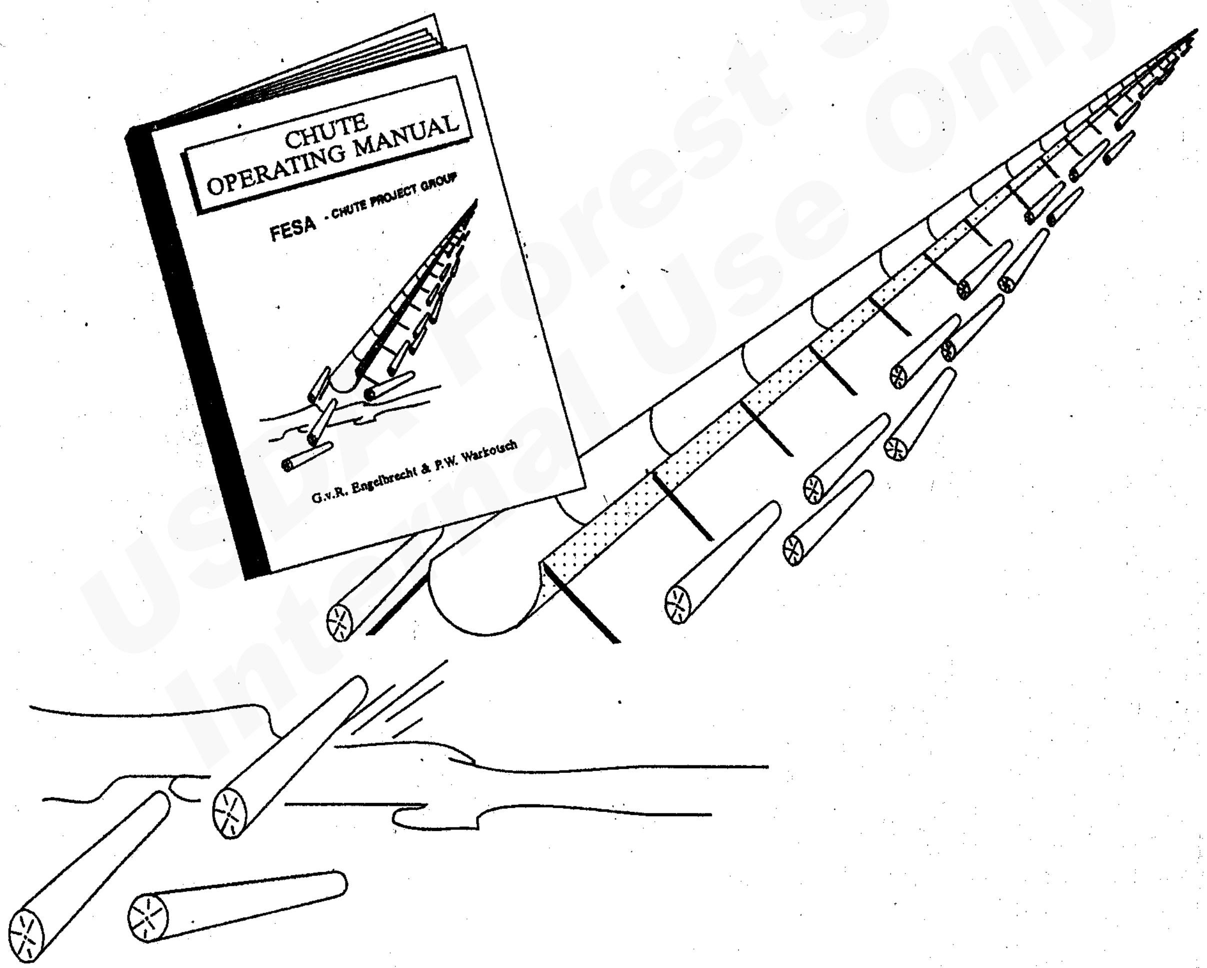
CHUTE OPERATING MANUAL

FESA - CHUTE PROJECT GROUP



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PREFACE

Timber chutes have been successfully used for several decades in a number of forestry countries. Chutes are regarded as a low tech, low cost timber extraction system without health hazards such as noise, vibration and exhaust gasses. Chutes can be operated by relatively low skilled workers and are proven to be environmentally friendly causing no soil compaction and only little soil disturbance when applied correctly.

In 1989 the Forest Engineering Working Group of South Africa (FESA) decided to form a Chute Project Group with the objective of investigating the viability of chutes and developing a chute system suitable for South African conditions. Special funds were allocated by the companies involved and the Forest Owners Association (FOA) as well as the Forest Engineering Technology (FET) of the University of Stellenbosch showed strong support and enthusiasm for the venture.

Many new ideas were developed, alternative materials tested and thus considerable progress was achieved.

During 1992 work commenced on the first chapters of the Chute Operating Manual. The information contained in this manual was collected from the research work documented in an M.Sc.thesis, a technical report, the minutes of the Chute Project Group meetings, overseas literature and the knowledge and experience gained by the members of the project group.

The Chute Manual was produced to serve as a supplementary tool, a source of information, a planning, operating and training aid to assist the concept of chuting to succeed in South Africa but also in other countries around the world with similar requirements.

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INTRODUCTION

1. Chute Concept

The chute is a channel system which has been developed to transport timber by guiding it down a slope to the roadside or a landing, from where it is easily accessible to other means of transport. Timber chutes make use of the most economic energy source available, namely gravity.

The chute line consists of round or half pipe pieces joined end to end, forming a continuous channel, and is stabilized by ropes or legs or both. The logs are fed into the chute manually and, by force of gravity, slide down the chute to a designated landing.

Due to the apparent simplicity of the system, managers tend to underestimate the importance of proper planning. When timber is extracted with the chuting method basic physical principles are involved, and when these rules are applied a successful operation can be anticipated.

Harvesting damage to sensitive growing sites has become a major concern to the Forest Industry. Environmental factors such as the adverse effects of compaction and soil erosion on site and water quality cannot be neglected. Loss of growth, as a result of applying the wrong extraction system, is a serious reality in many forestry areas.

The chute is an environmentally friendly extraction method that has little or no impact on the site. Soil disturbance is limited to a minimum and compaction does not occur.

2. Historical Review

Timber chutes have been used in a number of countries for decades. These chutes varied from chutes constructed from timber and steel to those constructed from various forms of plastic. Chutes constructed from timber require time and special carpentry skills, whereas metal chutes are heavy and time-consuming to install. These chutes were suitable as permanent or semi-permanent structures. The latest trend has been the development of lighter and more flexible materials such as polyethylene and nylon.

The application of chutes for timber extraction is a relatively new concept in the South African Forest Industry. This situation changed during the second half of the eighties when Lotzaba Forests, Sappi, NTE (now Mondi) and HL&H, together with the Forest Engineering Technology (FET) section of the University of Stellenbosch, formed the **Chute Project Group** of the **Forest Engineering Working Group of South Africa** (FESA). Field studies were done in close co-operation with the Department of Forestry and with harvesting contractors to test the various chute systems. The objective of the Chute Project Group was to investigate the viability of chutes and develop a chute system suitable for South African conditions.

When the application of chutes was initially investigated by Lotzaba Forests and FET in 1987, no suitable chutes were available in South Africa. In 1987 the Leykam Log-Line was imported from Austria to be tested. Unfortunately this system underwent growing pains which affected the credibility of the system. Nevertheless through the efforts of the Chute Project Group this perception has largely been overcome and the chute has proved successful.

Soon after the Chute Project Group had been established, NTE and Thermopipe - a plastic pipe manufacturer - were involved in a project named Widthene to develop a timber chute for the South African Forest Industry. High Density Polyethylene (HDPE) was investigated as an alternative material for chutes. During the initial trials, thick polyethylene pipes were cut in half and fitted with legs. These chutes were made up of 4 m lengths with a wall thickness of 17.3 mm and with a weight of 54 kg per piece. Since then the Project Group has advanced up the learning curve considerably, the result being strong, light and affordable chutes.

Initiated by FESA and in close co-operation with HL&H, Polypenco - a plastics engineering company - started developing a nylon timber chute during 1991. The nylon chute pieces were moulded (or cast) in their final form and during April 1991 the first nylon chute was put into operation at Satico Plantation.

During 1993 HL&H tested an HDPE round pipe chute supplied by Flowmech. Although the weight of the chute pieces was increased, installation and planning were simplified since the logs no longer bounced from the chute and the pipe was more stable. The round pipe chute can be used for straight down chuting as well as for traversing in relatively difficult terrain.

Since FESA was established several new chute ideas have been developed and tested under various conditions. Materials investigated included stainless steel, aluminium and fibreglass. It was found that some of these materials were either impractical or too expensive, while others had potential but needed to be investigated more thoroughly.

The Chute Project Group is now in a position to make recommendations on chute systems, materials, planning, training and chuting methods suitable for the South African forest conditions.

3. Objectives of the Chute Operating Manual

The Chute Operating Manual consists of two parts:

- **Section A: Operator's Manual**
- **Section B: Manager's Reference Manual.**

The Operator's Manual contains safety rules for chuting operations and practical step-by-step guidelines on how to use the different chutes. Section A can be removed and used by the supervisor both as a field guide, and for training purposes.

The Manager's Reference Manual serves as a guide to explain the Operator's Manual in more detail especially to managers, foresters and training instructors. Section B is important for tactical and operational planning since it explains the various types of chutes available and the types of terrain on which chutes can be used.

A specific concern of chuting is safety. All persons involved with the operation of a chute must be familiar with the safety rules included in the manual. Emphasis is placed on preplanning and training, the two major contributing factors to the success of the chute operation.

Appendix 4 contains information on how to use and sharpen the hand tools. It is imperative that these tools are sharpened according to specifications to ensure safe and effective timber handling.

For further information, a list of contact persons and recommended literature is set out in Appendix 1.

GLOSSARY

Annealed pipe: An HDPE half pipe that is heat-treated to relieve internal stresses, thereby preventing closure.

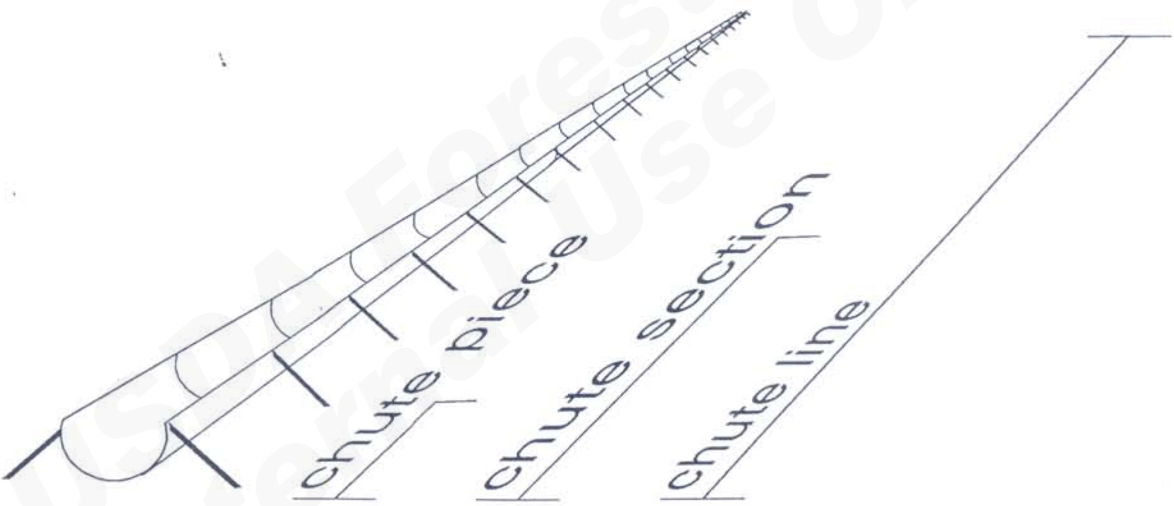
Braking system: Method used to slow the timber down.

Chute line: Several chute pieces joined together to form a continuous "pipe" used to extract the timber to a landing site (Figure 1).

Chute piece: A single segment of the chute (Figure 1).

Chute section: Part of the chute line consisting of two or more chute pieces (Figure 1).

Figure 1: Chute line, chute section and chute piece.



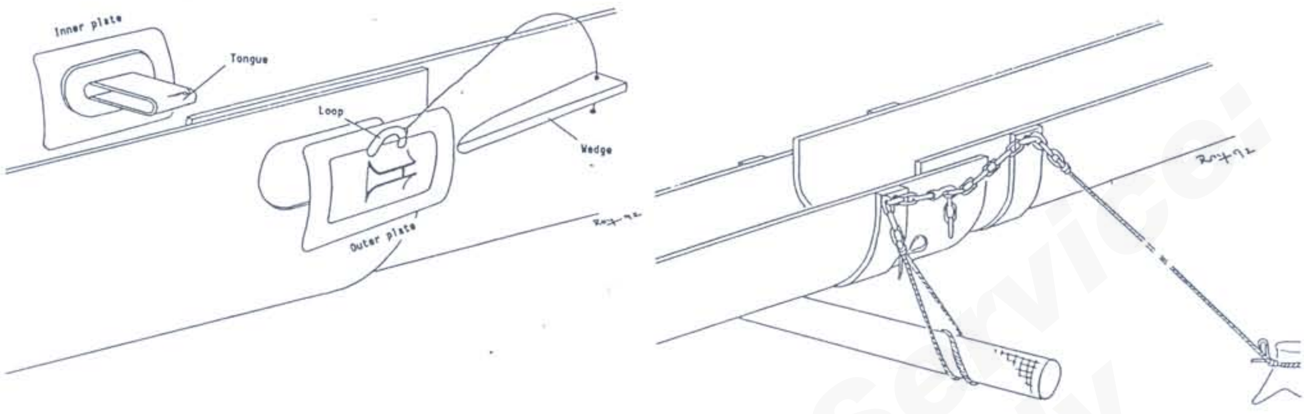
Chuting: Terminology for the extraction of timber using chutes.

Chuting slope: Horizontal angle at which a chute is erected (Figure 7).

Connecting: In some chute systems the chute pieces are connected to each other so that they do not dislodge or break up during extraction. Special connecting systems like the wedge lock or the grab-hook and chain are used (Figure 2). The pieces can also be loosely connected with a light chain.

Figure 2: Special connecting systems.

(a) Wedge lock (b) Grab-hook and chain

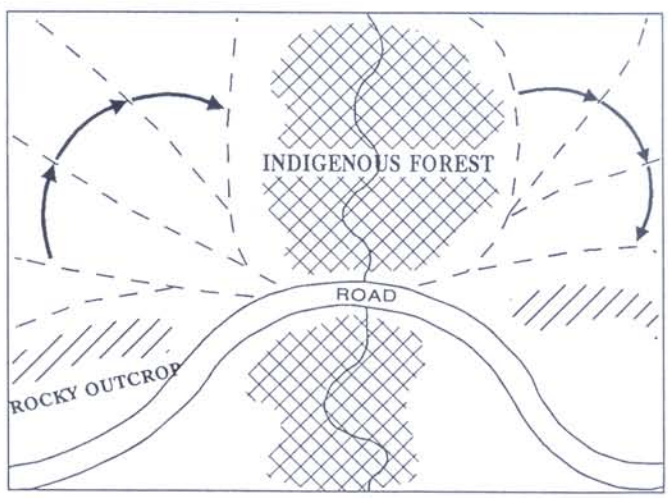


Extraction length and chute length:

- **Extraction length** refers to the total length of the area to be extracted by the chute.
- **Chute length** refers to the total length of the chute line (Figure 5).

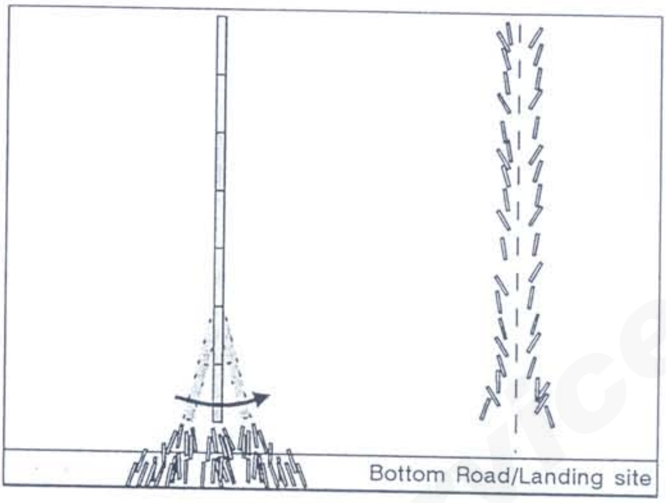
Fanning: A chuting method applied to extract timber by only moving a section of the chute. Recommended for the following situations:

* areas with a limited number of landing sites and terrain limitations



* areas where large obstacles must be avoided (e.g. rocky outcrops, dongas and indigenous forests)

* areas with the landing sites too small to take all the timber (to avoid cluttering up)



Feeding: Placing the timber into the chute. This is carried out manually with the aid of pulp hooks, log tongs or sappie hooks.

Free standing chutes: A chute which stands on supporting legs (it is not supported by means of ropes). This system can be used for straight down chuting only.

Friction coefficient (fc): The coefficient that indicates friction between the surfaces of the timber and the chute.

Gathering distance: The distance of timber being moved from the felling point to the rough line or chute (Figure 5).

Half pipe chute: Half pipe sections joined together to form a continuous gutter.

HDPE: High Density Polyethylene - a plastic material used for the fabrication of chutes.

Landing site: Final receiving point of timber for loading purposes.

Line density: Running metres per hectare (m/ha) calculated by dividing 10 000 m^2 (1 hectare) by the rack width (Figure 5).

Log tongs: Tongs designed for dragging and loading small logs (Figure 3 and Appendix 4).

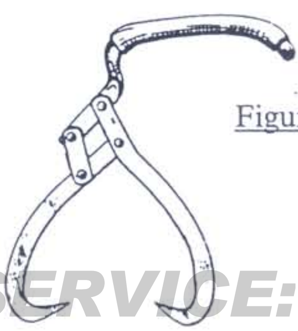


Figure 3: Log tongs (Skogsarbeten, 1983)

Nylon chute: The nylon chute is a chute moulded from a modified Nylon-6.

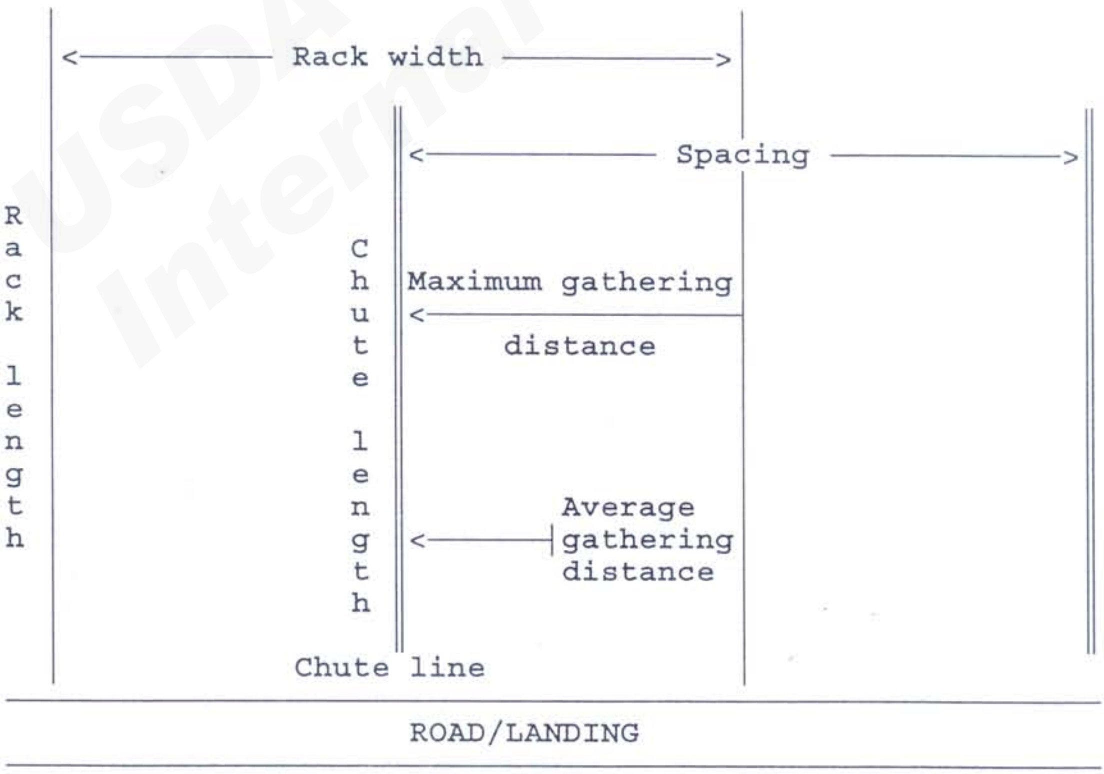
Piece-volume: Volume, expressed either in tons or m^3, per piece of timber (i.e. tree, log, pole, etc.).

Pulp hooks: Hooks for lifting turning and rolling logs, suitable for high lifts such as loading. Although more efficient, they are more dangerous than log tongs and are only recommended for more experienced operators (Figure 4 and Appendix 4).

Figure 4: Pulp hooks for feeding the chute (Skogsarbeten, 1983:85).

Rack: Length and width of an area to be extracted by a single chute line. The width is more or less equal to the spacing between each extraction line (Figure 5).

Figure 5: Rack for chuting.

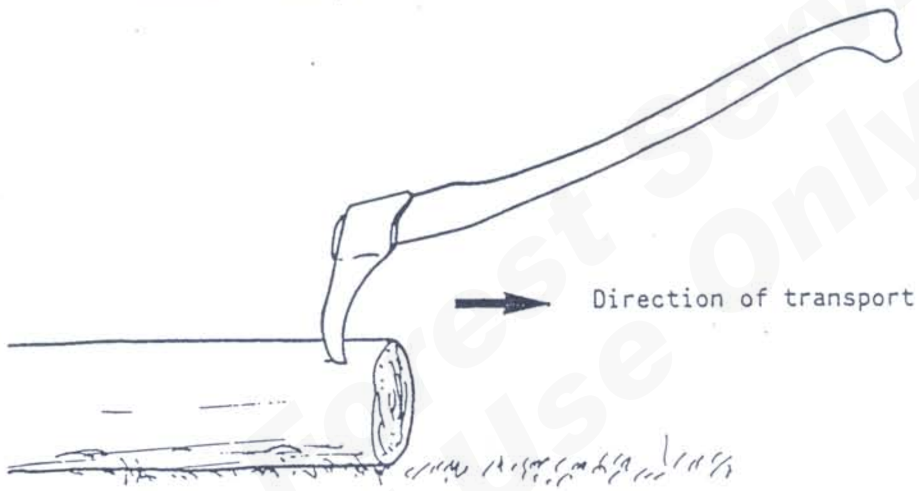


Rough lining: The rough gathering of timber along the chute line from where it can be fed into the chute.

Round pipe chute: Round pipe pieces that fit into each other to form a continuous enclosed tube.

Sappie hooks: A tool used for pulling and turning logs manually as illustrated in Figure 6 (also refer to Appendix 4).

Figure 6: Sappie hooks to pull the logs into the chute (International Labour Office, 1987:44).



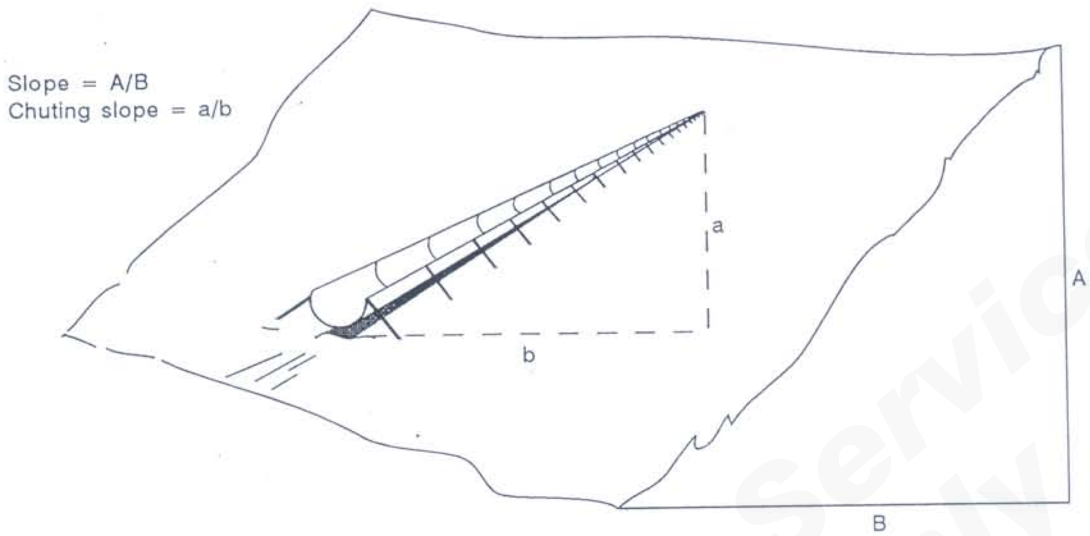
Scavenging: Extracting small pockets of timber from areas that are difficult to reach, or extracting timber through indigenous forests or sensitive areas. Due to the low environmental impact, chuting is ideal for these situations.

Scavenging alternatively means extracting remaining timber from areas already extracted by other means. Chuting must not be implemented on partly extracted areas as this results in low productivity and high costs.

Slope: The gradient of the terrain (Figure 7).

Spacing: Distance between the chute lines in metres. Spacing equals rack width (Figure 5).

Figure 7: Difference between slope and chuting slope.



Stabilizing: Once the chute sections are laid out infield and connected, they are to be stabilized to ensure that the chute line does not move (Figure 8).

Figure 8: Legs and ropes used for stabilizing.

(a) Legs (b) Ropes

Straight down chuting: Chuting timber perpendicular to the contour lines. In areas where straight down chuting is applied the chuting slope will be equal to the slope of the terrain.

Traversing: Movement across the slope.

Traversing chutes: A system used in steep terrain to extract timber across the slope, thus reducing the chuting slope. The chute pieces are connected to each other by means of a special coupling system and are stabilized with ropes. When traversing, the chuting slope is flatter than the slope of the terrain.

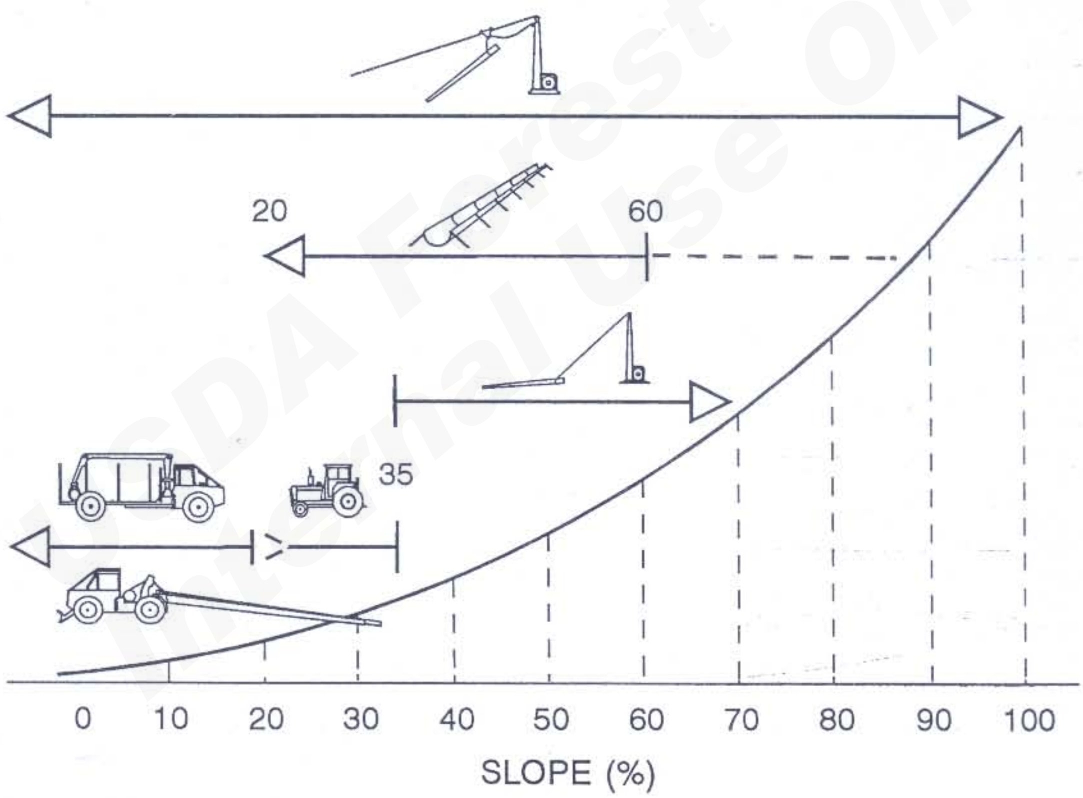
1. Site Conditions

Suitable conditions vary for the different chute systems and materials. There are, however, some basic principles which should be explained in order to understand these conditions better.

1.1 Slope

Based on studies of local harvesting methods and research on various national classification systems, Brink (1990:58) compiled a slope classification system as illustrated in Figure 1.1. The slope categories were kept as practical as possible and relate to international standards in terms of machine-terrain matching.

Figure 1.1: Extraction methods for various slope categories (Brink, 1990).



As illustrated in Figure 1.1, chutes are recommended for slopes between 20% and 60%. Chuting overlaps with both wheeled extraction and cable yarding. Chuting can be considered as a bridge between these two extraction methods. By utilizing a chuting system, unacceptably high machine costs, or insufficient access to the forest can be overcome on slopes steeper than 35%.

"Slope" has two meanings: firstly the **slope** of the area to be extracted, and secondly the **chuting slope** or horizontal angle at which the chute is constructed. In some systems the chuting slope is totally dependent on the slope of the terrain since these systems are set up perpendicular to the contour lines (straight down chuting), while others can be set up across steep slopes to reduce the chuting slope (traversing). If the latter case applies, the chute can be used in areas with steeper slopes.

The chuting slope is one of the controllable variables which determines the speed at which the log will travel and the force at which it will exit the chute. The chute must be set up in such a way that the speed of the logs can be controlled.

Reasons for controlling the log speed:

- Timber moving down the chute at a high speed can exit the chute or dislodge the chute pieces. This will cause serious damage to the chute, the soil, remaining trees, equipment and other timber, or injure workers.
- The higher the speed of the logs, the higher the force exerted on the chute and its supports. In these cases more time and attention are required for stabilizing the chute, resulting in higher costs.
- Logs bouncing out along the line cause unnecessary downtime since logs have to be collected and fed into the chute.
- Timber exiting the chute at a high speed can overshoot the landing, cause breakages and/or make sorting and stacking more difficult. This results in double handling.

The slope of the terrain determines the chuting slope at which the chute line is to be set up. The speed of the logs can be controlled by manipulating the chuting slope or inserting braking devices. Refer to Paragraph 3.1 for an explanation on how to determine the maximum and minimum chuting slope to ensure an effective chuting operation.

Braking devices are discussed in Paragraphs 4.1.4 (traversing chutes), 4.2.4 (free standing chutes) and 4.3.4 (round pipe chutes).

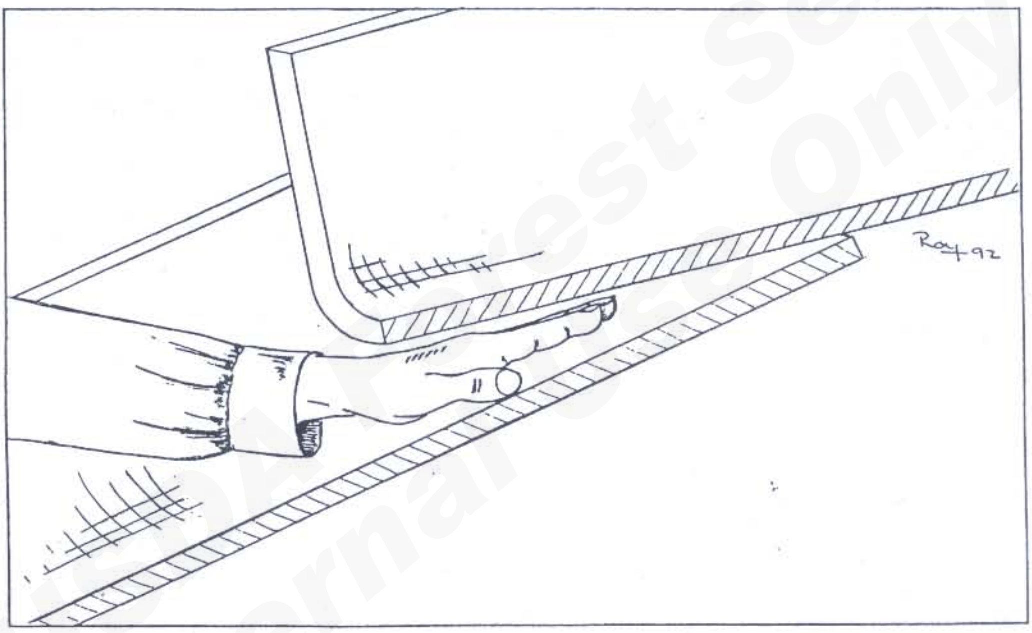
WARNING: LOG SPEED MUST BE CONTROLLED.

1.2 Terrain

Sudden slope changes and sharp bends in the chute line will lead to the logs exiting the chute, or the breaking up of the chute line. Krieg (1991:36) suggested that sudden changes of 8 to 10% in the slope must be avoided. Due to certain coupling and supporting methods applied, some chutes cannot change direction.

Rule of thumb: A man's hand must not fit into the gap at the joint between two chute pieces (Figure 1.2).

Figure 1.2: Judging the change in slope between chute pieces.



In areas where depressions do occur, a support must be constructed to aid the chute over the problem area. In areas where large dongas occur which cannot be crossed, the chutes should run parallel to the donga. If the donga is large enough, it might warrant its own separate chute line.

Avoid chuting in these areas as the chutes require extra time for setting up and pre-hauling. The higher cost and possible damage to the chute may not warrant the effort.

Refer to the **Operator's Manual**, Paragraphs 1.3, 2.3 and 3.3 of Section A, for measures to cross over problem areas.

1.3 Obstacles

Obstacles such as stumps, rocks and streams will cause problems during a chuting operation. In undulating terrain, free standing chutes equipped with legs are not easy to stabilize. Traversing chutes with special couplings and ropes are used in such areas. Installation time is longer due to special stabilizing efforts.

Tree stumps situated in the path of the chute have to be cut shorter, or the chute line has to be moved. Chutes resting on rocks or sharp objects will be damaged during the operation. Special constructions are required to cross over or go around small ravines and other obstacles.

Methods to overcome these problem areas are discussed under the various chute systems in Paragraphs 4.1.3 (traversing chutes), 4.2.3 (free standing chutes) and 4.3.3 (round pipe chutes).

Most of the problems caused by obstacles can be overcome by **detailed compartment planning**. Selected areas and extraction lines, planned and marked infield, will ensure that time and effort are saved. Identifying problem areas in advance can save the harvester and his chuting team time and money.

1.4 Landing Site

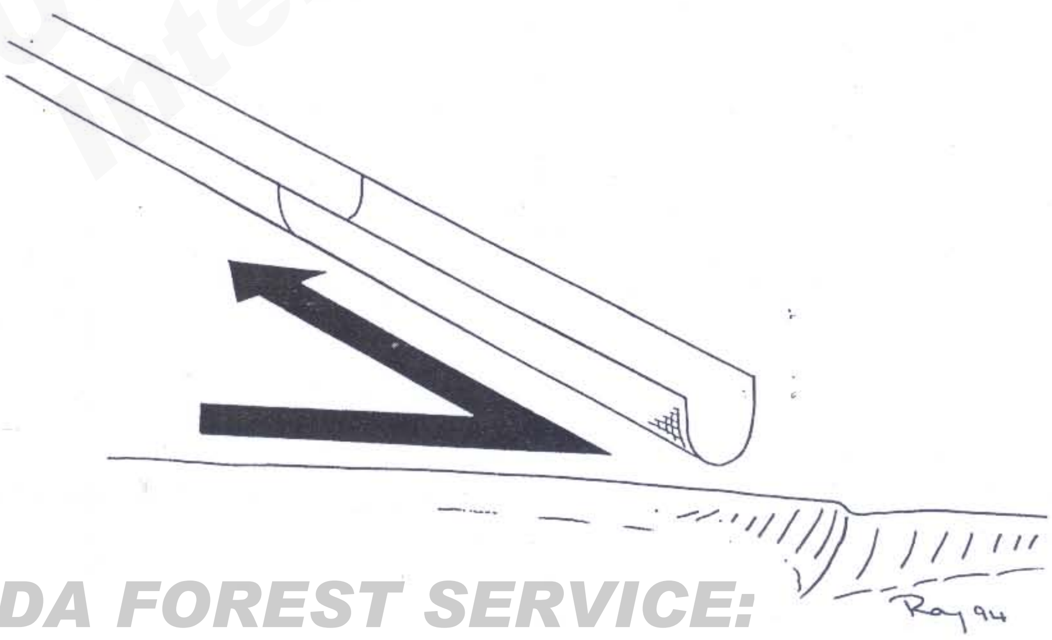
A well planned and prepared landing site is of the utmost importance for the success of the operation. Time and money will be lost due to a poor landing site. The following reasons can account for loss of time and money:

- Logs can overshoot the landing and end up well below it. This timber is either left there to rot, or requires extra manpower to be recovered.
- The logs will land in a big untidy pile ("matchstick explosion") which makes sorting and loading difficult.
- It can become dangerous if the pile becomes too big and the timber has to be loaded or sorted.
- Roads will become blocked and will take time to re-open.
- Uncontrolled exiting of logs from the chute will cause serious damage and/or injury.
- The landing filling up fast, causing congestion.

The landing site will depend mainly on the road, slope and terrain conditions as well as the chute system used. Available landing sites may also have an influence on the planning of the system. Although each chute system will require a different approach to the landing site, there are some guidelines which can be followed:

- The chute must not be set up too steep (Paragraph 3.1).
- Where the roads are narrow and the terrain is steep, the chute could be set up at an angle to the road to guide the timber along the road (Figure 1.3).

Figure 1.3: Chuting along the road.



- A curve is to be formed at the end of the chute. Due to the curving the logs are guided along the road axis and the friction of the curve helps to slow the logs down. Prefabricated curved chute pieces are available for some chute systems (Paragraph 4.2.4.1).
- The chute line can be ended before it reaches the landing site, causing the ground surface to brake the logs, slowing them down before they reach the landing site (Paragraph 4.2.4.2). This should **not be applied in environmentally sensitive areas** where soil disturbance could be severe.
- Use could be made of the embankment of the road to stop and/or guide the logs along the road.
- Where the road has a high embankment, the logs can be directed along the side of the wall - this will slow the logs down, allowing them to roll down the embankment onto the road.
- The chuting slope of the last chute pieces can be set up at a gradient that is flatter than the minimum required (Paragraph 3.1).
- Ensure that the landing is not on, or above a public road. Blocked roads are dangerous and disrupt the traffic.
- Roads used for landing sites, and other roads below this point must be closed and **warning signs** erected (Chapter 5).
- Brushwood has been tried as a braking system. Although a relatively effective system the branches interfered with sorting, stacking and loading.
- The end of the chute is to be lifted to prevent the landing from filling up too soon, and blocking the exit point. This will also help to slow the logs down (Paragraphs 4.1.3, 4.2.3 and 4.3.3).

1.5 Area

The chuting team and the chute must be seen as a production unit, and treated accordingly. Historically, one of the biggest drawbacks in the use of timber chute systems has been that it was not considered as a production unit, but as a stand-by unit available mainly for scavenging purposes in areas where other methods had been tried but had failed.

Through planning and implementation, chuting has proved to be a very effective and efficient extraction method. Guidelines for planning:

- Chutes must not be used for scavenging in partly extracted areas. This will result in low production and high costs.
- Allocating small areas for chuting should be avoided.
- Short distance chuting is undesirable (less than 60 m for traversing chutes and less than 30 m for free standing chutes).
- There are exceptions to the rules. However, if the chute were to be used in the following situations, productivity would be below normal:
  - small pockets where the chute is a more economical option than other systems
  - sensitive areas, i.e. extracting the timber through an indigenous forest or riparian zone
  - problem areas where one cannot enter with other extraction methods, or where entry is dangerous.

The initial installation time is long, since the chute pieces have to be moved infield from the roadside and over long distances. The final dismantling takes time since all the chute pieces have to be disconnected and moved back to the road. Moving the chute along the slope from one chute line to the next is less strenuous since the carrying distances are much shorter.

The efficiency of the operation is determined by the size of the extraction area. It determines how many racks can be extracted before the chute has to be moved to another location.

Consequently, the longer a chute is used in one site (minimizing the initial installation and dismantling times) the higher its average output per man-hour will be. The larger the area to be extracted the better. Depending on the terrain, landing, and timber volume, pockets should not be less than one hectare. Where possible the planner should allocate areas of five hectares or more. Installation, dismantling and transport times must be kept to a minimum.

2. Timber Specifications

2.1 Piece-volume and the Law of Piece-volume

Before looking at the recommended timber sizes it is important to understand piece-volume and the law of piece-volume. These describe the influence of timber size on time consumption, labour productivity and costs.

Piece-volume: Size or volume (m^3) per single unit or piece of timber.

The law of piece-volume states the following relationship between time consumption per piece and volume per piece (Figure 2.1):

$$t_p = a \times v + c \quad [1]$$

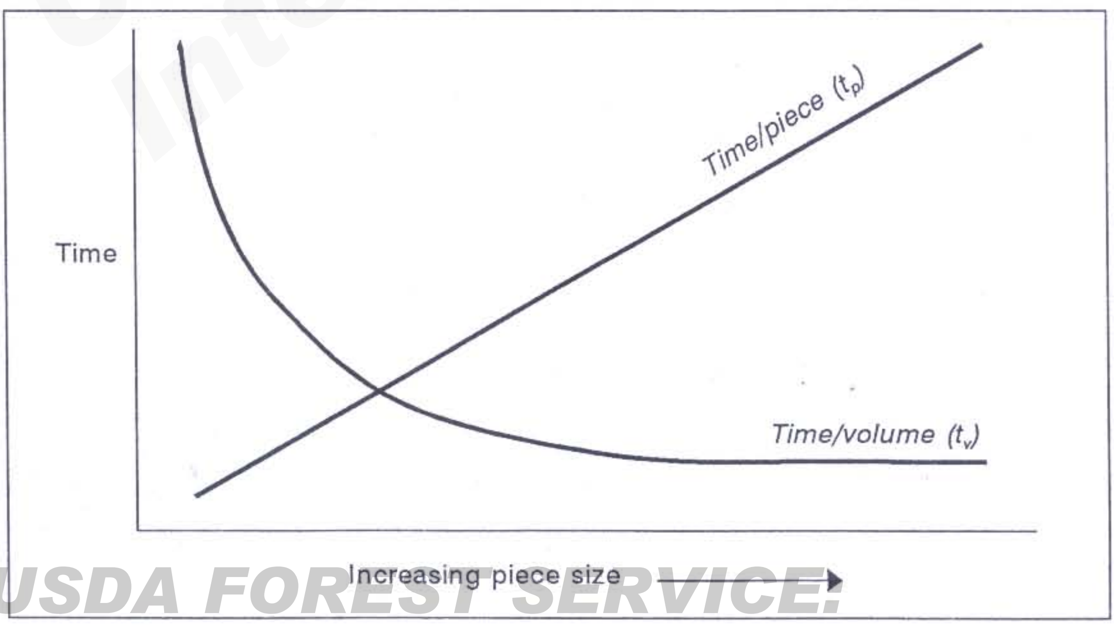
where: t_p = time consumption per piece
v = volume per piece (m^3)
$a;c$ = coefficients

$$t_v = a + c/v \quad [2]$$

where: t_v = time consumption per unit volume

The first formula [1] indicates that there is a linear relationship between time consumption per piece and piece-volume (i.e. smaller trees require less time to fell than larger trees).

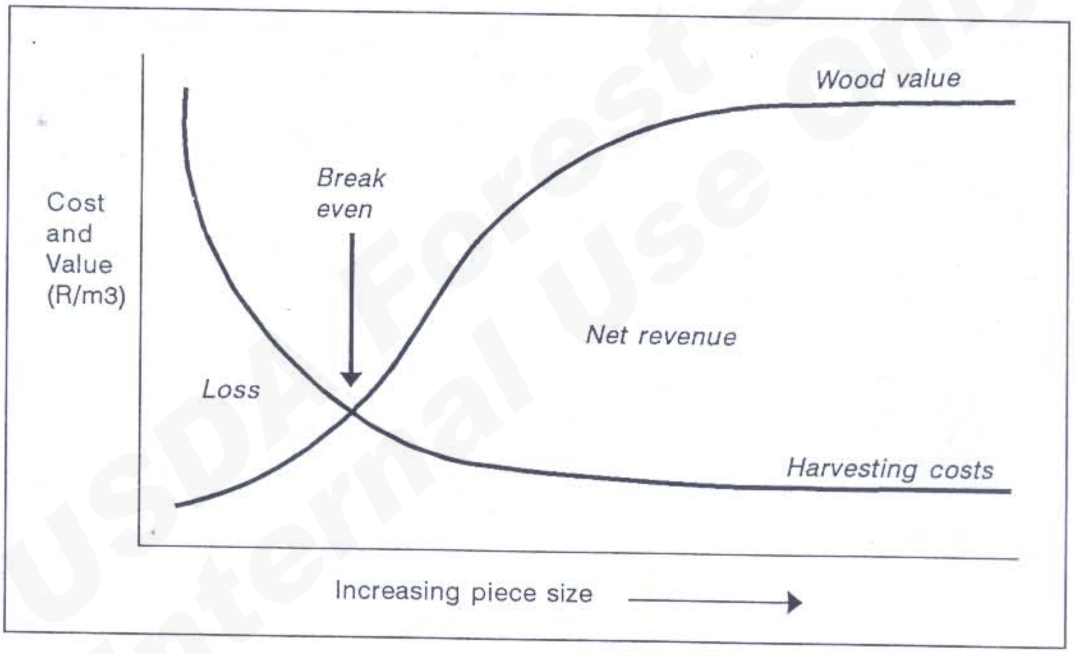
Figure 2.1: The relationship between tree size and time consumption



The second formula [2], however, indicates that the time consumption per unit volume decreases exponentially with an increasing piece-volume (Figure 2.1). This means that, although the time consumption per piece (t_p) is lower for small timber (e.g. pulp wood), the specific time consumption per unit volume (t_v) will decrease with an increase in timber size. Refer to Figure 2.2 for an illustration of the influence of piece-volume on harvesting costs and wood value.

This principle is based on the fact that many activities (i.e. walking time) are independent of the piece-volume, and are more or less constant per piece worked on, whereas the time consumption for other activities does not increase proportionally.

Figure 2.2: The typical relationship between tree size, wood value and harvesting costs (Refsdal, 1986:56).



The law of piece-volume is also valid in all other spheres of the timber industry. In the sawmilling industry the value of logs in general increases with the increasing piece-volume (Figure 2.1).

However, there is a point at which large timber will have a negative effect on cost and productivity. The reason is that the machine or method applied has a certain capacity and can only handle timber up to a certain size. Where manual labour is used, as in chuting, this point will be reached much sooner than with machines. Manual chuting activities (rough lining, gathering, feeding and stacking) are normally more easily accomplished when working with smaller sized timber.

2.2 Timber Requirements

Where timber size is concerned, there are two basic principles:

- The timber must fit into the chute.
- The chute operators must be able to handle the logs manually.

The maximum diameter of a log should be at least 5 cm smaller than that of the chute. This will allow for enough play for slight bends in the chute line without causing an obstruction.

Log length is unlimited as long as the chute is in a straight line. However, the logs have to be handled manually and the weight taken into consideration. With bends, the maximum length of the log will depend on the radius of the bend and the diameter of the log. Therefore longer lengths can be extracted with straight down chuting than with traversing.

As guidelines the following sizes are recommended:

- Maximum thick-end diameter: 30 cm, or at least 5 cm smaller than the inner diameter of the chute.
- Maximum length: 6 m

Branches and stubs cause damage to chute walls, therefore the logs have to be debranched before chuting starts. Logs with a severe crook or sweep do not fit and will start to rock the chute while travelling down the chute. This will cause the logs to exit the chute, or the chute line to break up, resulting in downtime.

3. Planning

The success of a chuting operation depends largely on the intensity and thoroughness of the planning. Chuting can become a financial loss if not carried out according to plan. The chute is a simple concept involving basic physics and mathematics which determine the effectiveness.

Before executing planning, some field work is required to determine the friction coefficient and optimum chute spacing. Once relevant information is collected and recorded for the various conditions, tables or graphs can be drawn up for easy reference.

Once the planner has determined which areas are suitable for chute extraction, a detailed harvesting plan has to be drawn up. This involves decisions on the recommended **chute length**, **chuting slope**, **line spacing** and **felling pattern** and whether **rough lining** is required or not.

With this information, the chute lines are planned and marked out in the field, during which time the felling pattern can be determined. Rough lining will depend on the availability of the chute and labour as well as the daily production expected.

3.1 Chute Length and Slope

The maximum safe speed for timber extraction is considered to be between 10 and 15 m/s or 36 to 54 km/h (Tauer, 1977). This is a safe speed to ensure that the logs do not bounce out of the half pipe chute. Note that the logs are still travelling at a dangerous speed and grave injuries can be inflicted.

The speed at which the logs move down the chute depends on the **friction coefficient**. The friction coefficient is determined by an experiment (see Step 2: Friction coefficient, page 13).

Graphs can be used to determine the maximum chuting slope and distance at which the chute can be set up to ensure that the logs stay within the safety limit (Krieg 1991:27). These graphs have been converted to chuting slope tables (refer to Appendix 3).

These tables have been calculated using the following formula (Krieg, 1991):

$$d = 0.051 \times (v^2 - c^2) / (\sin\alpha - fc \times \cos\alpha)$$

where: d = extraction distance (m)
v = terminal log speed (m/s) = 15 m/s
c = starting log speed (m/s) = 1 m/s
α = slope (degrees)
fc = friction coefficient

Table 3.1 is a simplified example of the tables in Appendix 3, rounded off to the closest 10 m. The table provides information to:

- Determine the minimum and maximum chuting slope for a **given** extraction distance.
- Determine the **maximum** extraction distance for a given slope.

Table 3.1: Table to determine chuting slopes and extraction length (rounded off to the closest 10 m).

SLOPE IN PERCENT	FRICTION COEFICIENT (fc) 0.10	0.15	0.20	0.25	0.30	0.35	0.40	SLOPE IN DEGREES
10.0%	200							6
12.5%	200							7
15.0%	200	200						9
17.5%	150	460						10
20.0%	120	230	200					11
22.5%	90	160	200					13
25.0%	80	120	200	200				14
27.5%	70	90	160	200				15
30.0%	60	80	120	200	200			17
32.5%	50	70	100	160	200			18
35.0%	50	60	80	120	200	200		19
37.5%	40	50	70	100	160	200		21
40.0%	40	50	60	80	120	200	200	22
42.5%	40	50	60	70	100	170	200	23
45.0%	40	40	50	60	80	130	200	24
47.5%	30	40	50	60	70	100	170	25
50.0%	30	40	40	50	60	90	130	27
52.5%	30	30	40	50	60	70	100	28
55.0%		30	40	40	50	70	90	29
57.5%		30	40	40	50	60	80	30
60.0%			30	40	40	50	70	31

(chuting distances rounded off to closest 10 m)

These recommended chuting slopes are for chutes that have been installed, connected and stabilized correctly. Any sudden kinks, depressions or unstable chute sections could cause the chute to break up or the logs to bounce out of the chute, even when travelling at a low speed.

In order to determine the slopes and the length, collect the required field data (this data is used to determine the friction coefficient). These criteria can be established in three steps:

Step 1: Field measurements

Information is required for planning purposes, and this must be collected infield and from reliable maps:

- Species (e.g. debarked eucalypt or pine with bark)
- Weather conditions (dry or wet)
- Slope of terrain
- Extraction length
- Piece-volume

The species and the weather conditions are required to determine the friction coefficient. Slope and extraction length are required to determine the chute length and a safe slope.

Step 2: Friction coefficient

There are several factors that influence the friction coefficient:

- Timber species: eucalypts, pine or wattle
- Surface condition of the logs (dry, moist, debarked, debranched, etc.)
- Surface condition of the chute (rough, smooth, dry, moist, etc.)
- Weather conditions: temperature and moisture

In South Africa these conditions are very heterogeneous and differ from region to region and from day to day, making it difficult to define friction coefficients that will suit all conditions. It is the task of the harvester to determine the various coefficients suited to the situation in his region. The friction coefficient is determined with a simple experiment:

Experiment: Determining the friction coefficient (fc)

A chute section (±30 m) is set up along a known slope. All the pieces are set up at a constant chuting slope. Several logs are fed into the chute.

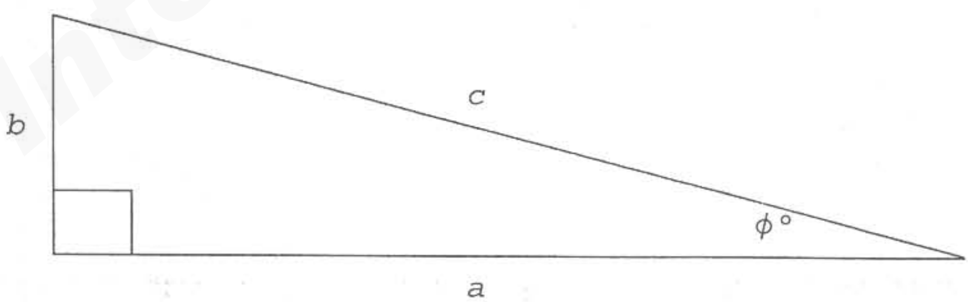
If the logs continuously accelerate while moving down the chute, the chuting slope is too steep. If the logs come to an abrupt standstill, the chuting slope is too flat. The point at which the logs will move along gently must be found between these two chuting slopes. As a rule of thumb this chuting slope, expressed in percentage, divided by 100, can be taken as the **friction coefficient (fc)**.

All influencing factors should be recorded every time the experiment is done to enable the operator to build up a data base for the specific area and the chute system used.

The **slope** of the chute can be measured directly by using a clinometer (e.g. Suuntu, Blume-Leiss or Abney level), or a measuring tape.

With a measuring tape, the horizontal distance (or length of the chute to calculate this) and the difference in height between the top and bottom end of the chute is measured (Figure 3.1). The percentage slope is the horizontal distance (a) divided by the vertical distance (b), which equals the **friction coefficient** (fc). It is recommended that one should take the measurements of one or two chute pieces only to simplify the task.

Figure 3.1: Determining the friction coefficient.



a = Horizontal distance between top and bottom end

b = Vertical distance

c = Length of chute

ϕ = Horizontal angle in degrees

Friction coefficient (fc) = b/a (x 100 = %)

[note: $c^2 = a^2 + b^2$ thus $a^2 = c^2 - b^2$]

If the chuting slope has been measured in degrees the percentage chuting slope can be calculated as follows:

Chuting slope in percentage (%) = tan of slope ($\phi°$) x 100
thus, the friction coefficient (fc) = tan $\phi°$

Refer to Appendix 2 for conversion tables to convert degrees into percentage and vice versa.

The lower the friction coefficient the higher the log speed.

The higher the friction coefficient, the steeper the minimum chuting slope should be at which the chute must be set up. In wet weather conditions, freshly debarked *Eucalyptus* will have a lower fc (e.g. 0.10) than dry debarked timber in dry conditions (e.g. 0.25). The planner should use his own initiative to determine the conditions.

Step 3: Using the tables

(a) Determining safe extraction distances

With a given slope, the maximum distance from which the timber can be extracted can be seen in Table 3.1. Locate the figure corresponding with the required slope (row) and friction coefficient (column). This figure in metres is the maximum distance at which the chute can be set up.

(b) Determining the minimum and maximum chuting slope

The **maximum slope** is determined by using Table 3.1. Find the friction coefficient (fc) that is closest to the calculated coefficient and follow the column down to the closest distance (m) corresponding to the required extraction distance. Follow this row to the side of the table and read off the slope (left for slope expressed in percent and right for degrees). This will be the maximum required slope.

In the case of the actual slope exceeding the chuting slope, one should look at extraction with cable yarders, hand rolling (for short distances), traversing, or using a braking device. If traversing is employed, the chute is set up across the slope at a chuting slope less than the maximum, but greater than the minimum.

The **minimum slope** equals the friction coefficient multiplied by one hundred (fc x 100). This is the minimum slope required to ensure that the timber will move all the way to the landing. If the slope is less than the minimum, extraction will have to be done by other means.

It is not viable to use lubricants to lower the friction. Initially oil is very effective, but dust and sand (which must be cleansed off) collects on the chute surface, and slows down the timber. Oil stains the timber, making it unacceptable for resale.

Never use oil in the chute.

Sand must not be used to lower the friction coefficient. In some cases it slows the timber down, while in other cases the speed of the timber increases. The sand acts as sandpaper which will shorten the life of the chute.

(c) Example:

Step 1: Field measurements

Product:	*Eucalyptus* mining logs (debarked)
	Felled, debranched and debarked five weeks previously
Terrain:	Slope 25 - 60%
	Extraction distance 160 m
	Dry winter conditions in Transvaal
System:	Leykam Log-Line (150 m)

Step 2: Friction coefficient

Two methods used to determine the gradient of the chute:

Method 1: measuring the length and height of the chute with a measuring tape
Method 2: using a dumpy level.

Method 1: measuring the distances with a measuring tape

- Chute length: 6 x 5 m pieces (c)
- Vertical difference (b): 1.20 m
- Horizontal difference: $a^2 = (5.0)^2 - (1.25)^2 = 23.56$

  thus: $a = \underline{4.854 \text{ m}}$ *
- Friction coefficient: $fc = 1.20/4.854 = \underline{0.247} \approx \underline{25\%}$

---

* *If the horizontal distance can be measured directly, this step would not be required.*

Table 3.2 provides estimated friction coefficients for the Leykam Log-Line (Krieg, 1992):

Table 3.2: Example of estimated friction coefficients for the Leykam Log-Line.

	Dry Weather	Wet weather
Pine with bark	0.25 - 0.35	0.15 - 0.18
Eucalypt debarked	0.22 - 0.25	0.10 - 0.15

Method 2: measuring the chuting slope using a dumpy level

- Chuting slope measured: $\phi = 14°$
- Friction coefficient: fc = $\tan \phi$ = 0.249 ≈ 25%

The tables in Appendix 2 can also be used to convert degrees into percent:

$$14° \doteq 24.9\%$$

Note that in this example the friction coefficient is relatively high for debarked *Eucalyptus* logs. This study was carried out during the dry winter months, when the logs had been drying in the field for five weeks.

Step 3: Using the tables

Table 3.1 can be adapted to suit a specific chute. For example Table 3.3 is a chuting table adapted for the Leykam Log-Line, based on the information given in Table 3.2.

Locate the column with a friction coefficient closest to 0.249 which is 0.25. If the friction coefficient is not known, look at the column for dry timber, extracted on a dry day. The figures provide the maximum chuting distance in metres.

Table 3.3: Table to determine chuting slopes and extraction length for the Leykam Log-Line.

	PINE WITH BARK			DEBARKED EUCALYPTUS				
WEATHER:	DRY	Moist	WET		DRY		WET	
				Timber:	Fresh	Dry		
fc	0.30	0.25	0.18		0.20	0.25	0.15	
15.0%							200	9
17.5%							200	10
20.0%			200		200		200	11
22.5%			200		200		160	13
S 25.0%		200	170		200	200	120	14 S
L 27.5%		200	120		160	200	90	15 L
O 30.0%	200	200	100		120	200	80	17 O
P 32.5%	200	160	80		100	160	70	18 P
E 35.0%	200	120	70		80	120	60	19 E
37.5%	160	100	60		70	100	50	21
I 40.0%	120	80	60		60	80	50	22 I
N 42.5%	100	70	50		60	70	50	23 N
45.0%	80	60	50		50	60	40	24
P 47.5%	70	60	40		50	60	40	25 D
E 50.0%	60	50	40		40	50	40	27 E
R 52.5%	60	50	40		40	50	30	28 G
C 55.0%	50	40	40		40	40	30	29 R
E 57.5%	50	40	30		40	40	30	30 E
N 60.0%	40	40	30		30	40	30	31 E
T 62.5%	40	40	30		30	40	30	32 S
65.0%	40	30	30		30	30	30	33
67.5%	40	30	30		30	30	30	34
70.0%	30	30	30		30	30	30	35
72.5%	30	30	30		30	30	20	36
75.0%	30	30	30		30	30	20	37
77.5%	30	30	20		30	30	20	38

(Chuting distance in meters rounded off to the closest ten)

From this table the following can be deduced:

- The minimum slope required for these conditions is 25% (fc = 0.25). Areas less than 25% should be extracted by skidding or cable yarding.

- For slopes from 25% to 32.5% the full 160 m can be extracted with straight down chuting (150 m of chute plus 10 m gathering distance on the top). For areas steeper than 32.5% the safe extraction distance decreases. As the slope increases other options could be considered:
  - * **shorter extraction distances**: e.g. not more than 70 m on the 42.5% slopes, and a maximum of 40 m on a 60% slope
  - * **traversing**: if the full 150 m of chute is used, the chute line must be set up across the contour at a chuting slope between 25% and 32.5%

* using a **braking system**: if a braking system is available
* applying an **alternative extraction method**

- For a free standing chute (straight down chuting) of 100 m, by using the full length: in the column with fc = 0.25, distances of more than 100 m fall between 25% and 37.5%. This is the slope at which the chute must be set up.

This exercise is carried out to determine the **extraction distance** and the **minimum and maximum slopes** required to ensure a trouble-free chuting operation. If the chuting slope is too low the timber will not move the whole distance, resulting in lost time and an alternative extraction method having to be found.

3.2 Spacing

The productivity and costs of the chuting system are influenced by the distance between the extraction lines (rack width). The closer the lines, the more time is spent on installing, moving and dismantling the line. The further the lines are apart, the further the timber has to be gathered.

Line density and line spacing are the same concept. **Line density** refers to the running metres of chute per hectare (m/ha), and **line spacing** refers to the distance between chute lines in metres (line spacing equals the average rack width).

Line density (LD) is converted into line spacing (LS) by using the following formula:

$$LS = 10\,000/LD = \text{metres}$$
$$\text{Thus } LD = 10\,000/LS = \text{m/ha}$$

The recommended line spacing for the different chute systems and situations varies.

> ***Higher timber volumes and easier terrain require narrower line spacing (longer gathering time).***

Factors which influence line density:

- **Chute system** used (some systems are more sensitive to certain variations than others):
  - * traversing or straight down chuting
  - * legs or ropes for stabilizing
  - * single line or fanning system.
- **Timber volume** per hectare (ton/ha or m^3/ha).
- **Terrain:**
  - * the rockiness and unevenness of the terrain influence construction and rough lining time
  - * ridges and rocky outcrops influence the chute path.
- **Piece-volume:** If the piece-volume is high, more timber can be hauled with every load.
- **Planting espacement:** The distance between remaining stumps also helps to determine line spacing: e.g. if for practical reasons the chute line is placed in every 5^{th} row, the line spacing would be 10.5 m in a compartment with 2.1 x 2.1 m planting espacement (line density = 952 m/ha).

- **Old brush lines*:** Old brush lines interfere with the stability of free standing chutes and must be avoided (normally this does not pose a problem with traversing chutes). Old brush lines are spread throughout the compartment at fixed intervals. Adapt the chute operation accordingly.
- **Landing:** Line spacing will depend on whether a central landing area or continuous landing is being used, as well as on the topography around the landing.

Due to the great variety of influencing factors, it is not possible to determine a fixed spacing for the various chuting methods and extraction conditions.

Time studies are required to determine the optimum line spacing and must be carried out according to the various conditions. Paragraph 3.2.1 provides practical guidelines of how the optimum line spacing was determined for the Leykam Log-Line in different conditions (Table 3.4).

3.2.1 Determining the optimum line spacing

Time studies have to be carried out for a specific area, the chute system used, and the product to be extracted. Calculations and graphs are based on a method used by Krieg (1991:28) at Lotzaba Forests, Barberton, to determine the optimum line density for the Leykam Log-Line.

From these studies the line spacing can be calculated. In this case an optimum line density range is determined which refers to that density range where chuting time is minimized.

When using time studies, two formulae are determined and are combined to determine the optimum point or line spacing. During these studies and calculations the following **assumptions** can be made:

(a) The area is a large rectangular piece of land on which the chute lines are constructed more or less parallel to each other.

(b) The timber supply is uniform over the entire area (uniform piece-volume and volume).

* *The spacing of new brush lines will depend on the planned chute spacing, and not vice versa.*

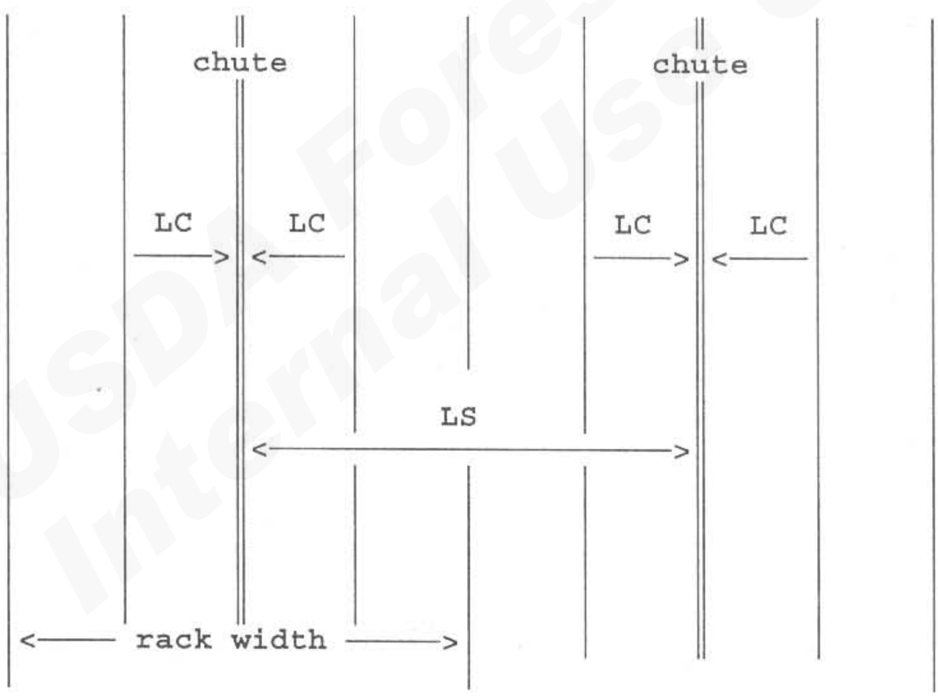
To convert the answers from line spacing (LS) to line density (LD), the following **definitions** are used (see Figure 3.2):

LD: chute line density in running metres per hectare (m/ha)
LS: extraction line spacing in metres (m)
LC: average distance over which the logs need to be gathered (m), LC is the maximum gathering distance divided by two

In these situations, the following relationships apply (refer to Figure 3.2):

$$LC = LS/4$$
$$LS = 10\,000/LD$$
$$LD = 10\,000/LS$$
$$LC = 2\,500/LD$$

Figure 3.2: Correlation between line density (LD), line spacing (LS) and gathering distance (LC).



The two formulae below apply to the following situations:

- Time required to gather the timber and feed the chute (Tg):

$$Tg = (a+C) + b \times LC \times Vol$$
$$= (a+C) + b \times (LS/4) \times Vol \quad \text{in min/ha} \ldots\ldots [1]$$

where: $C = \frac{(\text{number of logs/m}^3) \times (\text{inserting time/log})}{60 \text{ seconds}}$ in min/m³

"C" reflects the time needed to insert 1 m³ of timber into the chute. The average inserting time for the Lotzaba studies was 6 seconds per log, or 2.75 min/m³. The number of logs per m³ is influenced by piece-volume.

a = constant for the linear regression correlating haul-in distance with haul-in time ($y = a + bx$). 0.46 is the figure for mining timber and will change for different piece-volumes.

b = gradient for the linear regression correlating haul-in distance with haul-in time ($y = a + bx$). 2.11 is the figure determined for mining timber.

thus: $0.46 + 2.11x$ = time required to carry 1 m³ of timber over x metres.

Vol: Expected timber volume to be extracted per hectare, i.e. m³/ha or tons/ha.

Substitute these figures in formula [1]:

$$Tg = (0.46 + 2.75) + 2.11 \times (LS/4) \times Vol$$
$$= 3.21 + 2.11 \times (LS/4) \times Vol \quad \text{[2]}$$

- Time required to dismantle, move and reconstruct the chute line (Tm):

$$Tm = p + q \times LD$$
$$= p + q \times (10\,000/LS) \text{ in min/ha} \quad \text{[3]}$$

where:

p = constant in minutes required to transport LD (m) of chute LS (m) far. Based on time studies, this value for the Leykam Log-Line is 923.1 minutes.

q = gradient for the linear function is determined as 2.7 for the Leykam Log-Line.

Substitute these figures in formula [3]:

$$Tm = 923.1 + 2.70 \times (10\,000/LS) \quad \text{[4]}$$

These two formulae are then combined to determine the total time (Tt). The sum function [2] + [4] is:

- Total time required to extract the timber and move the chute line (Tt):

$$
\begin{aligned}
Tt &= Tg + Tm \\
&= [(a + C) + b \times (LS/4) \times Vol] + [p + q \times (10\,000/LS)] \\
&= [3.2 + 2.11 \times (LS/4) \times Vol] + [923.1 + 2.7 \times (10\,000/LS)] \\
&= 926.3 + 0.5275 \times LS \times Vol + 27\,000/LS \quad \ldots\ldots\ldots\ldots [5]
\end{aligned}
$$

To determine the minimum function of LS use the f prime g (optimum line spacing):

$$f'g(LS) = -0.5275 \times LS^2 \times Vol + 27\,000$$

Now set f'g(LS) = 0:

$$0 = -0.5275 \times LS^2 \times Vol + 27\,000$$

thus LS (min):

$$\sqrt{27\,000 / (0.5275 \times Vol)}$$

Example:

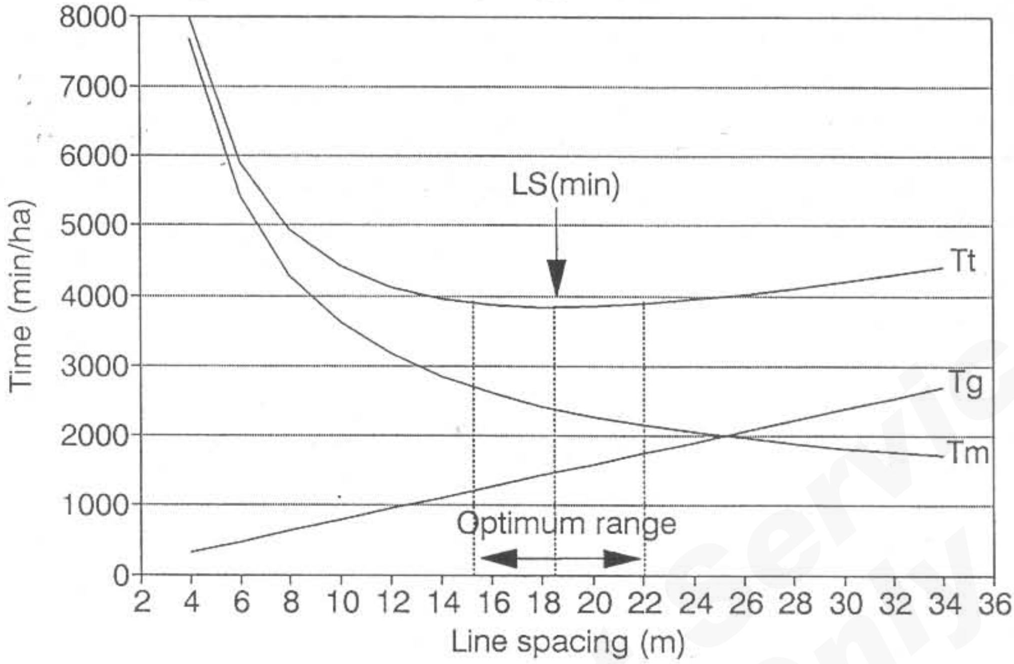
For 150 m^3/ha: LS(min) = 18.47 m

The functions ([2],[3] and [5]) above are plotted on a graph (Figure 3.3). The line spacing at which the curve is the lowest (time) is the recommended optimum line spacing.

Figure 3.3 is an example of how optimum line spacing was determined for a compartment with a timber volume of 150 m^3 per hectare. The top line is the combined time for the chute extraction (Tt). The optimum line spacing is at the point where this curve is at its lowest.

There is not much difference in time required between a line spacing of 16 m, 21 m and the optimum point 18.5 m. Consequently, a line spacing between any of these distances can be considered acceptable. The exact theoretical distance can be adapted to suit the practical situation.

Figure 3.3: Graph to determine line spacing.



Using the same formulae required for Figure 3.3, tables can be drawn up for the different volumes per hectare. The tables can be used for easy reference. Table 3.4 is an example of the recommended line spacing for the Leykam Log-Line.

Table 3.4: Recommended line spacing for extracting mining timber with the Leykam Log-Line.

Volume per ha (m3/ha)	LINE SPACING Recommended Range (m)
50 - 100	22 - 30
100 - 150	16 - 24
150 - 200	14 - 20
200 - 250	12 - 18
250 - 300	11 - 17
300 - 350	10 - 16
350 - 400	10 - 14
400 - 450	9 - 13
450 - 550	8 - 12

3.3 Directional Felling

The harvesting forester now has the necessary information available to do detailed planning. The minimum and maximum chuting slope, the desired chute line spacing and the extraction distance have been determined. With the help of a map and a field visit, the areas suitable for the chute operation can now be marked out.

The planned chute lines are marked in the field. The trees are felled according to a predetermined pattern (this is referred to as directional felling). The aim of directional felling is to direct the timber as close to the predetermined chute line as possible.

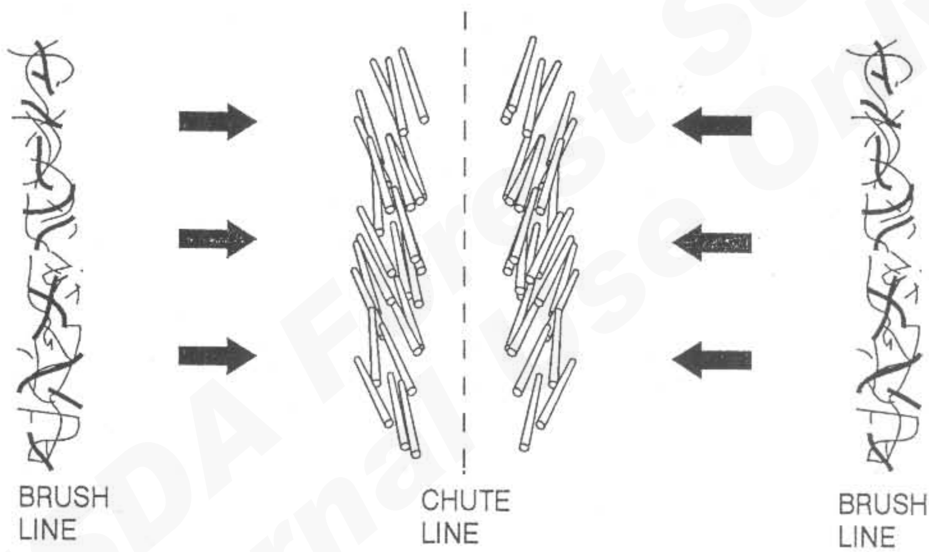
The feeding operation and rough lining (Paragraph 3.4) will be more easily accomplished through planning and directional felling.

3.4 Rough Lining

In many cases rough lining is recommended to facilitate the extraction process. Rough lining means that the logs are moved closer to the predetermined chute line.

In order to reduce the walking distance during extraction and to increase the output, the timber could either be stacked in neat stacks along the line (prestacking), or the logs can be rolled or carried closer to the planned chute line and left in a relatively rough order (rough lining). Generally rough lining is preferred to prestacking as overall production is higher.

Figure 3.4: During rough lining the lower end of the log is placed closer to the chute line than to the top end to facilitate feeding.



Rough lining and stacking both have the following **advantages**:

- Chute installation is easier and **safer**.
- Extraction is faster and less strenuous.
- A higher daily output is possible for the chute which leads to a better utilization of the chute.
- Work in general is **safer** due to the cleared areas. The possibility of damaging or dislodging the chute is decreased.
- The effective extraction length is increased (Figure 3.5).
- Obstacles and problem areas are more visible.

The **disadvantage** of rough lining is that more planning, co-ordination and control are required.

To streamline the feeding operation, the logs are placed at an angle to the chute with the upper end of the log further away from the chute than the lower end. This helps to direct the log into the chute when feeding (Figure 3.5).

Rough lining is **recommended** in the following situations:

- Difficult and steep terrain: Under these circumstances the chute lines are normally further apart than in easier terrain. Time spent on collecting and carrying will be less. This could minimize injury.
- Areas with a very high timber volume: Installation time can be reduced, since it is difficult to set up and feed the chute between hundreds of logs lying around in disorder.
- High availability: When high production is expected from the chute and extra labour is available to do the rough lining.

In cases where the chute cannot reach the timber, or where the top end of the area is too steep or too rough for chute extraction, logs can be rolled closer to the chute by hand and stacked at the top end (Figure 3.5).

The multiple application of short chutes to extract one block is not advisable, since this involves double handling of the timber. This situation can be prevented by proper planning, i.e. the proper choice of chuting areas and the purchasing of chutes of adequate length.

Figure 3.5: Hand rolling timber for rough lining.