Using the Leykam Logline to evaluate chuting in South Africa

by

Benno Wolfgang Krieg

Thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science

at the
Faculty of Forestry
University of Stellenbosch
Stellenbosch

October 1991

Study leader: Prof. W. Warkotsch

Declaration

I the undersigned hereby declare that the work contained in this thesis/study project is my own original work and has not previously in its entirety or in part been submitted to any university for a degree.

Date: 17/02/92.

Summary

Timber harvesting and extraction on sloping terrain has always proved to be a world wide problem. It is often associated with strenuous work and/or possible damage to the environment. Vehicular movement is normally handicapped on slopes exceeding 30 %. Their maximum payload volume decreases 2.5 % for every 1 % increase in the slope (Warkotsch, 1985). The introduction of chutes provides an acceptable alternative extraction method.

One of the first chute systems used in South Africa was the Leykam Logline, imported from Austria in 1986. General interest in chutes led to the development of several local versions, culminating in a coordinated project to determine the chute's applicability in South Africa.

The initial technology transfer for the Leykam Logline was insufficient with the necessary knowledge to operate that chute correctly lacking. European working procedures and principles were applied to determine their applicability under South African conditions. It was found that although some changes, for example to the braking system, were needed, these principles could be applied. Productivity during these trials averaged 0.8 to 1.2 m^3/man hour.

Despite drawbacks and initial teething problems, the chute represents a new dimension in modern harvesting technology in South Africa. It represents an important improvement in ergonomics when compared to the traditional hand-rolling method and it is a practical extraction aid. Finally and of great importance is the fact that the chute is an environmentally friendly extraction method.

Opsomming

Die ontginning van hout teen hellings was nog altyd 'n probleem. Dit word dikwels verbind met harde werk en/of moontlike skade aan die terrein. Warkotsch (1985) het bevind dat die gebruik van sleep trekkers ('skidders') op hellings steiler as 30 % beperk is. Die maksimum vrag volume neem met 2.5 % af vir elke 1 % styging in die helling. Die ingebruik neming van glybane ('chute') verskaf 'n moontlike alternatiewe metode van ontginning.

Een van die eerste glybaanstelsels wat in Suid-Afrika gebruik is, was die Leykam Logline wat in 1986 vanaf Oostenryk ingevoer is. Die algemene belanstelling in glybaanstelsels het gelei tot die ontwikkeling van verskeie lokale weergawes. 'n Gekoördineerde projek is begin om glybane se aanwending in Suid-Afrika te bepaal.

Die aanvanklike oordrag van tegnologie met betrekking tot die Leykam Logline was onvoldoende. Die nodige kennis vir die doeltreffende aanwending van die Leykam Logline het dus ontbreek. Die Europese werksbeginsels is toegepas om hulle bruikbaarheid onder Suid-Afrikaanse omstandighede te bepaal. Sekere veranderinge, waarvan die remstelsel die belangrikste is, was nodig.

Ten spyte van aanvanklike probleme verteenwoordig die glybaan 'n nuwe dimensie in die ontginnings tegnologie in Suid-Afrika. Dit is 'n praktiese ontginnings hulpmiddel met spesifieke toepassing op die mynhout- en papierhoutbedryf. Ergonomie en produktiwiteit kan verbeter word indien die glybaan die handrol metode vervang. Die feit dat min skade aan die terrein aangerig word tydens ontginning is 'n belangrike voordeel van die glybaan.

Acknowledgments

I would like to thank the following:

Lotzaba Forest Co. for making available the Leykam Logline, providing accommodation and help and for their financial support of the project.

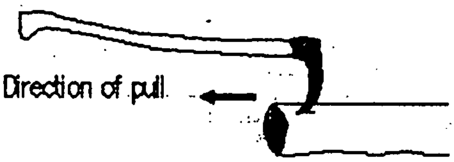
The Department of Water Affairs and Forestry for financial assistance and allowing me to attend important meetings of the Chute Project Group.

Miss R. Smith, and Miss C. Machiné and Mr G. Olsen for assisting with editing.

Glossary

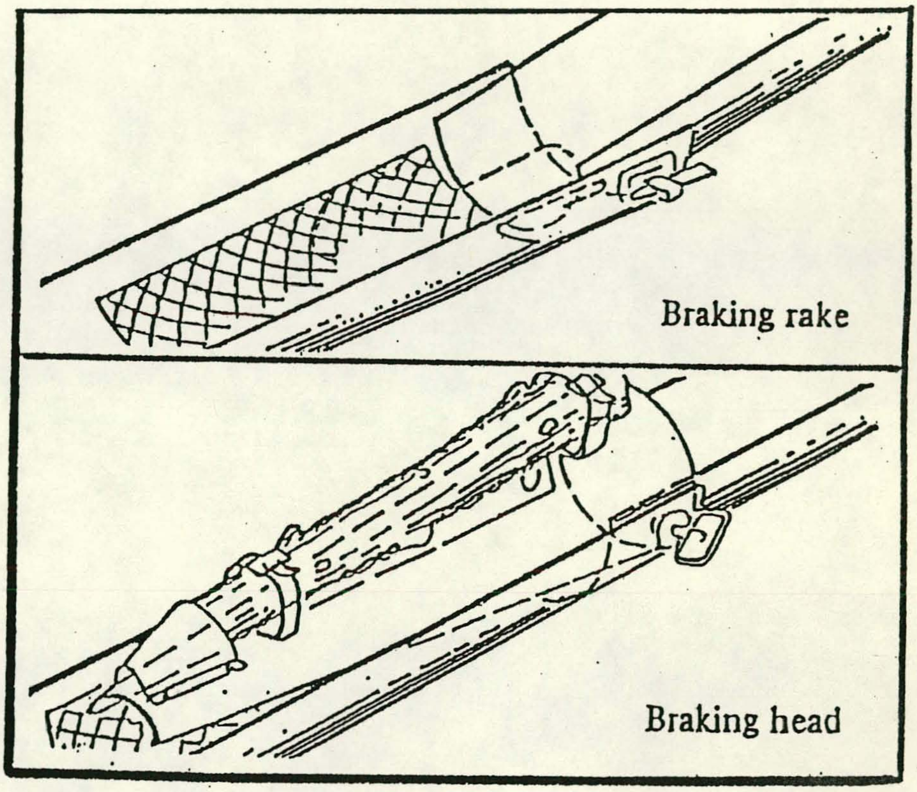
Annual utilization	- the total hours a machine is used during one year.
Brush lines	- branches and other waste material packed in lines spaced at pre-determined distances
Chute piece	- a single segment of a chute
Chute section	- a group of chute pieces linked together
Fan-chuting	- when the upper section of the chute is being swept from side to side to extract a larger area without having to shift the entire chute
Marginal sites	- sites on which tree growth is just sufficient to ensure a profitable investment.
Marginal utilization	- that utilization, which a machine has to achieve to become profitable - or where its capital lay-out is warranted.
Sappie hook	- a curved draw hook used to handle logs. They come in various weights (of the hooks) and lengths. The ranges are as follows:

Hook weights		Draw handle length	
minimum	maximum	minimum	maximum
300 g	1450 g	365 mm	1300 mm



Screw locks	- used instead of the wedge locks when the wolf construction is used
Traversing	- the chute does not follow the shortest path down the slope, but runs across the slope
Wedge locks	- it is a patented lock with which the chute pieces are locked together
Wolf construction	- (or braking head) a flap fitting over the

braking grid (or braking rake) of which the front end lies inside the chute. The braking head may be weighted. A log passing between the braking grid and the braking head, lifts the flap which presses the logs against the grid resulting in increased friction and braking the log.



Braking rake

Braking head

1. Introduction

Timber harvesting is an expensive operation. In South Africa the use of larger extraction equipment such as skidders and forwarders has become more common than in the past. Indiscriminate use of heavy machines on steep slopes, wetlands and sensitive soils are responsible for severe site damage. A lack of planning of harvesting operations and the incorrect application of equipment aggravate the problem.

Due to the high cost of extraction operations and the limitations of commonly used harvesting equipment, small sized timber has often been left unharvested. Traditional extraction methods of this small sized timber, such as hand-rolling, are often strenuous, labour intensive and unproductive. Advanced technology on the other hand, is often expensive and requires a higher degree of skill and improved training. Intermediate technology often bridges the gap between traditional methods and modern technology. Investment costs are reasonably low and the skills required can be easily acquired by the user. Chutes therefor have most of these favourable characteristics including a very low environmental impact.

1.1 Chutes - the concept

In principle the chute may be described as an inclined channel or vertical passage down in which various substances may be transported. It could also be regarded as a slide. The principle is only applicable on gradients where the force of gravity exceeds the frictional resistance between the chute and the substance sliding down the chute. In the timber industry chutes are mainly used to extract timber from steep or sensitive slopes.

1.2 Chute history

Chutes have a long tradition. Originally they were constructed in ravines using round timber which was aligned to form a rough platform for the timber to slide down. These chutes were often dangerous as there was little control over the speed and movement of the extracted timber. Building chutes then became a trade, requiring carpenter skills to construct a durable and relatively safe chute. Remuneration developments in Europe eventually made the construction of these chutes too expensive. During the early years of the second World War, the Americans produced the first steel chute (Figure 1). The chute was one of the first to comprise of various pieces which were assembled. This chute proved to be a considerable saving compared to the then conventional animal extraction. These chutes were generally used on permanent or semi-permanent extraction lines.

In Switzerland during 1969, Adolf Hess (Hess, 1975) developed an aluminium chute consisting of individual chute pieces. In 1975 the Leykam Logline (hereafter referred to as the LLL) was marketed in Austria (Figure 2). It was made from polyethylene which provided the characteristics of flexibility and durability.

1.3 Leykam Logline (LLL)

The LLL was imported to South Africa (R.S.A.) through the initiative of Mr. D. Daitz of the Lotzaba Forest Co. during 1987 (Daitz 1988; *pers. comm.*[1]). Unfortunately senior management could not be convinced that the additional cost of the transfer of technology in order to operate the chute effectively was necessary. This transfer could have been achieved either in the form of a training course or a seminar, whereby the distributor could share his knowledge of the system with the intended users.

The South African timber industry is at the bottom of the learning curve regarding many aspects. Operating a chute system efficiently requires a fair amount of skill and experience. The educational standard in the black work force is relatively low, making good technology transfer important yet difficult.

2. Objectives

Three primary objectives were identified:

2.1 To develop a chute system suitable for South African requirements and conditions. This chute system should be able to replace the existing method of free skidding by gravity. The following steps were identified:

---

[1] P.O.Box 298 Barberton 1300

- test the LLL as it was initially applied
- introduce and test the 'correct' application of the LLL
- identify shortcomings and problems of the LLL and rectify them if possible. Some of the problems were:
    - Training. Incorrect methods of application were entrenched and had to be changed.
    - Brakes. The brakes provided proved to be ineffective and alternative solutions had to be found.
    - Pre-planning. A lack of planning was evident. This was due to a combination of lack of skills and apathy.
    - Environmental aspects. Extremely high temperatures caused the chute to expand and bend under the strain of the stabilizing ropes.
    - The landing. The incorrect choice and use of landings resulted in 'match stick piles' and the duplication of work.
    - Stabilization. The principle and method was unclear and deemed unnecessary.
- provide suggestions as to how to improve the chute and its operation.
- To introduce a chute suitable for South African conditions.

2.2 To evaluate the relevant ergonomics and their influencing factors. The evaluation was mainly concentrated on the determination of energy requirements.

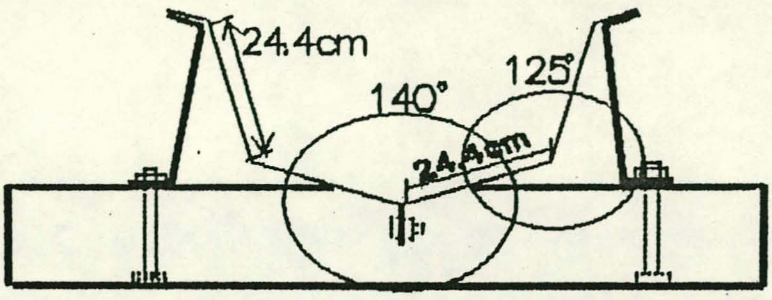
2.3 To prove that the chute has minimal environmental impacts on the site. A comparison with other extraction methods will be undertaken using the New Zealand Forest Practice Code.

3. Study approach

3.1 Situation analysis

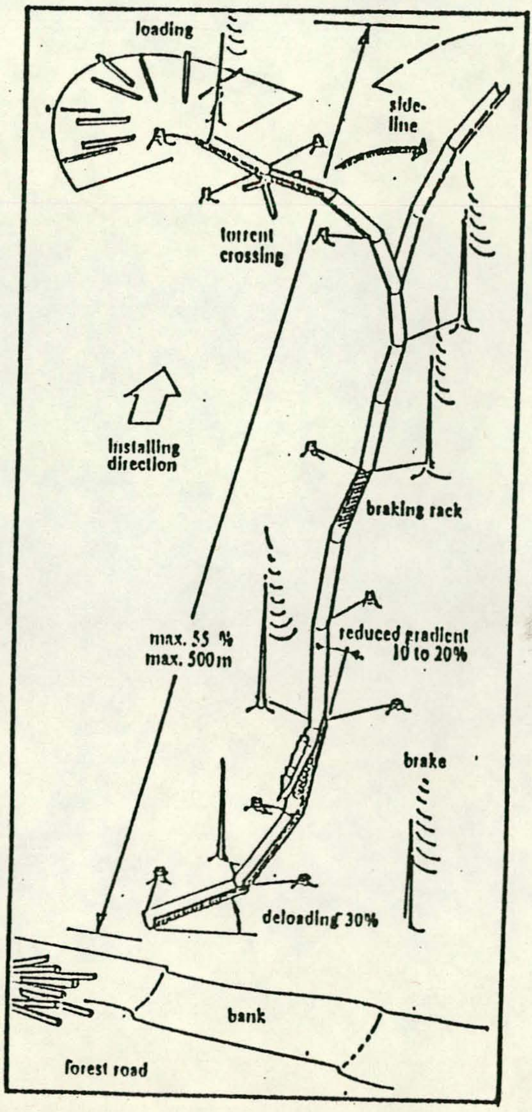
The principle of using chutes to extract short wood timber from steep sites was already generally accepted. At the inception of the project, various companies were experimenting with other chute systems. The individual chutes are described briefly:

Figure 1 - The post-war American steel-chute- a cross section



A sectional chute consisting of two sections bolted together

Figure 2 - The Leykam Logline (after Merkator)



3.1.1 Mondi (Natal Tanning Extract, or NTE)

This chute was made from high density plastic (HDP) consisting of individual chute pieces linked together to the required length. Each chute piece had a single set of legs, at one end only, on which it rested. The pieces were simply settled into one another and secured with chains. Fixed curved pieces could be added at the bottom to facilitate parallel landing on the road (Widdows 1989; pers. comm.[2]).

3.1.2 HL&H

HDP chutes were also used. One set of legs at each end were mounted on the sides of the chute. The pieces were assembled as above, without using a chain to secure the pieces (Bezuidenhout 1989; pers. comm.[3]).

3.1.3 The Department of Environment Affairs

Their chute was similar to the model used by Mondi, but with two sets of legs at each end (de Kok 1988; pers. comm.[4]).

3.1.4 SAPPI (South Africa Pulp and Paper Industry)

Similar to the chute used by the Dept. of Env. Aff. This chute was, however, slightly more stable possibly due to better designed legs (Botha 1989; pers. comm.[5]).

3.1.5 Hulett Aluminium

Aluminium pieces with legs similar to the above mentioned model were produced. A braking system was also available forming an integral part of the complete chute.

Simultaneous development and testing by various companies was done in semi-secrecy with the common aim to produce a South African chute. Most of these projects were, however, regarded as side line operations and did not receive sufficient funding and attention. Many of the prototypes suffered similar shortcomings. Due to a lack of communication and co-operation, some participants 're-invented the wheel' resulting in wasted time, money and effort.

---

[2] Mondi Forests, Richmond Natal
[3] HL&H Forests, P.O.Box 783 Piet Retief 2380
[4] University of Stellenbosch
[5] SAPPI Forests Private Bag X1002 Ngodwana

Lotzaba Forest Co.[6] decided to invest in the LLL in order to put a proven product to the test in South Africa. According to Warkotsch, Brink & Zietsman (1989) 1.36 million hectares are currently under plantation in South Africa. Of this total area 23 % exceeds a gradient of 20 % making it suitable for chute extraction.

3.2 The LLL

The LLL tests were conducted at the foothills of the Drakensberg Mountain range in the South Eastern Transvaal at Lotzaba Forest Co. The chute was mainly used for the extraction of short wood on slopes ranging from 25 to 70 %. Extracted logs ranged from 5 to 40 cm in diameter and 1.8 to 2.4 m in length, with respective averages of 15 cm and 2.4 m. The Continuous Timing method was chosen as the time study method with between one and three timers operating simultaneously. All field tests were subjected to strict management rules which required the chute to operate at maximum possible productivity. This put restrictions on the scope of the study. Observations were therefore often limited and at times invalid and therefore can only be used as indicators of trends.

The chute had been in use for approximately six months prior to the commencement of the project. On their own initiative Lotzaba Forest Co. established a modus operandi for the chute. It consisted of the repeated use of short chute sections in succession to extract timber down the slope. Several problems were experienced with this method. Some examples of such problems were:

- the instability of the chute due to insufficient stabilization
- the danger of unguided logs exiting the chute
- and the repeated effort needed to extract the same log more than once (multiple handling of logs)

This led to the implementation of a chuting system as promoted by the manufacturers. The chute is installed in one long section ranging between 80 and 200 metres, and then stabilized and tied down. The gradient of the descent is

---

[6] Lotzaba Forest Company, P.O.Box 298 Barberton

controlled by traversing the slope thereby controlling log speed.

4. Methods

4.1 Description of LLL

The LLL is made from polyethylene (polythene) and is reputed to withstand temperature fluctuations from -30°C to 90°C (Nydegger, 1986; Tauer, 1977). Schlaghamersky (1977) reports that the chute should, however, not be subjected to temperatures exceeding 60°C. The technical data of the chute is as follows:

- length of an individual chute piece	5 m
- overlap of the chute pieces	30 to 35 cm
- wall thickness	9 mm
- diameter	35 cm
- outer circumference	66 cm
- weight of an individual chute piece	25 kg

Stabilization is done using 8 or 10 mm thick nylon ropes, 4 to 5 m long. Additional equipment includes the U-shaped mesh iron braking grid and the Wolf construction (or braking head - referred to as Wolf hereafter - also see the glossary). The grid is between 3 and 4 m long, while the Wolf measures 3.5 to 4 m in length. The grid and Wolf are used in combination in the braking mechanism as illustrated in the glossary.

4.2 Description of European application

4.2.1 Material and tool requirements

Assuming a chute of 150 m and a slope of between 15 and 50 %.

- 30 chute pieces
- 60 wedge locks
- 40 ropes
- 1 braking grid
- 1 set of braking grid locks (screw locks)
- 1 small winch
- 1 chain saw
- 1 sappie hook (the lighter version)
- 1 small axe

- 1 petrol/oil container for chain saw
- 1 container with soapy solution
- 2 two-way radios

During the installation of the chute certain laws of physics have to be taken into account. The friction coefficient is the frictional resistance divided by the vertical pressure by an object on its support (Knaurs Lexikon a-z, 1975). As soon as the slope of the chute exceeds the friction coefficient (or critical angle), timber in the chute will accelerate uniformly (Nydegger, 1986; Helmer (1983)). This acceleration is further dependent on timber length, timber diameter, timber surface (moisture, resin, bark type, bad de-branching, etc.) and the path of the chute (horizontal and vertical changes). Curves have a braking effect on the timber. During dry conditions the ideal slope for the chute is between 25 and 30 %.

4.2.2 Work planning and organization

Site conditions

- The minimum slope, depending on the timber and climatic conditions, is 15 to 20 %.
- The maximum slope may, depending on the extraction length and braking strategy, be 50 to 60 %.
- Before installation of the chute, alternative extraction lines need to be examined.
- Strongly undulating sites cannot be extracted, due to high installation costs.

Timber conditions

- Maximum diameter of the log at the thick end (with or without bark) is 30 cm.
- Maximum length of the log is 6 m, while 2 to 4 m logs are regarded as optimal.

Installation of the chute line

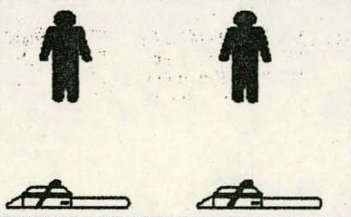
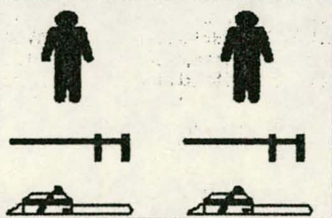
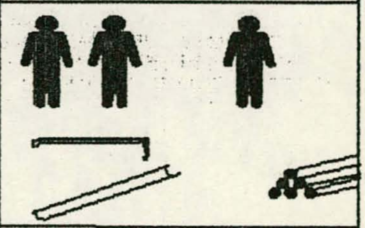
- The extraction lines are planned and marked before the thinning or clear-felling operation begins.
- A well executed felling operation can reduce chute installation times radically.
- Extraction lines straight down the slope are

recommended, depending on the slope and extraction length (i.e. log speed permitting). To facilitate easy storing of the timber at the landing, the chute must approach the landing at a sharp angle. This often results in logs rolling to a rest at the landing.

- Extraction across the slope (traversing). Traversing is used in conjunction with an effective braking strategy when log speeds become too high. The use of brakes and their positioning is mainly dependent on log speed.
- The distance between extraction lines has a direct influence on productivity. Depending on timber volume, the lateral distance the chute is shifted between extraction lines varies between 15 to 30 m. A small volume, depending on the terrain, requires a wider chute spacing. High volumes and favourable terrain (resulting in cheaper installations) favour closer chute spacings. Based on the ratio of installation cost versus the cost of carrying the timber to the chute the most favourable distance in dry weather is approximately 20 m.

4.2.3 Choice of operational method

Figure 3 - The chute operation (the European model)

Phase 1: Felling	Phase 2: De-branching and possibly cross-cutting	Phase 3: Timber extraction
		
Two man team working separately	Two man team working separately	Two to three man team

Extraction with the LLL is in principle a two-man team operation. When extraction lines exceed 200 m, a third man is added to ensure a safe operation. Currently two methods of operation are in use:

Operation A

The planning of extraction lines and their marking is done before felling commences. This enables the team to consider concentrated timber volumes.

a) Installation of the chute.

- Approximately 10 to 15 chute pieces are assembled on the forest road (chute piece overlaps facing down).
- The screw- and wedge locks are mounted on the outside. The handles of the screw-locks are parallel with the length of the chute (to prevent obstructions during the winching operation). Wedge locks are secured in line with the extraction direction.
- The assembled chute section is winched into the site with the aid of a small winch.
- The winched chute section is secured to prevent it from sliding down again.
- Stabilization starts at the bottom proceeding upwards (this is important due to the step-by-step dismantling as the operation progresses).
- The chute exit ends at a sharp angle to the landing.
- The chute is secured with ropes to available anchors such as stumps, trees, roots, etc.
- The knots used should not tighten themselves and should be easy to untie later (Figure 4).
- Logs are used to support the chute where necessary. If needed, the chute may be tied to the supports, especially in the curves.
- Additional stabilization is needed when the braking grid is being used, as additional forces are generated when the log meets with more resistance at the braking grid.

Figure 4 - Knots used to secure the chute (After Nydegger, 1986)

Knot on the chute

Knot on the anchor

b) Extraction of the timber.

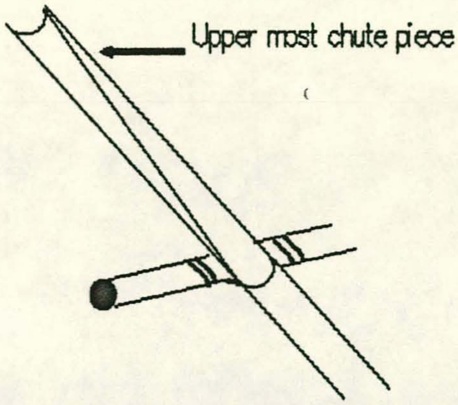
- The extraction begins at the top end of the extraction line.
- Logs may be fed in sorted groups or mixed, with the aid of Sappie hooks.
- After all the timber around the first chute piece has been extracted, the piece is dismantled and placed in position in the next chute line.
- This work procedure is repeated until the last extraction line is reached.

c) Reconstruction of the next installation.

- Proceed with the stabilization starting at the bottom working upwards.
- Proceed as described in point (b).

d) Dismantling of the installation.

- The extraction and the dismantling proceeds simultaneously, from the top downwards.
- Only those ropes which facilitate the removal of logs supporting the uppermost chute piece are loosened.



- In steeper areas where the chute pieces are transported by hand, each person should not have to carry (or drag) more than one chute pieces at a time.
- When a small winch is used, more chute pieces may be removed simultaneously.

Operation B

This method is used in wind-throws, where the felling operation cannot be planned in advance. The extraction strategy is only planned when the timber is already on the ground.

a) Installation of the chute.
  - The chute is built step-by-step from the bottom up. The extraction is done then from the bottom up following each step of the installation.
  - The chute is assembled and winched into position with the overlaps facing upwards and braking utensils provisionally attached.

b) Extraction of the timber.
  - After setting up the first chute piece, the timber directly above that chute piece is extracted using Sappie hooks.
  - When sufficient area is cleared of timber the next chute piece(s) is (are) attached.
  - This process is repeated until the extraction is

complete, or until the last chute piece has been attached.

c) Reconstruction of the next installation.
- Proceed to the next extraction line and start reconstructing from the bottom.
- Proceed as described under point (b).

d) Dismantling of the installation.
Dismantling procedure as described in operation A.

4.3 Description of the original local extraction method

Due to a lack of technology transfer and a lack of interest by certain sections of management, no guidelines for the application of the chute were available upon its arrival in South Africa. The chute was given to an unskilled team consisting of 7 members who were left to use their own initiative in developing an extraction method.

The chute was used in 20 to 30 m sections and simply placed at the top of the slope. Without securing the section, timber was moved along the length of the section. Upon completion of that section, the same chute section would be re-positioned below the already moved timber and the process would be repeated until the timber was finally extracted to roadside where it was stacked.

In compliance with the study objectives the European method was applied. The team received hands-on training for several weeks.

5. Results

Due to complications the time studies cannot be statistically validated. Results presented therefore indicate trends, rather than absolute findings.

5.1 Old extraction method (Lotzaba Forest method)

On average only 4 of the 7 team members worked at any given point in time. It was evident that too many people were involved, with labour standing idle, waiting for a turn. There was not enough working space around the chute to accommodate 7 members without endangering some of them. A distinct lack of coordination of activities was evident. Persistent stability problems were encountered with the chute. This led to the early exiting of logs over the side of the chute, aggravating the danger factor during operation. Additionally chute and log breakages occurred. The results of the time study of the above method are illustrated in Figure 5.

Delay times amounted to 37 % of the total extraction time. Logs would spill prematurely or remain in the chute altogether due to poor construction. Productivity achieved was 1.28 m^3 per man-hour over 55 m.

5.2 The European method (in principle)

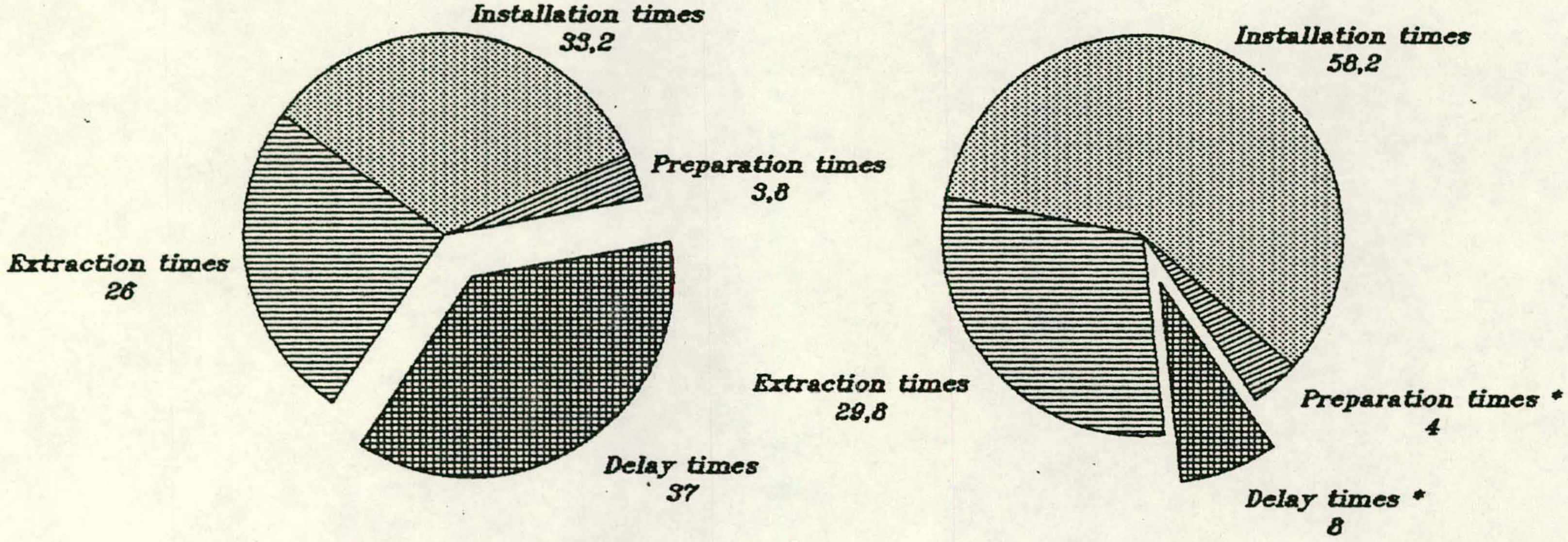
When this method was first tried a few changes were immediately necessary. These changes were:

- Pre-planning could not be properly done, as the extraction sites had already been clear-felled 6 weeks previously.
- The chute pieces had to be carried into the field by hand, as no winches were available.
- The extraction lengths were usually limited to less than 100 m.
- Within the first few installations it became apparent that the braking system was inadequate. The brakes were excluded from future operations in favour of traversing.

Figure 6 illustrates the findings. Construction and stabilization times were longer than those of the old method, while delay and extraction times were less. The new method attained a time saving of 24.6 % over the old method. Approximately 65 % of the total time, per extraction line, was spent on the construction and stabilization of the chute. Thirty percent of the construction time was spent stabilizing the chute, while the rest was needed to carry the chute infield and assemble it.

Figure 5 - A comparison between the old and the new extraction methods

Time consumption per activity



Lotzaba Forest method
First study

length of chute – 55m

New method
Second study

length of chute – 45m

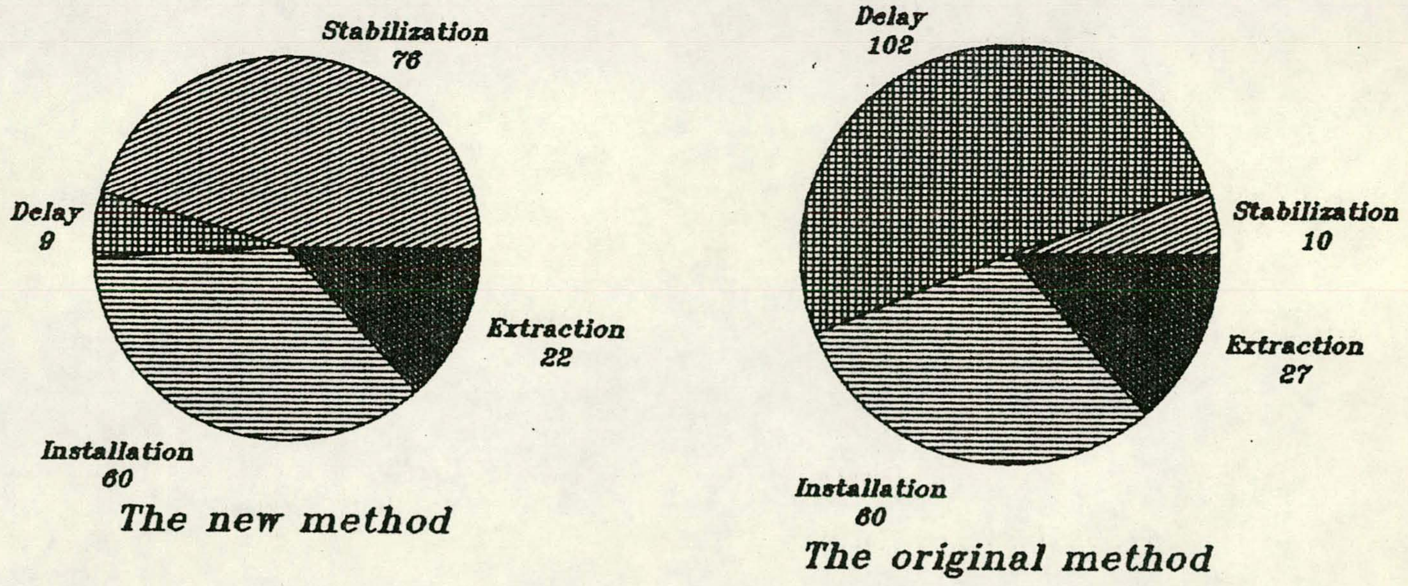
* estimated times

% of time per activity of the total time

Figure 6 - A comparison between the old and the new extraction methods

Projected time needed in minutes for an extraction length of *100* meters

A 16.1 % time saving achieved by the new method.



1.73 m~3/man-hour

1.17 m~3/man-hour

The new method represents a 32.4 % increase in productivity

6. Discussion

The results indicate that the new method (European method) appears to be more productive. An overall time saving, per extraction line, was achieved. Delay times were reduced, indicating a safer operation with less damage being caused to the logs and the chute.

6.1 Problems and possible improvements

6.1.1 The friction coefficient

The correct approximation of the friction coefficient is important, as it determines the braking strategy. It is possible to determine a rough friction coefficient with a simple trial-and-error procedure as supplied by Tauer (1977):

Set up a short chute (10 to 30 m) on a slope with a known gradient (for example 30 %). If a log in that chute accelerates, the friction coefficient is less than 0.3. Repeat this procedure on a more gentle slope by traversing the slope, until the log remains stationary or only slides a section of the chute. (For the exact calculation refer to Appendix A). For pine with bark, the optimal slope is estimated between 30 to 40 % provided the chute is shorter than 200 m (Tauer, 1977). For short-wood extraction of Eucalyptus the optimal slope is estimated between 25 and 35 %.

Friction coefficients

	Dry weather	Wet weather
Pine with bark (1)	0.22 - 0.25	0.15 - 0.18
The braking grid(1)	0.45 - 0.50	
Debarked Eucalyptus	0.25 - 0.35	0.10 - 0.15

(1) - (Tauer, 1977)

6.1.2 Log speed

The higher the log speeds, the higher the centrifugal forces exerted on the chute and its supports. Log speed is therefore a important consideration during the chute construction. Tauer (1977) considered the maximum safe speed of descent to be 15 m per second (m/s), while Schlaghamersky (1977) considered it to be between 10 and 12 m/s. Speeds exceeding this limit could cause:

- higher installation costs because of the need for better stabilization of the chute
- damage to the chute, logs and site due to timber spilling from the chute
- high recovery cost because logs may overshoot the landing
- the braking grid to become ineffective (for Eucalyptus)
- the operation to become unsafe

Calculation of log speed

Using the friction coefficient and the charts in Appendix B, log speed for a given extraction length and slope can be determined. Each chart represents a chosen friction coefficient and the most frequently used slopes. Although it is possible that a specific slope is not represented, log speeds could be extrapolated. For example, (Figure 7) if one assumes a friction coefficient of 0.25 and a slope of 35 %, after 150 m the log travels at approximately 17 m/s. (For a manual calculation refer to Appendix C).

This speed determination only applies to the standard chute configuration (a chute without brakes). On gentle slopes where the friction coefficient is too high for normal operation, it may be necessary to reduce the friction, by pouring a soapy solution into the chute.

6.1.3 Extraction length

The determination of the usable extraction length without exceeding safe log speeds presented the team with continuous problems. The length of an extraction line depends mainly on the location of the timber, the slope, the terrain and the location of the landing. (For a manual calculation refer to Appendix C). For example the viable extraction length for a friction coefficient of 0.35, with a maximum allowable log speed of 10 m/s, (without using brakes), on a slope of 50 %, is just over 40 m. For a maximum allowable log speed of 15 m/s on the same slope and friction, the maximum extraction length is approximately 90 m. This implies that logs in a chute will exceed the safe speed of 15 m/s after 90 m (Figure 8). (Refer also to Appendix D)

Figure 7 - Extrapolation of the maximum safe log speed

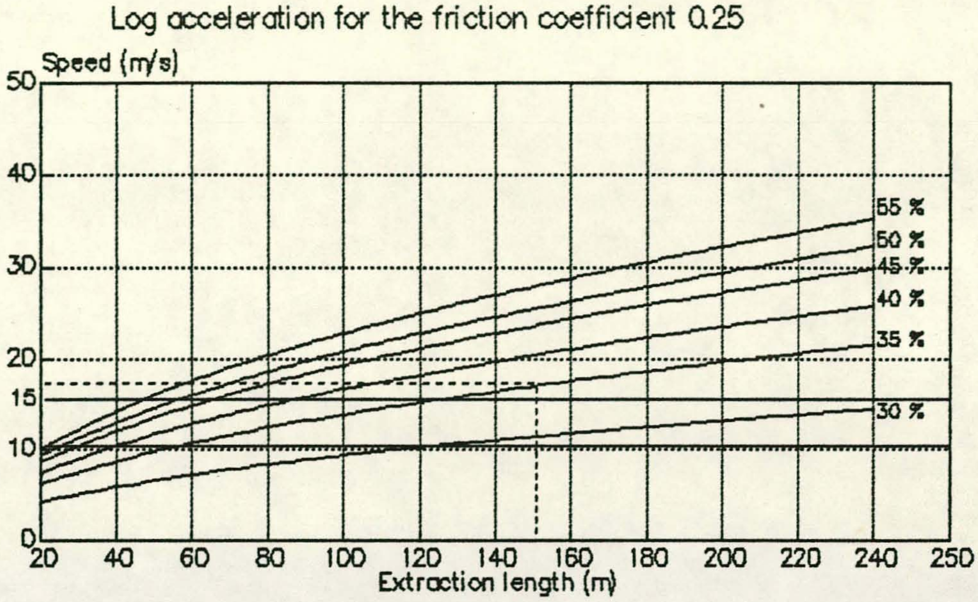
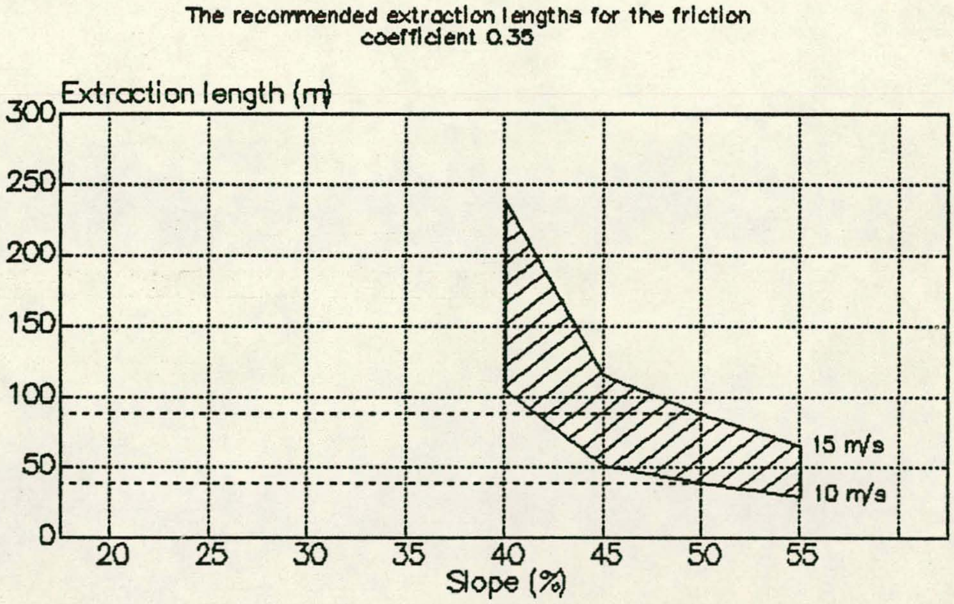


Figure 8 - Extrapolation of the maximum safe extraction length



6.1.4 Extraction line spacing

The extraction line needs to be chosen so as to optimize the difference between the construction spacing and extraction costs. Wide extraction line spacing will result in less installations per area, but longer extraction times. In Europe the recommended spacing is 15 to 30 m, 15 to 20 m extraction line spacing for pulp and 20 to 30 m for saw timber (Wörndl, 1981). Nydegger (1986) suggests that 300 to 400 m of chute per hectare is favourable, suggesting a extraction line spacing of 25 to 33 m.

Less timber per area and higher installation costs for the chute requires a wider line spacing, while more timber per area and lower installation costs allow narrow spacing. The following additional factors influence the extraction line spacing:

i) The rockiness and/or unevenness of the terrain influences the speed with which a log can be pre-skidded over a specific distance.

ii) The extraction technique (fan-chuting or single line extraction) to be used.

iii) The piece-volume - the higher the piece-volume the more timber is pre-skidded with every haul, but the more difficult the hauling is.

iv) The placing of the brush lines.

v) The availability of landings and the topography around a landing may influence extraction line spacing. The topography may necessitate a particular extraction pattern, which again may influence the extraction line spacing.

The calculation of the optimum extraction line spacing may be attempted as follows:

CONDITIONS

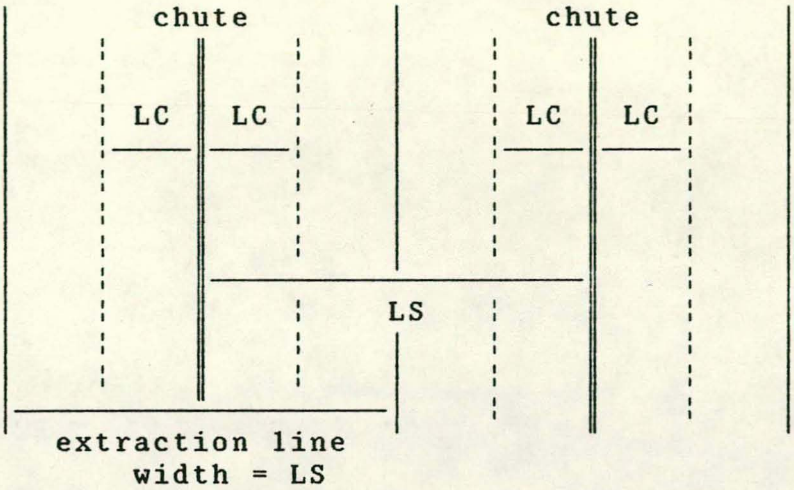
1. A large square or rectangular area of land on which the chute lines are constructed more or less parallel to each other.
2. A uniform timber supply over the entire area (uniform piece-volume).

DEFINITIONS

LD - chute line density in running metres per hectare (m/ha).

LS - extraction line spacing in metres (the average horizontal measured distance between the lines).

LC - average distance the logs need to be carried to the chute.



If condition 2 is true, then:

$LC=LS/4$ [A]

$LS=10\ 000/LD$ [B]

Substituting [B] in [A] $LC=2\ 500/LD$

I) THE INFLUENCE OF LINE DENSITY ON THE TIME NEEDED TO SELECT, HAUL THE TIMBER IN AND INSERT IT INTO THE CHUTE.

Assuming the regression $y=a+bx$ represents the time needed to find and haul-in the timber as a function of the hauling-in distance, where:

y = time needed to find and haul-in the timber

x = hauling-in distance

x may therefore be replaced with 2 500/LD.

The new function is: $y=a+b(2\ 500/LD)$ -> min/m^3 [C]

Basic time study data indicates that on average 6 seconds are needed to insert one log. With a piece-volume of 0.0364 per log there are 1/0.0364=27.47 logs per m^3. The time needed to insert 1 m^3 timber into the chute is thus (27.47*6)/60=2.75 minutes, which is the constant C.

The average clear felling volume per hectare is approximately 150 m^3.

The final formula is: $y=(a+C)+b(2\ 500/LD)$ -> min/m^3 [D]

By multiplying [D] with m^3/ha the time is calculated per hectare

thus: $y=(a+C)+b(2\ 500/LD)*(m^3/ha)$ -> min/ha

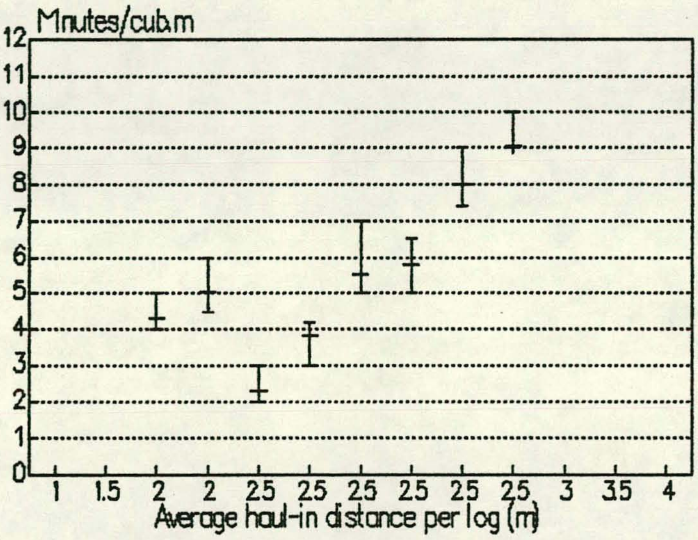
Assuming a function $y=a+bx$ represents the total time required to haul-in as a function of hauling-in distance, and:

y = tot. time required to haul-in

x = hauling-in distance

Only preliminary and inconclusive time study data were available on the influence of distance on hauling-in times.

Figure 9 - The time required for hauling-in logs for eight time studies



The following constants of a regression line from the data in Fig. 9 were calculated:

$a=0.46$

$b=2.11$

Substitute $a=0.46$ and $b=2.11$ in [D]:

$$y=(0.46+2.75)+2.11(2\,500/LD)*150 \qquad [E]$$

II) THE INFLUENCE OF LINE DENSITY ON THE TIME NEEDED TO TRANSPORT THE CHUTE PIECES.

The average time needed to transport a metre of chute for initial construction may be stated as follows:

$$\frac{\text{Tot. time to transport the entire chute}}{\text{Tot. length of extraction line}} = \qquad [F]$$

Time study data indicate a ratio of 60 min/65 m on slopes ranging from 20 to 45 percent

Applied in [F] => $60/65=0.9231$ min/m

The average time needed to transport 1 m of chute 1 m towards the next extraction line, thus for 1 m lateral transport, is determined by:

$$\frac{[F]}{\text{Average distance between chute lines}} = \qquad [G]$$

Assume 10 parallel extraction lines spaced 10 m apart.

Applied in [G]: $0.9231/10= 0.09231$ min/1 m extraction line and 1 m lateral transport

On 1 ha, however, LD m chute must be transported LS m therefore: $0.09231*LD*LS$ [H]

Substituting [A] in [H]

$fg(LD)=0.09231*LD*(10\ 000/LD)$ [I]

Simplify [I] = 923.1 min to transport LD m chute LS m far

III) THE INFLUENCE OF LINE DENSITY ON THE TIME NEEDED TO DISMANTLE, TRANSPORT AND RECONSTRUCT THE NEXT EXTRACTION LINE.

From basic data provided by Helmer (1983), the influence of the extraction lengths on the construction and dismantling of the chute was determined. The function describing this interaction is:

$$y=a+bx$$

$$y=1.75+2.70x \qquad [J]$$

where y = time needed to construct, dismantle and reconstruct the next extraction line.

x = extraction line length

from section II $y=923.1$

from $y=1.75+2.70x$ and section II the following function can be derived:

→ also = friction coefficient

$fg(LD)=923.1+2.70*LD$ [K]

fg(TD) = time needed in minutes for next construction of TD m chute

IV) OPTIMUM LINE DENSITY.

The optimum line density refers to the density of which the time required for timber selection, hauling the logs in, inserting the timber into the chute, construction, dismantling and shifting the chute to a new extraction line is the minimum (LDmin).

The sum function may be derived as follows:

From [E] $fg(LD)=(3.21+2.11(2\ 500/LD))*(m^3/ha)$

From [K] $fg(LD)=923.1+2.70*TD$ LD

The sum function is:

$$fg(LD)=(3.21+5275/LD)*(m^3/ha)+923.1+2.70*LD \quad [L]$$

$$=(3.21+5275/Ld)*150+923.1+2.70*LD \quad [L_1]$$

To derive the absolute minimum use f prime g:

$$f'g(LD)=-5275/LD^2*(m^3/ha)+2.70$$

Set equal to 0 $0=-5275/LD^2*(150)+2.70$

$$LDmin=\sqrt{}(5275*150/2.70)$$

$$=541.35m/ha$$

In $[L_1]$ replace LD with LDmin

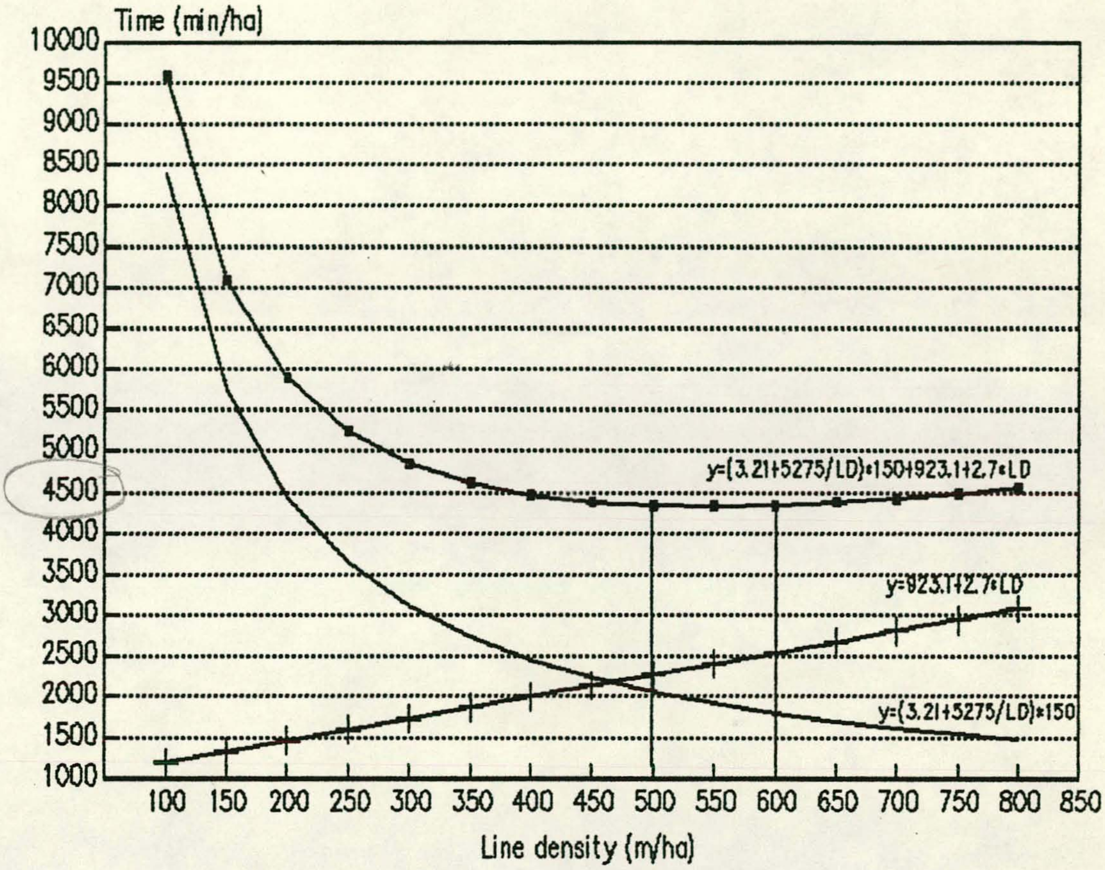
$fg(LD)=4327.87$ min/ha (the minimum time required)

4500 min/ha = 75 hours

= 9 days (8 hours/day)

150 tons/ha = 16,67 tons/day

Figure 10 - The optimal line density



The extraction line spacing may be calculated by dividing the derived line density into 10 000 m^2. Extraction line spacing has, however, not been sufficiently tested in local applications. Preliminary indications suggest an extraction line spacing exceeding 15 m (Figure 10).

During 1989 the average cost of one labourer was R14.14 per day (Edwards, 1989, <u>pers</u>. <u>comm</u>.[7]). This included basic wages (R9.43), service benefits (R4.24) and bonuses (R0.47). With a team of 4 workers earning the above mentioned wages it will cost R516 to extract one hectare or R3.44 per m^3 using the calculated optimum line spacing.

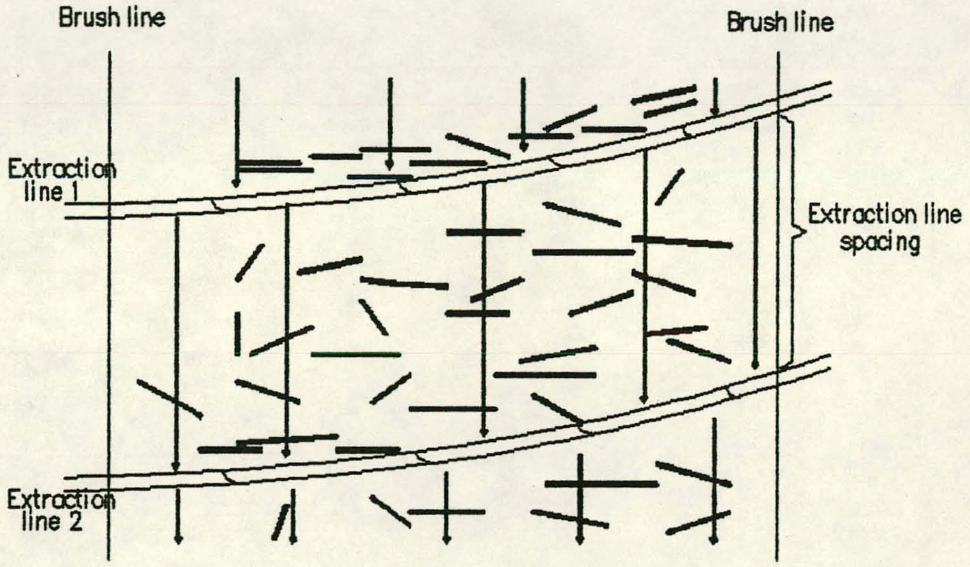
---

[7] Director, Forest Owners Association

6.1.5 Pre-skidding distance

The pre-skidding distance depends on the chosen extraction line spacing. When the chute runs straight down the slope, the haul-in distance should be as short as possible, implying that the chute should run as close as possible to the middle of the extraction line. When the chute runs across the slope (traversing), it is suggested that the chute be placed as close as possible to the bottom edge of the extraction line. The logs are only hauled from the top down, making use of gravity to assist the operation, as illustrated in Figure 11.

Figure 11 - When traversing the timber is only pre-hauled (hauled-in) from the top.



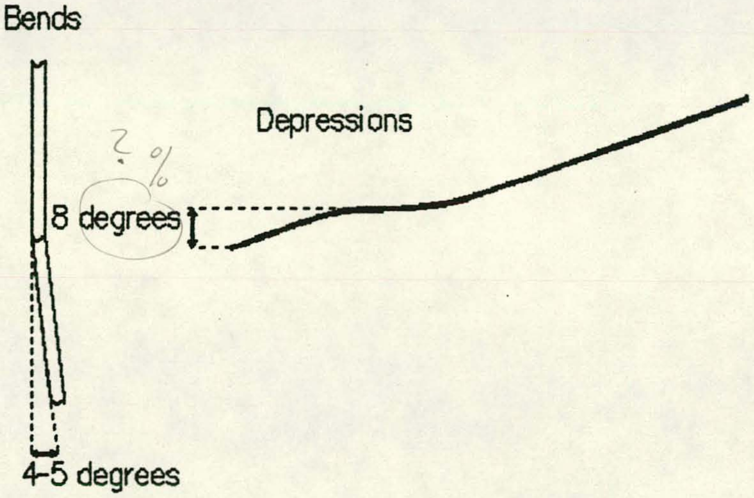
6.1.6 Slope

The slope is the most important constraint in a chute operation. The minimum gradient required for a chute operation is referred to as the critical slope. A minimum required slope of 25 % in dry weather and 20 % in wet weather is usually the norm. The optimum slope is approximately 30 to 35 %. On slopes steeper than the optimum, traversing should be considered to establish extraction lines as close as possible to the optimum gradient. The longer the extraction line, the more urgent is the need to control the speed of descent. The last 20 to 40 m of the chute should have a reduced gradient, preferably just less than the critical slope. This will help to reduce log speed before the landing is reached.

6.1.7 Terrain

The chute should not cross sudden slope changes exceeding 8 to 10 % from the general slope (Figure 12). The location and size of depressions and ridges in the terrain will determine the most feasible extraction method. Large ridges should be avoided where possible, while large depressions often warrant their own chute installation.

Figure 12 - The maximum bending of the chute in uneven terrain



If larger depressions or ridges are unavoidable, chutes should run parallel to them. One extraction line at the bottom of each slope and running the length of the depression or ridge is usually sufficient. Rocky conditions can complicate operations so much so that Nydegger, (1986) and Tauer (1977) recommended that such terrain should be considered as unsuitable for chute extraction, because of high deployment cost resulting mainly from high the European wages.

6.1.8 The landing

The location, size and accessibility of a landing is important. To determine the minimum size of a landing (alternatively the number of landings needed) the volume of the timber to be extracted, the distance and terrain between the landing and the timber must be known. The availability, gradient and width of the road leading to the landing also needs consideration. The landing should also accommodate the sorting process.

6.1.9 Team size

In Europe the team is responsible for pre-planning, felling and extraction (Altkofer, 1979). Tauer (1977) suggests that for extraction lines shorter than 200 m, two people are sufficient. A third or fourth person may be included in special cases where the terrain or the length of the extraction line, or safety factors necessitate it.

In South Africa the original team size consisted of six labourers and one supervisor. It was considered, however, that members of the team obstructed one another and the team size was then reduced to four members. A subsequent management decision (by Lotzaba Forests Co.) was to increase the team again to a maximum of six members. It was decided that the team lacked manpower, especially as the chute pieces had to be carried infield. Occasionally the team was to be used to free-skid (hand roll) an area, for which a team size of 6 was the minimum requirement. In principle the team could again be reduced to 4 members, provided that they worked exclusively on the chute.

6.1.10 The braking strategy

The friction coefficient for the braking grid (45 to 50 %) suggests that brakes are only effective on slopes less than 50 %. Before deciding on the braking strategy, the various installation strategies and extraction methods have to be evaluated in conjunction with the respective log speeds which can be generated. Kinetic energy increases four-fold with increasing speed (Tauer 1977), exerting great forces on the chute when high log speeds are allowed. Nydegger (1986) and Schlaghamersky (1977) agree that higher log speeds reduce the effectivity of the braking strategy.

Experience indicates that when debarked Eucalyptus is extracted on slopes exceeding 40 %, braking is only effective when complete brakes (grid with a weighted wolf) are spaced in intervals of three to four chute pieces. This, however, would necessitate a time consuming chute construction. The weight on the wolf often presents a problem, as logs with a low momentum may be jammed under a heavy wolf, while logs with a larger momentum may not be retarded sufficiently by a lighter wolf.

The supplied brakes were therefore found to be either inadequate or impractical. This is mainly due to the hardness and smoothness of debarked Eucalyptus logs. When extracting hard woods it is suggested that chutes be installed without the use of brakes, especially when different timber assortments are extracted in one installation. The descent of the logs may be retarded by applying the following methods:

- reducing the slope (traversing)
- making use of a positive (opposing) slope (a slope less than the critical slope)
- using curves (more friction is generated because of the higher centrifugal forces pressing the log against the chute)
- placing soil (free of pebbles) or dry grass into the chute (to increase the friction coefficient)

Tauer (1977) claims that soil in the chute can increase friction by up to 8 %, whereas grass increases it by 5 %. The most efficient way of managing log speed, however, is by controlling it from the beginning and keeping it under control by traversing.

6.1.11 Chute construction

The chute construction is the most time-consuming activity of the extraction operation. Schlaghamersky (1977) reports that in Europe 53 % of the time needed for an entire extraction operation was spent on construction and dismantling of the chutes.

Preliminary time studies in South Africa indicate that manual transportation of chute pieces into position require 60 to 70 % of the installation time. These figures compare poorly to the 15 to 30 % achieved in Germany (Helmer, 1983). Various factors influence the time needed to construct a chute:

- felling pattern
- terrain
- slope
- mechanical aids (such as a winch)
- and the chosen extraction method (going straight down the slope, traversing, length of chute, etc.).

The more difficult the terrain and the steeper the slope, the more difficult and dangerous the installation will be. The influence of the amount of loose logs (log concentration) on safe footholds cannot be disregarded. Chutes crossing brush lines require special handling.

During manual construction only one chute piece can be carried into the field at a time. This may be attributed to their length and smooth surface, which complicates their handling. Chute pieces are therefore normally pulled into position with the aid of ropes. The work force generally prefer transporting the chute pieces down the slope with aid of gravity. Downhill installation was found to be between 50 and 60 % faster than uphill installation.

It is, however, recommended that a winch be used for the construction. Although winch performance is dependent on slope, this dependence is less than that of a worker carrying the chute pieces up a slope. Generally 10 to 15 chute pieces can be winched uphill simultaneously (Nydegger 1986). An added advantage, is that a winch operation is generally safer and less strenuous.

During manual chute construction, 69.7 % of the total construction time (for a uphill construction) was spent transporting (dragging) the chute into position. This resulted in high construction times. Trials with a tractor-mounted winch indicated a substantial saving on the construction times. Assuming that the stabilization times and slope remained constant for both construction methods, the winch caused a time saving of between 30 and 50 % on the total construction time (Engelbrecht 1989; pers. comm.[8]).

6.1.12 Supporting and stabilizing the chute

The supports and stabilization should be primitive yet as strong as possible to minimize problems during the extraction. In South Africa the harvesting of short wood products is generally planned and extracted in two separate stages. The clear-felling operation is completed first, after which the extraction operation follows. This is often done because the two operations are performed by different teams. The planning of extraction lines is therefore generally not possible.

Figure 13 - Damaged chutes

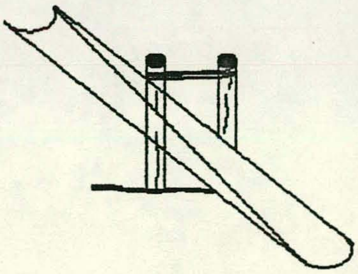
Securing the chute over loose logs proved to be a problem. During extraction the underlying logs would shift, resulting in the de-stabilization of the chute. This problem was overcome by first tying the chute to its support, before tying it to an anchor. Where the chute came into contact with rocks severe abrasion and cuts often resulted. The sun can also heat the rocks sufficiently to melt the polyethylene

---

[8] P.O.Box 298 Barberton

of the chute after prolonged contact. Damage of this kind cannot be repaired (Figure 13) and may be prevented by wedging something between the chute and the rock.

Curves require special attention. Centrifugal forces created by log speeds cause the chute to tilt, spilling the logs. Super-elevated curves can be constructed to prevent this. Tilting of a chute may also occur when the polyethylene heats up and expands. Trials proved that the chute can expand up to 5.64 cm per meter chute (Engelbrecht, 1989). A solution is to plant poles on both sides of the chute (opposite one another) to prevent it from tilting as indicated in the sketch below.



6.1.13 Inserting the logs into the chute

For the duration of the tests all logs were picked up and inserted over the side wall of the chute. Tauer (1977) and Helmer (1983), however, point out that lifting logs over the side wall of the chute requires considerable effort, especially when wrong lifting techniques are used. Although Sappie-hooks were not tested, they appear to be a more acceptable method of inserting the logs into the chute (an ergonomic evaluation follows later). Logs are hooked and pulled into the chute, enabling the labourer to work from a standing position. From a practical point of view excessive rockiness may present a problem. To alleviate this, a funnel may be attached to the top of the chute, providing a bigger entrance. Comprehensive tests still have to be conducted to assess the value of this method.

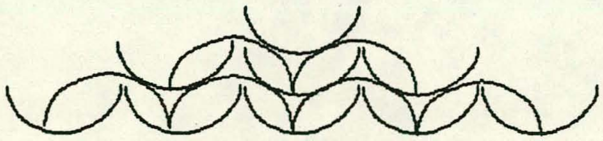
6.1.14 Communication

Good communication among team members is vital for a safe chute operation. When longer extraction lines are used the team should be provided with two-way radios.

6.1.15 Storage and handling of chute pieces

It is important that the chute be handled and stored correctly: incorrect storage may result in permanent deformation of the chute pieces. Chute pieces should not be allowed to lie inside one another, as this will force the chute pieces open. This may cause problems when they are fitted together, with more logs spilling over the side of the chute during extraction. The recommended way to store the individual chute pieces is illustrated in Figure 14.

Figure 14 - The correct method of storing chute pieces



If possible, the chute should be stored in the shade to protect it against deformation (Tauer, 1977). High radiation and severe temperature fluctuations can deform the chute beyond repair.

6.1.16 Equipment

Although the operation can be managed with the tools listed in chapter 4.2.1, the following additional tools may be of help in the field:

- A heavy hammer is needed to plant the stakes needed to stabilize the chute.
- A pick and shovel (or spade) may be useful to remove rocks, humps and other obstacles.
- Barrier tape may be used to mark extraction lines and to seal off the landing, especially if it is a forest road.
- Hatchets may be used to secure the wedge locks, but can also serve a multitude of other functions (to slash brush, sharpen stakes and clean poorly de-branched logs).

- Warning signs may be placed to warn against the dangers of spilt logs.

6.2 Productivity

Productivity presently fluctuates between 0.25 and 1.8 m^3/man hour. This high fluctuation is mainly due to the learning and testing of the new chuting techniques causing continuous interruptions during the operation. Average productivity was determined at about 0.8 to 1.2 m^3/man hour. A four-man team working eight hours per day would therefore provide 25 to 38 m^3/day (or 30 to 48 tons) per day (The applicable conversion factor was provided by Du Plessis 1988; *pers. comm.*[9]).

6.3 The timber

The volume of timber to be extracted and the places where logs are concentrated is of major importance for the economic viability of a chute operation. Log size uniformity also plays a role towards the viability of the operation. Larger logs travel faster requiring a firmer chute construction, better stabilization and a different braking strategy. Presenting and extracting the timber in assortments (according to size) is not an answer to the problem as the overall productivity would suffer severely. The removal of logs which are too large for the chute is done by hand, as other operations are not viable for small quantities of timber.

6.4 Hauling the logs in

During testing it was evident that the way the timber is presented for extraction influences productivity and safety. Hauling-in accounts for approximately 60 to 65 % of the extraction time (or 7 % of total operation time). Two basic approaches of hauling-in logs are:

- Hauling-in during extraction.
- Hauling-in before extraction.

For both approaches three options were considered: no hauling-in, rough haul-in and pre-stacking. Tests did not clearly indicate the best alternative. During rough haul-in

---

[9] P.O.Box 298 Barberton

the logs are roughly concentrated around the planned extraction line. Pre-stacking entails the orderly packing of logs on a pre-determined spot, selected along the extraction line. The logs are stacked at an angle to the chute so that the upper end of the log is further away from the chute than the lower end.

Advantages of rough haul-in and pre-stacking are:

- safety is increased by having less loose logs lying around
- the chute is easier to install for the same reason as above

Disadvantages are:

- proper co-ordination and control over the various activities is required
- it may be more labour intensive

The necessity of hauling-in before the operation is disputable. Time studies indicated little difference in productivity between rough hauling-in and no hauling in. Pre-stacking took twice as long as rough hauling-in and produced the same timber output during extraction, representing a decrease in productivity. It is suggested that rough haul-in be adopted as it improves safety during extraction and does not negatively affect productivity.

6.5 A new chute

Recently a new chute was developed in South Africa. The main aim was to develop a chute which would not be adversely affected by local extremes in temperatures and to reduce acquisition costs. The complete chute costs between R225/m (per metre) and R256/m. This chute is made of MOS_2 (molibdium bi sulphid) filled $nylon_6$ and is currently being tested. The chute's characteristics are as follows:

Wall thickness : 10 mm
Length of individual chute pieces : 3 m
Inner diameter at chute opening : 350 mm
Top opening : 300 mm
Semicircle : 210^o
Approximate weight of 3 m piece : 25 kg

7. Evaluation

7.1 Economic evaluation

Schlaghamersky (1977) reports that in Europe 30 to 40 tons of timber per hectare are needed to cover the cost of chute extraction (minimum economic utilization). Using the figures calculated in the optimum extraction line spacing calculation and machine cost calculation (Appendix F), the minimum economical utilization may be calculated. The thick line in Figure 15 illustrates the minimum economical utilization if the chute is used for 700 machine hours per year (700 mhrs/year is the marginal utilization as determined by the machine cost calculation). The other line represents a use of 1500 machine hours per year. (The machine cost calculation in assumes that a chute with a four-man team is used with the annual utilization of the chute being 1500 mhrs/year.) The minimum annual utilization (the utilization needed per year to make any extraction operation financially viable) in Europe is 1000 m^3 (Tauer, 1977). Figure 16 illustrates the South African utilization.

Figure 15 - Minimum economical utilization for the LLL

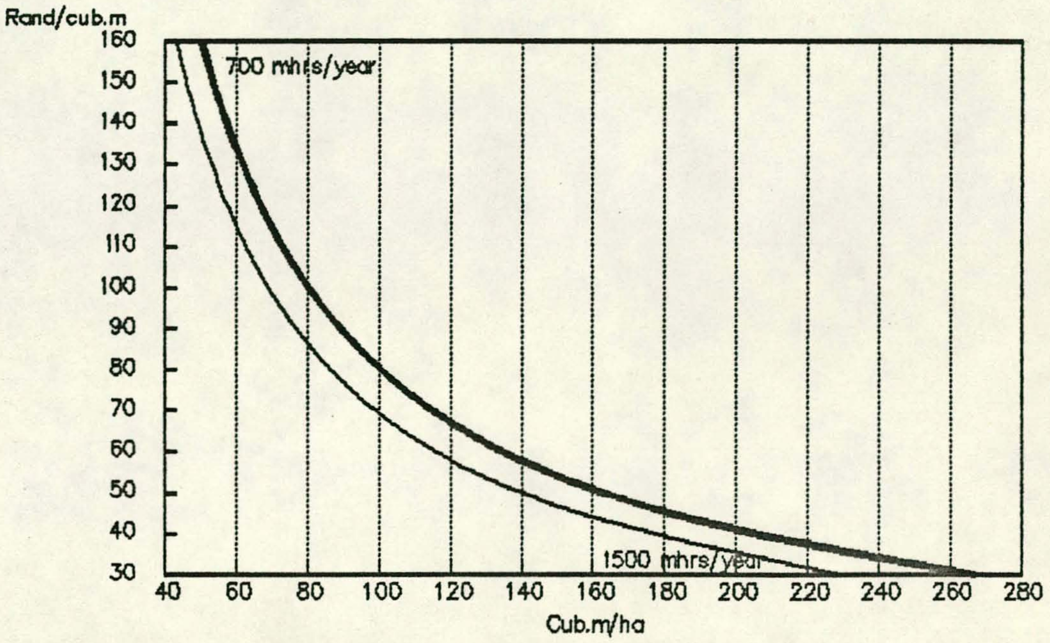
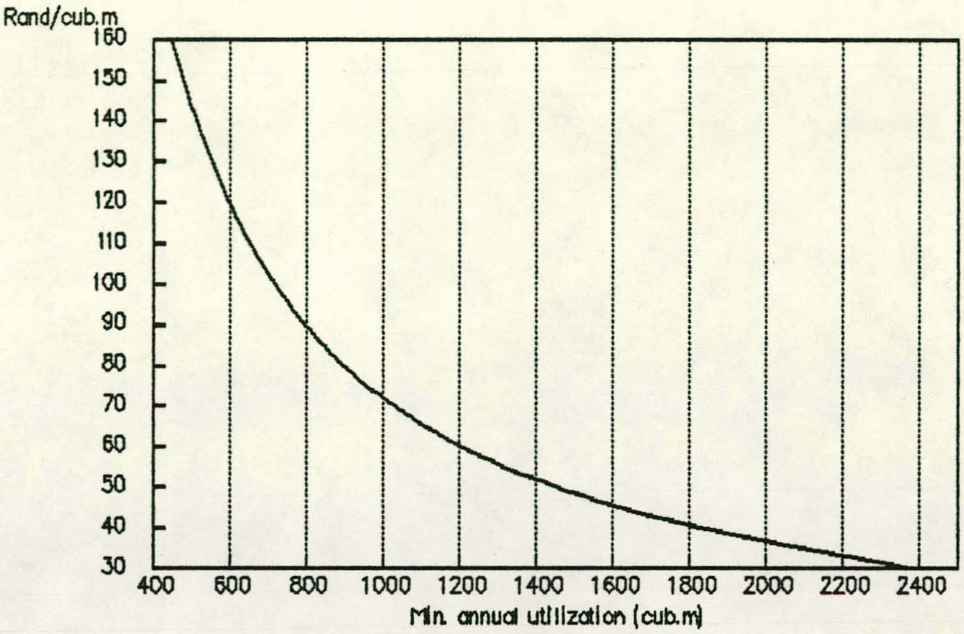


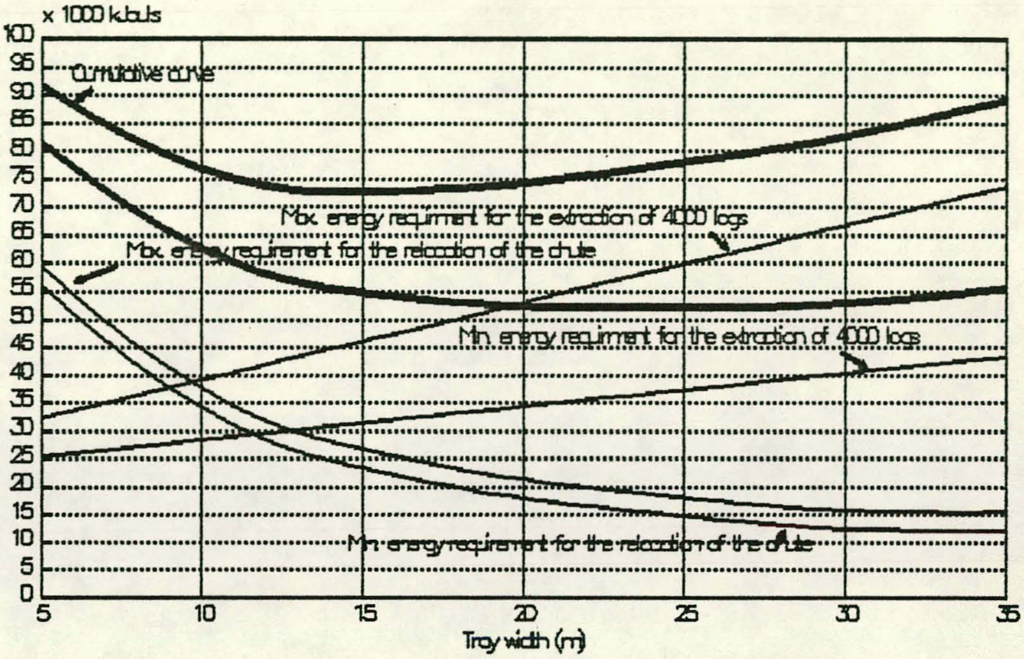
Figure 16 - Minimum annual utilization for the LLL



7.2 Ergonomic evaluation

Schlaghamersky (1977) considers a chute operation as a strenuous activity. Activities contributing to the heavy work load are the chute construction, hauling the logs in and feeding the logs into the chute. These activities account for about 85 % of the total time for each extraction. Under European conditions the estimated energy requirements for each member of the chute team is 7535 to 7950 kJoules per day (1800 to 1900 kcalories) (Schlaghamersky, 1977). For sustained continuous performance a daily energy consumption of 8790 to 9210 kJoules (2100 to 2200 kcal) should not be exceeded (Schlaghamersky, 1977). For males, Brechbiehl (1989) suggests a similar range of 8400 to 14400 kJoules per day. Calculations, based on local time studies, indicate that between 29700 and 38500 kJoules are required to extract 145.6 m^3 (204 to 264 kJoules per m^3) using 10 m wide extraction lines (Figure 17) (On an average stand on the testing site, 1 ha had 4000 logs representing 145.6 m^3). Appendix E provides the calculation of energy requirements for the extraction of a 100 m long chute with an 15 m extraction line width.

Figure 17 - The total energy requirement for the extraction of 1 ha



The construction.

A comparison between energy requirements for a manual chute construction and a construction using a winch was conducted by Engelbrecht (1989). Carrying a 100 m long chute into the field on level terrain requires a minimum of 1014 kJoules. The assumption is made that the chute pieces are lifted at least 1.25 m off the ground and are carried in one at a time. An identical installation using a winch requires only 492 kJoules representing a 51% energy saving. It is assumed that four individual chute sections of 25 m each are winched into position, and that two labourers accompany each section.

7.3 Environmental impact evaluation

Insufficient attention is given to the incorrect use of timber extraction equipment in plantations, resulting in detrimental environmental impacts. Several thousand years are needed to form one centimetre of top soil (Warkotsch, 1989) and only 50 % of the soil actually consists of solid soil particles. Soil contains the entire capacity of land to sustain life (Rabie and Theron, 1983).

Impact may be defined as the change of a specific environment parameter over a specific time period and within a defined area (Warthern, 1988). Harvesting operations affect the physical integrity of soils in two ways:

- <u>in situ</u> alterations of physical soil properties
- accelerated soil erosion (Cromack, Swanson, Grier, 1979)

Skidding, yarding and hauling destroys approximately 30 % of the forest soils during each harvesting operation (Kartowianta, 1979). Grey & Jacobs (1985) regarded soil compaction as the single most important impact on forest soils. After 2 to 3 passes approximately 70 % (Lull, 1968; Warkotsch, 1989) to 90 % (Höfle, 1976) of the maximum possible damage is being done.

Compaction can persist for decades and if not ameliorated possibly for ever (Thorud & Frissell, 1976; Warkotsch, 1989). Even light compaction is sufficient to substantially reduce water infiltration (Arnett, Williams and Tappeiner, 1971). Erosion is therefore high on compacted soils (Barger, 1975). The top soil that is washed away may contain as much as 90 % of all the nutrients available to plants (Grey and Jacobs, 1985).

The choice of harvesting methods and machines as an influencing factor on the type and amount of damage to the site is important (Klock, 1975). Harvesting impacts reduce the growth potential of a site significantly (Bredberg and Wästerlund ,; Gessel, 1981; Grey and Jacobs, 1985; Löffler, 1982; Sardo, 1981 ; Wray, 1989). Wingate-Hill and Jakobson (1982) claim that this growth reduction may be up to 12 %, while Cetinkoepruelue (1987) cites a 30 % reduction in basal area increment.

Four published forest practice codes were used to evaluate the use of chutes on slopes. A direct comparison of principles and rules as reflected by the codes was not possible, as there is no standardization of values. A short summary with regards to the chute versus skidder application follows:

The Fiji National Code of Logging Practice (1990)
Major skidding tracks may not be built on slopes exceeding 46 %. Small skid tracks on these slopes may not be spaced closer than 60 m apart and have to be contoured. No conventional extraction equipment is allowed on slopes exceeding 84 %. These slopes have to be extracted with cable systems or chutes.

Draft Code of Forest Practices - Victoria Australia (1987)
Extraction should only take place on slopes where the operator can proceed in safety, and where the long-term stability of the soil will not be threatened. Short-term or unacceptable off-site effects should be avoided. Harvesting operations should be limited to slopes of less than 58 %. During prolonged wet weather, operations should be suspended as soon as the soils become saturated and water starts running off.

Forest Practice Code - Tasmania (1988)
The general stated aim is to minimize long-term impacts on the environment and site productivity. The following rules are laid down:

a) Harvesting on sites suitable for wet and dry weather operation:
   - harvesting is limited to slopes of less than 35 %, unless specialized equipment is used.
   - harvesting is limited to low to average erosion classes.
   - harvesting is limited to stable soils only.

b) Harvesting on sites which are suitable for the dry season only:
   - harvesting is allowed on all slopes.
   - harvesting is allowed on low to high erosion classes.

c) Sensitive sites may only be harvested with suitable equipment.

d) Machines used in the operation should be 'matched' to the soil conditions.

e) A guide is provided as an indication of different skidding techniques for different forest conditions. The guide is based on a field assessment of:

- majority slopes (gradients)
- erosion classes
- logging under generally WET or DRY conditions

Categories of logging equipment for skidding:

C1 - Conventional logging equipment (skidders, tractor, etc.)

C2 - High flotation and low ground pressure machines (skidders with high flotation tyres, tracked machines, etc.)

C3 - Flexible tracked skidders or equipment producing similar environmental results

C4 - Cable system, chutes and aerial systems

Table 1 - Recommended skidding techniques for different forest conditions.

	MAJORITY SLOPE (GRADIENT)							
	0-20% low		21-35% med		36-49% steep		>50% very steep	
EROSION CLASS	WET season	DRY season	WET season	DRY season	WET season	DRY season	WET season	DRY season
Highly erodible or soil profile with low bearing strength	C 2-4	C 1-4	C 2-4	C 1-4	C 4	C 3-4	Generally no logging	Generally no logging
Average erodibility	C 1-4	C 1-4	C 2-4	C 1-4	C 3-4	C 2-4	C 4	C 4
Low erodibility	C 1-4	C 1-4	C 1-4	C 1-4	C 1-4	C 1-4	C 4	C 2-4

New Zealand Forest Code of Practices (Vaughan, 1990)

An impact checklist is provided with which it is possible to compare various extraction equipment. Although the checklist provides for various impacts to be assessed, only the harvesting impacts will be listed here. Three extraction systems are compared on a site with an average slope of 30%. A stream has to be crossed to the landing. For the chute the timber is cross-cut in-field, while the other systems extract tree lengths.

A - chutes
B - skidders
C - yarding

Each operation is assessed with the aid of the 9 values. The scoring is as follows:

Length of time affected	Degree of risk/ likely effect	Potential Impact	Checklist Symbol
Short-term	Minor	Minimal	.
Long-term	Minor	Low	+ or -
Short-term	Major	Intermediate	++ or --
Long-term	Major	High	+++ or ---

Key to the environmental values:

1 - Soil and water
2 - Scenic or landscape
3 - Recreational
4 - Scientific and/or ecological
5 - Cultural
6 - Forest health
7 - Site productivity
8 - Off-site impacts
9 - Safety

K - remains CONSTANT
X - not applicable

The summed pluses and minuses (as shown on the next page) are:

The chute - minus 5
The skidder - minus 41
Yarding - minus 14

This indicates that the chute will have the least impact on the site, while the skidder shows probable severe impacts.

The most important tool in site productivity is management (Wray, 1989). As the timber industry expands, more marginal sites will be planted to timber in the future. These sites will reflect soil related damages more acutely. Action needs to be taken in the form of extraction planning to curb the negative effects which harvesting has on sites.

STAGE OF DEVELOPM.		ENVIRONMENTAL VALUES									TOTALS		
Operation		1	2	3	4	5	6	7	8	9	A	B	C
Roading	A	K	K	K	K	X	K	K	K	K			
	B	K	K	K	K	X	K	K	K	K			
	C	K	K	K	K	X	K	K	K	K			
Stream crossing	A	.	.	X	X	X	.	.	.	-	1		
	B	---	-	X	X	X	---	---	--	--		14	
	C	-	.	X	X	X	.	-	-	.			3
Landings	A	-	.	X	X	X	-	X	X	X	2		
	B	--	-	X	X	X	-	X	X	X		4	
	C	--	--	X	X	X	-	X	X	X			5
Tracking	A	.	.	X	.	X	.	.	X	X			
	B	--	--	X	--	X	--	--	X	X		10	
	C	.	.	X	.	X	.	.	X	X			
Felling	A	K	K	X	K	X	K	K	K	K			
	B	K	K	X	K	X	K	K	K	K			
	C	K	K	X	K	X	K	K	K	K			
Extraction	A	.	X	X	.	X	.	.	-	-	2		
	B	---	X	X	--	X	--	--	--	.		11	
	C	-	X	X	-	X	.	-	--	.			5
Processing	A	-	K	X	+	X	+	.	.	-			
	B	.	K	X	.	X	-	.	-	.		2	
	C	.	K	X	.	X	-	.	-	.			2
Transportation	A	K	K	K	K	X	K	K	K	K			
	B	K	K	K	K	X	K	K	K	K			
	C	K	K	K	K	X	K	K	K	K			
								GRAND TOTAL			5	41	14

References

Altkofer, A (1979)

Richtlinien für den Einsatz der Kunststoffloite.

Waldarbeitsschule Laubau [p2-3]

Arnett, CM(Jr); T Williams and JC Tappeiner (1971)

Effect of winter harvesting methods on soil bulk and infiltration rates.

Minnesota Forestry Research Notes No. 228

Barger, RI (1975)

Towards more complete utilization.

Reprint: Western Wildlands

Brechbiehl, M (1989)

Untersuchung über das manuelle bündeln von Kurzholz auf einer Eukalyptusplantage in Südafrika.

Diplomarbeit an der Forstwissenschaftlichen Fakultät der Ludwig-Maximilians-Universität München.

Bredberg, J and I Wästerlund ()

Wurzel und Bodenschäden durch Fahrzeuge.

Cetinkoepruelue, R (1987)

Cable Yarding Systems for the extraction of small timber dimensions.

Forstwissenschaftlichen Fakultät der Ludwig-Maximilians-Universität München.

Cromack, K; FJ Swanson and CC Grier (1978 -1979)

A comparison of harvesting methods and their impacts on soil and environment in the Pacific Northwest.

Forest Soils and Land-use. Proc. Fifth Northern American Forest Soil Conference. Editor: CT Youngberg. [p451-471]

Daitz, LD; GvR Engelbrecht and PW Warkotsch (1989)

The LLL - a case study of transfer of technology.

Winterschool Sabie

Draft Code of Practice (1987)

Code of Forest Practices for Timber Production. Department of Conservation, Forest & Lands - Victoria

Engelbrecht, R (1989)

Unpublished report

Fiji National Code of Logging Practice (1990)
Ministry of Forests - First edition

Forest Practice Code (1987)
Forestry Commission Tasmania

Gessel, SP (1981)
Impacts of Forestry on Forestry Itself.
XVII IUFRO World Congress - Interdivisional. [p4->]

Grey, DC and EO Jacobs (1985)
The impact of mechanical harvesting systems on forestry site quality.
[p143->]

Helmer, O (1983)
Feldversuche mit der Kunststoff-Loite (Leykam-Log-Line) - Eine Betriebsuntersuchung.
Diplomarbeit an der Forstwissenschaftlichen Fakultät der Ludwig - Maximilians Universität München.

Hess, A (1975)
Die Alu-Riese als Schichtholz-Rutsche in Hanglage.
Die Waldarbeit. Forstwirtschaftliche Zentralstelle der Schweiz.
[p26-28]

Höfle, HH (1976)
Holzernte und Umweltschutz - ein unlösbarer Konflikt.
Seperatdruk aus : Schweizerische Zeitschrift für Forstwesen.
[p>7]

Kartowianta, K (1979)
An overview of the environmental consequences of the removal from the forest in Indonesia.
Biological and sociological basis for a rational use of forest resources for energy and organics. Proc. of an international workshop, Michigan State University [p133]

Klock, GO (1975)
Impact of five post-fire salvage logging systems on soils and vegetation.
Journal of Soil and Water Conservation. 3/4 1975 Vol.30(2)

Knaurs Lexikon a-z (1975)
Publisher: F.N. Mehling

Löffler, H (1982)

Risiken moderner forstlicher Arbeitsverfahren für Boden und Bestand.

Lull, HW (1968)

Soil compaction on forest and range lands.

<u>Forest Service United States Dept. of Agric. Washington, D.C.</u> [p1->]

Merkator, (GmbH)

LLL

<u>Das Aktuelle Holzbringungs System in Hanglagen.</u>

Nydegger, E (1986)

Holzrücken mit Log-Line. [p3-13]

Rabie, MA and CHB Theron (1983)

Conservation of renewable sources.

<u>Form: Environmental concerns in South Africa - Technical and legal perspectives. Juta & Co. Ltd.</u> [p143]

Sardo (Jr.), FP (1981)

Forest biomass predicted by soil-site factors.

<u>University Microfilms International Ann Arbor, Michigan U.S.A. London England</u> [p5->]

Schlaghamersky, A (1977)

Die Leykam Log Line bei der Schwachholzbringung [p1548-1553]

Tauer, H (1977)

Holzrückung mit Leykam Log-Line [p13-16]

Thorud, DB and SS Frissell (1976)

Time changes in soil density following compaction under an oak forest.

<u>Minnesota Forestry Research Note No.257</u>

Vaughan, L (1990)

New Zealand Forest Code of Practices

New Zealand Logging Industry Research Association (Inc)

Warkotsch, W (1985)

Unpublished notes.

Warkotsch, W (1989)

The influence of harvesting on long-term site productivity.

<u>Long-term site productivity seminar at Sezela and Ifafa.</u> [p41-44]

Warkotsch, W; MP Brink & HL Zietzman (1989)
Slope classification and mapping of the forestry area in the R.S.A.
University of Stellenbosch [p24]

Warthern, P (1988)
An introduction guide to EIA
From: Environmental Impact Assessment - Theory and practice (edited by Warthern) London UNWIN HYMAN

Wingate-Hill, R and BF Jakobson (1982)
Increased mechanization and soil damage in forests - a review.
New Zealand Journal of Forestry Science Vol.12 No.1 [p384]

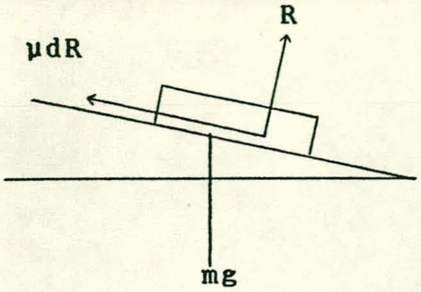
Wörndl, FR (1981)
Bericht über dir Einsatzvorführung der Leykam-Log-Line am 16.6.1981 der ODF München im Bereich des Forstamtes Bad Reichenfall. [p1-3]

Wray, JL (1989)
Long-term site productivity as influenced by financial expectations.
Long-term site productivity seminar at Sezela and Ifafa. [p1-4]

Appendixes

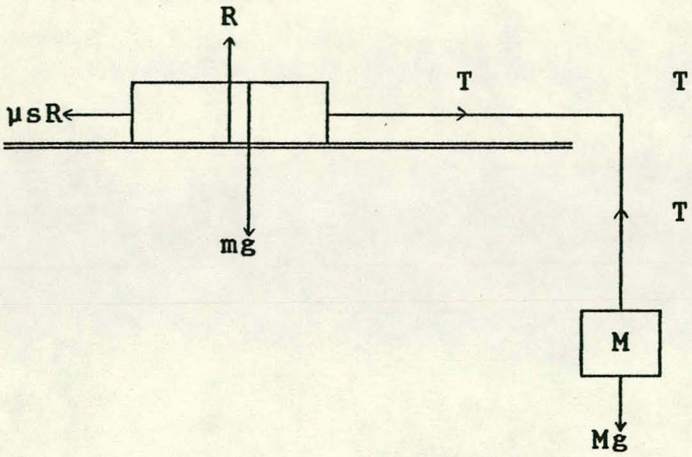
Appendix A

Determining the friction coefficient mathematically.



m - mass of block (kg)
g - gravitation (9.81 m/s)
R - reaction force
μd - dynamic friction coefficient (independent of slope)
μs - static friction coefficient
P - pulling force
M - weight pulling block (kg)

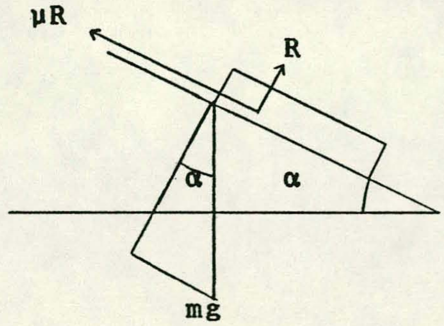
To determine μs

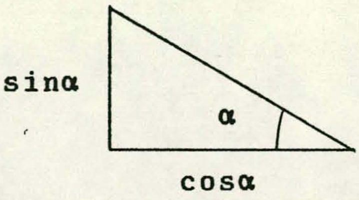


T = T (Equal opposing forces)

If this block were about to move, then: $T = Mg$ and $R = mg$
$T = \mu R$
substitute T and R => $Mg = \mu mg$
g cancels both sides $M = \mu m$
thus $\mu = M/m$

TO PROVE THE VALIDITY OF THE FIELD DETERMINATION OF THE FRICTION COEFFICIENT





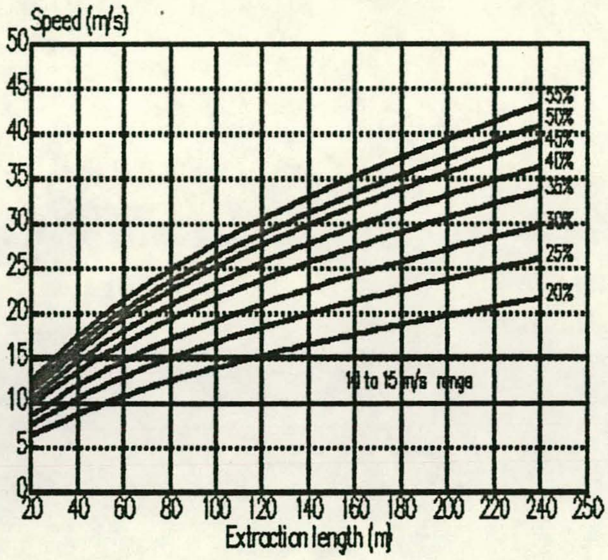
$mg \sin\alpha = \mu R$ ->1
$mg \cos\alpha = R$ ->2

divide 1 by 2 $mg \sin\alpha / mg \cos\alpha = \mu R/R$
mg and R cancel out $\sin\alpha/\cos\alpha = \mu$
$\sin\alpha/\cos\alpha = \tan\alpha$ $\underline{\tan\alpha = \mu}$

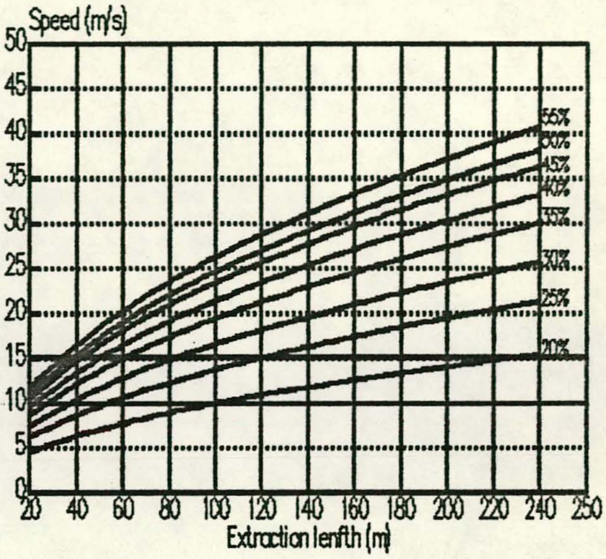
Appendix B

The derivation of log speed

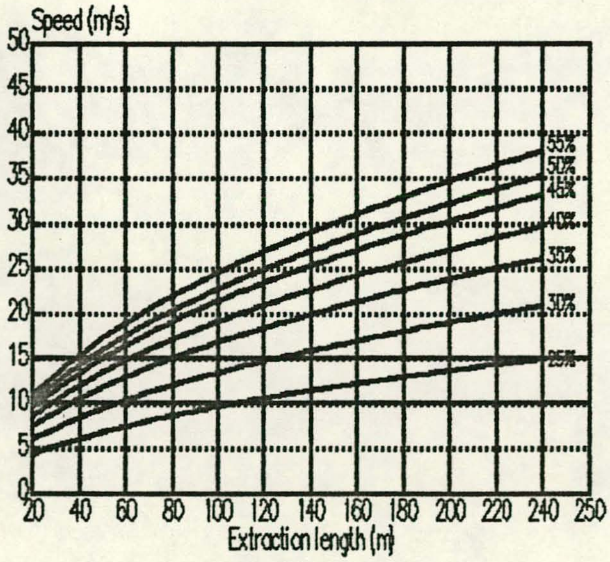
Log acceleration for the friction coefficient 0.10



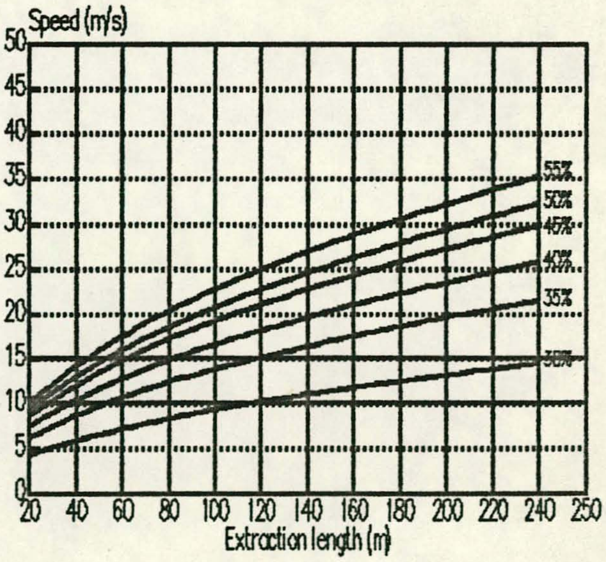
Log acceleration for the friction coefficient 0.15



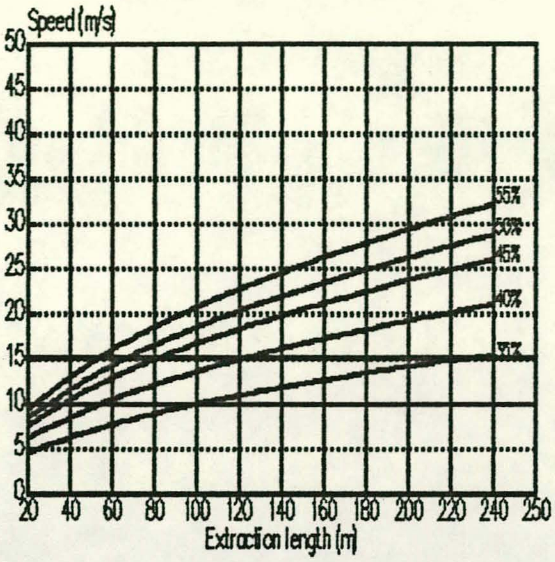
Log acceleration for the friction coefficient 0.20



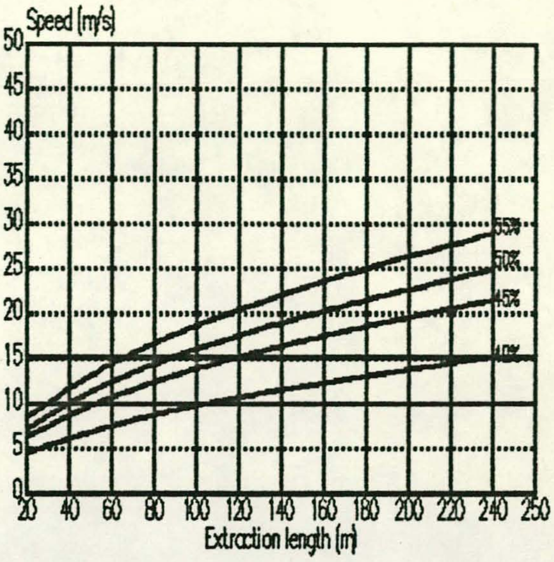
Log acceleration for the friction coefficient 0.25



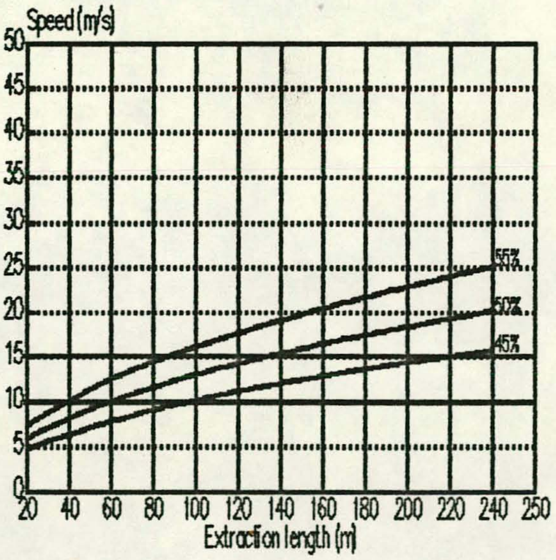
Log acceleration for the friction coefficient 0.30



Log acceleration for the friction coefficient 0.35



Log acceleration for the friction coefficient 0.40



Appendix C

The determination of log speed:

$$v = \sqrt{(2gs(\sin\alpha-fg*\cos\alpha)+c^2)}$$

Where: v - terminal log speed (m/s)
c - starting log speed (1 m/s)
fg - friction coefficient
s - extraction distance (m)
g - gravitation (9.81 m/s^2)
α - slope (degrees)

Thus for: $\alpha = 35\%$ (From Appendix H SLOPE - 19.3^{o})
$fg = 0.25$
$s = 150$ m

$v = 16.7$ m/s

The following can be used for the calculation of the required extraction length:

$$s = ((v^2-c^2)/(\sin\alpha-fg*\cos\alpha))*0.5g$$
$$= 0.051*((v^2-c^2)/(\sin\alpha-fg*\cos\alpha))$$

Where: s, v, c, fg, and α as above.
Thus for: $v = 10$ m/s
$c = 1$ m/s
$\alpha = 35\%$ (From Appendix H therefore 19.3^{o})
$fg = 0.25$

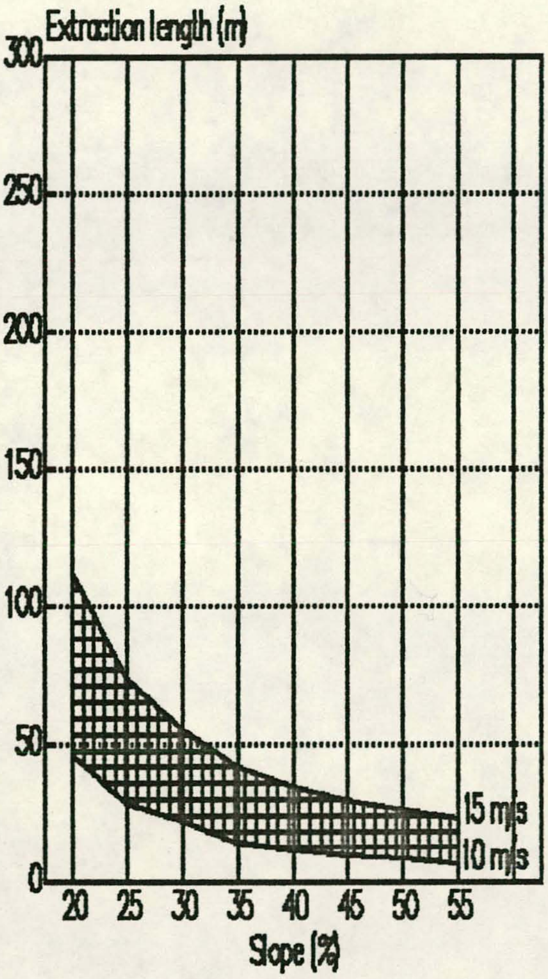
$$s = 0.051*((10^2-1^2)/(\sin 19.3-0.25*\cos 19.3))$$
$$= 53.4 \text{ m}$$

and for $v = 15$ m/s
$s = 120.8$ m

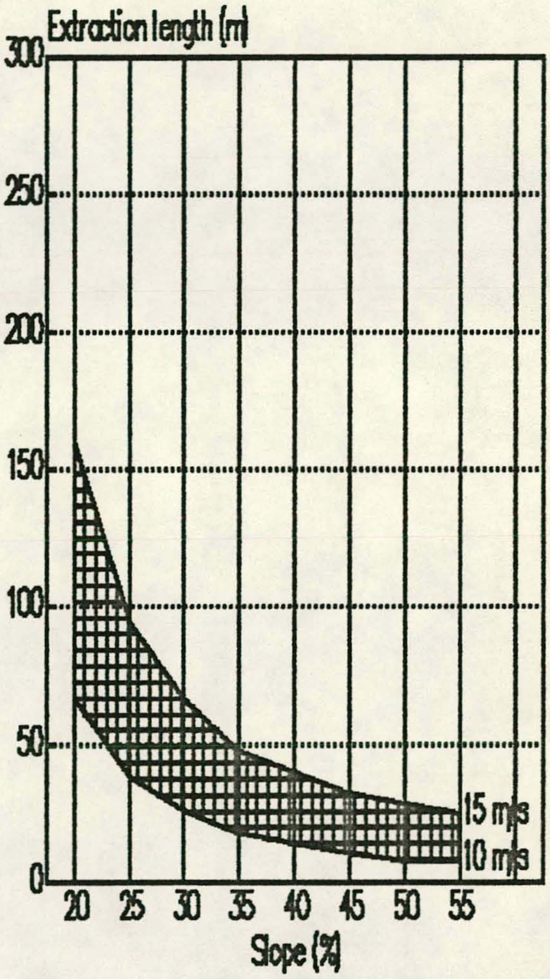
Appendix D

The derivation of required extraction slope

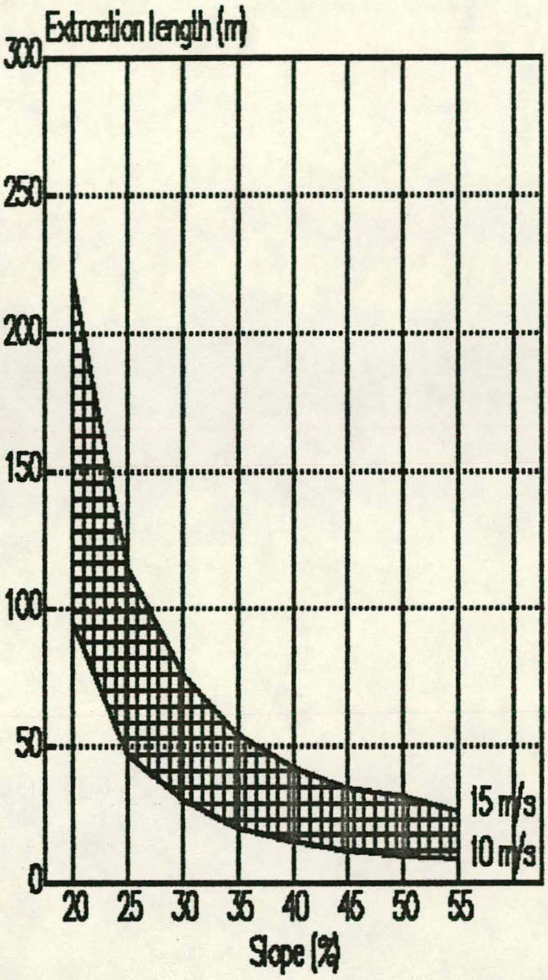
The recommended extraction lengths for the friction coefficient 0.10



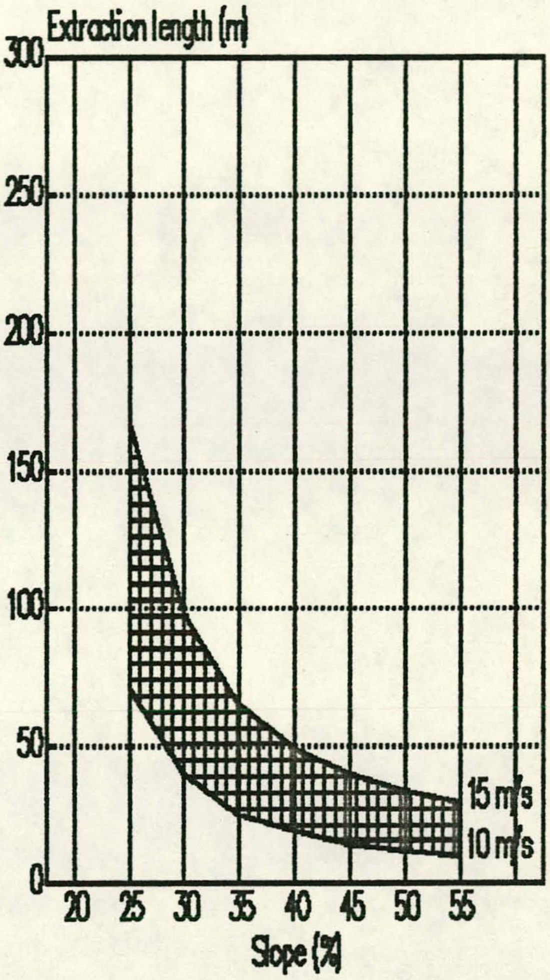
The recommended extraction lengths for the friction coefficient 0.13



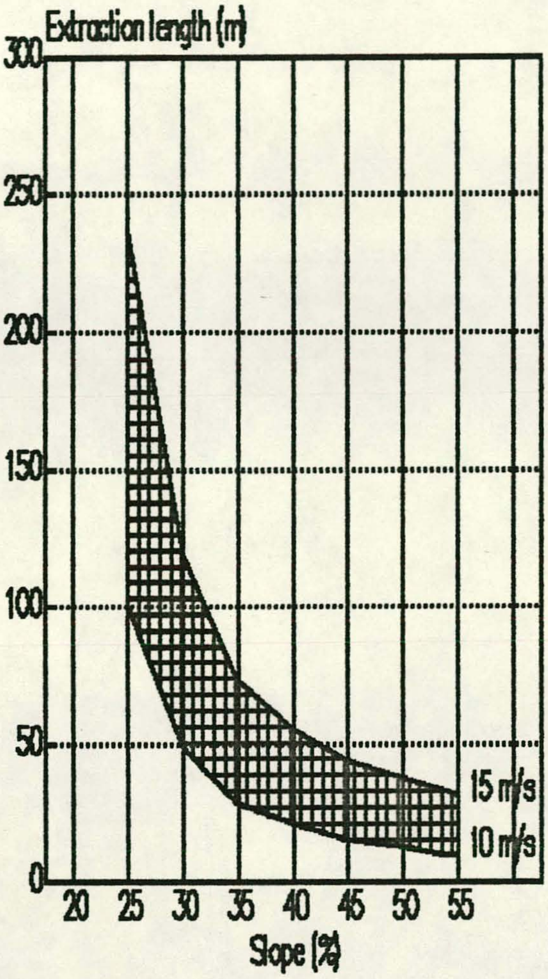
Recommended extraction lengths for the friction coefficient 0.15



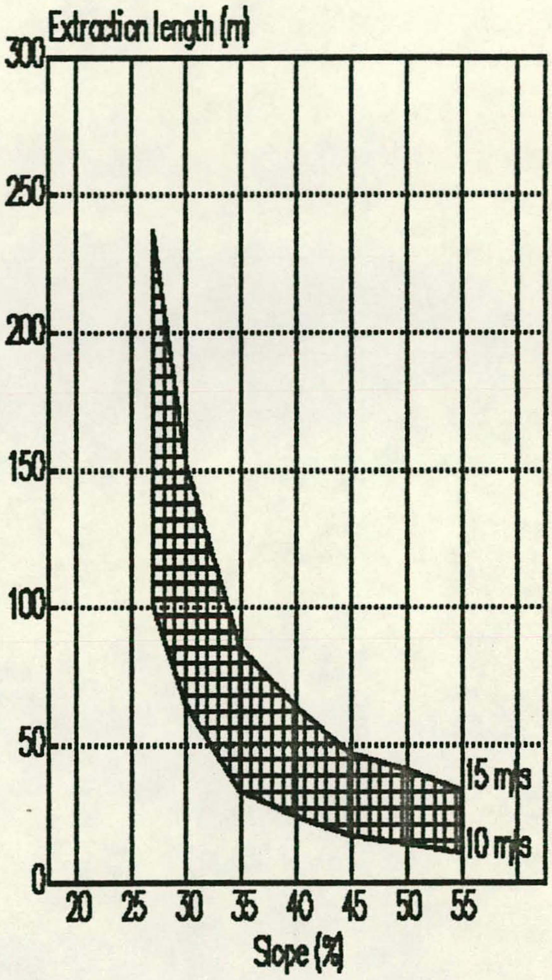
The recommended extraction lengths for the friction coefficient 0.18

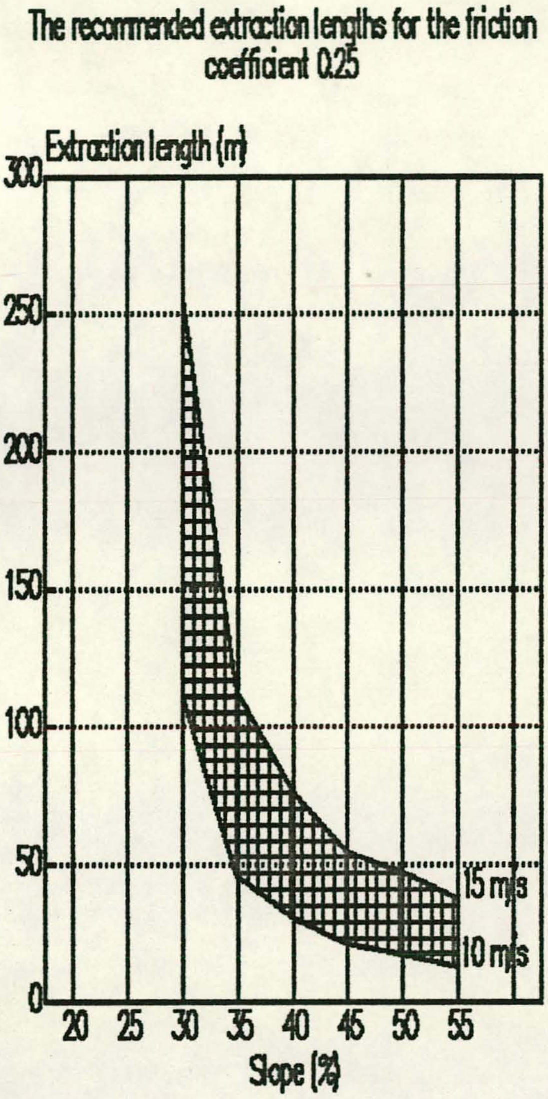


The recommended extraction lengths for the friction coefficient 0.20

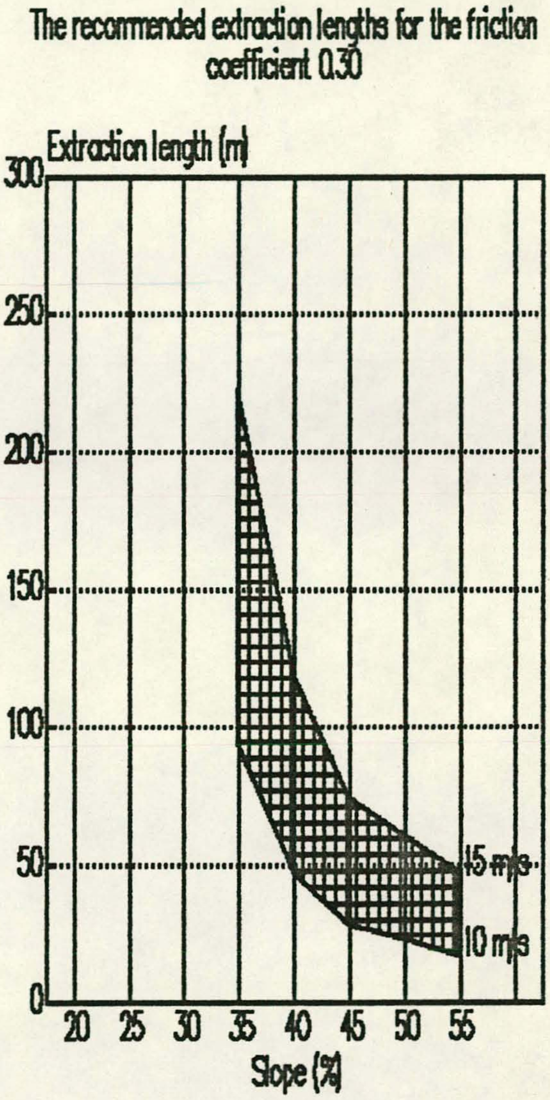


The recommended extraction lengths for the friction coefficient 0.22



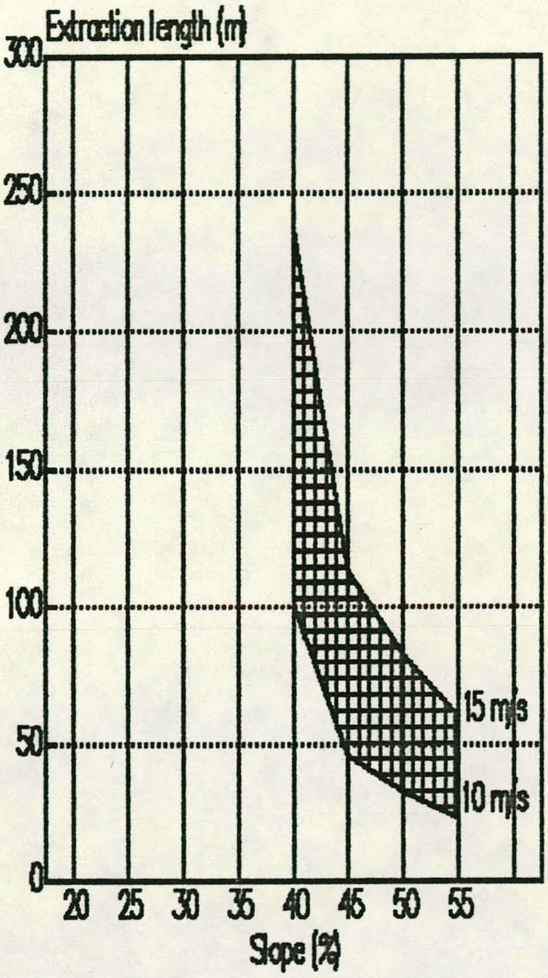


The recommended extraction lengths for the friction coefficient 0.25

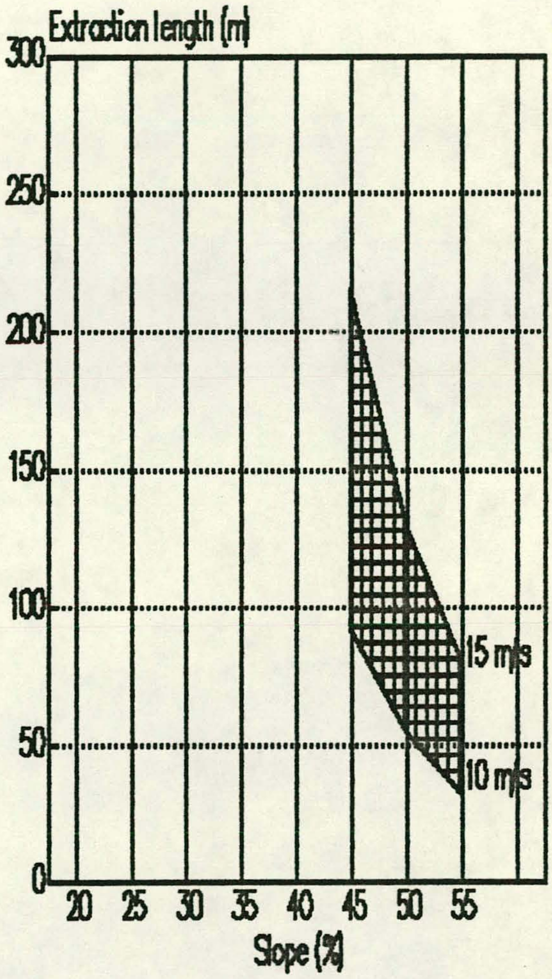


The recommended extraction lengths for the friction coefficient 0.30

The recommended extraction lengths for the friction coefficient 0.35



The recommended extraction length for the friction coefficient 0.40



Appendix E

The energy requirement calculation

The following assumptions are made (Helmer,1983):

- The construction (using a winch), the next construction and the hauling-in of timber of an extraction line straight down-hill	27.20 kJ/min
- Inserting the timber into the chute (straight down)	31.38 kJ/min
Inserting (traversing)	20.92 kJ/min
- Other chute related work (general work)	16.74 kJ/min
Other work (steep slopes)	18.83 kJ/min
- Not directly related work	12.55 kJ/min
- Breaks	5.10 kJ/min
Manual installation (estimated value)	35.25 kJ/min

Based on the above assumptions, energy requirements are calculated: For a 100 m long chute on a 30% slope with a 15 m wide extraction line (total extraction time without breaks and not related work times - 281 min).

Installation with a winch:

Tot. construct. times & haul-in	- 69% of 281 min	* 27.20	= 5274kJ
Inserting	- 27% " " "	* 31.38	= 2381kJ
Other related work	- 9% " " "	* 16.74	= 423kJ
Other not related work	- 25% " " "	* 12.55	= 882kJ
Breaks	- 45 min	* 5.10	= 230kJ
Total energy requirement			9190kJ

Installation by hand (manual):

Tot. construct. times & haul-in	- 69% of 281 min	* 35.25	= 6835kJ
Inserting	- 27% " " "	* 31.38	= 2381kJ
Other related work	- 9% " " "	* 16.74	= 423kJ
Other not related work	- 25% " " "	* 12.55	= 882kJ
Breaks	- 45 min	* 5.10	= 230kJ
Total energy requirement			10751kJ

Taxes = annual cost!

wages:
12.50/hour = ± R2200/month..

Appendix F

A machine cost calculation for the LLL based on a 150m long chute.

Main data input routine

1.Initial cost of machine delivered,incl.GST	R	24242.00	
2.Resale value of machine	R	0.00	
3.Interest factor or rate	%	21.00	
4.Premium paid for insurance	R/YEAR	54.80	
5.Useful life of machine	MHRS	6600.00	
6.Obsolescence time of machine	YEARS	10.00	
7.Amount paid for taxes on machine	R/YEAR	15896.00	p.a
8.Amount paid for garaging of machine	R/YEAR	50.00	
9.Repair cost factor	=	0.10	
10.Assistant(s) on the machine	NO	4	
11.Wage of machine operator	R/MHR	12.50	
12.Wage per assistant	R/MHR	8.50	
13.Social security contribution	%	46.00	
14.Maintenance	%	1.00	
15.Overheads	%	5.00	

Fuel cost calculation input scheme

1.Fuel consumption	l/MHR	0.77
2.Fuel price	R/l	1.30
3.Lubricant cost	R/MHR	0.07

```
                 Auxiliary equipment input scheme  No 1
--------------------------------------------------------------------------

1.Name of the equipment        - Chainsaw
2.Price of the Chainsaw                                R      1500.00
3.Useful life time of the Chainsaw                  MHRS      2000.00
4.Obsolescence lifetime of the Chainsaw            YEARS         5.00
5.Annual utilization of the Chainsaw                MHRS       300.00
6.Factor for repair cost of the Chainsaw               -         0.34
```

```
                  Summary of auxiliary equipment  No 1
--------------------------------------------------------------------------

1.Name of equipment             : Chainsaw
2.Purchase price                R  1500.00
3.Useful life time           MHRS  2000.00
4.Obsolescence lifetime     YEARS     5.00
5.Annual utilization         MHRS   300.00
6.Interest                  R/MHR     0.63
7.Depreciation              R/MHR     1.00
8.Repair cost               R/MHR     0.19


9.Total                     R/MHR     1.82
```

```
            Auxiliary equipment input scheme  No 2

1.Name of the equipment       - Sappie hooks
2.Price of the Sappie hooks                                 500.00
3.Useful life time of the Sappie hooks                     3000.00
4.Obsolescence lifetime of the Sappie hooks                   5.00
5.Annual utilization of the Sappie hooks                   1000.00
6.Factor for repair cost of the Sappie hooks                  0.10
```

```
             Summary of auxiliary equipment  No 2

1.Name of equipment             : Sappie hooks
2.Purchase price               R    500.00
3.Useful life time          MHRS   3000.00
4.Obsolescence lifetime    YEARS      5.00
5.Annual utilization        MHRS   1000.00
6.Interest                 R/MHR      0.06
7.Depreciation             R/MHR      0.17
8.Repair cost              R/MHR      0.02


9.Total                    R/MHR      0.25
```

```
             Auxiliary equipment input scheme  No 3
----------------------------------------------------------------------------

 1.Name of the equipment       - Ropes
 2.Price of the Ropes                             R              400.00
 3.Useful life time of the Ropes               MHRS             1300.00
 4.Obsolescence lifetime of the Ropes         YEARS                2.00
 5.Annual utilization of the Ropes             MHRS             1300.00
 6.Factor for repair cost of the Ropes            -                0.20
```

```
               Summary of auxiliary equipment  No 3
----------------------------------------------------------------------------

 1.Name of equipment            :      Ropes
 2.Purchase price               R     400.00
 3.Useful life time          MHRS    1300.00
 4.Obsolescence lifetime    YEARS       2.00
 5.Annual utilization        MHRS    1300.00
 6.Interest                 R/MHR       0.04
 7.Depreciation             R/MHR       0.31
 8.Repair cost              R/MHR       0.06


 9.Total                    R/MHR       0.41
```

```
                Auxiliary equipment input scheme  No 4
---------------------------------------------------------------------------

 1.Name of the equipment       - Other tools
 2.Price of the Other tools                                  500.00
 3.Useful life time of the Other tools                      6500.00
 4.Obsolescence lifetime of the Other tools                   10.00
 5.Annual utilization of the Other tools                     800.00
 6.Factor for repair cost of the Other tools                   0.10
```

```
                Summary of auxiliary equipment  No 4
---------------------------------------------------------------------------

 1.Name of equipment          : Other tools
 2.Purchase price            R    500.00
 3.Useful life time       MHRS   6500.00
 4.Obsolescence lifetime YEARS     10.00
 5.Annual utilization     MHRS    800.00
 6.Interest              R/MHR      0.08
 7.Depreciation          R/MHR      0.08
 8.Repair cost           R/MHR      0.01


 9.Total                 R/MHR      0.16
```

```
                        Utilization : 600 MHRS/YEAR
Name of machine    :
Commissioner       : BW Krieg
Date               :
 INPUT                                     OUTPUT
 1.Purchase price         R    24242.00  1.Value for depreciation  R      24242.00
 2.Resale value           R        0.00  2.Annual utilization   MHRS        660.00
 3.Useful lifetime     MHRS     6600.00  3.Actual utilization in YRS        10.00
 4.Annual utilization  MHRS      600.00  4.MHRS during obsolescence        6000.00
 5.Interest rate          %       21.00
 6.Insurance         R/YEAR       54.80   MARGINAL UTILIZATION NOT ACHIEVED
 7.Tax               R/YEAR    15896.00
 8.Garaging          R/YEAR       50.00   Total cost during lifespan of machine
 9.Obsolescence       YEARS       10.00  5.Total repair  costs    R        2424.20
10.Repair cost factor     %       10.00  6.Wage machine operator  R       75000.00
11.Fuel consumption   1/MHR        0.77  7.Total interest costs   R       30544.92
12.Fuel price           R/1        1.30
13.Fuel costs         R/MHR        1.00
14.Lubricants         R/MHR        0.07
15.Wage operator      R/MHR       12.50
16.Wage assistant(s)  R/MHR       34.00
18.Overheads              %        5.00  Cost per machine hour.....press ENTER



                              Cost per machine hour
Depreciation                       R/MHR        4.04
Interest                           R/MHR        5.09
Insurance                          R/MHR        0.09
Tax                                R/MHR       26.49
Garage                             R/MHR        0.08
 (A) Fixed costs                   R/MHR       35.80
Repairs                            R/MHR        0.33
Fuel costs                         R/MHR        1.00
Lubricants                         R/MHR        0.07
Accesories                         R/MHR        0.00
Auxiliary equipment                R/MHR        2.64
 (B) Variable costs                R/MHR        4.04
Wage     :operator                 R/MHR       18.25
Wage(s) :assistant(s)              R/MHR       49.64
Maintenance                        R/MHR        0.18
 (C) Wages costs                   R/MHR       68.07

Subtotal (A+B+C)                   R/MHR      107.92

 (D)  Overheads                    R/MHR        5.40
 -------------------------------------------------
 TOTAL (A+B+C+D)                   R/MHR      113.31
 =================================================
```

?

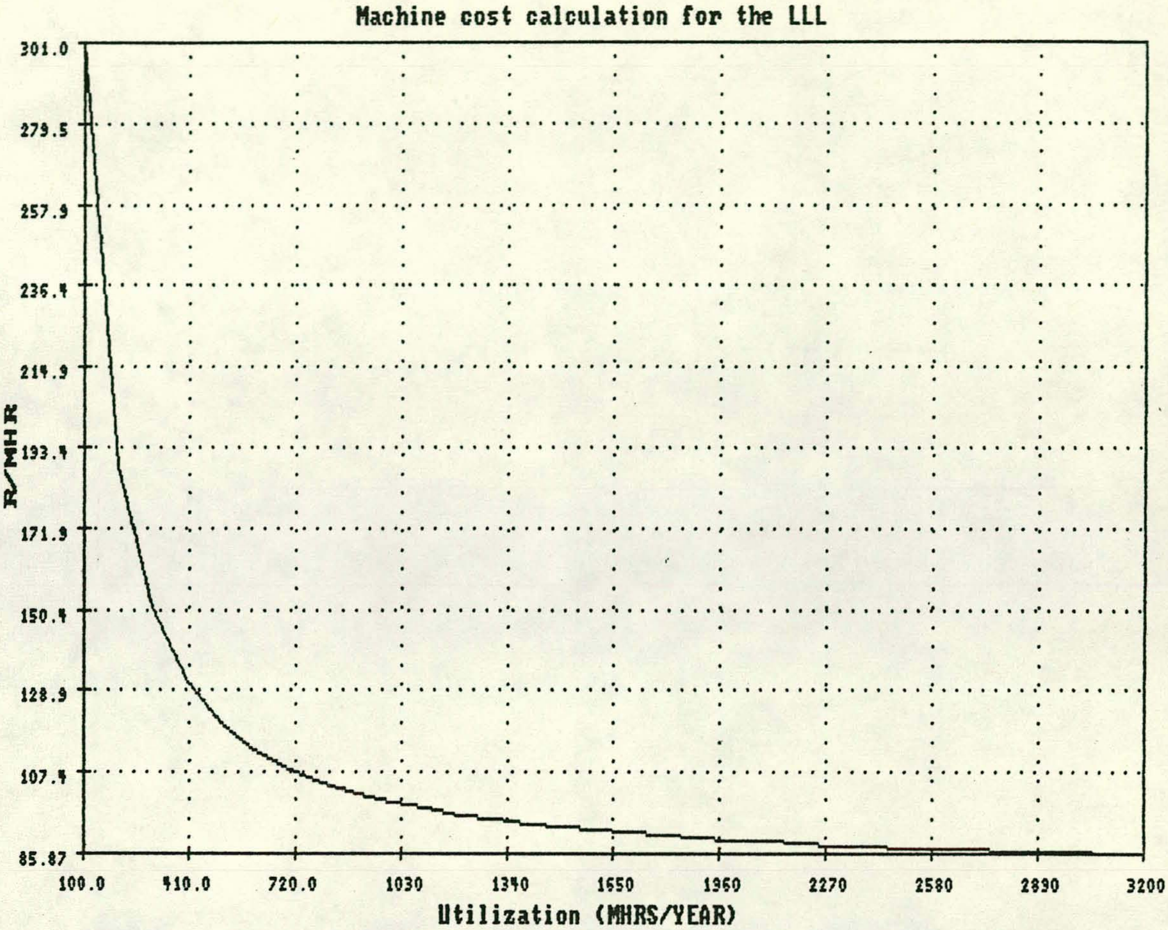
12000 p.a.? in 1991?

75000 p.a.?

```
                        Utilization : 700 MHRS/YEAR
Name of machine    :
Commissioner       : BW Krieg
Date               :
 INPUT                                        OUTPUT
 1.Purchase price          R    24242.00     1.Value for depreciation  R      24242.00
 2.Resale value            R        0.00     2.Annual utilization   MHRS        660.00
 3.Useful lifetime      MHRS     6600.00     3.Actual utilization in YRS         10.00
 4.Annual utilization MHRS        700.00     4.MHRS during obsolescence        7000.00
 5.Interest rate           %       21.00
 6.Insurance          R/YEAR       54.80      MARGINAL UTILIZATION ACHIEVED
 7.Tax                R/YEAR    15896.00
 8.Garaging           R/YEAR       50.00      Total cost during lifespan of machine
 9.Obsolescence        YEARS       10.00     5.Total repair  costs     R       2424.20
10.Repair cost factor      %       10.00     6.Wage machine operator   R      87500.00
11.Fuel consumption    l/MHR        0.77     7.Total interest costs    R      30544.92
12.Fuel price            R/l        1.30
13.Fuel costs          R/MHR        1.00
14.Lubricants          R/MHR        0.07
15.Wage operator       R/MHR       12.50
16.Wage assistant(s) R/MHR         34.00
18.Overheads               %        5.00     Cost per machine hour.....press ENTER
```

```
                            Cost per machine hour
Depreciation                      R/MHR        3.67
Interest                          R/MHR        4.36
Insurance                         R/MHR        0.08
Tax                               R/MHR       22.71
Garage                            R/MHR        0.07
 (A) Fixed costs                  R/MHR       30.89
Repairs                           R/MHR        0.37
Fuel costs                        R/MHR        1.00
Lubricants                        R/MHR        0.07
Accesories                        R/MHR        0.00
Auxiliary equipment               R/MHR        2.64
 (B) Variable costs               R/MHR        4.08
Wage      :operator               R/MHR       18.25
Wage(s) :assistant(s)             R/MHR       49.64
Maintenance                       R/MHR        0.18
 (C) Wages costs                  R/MHR       68.07

Subtotal (A+B+C)                  R/MHR      103.04

 (D)  Overheads                   R/MHR        5.15
 --------------------------------------------------
 TOTAL (A+B+C+D)                  R/MHR      108.20
 ==================================================
```

```
                       Utilization : 1500 MHRS/YEAR
Name of machine    :
Commissioner       : BW Krieg
Date               :
 INPUT                                     OUTPUT
 1.Purchase price        R    24242.00    1.Value for depreciation  R     24242.00
 2.Resale value          R        0.00    2.Annual utilization    MHRS      660.00
 3.Useful lifetime    MHRS     6600.00    3.Actual utilization in YRS        10.00
 4.Annual utilization MHRS     1500.00    4.MHRS during obsolescence      15000.00
 5.Interest rate         %       21.00
 6.Insurance        R/YEAR       54.80     MARGINAL UTILIZATION ACHIEVED
 7.Tax              R/YEAR    15896.00
 8.Garaging         R/YEAR       50.00     Total cost during lifespan of machine
 9.Obsolescence      YEARS       10.00    5.Total repair  costs     R      2424.20
10.Repair cost factor    %       10.00    6.Wage machine operator   R    187500.00
11.Fuel consumption  1/MHR        0.77    7.Total interest costs    R     30544.92
12.Fuel price          R/1        1.30
13.Fuel costs        R/MHR        1.00
14.Lubricants        R/MHR        0.07
15.Wage operator     R/MHR       12.50
16.Wage assistant(s) R/MHR       34.00
18.Overheads             %        5.00    Cost per machine hour.....press ENTER



                              Cost per machine hour
Depreciation                       R/MHR         3.67
Interest                           R/MHR         2.04
Insurance                          R/MHR         0.04
Tax                                R/MHR        10.60   X
Garage                             R/MHR         0.03
 (A) Fixed costs                   R/MHR        16.38
Repairs                            R/MHR         0.37
Fuel costs                         R/MHR         1.00
Lubricants                         R/MHR         0.07
Accesories                         R/MHR         0.00
Auxiliary equipment                R/MHR         2.64
 (B) Variable costs                R/MHR         4.08
Wage      :operator                R/MHR        18.25 x1500   = 27,375
Wage(s) :assistant(s)              R/MHR        49.64 x1500/4 =
Maintenance                        R/MHR         0.18
 (C) Wages costs                   R/MHR        68.07

Subtotal (A+B+C)                   R/MHR        88.53

 (D)  Overheads                    R/MHR         4.43
 ---------------------------------------------------------
 TOTAL (A+B+C+D)                   R/MHR        92.95
 =========================================================
```


Machine cost calculation for the LLL
R/MHR
301.0
279.5
257.9
236.4
214.9
193.4
171.9
150.4
128.9
107.4
85.87
100.0
410.0
720.0
1030
1340
1650
1960
2270
2580
2890
3200
Utilization (MHRS/YEAR)

Appendix G

A machine cost calculation for the a 150m long nylon$_6$ chute.

```
                        Main data input routine
----------------------------------------------------------------------

  1.Initial cost of machine delivered,incl.GST R          38400.00
  2.Resale value of machine                    R              0.00
  3.Interest factor or rate                    %             23.00
  4.Premium paid for insurance            R/YEAR             65.00
  5.Useful life of machine                  MHRS           6600.00
  6.Obsolescence time of machine           YEARS             10.00
  7.Amount paid for taxes on machine      R/YEAR              0.00
  8.Amount paid for garaging of machine   R/YEAR             70.00
  9.Repair cost factor                         =              0.10
 10.Assistant(s) on the machine               NO             4
 11.Wage of machine operator              R/MHR               3.30
 12.Wage per assistant                    R/MHR               2.70
 13.Social security contribution              %             45.00
 14.Maintenance                               %              1.00
 15.Overheads                                 %              5.00
```

```
                   Fuel cost calculation input scheme
----------------------------------------------------------------------


  1.Fuel consumption                       1/MHR           0.77
  2.Fuel price                               R/1           1.30
  3.Lubricant cost                         R/MHR           0.07
```

```
              Auxiliary equipment input scheme  No 1

1.Name of the equipment       - Chainsaw
2.Price of the Chainsaw                            R     1800.00
3.Useful life time of the Chainsaw              MHRS     2000.00
4.Obsolescence lifetime of the Chainsaw        YEARS        5.00
5.Annual utilization of the Chainsaw            MHRS      300.00
6.Factor for repair cost of the Chainsaw           -        0.34
```

```
              Summary of auxiliary equipment  No 1

1.Name of equipment           : Chainsaw
2.Purchase price             R  1800.00
3.Useful life time        MHRS  2000.00
4.Obsolescence lifetime  YEARS     5.00
5.Annual utilization      MHRS   300.00
6.Interest               R/MHR     0.83
7.Depreciation           R/MHR     1.20
8.Repair cost            R/MHR     0.23


9.Total                  R/MHR     2.26
```

```
                 Auxiliary equipment input scheme  No 2

 1.Name of the equipment       - Sappie hooks
 2.Price of the Sappie hooks                                    600.00
 3.Useful life time of the Sappie hooks                        3000.00
 4.Obsolescence lifetime of the Sappie hooks                      5.00
 5.Annual utilization of the Sappie hooks                      1000.00
 6.Factor for repair cost of the Sappie hooks                     0.10
```

```
                  Summary of auxiliary equipment  No 2

 1.Name of equipment          : Sappie hooks
 2.Purchase price             R   600.00
 3.Useful life time        MHRS  3000.00
 4.Obsolescence lifetime  YEARS     5.00
 5.Annual utilization      MHRS  1000.00
 6.Interest               R/MHR     0.08
 7.Depreciation           R/MHR     0.20
 8.Repair cost            R/MHR     0.02


 9.Total                  R/MHR     0.30
```

```
                  Auxiliary equipment input scheme  No 3

 1.Name of the equipment       - Ropes
 2.Price of the Ropes                          R           600.00
 3.Useful life time of the Ropes            MHRS          1300.00
 4.Obsolescence lifetime of the Ropes      YEARS             2.00
 5.Annual utilization of the Ropes          MHRS          1300.00
 6.Factor for repair cost of the Ropes         -             0.20
```

```
                    Summary of auxiliary equipment  No 3

 1.Name of equipment           :     Ropes
 2.Purchase price              R    600.00
 3.Useful life time         MHRS   1300.00
 4.Obsolescence lifetime   YEARS      2.00
 5.Annual utilization       MHRS   1300.00
 6.Interest                R/MHR      0.06
 7.Depreciation            R/MHR      0.46
 8.Repair cost             R/MHR      0.09


 9.Total                   R/MHR      0.62
```

```
                 Auxiliary equipment input scheme  No 4

1.Name of the equipment        - Other tools
2.Price of the Other tools                                   700.00
3.Useful life time of the Other tools                       6500.00
4.Obsolescence lifetime of the Other tools                    10.00
5.Annual utilization of the Other tools                      800.00
6.Factor for repair cost of the Other tools                    0.10
```

```
                  Summary of auxiliary equipment  No 4

1.Name of equipment            : Other tools
2.Purchase price              R    700.00
3.Useful life time         MHRS   6500.00
4.Obsolescence lifetime   YEARS     10.00
5.Annual utilization       MHRS    800.00
6.Interest                R/MHR      0.12
7.Depreciation            R/MHR      0.11
8.Repair cost             R/MHR      0.01


9.Total                   R/MHR      0.24
```

```
                          Utilization : 600 MHRS/YEAR
Name of machine      :
Commissioner         : BW Krieg
Date                 :
 INPUT                                       OUTPUT
 1.Purchase price          R    38400.00   1.Value for depreciation  R     38400.00
 2.Resale value            R        0.00   2.Annual utilization    MHRS      660.00
 3.Useful lifetime      MHRS     6600.00   3.Actual utilization in YRS       10.00
 4.Annual utilization MHRS        600.00   4.MHRS during obsolescence       6000.00
 5.Interest rate           %       23.00
 6.Insurance          R/YEAR       65.00    MARGINAL UTILIZATION NOT ACHIEVED
 7.Tax                R/YEAR        0.00
 8.Garaging           R/YEAR       70.00    Total cost during lifespan of machine
 9.Obsolescence        YEARS       10.00   5.Total repair  costs     R      3840.00
10.Repair cost factor      %       10.00   6.Wage machine operator   R     19800.00
11.Fuel consumption    1/MHR        0.77   7.Total interest costs    R     52992.00
12.Fuel price            R/1        1.30
13.Fuel costs          R/MHR        1.00
14.Lubricants          R/MHR        0.07
15.Wage operator       R/MHR        3.30
16.Wage assistant(s)   R/MHR       10.80
18.Overheads               %        5.00   Cost per machine hour.....press ENTER
```

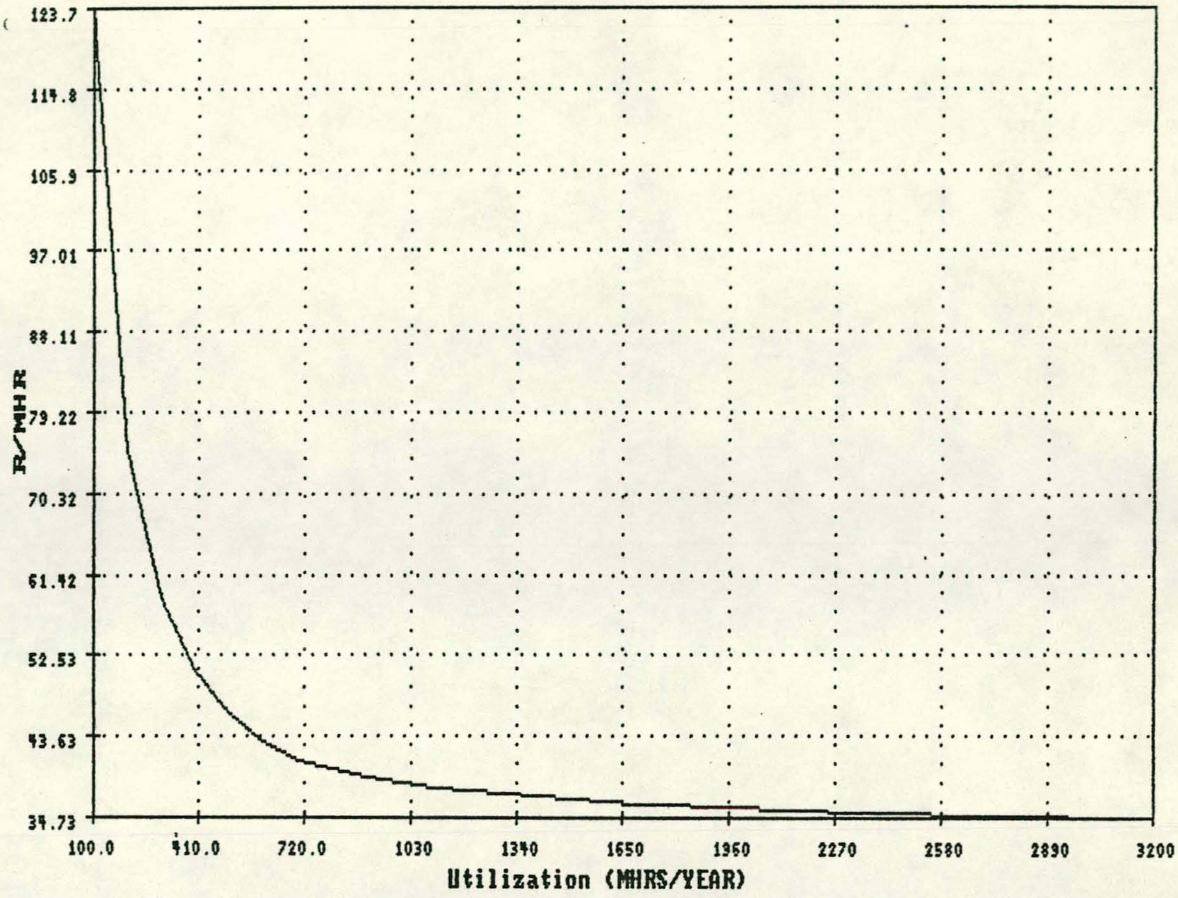
```
                              Cost per machine hour
Depreciation                       R/MHR        6.40
Interest                           R/MHR        8.83
Insurance                          R/MHR        0.11
Tax                                R/MHR        0.00
Garage                             R/MHR        0.12
 (A) Fixed costs                   R/MHR       15.46
Repairs                            R/MHR        0.53
Fuel costs                         R/MHR        1.00
Lubricants                         R/MHR        0.07
Accesories                         R/MHR        0.00
Auxiliary equipment                R/MHR        3.42
 (B) Variable costs                R/MHR        5.02
Wage      :operator                R/MHR        4.78
Wage(s) :assistant(s)              R/MHR       15.66
Maintenance                        R/MHR        0.05
 (C) Wages costs                   R/MHR       20.49

Subtotal (A+B+C)                   R/MHR       40.97

 (D)  Overheads                    R/MHR        2.05
 -------------------------------------------------
 TOTAL (A+B+C+D)                   R/MHR       43.02
 =================================================
```

```
                      Utilization : 700 MHRS/YEAR
Name of machine     :
Commissioner        : BW Krieg
Date                :
 INPUT                                        OUTPUT
 1.Purchase price         R    38400.00  1.Value for depreciation  R     38400.00
 2.Resale value           R        0.00  2.Annual utilization   MHRS       660.00
 3.Useful lifetime     MHRS     6600.00  3.Actual utilization in YRS        10.00
 4.Annual utilization MHRS       700.00  4.MHRS during obsolescence       7000.00
 5.Interest rate          %       23.00
 6.Insurance         R/YEAR       65.00   MARGINAL UTILIZATION ACHIEVED
 7.Tax               R/YEAR        0.00
 8.Garaging          R/YEAR       70.00   Total cost during lifespan of machine
 9.Obsolescence       YEARS       10.00  5.Total repair  costs     R      3840.00
10.Repair cost factor     %       10.00  6.Wage machine operator   R     23100.00
11.Fuel consumption  1/MHR         0.77  7.Total interest costs    R     52992.00
12.Fuel price           R/1        1.30
13.Fuel costs         R/MHR        1.00
14.Lubricants         R/MHR        0.07
15.Wage operator      R/MHR        3.30
16.Wage assistant(s) R/MHR        10.80
18.Overheads              %        5.00  Cost per machine hour.....press ENTER



                                  Cost per machine hour
Depreciation                            R/MHR          5.82
Interest                                R/MHR          7.57
Insurance                               R/MHR          0.09
Tax                                     R/MHR          0.00
Garage                                  R/MHR          0.10
 (A) Fixed costs                        R/MHR         13.58
Repairs                                 R/MHR          0.58
Fuel costs                              R/MHR          1.00
Lubricants                              R/MHR          0.07
Accesories                              R/MHR          0.00
Auxiliary equipment                     R/MHR          3.42
 (B) Variable costs                     R/MHR          5.07
Wage     :operator                      R/MHR          4.78
Wage(s) :assistant(s)                   R/MHR         15.66
Maintenance                             R/MHR          0.05
 (C) Wages costs                        R/MHR         20.49

Subtotal (A+B+C)                        R/MHR         39.14

 (D)  Overheads                         R/MHR          1.96
 -----------------------------------------------------
 TOTAL (A+B+C+D)                        R/MHR         41.10
 =====================================================
```

```
                         Utilization : 1500 MHRS/YEAR
Name of machine    :
Commissioner       : BW Krieg
Date               :
 INPUT                                     OUTPUT
 1.Purchase price          R    38400.00  1.Value for depreciation  R      38400.00
 2.Resale value            R        0.00  2.Annual utilization   MHRS        660.00
 3.Useful lifetime      MHRS     6600.00  3.Actual utilization in YRS         10.00
 4.Annual utilization MHRS       1500.00  4.MHRS during obsolescence       15000.00
 5.Interest rate           %       23.00
 6.Insurance          R/YEAR       65.00   MARGINAL UTILIZATION ACHIEVED
 7.Tax                R/YEAR        0.00
 8.Garaging           R/YEAR       70.00   Total cost during lifespan of machine
 9.Obsolescence        YEARS       10.00  5.Total repair  costs     R       3840.00
10.Repair cost factor      %       10.00  6.Wage machine operator   R      49500.00
11.Fuel consumption    1/MHR        0.77  7.Total interest costs    R      52992.00
12.Fuel price            R/1        1.30
13.Fuel costs          R/MHR        1.00
14.Lubricants          R/MHR        0.07
15.Wage operator       R/MHR        3.30
16.Wage assistant(s) R/MHR         10.80
18.Overheads               %        5.00  Cost per machine hour.....press ENTER



                              Cost per machine hour
Depreciation                          R/MHR         5.82
Interest                              R/MHR         3.53
Insurance                             R/MHR         0.04
Tax                                   R/MHR         0.00
Garage                                R/MHR         0.05
 (A) Fixed costs                      R/MHR         9.44
Repairs                               R/MHR         0.58
Fuel costs                            R/MHR         1.00
Lubricants                            R/MHR         0.07
Accesories                            R/MHR         0.00
Auxiliary equipment                   R/MHR         3.42
 (B) Variable costs                   R/MHR         5.07
Wage     :operator                    R/MHR         4.78
Wage(s) :assistant(s)                 R/MHR        15.66
Maintenance                           R/MHR         0.05
 (C) Wages costs                      R/MHR        20.49

Subtotal (A+B+C)                      R/MHR        35.00

 (D)  Overheads                       R/MHR         1.75
 ------------------------------------------------------
 TOTAL (A+B+C+D)                      R/MHR        36.75
 ======================================================
```

3154,8 p.a

Machine cost calculation for the Nylon_6 chute



Appendix H

Conversion for degrees to percentages (slopes).

Degrees	percentages	degrees	percentages
1	1.8	24	44.5
2	3.5	25	46.6
3	5.2	26	48.8
4	7.0	27	51.0
5	8.8	28	53.2
6	10.5	29	55.4
7	12.3	30	57.7
8	14.1	31	60.1
9	15.8	32	62.5
10	17.6	33	64.9
11	19.4	34	67.5
12	21.3	35	70.0
13	23.1	36	72.7
14	24.9	37	75.4
15	26.8	38	78.1
16	28.7	39	81.0
17	30.6	40	83.9
18	32.5	41	86.9
19	34.4	42	90.0
20	36.4	43	93.3
21	38.4	44	96.6
22	40.4	45	100.0
23	42.5		

Conversion from percentage to degrees (slope)

%	degrees	%	degrees	%	degrees
1		35	19.3	68	34.2
2	1.1	36	19.8	69	34.6
3	1.7	37	20.3	70	35.0
4	2.3	38	20.8	71	35.4
5	2.9	39	21.3	72	35.7
6	3.4	40	21.8	73	36.1
7	4.0	41	22.3	74	36.5
8	4.6	42	22.8	75	36.9
9	5.1	43	23.3	76	37.2
10	5.7	44	23.8	77	37.6
11	6.3	45	24.2	78	38.0
12	6.8	46	24.7	79	38.3
13	7.4	47	25.2	80	38.7
14	7.9	48	25.6	81	39.0
15	8.5	49	26.1	82	39.3
16	9.1	50	26.5	83	39.7
17	9.7	51	27.0	84	40.0
18	10.2	52	27.5	85	40.4
19	10.8	53	27.9	86	40.7
20	11.3	54	28.4	87	41.0
21	11.9	55	28.8	88	41.4
22	12.4	56	29.3	89	41.7
23	12.9	57	29.7	90	42.0
24	13.5	58	30.1	91	42.3
25	14.1	59	30.5	92	42.6
26	14.6	60	31.0	93	42.9
27	15.1	61	31.4	94	43.2
28	15.6	62	31.8	95	43.5
29	16.2	63	32.2	96	43.8
30	16.7	64	32.6	97	44.1
31	17.2	65	33.0	98	44.4
32	17.7	66	33.4	99	44.7
33	18.3	67	33.8	100	45.0
34	18.8				

DEPARTEMENT VAN WATERWESE EN BOSBOU
DEPARTMENT OF WATER AFFAIRS AND FORESTRY
REPUBLIEK VAN SUID-AFRIKA • REPUBLIC OF SOUTH AFRICA

OSBOU • FORESTRY

DIE STREEKDIREKTEUR
TAK BOSBOU
PRIVAATSAK X2413
LOUIS TRICHARDT
0920

Navrae: Enquiries: Mnr S van Niekerk

Telefoon: Telephone: (01551) 2201
Faks 5-1062

Verwysing: Reference: 11/11/1/902

Die Adjunk-Direkteur-Generaal
Departement van Waterwese en Bosbou
Tak Bosbou
Privaatsak X93
PRETORIA
0001

1992-02-17

VIR AANDAG: MNR A ROBERTSON

<u>AANSOEK OM PERSEEL : OPRIGTING VAN HUT MET OMHEINING : PIJPKOP HERHALER STASIE : DEPARTEMENT ONTWIKKELINGSHULP</u>

Aangeheg :

1. Aansoek van bogenoemde Departement.
2. Kaart vir lokaliteit van hut.
3. Skrywe van S.M.S. wat die hut sal oprig.
4. Plan van hut.
5. Afskrif van lisensie gedateer 1 September 1985.

Hierdie kantoor het nie beswaar teen oprigting van die hut nie. Daar is geen bome in gedrang nie. Die hut sal nie die omgewing verder ontsier nie.

STREEKDIREKTEUR
NOORD-TRANSVAAL

BYLAE A

LISENSIE UITGEREIK KRAGTENS DIE BEPALINGS VAN DIE BOSWET, 1968 (WET 72 VAN 1968), SOOS GEWYSIG

UITGEREIK AAN ..Departement Samewerking en Ontwikkeling, Pretoria.......... ....(hierna "die begunstigde" genoem).

Onderworpe aan die bepalings van die Boswet, 1968 en die standaardvoorwaardes in die aangehegte Bylae B sowel as die spesiale voorwaardes in die aangehegte Bylae .D.. word toestemming hiermee aan die begunstigde verleen om -

'n terrein, gemerk ABCD op die aangehegte skets op Woodbush-staatsbos te gebruik vir die oprigting en instandhouding van 'n radiohersendstasie waaraan slegs die begunstigde se eie, sowel as die antennas van mnre. B van Zyl en F de Beer gekoppel mag word.

GELDIGHEIDSDUUR VAN LISENSIE: Een (1) jaar vanaf ...1 September 1985........ tot .31 Augustus 1986........... (raadpleeg toepaslike hernuwingsklousule).

LISENSIEGELD van .R15-00...................... (..VYFTIEN...... Rand) is vir die geldigheidsduur van hierdie lisensie betaal.

GETEKEN te ..LOUIS TRICHARDT............., op hede die .15 de............ dag van ......OKTOBER............... 1985..

....

* DIREKTEUR-GENERAAL: OMGEWINGSAKE

....

* HANDTEKENING VAN BEGUNSTIGDE

GETUIES

Plek ..Pretoria........

* 1. ....

Datum ..17 Sept. 1985

* 2. ....

* L.W. Hierdie persone moet ook die Bylaes parafeer.

(2/1981)