LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

DAVID HENRY SCHOLARSHIP REPORT

PACIFIC NORTH WEST - NORTH AMERICA STUDY TOUR

December 1978 - March 1979

P.R.9 1979

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

P.O. Box 147 Rotorua New Zealand

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PREPARED BY:-

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- ACKNOWLEDGEMENTS -

I wish to express my thanks and gratitude to the Trustees of the David Henry Scholarship and N.Z. Forest Products Limited for awarding me a 1978 scholarship which financed all expenses incurred in this project.

The study tour was not only of great personal benefit but will assist LIRA in a number of its current research projects for the N.Z. logging industry.

I also wish to thank LIRA's Director and the Executive for their support and assistance in enabling me to undertake the study tour.

- OBJECTIVES OF TOUR -

The primary objective of the study tour was to improve knowledge and experience in some of the areas of research that LIRA is currently involved in for the logging industry in New Zealand.

Investigations and study primarily concentrated on cable logging, where the tour gave a wider perception and understanding of cable logging systems and equipment. Information was also sought on work covering environmental influences on logging and directional felling, currently part of LIRA's research programme.

A secondary objective was to gather material that would assist in the presentation of extension courses and information for the N.Z. logging industry to meet some of the recommendations of LIRA's 1978 Cable Logging Seminar, calling for improved technology to be applied in this country.

To meet these objectives the following was undertaken:

- The fourth bi-annual Skyline Logging Symposium held in Portland, Oregon, was attended.
- A ten week long Forest Engineering Course at Oregon State University was undertaken.
- Visits to logging research organisations and logging operations in Oregon, Washington, and British Columbia, were undertaken.

- INTRODUCTION -

As a result of being awarded a 1978 David Henry Scholarship, a three and a half month long study tour was undertaken to the Pacific North West Coast of North America.

Arrival in the U.S.A. coincided with the week long Skyline Logging Symposium in Portland Oregon, from the 4th of December 1978. This was followed by some three and a half weeks visiting logging research organisations and logging operations in Coastal British Columbia, Washington, and Oregon. On the 2nd of January 1979, a ten week long Forest Engineering Extension Course at Oregon State University was undertaken with the return to New Zealand following this course on the 13th of March 1979.

This report is presented to the Trustees of the David Henry Scholarship to fulfil an acceptance condition required of scholarship participants.

The report is presented in two parts:

Part I: Is a summary of the conferences, course, and research and industry organisations visited during the tour.

Part II: Covers some of the technical subject areas learnt or seen during the study tour, particularly those which are considered to have wider interest in N.Z. Reference material used in Part II was information gathered from the various sources mentioned in Part I of this report.

Further detail on any of these subjects is available from the author at LIRA.

- SUMMARY -

Attendance at the Skyline Logging Symposium and the well presented Forest Engineering Course at Oregon State University gave an opportunity to appreciate and discuss many of the logging problems, and management and planning research being conducted on the Pacific North West to overcome these problems.

Significant logging research and developments occurring in this part of North America, that could have future application for New Zealand are:

Smallwood Logging:
Greater emphasis is being placed on the logging of smallwood. Some of the private companies, universities, and other research groups appreciate that within a decade the old growth fir stands that have been the backbone of their industry will be logged out or locked up by Protection Acts. At this time N.Z. has already introduced technology resulting from PNW smallwood cable logging research, such as the intermediate supports for small haulers. This should continue through the importation of technology and the development of machines and systems for smallwood logging using cable systems.

Steep Terrain Logging:
Harvesting in the PNW is occurring more and more on very steep broken terrain which is served by high cost roading. Planning of road layout and construction methods, cable logging systems, equipment and advanced planning methods being employed, will be of direct benefit to assisting logging planners in this country in the future. The computer and programmable calculator has become an every day tool in the hands of planners on the PNW. Programs used with this equipment offer a wide range of options and alternative layouts to be assessed quickly during the planning process, and also the ability to determine the visual impact logging will have on a particular piece of land during the planning stage.

Soil Erosion and Soil Compaction:
Soil compaction and erosion caused by ground based equipment such as tractors and skidders, and the effects on tree growth with the second rotation, is being researched extensively. Results to date indicate that on fragile or easily compacted soils (i.e. high clay content), growth rate losses within the following rotation or the decline in the rate of increment increase in stands thinned by tractors or skidders, can be significant. To avoid excessive soil disturbance and compaction, cable methods are being

used, even on some easy terrain, and low ground pressure vehicles such as the FMC high speed track skidder, have gained considerable support in areas traditionally logged by tractor and skidder. The effects of soil compaction caused by logging equipment has not been well documented in this country.

Logging Equipment:
New Zealand has traditionally based its logging equipment on North American developments, with imported haulers and other machines from the PNW. This trend will probably continue. The range of alternative options available with haulers is immense and often they are designed to meet a specific type of operation or work technique. To therefore use these machines efficiently in the N.Z. situation, planners and operators must have a good understanding of how and where alternative types of equipment or systems work best.

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SKYLINE LOGGING SYMPOSIUM

The Fourth Bi-annual Skyline Logging Symposium held in Portland Oregon from the 4th - 9th December 1978,was attended. This symposium is used as a platform to present and review skyline logging research being undertaken in the Pacific North West. Chairman for the conference was John Garland, Logging Systems Specialist of Oregon State University (OSU).

1.1 BACKGROUND PAPERS:

Two introductory papers were presented:
"The Status of Skyline Logging and Future Prospects for the North West" by Donald Studier, Co-ordinator Forest Engineering Programme OSU.

This was basically a historical review and a look to the future development of skyline logging, from steam haulers through to the more recent trends. Reducing labour, carriage development to log long lateral distances thus reduce environmental problems, and enforced changes brought about by national environmental protection acts, were discussed. Studier considers the changes over the past ten years have been immense, however, over the next decade only minor changes in volumes logged would occur and most development and change would be in:-

- smallwood harvesting using small machines and intermediate supports, with further experimental work to look at ways of preventing damage to the residual crop.
- a need to review tractor operations to prevent soil compaction especially on high site index areas.
- a need for greater emphasis on training and motivation of current operators.

Current research in man-made anchors and early failure warning devices for anchors will continue as will the development of the Helistat - an airship powered by four helicopter rotors.

"The Interaction of Skyline Logging and Soil and Water Impacts" by Henry Froehlich, Forest Engineering Department, OSU.

In this address Froehlich reviewed the literature and research work done on requirements for roading systems and road densities for different logging systems.

The review also looked at deep soil disturbance created by different logging methods and soil compaction. Studies are being conducted on the affects soil compaction has on the future crop and how skid trails can be reduced. Streamside logging was also discussed in Froehlich's paper. He emphasised that skyline logging can reduce disturbance but in many cases, because of slope, debris was being swept away into streams even though logs were being fully suspended across the stream. He ended this topic by stating that special streamside logging techniques should be tried where they can, but we must also realise where they won't work.

1.2 GROUP LEARNING STATIONS:

An important part of the symposium was specific learning sessions on new research findings and skyline planning techniques. The symposium delegates were broken into smaller groups and circulated through each of the seven sessions. A summary of these sessions are:-

(1) Analysis of Skylines (taken by J. O'Leary, OSU and D. Dykstra, Yale University)
- by chain and board technique
- by hand held programmable calculators
- by desk top computers

(2) Cost Influences on Skyline Operations (taken by J. Sessions, USFS Washington DC)
This discussion revolved around a computer model Sessions has developed for Douglas fir thinnings. The model analysis can select the number of logs per cycle. By altering the number of chokers, the maximum haul capacity, the thinning density or the cutting pattern can be re-run to look at affects that these have on costs.From the work Sessions has done, he has concluded that the percentage change in harvesting cost is constant with the percentage of merchantable volume removed. Further analysis of the computer model relates logging costs with produce value to calculate the best regime for a stand. Also whether uphill versus downhill logging is best, what management strategy should be followed, or if pre-bunching for extraction with large yarders is cost efficient.

(3) Carriages (taken by M. Rowley and L. Kellogg,OSU)
This session covered the classification of the numerous types of carriages available and how they worked best.

(4) Mechanical Analysis of Intermediate Supports (taken by P. Peters, USFS West Virginia)
Peters discussed research work he has been involved

in for the calculation and analysis of forces and requirements for hanging intermediate supports, tail trees, and lift trees. Much of this research has been to assist in drawing up guidelines for the Oregon Safety Code.

(5) Guyline Analysis (taken by S. Reutebuch, Weyerhaeuser Tacoma Washington)
The importance of guyline placement in relation to the stresses and strains imposed on a 28 m steel spar were covered in this learning session. Variations in tensions in the tower caused by highlead and shotgun systems were indicated. A ten rule check list for guylines was given as well as an explanation of a computer program that can be used in critical situations.

(6) Review of Skyline Systems (taken by E. Aulerich Consultant, Corvallis Oregon)
In this session a wide range of topics related to different systems were discussed. A few key points of interest are covered here:
- very few highlead operations now operate in coastal Oregon. Wherever possible shotgun (gravity return) systems are used.
- wooden spars using a northbend skyline system are becoming popular again in Alaska, due to the high cost of steel spars and very high roading costs. Northbend swings are being used to reduce roading requirements.
- the scab skyline configuration is popular with many types of yarder. Horsepower is cheaper than a planetary or hydraulic interlock, where conventional running skylines can be used.
- investigations of skyline operations show that most operators under-load their skylines by some 40%.

(7) Equipment Suppliers
Machinery manufacturers and distributors were given an opportunity to display their advertising brochures and discuss their product lines with symposium delegates.

1.3 SKYLINE LOGGING RESEARCH:

One and a half days of the symposium were taken up with either panel sessions or the presentation of papers by experts discussing their research or new developments. A summary of these addresses is given:

"Guyline Research" by J.Jorgensen, Weyerhaeuser
There are four main reasons for guyline failure - lack of basic understanding; inexperience; changes in the yarding environment; and no pre-warning devices. Examples were given of the different forces between highlead and shotgun systems with indications of ways

of reducing the input loads into the tower and guys. The guyline analysis computer program allows quantification and creates a fine tuning for critical areas. Guyline inspection at times of shifting provides assurance that guys are operating at the rated capacity while devices such as the Tri-Coastal tension meter give a good indication of loads. Training of operators and crew will reduce the problems. Equipment could be designed with modification to reduce the maximum stall, and yarders could be designed with slip devices built in, rather than having drums dogged off.

"Smallwood Yarding Research at OSU" by E. Aulerich, Corvallis.

This presentation gave a summary of work done between 1972-78. Initial research was directed at quantifying the problems and cycle times of operating in smallwood (anything less than 50 cm dbh). This developed by attempting to establish the optimum size of yarder and included trials of pre-bundling,with extraction using a larger machine. The use of yarders with short towers introduced research into multispan skyline systems and intermediate supports using specifically the Igland-Jones Trailer Alp. Current thinning research at OSU is investigating the Alp Cat slack pulling carriage for downhill yarding.

"Development of the Pee Wee Yarder" by C. Mann, USFS Seattle.

This paper covered progress through development and testing of the new Pee Wee Yarder prototype. The machine has now been successfully tested and the concept and drum sets are available for industry to manufacture. Current research is looking at the development of a carriage suitable for a running skyline and with intermediate supports.

"Conversion of Cranes to Yarding Cranes" by D. Stone, Milo Equipment Spokane.

This speaker covered a development that is proving popular in Montana and Idaho - the conversion of Link-belt truck cranes to yarders with up to 310 m line capacity. Cost of the conversion is approximately US$120,000 (plus) depending on the condition of the base unit to start with.

"Optimal Allocation of Yarding Equipment" by D. Dykstra, Yale University.

This paper discussed a mathematical computer program developed to assist logging engineers in the layout of cutting units and the allocation of yarding equipment within these units. An area is laid off in a grid pattern. Topography, crop details, and logging

restrictions are combined with known cable logging systems to determine the feasibility and cost of harvesting each parcel of forest or grid. Attempts are then made to assign each grid to landings so that total log value, nett of fixed and variable costs, is maximised. This results in a detailed logging plan which delineates setting boundaries, gives the location of the skyline roads, lists the yarding equipment for each area, and gives a detailed summary of estimated cost. Further development of this research will be looking at optimising cutting patterns for value rather than total logging costs alone.

"Yarding Residues with a Skyline" by M. Consior, USFS Missoula Montana.

Research work that has been carried out to look at different treatments, mainly for an energy harvesting programme, was the basis of this presentation. Also covered was the development of a radio controlled self-propelled carriage, capable of lateral yarding (maximum 93 m), and pre-bunching under a skyline. A prototype has been tested and it is at a stage where it is now over to industry if they wish to develop the idea further.

"Long Reach Skylines Versus Conventional Yarding" by M. Nagy, FERIC Vancouver, B.C.

FERIC have conducted studies in British Columbia to look at long reach skylines (over 300 m) and compare their performance and costs with highlead logging. Data collected from studies of different types of machines was used to formulate a cost comparison of five different yarding systems, including balloon logging. The actual yarding cost for highlead was less than the other systems although the total logging cost, which includes road access, falling, loading, and trucking, was higher in all except the balloon logging.

"Visual Impact Analysis in Log Harvesting Design" by D. Nickerson, USFS Portland.

This paper discussed three different computer programs that have been developed for modelling the appearance of logging activities so that consideration of the scenic resource can be assessed during the planning process. These techniques, when combined with experience, can give planners a definite basis for including the visual impact in the planning of logging activities.

"New Developments in Anchoring Systems" by J. Warner, USFS Portland, and J. Edwards, USFS Equipment Development Centre, San Dimas Califoria.

The USFS has become involved in skyline anchor research because the lack of suitable anchors is preventing

certain areas from being harvested by skyline and in some cases has meant that expensive helicopter logging is the only alternative. Also a recent review in Washington and Oregon showed that 17 yarders had been tipped over in one year.

Four lines of research had been undertaken - skyline tension prediction; development of man-made anchors; the ability to predict anchor failure; and the development of a guyline tension predictor. The research also helped confirm guidelines for the Oregon Safety Code.

Two basic types of man-made anchors had been evaluated - a tipping plate and a picket. (See *Figures 1 & 2* below)

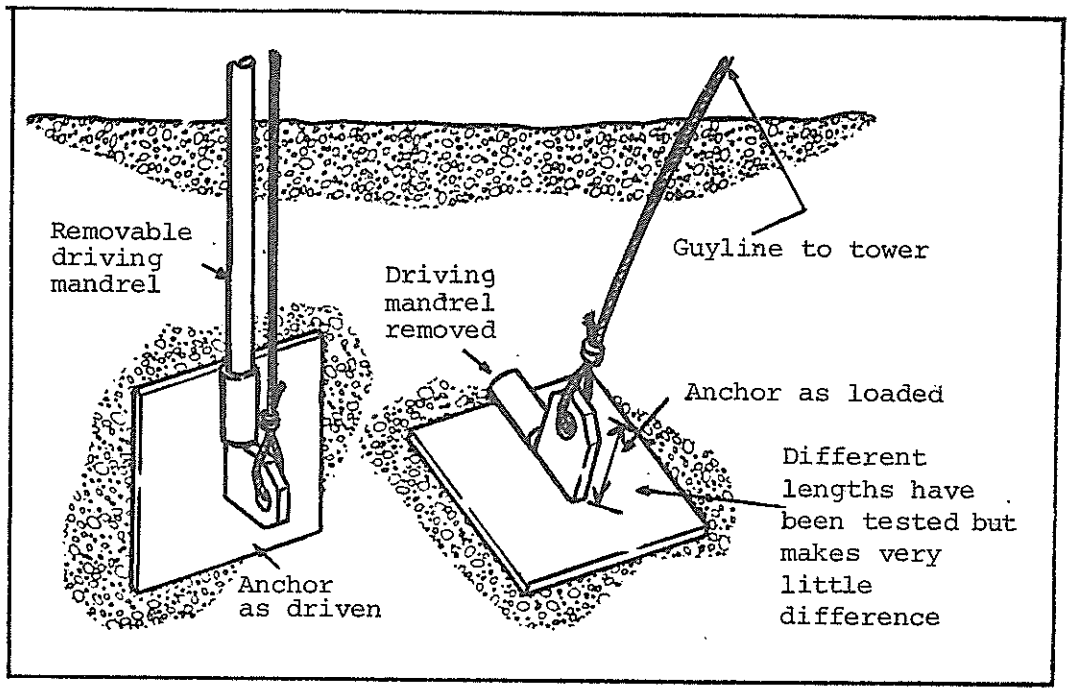

Figure 1. Plate Anchor

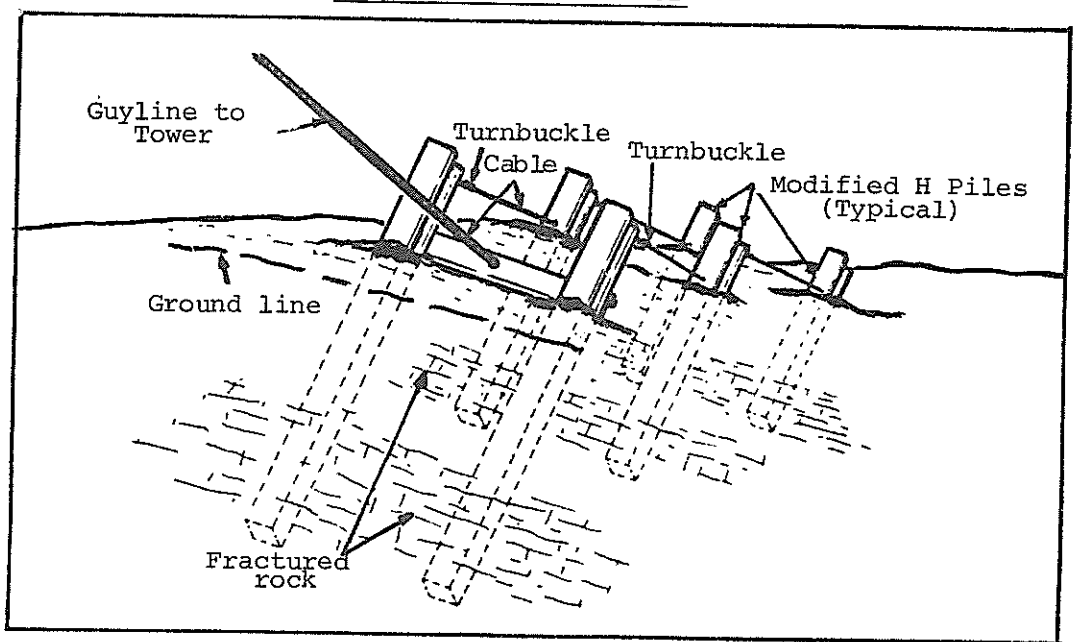

Figure 2. Picket Anchors

The tipping plate anchor is a 300 mm square plate with a lug fitted to it and it is driven into the ground to a depth of 2 - 3 m. When tension is applied, the plate moves into the horizontal position. In all tests, either the rope has broken or the welds have pulled apart before the plate has pulled out of the ground.

Picket anchors have proved most successful in a wide range of soil types. Failure has occurred at approx. 18 tonnes although it is usually only the first of the three pickets that fails. Improved design of the picket anchor is continuing. It is considered that hand setting of a man-made anchor should be possible for smallwood yarding.

The prediction of failure for anchors is being researched using very sensitive tilt gauges originally designed for use in military rocket alignment. The slightest movement in the anchor is indicated to the machine operator and he is able to shut down before anything happens.

Guyline failure or tension can now be monitored by a clip-on device which measures the elongation in the guyline wires. A signal is received by a micro-processor on the hauler and the tension in the guyline is indicated to the machine operator.

"Implications of Dynamic Loading for Skyline Systems" by W. Carson, University of Washington Seattle.

Safety factors are being built into the design of machines mainly because of lack of knowledge. Most research to date has looked at static forces imposed in a system but little is known about affects of dynamic forces. The variables influencing dynamic forces are such things as; the system configuration; yarder and carriages; and anchor systems. Specific influences include wire rope, carriage weight, log weight, span etc. while operational influences are whether logs are free off the ground, one end in contact, ground lead, sudden loads, hang-ups etc. Tests were conducted to determine system loadings, static magnitudes, and dynamic magnitudes and frequencies in the guylines and the skyline. The static data compared favourably with the predictions but the dynamic tensions produced peaks exceeding the yield in the skyline even though the static (mean) load was within safe limits. The tests clearly showed the importance of dynamics of the system and the necessity of dynamic modeling in skyline system design. A series of computer calculations looked at the affects of guylines bending over sheaves and it was concluded by Carson that the 6 x 19 Searle-type rope commonly used in logging is not a suitable rope for guys but a 8 x 21 Warrington rope, which has a high rupture value, should be used.

"Goal Setting: A Motivational Technique that Works" by G. Latham, University of Washington Seattle.

Goal setting theory states that specific goals lead to a higher performance than generalised goals, such as "do your best". Hard goals, if accepted, lead to higher performance than easy goals. Praise, feedback, competition, money, and participation, have no impact on a persons' behaviour unless they are used to set specific goals. Latham's paper developed this theory of goal setting and discusses the extensive research that has been undertaken in several different localities in the U.S.A., with logging workers.

The key factors for increased productivity are worker selection, performance appraisal, and finally, training and improvement of skills. Prior to employing a worker, do a job analysis so it is known exactly what the job is. After selection, focus on a worker's behaviour, not on results or performance. Performance is usually defined by cost related factors such as attendance, whereas behaviour looks at why things are being done and how they can be improved. Many training programmes do not meet their objectives because, on completion of the course, there is no follow up to see if what has been taught is being implemented. With goal setting and motivation, praise and credit should always be given to individuals for improved performance.

"System Flexibility and Yarding Delays in a B.C. Skyline Operation" by P. Cottell, University of British Columbia.

Intensive studies of a skyline operation over a 3 month period were conducted by UBC researchers. As well gross data gathered over a 12 month period was used to assess the distribution of productive time and delay time, nature and causes of the delays and output, so that future predictions can be made with some certainty. Logging systems used during the study included; slackline with simple carriage; radio controlled carriage; highlead scab skyline; and gravity return. Overall machine availability was 97% and machine utilisation 77%. The studies showed that by changing from one system to another, the best results were achieved. The key for achieving flexibility is that the equipment has built-in adapatability, and the supervisors and crew have the know-how and willingness to adjust methods to varying situations. Delay times indicated no significant increase in the proportion of time spent changing yarding roads or in other delay categories with the longer distance yarding systems.

The final panel session of the symposium involved several operators discussing features and problems pertaining to their logging operations.

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RESEARCH ORGANISATIONS VISITED

2.1 FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA (FERIC)

A two-day visit was made to the organisation's Western Division in Vancouver B.C., and discussions held with Mr R. Breadon, the Research Director, and several of the research staff available at the time. As well as discussing specific projects, research procedures and techniques for setting up research were also covered. A summary of the FERIC discussions is given:

2.1.1 Research Procedures

FERIC attempt to set up co-operative research funding with other participating companies. By doing this they are able to control the research better and are not hindered so much with operational delays. When conducting studies on machines, long term gross data is collected using Servis recorders and daily recording back-up with the co-operation of the operators. A relatively short stop watch study is then required to gather cycle times and more detailed information.

2.1.2 Projects Discussed

Steep country logging with small tractors: This was a co-operative investigation with Crestbrook Industries and although the study was completed, it had not been written up at the time of my visit. The project involved looking into the suitability of small John Deere 550 crawler tractors operating off slopes in excess of 30° in a clear cut area. Minimal impact tracking is required. Crestbrook have considered this logging method acceptable and now have 15 of these units operating in the Kootenay area. Production ranges from 28 m^3 to 42 m^3 per shift.

Transportation: FERIC's recent log transport research has been looking at alternative trailer design and the affects on truck traction, safety, and road surfacing. A preliminary survey showed that many trailers were being underloaded by 15%. Bunk scales can overcome this and are now at a reliable stage of development. Contract truckers in the interior of B.C. are using the bunk scales widely.

A major research project FERIC is doing with Crown Zellerbach involves a comparative study of two similar areas. One area is to be planned, laid out, and logged in the conventional manner using current road and

landing layouts, logging methods, and wood handling. This will be compared with the other area where only roads will be established. Whole tree logging will be carried out with no delimbing or cutting to length. Trees will be loaded without landings and carted off-highway to a reload yard where they will be delimbed, cut to length, and reloaded for highway transport to the mill.

A further transport study FERIC are doing involves a study on the affects of truck travel time, maintenance, and productivity before and after a given section of road is upgraded.

Tree breakage: FERIC have been conducting research into ways of reducing breakage in felling very large valuable cedar. Preliminary studies show that 22% of wood was being lost during felling as most of the cedar trees were hollow and shattered easily on impact with the ground. Trees felled uphill attained only 25% of the falling speed of trees felled downhill.

Several experiments were tried including placing 50 mm wide steel bands at breast height around the trees to reduce shatter. Hydraulic directional felling jacks used were limited to cedar trees of about 90 cm D.B.H. because of slabbing and excessive weight. Line pulling methods using an old yarder proved the most satisfactory although the size of the trees and the height to the first limb, made attaching the cable around the tree difficult. This was overcome by the use of an out-of-water harpoon gun (for shooting sharks) with a normal range of 90 m, used to shoot a light nylon line up the tree at about 18 m height. This line is used to pull a 10 mm polypropelene rope which in turn is used to pull a 13 mm rope that is attached through two eyes to a 16 mm main line. Using the steel band and line,pulling uphill has reduced breakage to about 6%. The cost of the harpoon gun is about Can$525.

FERIC found that climbing to attach the line was possible and was quicker, although in heavily branched spruce, where each branch had to be removed to allow climbing, the harpoon gun also proved successful.

FMC Skidders: Two studies involving the FMC have been completed recently. The first was a long term study where gross data on eight different machines was gathered, these being three FMC bunk grapple machines and five FMC choker arch machines. The other study was a comparison between the FMC 210CA and the Bombardier B-15 choker arch. In the first study the eight machines were working in a wide variety of situations and the study coincided with the time the FMC machines were upgraded from the 200 series to the 210 series. Machine availability before the change ranged between 75-85% and after modification, 82-95%. The study indicated that track costs are a major cost

item, being between 13 - 15% of the hourly machine cost, although down time because of track modification was reduced from 26% of total repair time to only 6% of total repair time. The study concluded that the FMC skidder will allow the range of ground skidding to be extended to steeper slopes and still meet production and environmental requirements. However, the cost of purchase and operating these machines is high and they should not be used where less expensive machines give satifactory performance.

The Bombardier B-15 and FMC 210CA comparison was conducted to see if the B-15 was comparable in performance to the FMC. The FMC, although economically viable in the U.S.A., operates under much less favourable financial conditions in Canada, due to a 12% import tax on the machine and spare parts. The B-15 is fairly comparable to the FMC although it was developed for eastern Canadian conditions and had very wide low ground pressure tracks that did not prove suitable in the Pacific North West conditions. The FMC out-produced the Bombardier in all conditions, but because of the duration of the trial it was not possible to get meaningful availability figures.

Cable Yarder Studies: Two recent studies on yarders have been completed. These were a machine developed by Crestbrook Industries called a Critical Site Logger (CSL) and a Washington 118. The CSL is a truck-mounted American loader converted to a 3 drum skyline and usually operates on a gravity return system with a Christy carriage. Although the study had not been written up at the time of my visit, it was intimated that the machine operated extremely well with production ranging from 150 to 300 logs per day.

A study on the Washington 118 yarding crane was carried out on the Olympic peninsular. The study had a lapse time of 2 years and gross data was collected throughout this period using company records. The study concluded that the Washington 118 is capable of high speed performance over long yarding distances (i.e. approx. twice that of most highlead machines) and its higher capital cost, approx. US$500,000 was justified by higher production rates.

2.1.3 Research for the Future

FERIC are co-operating in the development of the Cyclo-crane, which is an airship with four short wing stubs and propellors. This is not the same as a development in the U.S. known as the Helistat. The Cyclo crane is being developed with the Canadian Navy and a private company known an Aero Cranes, of Canada. The prototype will probably have a 2 tonne payload capacity with the working machine expected to have a 16 tonne working payload. The cost of this unit is anticipated to be a lot less than the Helistat.

2.2 U.S. FOREST SERVICE PACIFIC NORTH WEST FOREST AND RANGE EXPERIMENTAL STATION

One day was spent with this research group based in Seattle. Project leader is Mr Hilton Lysons. During this visit I familiarised myself with the research being done by this group and discussed the Pee Wee Yarder development. Unfortunately the prototype of the Pee Wee was not operating at the time of my visit, however I was able to see a model of the concept and films of the trials.

Computer program design using a Hewlett Packard 9830 computer is a major part of this group's work. Programs are written and tested for use in other U.S.Forest Service situations. The computer facilities offer many different logging or planning options to be tested, to ascertain the most cost effective method.

The Pee Wee Yarder research concept is now near completion and the concept is available to industry to develop further. Development using the hydraulic powered drum set is open to manufacturers in the U.S.A. and Lantec Industries have the foreign patents. Already four different machines have evolved based on the Pee Wee. The Pee Wee Yarder concept overcomes the need for large horsepower and there is no difference in the power requirements if the lines are tensioned to 3% or 13% deflection. For further comment on the Pee Wee Yarder, see Part II, page 33.

A carriage has been designed at this research station for use on a running skyline with intermediate supports. A prototype of this carriage is currently being built at the University of Washington's engineering workshop. The intermediate support system uses a sheave thus allowing the skyline to run and the slack pulling carriage has two sets of walking-beam runners which enable the carriage to cross the support. (See *Figure 3 below)*

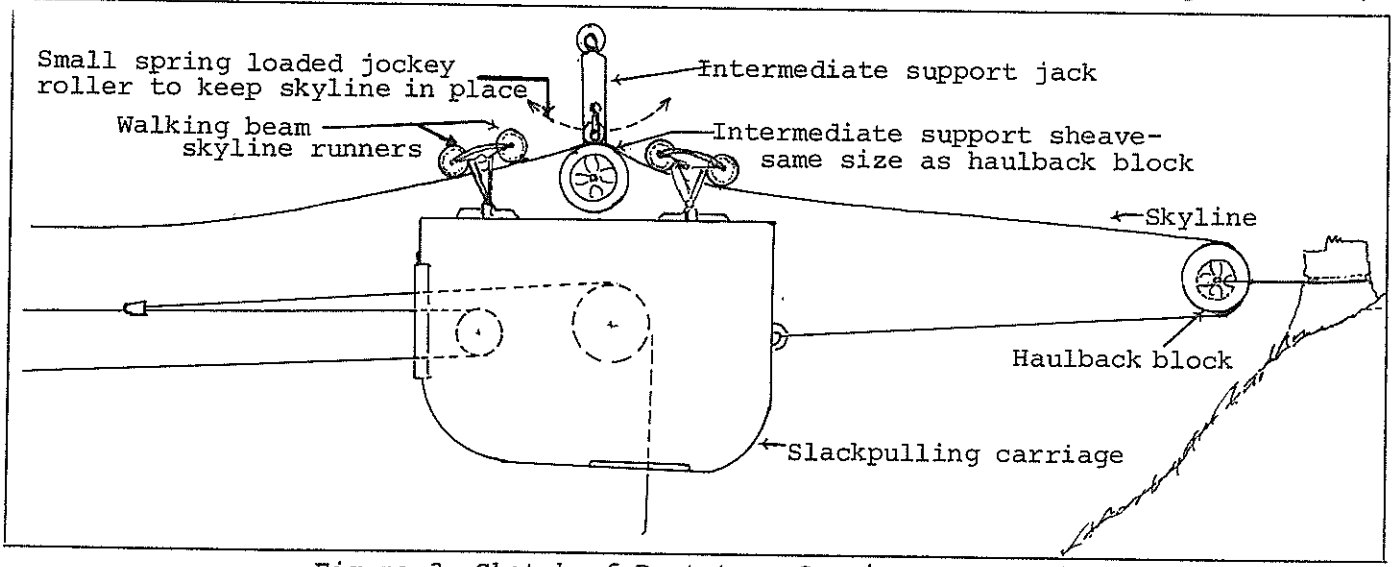

Figure 3. Sketch of Prototype Carriage on Running Skyline

- 3 -

LOGGING COMPANIES VISITED

3.1 GREATER VANCOUVER REGIONAL DISTRICT WATER BOARD

The Water Board of this organisation controls three major catchments totalling around 58,000 ha on the outskirts of Vancouver,B.C. Operations Forester A.Millen showed and discussed their operations to me. About one third of the area is under forest management, the remainder under watershed management. The total annual clear-felling in the catchments is 120 ha although each logging setting is restricted to 16 ha. Very strict security by the Water Board ensures that the public are kept out of the catchment. Those authorised to enter the catchments must be given clearances by security guards and are advised of health and hygiene regulations. Three cable logging operations were being carried out during my visit. These were; a Swiss crew operating a Wyssen W200; a contractor who operated a 'Stiff legger' double drum winch (see Section 2 Page 40 for discussion on this machine); and a Tyee with 28 metre spar.

3.2 MACMILLAN BLOEDEL - NANAIMO VANCOUVER ISLAND

Met with John Marlow, Woodlands Manager, and Bill Carter, Regional Engineer.

This company currently have 1.4 million ha of Forest Service land plus about 200,000 ha of their own forest under tree farm management. The company do not do much merchandising or value sorting of logs as most of their mills are old and scattered. Most B.C. logging companies including M.B., operate under a multiple referal planning system. All logging and roading plans must go through a series of referals, such as the B.C. Forest Service, Fisheries and Wildlife agencies, and others that think they may have an input. Often the Government agencies are not willing to make a decision and it is difficult at times for private companies to get two different Government Departments to agree.

MacMillan Bloedel's major push, over the last year, has been the installation and setting up of a computer system for a forest management model.

3.2.1 Forest Management Model: This is a complete planning model of all M.B.'s operations. The Head Office have very advanced computer facilities and analyse their

forest inventory and terrain. This information is then sent to the seventeen divisions who then dictate the inputs of machines, systems, and roading etc. The mapping and terrain section of the model has computer facilities to work on 64 layers. This is similar to an overlay system, but where the various alternatives can be analysed. One shortcoming in this aspect is the quality of the mapping and inventory data. They stated that their computer facilities are well in advance of their field data collecting facilities and so the latter will have to be improved.

Once the terrain and crop are analysed, the next step is for 20 year plans to be laid out. The localities of cuts for the 20 years are marked off by the divisional people and the volume and species for each area worked out. Inventory data, grade and special reports for each area are also calculated . Conversion tables for the types of timber cut or grades, predict the cuts in each area. Pricing information for the various grades give total gross value for each area. The input from the field engineers for each area or total watershed , give logging costs to the dump. They then can work out what percentage of this cost is for each area within a water shed. Within MacMillan Bloedel's operations, there are 6,000 - 7,000 of these areas in the 20 year plans. Special requirements are allowed for summer or winter logging and extra costs added in for the winter. The forest engineers are asked when they want to road into each area and when they would do it if they had the resources. Maintenance costs on the roads can be calculated. Royalty and stumpage costs on each area are also calculated, and spur road costs and mileages are given. Roading costs for each area are calculated over the total road rather than the road into that specific area. This then puts all areas on an even footing. The plan therefore optimises value for the areas and the roading. Production levels for each area are given.

This model has not only allowed McMillan Bloedel to optimise its cuttings from all its various divisions, but can show the value of any one cutting area within the 20 years. This has proved very useful in debate with the conservation type groups.

Two logging divisions of MacMillan Bloedel South of Nanaimo were visited:

3.2.2 Shawnigan Division - Divisional Manager J. Seaton, Logging Officer M. Pickard.
Yarding equipment within this division included two American grapple yarding cranes and a new Madill 044 grapple crane. The older American machines were being used on double shifts but it was hoped that replacement with new Madills would eliminate this need. Machine

operators worked 2 weeks on day shift and one week on night shift. They received $0.18 an hour extra on night shift but did not like this work. Planning is organised for night logging so that the lights of the machine are always shining onto a slope .A spotter is used but only directs the machine operator if he cannot see from the yarding crane. A mobile tail spar is used. Maximum yarding distance is about 90 metres although at the time of my visit, the maximum was only half this. Loop roads are planned so logs can be loaded out at all times. Loading out is done with a Chapman 1800 hydraulic loader and a Ruston Bucyrus 64 HL. The latter machine was being used to 'cherry pick' logs from beside the road and load directly onto trucks. By doing this, the on-truck cost was US$0.90/$m^3$ instead of US$3.20/$m^3$, if handled by the yarder. All operations were yarder controlled and the loaders had no trouble in keeping up.

3.2.3 Chemainus Division - Logging Officer Don Johnson. This division, some 42 km south of Nanaimo, includes part of the Nanaimo Water Catchment area. Logging commenced here in 1942 and about 20 years of old crop logging remains. The annual cut is 532,000 m^3 although this has been exceeded by up to 70,000 m^3 over recent years. The division operates 5 American grapple yarding cranes which produce 202 m^3 per day over a long term including moves, a Madill 071 which has produced 186 m^3 per day over a long term, a Madill 046 slackline which has produced 190 m^3 per day, and 3 Madill 009 highlead machines which have ranged from lows of 84 m^3 per day to highs of 504 m^3 per day.

3.3 WEYERHAEUSER COMPANY

Visits were made to two of this company's divisions, Twin Harbours Division at Cosmopolis Washington, and the Springfield Division at Springfield Oregon. The objective of visiting these areas was to look at the research being conducted by the Raw Materials Research and Development Section of Weyerhaeuser, who are investigating smallwood clearfelling at Twin Harbours and smallwood thinning at Springfield.

3.3.1 Twin Harbours Division - Contact W.J. Bramwell This Weyerhaeuser division have an annual cut of between 2,800 and 3,200 hectares of which about 60% (by volume) is done by their own company and 40% by contract. The research that has been conducted is looking at the affects on costs and productivity of a change in an average piece size from 1.4 m^3 to 0.85 m^3.

Nordfor, the Swedish Training Organisation, has been training fallers in this area, however many of the older experienced fallers would not adapt to the changed methods. The total cost between conventional felling,

cutting to length, and extraction, was similar to the Nordfor method although the latter felling method was slower. Advantages were gained in having better bunched logs which increased the haul volume and allowed easier choking and breaking-out. The Nordfor instructors experimented with the Nordfor felling bag and wedges, however the wedges were more successful in the taller trees. The normal felling practice in the area is to use wedges and cross-slope fell with first priority to prevent breakage and increase log volume, and second priority to aid in extraction. A range of different logging operations were seen in this division, including the FMC 210CA skidder, Madill 046 slackline yarder, Skagit 555 grapple yarder, Washington 118 yarding crane, Skagit GT3, and Skagit 739 yarder.

3.3.2 Springfield Division - Contact D.C. Hemphill

This division is scattered over a wide area and has an annual cut of some 2.2 million m^3. About 80% of the cut is in Douglas fir with 20% in Hemlock and other species. The thinning research programme was started as the company have a stated intention of intensive management with the objective of thinning every five years starting at age 20. In the past thinning was in 40 - 70 year old stands and larger tree sizes. The thinning research commenced in stands with tree sizes averaging 0.15 m^3, but are currently in stands of about 0.40 m^3. The Nordfor Training Organisation of Sweden had spent some time in this division and their technique is explained more fully in this report under Nordfor Felling Techniques, Part II Page 31.

The first trial included pre-bunching with a small radio controlled winch and extraction with a 104 kW Ecologger yarder using a Maki carriage and gravity return. The Ecologger was considered too small and in a later trial a 239 kW 5 drum Thunderbird yarder was used. Although data from these studies was not available, it was considered by Hemphill that a machine in the 149 kW class may be the most suitable for their situation.

A range of different logging equipment was seen operating in this division, including a Madill 046 with Skookum carriage, Skagit 739 with Berger tower, Madill 046 flying chokers and tongs, and a D8 tractor with a grapple arch.

Also visited was a small log computerised sawmill at Cottage Grove, Oregon.

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OREGON LOGGING CONFERENCE AND MACHINERY EXPOSITION

The Annual Logging Conference was held in Eugene, Oregon from 20-24 February, 1979. Two days were spent visiting the conference and machine show, which is one of the largest in the Pacific North West region. Some $US47 million of logging and related equipment was on display. Many useful discussions and contacts were made with equipment suppliers during the two days at the show.

The 1979 conference theme was on the affects that political and environmental pressure was having on the Oregon logging industry. The titles of papers by some of the major speakers at the conference reflected this e.g. "Logging Industry's Contribution - Why Don't They Believe Us?" , "The Public View Point", "The Loggers' Point of View", "The Structure of the Industry", "Wilderness or Wood", "It's Later Than You Think", "Ways Out of the Wilderness".

The main impression gained, (regarding relevance to New Zealand) from listening to some of the conference speakers, was that as external pressure is brought to bear on the logging and forest industry in New Zealand, be it by political or by environmental sections, the industry as a whole must be united in its defence of its actions or the restrictions that might be imposed. Also, the industry must have good data to support its arguments.

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OTHER VISITS

5.1 MALASPINA COLLEGE, NANAIMO - LOGGING TRAINING PROGRAMME

A visit was made to this community college and discussions had with Mr. J.P. Wapple, Dean of Instruction and Director of the Logging Training Programme.

The Logging Training Course was initiated by the Council of Forest Industries of B.C. and their Education Committee act as the Logging Course Advisory Committee.

The course is directed at basic logging or chokerman level for coastal B.C. logging conditions. It is two weeks long with an intake of 7 participants each Monday. Therefore 14 trainees are undertaking the course each fortnight.

The first day is an introduction to logging, appreciating ones'equipment, and learning the signals. Day 2 is spent on safety and first aid. Two further days of theory are given before the trainees are taken to the forest where a 18 m steel spar hauler is set up and the cadets undergo a training with a more or less static machine. Four days of the second week are in a production environment with the school's own two 28 m steel spar haulers. Recently the above mentioned council donated a steel spar which had been surplus to MacMillan Blodell's operations, at a cost of $US40,000. Skidders and crawler tractors are also in the production areas for safety training. Friday of the second week is kept for an examination.

Tuition fees for the two weeks is $7.50 plus living expenses. Canadian Manpower, (equivalent to the Labour Department in N.Z.) buy half the space in the course and the remainder usually comes from industry. The main emphasis on this course is safety and the results of the training and the course participants are generally well received by the industry.

A more extensive 6 week course was offered previously where chainsaw maintenance and use, rope splicing etc., were taught. This longer course was not so well received and was replaced by the 2 week long programme.

Prince George College offers a training programme for B.C. Interior logging.

Wapple stated that he would like to extend this basic course into other aspects of the forest industries. He is also in favour of certification and retraining,

especially with fallers and buckers. Crown Zellerbach Company are also pushing this point as their Logging Manager, Frank Lucy, estimates there is some 30% lost in log value through poor cutting selection.

5.2 S. MADILL LTD. - MANUFACTURING EQUIPMENT COMPANY

This Nanaimo based firm was visited and discussions had about their range of yarders manufactured.

S. Madill Ltd. first started manufacturing mining equipment in the early 1900's. They then got into producing spars and boom boats before getting into winch units. Their current factory was established in 1965, and employs some 200 people. They have a very stable workforce who are well paid, and the workshop is very modern with most components manufactured locally. Generally they build to order.

The model 071 is the biggest seller in the United States and the model 009 is the main seller in British Columbia. Yarding cranes (model 044) are increasing in popularity. Sales Manager, Burt Holbrook, stated that as far as Madill are concerned, horsepower is still cheaper than interlock, therefore their model 044 yarding crane can compete with the Washington 118 or 108 interlock yarders.

Madill are now producing a loader which has the hydraulic swing and gear drive out of a Cat 245 swing loader. They are also B.C. agents for Northwest loading cranes, and mount Northwest upper structures on Madill carriers.

They have no other new developments at this stage.

December 1978 Prices (Canadian Dollars ex Yard)

Track 009	$194,519	
Rubber 009	222,039	
Rubber 044	419,265	
Track 044	430,097	(Higher cost because of drive train to tracks)
Track 071	143,550	
Rubber 071	181,500	
Rubber 046	351,398	
Track 046	325,580	
Note 052 no longer made		
Northwest - Madill Loader	298,000	Plus 10%
Madill Loader	270,000	(Currently under test)

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FOREST ENGINEERING INSTITUTE (F.E.I.)

The F.E.I. is a U.S. Forest Service promoted ten week long extension course which is contracted to Oregon State University to run. The F.E.I. programmes commenced in 1973, when it was realised that in some U.S. Forest Service regions, re-works because of error or lack of knowledge, were taking up 30% of peoples' time.

The basic objective of F.E.I. was stated as the improvement of knowledge, (not to make a forest engineer). To this end the course objective was adequately met, as it was an intensive and well received ten week learning programme. The Course Director was Professor John O'Leary, and the Course Co-ordinator, Donald Studier. This F.E.I., the twelfth held, was attended by 50 people, the majority being U.S. Forest Service foresters and engineers, but also some from other U.S. Government agencies, and some from private industry. The F.E.I. is primarily designed around the requirements of the U.S. Forest Service planning and forest appraisal system, however, it also covered many of the latest logging research findings, particularly work being undertaken at Oregon State University.

6.1 COURSE PROGRAMME

F.E.I. time was allocated to six different subjects:

1. Logging Systems - 44% of lecture time.
2. Engineering Economics - 10.5% of lecture time.
3. Watershed Management - 14% of lecture time.
4. Forest Engineering - 7% of lecture time.
5. Operation Research Techniques - 14% of lecture time.
6. Photogrametry - 10.5% of lecture time.

Also five full day field trips were organised during the ten weeks, which included 2 days at the Oregon Logging Conference.

6.2 DETAILS OF INDIVIDUAL SUBJECTS

6.2.1. Logging Systems

This programme was the most comprehensive of the various subjects taught, and although primarily concentrated on aspects of cable logging, also covered ground based skidding methods and equipment, and aerial logging methods using balloons and helicopters.

Some of the aspects covered were:

All rigging, including lines, blocks, and carriages. Detailed studies of single and multiple span skyline mechanics and payload analysis, using techniques such as the chain and board, graphical methods, programmable calculators and desk top computers. Calculations to determine anchoring methods and analysis of guy lines for towers, tail trees or lift trees were also covered in depth. The latest logging systems planning using analytical techniques with programmable handheld calculators and desk top computers accounted for a large part of this subject. Special attention was given to the selection of the best system for the job and the evaluation of harvesting system impact on aesthetics.

6.2.2 Engineering Economics

The primary objectives of this subject were to give information and techniques to determine costs and production rates for the various logging systems. Also, to provide techniques whereby the cost of alternative logging plans could be compared, particularly trade-offs between road spacing and harvesting systems.

Topics on machine owning and operating costs including depreciation, maintenance, average annual investment, etc., were covered. Production rates,regression, inflation, effective operating time, and appraisals lead into various break-even analysis and road-spacing decision models. The final aspect was in fiscal management with discounting cost benefit ratios, etc.

6.2.3 Watershed Management

This course, lectured by Professor Henry Froehlich, covered soil and water topics and the affects on them by log harvesting. Soil details covered were on the physical property and the influence of logging on soil fertility. Soil compaction and disturbance by various logging methods and the affects of erosion and erosion control on roadways, made up half of this programme.

Water topics included cross-drain spacing on roadways, logging affects on water yeild and peak flows, culvert design, and stream temperature changes due to logging. Also covered was buffer strip design for stream protection and stream clean up requirements.

6.2.4 Forest Engineering

This series of lectures covered aspects of transportation planning with long term planning requirements for log trucking and alternative route analysis. Road reconaisance, location, survey, and design were discussed, along with roading costs. The surveying law requirements covered were primarily related to the States of Oregon and Washington. Calculations for assessing the gradeability

and traction of trucks with different power and drive-train configurations, were also covered in some depth. Off-highway transportation was also discussed.

6.2.5 Operations Research Techniques

This series of lectures commenced with a review of yarding cycle times and the variables which influence it. Considerable time was spent on statistical calculations including sample size determination and sampling techniques. This lead into simple multiple and linear regression calculations.

6.2.6 Aerial Photography

This course covered the geometry of vertical aerial photography, including calculations of vertical and horizontal scale, horizontal measurements and displacement The transfer of information from aerial photographs to maps of differing scales was also covered as was the procedures for planning a photo mission. Lectures were given on the means of recognising various types of geology and land forms from aerial photographs, for use in logging planning procedures.

6.3 FIELD TRIPS

Three full day field trips were undertaken to view logging operations, planning requirements, landing size and organisation, various yarding equipment and methods, and other matters relating directly to course lectures. Winter weather conditions limited field visits to the Siuslaw National Forest along the Oregon Coast Range. Inland Oregon operations were mostly inoperable due to snow and ice.

6.3.1 Field Trip 1 - Hebo Area, North West Corvallis, Oregon

Operations visited:
Madill 071 and West Coast carriage.
West Coast yarder with Danebo slack pulling carriage.
Skagit BU737 highlead.
FMC 210CA skidder.

6.3.2 Field Trip 2 - Mapleton Ranger District, West of Corvallis, Oregon

Operations visited
Skookum-Tyee 34 m tower. Shotgun operation with homemade carriage.
Skagit BU98 34 m tower with Young 300 radio controlled clamping carriage.
Skagit BU98 34 m tower. Shotgun carriage with a mainline separating block.
(See sketch overleaf)

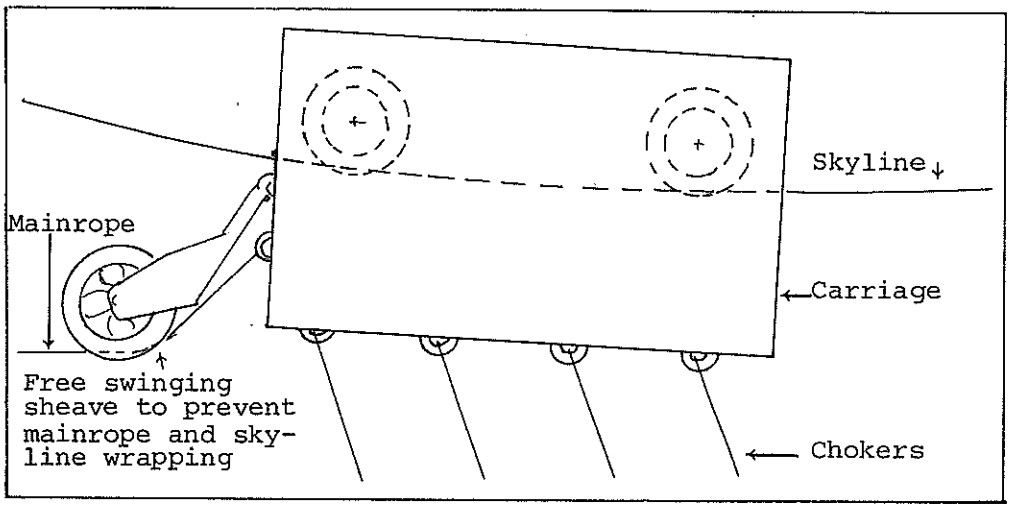

Figure 4. "Shotgun" - Gravity Return Carriage

6.3.3 Field Trip 3 - Alsea Ranger District, South West of Corvallis, Oregon

Operations visited:

Skagit BU80 28 m tower, shotgun system with Danebo carriage.
Skagit BU98 slackline yarder rigged as scab skyline. Also had available a Danebo shotgun carriage.
Berger 34 m tower with Young 300 radio clamp carraige.
A Gem yarder model 5000 (uses Skagit drum sets), thinning Douglas fir with Danebo M20 carriage.
Skagit SJ4RT thinning Douglas fir with a highlead system.

The latter two thinning machines were operating in 100-120 year old Douglas fir. The thinning was only to meet regional directives and very little growth release was expected as a result of the thinning.

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LOGGING RESEARCH, APPLIED TECHNIQUES, AND EQUIPMENT DEVELOPMENTS THAT COULD HAVE FUTURE RELEVANCE IN NEW ZEALAND

7.1 PLANNING TECHNIQUES

7.1.1 Introduction and Background

Approximately one third of the volume sold in the Western U.S.A is logged with some type of skyline system. Skyline logging is increasing in importance in the British Columbian coastal logging operations where highlead logging is more common.

Considerable advances have occurred in the equipment and the requirements for better and more thorough planning over the past few years. This has been mainly because of environmental constraints and the search for greater productivity.

Traditional N.Z. skyline methods, such as the North Bend, are not commonly used in North America, as new yarder and carriage designs have given an increase in flexibility for skylining techniques.

There are several important differences between skyline logging in the U.S. and in N.Z. that must be recognised. In N.Z., tree length logging is carried out, whereas on the Pacific West Coast, trees are cut to length before extraction. Environmental pressure, especially in the public forests of the U.S., has resulted in small clear cutting coups or partial cutting and minimal roading and soil disturbance. The latter results in very small landings and hot logging using rope or hydraulic cranes. Logging in the U.S. is mostly on a stumpage sale basis, therefore a detailed appraisal and planning process must be undertaken prior to an area being put up for sale. The wide range of equipment available allows the planners to choose alternative machines and equipment that will optimise costs and productivity while still meeting the constraints such as visual management, soil disturbances, etc. Often planners in N.Z. are restricted because they must plan to suit the existing equipment available.

7.1.2 Skyline Payload Analysis

The purpose of these calculations is to achieve the maximum safe load for any given system. Skyline systems can be divided into three classes: standing; live; and running. Standing skylines can be further subdivided into single span or multi span. Carriages are also categorised into three classes: clamped; unclamped; and clamped with an active mainline.

Tension, deflection, and the load carrying capability of a skyline can be found by a number of methods, but the fundamentals of all calculations are the geometry of the lines, loads, and corresponding forces imparted in the lines. In a sloping skyline, maximum tension always occurs when the load is at or near mid span, and is recorded at the upper end of the sloping skyline, i.e. at the top of the tower. Generally therefore greater loads can be applied, (may be by increasing the number of chokers) to a skyline when logging in front of the mid span compared to working beyond the mid span. Investigations of skyline analysis show that most operators underload their skylines by some 40%. In all skyline calculations a minimum safety factor of three is applied.

Chain and Board System - This is a simple model for determining unloaded allowable skyline deflection, unloaded tension, and total safe maximum load. The terrain profile of critical skyline roads are plotted on graph paper and with the use of pins, string, a light chain and a small weight. Slope distance, chord slope,deflection, and clearance can be easily measured off. After having determined certain measurements, allowable payloads at critical terrain points can be read off on charts in the Chain and Board Handbook. Estimates of mainline tension, which could be the limiting factor, can also be calculated using the chain and board technique.

Graphical Methods for Skyline Payload Calculations - Simple graphical methods can be used to determine payload after the critical points have been determined by the chain and board. Lines drawn through points representing the head spar, carriage, and tail spar location, are extended and with the use of a convenient scale, points on these lines representing the skyline safe working load are determined. By the extension of lines and the measurement of various line segments, fairly accurate skyline load carrying capacities can be solved.

Programmable Calculators - Programs for determining skyline payloads and mainline tension with small hand held programmable calculators have been developed since 1976 and have eliminated the need for the

previously explained methods. Many other programs are also available for solving skyline design problems. The greatest advantages of these programs is that changes can be readily made in the conditions that influence payload etc.,i.e. by altering yarder location, varying tail spar height, variation in rope or carriage size, recalculations are quickly analysed. Depending on the data input, the location of the critical terrain point or the clearance desired or payload capabilities desired, the maximum load capacity at the critical point can be determined.

7.1.3 Visual Management

Visual management or the design of harvesting areas to reduce the visual impact when observed from major viewing points, is becoming increasingly important in the planning process, especially on public forests.

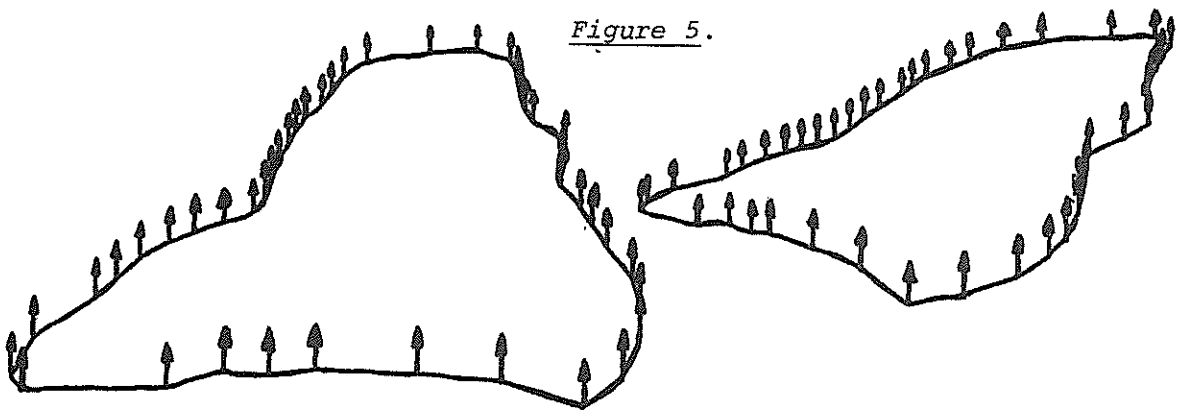
The main concepts in visual management are:

1. Regardless of size, the landscape being viewed has individual character.
2. Visually acceptable variety is desirable.
3. Deviation from the characteristic landscape vary in their degree of contrast and may be manipulated to achieve visually acceptable variety.

Visual management planners work in close liaison with forest engineerers when logging and roading plans are being compiled.

As with other planning techniques, the desk top computer is now used to assist in landscape design. Computer programs have been written which will give a perspective view printout from critical viewing areas of clear and partial cuts. Data input is from topographic maps and known or assumed crop characteristics, such as tree height, crown depth and width, etc. The affects of manipulating cutting area boundaries , or the impact created by time due to the number of entries into one viewing sphere, can be quickly assessed.

Figure 5.



Perspective Plot Depiction of the Harvest Activity Seen From Two Different Viewpoints

7.2 GUYLINE FUNDAMENTALS

The use of guylines in cable logging operations are extremely important, and their improper use can have disastrous effects both through economic losses and human safety.

Considerable guyline research has been undertaken in both the U.S. and Canada in an effort to reduce the number of guyline failures and often accidents, which occur each year. The fundamentals of guyline forces and tensions are based on similar propositions to the skyline payload anaylsis. Horizontal forces exerted on a spar or tower by the skyline, or other running line, must be matched by the guys. The angle in which the guys are set to the direction of pull influence this. The buckling force exerted down the spar must also be considered. Guyline anchor stumps are not always available in the most advantageous positions, therefore it is important to know the affects that different guyline lengths and angles in which they are set, have on the strength of the system. A simple approach for guyline placement is "if it looks bad, it is bad".

7.2.1 Ten Rules for Guyline Placement (for 28 m steel spar)

1. Always have six guylines.
2. Always have at least three in back half.
3. Always have at least two in the front half.
4. If two guys are in the back half, never have them more than 60° apart or less than 20° apart.
5. At least one snap guy in front.
6. At least one side guy on each side.
7. The angle to the horizontal should not exceed 45°,
8. Nowhere should guys be greater than 90°apart.
9. Avoid excessively long guys i.e. twice the length of the short guys.
10. If it looks bad, it is bad.

7.2.2 Guyline Research

The U.S. Forest Service, Weyerhaeuser Company, and the University of Washington have been conducting co-operative research in this area. Computers and other electronic devices have been used in the study of the affect guyline placement has on various component forces, and as a result, guiding rules for loggers have been drawn up.

Field tests have been carried out with measurement load cells fitted in the guyline and dynamic forces measured. This work has been done in conjunction with development of anchors for guylines.

7.2.3 Guyline Anchor Research

This research has been undertaken because there is becoming in the U.S., an increasing number of situations where anchor stumps are no longer available in cutover second growth or on non-forested ridges. There was no information available on the forces that were imposed on anchors, (stumps) during the yarding cycle. Tests were carried out to measure static guyline tension, guyline transfer vibration, impact tests on stumps, sudden load response on guylines and subsequent shock loading, yarding sequence measurements, and yarding sequence with hangups.

A number of different man-made anchors have been developed, and these were tested in different soil types. They include the conventional deadman,and other deadman type anchors such as the concrete pile. Also picket anchors, screw anchors, and plate anchors. The plate anchor has proved very successful in soils without much rock, although it must be driven into the ground by some driving mechanism.

An early warning system to detect anchor failure is also part of this research programme. Very sensitive tilt measuring meters designed for missile navigational systems have been used for detecting stump or anchor movement, but as yet commercial applications have not been developed.

7.3 INTERMEDIATE SUPPORTS (MULTI-SPAN) ANALYSIS AND RESEARCH

The use of multi-span systems commenced in the U.S. in the mid 1950's, but have been used infrequently since then. With the advent of more intensive smallwood thinning using small yarders, and the need for less roading because of economic or environmental reasons, the use of multi-span logging is now more prominent in the minds of planners.

To rig a multi-span system, intermediate supports must be used, and although there are several different ways of rigging these, the most common is hanging the skyline support jack on a cable which is hung between two closely spaced trees.

Multi-span research conducted over the last year or so has been in the development of desk-top computer programs for analysing payload clearance at critical terrain

points and with the shortest line length. The program gives the maximum allowable load that can be carried when the head spar tension is maximised. Also determined is whether the shape of the skyline profile in relationship to the intermediate support is satisfactory so that the carriage and load will pass over the jack. The chain and board analysis can be used to determine deflection in a multi-span system, but it is limited beyond that.

Research on the problems associated with intermediate supports has been more intensive during the past year, as there was a need for regulations governing their use in the State Safety Codes. Experiments have been conducted at Oregon State University to determine the forces and tensions imposed on the intermediate support, support cable, and anchor, and with regard to the buckling forces in support trees. The guiding principle with the support system is to load support trees in compression. As a result of this work recommendations have been made to the Oregon State Safefy Code on the correct rigging procedure, sizes of support trees for various payloads, etc. Other guidelines on the planning procedures of multi-span skyline systems and the use of intermediate supports have been put out.

7.4 SOIL DISTURBANCE AND SOIL COMPACTION

Research by soil scientists and forest engineers has been undertaken in the U.S. over a number of years,and has involved soil related problems caused by different logging systems. Findings are generally that ground based systems, (tractor or skidder) disturb as much as two thirds of an area, although only about one third is deep disturbances. Deep disturbance is taken to mean the exposure of the less fertile sub-soils. A number of different studies have produced varying figures on the difference between tractor or skidder and cable or aerial systems, although the relationships are often similar. Soil disturbance at any given site will depend not only on the logging system, but also on factors such as slope, slope roughness, and the size and volume of the trees being harvested.

Deep soil disturbance may or may not include soil compaction. Compaction has been proven to have an adverse affect on seedlings and tree growth, particularly Douglas fir on the West coast of U.S.A. Pressure and vibration from tractors and skidders is the major cause of soil compaction and it mostly occurs in the top 30 cm of soil. Research has shown that with skidders maximum compaction occurs after five or six passes and the degree of compaction depends on the moisture content of the soil. Dryer summer soils can be compacted

although it takes a little longer. Recovery of compacted soils is often slow, and depends on natural elements such as frost heave. Some soils have not recovered after 40 years. Deep ripping gives some recovery, although if soils are very wet greater compaction could occur with the ripping machine. Typically, 25-30% of a clear felled area is in skid trails and on some intensively thinned stands, compaction by area is as high as 60%. Soil compaction of a skid trail is typically high enough to affect tree growth. The impact on growth is proportional to the degree of soil compaction in the root zone. Research in Douglas fir stands has shown that growth per acre may be about 10% less than if the stand was thinned without soil compaction. The affects on tree growth can be minimised by planned skid trail development.

7.5 DIRECTIONAL FELLING

Directional felling using specially designed tree jacks or by line pulling, is common in many localities on the P.N.W. of U.S. and in Canada. These methods are primarily used to fell trees uphill or into such positions as to reduce breakage.The value of the wood is such, that although felling is more costly,increases in the yield compensate the extra costs.

Research results by the State and Private Forestry Departments in Portland, Oregon, show from a range of different studies, (both species and terrain) that a three to five percent saving in wood volume is available through directional felling. Gains of between four and seventeen percent were achieved in the ability to cut the preferred lengths. Cost analysis results showed that although directional felling costs were higher than free falling, extraction costs were cheaper to the extent of giving directional felled logs a cost advantage at the mill door.

Other advantages of directional felling, such as the protection of an environmentally sensitive area, have application in New Zealand. Some types of hydraulic tree jacks have been tried in this country with varying success. A set of tree jacks and hand pump have been loaned to LIRA by the U.S. manufacturer and these are being currently evaluated.

N.Z. tree and wood characteristics, especially radiata, differ greatly from the U.S. trees, where directional felling is common. Because of these differences, variation in techniques to suit local conditions need to be adopted with these felling aids. With reference to this subject see also a research project undertaken by FERIC on Page 10 Part I of this report.

7.6 SMALLWOOD LOGGING RESEARCH

7.6.1 Research Being Undertaken

Approximately 133,500 ha (about 24% of the commercial forest area) of the Douglas fir region in Washington and Oregon, is aged between 20-70 years and these stands consist mostly of trees under 50 cm dbh .
The old crop Douglas fir stands are rapidly being depleted or locked up by conservationists thus the problem is being compounded.

The most significant smallwood research undertaken in the Pacific North West has been conducted by Oregon State University, especially with the design and use of multi-span systems using intermediate supports. Also current thinning research is being undertaken by the Weyerhaeuser Company at Springfield, Oregon. Reports and graduate student theses are available on the O.S.U. studies. The Weyerhaeuser findings are not available. Weyerhaeuser have commissioned the Swedish Nordfor Training Team to assist them in their research programme and the benefits of this training were seen and are reported on.

7.6.2 Nordfor Felling Techniques

A recent trial being undertaken by Weyerhaeuser in their Springfield Division, Oregon, was in a Douglas fir stand that was reduced from 670 spha to 296-320 spha. Although it was a regenerated stand it was being used to simulate a plantation stand of similar tree size. The 38 year old Douglas fir ranged between 0.3 and 0.5 m^3 but was variable and had a fairly open canopy. Extraction strips were indicated at approximately 45 m, although this depended on the location of a suitable tail tree. Terrain was generally easy and had this not been a trial for yarding extraction, it could have been skidder logged.

Felling Equipment - The Nordfor trained operators used Jonsered 45 and Husqvarna 61 saws with 30 cm and 36 cm Oregon roll-tip cutter bars and standard Oregon chain. The saws were not fitted with felling dogs. Husqvarna saws were preferred by the fallers although Nordfor preferred Jonsered. Helmets incorporated ear muffs and fine gauze lift up visors. Other Nordfor apparatus included pry-bar hook and belt with wedges and loggers' tape.

Felling Techniques - The method of getting the tree on the ground is only a small part of the Nordfor technique. Much of the time is spent in pre-planning the lateral extraction track or trees to be removed to ensure extraction is optimised.

Fallers stand on the righthand side of the tree and lean into the back of the tree with the left shoulder. Considerable care is taken in aiming the top scarf for direction. The horizontal cut is put in second. Often this meant having to put the saw back in the top angle cut to complete the scarf. Although this seemed slow, the two cuts were not overcut. The fallers tended to hold back the saws rather than let them cut through the wood quickly. The back cut was brought through very carefully, with the operator still on the same side of the tree and using the top of the bar. Generally he watched the cut on the far side of the tree by looking around the front of the tree. The fallers do not worry about the top, but can tell whether the tree is starting to move forward or sit back by the pressure on their shoulder. Their lean can also help push the tree over. Watching three cutters all day, I did not see one occasion when the holding wood was cut. On larger trees, the back cut was brought through on one side of the tree only. A plastic wedge or the hook was then inserted in the cut and the faller moved to the opposite side of the tree to complete the cut. Seldom was any driving done and any tree which sat back or hung up, was either pryed, wedged, pushed, or rolled off with the hook. No trimming, topping, or sloven cuts were made.

The planning aspect was most important. The fallers spent a lot of time walking around their immediate falling area to plan a mental picture of which tree would be removed and how they should be felled for maximum haul capacity of each drag. This greatly influenced their falling production and the results of their planning wouldn't be evident until hauling. In this research the cutters are also doing the extraction, so fully understood the requirements. However with these same cutters having productivity of a yarder in mind, it could be argued that the stand was not retaining its best selection of crop trees.

These Nordfor trained operators had very limited falling experience in this crop size or in a thinning operation. They had however been on the job for about 8 or 9 months and their level of expertise and attitude to the job was excellent, as a result of the Nordfor systematical training approach.

7.7 LOGGING EQUIPMENT

Many different types of logging equipment were seen during the tour, either in operation or on display. Mention is made here of only some of the new developments.

7.7.1 Yarders

New yarding equipment comes on the U.S. market at frequent intervals, as each of the major yarding manufacturers attempt to win their share of a very competitive market. New machines are purchased by contractors or companies, not because their existing equipment is worn out, but more because of the taxation benefits that can be accrued by such purchases. There is therefore also very good quality second hand equipment available. Two of the latest yarder developments seen were:

Pee Wee - The initial development and research of this small skidder mounted yarder using 13 mm lines, has now reached the stage where different units have or are being manufactured for operations. The completely hydrostatic drum set concept has proven satisfactory in trials, and further use in development of the drums is open to industry in the U.S. Lantec Industries, who did the initial development, have the foreign patents. To date the Pee Wee has been built in four sizes. Norwegian interests have taken one unit, fitted with 11 mm lines and with increases in line pulls. The Berger Equipment Company have developed a unit called the Berger 25Y with 14 mm lines, and this is mounted on an American 25 swing crane undercarriage (*See Figure 6.*). A further machine was being built with 16 mm lines and mounted on a Cat 235 excavator. The only other unit completed was one manufactured by Traxxon Company, and mounted on a tank track type undercarriage (*See Figure 7.*). A further interesting proposal is the mounting of a Pee Wee unit in the mid section of a Hahn delimber (*See Figure 8.*).

The Pee Wee concept of completely hydraulic interlock to operate a running skyline system is excellent and now proven. Originally it was anticipated that the machine would cost around $100,000 which would be within a range for consideration in New Zealand. However, it would seem that for the U.S. market, development is towards machines larger than the original prototype and based on expensive undercarriages. If this trend continues it would seem that machines using the Pee Wee concept could not be economically justified in this country at present.

Figure 6. Berger 257

Figure 7. Pee Wee by Traxcon

Figure 8. Pee Wee on Hahn Pallet

Skagit SY717 - This is the latest Skagit model and is their answer to the other makes of swing interlock yarders. The machine, which is in the Skagit GT3 size range, has a mechanical interlock system and is designed with very wide drums to compensate changes in the drum speed caused by winding of the main and haul back ropes on or off. Although the Sy717 is called a smallwood yarder,(in comparison to the other Skagit machines) its cost would preclude it from our smallwood operations in New Zealand.

Many different makes and models of yarders were seen in operation or on display during the tour. An indication of the range of machine types and models by the various categories, is listed below. Specifications and details were collected on most of these machines and are available in the LIRA library.

Large Three Drum Slackline Yarders

Edco Wildcat II
Washington 137
Skagit 739
Skagit BU99
Skagit 737
Madill 046
Berger IIIR

Highlead Two Drum

Skagit 737
Washington 127W
Edco Wildcat
Madill 009
Berger IIR

Swing Boom Running Skyline

PSY 200
Washington 118
Washington 78
Skagit GT3
Skagit SY717

Small Slackline or Skidder Yarders

Madill 071
Mustang II
Thunderbird
Ecologger

Also seen were Madill and American grapple yarding cranes.

7.7.2 Carriages

As with yarders, numerous carriages are manufactured for sale or built to an operator's design, by some small engineering shop. It was common to see different types of carriages on logging sites, which would indicate that changes are made in the system to suit the terrain or other conditions being experienced. Home built shotgun or gravity return carriages were common on many of the operations visited. A list of the more commonly used carriages by function, is as follows:

SLACKPULLING

Manual	Mechanical	
	Carriage Controlled	Yarder Controlled
Danebo M-20, M-30	Danedo M-110 Splitter	Danebo S-30 D-L
Maki	Skagit Rcc-15	Danebo MSP
Christy	RMS Skyhawk	Danebo S-30, S-40, S-50
Western Flyer		Young Ironbird HR-300
		Young YCC12, 13
		Mar 30, 36
		Rowley Parker
		West Coast (Madill)

NON-SLACKPULLING (SHOTGUN)

Danebo B1, B2 (Radio Controlled Clamp)

Danedo MINY G, MINY G.2

Young SR75 (Radio Controlled with Hydraulic Clamp)

Specifications are available in the LIRA library on most of the above mentioned carriages.

7.7.3 Low Ground Pressure Logging Machines

These vehicles, such as the FMC and Bombardier, are now relatively common in the U.S.A. and Canada.

The Bombardier, originally developed for use in Eastern Canada's fragile soils and Southern U.S. swamp type country, has a lower ground pressure than the FMC machine. Studies carried out in British Columbia (see notes on FERIC's research, Part I Page 10 of this report) indicate that the track arrangement of the Bombadier does not appear to be suitable on adverse slopes or where there may be rocks or other obstructions. (*See Figure 9*)

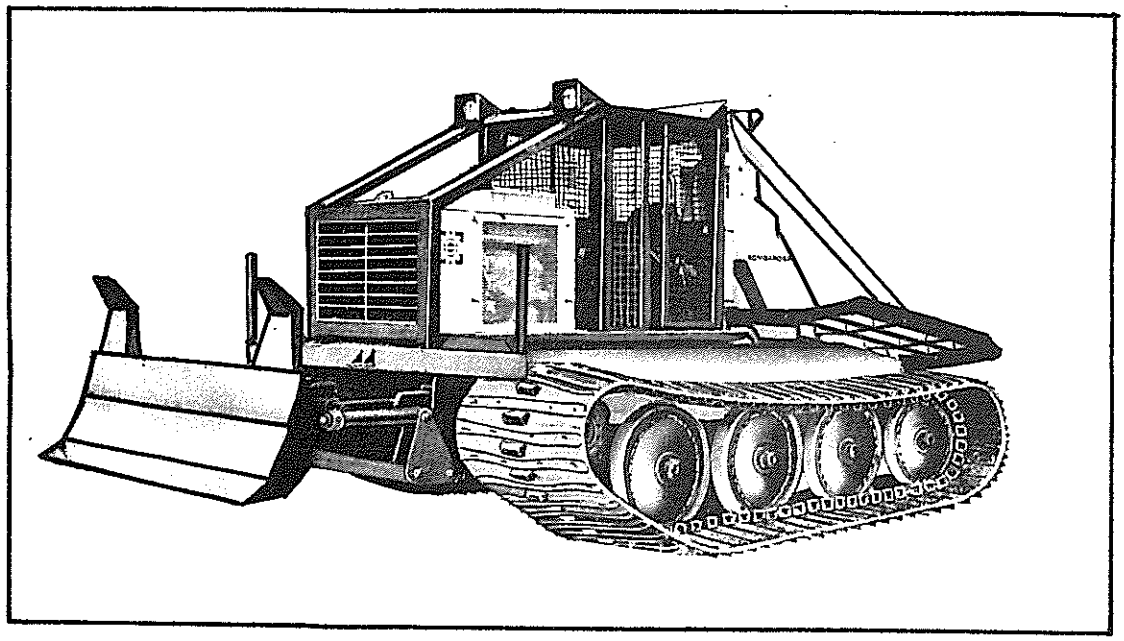


Figure 9. Bombadier B-15

The FMC Model 210 choker arch skidder is now being widely used throughout the Pacific North West in areas previously dominated by crawler tractors in the D7 (149 kW) class. In a number of instances the FMC s were seen working adjacent to yarder operations where they were being used to clean up small areas left by the yarder. Although considerable advancements, (especially with track gear) were made in the FMC 210 model machine over the earlier 200 series, operators informed me that the tracks and the torsion bar suspension are still the major maintenance items. Most of the models seen in operation were the 210 series. These have however been superseded by a new model, the 220.

FMC no longer manufacture a bunk grapple (BG) model, but have included in their range a 210 AG (Arch/Grapple). This unit is fitted with an Esco M45P logging grapple which is attached to the arch. The winch is also available and can be used with or instead of the grapple. *(See Figure 10)*

The FMC Company are currently working on a new model machine which will be in the 75 - 90 kW class. It will be 120 cm shorter in the track frame and narrower in the wheel base than the presently produced 220 series. The company hope that this smaller model, which is expected to cost approximately $US44,000, will be more competitive with smaller wheel skidders. Testing of a prototype will be undertaken for about a year before production models are produced. New low ground pressure vehicles, such as the FMC and Bombardier, have the ability to operate on slopes greater than conventional track laying machines, travel at higher speeds and cause

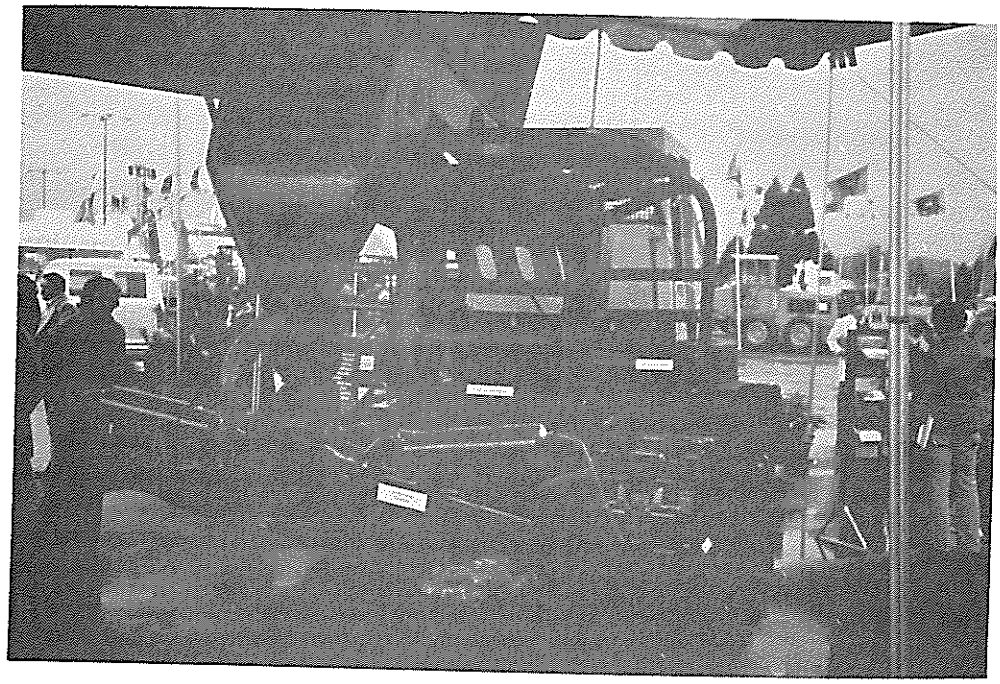


Figure 10. FMC Model 210 Arch Grapple

less soil disturbance. These factors rate highly for their success in certain areas of the Pacific North West. However, studies conducted by FERIC in Canada have shown that because of the FMC's higher initial and operating costs, they should not be used where less expensive machines give satisfactory performance.

7.7.4 Other Equipment

Line Tension Monitors - One of the recognised difficulties in skyline logging is the ability to load the system to achieve maximum haul capacity while still ensuring that the safety limits of the lines are not exceeded. A Seattle based company called Tri Coastal, have developed a strain measuring device which can give the yarder operator an accurate indication of the tensions in the lines.

A tension or instrumented measuring pin replaces the existing sheave pin in the skyline, or mainline sheave, and this measures the tension imposed in the line. The yarder operator has a simple cab mounted indicator gauge which can be easily calibrated and this shows the actual tension expressed in pounds and can therefore tell if increased or decreased volume can be extracted. The tension meter (tensiometer) can be easily installed in any machine at an installed cost of $US3,700. Although this is a relatively new device, it was seen being used on some of the larger slackline yarders visited. In swing yarders, where a sheave pin installation cannot be applied, a line rider is installed which contains the instrumented pin and gives the read out. *(See Figure 11)*

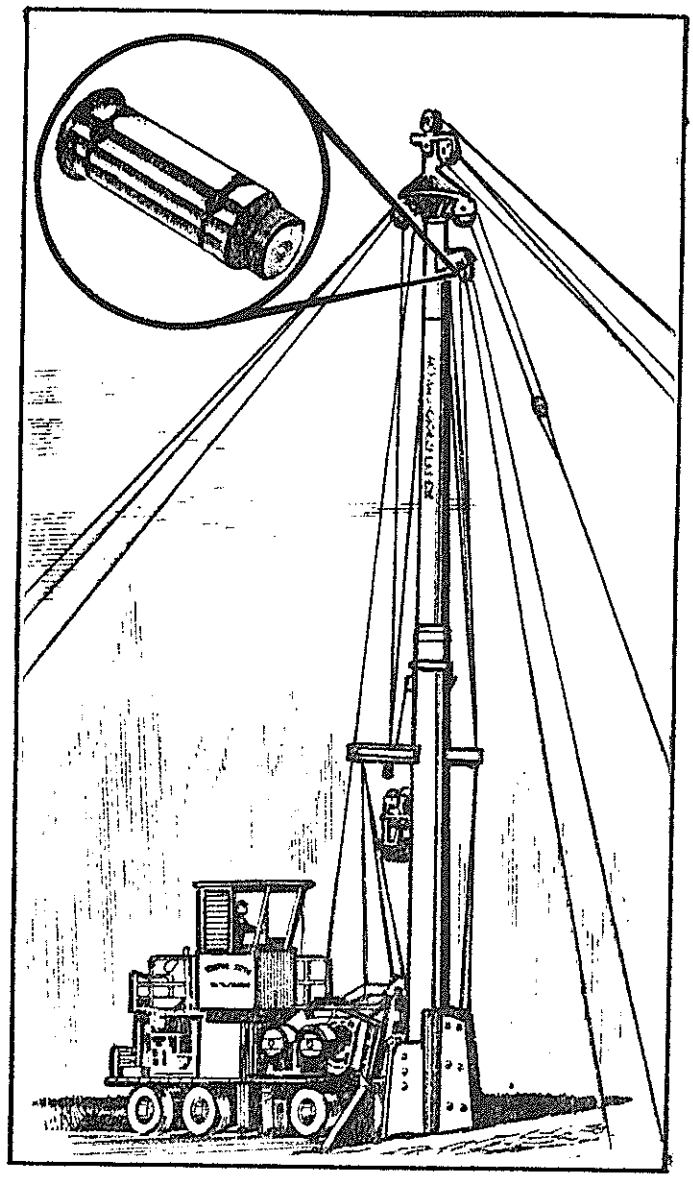


Figure 11 - Tension Monitor

Tree Felling Jacks - A contact was made with the Silvey Precision Chain Grinder Company, manufacturers of the Silvey Tree Saver felling jacks, at the Oregon Logging Conference.

After discussions with members of this firm, they agreed to lend LIRA a set of the 'Little Feller' jacks which consist of two rams each with a 35 tonne capacity lift, plus the handpump. These will be evaluated by LIRA under a range of N.Z. conditions and tree sizes.

LIRA acknowledges this very generous offer by Ray Silvey, President of the Company. Trials are currently being undertaken by LIRA using the felling jacks. (See Figure 12)

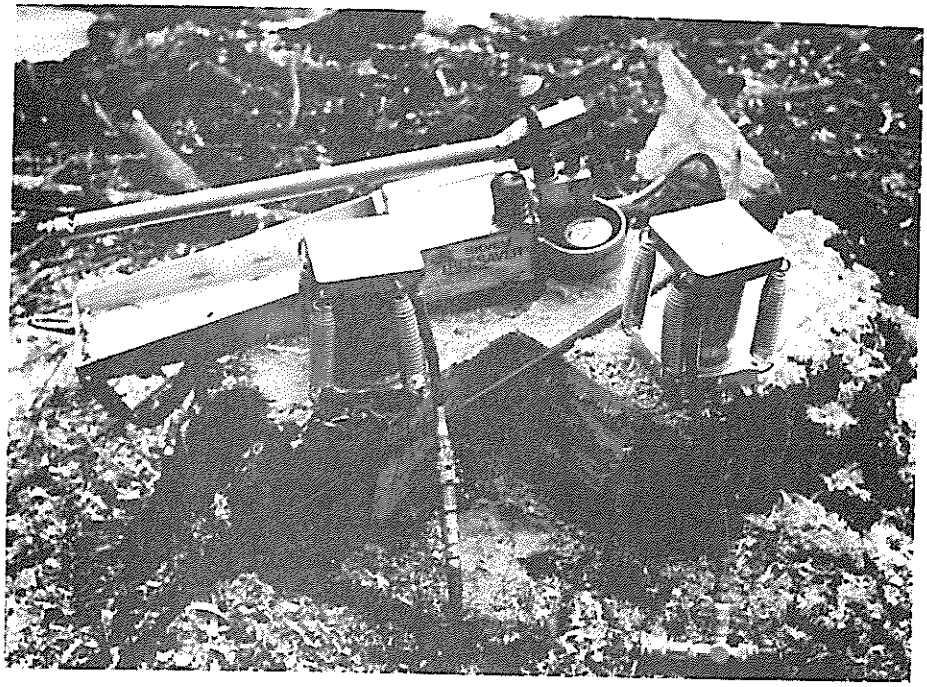
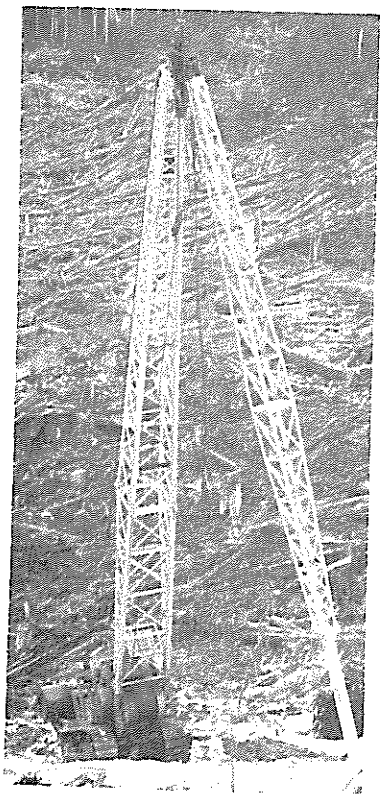


Figure 12 - Felling Jacks

Stifflegger - This new hauler spar concept was built by Rosedale Machine Shop of Rosedale, British Columbia. A 15.2 m aluminium lattice constructed spar is supported by a single aluminium leg. The spar and leg are stabilised by one guyline which must be set at no more than 5 degrees from the opposing lead direction.



The 'stifflegger' seen was mounted on an Allis Chalmers HD21 crawler tractor fitted with a Hyster D98B double drum winch. The biggest advantages of the concept is that setting up and shift times are fast with only one guyline to be set. Should the guyline break, the spar will pivot on the support leg but not fall over. Logs are yarded into the area between the support leg and the winch machine.

Rosedale Machine Shop stated that they are developing an 'A Frame' support leg that will require no guy line at all.

Figure 13 -Stifflegger

- 8 -

GENERAL OBSERVATIONS

Some of the significant future difficulties seen to be facing loggers and managers on the Pacific North West are:

8.1 A Trend to Smallwood Logging

Many companies or general areas will have depleted their old crop Douglas fir stands in about 10-15 years. Changes will be required in the methods, techniques, and equipment to meet this change, although to date there is very little research being undertaken.

8.2 Logging in More Broken and Inaccessible Terrain

Also as the large diameter trees become more scarce, harvesting will occur in areas previously avoided because of their difficulty. Roading costs are going to be extremely high and aerial logging systems such as the balloon and helicopter, will be a viable alternative to cable methods. A limiting factor for helicopters could be fuel usage however.

8.3 Soil Erosion and Soil Compaction

The research that has been conducted to date shows a significant reduction in tree growth where soil has been severely compacted. Cable logging methods will be used on the more fragile soil types even on easy terrain, and low ground pressure skidders will become more significant.

8.4 Multi-use Forests and Aesthetic Design of Logging Areas

In the U.S. the populace are demanding greater access into public forests and also demanding that logging activity does not visually degrade areas from certain vistas. This has meant that landscape architects are having an important input into the logging engineers planning requirements.

APPENDIX I

ITINERARY

December 1978

1	Arrived Portland, Oregon, from New Zealand
2-3	Portland
4-8	Skyline Logging Symposium - Portland
9	Travel Portland - Vancouver B.C.
10	Vancouver B.C.
11-12	Discussions with FERIC research staff Visit Greater Vancouver Regional Water Board logging operations Travel Vancouver - Nanaimo (Vancouver Island) in evening
13	Visit Malaspina College - Logging Training Programme Visit MacMillan Bloedel Company
14	MacMillan Bloedel field operations
15	S. Madill Limited - equipment manufacturers Travel Nanaimo - Victoria
16	Travel Victoria (V.Is) - Port Angles (USA)
17-18	Port Angeles- Discussions with Merrill Ring Logging Company Travel Port Angeles- Seattle
19	Discussions with USFS Pacific N.W. Forest Range Experimental Station personnel Travel Seattle - Cosmopolis (evening)
20	Visited Weyerhaeuser Twin Harbours Division
21	Travel Cosmopolis (Wa) - Springfield (Or) Visited Weyerhaeuser thinning research programme and Weyerhaeuser small log computerised sawmill at Cottage Grove (Or)
22	Visited a range of cable logging operations in Weyerhaeuser Company forests
23-26	Springfield and Eugene, Oregon
27	Weyerhaeuser thinning research programme · Nordfor trained logging gang
28	Visit Bohemia Timber Company - Cottage Grove Or.
29-31	Eugene (Or)

January 1979

1	Travel Eugene - Corvallis to Oregon State University
2-31	Forest Engineering Institute, OSU, Corvallis

February 1979

1-28	Forest Engineering Institute, OSU, Corvallis
22-23 (Also)	Oregon Logging Conference and Equipment Show, Oregon

March 1979

1-9	Forest Engineering Institute Travel Eugene - San Francisco
10-11	San Francisco
12-13	Travel San Francisco - Auckland, N.Z.