment of the maximum slope that the machine was able to scarify, it was found that generally the machine could scarify uphill to slopes of 25%. Some slopes less than 25% could not be scarified but this was due to a combination of both slope and ground roughness. A side slope with a maximum of 21% was scarified in Block 2 but the operator travelled at a slower speed due to the danger of rolling over while riding over large stumps.

Post-Treatment Assessments

The assessment of plantable spots is given in Table 10.

The intrinsic spacing is the distance between planting spots as preset by the distance between the discs. The extrinsic spacing is dependent solely on the operator and is a reflection of his judgement to place the next pass at the proper distance from the last outside furrow. Extrinsic and intrinsic furrow spacing are therefore alternate.

Table 10. Results of plantable spot assessment and actual number of seedlings planted.

Location	Planting Spots (no/ha)	Extrinsic Between Row Spacing (m)	Intrinsic Between Row Spacing (m)	Avg. Between Row Spacing (m)	Seedlings Planted (no/ha)	Actual Along Row Spacing (m)	Actual Between Row Spacing (m)
Block 1	1820	2.00	2.5	2.25	2120	2.07	2.25
Block 2	2200	1.86	2.5	2.18	1840	1.94	2.34
Block 3	2000	1.86	2.5	2.18	2160	2.00	2.25
Overall[a]	1968	1.92	2.5	2.21	2080	2.02	2.27

[a] Weighted averages where appropriate.

Jack pine bareroot stock were planted in May of 1982. The actual number of trees per hectare that were planted is given in Table 10, based on the same 50 m^2 plots as in the post-treatment assessment. Les Industries James Maclaren Inc. reports an average of 2111 seedlings/hectare actually planted.

Results of mineral soil exposure assessments are given in Table 11. 'Net Mineral Soil Exposure' reflects the ability of the scarifier to expose mineral soil over the area it has passed. (i.e. within the confines of the furrow). 'Gross Mineral Soil Exposure' relates the exposed mineral soil to the total area scarified. Therefore, net M.S.E. is a measure of the effectiveness of the scarifier to handle a particular site while gross M.S.E. is a measure of both the effectiveness of the equipment and the operation. Net M.S.E. averaged 76% and the gross M.S.E. was 14.9% on the total area in the study.

Table 11. Results of mineral soil exposure from post-treatment assessment.

Area	Net Mineral Soil Exposure (%)	Range (%)	Gross Mineral Soil Exposure (%)	Range (%)	Avg. Width of Exposed Mineral (cm)	Range (cm)
Block 1	74.2	33.3-100.	13.0	6.4-18.0	44	10-70
Block 2	79.1	68.4-86.4	18.0	14.4-24.4	53	20-90
Block 3	76.1	28.6-100.	15.3	5.4-20.6	46	10-80
Overall[a]	76.0	28.6-100.	14.9	5.4-24.4	47	10-90

[a] Weighted average where appropriate.

Only the exposed mineral soil within the furrow was used to determine M.S.E. values. The mineral soil that was thrown on top of the humus, woody plant layer and debris was not included. In general, only the Ae layer or the top B horizon was exposed. The depth of the furrow was rarely greater than 10 cm below the surface of the duff. In a number of places, the duff "sod" was picked up or ripped off the surface exposing the Ae horizon and little mineral soil was removed and deposited on the overturned duff.

Figures 10 through 12 show the effects of scarifying with the Donaren 180D. Figure 12 shows an actual cross-section through the outside portion of a furrow. Note that little mineral soil was mixed into the organic soil. The mineral soil was simply deposited on top of the overturned duff. The duff resembled a thick sod due to consolidation by the root mass of the dense raspberry, young trees and other woody plants. The slash was well parted from the exposed mineral soil of the furrow.

The berm of overturned humus and mineral soil was not continuous. It was often interrupted by mounds of parted slash and brush. The width of the berm ranged from 0 to 70 cm but averaged 50 cm. Undisturbed competing vegetation was therefore approximately one-half metre from the seedlings if planted on the side slope. However, the metre-high raspberry would still be able to lean over onto the seedling, and revegetation of the berm and furrow will probably necessitate herbicide treatment in a few years.

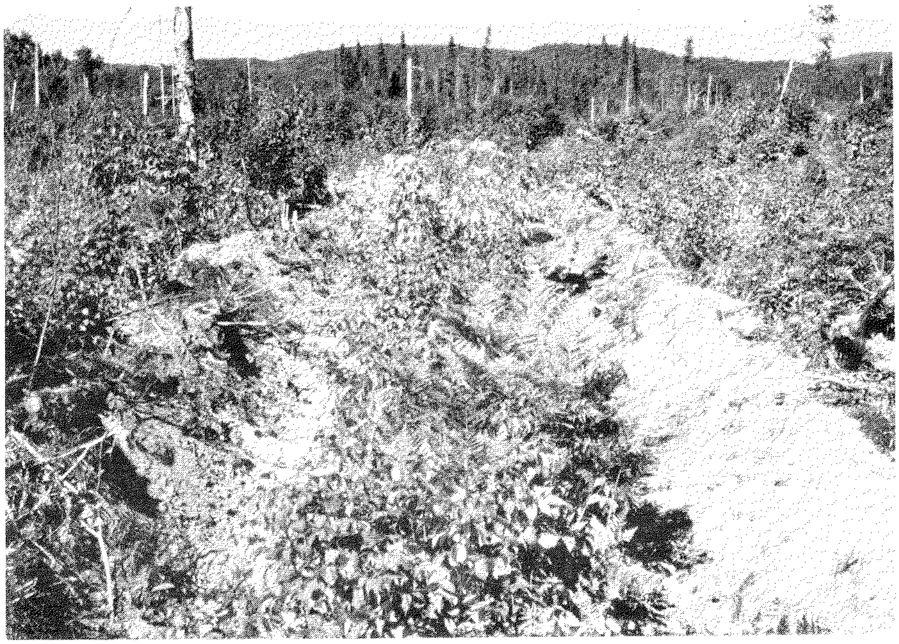

Figure 10. View of the two furrows created after a pass by the Donaren 180D. Soil and debris is pushed to the outside of each furrow. The raspberry is undisturbed at the centre of each pass.

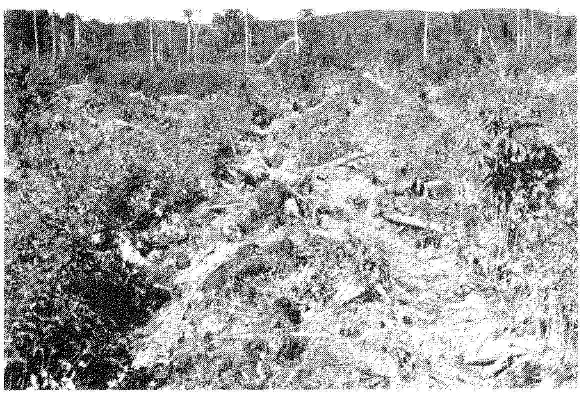

Figure 11. View of the debris piled up between two passes.

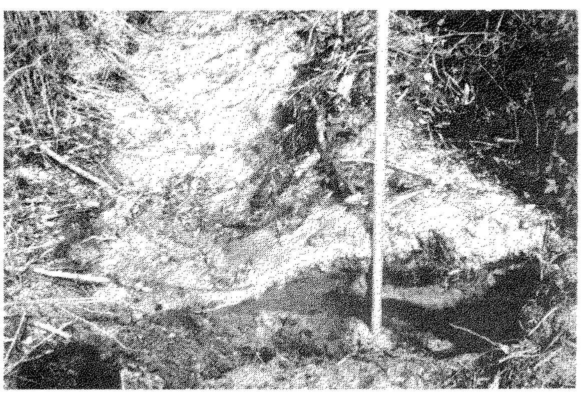

Figure 12. A cut has been made through the overturned portion of a furrow to expose the layers of humus and mineral soil. The location chosen to base the planting spot assessment is just left of the metre stick on the upper slope of the furrow.

DISCUSSION

Effect of Site Conditions on the Scarifier

A wide range of slopes between 0 and 30% was found in the study area. On slopes greater than 10%, there was a pronounced decrease in travel speed while scarifying. The machine could not scarify while travelling against the grade when the slope exceeded 25%. This was due not only to slope but also as a result of the ground roughness. The fact that the discs rotate in the same direction as the wheels should help to push the machine forward and aid in the overall gradeability of the machine.

The only stumps to pose any problems were the large white pine and white spruce stumps that were very scattered but tended to be hidden by the dense raspberry cover. Small balsam fir and spruce stumps were often ripped out by the disc trencher. The hydraulic overload accumulator circuit allowed the discs to ride over the larger stumps and return immediately to the soil.

Ground conditions were good for machine travel and for easy exposure of the loamy fine sand. The ability of the disc scarifier to handle terrain with stones and boulders cannot be stated as there were none found on the trial area. The discs and teeth showed no signs of wear after 125 machine hours.

The dead balsam fir residuals were not an obstacle to the machine as they could be pushed over with the blade or they would often break apart. One short delay was caused by a top that jammed next to the muffler of the skidder and began to smoulder. The operator would manoeuver around white birch residuals if they occurred in clumps. Individual white birch, up to 20 cm at d.b.h. could be pushed over. However, occasionally the upturned mass of roots and soil would impede further forward movement or the skidder would get hung-up as it rode over the upturned roots.

Brush had no effect on the productivity or quality of scarification except that occasionally a sapling would be twisted around a disk.

The moderate slash loadings were not a major impediment to the scarification. The two-year old slash was dry and often brittle. The powered disks and long teeth were able to penetrate the slash, expose mineral soil and transmit the slash away from the furrow. Generally, the added hydraulic downpressure was not required, and the float position was used. Slash was only a problem when a large and long stem, laying perpendicular to the direction of travel, caught between the teeth of both discs. The piece would then be dragged until it broke or was knocked off against a stump. Recently blown or knocked-down birch would not allow the discs to reach mineral soil but the discs would immediately return to expose mineral soil after riding over them. The same can be said for the obstacles presented by large stumps, long pieces of slash of large diameter (depending upon their alignment), and white pine tops. The arms would raise and the discs would ride over the obstacle. On a few occasions, the operator would raise the discs just in time to pass over the obstacle and then return them to the ground.

Productivity and Quality of Scarification

Productivity was good despite the following factors:

- frequent mechanical delays caused by the prime mover;
- the moderately difficult site conditions;
- small size of blocks to be treated;
- short pass length causing a high proportion of manoeuvering time;
- an operator with only two weeks prior experience on the machine and no previous scarification experience.

Following scarification, the debris was well removed from the planting microsite. The furrows were well defined and readily recognizable. The combination of these factors with the furrows running perpendicular to the road facilitates high manual planting productivity.

The Donaren produced an acceptable number of plantable spots. In a comparison of assessed planting spots and actual trees planted, the actual numbers planted were higher for Blocks 1 and 3. This would be expected since the estimated value is based only on the locations created by the scarifier, and the planter can often fill in areas not prepared. The lower value in Block 2 is a result of some furrows being missed by the planters.

The powered discs did not appear to mix the mineral and organic soils more than a passive disc trencher. The mineral soil that was removed from the furrow was well placed on top of the overturned humus at the side of furrow. The effect was therefore a good overturning of the soil but the mineral soil was not actually mixed or incorporated into the humus. This may have been site specific due to the sod-like duff layer found on the area.

The gross Mineral Soil Exposure was approximately 15% and the net M.S.E. was 76%. Armson (1978) reports an average of 5% gross M.S.E. (range: 2-10%) and 53% net M.S.E. (range: 33-81%) in a survey of 6 scarification projects using conventional TTS disc trenchers in Ontario.

The 15% gross M.S.E. produced by the Donaren is slightly under the 20% mineral soil exposure recommended for successful jack pine aerial seeding for Northeastern Ontario based on milacre plots and a seeding rate of 49 500 seeds per hectare (Riley 1980). However, the Donaren was set up and run with the intent that planting would be the following operation. Moreover, the 15% figure includes only the soil in the furrow exposed by the Donaren and does not include the mineral soil overturned and lying on top of the humus or the other areas of mineral soil created by other sources such as logging disturbance. The Donaren gave good distribution of mineral soil along a furrow as indicated by the net M.S.E. figure of 76%. Spacing between the discs could easily be decreased and the passes run closer together to increase the mineral soil exposure to accomodate a required standard of mineral soil exposure but at a penalty of lost production.

Advantages and Disadvantages of the Donaren 180D

Comparative trials of various trenchers on the same site or different sites in other regions were not made. However, the Donaren 180D, as studied in this project mounted on a modified skidder, demonstrated a number of advantages and disadvantages when compared to conventional disc trenchers.

Disadvantages

The Donaren 180D requires a slightly lower drawbar pull than conventional disc trenchers but there must be an addition of 35 kW to power the hydraulics of the Donaren. This added power requirement may be supplied by stepping up to a larger class of skidder or by an auxiliary engine. However, the Donaren requires a constant speed drive and any fluctuation in its speed lowers the effectiveness of scarification. A large skidder with a single engine will not function adequately unless equipped with a hydrostatic drive with priority to the Donaren.

The combination of purchase price and cost of modifications for the Donaren 180D and prime mover will produce a capital expenditure between two and three times greater than the strictly mechanical trencher.

Since the powered scarifier is more complicated, the mechanical availability may be expected to be lower, and the cost of maintenance and repair potentially higher than a convential disc trencher. However, the Donaren is direct-mounted, thus avoiding common trouble areas of the winch, cable and hitch. Mechanical availability may therefore be similar.

All powered and direct-mounted equipment require either a detachable, modified rear chassis or extensive modification on a larger, standard prime mover. This type of arrangement is very restrictive in a yearly, tendered site preparation contract system where one agency owns the silvicultural equipment and another supplies the prime mover. No longer can the hitch be simply welded or bolted onto the butt plate and the winch attached for the machine to be ready to scarify.

Advantages in Operation, Safety and Comfort

It is simple to change the spacing between the discs on the Donaren. Conventional disc trenchers have discs that are permanently set and the distance cannot be changed.

The hydraulic system dampens the shock of striking an obstacle rather than the discs, hitch and prime mover taking the shock.

The direct-mounted Donaren cannot be tipped independantly of the prime mover. The machine as a whole is more stable while scarifying. Hitch-mounted scarifiers are vulnerable to tipping and then may turn over the skidder, causing a long delay.

The detachable teeth on the Donaren are much more resistant to abrasive wear and to bending. Teeth are easy to replace by knocking out the locking pin. The teeth on a number of conventional models are more susceptible to bending because the metal and design are not as strong and the teeth and discs must take much of the shocks when running into stumps and boulders. These teeth are difficult to replace and extentions must be welded onto worn teeth or a complete disc replaced.

The discs can be lifted at the press of a button over large obstructions and while passing over bedrock. They can also be raised to straddle or go around advanced regeneration, which may make it feasible to treat patchy failure areas.

All trenchers produce spaced, continuous furrows which have a number of advantages over dip and raise techniques, or patch scarifiers for subsequent planting. However, continuous furrows are erosion prone when made directly up- or downhill, yet this may be the only practical technique since scarifying side slope becomes a safety risk on slopes over 15-20%. With the Donaren, it is feasible to periodically interrupt the furrow while scarifying up or down the slope, thus decreasing the risk of erosion.

The raising of the discs by the touch of a button results in less time being taken while manoeuvering or moving between blocks. This becomes more important as the blocks get smaller. Conventional disc trenchers, after being raised by the winch (if they can be?), are allowed to sway from side to side until they hit the buttplate. This makes the unit unsafe, and it can cause damage to the trencher and buttplate, and strains the hitch. The Donaren is therefore safer and faster while manoeuvering around obstacles along a pass or between passes. There were a number of areas encountered during the study where turning on a ridge would have been unsafe with fixed hitch and winch raised equipment.

Both types of disc trenchers need only a small lowbed trailer if mounted on standard or modified North American prime movers. Some piece of silvicultural equipment require special lowbeds. In the case with drags, a loader of some form is also required.

For long moves on a float, the Donaren has locking bars to hold the arms up as a safety precaution. Standard trenchers do not have such a convenience.

A smoother ride for more operator comfort and less fatigue is possible with the Donaren since, as previously stated, the shocks from hitting obstacles are taken by the hydraulics. The mechanical trenchers transfer more shocks to the prime mover. As well, the longer wheelbase, created by using a forwarder chassis, produces a smoother ride. However, this is at the expense of a wider turning circle.

Advantages in Effectiveness of Scarification

Conventional trenchers can be adapted for different site conditions in two ways: by adding weight into the bunk between the discs, and by changing the angle of the discs. A wide angle produces a wider, shallower furrow. However, it is more difficult to handle slash and there is a greater tendency for the discs to drag, resulting in retarded disc rotation and poorer clearing of slash and soil away from the furrow. A narrow setting results in a narrow, deep furrow and the discs can penetrate through the slash more readily. The discs turn more freely but in heavy slash the discs may simply turn and ride over on top of the slash if there is insufficient weight. The narrow setting may also produce too deep a furrow. In any setting, slash and debris can fall back into the trough if the rotation speed of the discs is too slow. Lengths of slash greater than 2 metres can lodge between the discs and are then dragged. Heavy slash is therefore the main obstruction to the conventional disc trencher's effectiveness.

Changing angles and weights to cope with various site conditions is an advantage. However, it is not feasible to change angles or loads in areas of rapidly changing soil and slash conditions. Changing the angle alone can take 5 to 10 minutes.

In moderate to heavy slash, there is a dilemma if aerial seeding is to follow. The angle must be made narrower in order to penetrate slash, however, the furrow width and resulting gross M.S.E. is greatly reduced.

Also, the conventional trenchers can bounce into the air with frequent encounters with boulders and stumps at higher speeds. This causes missed spots or over-scarification if all the weight of the trencher is on one disc.

The Donaren has, in its design, alleviated many of the inherent problems of conventional disc trenchers. The Donaren can produce a constantly higher mineral soil exposure because the discs are permanently set at a wide angle producing a wider and shallower furrow. Slash penetration, debris transmission from the furrow and constant disc rotation are provided by hydraulic downpressure and powered discs. M.S.E. values will therefore be higher in both 'net' and 'gross' terms. As well, the arms and discs work completely independent of each other. The discs raise and ride over obstacles and then immediately return to the ground. They do not bounce into the air, but they keep in constant contact with the ground or an obstacle.

It should also be noted that when the discs rise and fall to follow the contours of the terrain they remain parallel to each other and perpendicular to the ground. Thus, constant spacing is maintained between the discs and the furrows. Some hydraulic disc trenchers have a deltoid action as the discs are raised or lowered. This results in an increased furrow spacing when the discs are below the contact surface between tire and ground and a decreased spacing occurs when the discs are higher in relation to the tire and ground contact.

Ergonomics

The cage that protects the auxiliary power unit does not allow a clear view of the scarifying discs.

Both the floor mounted switch to control the power to the discs and the panel to control the operating position of the discs were easy to use and within easy reach of the operator.

Sound levels in the skidder cab fell outside the acceptable limits prescribed by the province of Québec and by the U.S. Department of Labour. Details of the noise measurements are presented in Appendix D.

An operator is not exposed to a high continuous noise level on a cable skidder during skidding operations since he is off the machine during choking and unchoking. On the other hand, there is a continuously high noise level when a skidder is used on scarification. Therefore, the average dBA reading is much more critical in skidders when used on scarification operations. The operator wore hearing protection during the study.

Modifications

The main mechanical problem experienced with the Donaren by the company was the lack of guarding of the hoses. The heavier slash and brush in Canadian cutover conditions compared to Scandinavian ones has resulted in the company running guards along the downpressure cylinders and around the hydraulic motors to prevent debris from striking the hoses and valve fitting leading to the hydraulics motors and to the end of the cylinders.

As well, the problem of young saplings being twisted around the discs has been reduced by welding a cleaning stop on the arm close to the disc as shown in Figure 13.

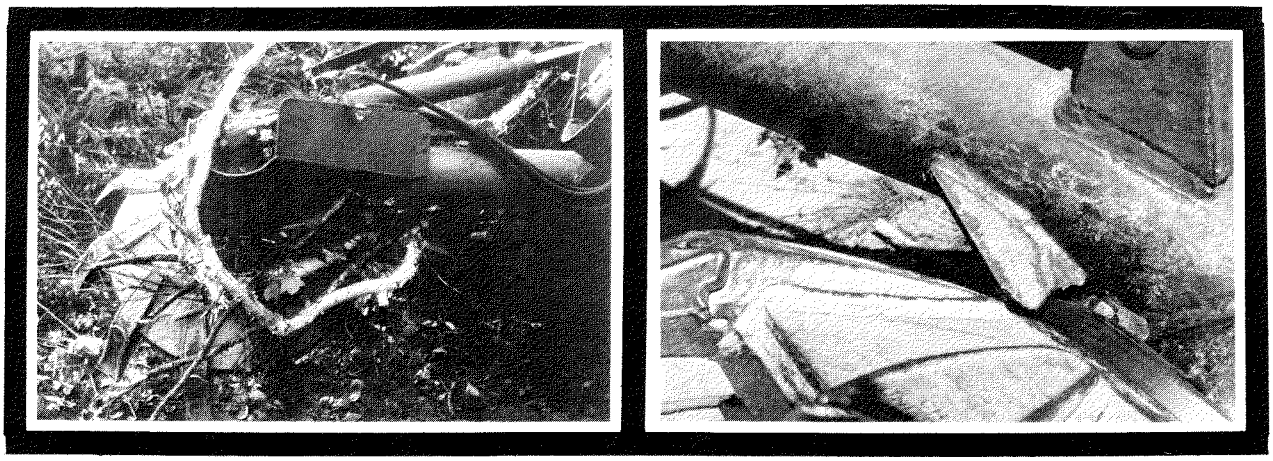

Figure 13. Build up of brush around the disk is shown on the left. A piece of metal welded on the arm near the disc (right·photo) helped reduce this problem.

CONCLUSION

In the study, the Donaren 180D produced good results in terms of productivity, and in its ability to prepare planting spots and expose mineral soil along the confines of the furrow. The hydraulic features of the scarifier increase the effectiveness of scarification and produce a number of operational advantages over mechanical disc trenchers.

Due to the short duration of the study, the site condition variables were limited. The performance of the Donaren in sites with dense brush, boulders, stony soils, fine-grained soils, and fresh slash has not been demonstrated. However, the results of this study suggest that the Donaren may handle these untested site conditions better than conventional disc trenchers.

The Donaren has a higher capital cost compared to non-powered trenchers and requires more costly prime mover modifications. Whether the machine can reduce the cost per hectare cannot be answered by this short-term study. Availability and longer-term productivity must be evaluated in a long-term "Shift Level Availability and Productivity" study which FERIC normally uses to follow-up a short-term evaluation. Moreover, the ultimate success of the Donaren will depend not only on its productivity, but also on its mechanical availability, cost of maintenance, and utilization. However, other factors favour the Donaren such as better scarifier effectiveness resulting in better biological results, and the ability to treat a larger number of site types and more difficult sites.

The extensive prime mover modifications may be a deterrent under the arrangement of one party owning the piece of silvicultural equipment and another supplying the prime mover on a tendered basis. This arrangement is prevalent in a number of provinces across Canada.

The choice of any powered equipment over passive models is not only a question of increased scarifier effectiveness in various site conditions, initial capital cost, or productivity; it is also governed by the availability of a proper sized prime mover and the feasibility of making permanent or annual modifications. Scandinavian powered scarifiers are designed to be mounted on large forwarders which are not generally used in Canada. The more common sizes of North American skidders may not have the required power. If an auxiliary engine is to be used on a smaller skidder, the rear chassis must be modified by removing butt plate, arch and winch. There may simply not be enough room on the standard rear chassis for all the modifications. If the required prime mover is larger than the models in a company's fleet, then a decision is required whether to commit a larger prime mover for site preparation or to modify a rear chassis to which an auxiliary motor can be attached.

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APPENDIX A
TECHNICAL DATA ON THE MACHINE

Donaren 180D

disc diameter	- 950 mm
diameter including teeth	- 1250 mm
number of teeth/disc	- 10
length of teeth	- 150 mm
furrow spacing adjustment	- 1.0-2.75 m
maximum movement - up	- 1200 mm above ground surface
- down	- 1250 mm under ground surface
disc rotation adjustment	- 15-30 rpm
hydraulic motor	- Danfoss - 315 cm^3 displacement
planetary drive	- Reggiana Riduttori 'Gear Type' (7 to 1 ratio)
necessary hydraulic pressure	- 16 mPa
necessary flow at 20 rpm	- 88 L/min
torque (at 16 mPa)	- 4700 Nm (480 kpm)
required power on prime mover	- 90-115 kW (with driven discs add 35 kW)
weight	- 2300 kg

Auxiliary Power Unit

Engine: Deutz (model F4L-912)
- air cooled
- 4 cylinders
- 41 kW @ 2000 rpm DIN 6270
- 3.77 litre displacement
- dimensions - length - 810 mm
  width - 661 mm
  height - 803 mm
- weight - 300 kg

Pump - Dowty (model 3P-3180)
- gear type
- fixed displacement
- 110 litres/min capacity @ 2000 rpm, 3000 psi

Reservoir Capacity ....
- hydraulic oil (Donaren 180D) - 182 litres
- fuel tank (Deutz) - 104 L
- fuel tank (Clark 667C) - 195 L

Prime Mover

Clark 667C grapple

engine - Cummins diesel (V-378C) - 104 kW SAE (J816)

power train - torque converter - Clark industrial type
- transmission - Clark powershift, 3 speed
- travel speeds shown are with 24.5-32, 16 PR tires,

1st	2nd	3rd
8.2 km/h	15.3 km/h	30.0 km/h

tires: 30.5-32, 16PR

Further specifications are available from the manufacturers on request.

APPENDIX B
TREE SPECIES FOUND IN STUDY AREA

Common Name	Scientific
Spruce	*Picea* A. Dietr.
Black Spruce	*Picea mariana* (Mill) B.S.P.
White Spruce	*Picea glauca* (Moench) Voss
Blasam fir	*Abies balsamea* (L.) Mill
White Pine	*Pinus strobus* L.
White Birch	*Betula papyrifera* Marsh.
Yellow Birch	*Betula alleghaniensis* Britton
Pin Cherry	*Prunus pensylvanica* L.f.
Beaked Hazel	*Corylus cornuta* Marsh.
Red Elderberry	*Sambucus pubens* Michx.
Mountain Ash	*Sorbus* L.
Red Maple	*Acer rubrum* L.
Sugar Maple	*Acer saccharum* Marsh.
Mountain Maple	*Acer spicatum* Lam.
Nannyberry	*Viburnum lentago* L.

APPENDIX C
DEFINITION OF TIME ELEMENTS

To assess the productivity of the Donaren 180D, time studies were carried out using an electronic watchboard. Productive time of the machine was divided into the following elements:

1. Scarify: begins when the discs touch the ground and the machine starts moving, and ends when the discs are raised.

2. Move During Pass: occurs during a scarification pass when the operator chooses to move around an obstacle. If the machine stops or is put into reverse for greater than 15 cmin it is recorded as a 'delay'. The element begins when the discs are raised and ends when the discs enter the ground to begin scarification along the same pass.

3. Clean Discs: begins when the discs are raised to be cleared of debris and the machine stops forward motion, and lasts until the discs enter the ground and the machine continues forward motion.

4. Manoeuver: occurs after the completion of a pass and includes the manoeuvering time required to begin another pass. It begins with the raising of the discs and ends when the discs touch the ground to begin scarifying.

5. Delay: includes operational delays such as being stuck, supervision, mechanical breakdowns, and personal delays. These were allocated differently depending upon their duration.

0 - 15 cmin:	were included in the first four time elements.
15 cmin - 15 min :	were recorded as 'delay' under the cause of delay.
15 min or greater:	were not considered as productive time (PMH) and were therefore excluded.

APPENDIX D
MEASUREMENT OF LEVEL AND FREQUENCY OF NOISE

Measurements of level and frequency of noise were made inside the cab during the study period, using a Brüel & Kjaer precision sound meter (model 2204) and an octave filter set (model 1613). The machine was stationary at roadside but the engine speed was set at an rpm that the operator felt was typical when scarifying. The skidder had an enclosed cab but both side windows were jammed open by approximately 5 centimetres.

Average sound pressure levels were obtained giving an average of 101 dBA with the Clark engine only, 82 dBA with the auxiliary engine only, and 103 dBA with both engines running. Figure D.1 shows the observed dBA value for both engines running plotted over an estimated exposure time during a shift. The duration of exposure is calculated from data recorded during the study and from a one month shift level availability study. The permissible exposure curve adopted in 1969 by the U.S. Department of Labour (Beranek 1970) is also shown and is equivalent to Québec's regulations. This curve assumes a continuous period of noise of specified length. The noise level is somewhat variable during scarification which is an advantage over continuous noise.

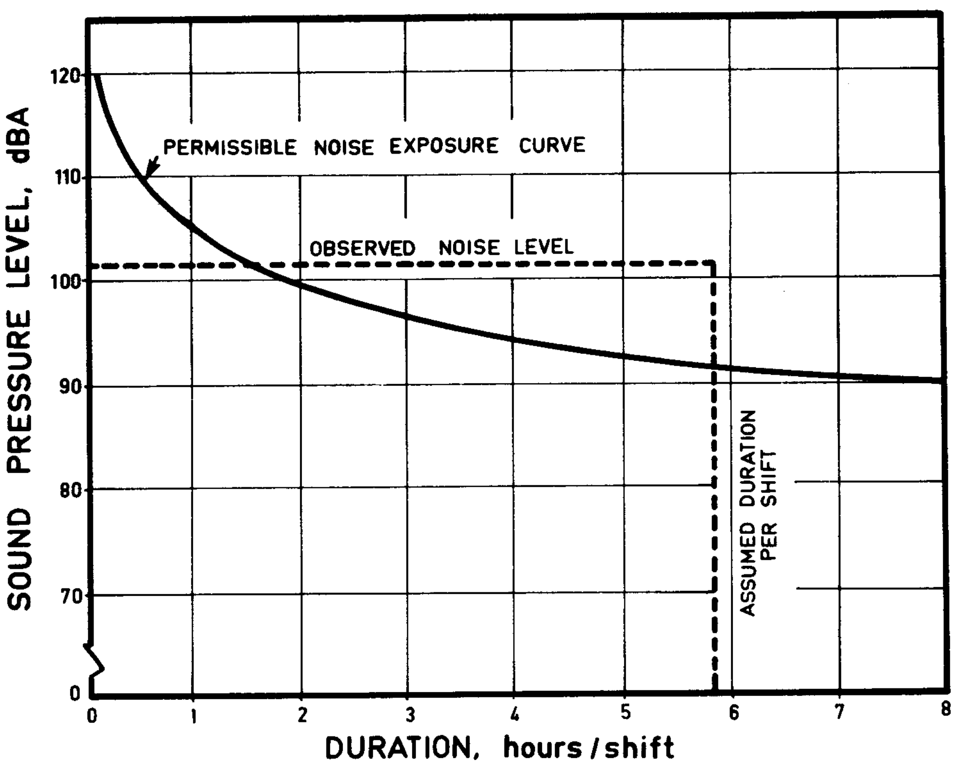

Figure D.1. Observed average noise level (dBA) inside cab, plotted over estimated exposure time, compared to the permissible exposure curve of U.S. Department of Labour. Cab side windows open and both engines running.

Sound pressure levels within octave bands were measured and illustrated in Figure D.2. Average values are given for skidder engine only, auxiliary engine only and for both engines. Maximum values are given for both engines running.

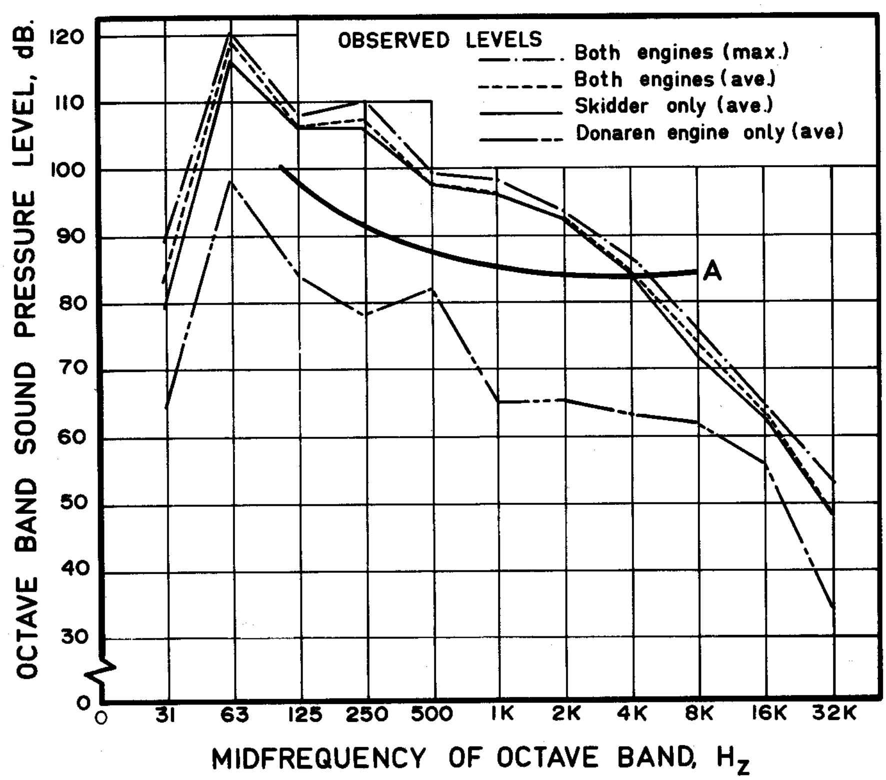

Figure D.2. Observed noise levels in octave bands. Curve A shows the damage risk curve for one exposure per day of duration less than 6 hours to 1-octave band of noise. This curve is interpolated from Kryter, et al. (1966).

During the study, measurements of noise level (between 90 and 114 dBA) integrated with duration of exposure were taken using a Columbia Research Personal Noise Dosimeter (model SPL-104 AB). The readings from the Dosimeter are plotted against time in Figure D.3. The instrument is calibrated to read 1000 when the product of noise level and time has reached the permissible noise exposure limit. The mean value of the measured shifts indicates that the permissible exposure limit was reached prior to 2 hours of operation and the noise level inside the cab is approximately 102 dBA.

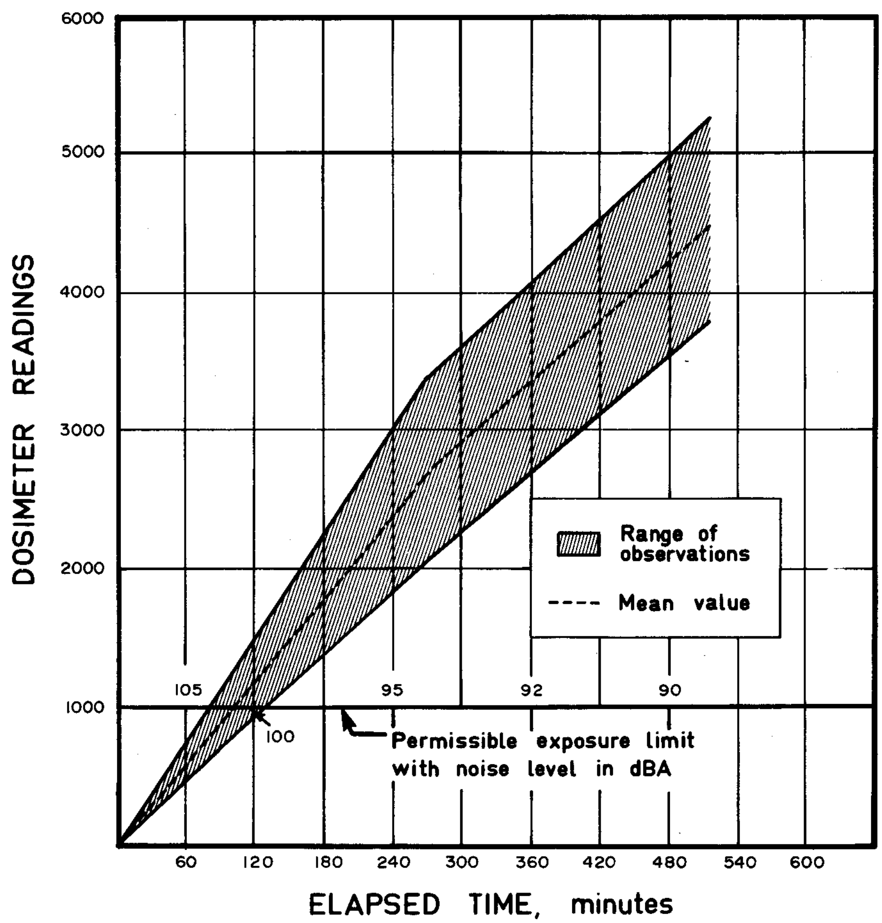

Figure D.3. Observed noise levels (dBA) integrated with time of duration as measured with a Noise Dosimeter.

The noise levels measured in the study greatly exceeded the current permissible limits of the U.S. Department of Labour based on dBA and octave band criteria. The main source of noise was from the skidder engine. The auxiliary engine to power the hydraulics of the Donaren did not add significantly to the high sound pressure levels in the cab. The age of the skidder and the improperly closed side windows contributed to the noise problem.

APPENDIX E
CONVERSION TABLE

1 mm (millimetre)	=	0.039 inch
1 cm (centimetre)	=	0.39 inch
1 m (metre)	=	3.28 feet
1 km (kilometre)	=	0.62 mile
1 ha (hectare)	=	2.47 acres
1 L (litre)	=	0.22 Imperial gallon 0.26 American gallon
1 kg (kilogram)	=	2.20 pounds
1 kPa (kilopascal)	=	0.145 pounds per square inch (psi)
1 kW (kilowatt)	=	1.34 horse-power