LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

- HELICOPTER LOGGING -

A REVIEW

P.R.17

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N.Z. LOGGING INDUSTRY RESEARCH ASSOCIATION (INC.)

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- HELICOPTER LOGGING -

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Material upon which part of this account is based was generously provided by staff of the U.S.D.A. - Forest Service, British Columbia Forest Service, Forest Engineering Research Institute of Canada and various helicopter companies in the Pacific Northwest region of North America.

Much of the New Zealand helicopter logging information is based upon work undertaken at Russell Forest, Northland. The assistance of forest staff and also Mr J.G. Beachman of the N.Z. Forest Service is acknowledged with appreciation.

It is recognised that other trial work has taken place in New Zealand but as the authors knowledge of this is limited he has concentrated on the Northland work in describing the New Zealand situation.

PHOTOGRAPH CREDITS

	Plate Numbers
Columbia Helicopters Inc.	2, 4, 15
J.C. Halkett	5, 10A, 13, 14, 16
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- SUMMARY -

The use of helicopters in extracting logs from the forest is a relatively new innovation to the logging industry in New Zealand. The first helicopter operation took place in 1977, and since then several small scale trials have been undertaken. Prior to any further development or introduction of routine production operations in New Zealand, there is a need to review the relevant knowledge from both local and overseas sources. That is the objective of this report.

Overseas, the first tests were carried out in 1956. However, it was not until the 1970's that serious trials got underway in North America, and now helicopter logging is a routine technique in several areas of the world.

By New Zealand standards the North American operations are colossal, using medium to heavy lift helicopters which give high production rates. Aerial logging activity in New Zealand is likely to be restricted to small yields from indigenous forests and small areas of exotic forests.

There is one principle objective when operating a helicopter logging system - to maximise turn efficiency, attained by minimising turn cycle time and maximising the utilisation of lift capacity. This requires careful planning of procedures, equipment, felling methods, landing design, and safety requirements. All are essential to ensure that the helicopter is used most efficiently as delays can mean economic disaster.

The use of helicopters for logging offers some major management and environmental advantages over conventional methods. They can provide an extended reach system which is able to operate when other methods are environmentally sensitive, uneconomic, or present extreme engineering difficulties.

The advantages and disadvantages need to be carefully considered before contemplating helicopter operations. The major disadvantage (cost) can often be obscured by such advantages as reduced need for roading, water and soil considerations, and lesser impact on the residual stand. If these indirect costs are subtracted from the direct costs, the total relative costs derived could indicate that helicopter logging may cost less in the final analyses than traditional methods.

Helicopter logging will not supplant existing harvesting methods, but should be seen as a supplementary technique applicable in areas where special considerations prevail.

- TABLE OF CONTENTS -

- LIST OF PLATES -

- LIST OF FIGURES -

- LIST OF TABLES -

- INTRODUCTION -

Considerable interest focuses on helicopters as a logging method with potential for overcoming the most difficult log extraction and transport problems.

Many logging managements have contemplated testing this system, and helicopter companies are keen to exploit potentials for extending their activities into a new field that may open up long term opportunities.

This report is aimed at summarising the background to the history of helicopter logging, and at exploring and explaining the factors that must be understood by logging management prior to introducing the system.

To compile this "state of the art" account, LIRA commissioned John Halkett, who has been closely involved in the introduction and management of helicopter operations in selection logging of kauri in Northland, and who has recently studied helicopter operations on the North American continent.

HISTORICAL REVIEW

> *"In the colourful and innovative history of the logging industry there have been times and places where the most inventive talents of the toughest logging boss have failed to produce an operable logging side. Impractical road construction costs, steep and broken slopes, inadequate deflection and tail-hold opportunities for cable loggers, unfavourable terrain and economics for tractor loggers have caused more than one bull in the woods to stomp on his hat in frustration. As a result, large areas of timber have been bypassed while the industry waited for the development of a usuable "skyhook" system to harvest this inaccessible volume."*
>
> *Anon. 1979*

A brief traverse of the history of helicopter logging may assist in lending some perspective to the topic. It should provide the datum from which the advantages and limitations of the system plus the technical aspects which influence efficiency and economics may be examined.

Helicopters started to enter the commercial aviation field following the second world war. The prospects of transporting logs by this newly developed aircraft very quickly became apparent.

The first investigations associated with helicopter logging are credited to Dr E. Pestral an Austrian forest engineer. He conducted trials in the Austrian Alps in 1955 and 1956 to examine the influence of wind currents on helicopter flight. He postulated the possible effect of wind on aerial logging missions. This work was terminated when Dr Pestral was re-assigned to skyline logging research work (Schutzbank 1974).

The first recorded helicopter logging tests were carried out in Scotland in 1956 using a small Bell 475 helicopter which had a nett lift capacity of 272 kg. Numerous difficulties were experienced with log pickup techniques and the trials were considered to be an economic failure (Stevens and Clarke 1974).

Experimental logging trials which involved the removal of bundled pulpwood were conducted in eastern Canada in 1957. Problems with bundle attachment coupled with the restricted lift capacity of available helicopters resulted in the rejection of this innovative logging technique on economic grounds.

Experimental aerial logging operations were undertaken in the North Caucasian mountains of Russia in 1959. Again difficulties were experienced with log uplift techniques and limited aircraft lift capability. (Vinogorov 1961).

Other early helicopter trials were also carried out during the early 1960's in Norway, Germany and the United States of America. Results from these trials suggested that, although the concept of helicopter logging was viable, the combination of limited load carrying capacity and low product value made helicopter logging economically unattractive.

Because of the relatively low load carrying capability of helicopters at that time consideration was given to dragging logs rather than attempting to transport them fully suspended. This concept was tested in the United States of America in 1962 using a Sikorsky S-58 helicopter. Loads up to twice the fully suspended lift capacity of the aircraft were transported. However, log extraction was slow and the venture was considered too dangerous to explore further.

The advent of the turbine engine was the awaited innovation which changed the course of aerial logging. Its high power output and reliability resulted in a significant increase in aircraft lift capacity. This development combined with escalating timber prices heralded a renewed interest in helicopter logging in the early 1970's. Serious trials were initiated in North America. Several of these projects were motivated by pressures to maintain wood supply from areas where conventional logging practices had become inhibited by requirements to reduce the environmental impact of timber harvesting.

In 1970 several timber sales were offered exclusively for helicopter log extraction in the United States of America. These sales in old growth stands were unsuitable for conventional logging techniques because of terrain, soil considerations or harvesting prescription. In June 1971 a helicopter logging sale involving 41,000 m^3 of timber on 210 ha of steep rocky terrain was undertaken in California. By 1973 the U.S. Forest Service in conjunction with several helicopter companies had conducted helicopter logging operations in California, Oregon, Washington, Montana and Idaho. The bulk of this timber was harvested using Sikorsky S-58, S-61 and S-64 helicopters plus the Boeing Vertol 107 helicopter.

Helicopter logging is now a routine timber harvesting technique in North America and several other areas of the world.

NEW ZEALAND'S EXPERIENCE

The first aerial timber extraction to occur in New Zealand was undertaken in 1977 by Mr W. Davies of Kerikeri. This operation involved salvaging timber from fallen or standing dead mature kauri. A light-weight portable sawmill was employed to mill trees in situ. A helicopter ferried the mill, men and equipment to the work site and to carry the sawn timber out to the nearest road access. This or similar operations have continued intermittently whenever suitable windthrown or standing dead trees are located within management zones which permit this activity.

A helicopter logging trial in second crop kauri was conducted in Russell Forest, Northland in 1980 (Halkett 1980) (see Plate 1).

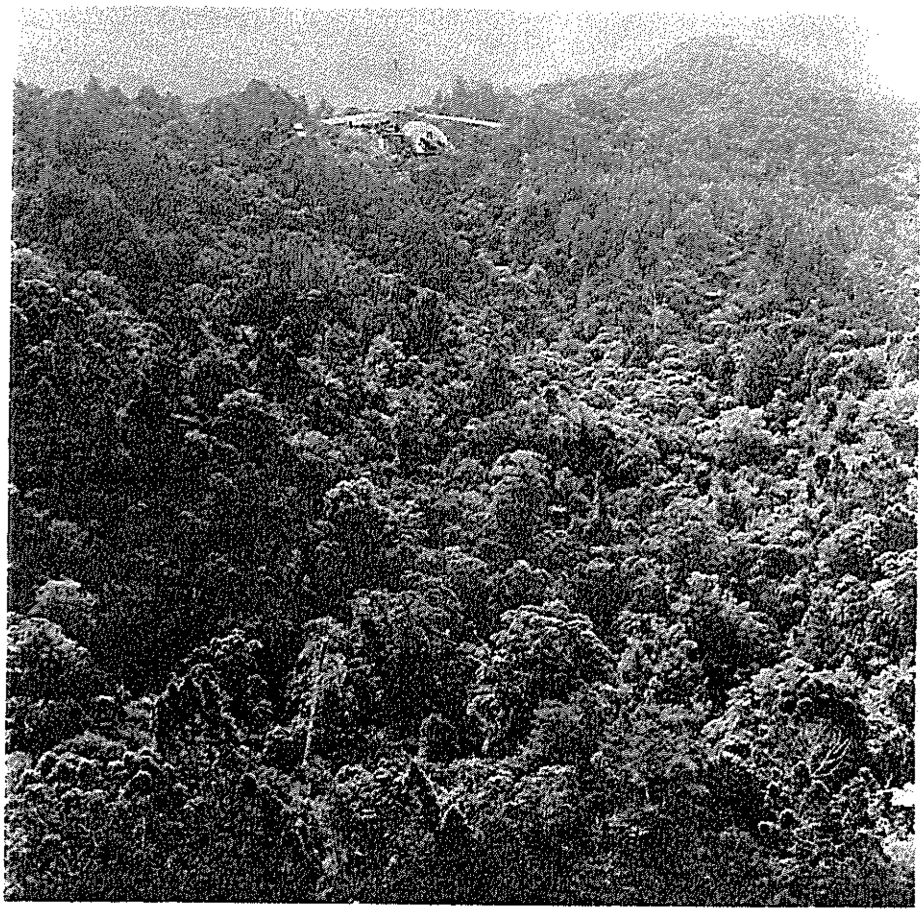


Plate 1 - Helicopter Logging Trial in Second Crop Kauri at Russel Forest, Northland

This study demonstrated that aerial logging in this particular forest type was technically feasible. However, it was a relatively expensive logging method and justification for its use needed to include the recognition of the importance of non-wood values. The trial also indicated that the use of helicopters offers some management and environmental advantages over conventional logging methods. Helicopter logging is now viewed as the standard harvesting method for second crop kauri forest.

Radiata pine posts have been extracted on a trial basis in the Auckland Regional Authorities forest at Hunua. Bundled material was removed from steep terrain within a water supply area where ground disturbance was unacceptable. A similar operation has also been conducted in the Wairarapa region and pulpwood was removed from a 15 year old radiata pine stand in Kaingaroa Forest in 1978 (Blundell 1979).

HELICOPTER MODIFICATION, DEVELOPMENT AND FLIGHT CHARACTERISTICS

Helicopters used for logging activity have been developed for purposes other than timber extraction. For this reason most machines require some minor modification before they can be used on logging ventures. The most conspicuous modification to many helicopters used in North America is a 'Direct Visual Operational Control' bubble window which replaces the standard side window and through which the pilot is able to look directly downward as he manoeuvres the aircraft (see Plate 2). This innovation has not yet been introduced into New Zealand. Instead the pilot removes the side door so that he may lean out and view below the helicopter.

Plate 2 - Boeing-Vertol 107II Helicopter Fitted with a "Direct Visual Operational Control" Bubble Window Fitted to the Left Side.

Suggestions that bigger helicopters might improve logging efficiency do not appear valid. Designing a larger helicopter represents a considerably more difficult problem than merely scaling up a smaller one. Aerodynamic forces increase as the square of the size of the aircraft, but structural weight increases as the cube of the size. The Helicopter, like the logging truck, has reached the end of a technological line. It is a mature design concept and only minor mechanical improvements now seem possible. Early predictions were that high log extraction costs would be reduced by technology improvements. However, over a period of years substantial improvements in technology were not forthcoming. The expotential increase in power required extended payload capability dramatically increased fuel consumption and running costs. Large helicopters are extremely energy inefficient (see Plate 3). The Sikorsky S-64E which has a maximum nett lift capability of 8.61 tonnes, generates 9,000 horsepower which is similar to the energy required to propel 25-30 logging trucks with a total payload capacity of around 550 tonnes.

Plate 3 - Sikorsky S-64E (Skycrane)

Atmospheric conditions, particularly air density and air movement, have a considerable effect on helicopter logging activities (Stevens 1972). Air density is essentially a function of temperature, humidity and altitude. Helicopter lift capacity decreases with increasing temperature or altitude and for any given altitude will decrease with increasing temperature. Figure 1 depicts these variations for several types of helicopter (for logging condition of "hover-out-of-ground effect").

Air density increases with raising humidity. However, the effect of increasing humidity is reversed when a helicopter operates in rain as the rotor blades become slick and there is a resultant decrease in helicopter lifting ability.

Helicopter rotor blades act as an airfoil in the same way as the wings of an aeroplane. Wind is therefore an important variable in measuring flight efficiency. If there is a steady wind and the helicopter can operate "into the wind" lift capacity will increase. However, wind speeds exceeding 40-50 km/hr generally have a detrimental affect on work precision and so decreases efficiency.

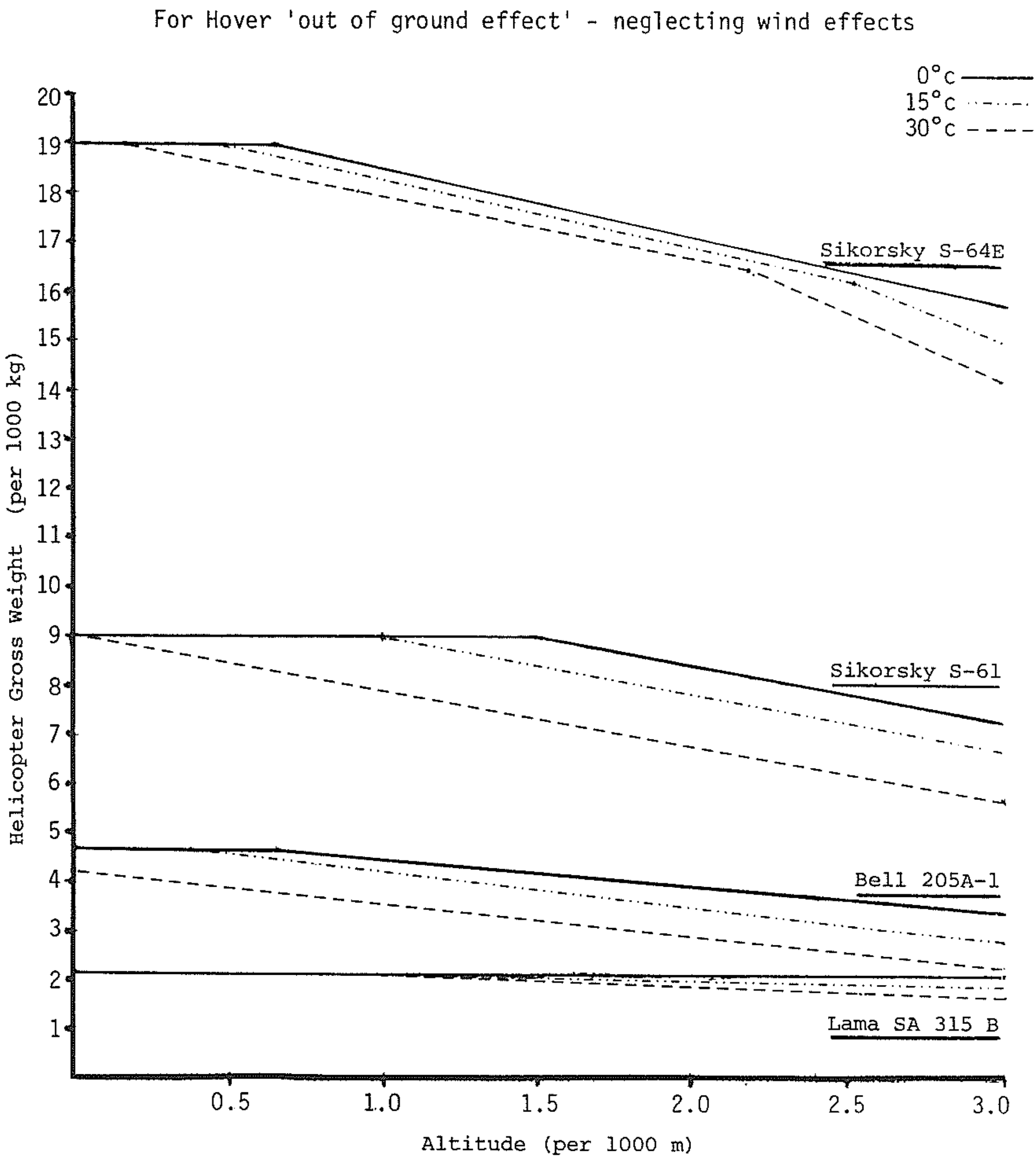


Figure 1 - Temperature/Altitude Relationships for Several Types of Helicopter

A CHANGING HARVESTING PHILOSOPHY

Helicopter logging is essentially just a harvesting system where the conventional ground hauling device has been replaced by a free flying crane. Logging procedures, whilst slightly modified to accommodate the particular demands of this aerial log hauler are much the same as they have been for decades past. A brief examination of the factors and considerations which have influenced the development of timber harvesting systems should provide a basis upon which the use of helicopters for logging can be viewed more rationally.

For aeons logging was constrained by limitations imposed by the use of animal or manpower and natural fibre rope logging was generally restricted to short hauls on easy terrain often adjacent to rivers or other watercourses. The introduction of wire rope and static steam powered haulers heralded a new era in timber exploitation. Haul distances increased dramatically, up to 900 to 1,200 m.

During the late 1940's and 1950's haul distances became shorter due to the advent of the crawler tractor and the diesel powered engines which provided rapid technological advances in road construction and truck transport. However, in the late 1960's and early 1970's some parts of the world witnessed a reversal of this trend. Roading costs began to escalate faster than hauling costs. More difficult terrain was beginning to be encountered, roading standards increased and environmental safeguards further fuelled the cost spiral. As a result, in Europe and North America, every endeavour was made to reduce roading density and hauling distances again increased. Sophisticated carriages and multispan skylines appeared in profusion and other new harvesting techniques were developed. Many of these methods were capable of haul distances of 1,500 m or greater. Helicopter logging received its initial boost during this period. The helicopter offered a system of new roadless logging and its introduction was greeted enthusiastically by the timber industry.

Helicopter logging first made a noticable contribution to the total timber production for a portion of the Pacific Northwest of North America in 1973. This is depicted in Table 1. The most significant trend in Table 1 is the sharp increase in the use of skyline logging systems which partially or totally suspended logs and the decrease in the use of tractor skidding.

Logging System	1972	1973	1974	1975	1976	1977	1978
Tractor	62	57	40	40	40	35	30
Highlead	30	25	39	25	32	29	34
Skyline	8	10	18	35	25	34	30
Helicopter	0	8	3	0	3	2	6

TABLE 1 : Percentage of the annual timber harvest by four logging methods for a portion of the Pacific Northwest of North America for the period 1972-1978.

However, the philosophy behind the most appropriate hauling distances appears to be a relatively dynamic one. In the past few years there has again been support for reducing haul distances. This is particularly noticable in the western United States where it has been realised that roading is required for the silvicultural tending necessary for second crop management. This is also the situation in New Zealand. The obvious conclusion reached has been that this roading cost is best offset against the high value 'free' old growth forests rather than being added to and further inflating the establishment and tending costs of second crop stands.

The rationale negates some of the economic and management advantages attributed to helicopter logging. A effect of this has been a downturn in aerial logging activity in the last 1-2 years. This trend will, in all probability, continue.

LOGGING METHODOLOGY

There is nothing this side of Disneyland that can equal a logging "show" for its complexity of motion. Until you have seen it up close, the scale of it is inconceivable. Offshore petroleum operations are complex for their sheer size and the numbers in the fleet. Construction operations are precise, delicate, carefully tailored to costs. There is no rival to the choreographed splendour of logging by helicopter, however. Patton's counterattack at the Battle of the Bulge pales by comparison.

George C.Larson (1978)

Introduction

Superficially, helicopter logging is nothing more than the substitution of a helicopter for more conventional log hauling equipment. Trees are felled and logs prepared and extracted to a landing for loading onto trucks. It is the translation of these simple activities to fit the time and cost constraints of helicopter logging that distinguishes this system from other harvesting methods.

To a large extent helicopter logging is unencumbered by many of the physical obstacles which impede the use of ground skidding and cable equipment. Helicopters are therefore able to provide an extended reach system which, given certain conditions, can allow timber harvesting to proceed when the use of conventional logging techniques is not appropriate.

Operational Procedure

By New Zealand standards wood gathering activity in the Pacific Northwest of North America is colossal. Logging is confined predominantly to old growth softwood forest and helicopter logging activity in this region is centred around medium or heavy lift helicopters with resultant high production rates (see Plate 4). By comparison, helicopter logging activity in New Zealand is restricted to small yields from indigenous forests or small areas of exotic forest which, because of environmental limitations, cannot be harvested by conventional means.

Plate 4 - Boeing-Vertol 107II Helicopter Logging in Old Growth Douglas Fir/Western Hemlock Forest, Oregon, U.S.A.

Typically the following equipment and personnel is normally found in North American logging operations which employ helicopters with a lift capacity exceeding 4,500 kg :

Logging helicopter
Rubber-tyre loader
Swing boom loader
Bulk fuel handling system
Small utility helicopter (optional)
maintenance support equipment
Strops (see Plate 5)

Personnel :

Felling and log preparation crew
6-10 crosscutters
3 Log weight scalers
3-4 Turn makers
Breaking out crew
4 Strop setters
2-3 Hookers

Plate 5 - 100 - 150 Wire Strops are Required on a Helicopter Logging Operation Employing Medium or Heavy Lift Aircraft

Landing Crew
2-4 Strop chasers
2 Loader operators

Helicopter Crew
4-5 Pilots
5 Maintenance and Refuelling Crew

1 Project Supervisor

New Zealand Operations

To date the majority of the experience with helicopter logging in New Zealand has been gained in second crop kauri forest. A Lama SA 315B helicopter has been used in these operations. It is powered by a 858 horsepower turbine engine and is capable of lifting 1,000 kg (see Plate 6). The tag-line assembly has a breaking strain of 4,640 kg and the strops are 'continuous band' type manufactured from 14 mm "Proplon" (polypropylene) with a breaking strain of 2,790 kg. About 30-50 strops are required and these vary in length from 4.5 m to 10 m (see Plate 7). A rubber-tyre front end loader and a bulk fuel handling system are also needed.

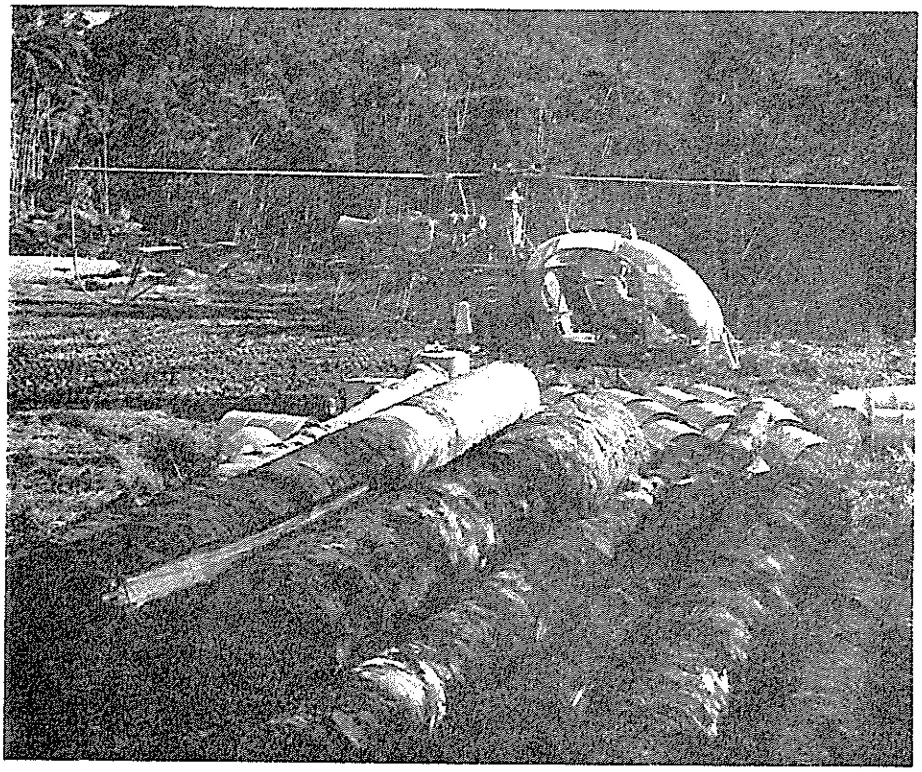


Plate 6 - Lama SA 315 B Helicopter

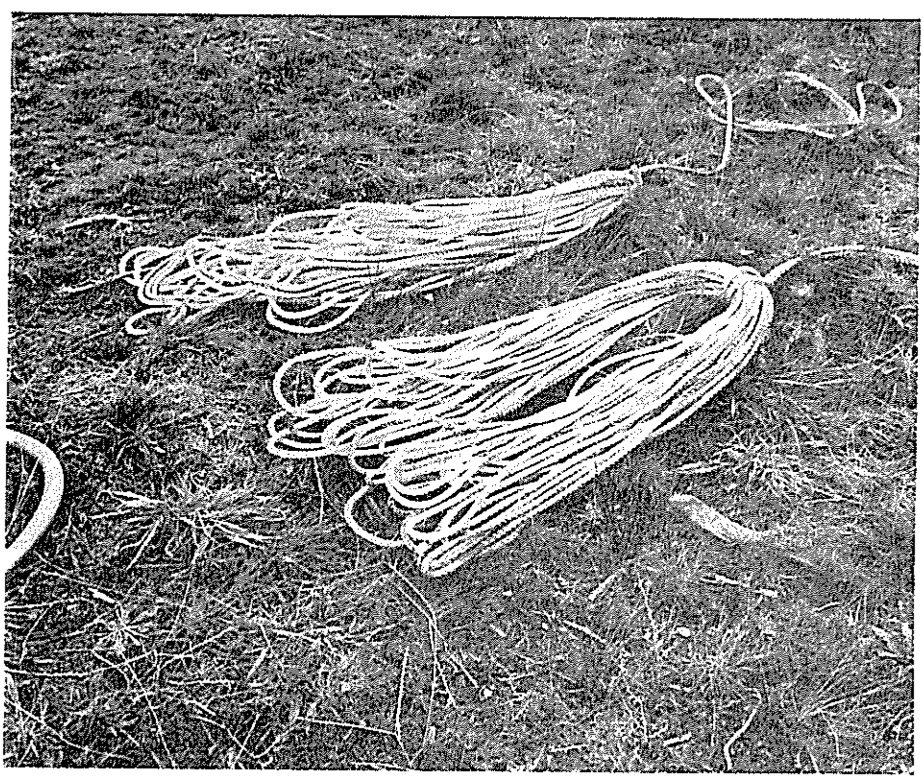


Plate 7 - Bundled "Continuous Band" Type Polypropylene Strops

Personnel :

Felling and Log Preparation Crew
1-2 Crosscutters
2 Log weight scalers
1 Limbing and Log Preparation

Breaking Our Crew
1-2 Strop setters
2 Hookers
1 Controller

Landing Crew
1 Strop Chaser/refueller
1 Loader operator

Helicopter Crew
1 Pilot

1 Project Supervisor

Following tree felling logs are prepared with the aid of a diameter/length/weight table. Some logs however have to be cut to specific lengths to meet end use requirements. This will usually result in some under utilisation in helicopter lift capacity. Strops are attached close to the butt end of each log. One or two hookers working under the direction of the controller attach logs to the helicopter tag-line (see Plate 8).

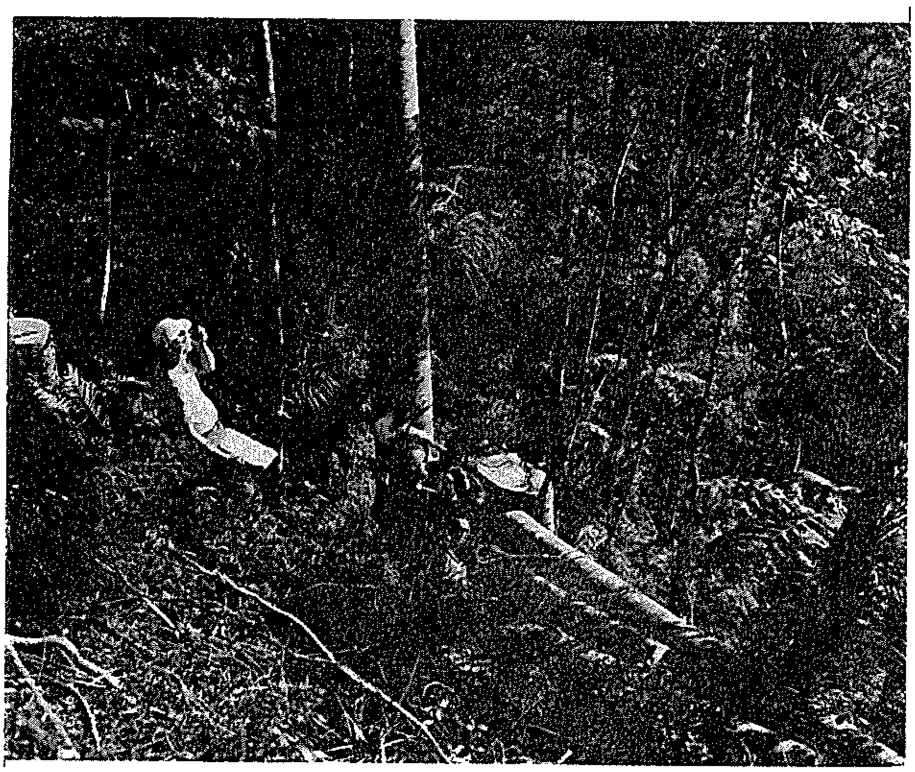


Plate 8 - Breaking-Out Crew -Controller, left, and Two Hookers, Russel Forest, Northland

At the landing the chaser retrieves and bundles strops. These are hooked onto the tagline and returned to the breaking out crew as required.

Because of the limit payload capability of the Lama SA 315B which to date has been the largest helicopter used for logging in New Zealand a light weight man-portable mill has been used to precision rip logs either in half or into flitches (see Plate 9). The mill consists of a lightweight frame incorporating the cutter bar of powersaw with a special ripping chain. The mill slides along aluminium rails which are spiked into the ends of the log.

Plate 9 - Precision Ripped Logs Waiting to be Uplifted

Principles and Broad Outlines

Helicopter logging's objective is to maximise turn efficiency. This goal is attained by endeavouring to minimise cycle time and maximise the helicopter's payload. Thisnecessitates careful thorough planning of every aspect of log preparation and extraction.

Because weight considerations are so important the ground crew must produce logs and make up turns that are close to the helicopters maximum permissable payload. While the problem of endeavouring to obtain maximum loads is common to all harvesting systems it is more critical with helicopters because of the high hourly costs and the zero overload tolerance. Miscalculations in load planning will have a serious affect on the economics of the operation.

A typical turn cycle consists of flying from the landing to the breaking-out area, positioning and hovering whilst the load is attached to the tagline, returning to the landing, setting down and electrically releasing the load. The cycle is then repeated. At the landing strops are removed from logs, bundled and returned to the breaking-out team as required.

Figure 2 depicts typical turn cycle time distributions for a Lama SA 315B helicopter operating in a selective logging setting and a Sikorsky S-61 working in a clearfelling area.

To maximise the log carrying capacity of the aircraft only sufficient fuel for 40-60 minutes flight time is carried. Radio communication between the pilot(s) and ground crew is absolutely essential to conduct and co-ordinate the operation.

Turn Cycle

Hauling distance. The turn cycle time is to a very large extent a function of haul distance, descent rate and aircraft cruising velocity. Initially hauling velocity increases in proportion to increasing extraction distance. This has the phenomena of making flight time independent of haul distance until the distance from the landing to the log pickup point is such that the helicopter is operating at maximum speed. This distance is usually between 0.5 and 1.5 km. Any increase in haul distance beyond this point will increase total cycle time linearly with flight distance.

Log hookup and release time should remain relatively constant for areas of uniform timber size, log density and terrain conditions. However, the percent distribution shown in Figure 2 will vary with haul distance. As flight distance increases beyond the point where the aircraft has attained maximum speed, the percent of time spent hooking on and releasing logs will decrease.

Elevation Differences

Helicopters have a maximum rate of descent and for this reason differences in altitude between the log pickup point and the landing may influence turn cycle time. There is also a relationship between aircraft velocity and descent rate. The descent rate is, of course, dictated by the terrain, and a flight speed needs to be selected that will achieve the minimum fly-in time. In general terms, aircraft velocity depends on the average slope of the direct haul route and the maximum helicopter descent rate. Figure 3 can be used to illustrate this phenomena. On slopes up to about 10° the helicopter is able to operate at its maximum cruise speed of 130-160 km/h (2,170-2,670 m/min). As the slope becomes steeper the speed needs to be reduced. At slopes of about 20°, velocity would need to be lowered to around 100-110 km/h. When the aircraft is operating at the maximum descent rate which is generally in the vicinity of 30°, speed would need to be lowered to about 80 km/h (Duggleby 1981).

Typical Time Distributions for Turn Cycles for:
(a) Sikorsky S-61 operating in a clearfelling setting
(b) Lama SA 315 B operating in a partial cutting setting

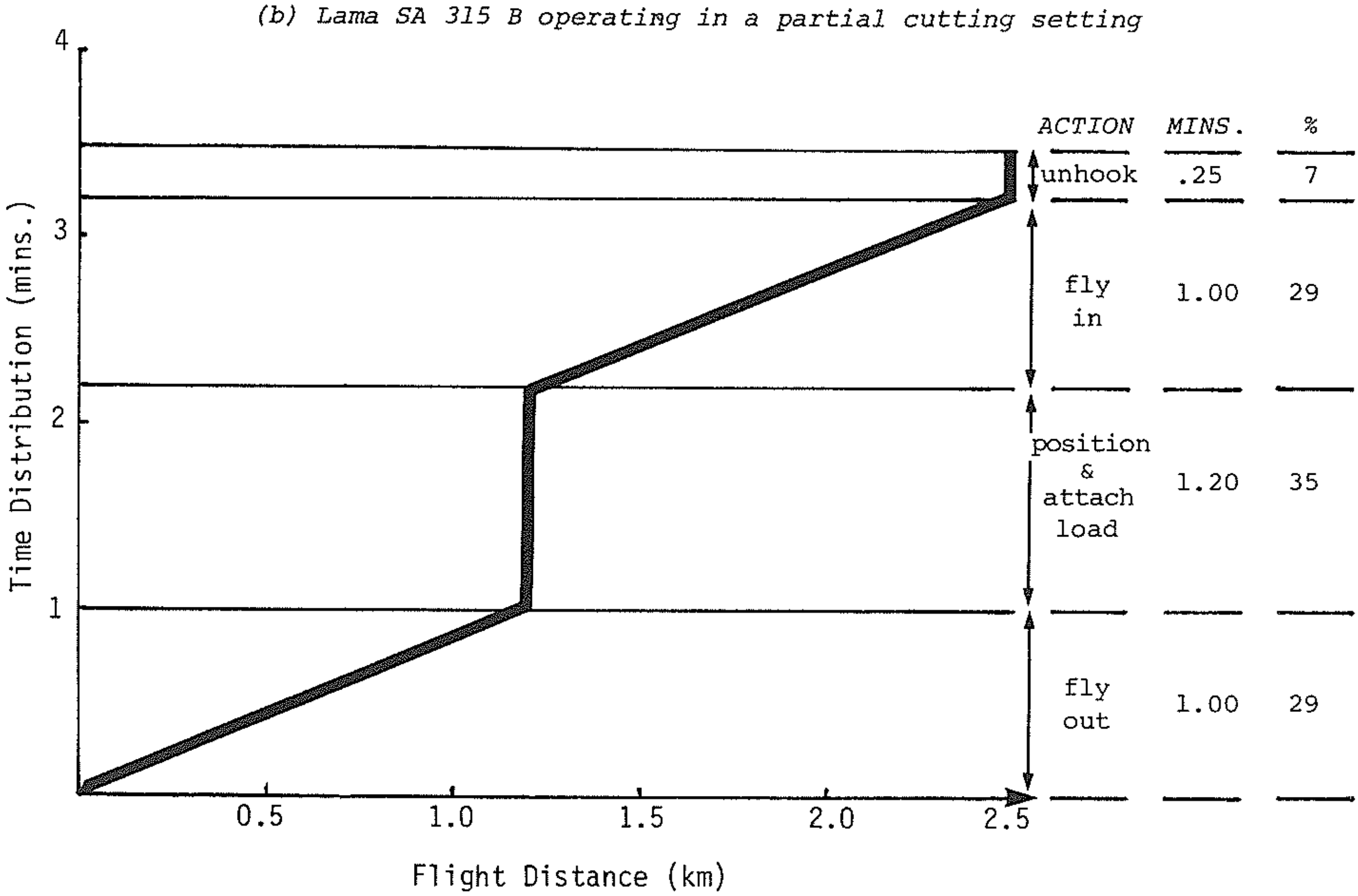
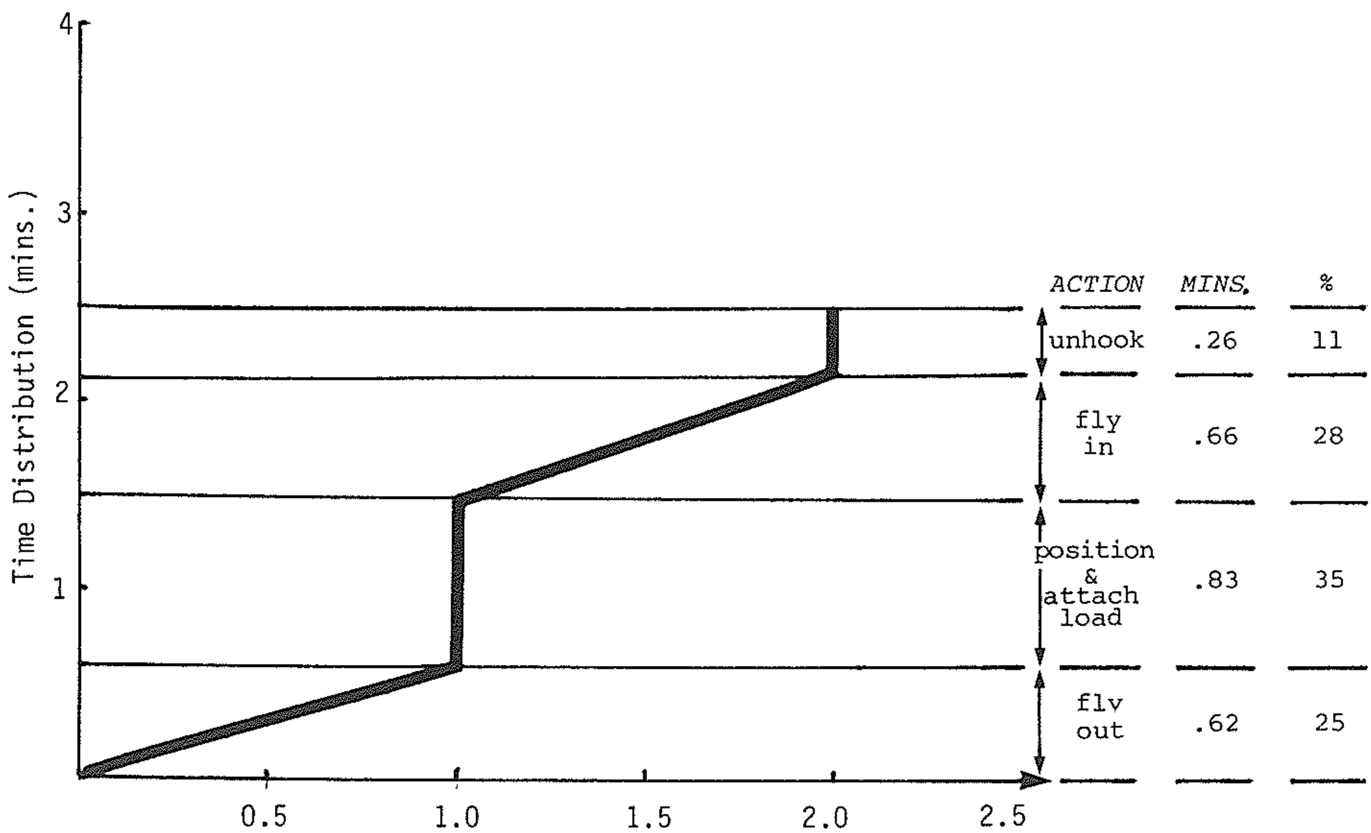


Figure 2(a) - Sikorsky S-61



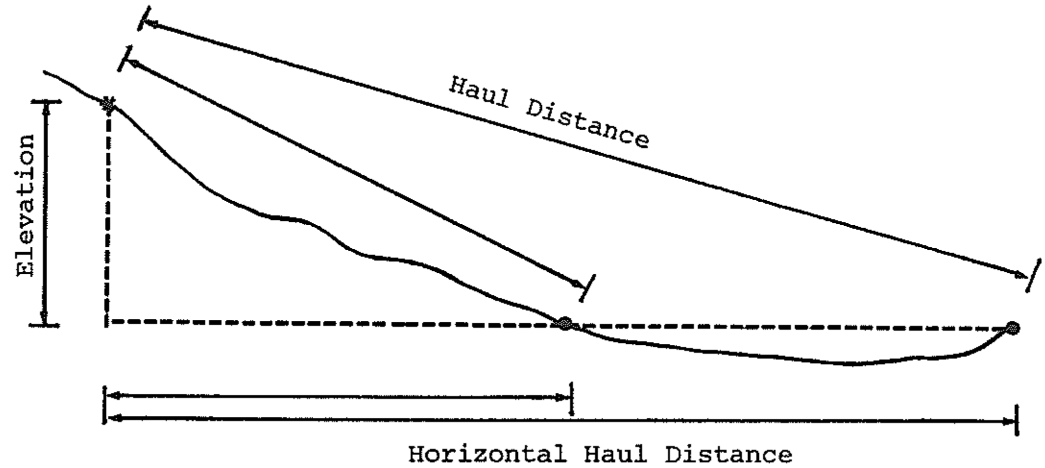


Figure 3

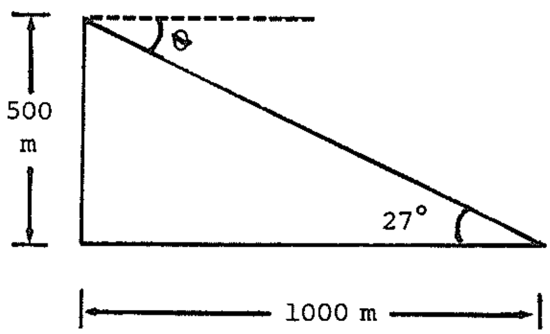


Figure 3(a)

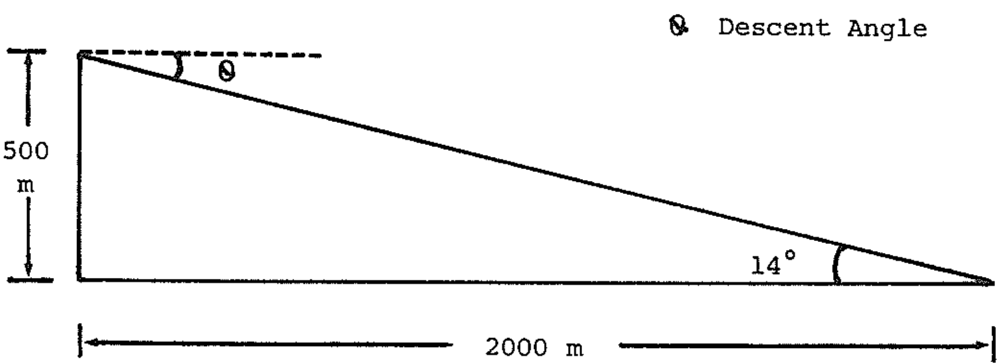


Figure 3(b)

Figure 3 - Example of the Effect of the Elevation Difference Between the Pickup Point and the Landing on Turn Cycle Time

In the example shown in Figure 3a it is assumed that the elevation difference between the log pickup point and the landing is 500 m and that the horizontal haul distance is 1,000 m. The descent angle is 27° and the maximum rate of descent is 600 m/min. The helicopter must fly 1,000 m in the horizontal plane to arrive at the landing. The fly-in time is therefore constrained by the maximum rate of descent and would take 0.8 min. If the helicopter increased its forward speed it would have too much altitude when it arrived at the landing and would have to hover to descend. This would increase fly-in time. In the example shown in Figure 3b the horizontal haul distance has been doubled. The helicopter can therefore increase its forward speed because the descent angle has been reduced. If it travels at a velocity of 2,000 m/min (120 km/h) it will also have a fly-in time of 0.8 min. If the landing is located at a horizontal distance greater than 2,670 m from the log pickup point the fly-in time would increase as the forward speed necessary to make the descent in 0.8 min would exceed the aircrafts capability.

It is therefore obvious that turn cycle time is not necessarily minimised when landings are located as close as possible to the log pickup area. Limitations imposed by the maximum possible angle of descent and differences in elevation between the pickup point and the landing may be important considerations.

Partial Cutting Requirements

Most helicopter logging operations in New Zealand to date have bveen in partial cutting conditions. In these situations, in addition to horizontal haul distance and elevation difference it has been found that canopy density and log frequency can substantially affect turn cycle times.

Delivering the hook through the canopy to the breaking out crew is often a time consuming and difficult manoeuvre. It is necessary to ensure that stand canopies are sufficiently opened to enable the pilot to see the hooker and lower the tagline to him. In addition, enough timber must be available to allow economic turns to be made up without having to mechanically pre-bunch logs on the ground. Experience suggests that at least 40-60 m^3/ha needs to be available for uplift to economically operate a smaller class helicopter.

Landing Design

The landing area should be sufficiently large to accommodate a log drop zone, log sorting, stacking and storage area, and possibly helicopter refuelling and service area. It may be desirable to locate the refuelling and service area adjacent to or even some distance from the logging landing. Landing size is influenced by several factors including terrain and environmental considerations.

Figure 4 shows the layout of two helicopter logging landings. One for a Sikorsky S-64 hauling about 130 m^3/hr and the other a Lama SA 315B with a production rate of 18m^3/hr. The log drop zone diameter should be approximately 2.5 times the longest log hauled. (U.S.D.A. - Forest Service 1978). This will provide a margin of safety for sliding logs and pilot error. The front end loader should have a safe area to retreat to whilst logs are being released. Landings should always be of adequate size as advantages gained through efficiency and fast cycling activity at the breaking out face may be lost if the helicopter

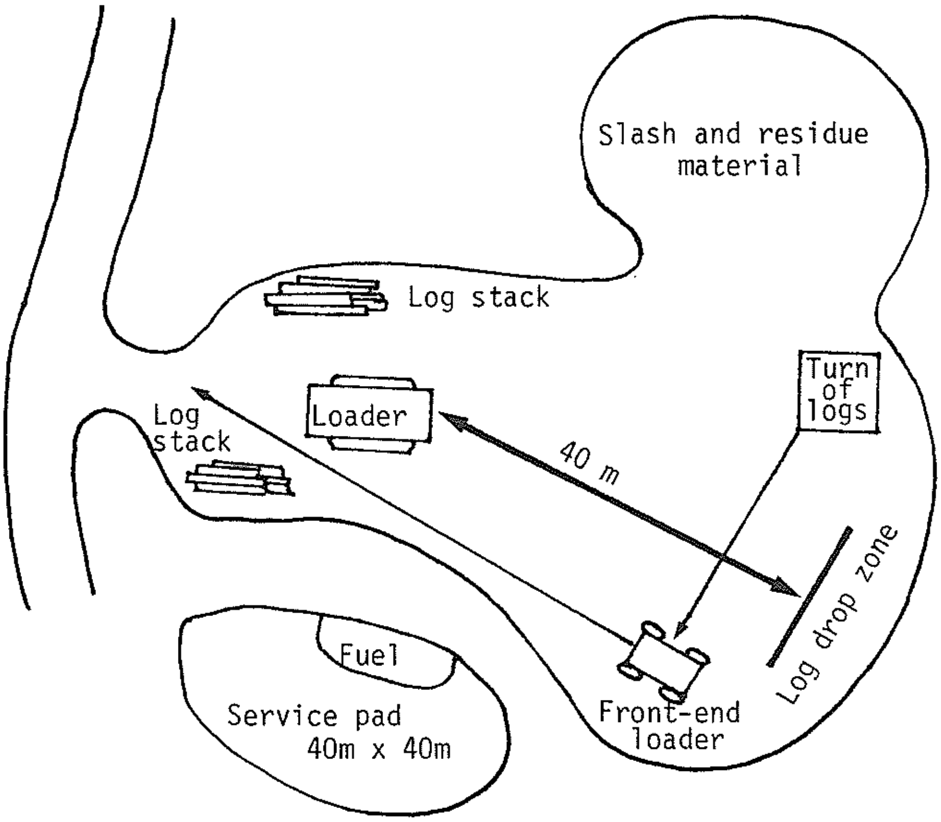


Figure 4 (a) - Landing Configuration for Heavy Lift Helicopter, 0.5 - 0.8 ha in Size

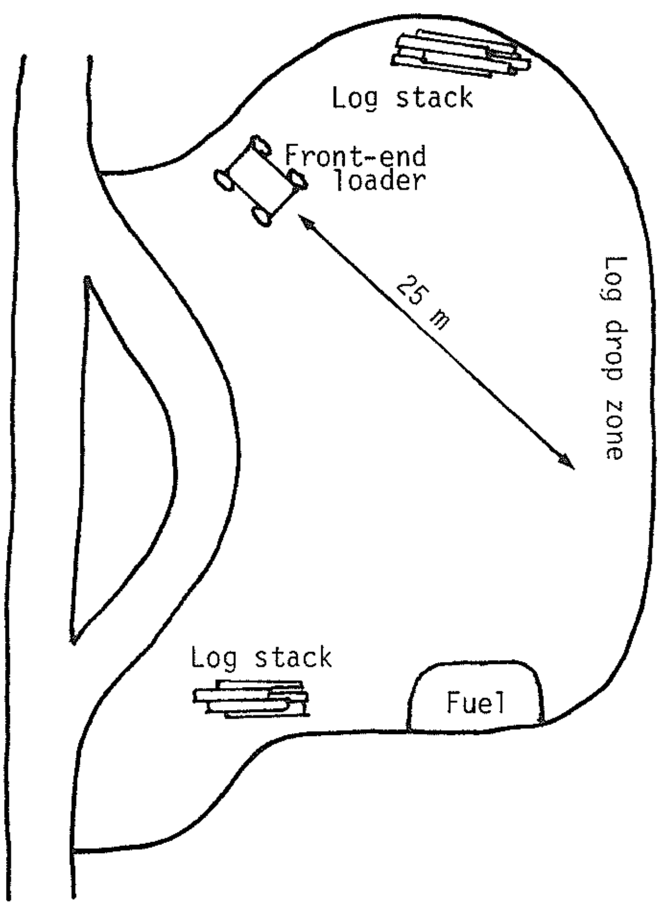


Figure 4 (b) - Landing Configuration for a Light Lift Helicopter, Approx. 0.3 ha in size is required to hover and intricately manoeuvre the logs onto a small landing.

Wherever possible landings should be positioned so that the inward flight path is into the wind. If the loaded helicopter has to fly with the wind it will generally have to turn into the wind before releasing its load. This would increase cycle turn time and therefore costs.

Planning Requirements

Because helicopters are essentially uninhibited by terrain considerations harvesting operations do not require the same intense planning as do cable systems. However, it is a fallacy to assume that only very minor planning is needed. Detailed layout of the cutting setting including landing locations, hauling distances, elevation differences, wind direction and estimated turn cycle time is the minimum requirement.

The logistics associated with the helicopter logging operation require careful forward planning. Trucking schedules, fuel storage, large numbers of ground personnel, weather factors and seculiar safety factors all require close appraisal.

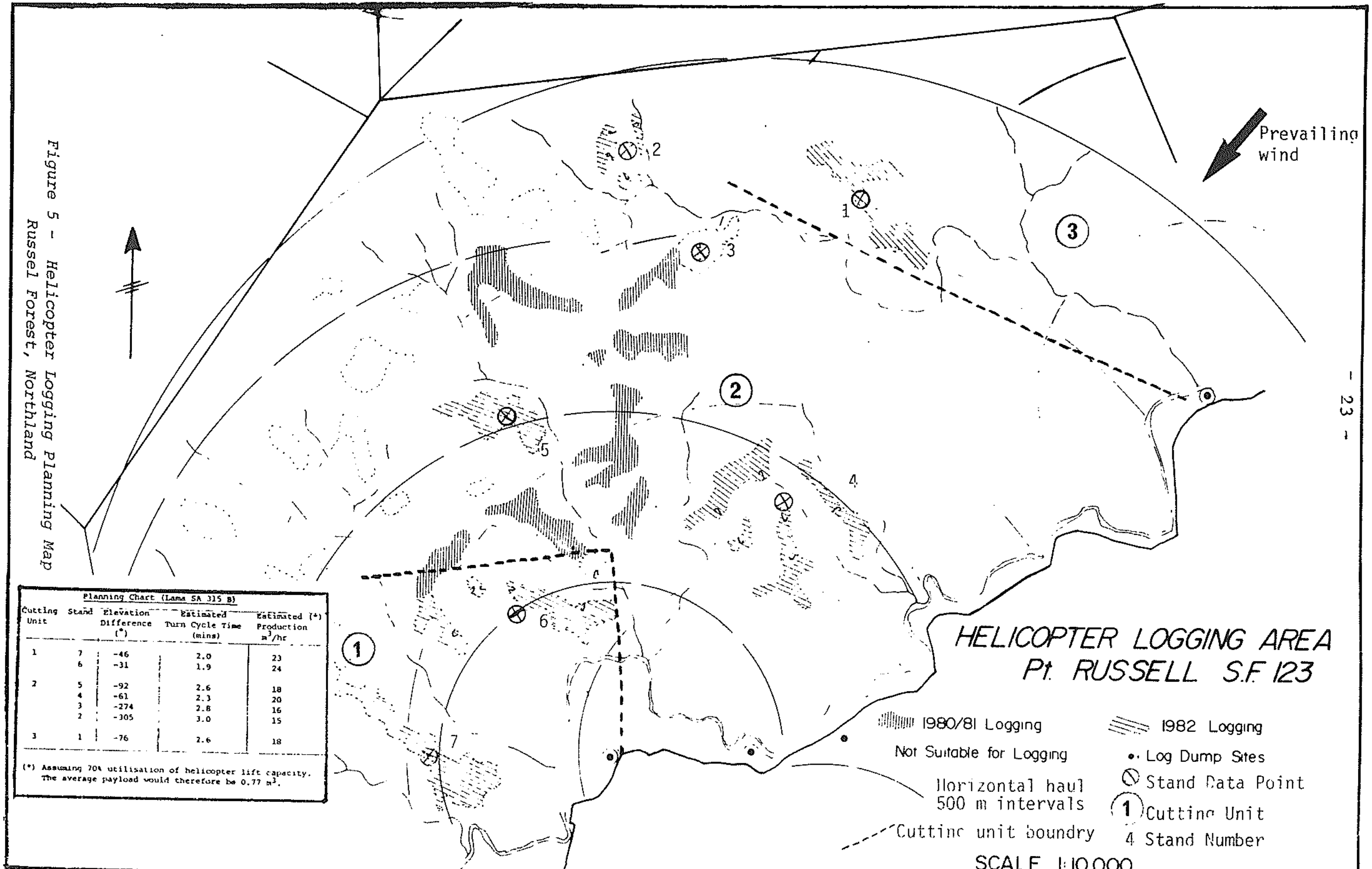
The harvest planning map for a sale volume of approximately 900 m^3 of sawlogs from a partial cutting operation in second crop kauri forest is contained in Figure 5.

Tagline Assembly

The tagline diameter is dictated by helicopter lift capacity. 8 mm diameter is used with a Lama SA 315B (payload capability of 1,000 kg) and 15-22 mm diameter material is used with large aircraft capable of lifting loads up to 8,610 kg.

Residual tree height is the major factor in determining tagline length. A clearance between the residual forest canopy and the helicopter of 3-7 m is needed. Very steep ground slopes may necessitate longer tagline length to ensure that the aircraft has adequate horizontal clearance between the main rotor and residual trees. When operating in clearfelling setting the influence of rotor downwash needs to be considered. Tagline lengths range between 30 m and 90 m. Experience indicates that cycle turn is significantly increased when tagline length exceeds about 60 m.

The tagline assembly normally has a load cell which records load weight and indicates overloading when it occurs. The tagline assembly is illustrated in Figure 6. The strops are attached to a load release hook which can be released electrically or manually at the landing (see Plate 10 a & b). There is also an emergency release hook which can be electrically activated by the pilot to jettison the load and tagline assembly should an emergency situation arise (see Plates 11 and 12).



Planning Chart (Lama SA 315 B)

Cutting Unit	Stand	Elevation Difference (*)	Estimated Turn Cycle Time (mins)	Estimated (*) Production m³/hr
1	7	-46	2.0	23
	6	-31	1.9	24
2	5	-92	2.6	18
	4	-61	2.3	20
	3	-274	2.8	16
	2	-305	3.0	15
3	1	-76	2.6	18

(*) Assuming 70% utilisation of helicopter lift capacity. The average payload would therefore be 0.77 m³.

Figure 5 - Helicopter Logging Planning Map Russel Forest, Northland

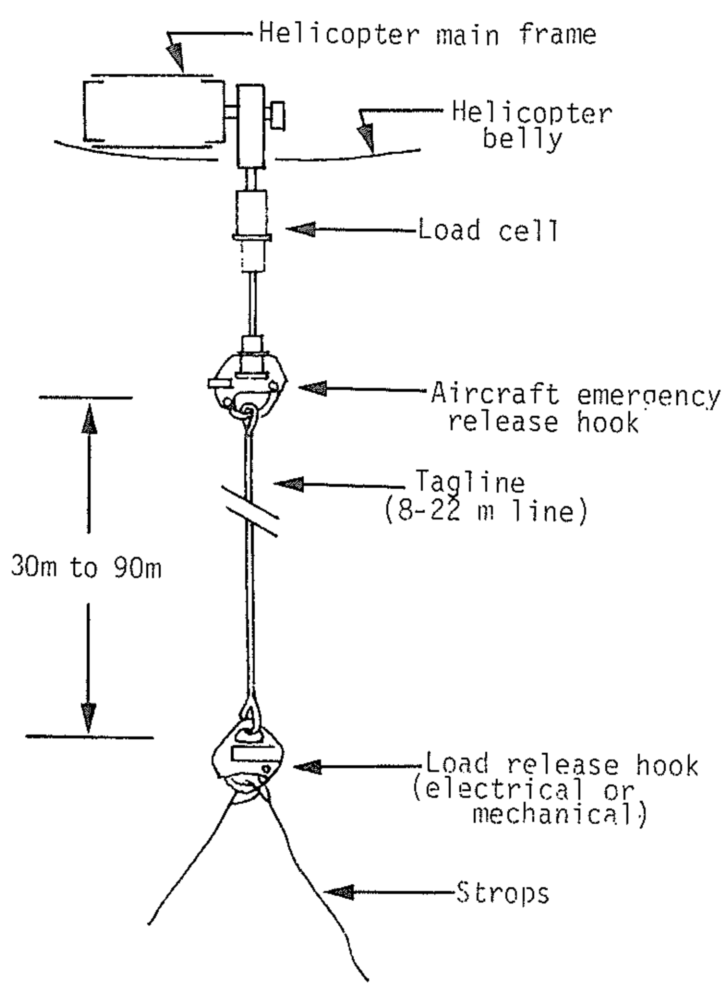


Figure 6 - Representation of the helicopter hook and tagline assembly

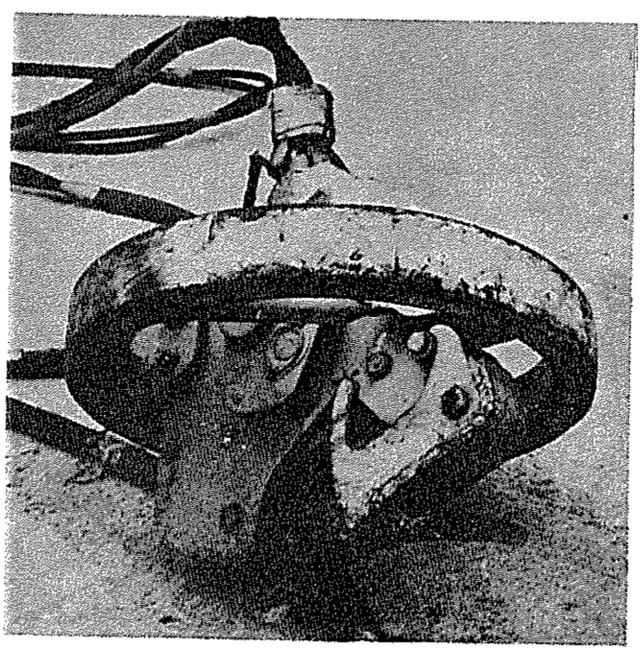


Plate 10(a) - Hooking Device Used in Association with a Boeing-Vertol 107II Helicopter

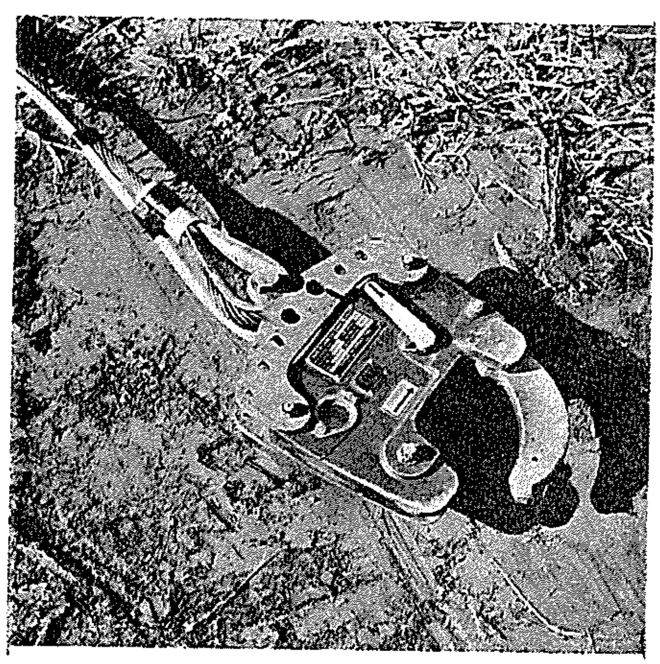


Plate 10(b) - Eastern Rotor Craft Cargo Hook Used in Association with a Lama SA 315 B Helicopter

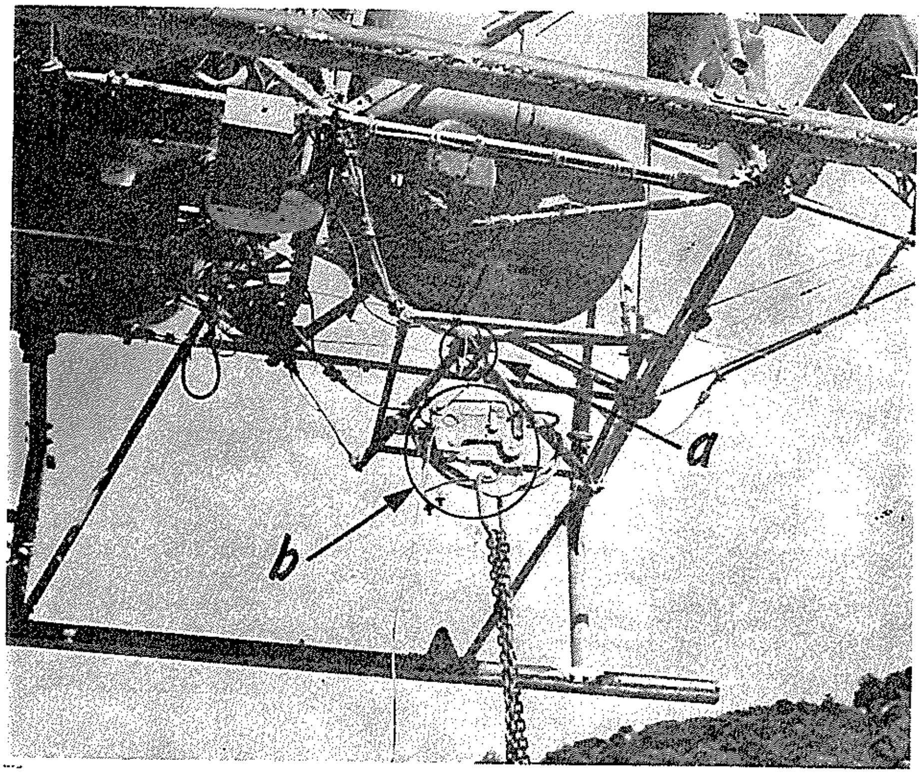


Plate 11 - Load Recording Cell (a) and Emergency Release Hook (b) Beneath a Lama SA 315 B Helicopter

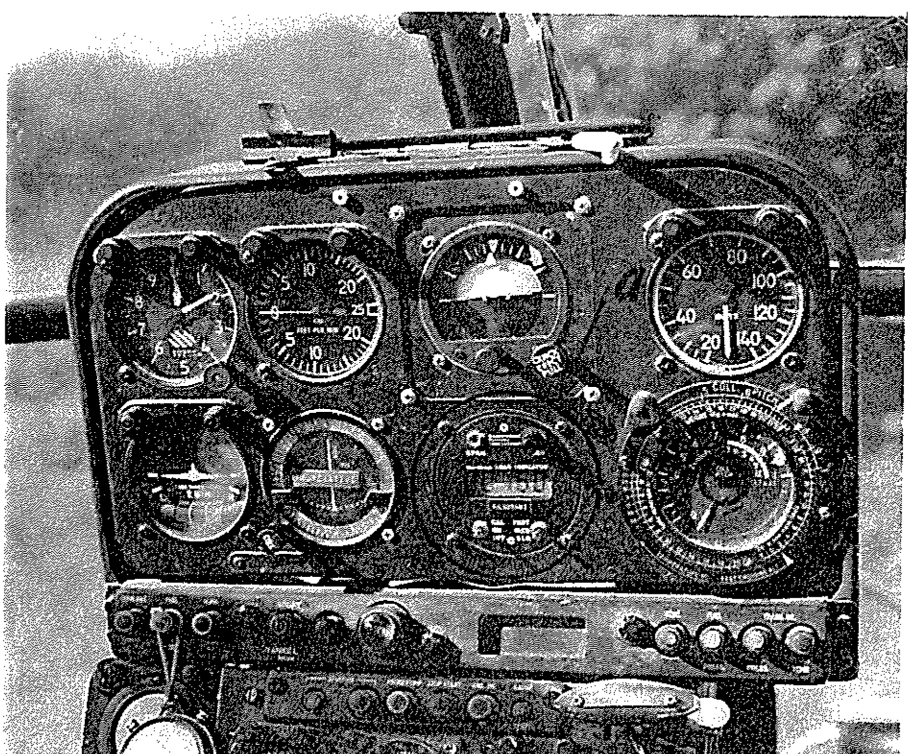


Plate 12 - Digital Weight Readout (a) on Cockpit Instrument Panel

Delays

Nett helicopter availability for hauling is generally in the region of 50-55 minutes per hour. The balance of the time is required for refuelling. However, in addition to refuelling there are several other conditions which may cause delays and so further reduce aircraft availability. Other major sources of delay are most likely to be weather related or due to aircraft and equipment malfunctions or ground crew errors.

North American experience suggests that the distribution of delays approximately follows that which is outlined in Table 2.

Delay Factor	Nett Available Flight Time (%)
Weather conditions	35
Aircraft Maintenance	4
Other Mechanical Equipment Maintenance	3
Sundry Minor Delays	6
	48%

(1) Minor delays may be caused by a multitude of reasons. Amongst these are :-

1. Overweight load which has to be aborted.
2. Poor strop setting resulting in logs being lost or necessitating the repositioning of strops.
3. Inability of pilot to locate the hooker.
4. Return of strops to breaking out team.
5. Release hook malfunction. Ground crew have to manually release the hook.
6. Difficulty in delivering the hook to the hooker because of residual trees or undergrowth interference.

TABLE 2 : Delay Factors and their influence on nett available flight time for helicopter logging operations.

The time lost during delays in Table 2 leaves only 52% of the nett available flight time for log extraction. This percentage may vary considerably. In the western United States 70% availability is thought to be the maximum attainable and 50% is about average. New Zealand experience to date suggests that, with operations of limited duration about, 80% availability is achievable. This high availability is probably attributable to the fact that log extraction activity can often be scheduled when weather conditions are not likely to pose major delays and removal is usually completed before aircraft and other equipment requires any significant maintenance.

Delays can have a serious impact on the economics of helicopter logging operations and every attempt needs to be made to minimise them. Many of the trivial delays can be avoided by sound planning, good supervision and workmanship.

Safety Considerations

Safety is the paramount consideration during all helicopter logging activity. Because of the nature of the operation any accident which occurs during the log extraction phase has a high probability of being serious. Safety requirements should first be catered for during planning. Special attention should be paid to aspects such as flight routes, landing location and size and prevailing wind direction. It is essential that all ground personnel are familiar with the safety rules which apply when working around helicopters.

A large number of personnel are required to support a helicopter operation and because activity proceeds at a swift pace, there is a need for increased safety consciousness as well as increased diligence. Landings are a constant hive of activity and personnel must remain alert at all times (see Plate 13). The flight path to and from landings should avoid ground crew. Conspicious signs prohibiting entry should be posted at points of public access to the logging setting.

Plate 13 - Landing Activity. Logging with a Bell 214B Helicopter in Old Growth Mixed Conifer Forest, Washington, U.S.A.

In addition to all the usual safety provisions which apply to ground based harvesting systems, there are some aspects of helicopter logging which require special attention.

All ground crew working beneath aircraft either at the log pickup point or landing should, in addition to their normal safety equipment, wear brightly coloured vests to aid their identification from the air. The hookers probably have the most hazardous on-the-ground job in the system. The speed at which they must work calls for agile, vigilant workmen with an appreciation of the several hazardous situations with which they are likely to be confronted (see Plate 14).

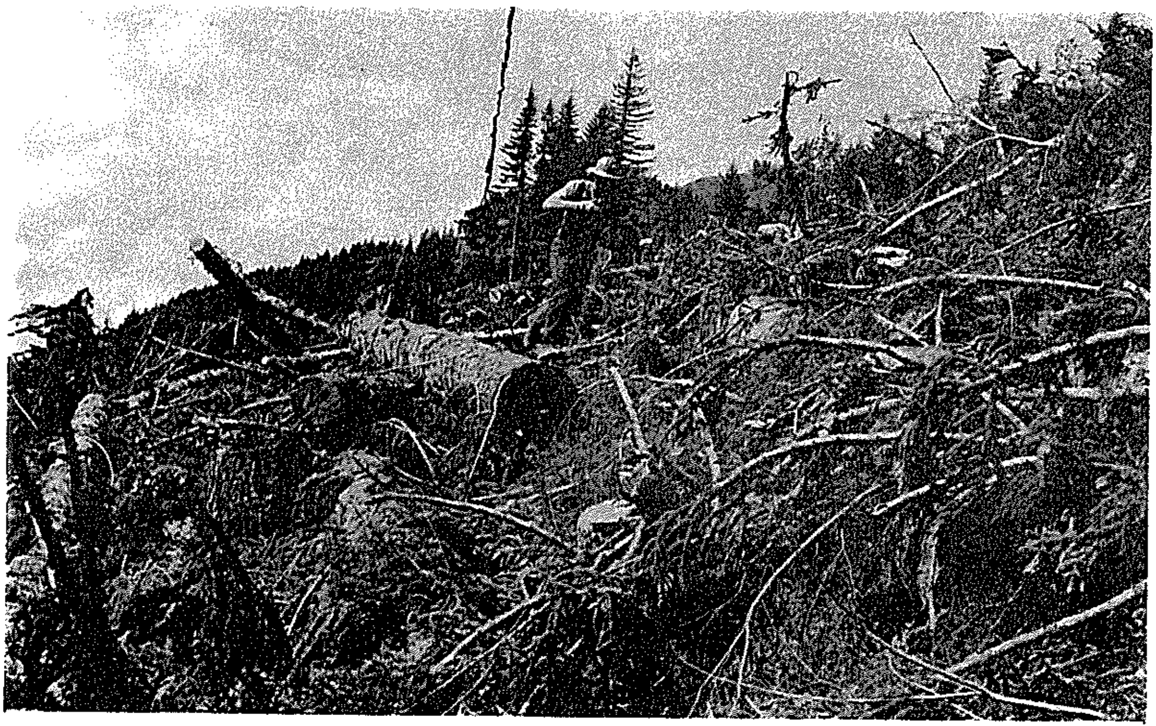


Plate 14 - Hooker Moving Away From the Danger Zone After Attaching a Turn to the Tag Line, Washington, U.S.A.

A problem is sometimes created by the downwash from the helicopter main rotor. The resultant buffeting may cause loose limbs and rotten tops to fall from residual trees in partial cutting operations. Downwash also causes severe dust swirls beneath the helicopter. This may create a hazard on landings and where it becomes acute landings may require regular watering or metalling to alleviate the situation.

PRODUCTIVITY, COSTS, AND COMPARISON WITH OTHER HARVESTING METHODS

With operating ranges far greater than those of conventional equipment, and an ease of manoeuverability not enjoyed by tractors and skidders, highlead or skyline, the helicopter is often viewed with something less than scientific objectivity.

Jorgensen (1973)

Estimating the productivity and harvesting costs of any logging system is complicated by the influence of variables such as hauling distance, setting layout, topography, volume per hectare, piece size machine capability and crew efficiency (Peters 1972). Attemtping to contrast two different harvesting systems presents even greater problems particularly when an endeavour is made to compare helicopter logging with conventional ground based methods.

Helicopter logging costs are usually derived from operations with a lengthy haul distance, rugged terrain and with other unattractive features. If this data is then matched with costs obtained from conventional equipment in entirely different forest conditions the comparison will undoubtedly disadvantage helicopter logging. Nonetheless, systems evaluation requires some attempt at objective contrast and in lieu of more compatible data this approach is often followed.

Production Rates: The productivity of helicopter logging operations far exceeds that of conventional systems. Production is generally a function of maximum payload, the percentage utilisation of lift capability and average turn cycle time (Curtis 1978). Production rates are also likely to be affected by the following factors :-

Stand and Log Quality: Because of the sensitive cost situation, low stand density and low value or highly defective logs are likely to have a major influence on the economics of helicopter logging. Helicopters perform most favourably in high quality, high value stands or in stands where only high value, high quality timber is to be removed.

Bunching: In instances where there are insufficient logs at the same location to make up a turn of adequate weight the helicopter may need to fleet logs together before a load can be assembled. This action would increase turn cycle time.

Understorey Vegetation: Cycle time may be increased further if dense ground or shrub cover impedes the movement of the hooker whilst attaching strops to the tagline or moving away from the danger zone before logs are uplifted.

Payload Size: The cost of production for any harvesting system is generally influenced by the average load size hauled. This is particularly true of helicopter logging. A high average load factor is sometimes difficult to achieve because of variation in wood density, form irregularity of logs and market requirements for logs of specific lengths.

Medium and heavy lift helicopters which usually carry multi-log turns generally have an average loading factor of 50-60% utilisation of payload capacity. Load weight for smaller helicopters which generally haul single log turns can be assessed with a greater degree of precision. For this reason helicopters such as the Lama SA 315B and the Bell 205A-1 are capable of average turn weights of 70-80% of maximum load capacity.

Figure 7 illustrates the relationship between direct log extraction costs and average payload weight for a Bell 205A-1 helicopter. Hauling costs escalate rapidly as turn weight falls below the 75% utilisation of lift capacity which was achieved during the trial from which the cost/load volume relationship was derived.

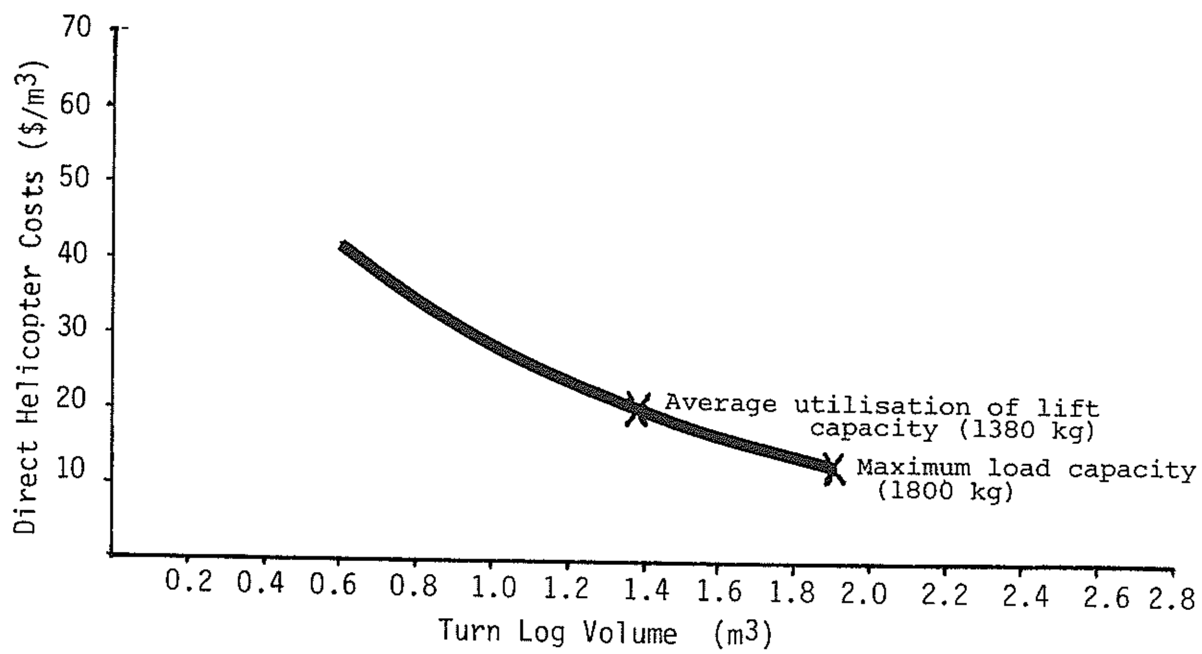


Figure 7 - Relationship Between Load Size and Direct Helicopter Costs For a Bell 205 A-1 Helicopter
(Allegheny National Forest, Pennsylvania, USA)

TABLE 3 : Estimated Hourly Logging Crew Costs, in Dollars per Hour ($US at 1974)

Position	Total Hourly cost [1]	Men in each job			Resultant hourly Cost		
		Sky-line	Bal-loon	Heli-copter	Sky-line	Bal-loon	Heli-copter
Hooktender	8.25	0	1	1	0	8.25	8.25
Hauler operator	7.08	1	1	0	7.08	7.08	0
Rigging slinger	6.77	1	1	0	6.77	6.77	0
Hooker	6.01	0	0	2	0	0	6.01
Strop setter	6.01	1	2	4	6.01	12.02	24.04
Strop chaser	6.01	2	2	4	12.02	12.02	24.0
Pilot	14.06	0	0	4	0	0	56.24
Aircraft mechanic	7.81	0	0	4	0	0	31.24
					31.88	46.14	149.82

1. Felling and Log Preparation costs are not included.

Comparison of production rates and costs for Cable, Balloon and Helicopter Hauling systems

During 1973 and 1974 a comprehensive study was made in which harvesting production rates and costs were from conventional and aerial systems (Dykstra 1976a, Dykstra 1976b). This study was located in old growth Douglas fir forest in the Pansy Creek catchment of Mount Hood National Forest, Oregon, U.S.A. Its aims were :-

1. To derive comparative production and cost data.

2. To identify the best hauling arrangement for each system.

3. To indicate possible efficiency improvements whilst recognising constraints imposed by environmental considerations and difficult topography.

Both partial cutting and clearfelling areas were harvested and three logging methods were tested. These were :-

1. A running skyline system in slackpulling configuration consisting of a medium-size, mobile hauler-tower combination mounted on a trailer.

2. A 15,000 m^3 natural-shape logging balloon in a haulback set-up.

3. A heavy-lift helicopter with standard logging rigging.

This investigation used detailed time study analysis methods. It identified many variables as having an impact on productivity. Important variables examined were hauling distance, number of logs per turn, chordslope, groundslope, lateral haul distance and type of cut. Costs were subdivided into labour and equipment. Both were calculated assuming a 1,600 hour year except costs of helicopter time which was based on a 1,200 flight hour year.

Labour requirements and direct costs for each system examined are shown in Table 3.

Production data from time studies was combined with labour and equipment costs. This information is outlined in Table 4.

TABLE 4 : Logging Cost Summary ($US at 1974)

Logging system	(A) Equipment Cost	(B) Labour Costs	(C) Production Rate	(D)=(A+B)/C Equipment and Labour Costs	(E) wire rope Costs	D+E = Total Cost
	S/hr	S/hr	m^3/hr	S/m^3	S/m^3	S/m^3
Skyline	18.83	31.88	19.8	2.56	0.12	2.68
Balloon	56.43	46.14	22.1	4.65	0.25	4.90
Helicopter	1,363.62	149.82	163.1	9.28	0.02	9.30

This extensive study was able to demonstrate that, for all systems reviewed, production is a function of haul distance volume per turn and per log, chordslope and the number of logs or strops per turn. It also showed that for the running skyline system operating in a partial cutting and the balloon system in a clearfelled area, lateral haul distance is also an important determinant of productivity. It was also found that for helicopter systems the slope of the ground at the pickup point influenced production rates. This appeared to result primarily from the difficulty the helicopter pilot had in manoeuvring the aircraft and tagline above the pickup point. On steeper sideslopes trees adjacent to the pickup point forces the aircraft to hover higher than would otherwise be required thus making control of the aircraft and tagline more difficult. The study demonstrated that helicopter logging is not sensitive to the type of cut, at least for the relatively heavy partial cuttings for which data was obtained.

In round turns the study showed that, given comparability between the important independent variables, helicopter logging was more than three times the cost of skyline logging and balloon logging proved to be about twice as expensive. However, despite these cost differences the study suggested that helicopter logging was likely to expand because of its ability to reach into areas where roadbuilding either creates too much environmental impact, presents engineering difficulties or would prove uneconomic considering the volume of timber to be cut.

Helicopter Logging Costs

Generalisations regarding cost data are fraught with peril. At best standardised cost information is imprecise because of the many variables to be considered and also the uncertainty regarding the incorporation or omission of indirect costs. However, some data is presented in an endeavour to provide an indication of the order of magnitude of costs.

Current data from the Pacific North-west region of the United States of America suggests that direct helicopter extraction costs for haul distances of 0.75 km to 4.5 km range from \$US25-\$US60 m^3 (Binkley 1971, Burke 1974). These costs apply to areas logged with helicopters having a payload capability exceeding 4,500 kg. Canadian experience with lighter lift helicopter indicates that direct extraction costs are in the vicinity of \$US25-\$US35 m^3 for haul distances between 0.4 km to 2.0 km (Silversides and Richenhaller 1975).

As a general rule total hourly labour costs are greater for helicopter logging activity than on ground based systems. However, because of the significantly greater production rates on helicopter operations the direct labour cost per m^3 is usually 20-50% less that it is for conventional systems. This is no doubt attributable to the greater degree of labour efficiency which is a feature of helicopter logging undertakings.

Cost information from New Zealand helicopter logging operations generally related to trial situations. A proportion of the total harvesting costs in these projects could probably be assigned to systems development and other aspects of research. However, partial cutting activity in second crop kauri stands at Russell Forest, Northland is now approaching an operational footing. Cost data for this operation is presented in Table 5 (Beachman 1981). The helicopter horizontal haul distance ranged from 0.5-1.5 km and average turn cycle times for stands logged during 1981 varied from 1.9 minutes to 2.5 minutes. Altitude differences between log pickup points and the land was not a constraining factor.

TABLE 5 : Direct Logging Cost Summary for Partial Cutting in Second Crop Kauri Forest ($NZ at 1981)

Cost Component	Cost ($NZ/m^3)
Labour	
Felling, Cut to length	4.34
Log Measurement (Turnmaking)	4.13
Strop setting, Hooking & Strop chasing	4.10
Loader Operator	0.46
	13.03
Equipment	
Helicopter	33.87
Loader	1.19
Powersaws	1.14
Vehicles	0.62
	36.82
Total	49.85

The hauling cost of $NZ33.87 is towards the upper limit of costs for comparable hauling conditions in North America. In large part this is due to the more expensive helicopter operating costs which prevail in New Zealand. The use of a light payload aircraft such as the Lama SA 315B contributes significantly to increasing the labour component particularly the costs associated with log preparation.

<u>Comparison with other Harvesting Systems</u>

Bearing in mind the need to interpret the information with suspicion. The direct costs of logs at the landing in helicopter logging operations is usually at least two to three times that of conventional cable extraction methods.

The average operating costs calculated for 218 stumpage appraisals in Vancouver Forest District of British Columbia, Canada to the 1 January 1981 for cable systems was $US41.48. However this figure includes operating and administration overheads plus loading, trucking, barging and other activities beyond the log landing. Direct logging costs for these operations which take place in old growth softwood forest on steep terrain which limits most harvesting to cable techniques is in the order of $US16-$US20/m^3. Helicopter logging activity within the same forest district during 1981 realised a cost, solely for helicopter hauling, of about $US25/$m^3$.

An obvious conclusion based upon this data is that, from an economic viewpoint, helicopter logging could never be considered as a replacement for ground based systems. Rather it must be viewed as an adjunct to them. Its use should be relegated to steep terrain where engineering, financial or environmental factors weigh against the use of one of the more traditional logging methods.

ADVANTAGES AND DISADVANTAGES OF HELICOPTER LOGGING

Although forestry will be important in the future prosperity of Marlborough, it should not be to the detriment of other users of the Sounds, as this area has a very high value for other uses such as recreation and marine farming. Expansion of forestry in this area of steep slopes and sensitive soils will require that particular attention be given to soil conservation..... Sedimentation around the rest of the forest has probably resulted partly from the erosion of hill slopes disturbed by dragging logs across them, and partly from erosion of logging tracks.

Johnson, et al. (1981)

The use of helicopters for logging offers some major management and environmental advantages over conventional logging methods, particularly on terrain where the impact of harvesting on forest values such as soil and water, aesthetic and animal habitat would be severe. (see Plate 15) In many partial cutting situations helicopter harvesting appreciably reduces the damage inflicted upon residual trees during the log extraction phase.

Plate 15 - Strop Setting for Helicopter Extraction in a Swamp Forest Logging Operation, Southeastern U.S.A. It is most unlikely that these areas could be harvested by any ground based method

Although helicopter logging is not affected by many of the factors which restrict the use of ground based methods, it must, like any logging system, be based on its capabilities and the economics of their application. The specific conditions which apply to a particular logging venture should be such that the advantages which accrue due to the use of helicopters are maximised and, the factors which negate against their use minimised or rendered irrelevant under the conditions which prevail.

The following factors all impinge upon the decision to use helicopters or conventional techniques for logging. The merits and disadvantages of each are presented.

Roading: A reduction in road building requirements can provide useful savings during a period when roading building costs are increasing more rapidly than hauling costs. Savings also accrue from the reduction in road maintenance and transportation charges. There is also a saving realised as ground normally utilised for secondary logging roading is not taken out of production (Lysons 1976). See Plate 16.

Plate 16 - Helicopter Logging on Steep Terrain Adjacent to a Coastal Inlet in British Columbia, Canada

However, any long reach harvesting system influences the management of the subsequent forest crop. Roads though initially expensive, afford the opportunity to use more economical harvesting techniques and to reduce the cost of re-afforestation and subsequent silvicultural work. Lack of desirable tending generally results in a reduction in stand productivity and timber quality.

Soil and Water Considerations: It is often difficult to quantify the impact of logging on soil stability and forest productivity because of variations due to soil type, logging technique and terrain. An attempt to do this was made at Mt.Hood Forest, Washington, U.S.A. This study illustrated the effects on three soil groups, (each subdivided into three slope categories) of five common harvesting methods. The study findings are depicted in Figure 8. For example, a clay loam soil on a 0-14° slope logged by a conventional skidder generally results in moderate to severe soil damage while the same area logged with a skyline or helicopter system usually sustains only slight temporary damage.

Logging Systems	Soil Group	Loamy Sand			Loam			Clay Loam		
	Slope (°)	0-14	14-27	>27	0-14	14-27	>27	0-14	14-27	>27
	Ground Skidders	◉	X	X	●	X	X	●	X	X
	Low Ground Pressure Skidders	○	X	X	○	X	X	○	X	X
	High Lead Cable	○	●	⬤	○	◯	●	◯	◉	●
	Skyline Cable	○	◉	●	○	○	◉	○	○	◉
	Helicopter	○	◯	◉	○	○	○	○	○	◯

○ Little or no permanent soil damage. Erosion and reduction of growing potential would be minimal.

◯ Some obvious erosion - no reduction in growing potential.

◉ Some obvious erosion and small reduction in growing potential.

● Obvious erosion,significant reduction of growing potential on eroded area.

⬤ Significant amounts of soil damage. Erosion and reduction of growing potential will be significant.

X Logging system either unusable or unacceptable resource damage will occur.

Figure 8 - The Impact of Different Harvesting Methods on Three Soil Groups (each subdivided into three slope categories)

Much of the soil surface erosion and long term effects on soil may be attributed to road building. In addition to the permanent removal of land from production natural drainage patterns are altered. Surface runoff is concentrated into ditches and onto unvegetated slopes which are highly susceptible to surface erosion (U.S.D.A.-F.S. 1979).

A study conducted in the Entiat River Basin in Washington demonstrated that forest productivity was related to topsoil erosion. Biomass yield was reduced by 80.5% with the removal of 3 cm of surface soil. The cost of adding fertiliser to replace site productivity and also the cost of extracting sediment flushed into reserviours were determined. If these indirect costs, which varied for the different logging systems examined, were added to the direct logging costs, total relative logging costs could be derived. The study demonstrated that, given certain site conditions environmentally acceptable advanced logging systems such as multi-span skylines and helicopter could cost less in the final analysis than traditional methods. It was concluded that when selecting a logging method for use close attention should be paid to choosing a system which minimises erosion, surface compaction and to the extent practical, roading density.

Impact on Residual Forest

A long standing problem with partial cutting undertakings has been the influence of the damage suffered by the residual trees during tree felling and more particularly during log extraction on forest health and productivity. The results from a study conducted to contrast damage to residual trees inflicted during selective logging in kauri forest, using ground skidding and helicopter log extraction, is shown in Table 6. It indicates that the extent and severity of damage to residual trees following helicopter log extraction was trivial compared with the injuries sustained by the remaining trees during selective logging using ground skidding (Halkett et al 1980). The study considered that the substantially reduced impact on the residual crop indicated that, in some partial cutting situations, aerial logging can offer considerable management advantages over conventional ground based methods.

	Damage Categories (%) (1)							
Logging Method	Root Plate				Stem			
	Nil	Light	Moderate	Severe	Nil	Light	Moderate	Severe
Ground Skidder	37	11	15	37	79	13	4	4
Helicopter	100	0	0	0	92	3	5	-

(1) Damage Categories

Root Plate:	Light	- Visible surface disturbance
	Moderate	- 0-25% of root plate area damaged
	Severe	- More than 25% of root plate damaged
Stem:	Light	- Bark scraped or bruised
	Moderate	- Small amount of bark removed
	Severe	- Bark removed from 25% of the bole circumference or more

TABLE 6 : Damage to residual trees during harvesting operations in Kauri forest. A comparison between ground skidding and helicopter logging.

HELICOPTER LOGGING - ITS POTENTIAL

".... the harvesting system to be used is not selected primarily because it will give the greatest dollar return or the greatest unit output of timber."

(U.S.A) National Forest Management Act (1976)

In terms of systems evolution, when compared with traditional ground based methods, helicopter logging is still in the embryonic stage. Some of the aspects which detract from its wider use have not yet been fully investigated. Improvements in these areas may well result in increased efficiency, greater productivity, reduced costs and wider acceptance of the system. The operating costs of helicopters makes stringent organisation and control vital requirements particularly during log extraction. Labour or machine inadequacies must be eliminated. Inefficiences of any kind cannot be tolerated.

The time consumed by the log hookup phase fluctuates widely. Improvements in areas such as flight path planning, log preparation and pilot ability may improve this activity. More precise log weight estimates would reduce the frequency of aborts and increase the average percent utilisation of lift capacity. Unfortunately this possibility may be frustrated because of the requirement, in some cases, that logs be of specific lengths to meet manufacturing needs, by the restricted assortment of logs available at any particular pickup point and by the inherent variation in log form and timber density. These considerations may negate improvements in helicopter payload utilisation as well as necessitating the incorportion of a variation tolerance into weight calculations.

No attempt has been made to suggest that helicopter logging will displace harvesting systems currently in use. However, it will probably continue to provide the catalyst for technological and efficiency improvements which can then be transferred to other systems. However, the nett result of this action is that the relative competitive position of helicopter logging remains about the same.

Helicopter logging has been cited as a useful harvesting technique when road construction is environmentally or economically prohibitive. The relationship between roading costs and hauling costs for a given set of site and environmental conditions needs to be understood and evaluated before it is possible to gauge the potential suitability of helicopters or any advanced harvesting system for a particular site.

Not only economic considerations but all variables should be thoroughly examined before any logging system is selected. Helicopter logging would be favoured if the timber to be extracted was of high value and high road construction costs or sensitive environmental conditions prevailed. It may also offer some management advantages in partial cutting situations or when prompt harvesting is required as might be the case when pathological disorders or fire damage promote rapid timber degrade.

The economics of the forest industry dictate that helicopter logging will not supplant existing harvesting methods where skidder or cable systems can be used effectively these methods will continue to be employed. Helicopter logging should be seen as a supplementary technique applicable in areas where special considerations preclude the use of traditional methods.

REFERENCES

Annon, 1979 : Heli-logging - A new sound in the woods. 4 pp.

Beachman, J.G. 1981 : 1981 Helicopter logging : Russell Forest N.Z.F.S. (unpub.rep).

Binkley, Virgil W, 1971 : Helicopter logging with the S-64E Skycrane. Report on sale U.S.D.A.-F.S. (unpub.rep).

Blundell, W.H., 1979 : Helicopter logging in young crop Radiata pine. LIRA Tech. Rel. Vol.1 No.2

Burke, Doyle, 1974 : Helicopter logging : Advantages and disadvantages must be weighed. Commonw. For. Rev. Vol.53(3) No.157

Curtis, Richard J., 1978 : Production rates of skyline, balloon and helicopter yarding systems from gross time study analysis. O.S.U. S. of F. (unpub. thesis)

Diggleby, Jim, 1981 : Understanding the business of helicopter logging. B.C. Lumberman mag. Jan.1981.

Dykstra, Dennis P., 1975 : Production rates and costs for cable, balloon and helicopter yarding systems in old growth Douglas fir. O.S.U. For. Res. Lab. Res. Bull. 18

------- 1976a : Production rates and costs for yarding by cable, balloon and helicopter compared with clear-cuttings and partial cuttings. O.S.U. For. Res. Lab. Res. Bull. 22

------- 1976b : Yarding delays for advanced logging systems. O.S.U. For. Res. Lab. Res. Pap 33

Halkett, J.C. 1980 : Helicopter logging trial in second crop kauri forest. LIRA Tech. Rel. Vol.2 No.2

Halkett, J.C., Nieuwland, P.R. and Cooper, T.J., 1980 : Residual forest condition following helicopter logging - A comparison with other selective logging methods. For. Ser. Res. Inst. Ind. For. Man. rep. No.29

Johnston, A., Mace, J. and Laffan, H., 1981 : The saw, the soil and the sounds. Soil and Water mag. Vol.17 No.3 and 4.

Jorgensen, Jens E., 1976 : Aerial Logging. Chap.15 in Conway Steve, Logging Practices. Miller Freeman.

Larson, George C., 1978 : Lumbering Grant. Flying mag. April 1978 Ziff-Davies Pub. Co.

Ledoux, Chris B., 1975 : Simulation of a helicopter yarding system in old growth forest stands. O.S.U. S. of F. (unpub thesis).

Lysons, Hilton H., 1976 : Why log with skylines? Proceedings Skyline Logging Symp. Vancouver B.C. pp 1-8

Mifflin, Ronald W. and Lysons, Hilton H., 1979 : Glossary of forest engineering terms. U.S.D.A.-F.S. P.N.W. rep.

Peters, Penn A., 1972 : Estimating production of a skyline yarding system. U.S.D.A.-F.S. (unpub. rep.)

Saunder, B.J. and Nagy, M.M. 1977 : Coast logging : Highlead versus long-reach alternatives. FERIC Tech. Rep. No.TR-19

Schutzbank, Al., 1974 : Boeing Vertol model 107's. Role in the timber industry. Boeing Vertol Coy.

Silversides, C.R. and Richenhaller J., 1975 : Helicopter logging trials in Temangami. Forestry Chronicle Vol.51 No.3.

Stevens, P.H. 1972 : Helicopter technical summary. Felcon report. U.S.D.A.-F.S. Rep. No.ATR-72 (57266) -1

Stevens, P.M. and Clarke, Edward, H., 1974 : Helicopters for logging. Characteristics, operation and safety considerations U.S.D.A.-F.S. P.N.W. Rep.No.20.

U.S.D.A.-Forest Service, 1978 : Logging systems guide. U.S.D.A.-F.S. Series No.R10-21.

-------- 1979 : Final environmental statement for the timber management plan for Mt.Hood National Forest. U.S.D.A.-F.S. (in press)

-------- 1981 : Timber sales preparation guide for helicopter logging. U.S.D.A.-F.S. (unpub.rep.)

Vinogorov, G.K., 1961 : Logging-by-helicopter trials in the U.S.S.R. FAO/ECE/LOG/96 Geneva

LIMITED GLOSSARY

Only words and terms which are particularly associated with helicopter logging are defined below. General logging terminology is not included.

abort — Occurs when a load of logs cannot be uplifted or is jettisoned by the helicopter pilot because it exceeds the payload capacity of the aircraft.

chordslope — Is the slope of a line segment which connects the skyline fairlead on the hauler tower to the tailhold. For a helicopter, it is the slope of a line segment which connects the landing and the log pick-up point.

groundslope — Is an average side slope measured perpendicular to the contours of the log pick-up point.

hooker(s) — The ground crew member(s) who attaches the strops to the helicopter tagline at the log pick-up point.

hover 'out of ground effect' — Occurs when a helicopter hovers more than half the main rotor sweep diameter above the ground. 'Ground effect' is the packing of air between the ground and the helicopter's main rotor when the helicopter hovers near the surface. This 'ground effect' increases lift capacity for low-level hovering but has no influence in helicopter logging because helicopter operates out of ground effect.

turn — The log(s) brought to the land in any one hauling cycle. For the helicopter logging a cycle consists of four phases : Fly out, Position and attach load, Fly in and Unhook.