

mountain forest roads and harvesting

technical report

of the

**second fao/austria training course
on forest roads and harvesting
in mountainous forests**

ort and ossiach, austria, 3 june - 2 july 1978

**compiled and edited under the supervision of
r. heinrich
forest industries division**

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TECHNICAL REPORT
OF
SECOND FAO/AUSTRIA TRAINING COURSE
ON FOREST ROADS AND HARVESTING IN MOUNTAINOUS FORESTS

Ort and Ossiach, Austria, 3 June - 2 July 1978

Compiled and edited under the supervision of
R. Heinrich
Forest Industries Division

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1978

EDITORIAL NOTE

The papers presented in this report have been edited to the extent considered necessary for the reader's assistance.

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Cover Photo: Loading a truck at a cable crane landing. A log load transported by cable arriving at the landing (Photo T. Pasca).

Please note: Austrian Schillings: A.S. 14 = US\$ 1.00 (September 1978)



Participants in the road location course (Photo R. Heinrich)

ABSTRACT

The Second FAO/Austria Training Course on Forest Roads and Harvesting in Mountainous Forests was held in Ort and Ossiach, Austria, from 3 June to 2 July, 1978. The Course was organized by FAO in cooperation with the Austrian Government, at the Forestry Training Centres at Ort and Ossiach.

Thirty-three forestry officers from the following 20 countries participated in the Training Course:

Afghanistan, Bhutan, Belize, Brazil, Cyprus, Germany (Fed. Rep. of), Greece, Guinea, Guyana, India, Indonesia, Iran, Jamaica, Kenya, Malaysia, Mexico, Nigeria, Poland, Tanzania, Thailand, and one observer from FAO.

Eleven participants were sponsored by Austria, fourteen by FAO, eight through other sources. Participants from institutions such as ministries of agriculture and forestry, public forestry administrations, forestry universities, forest research institutes, forestry schools, as well as public and private forest enterprises, attended the Course.

The main objectives were to train forestry professionals in the technology and economics of forest road construction and forest operations in steep terrain. Particular emphasis was laid on the practical planning, construction and maintenance of forest road networks. Further objectives were the extraction to roadside by cable methods and specialized logging equipment as well as reduction of harmful effects on the soil and stand.

FAO gratefully acknowledges its indebtedness to the Government of Austria for having sponsored this Training Course.

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FOREWORD

1. BACKGROUND

The steady increase in world wood demand and the relinquishment of forest areas to agriculture in flat and hilly terrain in many developing countries because of population increases make the conditions in which forestry operations are to be carried out more and more difficult.

Developing countries in particular are very often confronted with the problem of proper wood harvesting in steep terrain to secure a sustained wood yield, guaranteeing a steady wood supply to industry, and to secure water resources and balanced climatical conditions for the agricultural food crops as well as for urban needs. In steep terrain, very often through improper harvesting methods and forest road construction techniques, severe erosion problems occur; therefore, great attention should be paid and priority given to forest protection and proper forest management. In remote areas, through intensive forest management, forestry may also contribute substantially to improving the employment situation for the local people and contribute to their economic and social development.

Especially in mountainous forests, because of their specific conditions, more work-intensive extraction and wood harvesting systems have to be applied than on easy terrain, offering large employment possibilities. Additional employment opportunities are offered by forest road construction and maintenance, rehabilitation of devastated land, afforestation, tending measures, stream channel and watershed protection measures.

Based on the recommendations of the first session of the Committee on Forestry (COFO) which underlined the importance of training related to logging and transport, the Government of Austria generously supported the FAO logging training activities by financing and hosting the first FAO/Austria Training Course on Forest Roads and Harvesting in Mountainous Forests in June 1975 in Ossiach, Austria.

In connection with the first training course an illustrative technical report was prepared to serve as guidelines for foresters in developing countries on proper road planning and construction as well as harvesting operations in steep terrain.

On the grounds of the positive results of the first training course, the Austrian Government decided to sponsor the Second FAO/Austria Training Course, held in Ort and Ossiach, from 3 June to 2 July 1978. Again, at the Fourth Session of the Committee on Forestry in Rome, the Austrian Delegate assured FAO that the series of training courses in logging techniques and forest road construction will be continued under a joint FAO/Austria programme.

2. ORGANIZATION AND ADMINISTRATION OF THE TRAINING COURSE

The preparatory work and the organization of the course were carried out in close collaboration between the Forest Logging and Transport Branch of FAO, the Ministry of Agriculture and Forestry, Vienna, and the Forestry Training Centres at Ort and Ossiach.

The overall coordination of the training course was the responsibility of Dr. H. Redl, Head of the International Division, and his collaborators. On technical and administrative questions Dr. E. Neuburger, Dr. H. Dürr, Dr. K. Puhane, Mr. D. Hanak-Hammerl and Mr. J. Pernerstorfer gave assistance. For conducting the training course, Mr. O. Frauenholz, Mr. A. Trzesniowski, Austria, and R. Heinrich, FAO, were appointed as course directors. Besides the course directors, 37 lecturers and speakers contributed to the course programme in the form of teaching, demonstrations or commentary at field excursions. Altogether 22 excursions and outdoor demonstrations were provided.

3. PARTICIPANTS

In total 33 participants from the following 20 countries participated in the training course : Afghanistan, Bhutan, Belize, Brazil, Cyprus, Germany (Fed. Rep. of), Greece, Guinea, Guyana, India, Indonesia, Iran, Jamaica, Kenya, Malaysia, Mexico, Nigeria, Poland, Tanzania, Thailand, and one observer from FAO.

Eleven participants were sponsored by Austria, fourteen by FAO, eight through other sources. Participants from institutions such as Ministries of Agriculture and Forestry, public forestry administrations, forest universities, forest research institutes, forestry schools as well as public and private forest enterprises, attended the Course.

4. OBJECTIVES

The main objectives were to train forestry professionals in the technology and economics of forest road construction and forest operations on steep terrain. Particular emphasis was laid on the practical planning, construction and maintenance of forest road networks. Further objectives were the extraction to roadside by cable methods and specialized logging equipment as well as reduction of harmful effects on the soil and stand.

5. RESULTS AND RECOMMENDATIONS

The Course was essentially practical, and classroom work was kept to the minimum. The participants surveyed 1.5 km of a forest road in a mountainous forest area and studied clearing, felling of timber and formation of a road, rock blasting, gravelling, surfacing and other engineering and biological structures. A detailed project of a cable crane was elaborated in the field and various wood harvesting methods demonstrated. Evaluation of the course by the participants showed that:

- (a) Field work and demonstrations as well as excursions and practical exercises were highly appreciated;
- (b) Training in logging and harvesting in mountainous country was important to them;
- (c) Such courses should be held regularly;
- (d) The two Training Centres were ideal in that they are well equipped and have suitable instruction areas in the vicinity.

6. Mr A. Leslie, Director of the Forest Industries Division, FAO Forestry Department, in his inaugural speech wished the participants success in developing their practical ability to carry out all aspects of planning and managing forest operations in steep terrain which were offered in this Training Course, through field work, excursions and demonstrations. Mr Leslie especially pointed out that although Austrian forests are very different from most of the forests that the participants would have to deal with, they had similarities of terrain, soil conditions and forest management which make this exercise extremely relevant. He further thought that the social conditions in and around the Austrian mountain forests offer outstanding examples of many of the situations with which the FAO Forestry for Local Community Development programme is concerned.

7. High interest was given to the presentation of country reports delivered by the participants. There was an exchange of views which led to a deeper understanding of logging and road construction problems under specific, difficult terrain conditions in the various countries throughout the world.

ACKNOWLEDGEMENTS

8. FAO greatly appreciated and is very much indebted to Austria for its sponsorship and hosting of the Second Training Course. Special thanks are extended to the Federal Chancellery, the International Division, and the Forest Working Techniques and Education Branches of the Ministry of Agriculture and Forestry, as well as the Directors and the technical and administrative staff of the Forestry Training Centres. Many thanks are also extended to the lecturers and speakers, as well as to the forestry enterprises and equipment firms who contributed to the full success of this Training Course.

AUSTRIA'S FORESTS AND HER FUTURE-ORIENTED FOREST RESEARCH

by

Johann Egger
Forstliche Bundesversuchsanstalt^{1/}

Austria is a mountainous country extending over 525 km from east to west and over 265 km from north to south. Of its total area of 83 849 km², 25 percent is lowlands and hills, 15 percent comprises mountains of medium height and 60 percent is covered by high mountains. From the Hungarian border the landscape starts to rise from a height of 130 m above sea level until it reaches 3 797 m with its highest mountain, the Grossglockner. Because of their barrier effect the Alps have a decisive influence on the weather. They divide Austria's climate into a Pannonian, a European transitional and an Alpine zone. Accordingly the rainfall figures vary from 576 mm in the east to 2 594 mm in the west (2 700 mm on the Feuerkogel). Average annual temperatures range from + 9.9°C to -6.2°C (the lowest temperature ever measured in Austria was -52.6°C at Lunz/Obersee).

The granite and gneiss highlands north of the Danube account for 10.1 percent of the total area and are characterized by medium rainfall and a predominantly cool climate. The forests consist of spruce, beech and fir, with spruce predominating in higher regions. The forests in the warmer south-eastern areas contain also oak, beech and pine.

The Alpine and Carpathian foothills cover 11.3 percent of the total area. They consist of tertiary gravel layers (clays and sands); rainfall figures are high. Beech and fir forests are characteristic for this area. The adjoining eastern Alps show a clear east-west folding and account for 62.8 percent of Austria's total area. They fall into a zone of sandstone (flysh), a zone of northern limestone Alps, one of crystalline central Alps (slate) and the southern limestone Alps.

The northern edge of the Alps (the flysh zone and the northern limestone Alps) has a humid climate. The beech-fir-spruce forests growing in this area are highly productive. The central Alps are a natural homeland of the spruce with larches occurring sporadically. In higher regions the Swiss stone pine becomes more frequent.

The southern limestone Alps (including the crystalline strata in the Karnische Alps) have hot summers and cold winters with typically late frosts. This kind of climate accounts for the absence of firs and the presence of spruce, pine and oak. The Vienna basin is situated in the east between the Alps and the Carpathian Mountains. Its formation can be traced back to sea and river sedimentation. Its climate is continental and there is little rainfall, with warm summers and cold winters. The percentage of forest in the Vienna basin is low; there are mainly oak and hornbeam forests.

The south-eastern link with the Pannonian lowlands comprises highlands and hills, the so-called foreland. Its origin goes back to tertiary sea-water and freshwater sedimentation. This fringe area is characterized by a strongly Pannonian climate and houses beech-fir-spruce forests in its higher regions, beech-fir forests in its regions of medium altitude, and pine forests with naturally occurring sweet chestnuts in the climatically most favourable places.

^{1/} Federal Forestry Research Institute, Austria

In Austria the proportion of woodland is among the highest in Europe. Roughly half of its total area - 3.7 million hectares - is covered by wood. The forest area grows from year to year. The wooded area has increased as follows:

- 3 613 000 hectares in the survey period 1961 to 1963;
- 3 685 000 hectares in the survey period 1971 to 1973;
- 3 705 000 hectares in the survey period 1973 to 1975.

This increase is due partly to afforestation of formerly arable land and still more to a natural shift from abandoned pasture land in higher regions to woodland.

There are 250 000 forest owners, from small ones owning only a couple of hectares to the Austrian State Forest Enterprise with an area of 581 683 hectares under its control. About three quarters of the Austrian forest land (76.6 percent or 2 838 200 hectares) are fully productive high forests, according to the forest inventory of the years 1971/75. Nine percent of the woodland comprises protective forests (332 100 hectares) growing on endangered sites. They are mostly insufficiently opened up and because of their protective nature wood harvesting is restricted and has to be carefully carried out and therefore costs are higher. Their significance for soil protection and water conservation is correspondingly all the higher.

A percentage (12.8%) of the forest covered area (472 600 ha) is not directly productive. It consists of green alders and mountain pines or forest stands in extremely steep and sometimes inaccessible areas, and it serves only protective purposes. Avalanches, torrents and landslides can be avoided or at least damages kept to a minimum by a fully stocked protective forest.

The total area of the "productive high forest" is divided as follows:

	Hectares	Percent
i. small forests of up to 200 ha, usually without permanently employed forest staff	1 996 935	53.9
ii. enterprises of over 200 ha, usually with forest staff	1 126 896	30.4
iii. Austrian State Forest Enterprise	581 638	15.4
Total	3 705 469	100.0
	=====	=====

The following table with a breakdown by altitudes shows that 55 percent of the productive forest is situated below and 45 percent above 900 m altitude.

Altitudes and area distribution in percent

	Productive high forest	Protective forest
up to - 300 m	2.6	0.1
301 - 600 m	25.4	2.4
601 - 900 m	27.0	11.0
901 - 1 200 m	23.6	20.2
1 201 - 1 500 m	16.0	29.0
1 501 - 1 800 m	5.2	29.0
above 1 800 m	0.2	8.3
	100.0	100.0

Protective forests are mostly located above 1 201 m altitude, and 66.3 percent still above this altitude.

As regards the mechanization of forestry it is of particular interest that 56.7 percent of the productive high forests is to be found in flat areas, that is in areas with a gradient of 0-40 percent, and 43.3 percent is in steep areas with a gradient of more than 40 percent.

In productive forests tree species are distributed as follows:

<u>Conifers</u>		<u>Deciduous wood</u>	
spruce	63.5 %	beech	9.4 %
fir	3.3 %	oak	1.7 %
larch	3.8 %	other deciduous hardwoods	4.0 %
pine	8.7 %	deciduous softwoods	3.6 %
Austrian black pine	0.9 %	shrubs	0.9 %
Swiss stone pine	0.2 %		
Total	80.4 % =====	Total	19.6 % =====

Arising from the composition of the tree species the following proportions of forest types are found :

purely coniferous	73.6 %
purely deciduous	11.4 %
mixed	15.0 %

The total standing wood volume amounted to 773 792 000 m³ in the period 1971/75.

The total wood increment per annum was 18 971 000 m³, and the total average yearly wood harvesting was 10 400 000 m³.

The standing wood volume per ha amounts to 257 m³; the wood increment per annum, per ha in productive high forest is 6.6 m³. With the applied rate of wood harvesting the total standing wood volume increased considerably over the past years.

At 44 percent the percentage of wooded area is relatively high in Austria compared with other Central European countries. More than 100 years ago, through a far-sighted forest law (1852) and the foundation of the Federal Forest Research Institute, experts paved the way for good solutions to all the management problems that would arise in a future in which forestry and the environment would be so important.

I shall now try to give you an idea of some of the results of 100 years of research: results of particular significance for forestry and also for a wider range of human interests.

Silvicultural studies started with research into sites of various species and comparative tests of origin, and went on to the study of individual hereditary characteristics of forest trees and subsequently to ecological and plant-geographic research into the natural distribution of tree species in the eastern Alps. Legislation on forest seeds is based on preparatory work by the Federal Forest Research Institute. It is designed to guarantee that by taking existing stocks into account subsequent use is made of seed appropriate to the area; such seed is obtained from trees that have adapted their characteristics to various altitudes.

Successful afforestation takes into account not only the origin of seeds but also their quality. Degrees of quality have been standardized and nurseries are subject to constant control in order to raise the level of plant quality.

Another research project is to discover how far the growing site may influence the growth of our major tree species. The test areas correspond to the geographic subdivisions such as the flysh zone, northern limestone Alps, and so on, each with an area of about 5 000 hectares. After the growing site has been thoroughly studied, at least 20 000 trees of all ages are accurately measured. The result for which applied forestry is waiting is the answer to the question, which tree species or combination of species show the best long-term growth performance on the frequently highly variegated growing sites? Another answer awaited is: by what percentage may the distribution of species be varied without long-term deterioration of the soil condition?

At the moment one of our main programmes concerns high altitude forests, some of which are endangered. The objective is to find silvicultural guidelines for their preservation and regeneration.

In the Tulln nursery comparative studies of the poplar species existing in Austria have been and are still being carried out. The purpose is to increase the number of very good and good poplar seeds and species. Since 1957 the provenances of spruce groups and stocks have been tested and the distribution of mountainous spruce forests in relation to altitude is being examined. Test areas have been set up at different altitudes to back up the early test results (hereditary, physiological and morphological qualities of the spruce).

Apart from studies to determine the density of timber, the characteristic structure of year rings and the natural limbing of forest trees, the project "On the Strength and Elasticity of Austrian Construction Timber" is of special interest. From here a direct line leads to the recently started investigations into the structure of spruce from various Austrian sites and altitudes.

Even in the very first days of forestry research studies of the water supply in flat and mountainous terrain were carried out. The most recent emphasis lies on a uniform presentation of Austria's forest stocks, supported by soil analyses and plant-sociological surveys.

Surveys of forest sites and the preparation of relevant maps are to serve as bases to derive optimal economic solutions on the control (and as documentary material for reference) for hydro-electric power stations.

Furthermore, they will help to provide a more exact delineation of growing sites in Austria. The same objective also underlies the growing-site surveys carried out under the Austrian Forest Inventory Programme.

From the field of forest protection let me just mention the studies on the fir sprout tortrix, the nun moth, the small spruce gall wasp, the fir sprout aphid and the bark beetle. As far back as 1890 Wachtl hit upon the idea of using the polyeder disease affecting the nun moth as a biological means to fight this pest. Zederbauer presented suggestions to prevent pine needle blight by breeding particularly resistant species. These ideas, first formulated 70 years ago, are of paramount importance in today's research, where contamination and the employment of insecticides and fungicides play an important role.

The question of "emission damage" from industrial air pollution is older than our research institute. Originally, studies were made only on air pollution, which was investigated by analysing air and needles. Later survey maps were prepared and only very recently have so-called false colour films been used to determine quickly the size of the afflicted area. After 1965 studies of damage caused by smoke were supplemented and completed in cooperation with the Production Research Institute, the loss of wood increment being determined.

Damage to forest and pasture caused by game was already an important issue in 1884, as seen from studies on the protection of young stands from animals' gnawing and grazing. Only after a long interval, from 1956 onwards, was more emphasis given to the question of "forest and game". It is the objective of this long-term series of tests to study the influence of game grazing on vegetation and on forest plants in particular. In addition, topics such as the quantity and distribution of game and the range of damage they cause are being investigated and protective measures against game are tested for their effectiveness.

The solid content and the weight of newly-cut and forest-dried timber were the first published results of production research in 1897. Back in 1892 tree stem distribution and tree crown projection charts were made, photographic tree crown charts were prepared and criteria worked out, and are still applicable today for tests carried out according to biometric principles. Between 1899 and 1908 studies on the shape and content of spruce, larch, white pine and fir were issued at short intervals. Schiffel tried to characterize the tree shape by a (small) number of shape characteristics. Similarly important were the contributions he made in 1910 on the choice of plant unions and the maintenance of stocks as factors in spruce raising. In his paper "Growth Principles of Normal Spruce Stands" Schiffel paved the scientific way which was continued and completed by Krenn, Assmann and Franz.

From 1960 the emphasis of research shifted to forest fertilization tests and tests on maintaining constant stem numbers and thinning spruce and pine forests.

Initially questions of timber measurement were important in the field of production and management. In the decades following, management questions such as wood increment in stands damaged by industrial emissions became more and more important. The questions of productive plant unions and the best ways of thinning, so important nowadays, could not have been answered with professional competence if long-term tests in the first years of the Institute's existence had not been carried out. The Hauersteig (spruce) tree spacing test carried out in 1892 by Gieslar serves as a good example of such preparatory work.

The first studies in forest working techniques concentrated on the employment of the wedge and subsequently on the methods of aligning skidding tracks (timber slides). After a long interval the studies were taken up again in 1940 and led to the construction of the Mariabrunn cable crane. The yarder was developed as a so called "sledge winch" serving a short distance cable crane which was intensively tested in practice. These tests served to develop methods of simple cable extraction.

Subsequently various new long-distance cable cranes were developed which had to be tested in practice for their technical suitability. Useful surveying methods, calculation, rigging methods and operation had to be developed and tested, new skyline supports and anchor types had to be constructed. In close cooperation with the University of Agriculture and Forests the time, material and money required for mounting and dismantling cable cranes under various working conditions were determined. The valuable results of all these tests were conveyed to foresters in many training courses.

The worker himself has always been at the centre of all research into working technique. In 1958 an international operational and ergo-physiological survey was carried out with the support of Section 32 of IUFRO. One-man felling operations of coniferous timber with hand tools was studied in flat and mountainous terrain. The Federal Republic of Germany, Sweden and Austria participated in this comparative study with the object of finding out on the one hand what performance could be expected from the forest worker, and on the other, what ergonomic stress it caused.

In cooperation with the Vienna University Institute of Hygiene, "early-summer meningo-encephalitis", a virus disease spread by ticks, was analyzed. The first outcome was a map showing the areas in which the disease occurred as well as the conclusion that it is an occupational disease which afflicts forest workers and forest staff. To fight it on a large scale an immunizing vaccine was developed.

A study to determine working stress in one-man felling operations for coniferous stands without debarking in the forest, confirmed the correctness of the method by which the operation was carried out and the appropriate rest and recuperation intervals.

The trend to mechanization and increased use of technology made it necessary to study carefully all new machines and devices, to test them for their suitability in mountainous areas and to study the most suitable working methods. The constantly changing degree of mechanization was closely observed. Forest work studies and work analyses of power sawing, of skidding with articulated wheeled skidders and short-distance mobile tower cable cranes yielded directly applicable results, such as standard data charts for power sawing, operational time calculations, technical combinations of machines and devices as well as suggestions for improvement of these machines.

The Austrian Forestry Inventory Project, developed from the forest stocks investigation of 1952 to 1956, is now in its second phase after the initial investigation period from 1961 to 1970. The objective of this inventory project is to determine the conditions and possible changes in them by constantly examining forest stocks over the whole country to determine the long-term cutting rate and the actual cutting performed per annum. The results of the first ten-year inventory project from 1961 to 1970 take up 122 000 pages and have been summarized in information booklet No. 103. In this detailed elaboration of the data obtained, Austrian forest management has valuable material at hand to help in political and economic decisions in the field of forestry. The new inventory project 1971 to 1980 was reduced in scope after consultation with the Federal Ministry of Agriculture and Forestry. The working capacity saved is to be utilized for special surveys of, for example, sample forests belonging to farms, which will serve as a basis for the forestry report.

Conscious of the recreational value of the forests, attempts were made as far back as a century ago to preserve them and to increase their area. Scientific examinations of this recreational value and of the interrelation between forest and civilization were carried out. Subsequently a network of observation stations was set up under the forest-meteorological programme which was then incorporated in the network of the central hydrographic office.

In scientific papers the question of forests and water occurs again and again. The war and inter-war periods saw a standstill of research, not only in this field. Only the avalanche disasters of 1951/54 led to an avalanche register in the Tyrol. They also

induced Fromme to prove that the alpine timber line has become considerably lower over the last 200 years. A vegetation register for the Tyrol was elaborated and the close interrelation between clearcutting and avalanches and torrent hazards was supported by evidence.

The fact that two thirds of all avalanches start from below the potential timber line was a particularly far-reaching finding. It suggested the possibility of avalanche control not only by technically elaborate protection walls but especially by long-term afforestation. A precondition of afforestation in high altitudes was comprehensive and intensive microclimatic analyses of the metabolisms of the most important forest tree species. In order to examine the reactions of various species to their environment as quickly and as efficiently as possible a test centre was installed on the Patscherkofel near Innsbruck. There the plants to be examined are exposed to climatic conditions in three air-conditioned wind tunnels and their reactions are examined from their CO₂ exchange, simulating climatic conditions in high altitudes. The test centre has been in full operation since 1964 and valuable findings have already been made on the afforestation shock, the evaporation shock, the resistance of young plants and interrelation with external factors. The soil biology department has succeeded in selecting valuable fungus partners for our forest trees. They are bred in monocultures and are used as vaccines to increase the growth and resistance of the vaccinated plants to be used for afforestation.

The unfinished project of a vegetation register of the Tyrol has been taken up again. The register is to consist of 12 sectional sheets with a scale of 1 : 100 000. Of these six have already been published. Most recently, the project of revitalizing protective forests has been started, which together with the question of afforestation in high altitudes is of increasing significance.

After the flood and landslide disasters of 1965 the Federal Forestry Research Institute established a branch for torrent and avalanche research in Vienna which is to complement the biological research done in Innsbruck. The problems dealt with in Vienna are torrent erosion, constructional control measures of torrents and avalanches.

The problem of torrent erosion is being studied in selected model torrent catchment areas and attempts are being made to prove by hydrographic and morphometric measurements the efficiency of morphological and constructional measures. In the model catchment area of Trattenbach, data-finding methods have been tested for their applicability and suitable testing methods worked out. To date, the following results are available for practical application: suggestions for finding better and more accurate dimensioning data and construction methods, a further development of open check dams, strain and elasticity tests of steel constructions and the publication of the incidence of avalanches in Austria.

Many of the projects mentioned have decisively influenced Austria's forestry. This was also stated and confirmed by Dipl. Ing. Dr. O. Weihs, Federal Minister of Forestry and Agriculture, when he said in 1974: "I am happy to state on the occasion of the 100th anniversary of the Forestry Research Institute that this institute has excellently fulfilled its objectives in the last 100 years. Austria's forestry and economy have greatly profited from the results achieved."



Results of applied forest research (Photo R. Heinrich)

FORESTRY AND ECOLOGY
IN THE MOUNTAINS OF CENTRAL EUROPE

by

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1. INTRODUCTION

It is the objective of well-managed forests to guarantee a continuous yield resulting from the various uses of forests. Of these, the production of timber is still the most important. The productivity of a forest depends on various ecological factors and their positive or negative effects. A basic requirement for continuous yield is the assurance of a stable environment, in which all the various ecological functions are maintained. This is true of man-made forests as well as of natural forests which are used for production.

This paper deals with ecological considerations to be taken into account in the opening-up by road and harvesting of forests. It will concentrate on ecological factors empirically prevailing in mountainous areas as well as measures that will be needed if these are to be taken into consideration.

It is quite understandable that a compromise between economic and ecological intentions has to be sought. It would be wrong to plan forestry measures only on the basis of currently available economic facts and figures. Major natural disasters in Central Europe were the outcome of such a misconception.

2. FORESTS AND WATER

In Central Europe - and in almost all mountainous areas of the world - precipitation increases with altitude. Apart from the fact that dry periods occur in certain seasons of the year and that some areas may have no rainfall at all, it is still generally true that water is abundant in mountainous regions. As experience has shown, an over-abundant supply of water - in particular the type of precipitation which occurs suddenly - is the main ecological problem in mountainous areas.

Since slope gradients are steep in mountainous areas, especially in geologically younger formations, the hydrological problem is inseparably connected with the erosion problem.

Studies carried out decades ago in various parts of the world have clearly shown that of all the different types of vegetation it is the forest that can prevent major disasters and guarantee the conservation of landscape and soil. Other points to be raised in favour of the preservation of mountainous forests are the good future prospects for selling timber and improvement in the technology of wood harvesting, in particular of extraction methods.

3. SOME EXAMPLES OF STUDY RESULTS

3.1 Surface runoff

Precipitation runoff is compared for two neighbouring valleys with different degrees of forest density.

^{1/}Federal Ministry of Agriculture and Forestry, Austria

Valley	Forest density %	Precipitation mm	Runoff l/ha/sec.
Sperbelgraben	95	35	8.4
Rappengraben	35	35	above 33

(Study carried out by Engler, 1900, Switzerland)

After heavy rainfall the flood peak in forest-covered terrain was reached only after 36 minutes. In clear-cut terrain it was registered after 15 minutes and it was 2.5 times higher. (Study carried out by Hibbert).

Still higher runoff figures were found on ski slopes in clear-cut terrain (comparable to pastures, compacted soil): the runoff was six times higher than in forests; rain infiltration into the soil was 30 cm, whereas into forest-covered soil it was 110 cm. (Study carried out by Stauder, Austria).

Decrease of runoff with increasing stand density:

Example of a pine stand

<u>Degree of stock density</u>	<u>Runoff in %</u>
0.2	25
0.6	9
0.8	2

3.2 Erosion

A soil layer of 18 cm in mixed deciduous forest is theoretically eroded after 575 000 years, in meadows and pastures after 82 000 years.

If the same soil layer carries no vegetation at all, under the same conditions, erosion takes only 18 years. (Study carried out by H. Walter).

Avoiding erosion by a low cover

Degree of area covering in %	Precipitation (thunderstorm) in mm	Runoff in %	Soil erosion kg/ha
75	60	2	100
10	60	73	10 000

(Study carried out by Susmel)

Erosion rates before and after road construction.

Annual precipitation: 1 500 mm.

kg

Erosion rate of soil/ha/year before opening-up	20 - 30
During construction (newly excavated roadbed	2 000 - 4 000
After termination of works and revegetation of the batters	100 - 150

(Quoted from Pestal, studies carried out in the USA)

3.3 Avalanches

Snow is irregularly stored in the forest; dangerous stratification is avoided. Trees have the effect of poles which support the snow cover. An irregular high-density forest in which the stand structure is stratified gives the best protection.

4. MOUNTAIN FORESTRY BASED ON ECOLOGICAL CRITERIA

Study results have shown that particularly in mountainous areas forestry has to be adjusted to ecological requirements. In order to preserve the environment forest economists have to try to avoid the following hazards:

- major surface runoff
- erosion
- avalanches in forest-covered areas

Whereas floods and avalanches cause mostly temporary damage, even if it can be repaired only after decades, erosion causes permanent and irreparable damage to soil in almost all cases. Unfortunately, it is still not widely known that the top layers, i.e. the humus layer and the humus- and mineral-containing soil layers (often only a few centimeters in depth) are responsible for the supply of nutrients. Mass timber production depends for the most part on these top layers. It can be seen from this fact that erosion is not only an ecological problem; it is also an economic one. Central European foresters prefer mechanization to be adjusted to silvicultural rather than other needs.

Ecological considerations will always affect economic decisions. Measures which take ecology into account should not be directed at maximising short-term profits but should be based on the long-term uses of forests.

I do not want to give the impression, however, that in Europe the profit-earnings ratio is so favourable that rationalization and mechanization can be sacrificed for the sake of fulfilling sophisticated ecological demands. Quite the contrary is true: high labour costs and a shortage of labour on the one hand, and only a slight rise in timber prices on the other are a permanent challenge for forest economists to find new ways to harmonize economics and ecology. Let me illustrate my arguments with some figures:

5. DATA FROM AUSTRIAN FORESTRY

Of all Central European countries, Austria has the highest percentage of woodlands: 44 percent, (compared with Czechoslovakia 35 percent; France 24 percent; Fed. Rep. of Germany 30 percent; Italy 21 percent; Switzerland 24 percent; and Yugoslavia 30 percent). This corresponds roughly to 3.7 million ha, of which about 3.2 million ha are productive forest areas.

Austria's forests are situated mainly in mountainous terrain.

Altitude above sea level in m		Productive forest area in %
Up to	900	51
From 901 to	1 200	22
From 1 201 to	1 800	27

Slope gradients in forest areas

Slope gradient In degree In percentage		Productive forest area in %
0 - 20	- 36	49
21 to above 40	+ 84	51

In 1976 roundwood production accounted for roughly 10 million m³ from an area of 30 000 ha. Of this, 18 200 ha were clear-cuttings and on 12 500 ha selective felling was carried out. The average harvested wood volume of final cuts was 324 m³ per ha, representing a standing volume of 400 m³ per ha. In 1976 the area reforested amounted to 17 700 ha.

Earnings - cost ratio

- The hourly wage of forest workers increased by almost 100 percent between 1970 and 1976.
- The price of roundwood to be used as sawn timber (spruce, fir) increased by some 20 percent in the same period.

Cost components 1975 (large forests) in % of earnings		Types of costs 1975 (large forests) in % of earnings	
Timber harvesting	43	Wages	39
Silviculture	8	Salaries	58
Skidding equipment	10	Material	7
Administration	33	Outside labour	16
Buildings	6	Business tax	5
		Depreciation	9
		Others	5

- Earnings per ha of productive forest area obtained from final cutting and thinning in 1975: A.S.2 743 (US\$182).
- Costs for reforestation per ha including tending and weeding were roughly A.S.15 000 (US\$1 000).

= Examples of average productivity in power sawing (Austrian Federal Forest Enterprise):

	Wood volume in m ³ felled per working hour		Increase in %
	1970	1976	
Final cutting	0.59	0.88	50
Thinnings	0.35	0.57	63

6. BASIC ECOLOGICAL PRINCIPLES

The above data, the prevailing situation and experience from this situation point out the need for ecological principles to be applied to forestry. In view of the general topic of this Course I will concentrate on the opening-up of forests and timber extraction.

6.1 Opening-up of forests

Road construction is the first silvicultural activity of environmentally-conscious forestry in mountainous areas.

Careful planning Any opening-up project requires far-sighted decisions that will determine the development of the area over a long time. Planning errors will become obvious and frequently cannot be corrected later.

Integrated planning Timber transport accounts for only 30 percent, or less, of forest road use. In most cases the roads serve multiple purposes in intensive forest management (reforestation, tending, forest protection, among others) and also in social services (transport of workers, transport in case of accidents, and so on).

Clearing plans The first opening-up of virgin forest includes the clearing of the forest and its conversion into arable land. This clearing, in particular the distribution of forest land, must be given special attention because of the erosion hazard. In mountainous areas the percentage of woodlands should be kept high.

If there is a potential hazard of avalanches in winter a wide forest belt on the valley slopes should be maintained.

Degree of opening-up Empirical data have shown that with the present degree of mechanization the optimum density of roads in Central European forests can be reached only at 30-40 m per ha of productive forest area. Only this high roadnet density makes cutting feasible on a small area.

Extraction alternatives The road network will always be the backbone of an opening-up project. In steep or rocky terrain or on soils with low bearing capacities, road construction may have disastrous consequences. In these cases, alternatives have to be considered (e.g. use of temporary cable installations, etc.).

Careful construction Storage of large masses on steep or rocky terrain should be avoided. Roads and skidding trails should be designed to suit the terrain. Gradients have to be kept low. Drainage of the road surface must be sufficient. Natural or artificial revegetation of the batters is essential, particularly in rocky terrain.

Only consistent control of construction works will guarantee efficiency and good results.

6.2 Timber harvesting

At present and in the future forestry work which is based on ecological principles will not be possible without using large-size machinery. Big machines are profitable, however, only if they are used on a large scale. This is unfavourable from an ecological point of view in steep terrain. Heavy machinery is usually not employed in mountainous areas.

Harvesting has to be carefully planned. Various harvesting and skidding methods have to be compared. The method involving the least costs need not necessarily be the cheapest. Higher costs are justified if damage can be substantially reduced. Logging in steep terrain and close to the timber line of high altitudes must be carried out cautiously.

Small clear-cuttings: Large size clear-cuttings are no longer carried out in Austria. Well-spaced small clear-cuttings (strip to very narrow strip cuttings) help to prevent major erosion.

Harvesting methods. Methods in which leaves, needles, branches and stumps remain on the felling site are preferable. Whole-tree logging leads to a reduction of the nutritive substances in poor soils. Even equivalent mineral fertilization cannot completely compensate the loss of nutritive substances. Branches and stumps are important to counteract erosion in steep and mountainous terrain.

Skidding. Machines which cut furrows into the soil are not advisable because they result in soil compaction and erosion. Gravity skidding is not advantageous over long distances. An alternative would be uphill winch skidding.

Skidding in selective fellings. Trees should fall in a fishbone pattern with the skidding corridor as their centre line. Damage to trunk and roots of remaining trees has to be avoided by support measures: cushioning with branches; use of chutes etc.

Torrent beds. Extracted timber must be quickly removed from torrent beds and stored at a site which is safe from floods.

Felling sites must be reforested right away (soil must be covered quickly) with plants that are compatible with the stand. Seedlings should be taken from the same altitude as the area to be afforested.

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Modern mobile cable crane in action. (Photo R. Hinteregger).



In steep terrain forest roads are often used as landings.
(Photo R. Heinrich)

THE IMPACT OF FOREST ROAD CONSTRUCTION ON LONG-TERM FOREST POLICY

by

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1. INTRODUCTION

As head of the Forestry Department of the Austrian Federal Ministry of Agriculture and Forestry I have the honour of presenting this paper. During the next four weeks you will work together on technical questions concerning the opening-up of forests. It is therefore obvious and appropriate for me to talk in the first lecture about fundamental interrelations. This is why I have chosen for my theme "The Impact of Forest Road Construction on Long-Term Forest Policy". I ask for your understanding when I say that I am going to discuss the topic from an Austrian point of view. For one thing, I can give you a more substantial account of the Austrian than of the international situation. For another, I think that it is necessary and important for you to learn about the sphere of political interests in which Austrian forestry is operating.

Today's gathering is made up of people representing large parts of our globe. At home you all live in different social systems. Here you will encounter our way of life - if you don't already know it from earlier visits - apart from enlarging your expert knowledge.

Fewer working hours and a high national product have increased expectations of the recreative value of our countryside and have led to an intensive recreational use of our environment.

Forest road construction in Austria is therefore not only a matter of opening up forests. It is at the centre of public interest. Apart from having a more intensive recreational value, nature and the protection of the environment are decisive factors in planning the opening up of forests; according to the individual situation these factors may be positive or negative.

There is no doubt that technological progress and new methods of construction have caused revolutionary changes in forest road construction and have substantially influenced the objectives of forest policy.

This is why I am wondering whether the theme of my paper could not just as well have been put the other way round, "The Impact of Forest Policy on Long-Term Planning of Forest Road Construction". Either way, the content of my address would be the same.

From an Austrian point of view - and conditions in other European countries are similar - one can say that a permanent feed-back process can be observed between numerous mutually reacting factors. Let me give you some examples:

- | | |
|--|---|
| - Increasing demand for timber | * more intensive timber harvesting |
| - Rationalization and mechanization | * labour shortage |
| - Increasing work capacities of machines | * increasing control of machinery affecting the environment |

^{1/} Federal Ministry of Agriculture and Forestry, Austria.

- General technological progress * need to preserve the vital quality
of the environment
- More public interest in the
preservation of the forest's qualities * intervention by the state through
laws and subsidies

2. THE FOREST AND ITS SIGNIFICANCE AS A SOURCE OF RAW MATERIAL AND AN ENVIRONMENTAL FACTOR

In the planning of forest road construction the function of the forest as an amenity is an important criterion. Studies carried out by international organizations on the development of the demand for raw materials are of fundamental significance. On the occasion of the 1977 Interforesta Conference in Verona, Dr. Kalkinen presented a forecast of European timber consumption until the year 2000 which had been elaborated by the ECE Timber Committee. According to this forecast an increase from 430 million m³ a year to 780 million m³ a year is to be expected. Short-term observation of the Central European situation will not show this great increase of about 80 percent in only 22 years, but I still think that the overall forecast is correct. In numerous areas with large-scale timber production the exploitation phase is coming to an end, and raw material will have to be supplied by those areas which have been rather cautious so far, because they kept strictly to the principle of sustained yield.

This consistent observation of the principle of sustained yield is the result of the experience of almost 200 years ago, in the so-called mining age, when the first wave of industrialisation was the reason for the exploitation of forests.

The essential significance of timber as a raw material in comparison with its main competitors, steel and plastic, is to be found in the fact that it is renewable - even if quantitatively limited - and that energy consumption for its production and processing is low.

Present scientific knowledge tells us that sustained yield is not only indispensable as a long-term safeguard of raw material production but - and this has become much more important - it is a matter of survival.

In many cases the forest is replaceable as a supplier of raw material, but as an environmental factor it has no alternative.

Among others there are the following ways to satisfy increased demand for timber:

- increased production → with the question of forest fertilization always gaining in importance
- the opening-up of forest areas not utilized so far
- more intensive use of timber, waste and residue
- improved methods of recycling timber products.

The two last items are largely beyond the scope of forestry, but the two first items are our most elementary concern, our central mission. Both objectives require an intensive and continued opening up of forests mainly by forest road construction to guarantee sustained yield.

This brings us back to the theme not only of my paper but also of the Second FAO/Austria Training Course.

3. THE OPENING UP OF AUSTRIAN FORESTS, ITS DEVELOPMENT AND SIGNIFICANCE

Sustained yield is the central principle of Austrian forest policy. The Austrian Forest Law of 1975 includes the following passage in Article 12:

"To ensure the beneficial effects of forests in the public interest the following principles shall be observed, as provided in this Federal Act:

- a) forest areas shall be preserved as such;
- b) forests shall be maintained to preserve their productivity and sustained yield (Article 1.1) of their soils;
- c) wood harvesting shall be carried out with a view to long-term forest production and the realization of existing planning, and in line with the objective of leaving harvests for future generations."

Thus, the Austrian Forest Law stipulates the preservation not only of the soil's productive force but also of the forest's multi-purpose quality.

Apart from amenity, the service functions of forests include protection, welfare and recreation. To serve these purposes, forest management concentrates on the key words: continuity, consistency and regularity. It would be impossible to work in line with these requirements without opening up forests. Forest road construction is therefore the basis of applied forest policy.

In 1945 at the end of the Second World War, there were only a few stabilized roads accessible by lorry and wheel tractor in Austria. The first years of the post-war period were used for the mechanization of road construction, at first by employing angle dozers. Over the period of 30-odd years, better and more sophisticated machines and methods have been developed.

Two-thirds of Austria's territory is a mountainous area of medium and high altitudes. Austria's forests are almost exclusively situated in this area. The development of rational, economically justifiable methods of road construction has made it possible to reach many hardly opened-up and extensively-managed forests, thereby intensifying forest operations and increasing wood production. At lower altitudes the forest road networks are rather dense, almost completed, whereas at higher altitudes there is still much left to be done.

4. PROGRESS IN THE OPENING UP OF FORESTS AND IN WOOD HARVESTING

4.1 Forests at high altitudes

Because of improvements in economic methods of forest road construction, a more intensive management of forests at high altitudes was only a question of time. Even if the advantages of protection and welfare provided by such forests are presently our main concern, their productive reserves cannot remain idle, because of the expected rise in timber demand. Forests located at high altitudes have so far hardly been utilized because of their inaccessibility. Overaged, unharvested forests have become increasingly noticeable and they were and still are on the verge of decay. An immediate consequence is the danger that they may lose their multi-purpose qualities. Forests at high altitudes have the following important protective functions:

- protection against avalanches, falling rocks and landslides
- prevention of erosion and subsequent karst formation
- reduction of floods

Because of high harvesting costs cuttings in such regions were very rare and management was almost negligible.

Forest operations over large areas are possible only if opening-up measures make main and intermediate cuttings profitable or at least marginally profitable.

Therefore, long-term forestry policy and forest law emphasize an optimum opening-up of forests at high altitudes: the owners of such protection forests are obliged to invest profits from cuttings into the forests for their recovery; protection forests are subject to special management regulations which are stricter than for the so-called "economic forests"; applications for forest subsidies, particularly for opening-up projects, are preferentially treated; and subsidies are higher than for economic forests. They cover up to 90 percent of total costs, the state paying for up to 60 percent, and the federal province for up to 30 percent.

In this way a long-term programme has been introduced with the objective of recovering protection forests and subsequently raising the timber line to the climatically possible limit.

4.2 Wind damage - mechanization of timber harvesting

The winter of 1966-67 can rightly be called a disastrous one in European forest history. Storm-damaged timber amounted to roughly 35 million m³. The countries most badly hit were the Federal Republic of Germany and Switzerland. For Austria, too, it was the most disastrous year for wind damage ever. Almost 4 million m³ was blown down or broken. The largest amount of storm-damaged timber occurred in badly opened-up areas. To protect the forests, harvesting had to be carried out as quickly as possible. The amount of damaged timber was two-thirds of annual cuttings, which may well illustrate the dimension of the disaster.

Apart from the pressure of time in which the damaged forests had to be opened up, timber harvesting could not be carried out in any traditional way but largely with the help of machines.

It was mainly the Austrian State Forest Enterprise which employed articulated wheeled skidders, de-barking units, mobile cable cranes and so forth, on a large scale. It was frequently necessary to adjust these machines to Austrian working and terrain conditions.

Using the experience gained from the employment of these heavy-duty machines, the Austrian State Forest Enterprise has developed the mobile harvesting unit. Private forest enterprises have also mechanized wood harvesting as a consequence of that disastrous winter. It was then that the articulated wheeled skidder entered Austrian forests.

A dense road net is a prerequisite for any mechanization of wood harvesting in the mountains, which again underlines very clearly the significance of the opening-up of forests.

4.3 Public opinion and forest road construction

Shorter working hours and an increasingly wealthy population raise people's expectations in recreational areas. They call for more leisure-time opportunities and more intensive recreation. Better opening-up of forests, healthier environment and better-kept landscape are therefore general claims of society.

Like any type of construction, road construction, too, means cutting wounds into nature. It has to outweigh the clash of interests between economy and ecology. In the highly civilized societies of Central Europe the conservation of nature has been nostalgically idealized, in most cases outside official organizations, by semi-professional supporters. The genuine questions of nature conservation have frequently not been given due consideration. One of these idealized concerns is forest road construction.

It would go beyond the subject of this paper to enlarge on the problems arising from the conflict between economic road construction and elimination of irreparable damage to the landscape.

It is a fact that Central Europe's landscape is no longer in its original state. If nature is to stay untouched, as with virgin land or virgin forests, it offers few conveniences indeed, and who is really prepared to live in this kind of environment?

Our civilization is based on an intensive utilization of earth's natural resources and the supply of the energy required for it. The engineer's task is to discover and create reasonable ways and means to live a civilized life.

It is, however, also a fact that under the cover of economic necessity, engineers have frequently signed against the ecological balance of the environment. In opening forests up the landscape has been disturbed, road cuts and fills have not been greened, and ill-planned roads have contributed to a generally negative attitude toward this forestry operation. It is noteworthy that criticism has concentrated on visual disturbances in nature. Ecological damage caused by road construction works has been criticized much less frequently. However, it is a much more important obligation on forest road experts to provide for the safe and forest-related depositing of excavated material, for the correct transition of erosion lines and the appropriate discharge of water from rainfall.

Using forest land for housing, transport, energy production, tourism and skiing is accepted as a matter of course. Forest road construction and wood harvesting, however, create heavy setbacks in the relationship between the general public and forestry. It is a major task of forest organizations to explain forest utilization not in terms of the destruction of nature but as a prerequisite to keeping up those functions which are quite naturally expected of forests by our welfare and consumer society.

It is the major task of foresters to keep forest management ecologically balanced. Foresters must develop an understanding of the increasing ecological and aesthetic consciousness of society with regard to environment and landscape. Discussion and exchange of opinions between equally qualified representatives will be the key to success if the general public is to develop a positive attitude toward forestry.

Last year's seminar on forest roads held in the Forestry Training Centre at Ort, demonstrated that straightforward exchange of opinions leads to an assimilation of different viewpoints. For several days, representatives of forestry and of nature- and landscape-conservation associations discussed their viewpoints on forest road construction in an unemotional and objective atmosphere. As a result there was a notable readiness to understand the problems of forestry. This open attitude of nature conservationists should constitute a challenge to and an obligation on foresters to look in the future for more frequent discussion and contact with leaders of opinion outside forestry. It is the only way to turn the forest-minded public into a forest-management-minded general public.

5. IMPACT ON FOREST LAW

I said at the beginning that I have used three examples to try to explain to you how forest policy and the opening-up of forests underlie a permanent feed-back process.

A natural consequence of this process is the adjustment of forest law to technological and political changes.

In forestry the production process extends over several decades and needs appropriate management techniques. Wood harvesting may be considered as a final intervention in forest management. The nature and order of these interventions must be regulated by law. Since opening-up is a prerequisite for them it must be included in these regulations. Austria's Forest Law of 1975 deals among other matters with the preservation of forests, wood harvesting devices, and principles of forestry promotion. The new law was passed,

after years of debate, by unanimous parliamentary vote and replaced the Forest Law of 1852. This revision of forestry legislation was amply justified by the social changes which had occurred over the previous 100 years.

Our modern society is developing a strong desire for recreation in "free nature". The opening-up of forests is widely in line with the wish to reach the recreational area quickly. By entitling everybody to enter forests freely for recreational purposes, the Austrian legislator satisfied a justified desire of society. At the same time he realized that it would create serious problems for forest management if forest roads were opened to the traffic of weekend tourists and visitors in search of recreation. Therefore, access by road was made dependent on the owner's permission. For management reasons this permission is granted only in exceptional cases, and so the forest owner contributes substantially to the preservation of nature. The forest's recreational value is considerably increased by opening it up by roads and at the same time keeping visitors' cars away.

6. CONCLUSIONS

Forest road construction is a decisive factor in long-term forest policy. The forest inventory carried out between 1966 and 1973 showed an average road net density per ha of forest area of roughly 32 linear m in small forests, of 26 linear m in private forest enterprises and of 21 linear m in forests administered by the Austrian State Forest Enterprise.

Natural terrain conditions exert a substantial influence on the progress of opening-up forests. Thus, road net density in productive forests at altitudes of up to 900 m is roughly 33 linear m/ha, at altitudes of up to 1 200 m it is roughly 28 linear m/ha, and at altitudes above 1 200 m it is presently only 19 linear m/ha. These figures are clear indicators of how many road construction projects, particularly in the ecologically more sensitive higher regions, must be planned and carried out in order to reach the objective of 40 to 50 linear metres of road per ha of forest area.

Those methods of timber production which preserve the forest and its ecological balance are in the long run the most effective ones. In the interest of an optimum "exploitation" of nature, forestry forces man to keep nature as healthy as possible for as long as possible and to renew it where it has been disturbed or even destroyed.

This does not mean that forestry equals pure landscape and nature conservation in the sense of preserving nature untouched. The most important objective of forestry will always be to produce the raw material, timber, as rationally as possible.

This means that forestry cannot work against natural conditions. Quite the contrary. Since timber needs a period of several generations to attain the form and quality useful to man, man is obliged to create consistent long-term conditions which enable nature, i.e. the forest ecosystem, to produce timber.

I have tried to explain the situation of Austrian forestry and to underline the significance of forest technology in the ecological balance in nature, as well as to demonstrate the tension between forest technology and social interests.

THE FOREST ROAD INVENTORY PROJECT AND ITS EFFECT
ON FINANCING AND PLANNING MEASURES

by

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This paper tries to describe the Austrian situation and our ways of building forest roads and you may regard it as a stimulus to finding out the best solutions to similar problems.

Austria is a country with private as well as state-owned forests, which are distributed among 250 000 owners. The major part, about 54 percent, own up to 200 ha, 30 percent own more than 200 ha and 16 percent of the forests are state-owned. These figures are taken from the forest inventory report 1961-70. The data relate to a forest area of 3 705 469 ha.

The exigencies of the post-war period and a certain personnel shortage induced owners and the various authorities to open up the available forest land. A decisive factor in all these projects was the need for timber as a raw material for construction and industry. With the help of the first inventory results, papers were prepared describing the degree of opening up of Austria's forest land. They were then used as a basis for further development.

This collection of basic data, the theoretic background which was the work of the French scientist Buffon, was started in 1966, and is still being worked upon. Calculations of road length and road net density are based on the number of junctions and the influence a certain forest section exerts on the road.

The working guidelines for the surveying staff contained the following criteria:

- determination of altitude given in steps of 300 m each;
- specification according to public tracks or roads;
 - cooperative, transport and forest roads with private or public right of use;
 - private tracks or roads owned by individual forest owners;
- determination of road width:

2 - 3 m	roads or tracks for lorries or timber
3 - 5 m	transport vehicles
5 m and more	
- determination of road surface:

not reinforced
reinforced base (gravel, compacted and stabilized)
reinforced base and special surface (macadamized, concrete covered).

The road length data are taken from the last evaluation of the forest inventory results (period from 1971 to 1975). The data for area, supply and production are taken from the inventory of 1961-70.

The following results were obtained by the survey:

Roads accessible by lorry

The following were the data for road length and road net density in fully productive high forests and protective forests in production.

<u>Forest specification</u>	<u>Road length</u>		<u>Road net density linear m/ha</u>
	<u>Km</u>	<u>%</u>	
Fully productive high forest	91 410	96.6	33.3
Protective forest in production	3 237	3.4	8.6
Total: high forest in production:	94 647	100.0	30.3

It will be seen that density of roads accessible by lorry in fully productive high forests is almost four times as high as in protective forests in production. The road length figure for protective forests in production given as a percentage of the area is only 3.4 percent while it is 21.1 percent of the area of high forests in production.

1.1 Types of ownership

For the various types of ownership the following figures are given by the forest inventory for fully productive high forests:

<u>Types of ownership</u>	<u>Road length</u>		<u>Road net density linear m/ha</u>
	<u>Km</u>	<u>%</u>	
Small forests	61 682	67.5	37.1
Forest enterprises	22 273	24.4	29.7
State forests	7 454	8.1	22.3

Forest enterprises and state forests have a considerably smaller road net density, which can be explained by the fact that roads in big forests are mainly for opening-up. In smaller forests the public road net and agricultural transport roads contribute to a higher figure of road net density. The definition of the fully productive high forest as given by the forest inventory differs slightly from the one applied by the Austrian State Forest Enterprise.

In protective forests in production the small densities of 7.0 to 9.5 linear m/ha are sufficient.

1.2 Altitudes

<u>Altitude, above sea level</u>	<u>Size of forest area, ha</u>	<u>Fully productive high forest Road length</u>		<u>Road net density linear m/ha</u>
		<u>Km</u>	<u>%</u>	
Up to 900 m	1 549 864	57 525	62.9	37.1
Up to 1200 m	608 758	20 788	22.8	34.1
Above 1200 m	589 480	13 097	14.3	22.2

The road net density in fully productive high forest decreases considerably with rising altitude. Road net density at altitudes up to 1 200 m above sea level is 91.9 percent of the density figure for the lowest level; at altitudes above 1 200 m it is only 59.8 percent of the density figure at the lowest step.

In the following, the distribution of forest area and percentages of total supply and cuttings as given by the stock inventory are compared with the distribution of road length figures at the three levels of altitude.

<u>Altitude above sea level</u>	<u>Forest area %</u>	<u>Total supply %</u>	<u>Cuttings p.a. %</u>	<u>Road length %</u>
Up to 900 m	56.4	52.9	59.0	62.9
Up to 1 200 m	22.2	23.5	22.6	22.8
Above 1 200 m	21.4	23.6	18.4	14.3

This comparison confirms that road net density decreases with rising altitude. It shows that road length distribution in the three altitudes does not conform but differs considerably from the corresponding percentages of forest area and total supply. At 62.9 percent the length percentage in altitudes up to 900 m is considerably higher than the percentage of supply. The road length percentage of 14.3 in altitudes above 1 200 m is lower on the other hand than the supply percentage of 23.6 by almost the same amount.

The distribution of the annual cutting figures in the various altitudes is roughly to be found between the supply and the road length percentages. Cutting figures are larger in the lower altitudes, smaller in the higher altitudes. The percentage of cuttings is nevertheless above the road length percentage at the highest level, which means that opening up considerably lags behind actual cutting activities.

Protective forest in production

<u>Altitude above sea level</u>	<u>Size of forest area ha</u>	<u>Road length Km %</u>	<u>Road net density linear m/ha</u>
Up to 900 m	54 518	624 19.3	11.4
Up to 1 200 m	69 438	653 20.2	9.4
Above 1 200 m	250 547	1 960 60.5	7.8

Here the decrease of road net density with rising altitude is much greater even than in fully productive high forest.

Distribution of forest area, supply,
and road length at various altitudes

<u>Altitude above sea level</u>	<u>Forest area %</u>	<u>Total supply %</u>	<u>Road length %</u>
Up to 900 m	14.6	14.8	19.3
Up to 1 200 m	18.5	21.6	20.2
Above 1 200 m	66.9	63.6	60.5

The percentage of road length in protective forests at altitudes up to 900 m is 1.3 times as high as the percentage of supply in this altitude; for the highest altitude of above 1 200 m it is only 95 percent of the supply percentage, and 90 percent of the forest area percentage.

1.3 Road Specification

<u>Type of roads</u>	<u>Fully productive high forests total road length</u>	
	<u>Km</u>	<u>%</u>
Public	29 728	32.5
Cooperative	38 132	41.7
Private	23 550	25.8
	<u>91 410</u>	<u>100.0</u>

Of all the roads in the fully productive high forest, almost a third is made up of public roads, just under a quarter are private and belong to individual forest owners, and the remaining 42 percent are cooperative roads.

<u>Type of roads</u>	<u>Fully productive high forests</u>					
	<u>Small forests road length</u>		<u>Forest enterprises road length</u>		<u>Austrian State Forest Enterprise, road length</u>	
	<u>Km</u>	<u>%</u>	<u>Km</u>	<u>%</u>	<u>Km</u>	<u>%</u>
Public	24 738	40.1	3 564	16.0	1 425	19.1
Cooperative	33 262	53.9	3 801	17.1	1 069	14.3
Private	3 683	6.0	14 908	66.9	4 960	66.6
	<u>61 683</u>	<u>100.0</u>	<u>22 273</u>	<u>100.0</u>	<u>7 454</u>	<u>100.0</u>

1.4 Road Width

<u>Road width</u>	<u>Fully productive high forests total road length</u>	
	<u>Km</u>	<u>%</u>
2 to < 3 m	51 585	56.4
3 to < 5 m	32 846	35.9
5 m and more	6 979	7.7
	<u>91 410</u>	<u>100.0</u>

<u>Road width</u>	<u>Fully productive high forests</u>					
	<u>Small forests road length</u>		<u>Forest enterprises road length</u>		<u>Austrian State Forest Enterprise, road length</u>	
	<u>Km</u>	<u>%</u>	<u>Km</u>	<u>%</u>	<u>Km</u>	<u>%</u>
2 to < 3 m	35 043	56.8	12 206	54.8	4 336	58.2
3 to < 5 m	21 828	35.4	8 375	37.6	2 643	35.4
5 m and more	4 811	7.8	1 693	7.6	475	6.4
	<u>61 682</u>	<u>100.0</u>	<u>22 274</u>	<u>100.0</u>	<u>7 454</u>	<u>100.0</u>

The percentage of roads with a carriageway width of 2 to 3 m in forest enterprises is only just under the figure for small forests.

From these data collected in all of Austria's forests, results can also be obtained for the federal provinces and communities. However, the margin of error is relatively high in calculations for small community areas, so that the data cannot be considered accurate. They are just an indication as to whether in these smallest units there is a tendency toward or away from the set targets.

When opening-up activities were first started in 1948 the planning objective was set at a density of about 20 linear m/ha (average figure for Austria's total area). The results conveyed above required a revision of objectives effected on the occasion of a seminar in the spring of 1977.

In 1975 a new Austrian Forest Act was passed which among other things includes a passage on the promotion of forestry in general. The individual sectors in which promotion is to be carried out are clearly defined and they include forest road building. The maximum subsidy given is 45 percent. In the highest altitudes above 1 200 m the road net density is smallest, but supply is well above average. In order to stimulate the opening up of high forests the Federal Ministry of Forestry and Agriculture issued guidelines in which the maximum subsidy of 45 percent stipulated in the law is granted only for forest roads at altitudes above 1 200 m. Roads below this altitude are just subsidized for 30 percent of their total costs. This public subsidy is allocated only if the applicant is qualified to carry out the project and if he does not have the necessary financial means himself.

Another kind of promotion is the granting of interest allowances. These are paid from the Federal budget and help to pay the interest on agricultural investment loans granted by banks under special contract with the Federal Ministry. For this subsidy from public means the interest rate is supported so that in practice the applicant will pay interest of only 5 percent. These loans are restricted to a term of 10 years and their amount must not exceed 60 percent of the total costs. In extreme situations, such as after snow break disasters, subsidies may be granted in any kind of combination; but 20 percent must be paid from the applicant's own purse.

To big forest owners - minimum size 200 ha - credits are granted from the so-called ERP Fund. This was created by the United States Government for the reconstruction of Europe after the Second World War. The fund passed into Austrian administration after 1955. Under the ERP Scheme, loans of up to 70 percent of the total production costs are granted at an interest rate of 3 percent. The term of this loan is 15 years. The scheme also provides for forest machinery, such as lorries, de-barking machines and other machinery employed for timber harvesting, to be subsidized by an ERP loan. The term of these loans for machinery is only 5 years and interest is at 5 percent.

As can be seen from the figures mentioned previously, Austria already has a basic network of opening-up roads. However, this needs to be improved as far as density and altitude are concerned. Damage to the landscape caused by future opening-up activities will be more noticed by the general public than ever before. Preventive measures have to be taken to keep this damage to a minimum and objectives in opening-up have had to be revised. In April 1977 a seminar was held at the Forestry Training Centre, Gmunden, for the purpose of studying the opening-up of forests and the public interest.

When entering difficult terrain and protective forests, the forester responsible for the planning and construction of roads will be increasingly criticized by public opinion. Forest roads are nevertheless necessary for careful management and for the preservation of our forests. Forest roads can be supplemented by cable devices, but they cannot be omitted. In order to find the most uniform answer to these problems representatives at various administrative levels within the forest authorities and chambers of agriculture, the environmental association, the Austrian State Forest Enterprise, the Federal Forestry Research Institute,

the Office for Torrent and Avalanche Control, private forest enterprises and civil engineering associations, and several experts in silviculture, forest protection and forest technology were invited to the seminar by the Federal Ministry of Agriculture and Forestry.

After two introductory lectures, of which the first conveyed the findings of the nature preservation experts, and the second those of the forest technology experts, four study groups were formed to discuss the answers to a questionnaire. The first study group was to represent the point of view of forest technology, the second that of the private forest enterprises, the third that of silviculture and forest protection, and the fourth that of the forest authorities.

The group discussions were summarized and reported to all the other participants by a group speaker. The results achieved in the individual study groups were again discussed and the following general findings were agreed upon:

Contrary to general practice in the past, road net density for the total area of the country should not be determined at the beginning of an opening-up programme. It should be adjusted to the structure and type of ownership. For the Austrian State Forest Enterprise a density of about 25 linear m/ha was recommended in order to keep timber transport costs down. Taking into account the high degree of mechanization the recommended density for private forest enterprises was 30 to 35 linear m/ha. The small forests owned by farmers should have a target density of 40 to 50 linear m/ha in order to match this level of mechanization. About this last figure the representatives of the Torrent and Avalanche Control Office were sceptical because they believed that depending on the type of sub-base, building sites might exert a negative effect on erosion statistics.

Because of an increasing degree of mechanization planning activities were rationalized and simplified. This was not always for the better. Since there is a general tendency toward the best work at the lowest cost, the quality of planning will also have to be improved in some instances, and for difficult projects general and detailed plans will have to be prepared. Construction defects which are due to imperfect preparatory work must be avoided in the future.

Young foresters will have to be trained in courses and seminars before working on road projects. Planting of the batter should be carried out as soon as possible not only because of its visual effect but also because a reinforcement of the batter has a positive influence on the road quality. Junctions of walking paths should be situated on forest roads. To realize the general opening-up objectives the best combination between roads and cableways should be striven for.

In all groups there was a clear consensus of opinion on the desirability in a densely populated country like Austria of considerably intensifying public relations work and it was felt that for this purpose all media available should be employed. The general public needs to be informed about all objectives and exigencies of forestry so that when various measures have to be taken, insight and understanding can be expected from the public.

At the planning stage a comparison of various possible routes is of paramount importance in order to achieve the greatest success with the least expense and damage to the landscape. Parking space and playgrounds should be given special consideration so that visitors find guidance in the forest. This means additional costs for private forest enterprises. The representatives expressed their hope that these additional costs in road construction spent to make environment more inviting would be borne by the general public. Continual attempts should be made to obtain the cooperation of various forest owners for road building projects. Such a joint venture would frequently make the routing less costly and more in line with needs. It would also be in the interest of the public authorities because higher efficiency might be expected.

Private forest owners cherish the understandable hope that promotion will not be different for the individual types of ownership and that they could expect adequate credits

and subsidies to be granted. Their concern is understandable because help would for the most part depend not only on the financial situation of the state but also on the general public's understanding of forestry and its achievements. Since the public is frequently aware of forest road building and since on the other hand there is no doubt about the necessity for and advantage of opening up our forests the group of private forest owners underlined their hope that future public relations work would focus on the usefulness and nationwide significance of such projects. It is not only the forest owner who profits from his forest but also many thousands of Austrian employees. They earn their living through jobs that are directly or indirectly guaranteed by forestry. Therefore, forestry deserves the concern of the whole nation.

The following points were brought out by the silvicultural group:

The higher the altitudes that are reached by opening-up projects the more obvious will road building be for the general public. Road construction is welcomed by silvicultural experts because it is only by means of a road that a forest can be preserved and the necessary thinnings can be carried out; clear-cuttings can be reduced and timber harvested by more powerful machines can be extracted and processed more easily (regarded as an advantage mainly by forest protection experts).

Torrent control representatives made observations both in favour of and against road building. The positive aspects included better accessibility of the terrain and the hydrological advantages of less frequent clear-cuttings. Negative aspects were landslides, new water concentrations through insufficient discharge of water and, as a consequence, new centres of erosion.

The group of silvicultural and forest protection experts stated that forest road construction should be carried out according to the principle of rentability. Measures whose cost exceeded this rentability should be financed by the interested parties. (Such parties might include people living on or interested in tourism and other people profiting from forest roads).

As far as legislation was concerned, it was the general opinion that the legal basis for proper road construction is sufficient. It is essential to support readiness to implement legal provisions consistently, on the part of the authority as well as on the part of the forest owner.

Special importance was attributed to careful control of construction. In road construction, economic effects should harmonize with ecological effects; forest roads should be in line with nature and the landscape; terrain limits should be observed. To keep construction costs at a minimum cannot be the exclusive objective of such a far-reaching project. Safety measures are part of the construction, which explains why their costs are justly subsidized.

In this attempt to outline opening-up activities, as they are presently carried out in Austria it is hoped that participants will find a basis for successful solutions to similar problems in their own countries.



Forest road networks which are planned and laid out well are the basis of efficient and intensive forest operations. (Photos R. Heinrich; E. Pestal)

GENERAL PRINCIPLES FOR THE PLANNING
OF A FOREST ROAD NETWORK

by

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1. INTRODUCTION

The general project for opening up a forest area constitutes the framework for the detailed planning of individual facilities. The basic principle to be followed is to plan from the general to the particular.

The general project includes not only the road network but also supplementary facilities such as medium - and long - distance cable cranes for steep terrain.

From a point of view of economy a general project should be elaborated only when an area above a certain minimum size is involved (in Austria a forest area from about 300 to 500 ha or 15-20 km of total road length). In the case of smaller projects general planning and detailed planning are virtually identical.

Planning principles

- a) Planning is not an end in itself but a means to an end. Surveying and studying the actual terrain should be intensive, and office work should be limited to a minimum.
- b) There is no other field in forestry where planning mistakes are as irreversible and permanent as in forest road construction.
- c) A forest road network should be planned only by experienced and qualified foresters. Those without practical experience ought to receive thorough training.
- d) Specialists and people who know the area should cooperate in order to achieve the best results from the planning.

2. DEFINITION OF TERMS

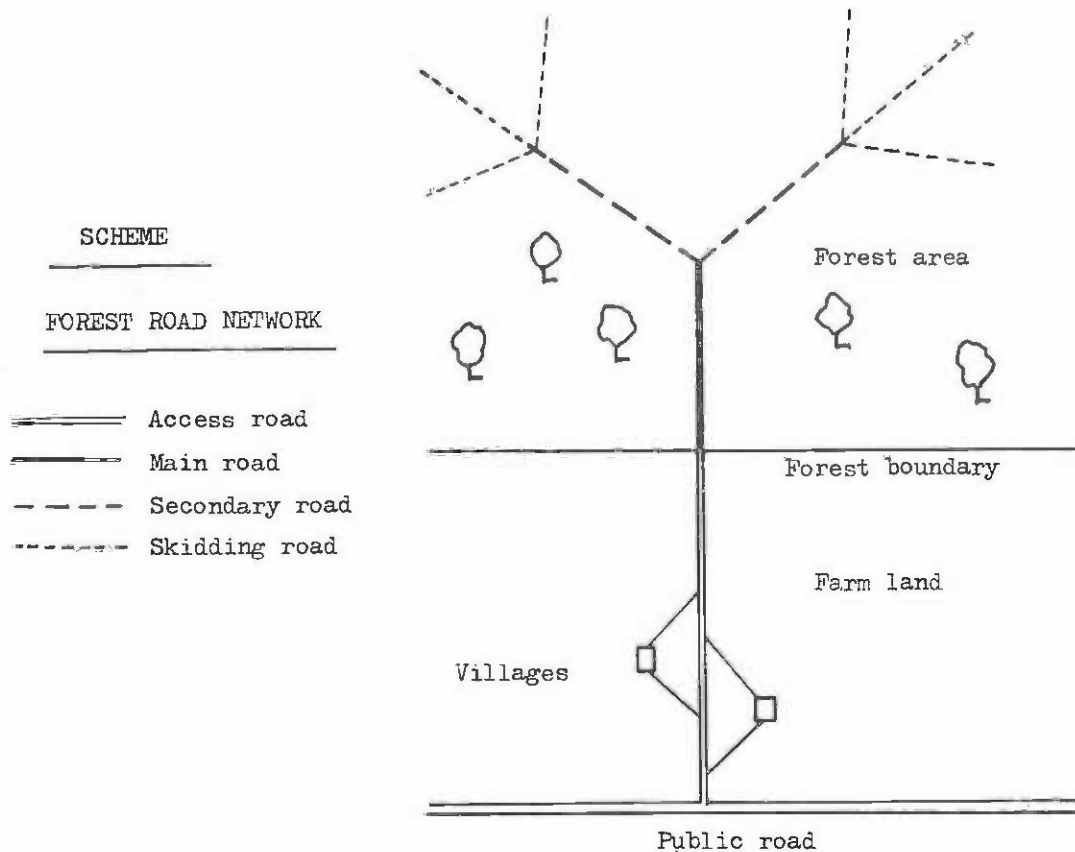
2.1 External and internal opening-up

Access roads connect a forest area with the public road network, thus opening up the forest area "from outside". Their primary function is a double one: either they give access to one particular area of terrain or they provide a longitudinal link, connecting different points of terrain over the shortest distance. In Europe these access roads are mostly public roads.

The main function of the forest road network is to open up forest areas internally.

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Fig. 1 - Types of forest road



2.2 Road standards

A-Roads (access roads and main forest roads)

These are used for opening-up and connection. They have a good standard of construction and are accessible by truck all year round. In Europe they usually have only a single lane, while in tropical areas two lanes are frequent. Bituminous surfaced roads are used where there is heavy traffic.

B-Roads (subsidiary or secondary roads, feeder roads)

These subdivide the forest into individual sections and provide a connection between the landings and the main roads. They have a simple standard of construction and are accessible by truck only under favourable weather conditions.

C-Roads (skidding roads)

These provide a connection between the felling sites and the landings. They have no surfacing and are accessible by extraction equipment.

The following two tables give road classifications for Austria and tropical high forests:

TABLE 1

ROAD CLASSIFICATION FOR AUSTRIA

Specification	Type of forest road		
	Main road A	Subsidiary road B	Skidding road C
width of formation b (m)	5.0 - 5.5	4.5 - 5.0	3.0 - 4.0
width of carriage- way f (m)	3.5 - 4.0	3.0 - 3.5	-
maximum gradient g_{\max} (%)	9	10 (12)	12 (16)
minimum gradient g_{\min} (%)	2 - 3	2 - 3	3 - 4
maximum gradient in adverse direction g' (%)	6	8	10
maximum wheel pressure P (t)	5 (7)	5 (7)	1 (1.5)



Participants inspecting a high standard mountain forest road. (Photo O. Sedlak)

TABLE 2
ROAD CLASSIFICATION FOR TROPICAL HIGH FORESTS

Road	Road use	Road width carriage- way inclu- ding shoul- ders in m ¹ /	Width of carriage- way in m ¹	Min. curve radius in m	Max. gradient in %	Truck loads per day	Traffic speed in km per hour	Cost estimate in US\$ per m of road
Access road	Truck pick-up, permanent	9-12	7-10	50	6 (8) ² /	More than 50	50-60	10-15
Main forest road	Truck pick-up, permanent	8-10	6-8	30	8 (10) ² /	Up to 50	25-40	7-10
Secondary forest road	Truck pick-up, temporary	6-8	5-6	20	10 (12) ³ /	Up to 6	15-25	1-7
Skidding road	Wheeled skidder wheeled tractor crawler tractor		3.5-4.5					0.3-1
Skidding trail	Crawler tractor		3.5-4.5					0.05-0.1

(Heinrich 1975)

- ¹/ In steep and difficult terrain conditions the road widths given above have to be reduced considerably.
- ²/ Maximum gradient in steep, difficult terrain for unloaded trucks when driving uphill.
- ³/ Maximum gradient in steep, difficult terrain for a short distance.

2.3 Road spacing, road density, skidding distance

Road spacing is the average horizontal distance in m between the roads in a forest (disregarding skidding roads).

Road density is the average road length in m/ha.

$$RD \text{ (m/ha)} = \frac{10.000}{RS}$$

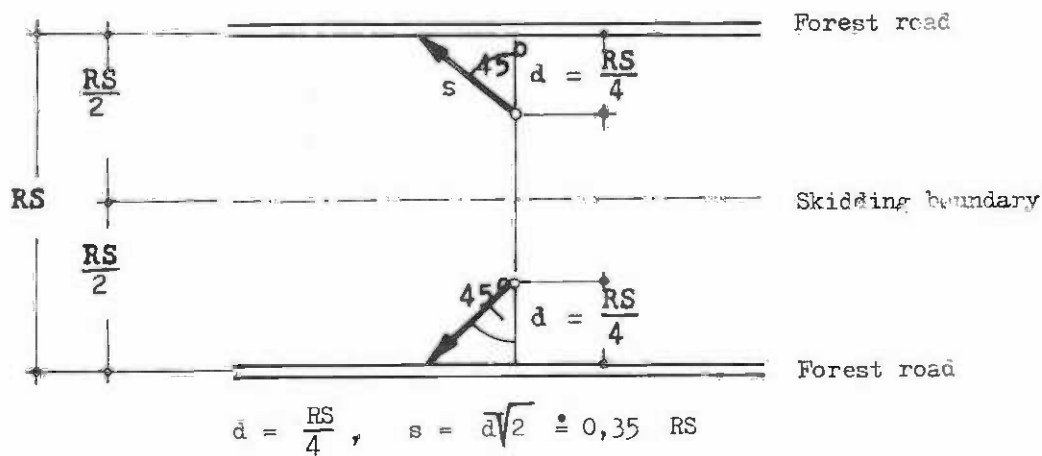
Skidding distance is the mean value of the theoretical skidding distance in an opened-up forest area. It depends on road spacing, topography and skidding techniques.

Road spacing and the average skidding distances are characterized by the following relationships:

2.3.1 Flat terrain

In practice, the mean skidding distance does not correspond to the shortest possible skidding distance ($RS/4$). According to Volkert it is approximately 20-30 percent longer. For rough calculations it is sufficient to assume a 45° angle between the skidding direction and the forest road.

Fig. 2 - Mean skidding distance

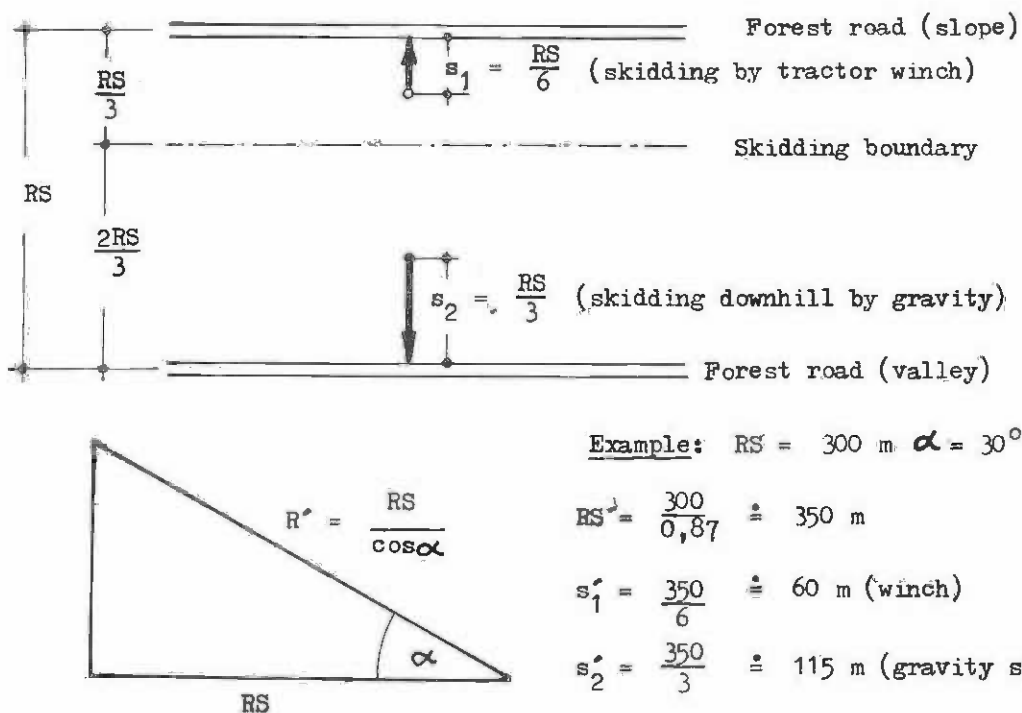


Example : $RS = 400 \text{ m}, \quad s = 140 \text{ m}$

2.3.2 Slope extraction

The skidding boundary is determined by the techniques applied. If the gradient is rather steep, the difference between length of the slope and horizontal projection must be considered as well. The following are examples of uphill skidding by winch and downhill skidding by gravity.

Fig. 3 Uphill and downhill skidding



Road density and skidding distance can also be computed by means of the "road efficiency" factor according to Segebaden (FAO):

$$RD = \frac{a}{s}$$

a = road efficiency factor, normally between 5 and 9: 4-5 for flat terrain, 5-7 for hilly terrain, 7-9 for steep terrain; 9 and above for very steep, difficult terrain.

s = average skidding distance (km)

2.4 Planning optimum road density and road spacing

When a road net is planned to open up a forest, it ought to be done in such a way as to keep total expenditure for timber transport as low as possible (Volkert). The costs for the transport of timber consist of the skidding costs (for skidding operations and skidding tracks) and costs of transport via forest roads (for transport operations as well as those for the construction and maintenance of the forest road net).

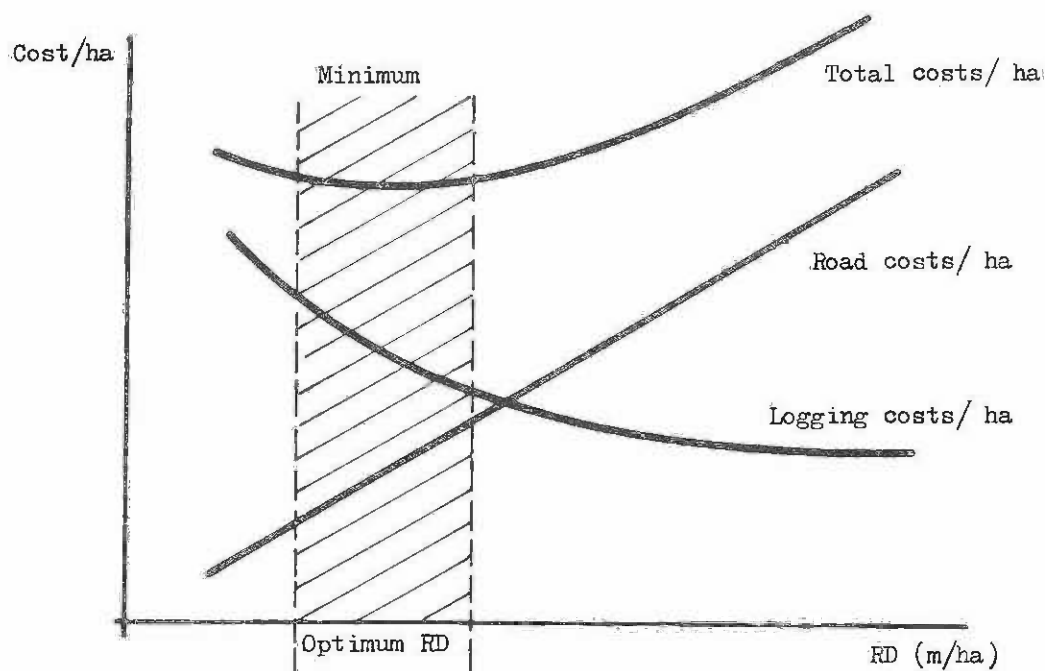
Optimum forest road density and optimum average road spacing cannot be accurately assessed in practice, although numerous methods of approximation have been developed (FAO). The most important factors in such calculations are:

- average annual quantity of timber harvested/ha
- average skidding costs/ha
- average road costs/ha (construction and maintenance)

If these parameters are used for calculating the different versions of road density, the theoretical optimum is obtained.

Fig. 4 shows the relationship between road costs and skidding costs as well as the curve indicating the total costs.

Fig. 4 Relationship of costs



RD = Road density

For the Federal Republic of Germany, König calculated theoretical optimum values for road spacing as follows:

Annual road costs	Annual increment of timber			
	(low) 3 m ³ /ha		(high) 9 m ³ /ha	
	flat terrain	hills	flat terrain	hills
low	700 m	450 m	400 m	250 m
medium	1 000 m	600 m	550 m	350 m
high	1 000 m	750 m	700 m	450 m

Assuming an average increment and average construction costs, the empirical values for road spacing for Austria are as listed below:

TABLE 3

Gradient	Terrain	Skidding	Large forest (> 2 000 ha)	Medium-sized private forest (200-2 000 ha)	Small forest (< 200 ha)
0-15 %	flat terrain	wheeled skidder, uphill and downhill	500-600m	400-500m	300-400m
15-30 %	hills	wheeled skidder, downhill	500m	300-400m	300m
30-60 %	hills and mountains	wheeled skidder on skidding tracks, uphill skidding by winch, downhill skidding by gravity	300-400m	300m	250m
> 60 %	steep terrain	skidding by winch, downhill skidding by gravity	400m	300-400m	300m

A comparison of the road density values which are presently found in Austria and which are based on the Austrian Forest Inventory is also of interest. The public road network (except for highways) is included in these figures:

Type of ownership	Road density m/ha
Small privately owned forests	32
Medium and large-sized privately owned forests	26
State-owned forests	20

The proximity of the small private forests to the public road network largely explains their relatively high road density.

Finally, it should be emphasized that these theoretical mean values are rarely used in concrete planning. Practical planning depends on the terrain and the skidding conditions. Such values can, however, be advantageously used for comparison and control.

2.5 Logging area

The general planning of the road net usually covers a logging area for which a continuous transport system must be developed. When the planning work is started, the boundaries of this area are marked. On account of the gravity borders this is relatively simple in mountainous terrain. In flat and hilly terrain it is more difficult because the natural boundaries are less pronounced.

The forest road net should be developed in such a way as to take full advantage of gravity for skidding operations. This is especially important in view of the rising costs of energy. In many regions cable logging has resulted in opening up from above, since cable logging is easier uphill than downhill. Unless the terrain is extremely difficult the forest road net should be developed from its lowest points, the valleys should be opened up and the slopes should be subdivided into sections. If such a road network exists, uphill as well as downhill logging is possible. A forest road net which is based solely on cable logging and does not make full use of gravity is not the best solution in the long run.

2.6 Gradient and classification of terrain

Gradient	Classification of terrain	Kind of construction
0 - 30 %	flat and hilly terrain	simple road construction, few rocks or none, only minor damage to the environment
30 - 60 %	medium hilly and mountainous terrain	
60 - 80 %	steep terrain	difficult road construction, with a rising gradient; more and more rocks and damage; if the gradient exceeds 80 % the question should be asked whether road construction is really necessary
> 80 %	very steep terrain	

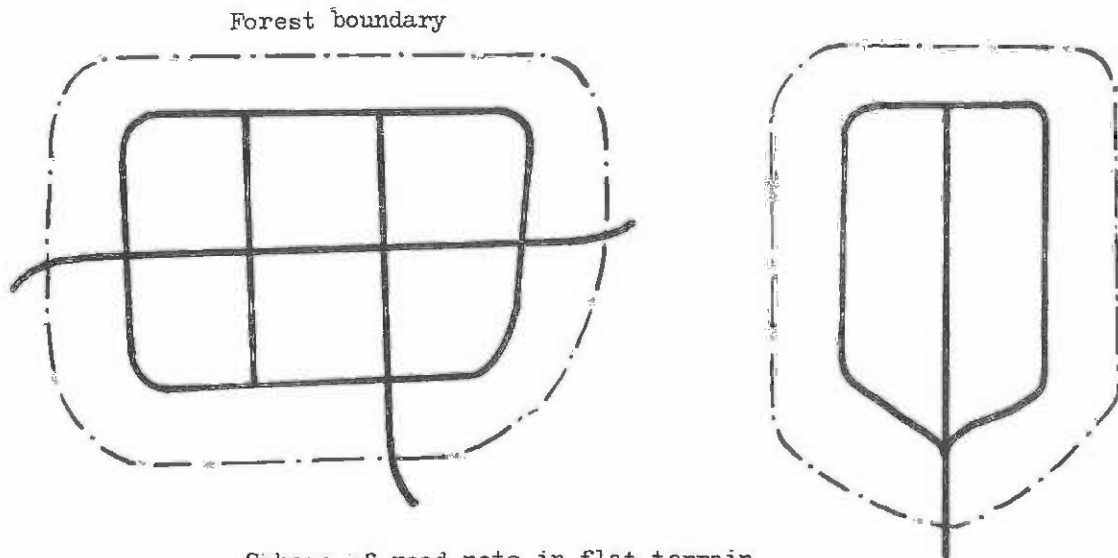
2.7 Systems of opening-up and routing

The forest road networks can have as much diversity as the terrain itself. Nevertheless, there are typical kinds of opening up and routing. The following are some examples:

2.7.1 Flat terrain

When a road network in flat terrain is planned, the spacing can be kept rather constant. Therefore practical results correspond to theoretical models fairly well.

Fig. 5 - Models of road spacing



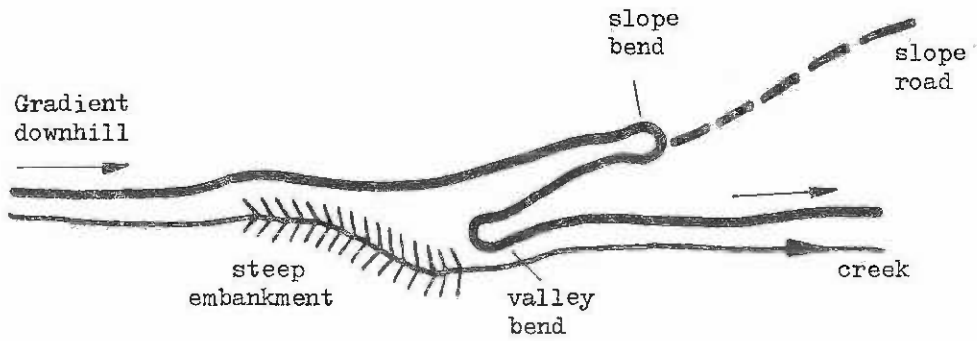
Scheme of road nets in flat terrain

2.7.2 Hilly and mountainous terrain

Valley roads

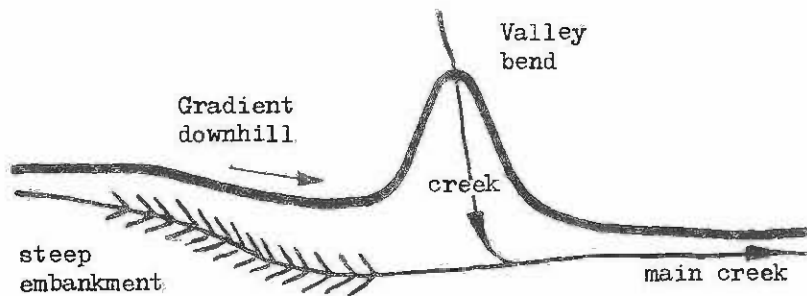
These are usually main roads which are designed to open up the bottom of the valley. The road should be routed along one bank, as bridges are expensive.

Fig. 6A - Routing of Valley Roads



Valley road in a steep part

Fig. 6B - Routing of Valley Roads



Valley road in a steep part

Slope roads

These start from valley roads and subdivide slopes. A distinction can be made between serpentine and diagonal systems.

Fig. 7A - Routing of slope roads

Serpentine system (on steep, long slopes)

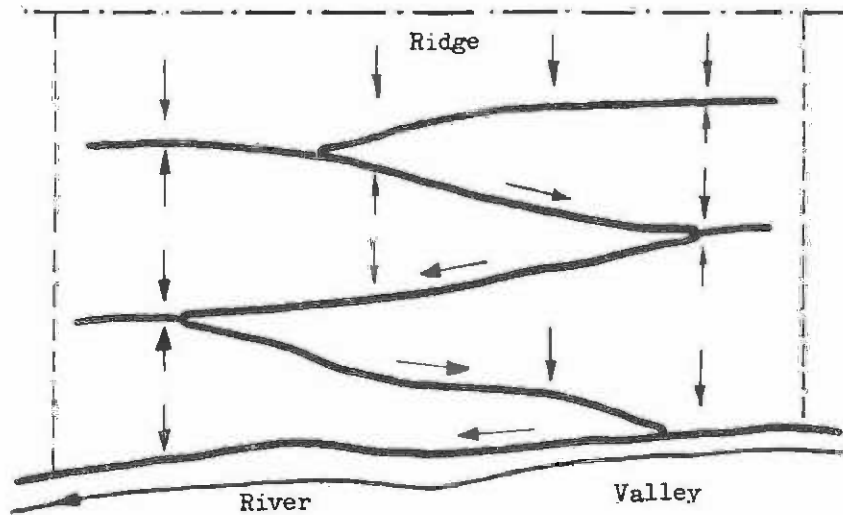
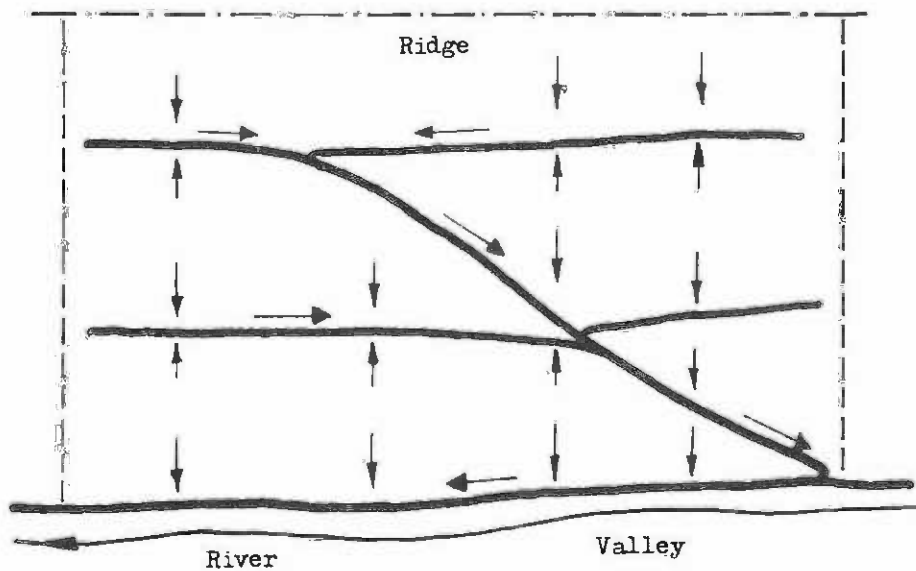


Fig. 7B - Routing of slope roads

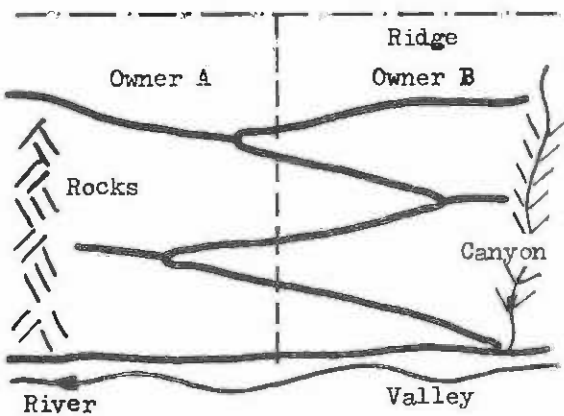
Diagonal system (on gentle slopes)



In planning these roads a special effort should be made to keep the number of bends to a minimum, since otherwise routing may result in badly designed road systems. The owners of small forests should cooperate (See Fig. 8).

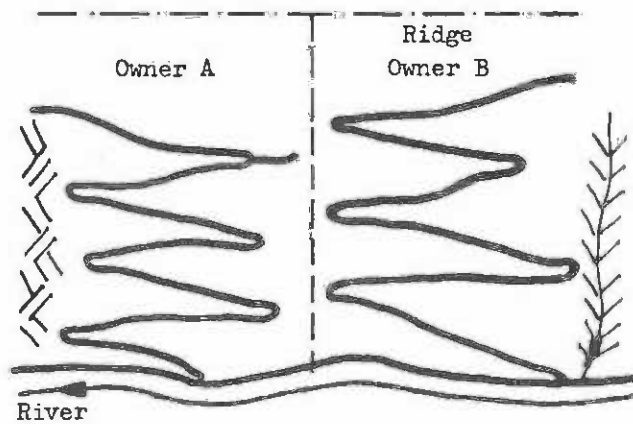
Fig. 8 - Bends in Road System

Cooperatively planned roads



C O R R E C T

Individually planned roads

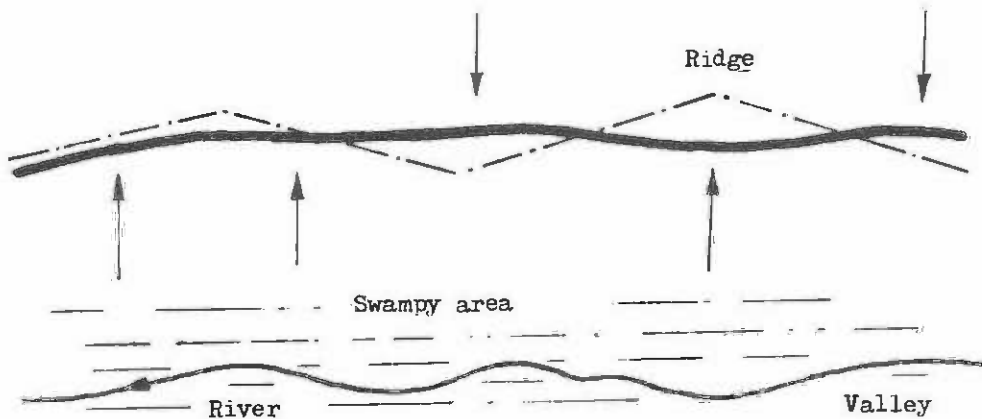


W R O N G !

Ridge roads

These are the cheapest type of road in hilly terrain. However, they open up the terrain to only a very limited extent. At present they are frequently used for cable logging. They should be planned only if the valleys are inaccessible or swampy.

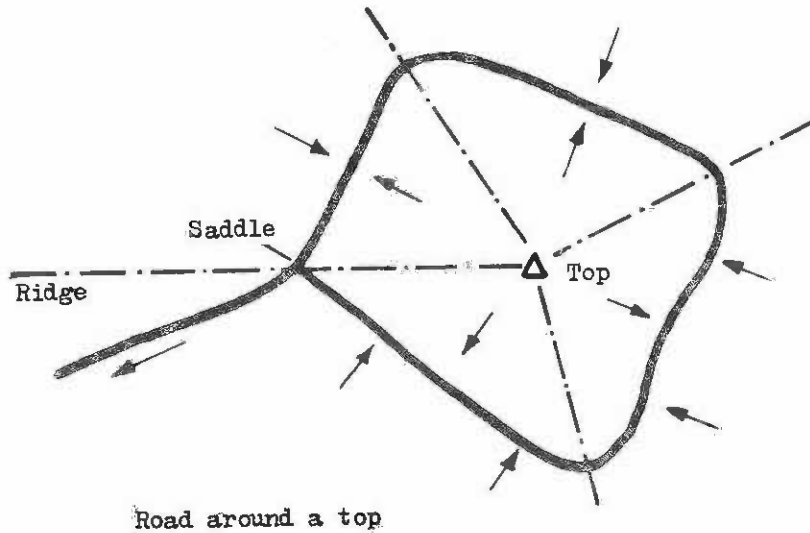
Fig. 9 - Ridge road



Mountain and hill tops

Circular routing, starting from a saddle, should be used to open up mountain and hill tops.

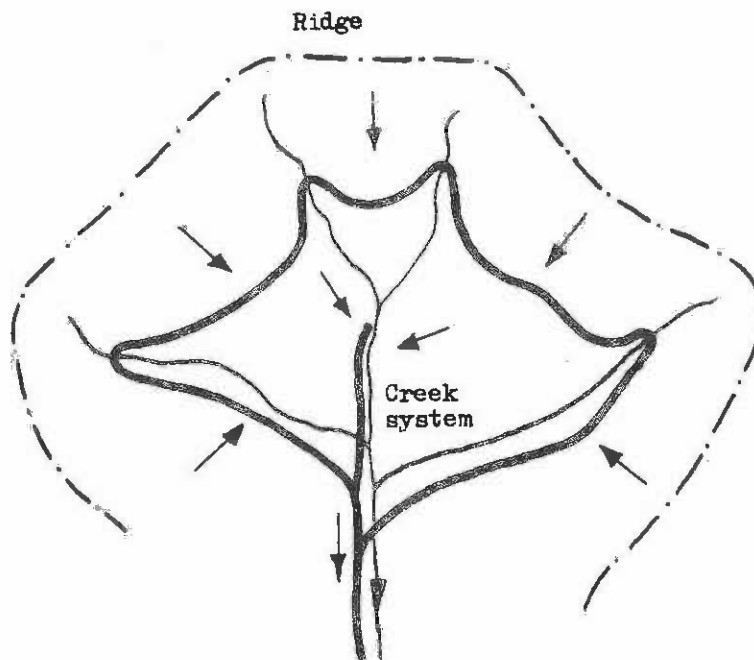
Fig. 10A - Circular routing for tops



Valley bottoms

These should be opened up by means of a circular road system, provided that the terrain is not too difficult.

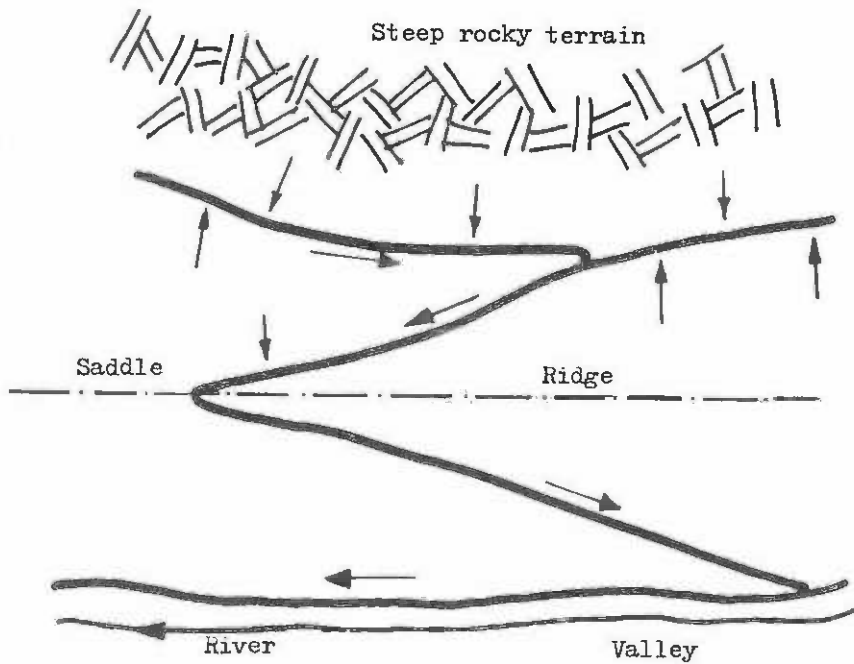
Fig. 10B - Circular routing for valley bottoms



Logging areas on ridges

These should be opened up by crossing the natural gravity boundary (ridge) and using the countergradient.

Fig.11 - Logging areas on ridges



3. PRACTICAL PLANNING WORK

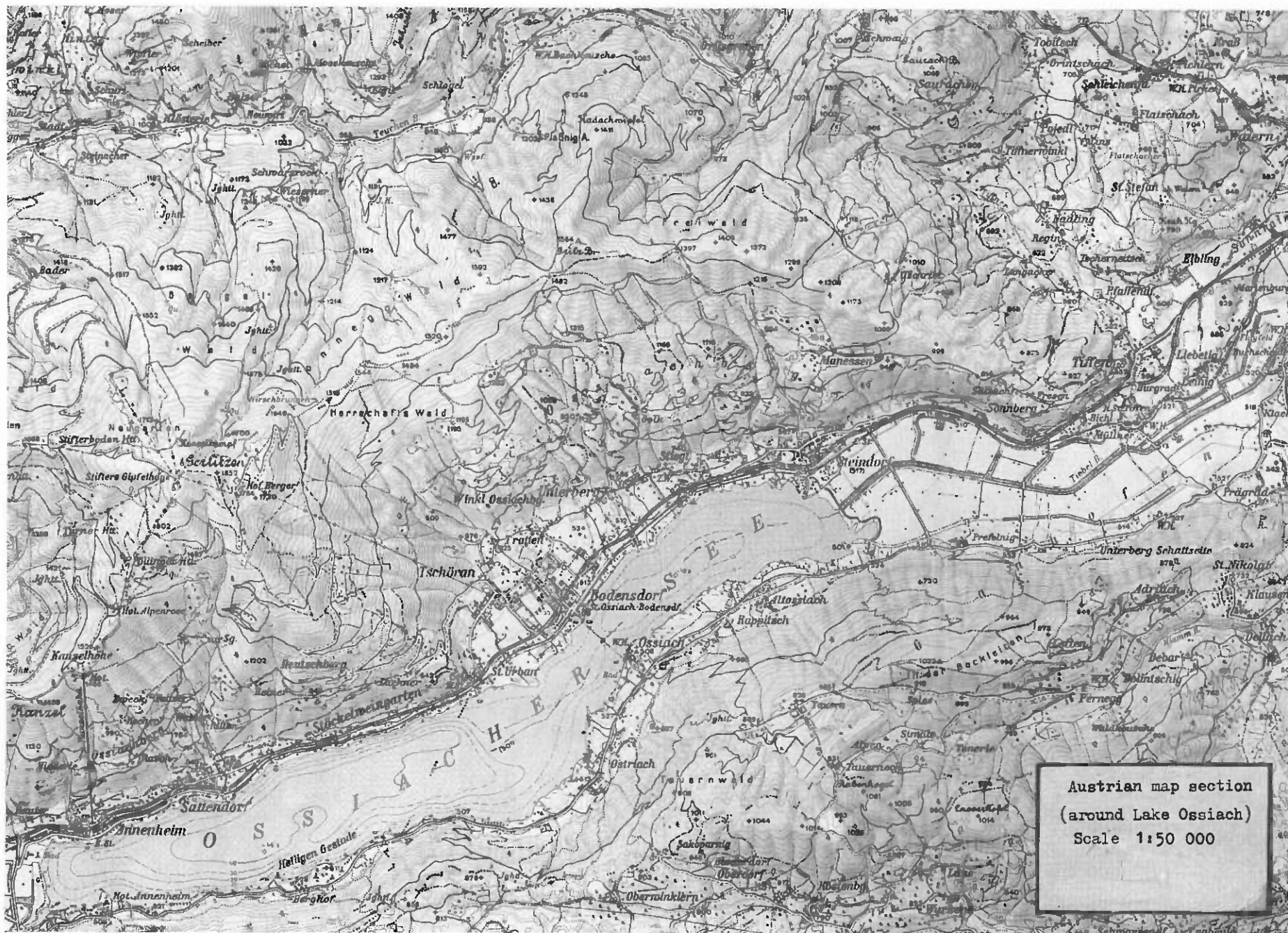
3.1 Preparation

Before surveying is started it is necessary to collect all available basic data on the area.

3.1.1 Maps

These are indispensable for road planning. In Europe there are very good topographical maps provided by the national survey authorities. They are based on the evaluation of aerial photographs. Their scale is between 1:25 000 and 1:50 000; the distance of the contour lines is 10-20 m. The example provided is an Austrian map, scale 1:50 000.

Modern forest maps usually have a scale of 1:10 000 (to 1:5 000) and are also based on the evaluation of aerial photographs.



Austrian map section
(around Lake Ossiach)
Scale 1:50 000

3.1.2 Aerial photographs

In developing countries aerial photographs are frequently the only means available for planning and orientation. For flat terrain they can be used as aerial photomaps which can easily be evaluated. For mountainous terrain orthophotography is used.

If new aerial photographs are available or if the taking of aerial photographs is planned, a photogrammetric evaluation is indispensable for the evaluation of forest maps.

3.1.3 Forestry and engineering data

These are location and size of the forest area, timber resources, increment, felling and forest management data, previous production (costs, prices, sales conditions), previous timber haulage; geological and hydrographic data, organization of forest road construction and availability of road construction material (e.g. gravel deposits).

3.2 Work method

3.2.1 Study of alternative routings for forest road networks

Detailed personal reconnaissance cannot be replaced by maps, aerial photographs or helicopter flights. It is therefore necessary to systematically survey the area with the help of local forest personnel and to compare terrain conditions with the available documents (maps or aerial photographs). The main points which have to be opened up are determined on the basis of existing roads and valleys when planning the new forest road net.

Main points

Positive main points are, for example, parts of the terrain that are to be opened up by forest roads, gentle slopes in steep terrain that may be used for hairpin bends, saddles, fords, gravel deposits and buildings.

Negative main points, such as swamps, unstable slopes and rocks, should be avoided.

Height measurements

The gradients are dependent upon distances between the main points. Even if accurate forest maps are available height measurements should be checked. If there are no maps available the most important points are identified on the aerial photographs and their heights are measured. In this way it is possible to get at least a rough idea of alternative routings.

Barometric altimeters

The Thommen Pocket Altimeter, made in Switzerland, is a small pocket instrument with an accuracy of ± 20 m and is suitable for general surveys.

The Paulin Precision Altimeter, made in Sweden, is a precision instrument with an accuracy of ± 5 to 10 m.

3.2.2 Draft plan

An optimum road system for the opening up of the terrain can be achieved only if the above-mentioned planning steps are taken (reconnaissance survey, height measurement and study of the various possible routes). It is advisable to explore the main routings of the terrain along the zero line by means of a clinometer and to conduct feasibility studies. Frequently corrections must be made or parts of the draft plan modified.

The main routes may be marked on trees.

3.2.3. General project

The general project embodies the results of the preliminary planning stage and consists of a written report and the plans.

Technical report This consists of the following:

description of the area under consideration and its previous management (wood harvesting and haulage);

improvements expected after opening up;

plan for opening up (principles of road net planning, optimum road spacing with regard to skidding techniques, description of the individual routings);

construction methods and organization;

general cost estimate: If there are no local empirical values available, the approximate costs may be determined according to the Sundberg formula:

$$C_i = 230 + 17 \times SL + 660 \times ST_i + 30 \times SL \times ST_i$$

C_i direct cost in US\$ per km for road standard i (supervision and overheads excluded)

SL inclination in percent of the major slopes of the hillsides

ST_i road standard, 0 for skidding trails, 1-2 for secondary roads,
3 for main and access roads;

estimate of economic returns;

summary: preferably in the form of tables (showing routings, distances, costs, time schedule).

Plans These would consist of the following:

general survey map with a scale of 1:50 000;

location survey map with a scale of 1:10 000;

general cross-section profiles 1:50;

general construction systems (culverts, bridges).

If there are no maps or plans available, the intended road net should be drawn on aerial photographs.

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Angledozer excavating soft rock. (Photo E. Pestal)



Traxcavators work more carefully than angledozers. Their use is promoted by environmental organizations. (Photo E. Pestal)

DETAILED PLANNING OF FOREST ROADS IN PRACTICE

by

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1. GENERAL REMARKS

A forest road is part of a general project and has to be planned in detail before construction can be started.

If forest roads are constructed manually, as is the case in areas with underemployment and low wage costs, the relatively high expenditure for detailed planning is justified. The so-called "classical method" of road planning is applied (with staking out of the centre-line, levelling, cross sections, mass balancing and so forth).

For mechanized road construction, much simpler planning suffices since machine output is high and earth mass movements need not be exactly predetermined. Simpler planning must not, however, be confounded with careless planning. Gradients have to be determined as accurately as for the classical method.

Since mechanized road construction is much more frequent nowadays, simple planning for mechanized construction will be discussed.

Detailed planning may be divided into two stages:

a) Practical routing

Gradients and directions of the forest roads are determined in the terrain. Here, available technology must be taken into account.

b) Elaboration of a detailed project

This contains all the information necessary for authorization and financing as well as for construction and its supervision.

2. PRACTICAL ROUTING

Forest roads are almost always routed in the terrain, the routing method depending on the terrain.

2.1 Routing on level ground

The centre-line polygon is pegged out. Several variants have to be studied before the best route can be found. Once the polygon has been determined, the main points of the circle bends are found by means of circle tables; these are subsequently staked out.

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The zero-line is a free polygon with a gradient that is adjusted to the terrain. It also represents the cutting line between the road bed and the slope.

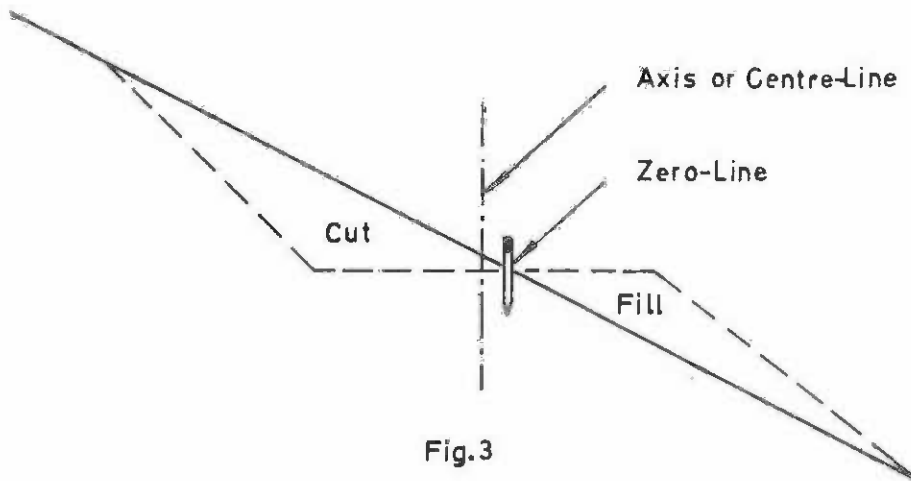


Fig.3

This method, like any other one, requires practice and experience. The zero-line can be quickly and accurately pegged out by means of a clinometer. The individual points of the polygon are staked out at distances of about 20 to 30 m. In almost all cases the zero-line provides a sufficiently accurate guideline for the mechanized construction of forest roads on slopes. In standard cases the centre-line is not additionally staked out. Because of the mass surplus required in mechanized road construction, the centre-line is mostly situated within the cut. (see Fig. 3). In difficult sections of the route, such as bridges, embankments or long cuttings in ridges, the centre-line is also staked out in order to avoid errors in direction.

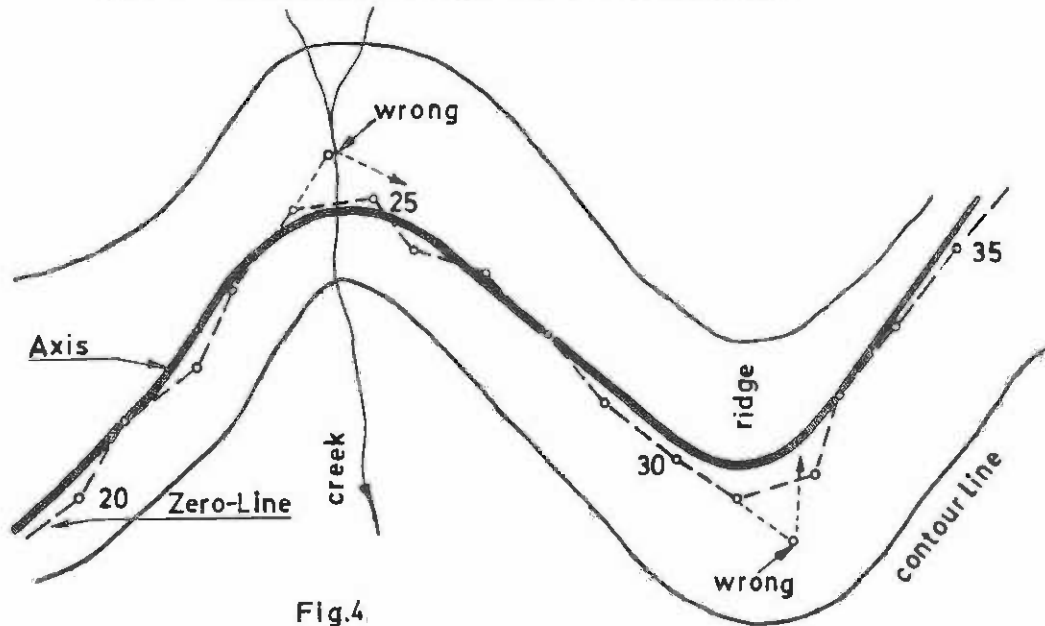
2.2.1 Routing rules

The zero-line can be staked out only with exact knowledge of the required gradients. One or two variants have to be studied before the correct route can be found.

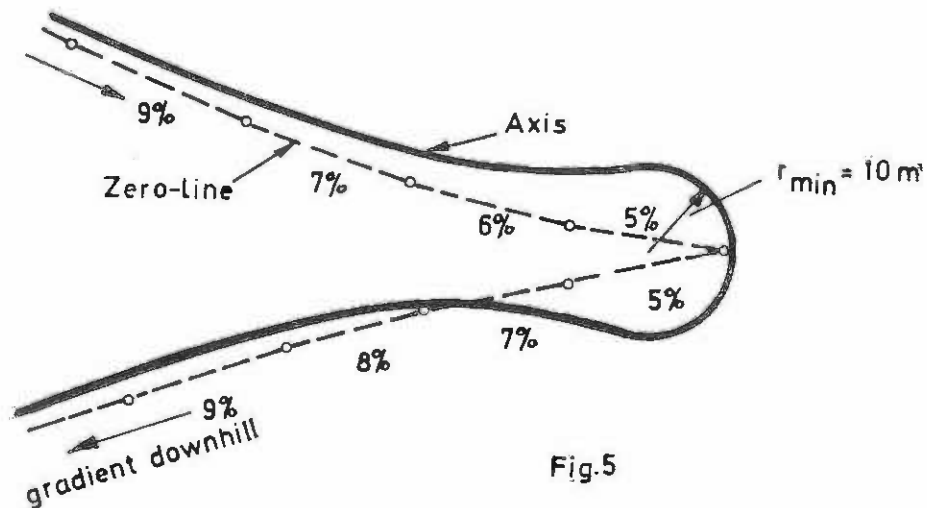
The gradient between any two main points should be kept fairly constant. The maximum surveying deflection tolerated in case of gradient changes in the polygon is two to three percent.

The zero-line has to be staked out as closely as possible to the future centre-line in order to avoid major differences in gradient between the two lines (ridges and creeks: see Fig. 4).

Zero-Line and axis on a slope



In such bends, deflections between zero-line and centre-line cannot be completely avoided, so the zero-line is longer than the axis of the forest road after construction. Therefore, the zero-line gradient must be reduced. If a hairpin bend is required the following routing process is recommended.



Long distances are routed in individual sections, always proceeding from the fixed main points to the variable points. Both uphill and downhill road surveys are possible.

The routing expert carrying the clinometer walks ahead of his working team and looks back to the surveying rod from suitable measuring points.

2.2.2 Standard forest road surveying method in Austria

On the first walk the following steps are taken: the gradient required is checked, a detailed reconnaissance of the terrain is carried out, a pre-preliminary zero-line with the longest possible sight lines is fixed, trees are marked (by means of plastic tapes, cardboard labels, etc.).

If the gradient corresponds fairly well to the actual conditions detailed routing is possible on the second walk.

In case of major deviations the height difference is measured (simple stepwise measurement with the clinometer) and on the way back a second zero-line is determined with the corrected gradient. Then the zero-line can usually be pegged out in detail.

After detailed routing, the zero-line polygon is surveyed by means of a pocket compass and a measuring tape. If terrain conditions are uneven and rock components vary, model cross-sections are measured with the clinometer and the rock component is estimated.

2.2.3 Form for routing a forest road

Peg		14 cm					14 cm		Remarks and Sketches
		from	to	Gradient g (%)	Distance d (m)	Bearing b (°)			

Fig. 6

2.2.4 Instruments

Instruments for routing zero-lines and surveying are as follows:

Clinometers: free-hand instruments; accurate, strong and reliable.
MERIDIAN (Switzerland) and SUUNTO (Finland)

Pocket compasses: free-hand device with or without liquid shock-absorber.
BEZARD (Germany): various models that allow direct mapping.
MERIDIAN (Switzerland): various models, prism reading, accurate.
SUUNTO (Finland): closed case, light-intensive and accurate.

Measuring tapes: average length 30 m, stainless steel or fibre-glass.

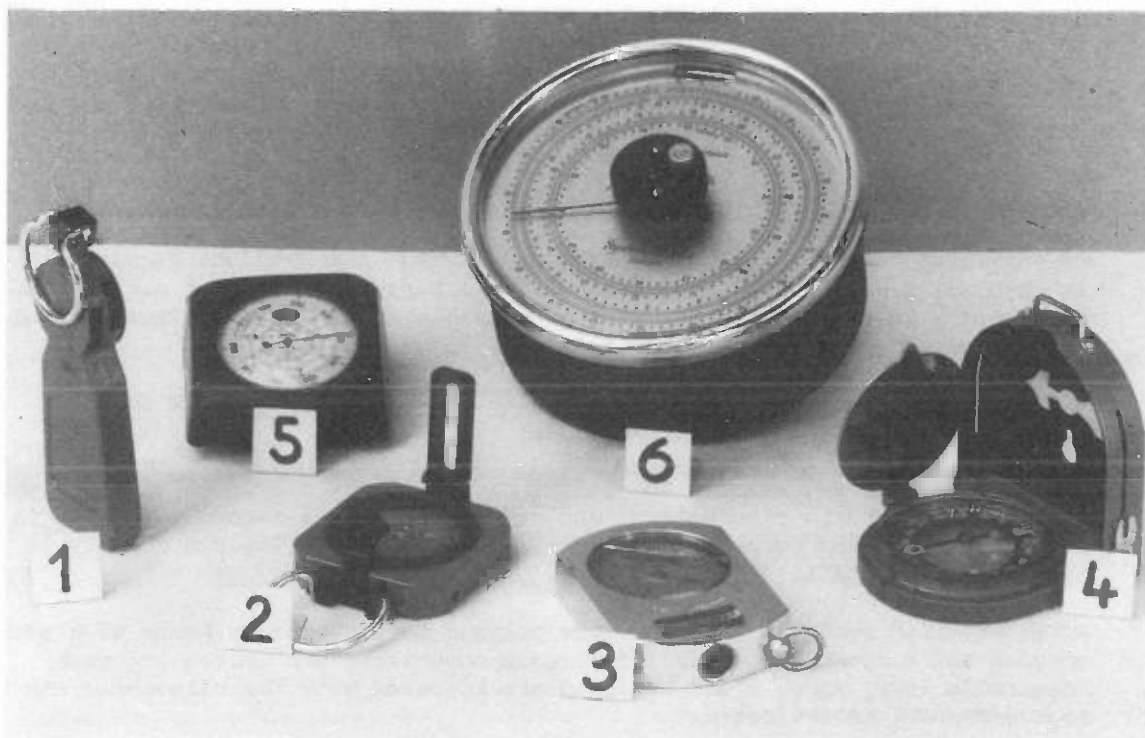


Fig. 7

Fig.7 Instruments for surveying forest roads:

- | | |
|------------------------|-------------------------------|
| 1. MERIDIAN clinometer | 4. BEZARD compass |
| 2. MERIDIAN compass | 5. THOMMEN pocket altimeter |
| 3. SUUNTO compass | 6. PAULIN precision altimeter |

2.2.5 Personnel and time requirements

The expenditure for each kilometer of detailed variants studied and for the staking and measuring of the zero-line depends largely on the accessibility of the road project, on the forest stand and on the terrain conditions.

The following values can be given as a guide:

<u>Terrain condition</u>	<u>Personnel required</u>	<u>Time required</u>
Normal (forests in moderate climate, easy terrain)	1 engineer 3 workers	5-7 hrs/km 15-20 hrs/km
Difficult (forests in tropical areas, difficult terrain)	1 engineer 5-6 workers	8-12 hrs/km 40-60 hrs/km

3. ELABORATION OF THE DETAILED ROAD PROJECT

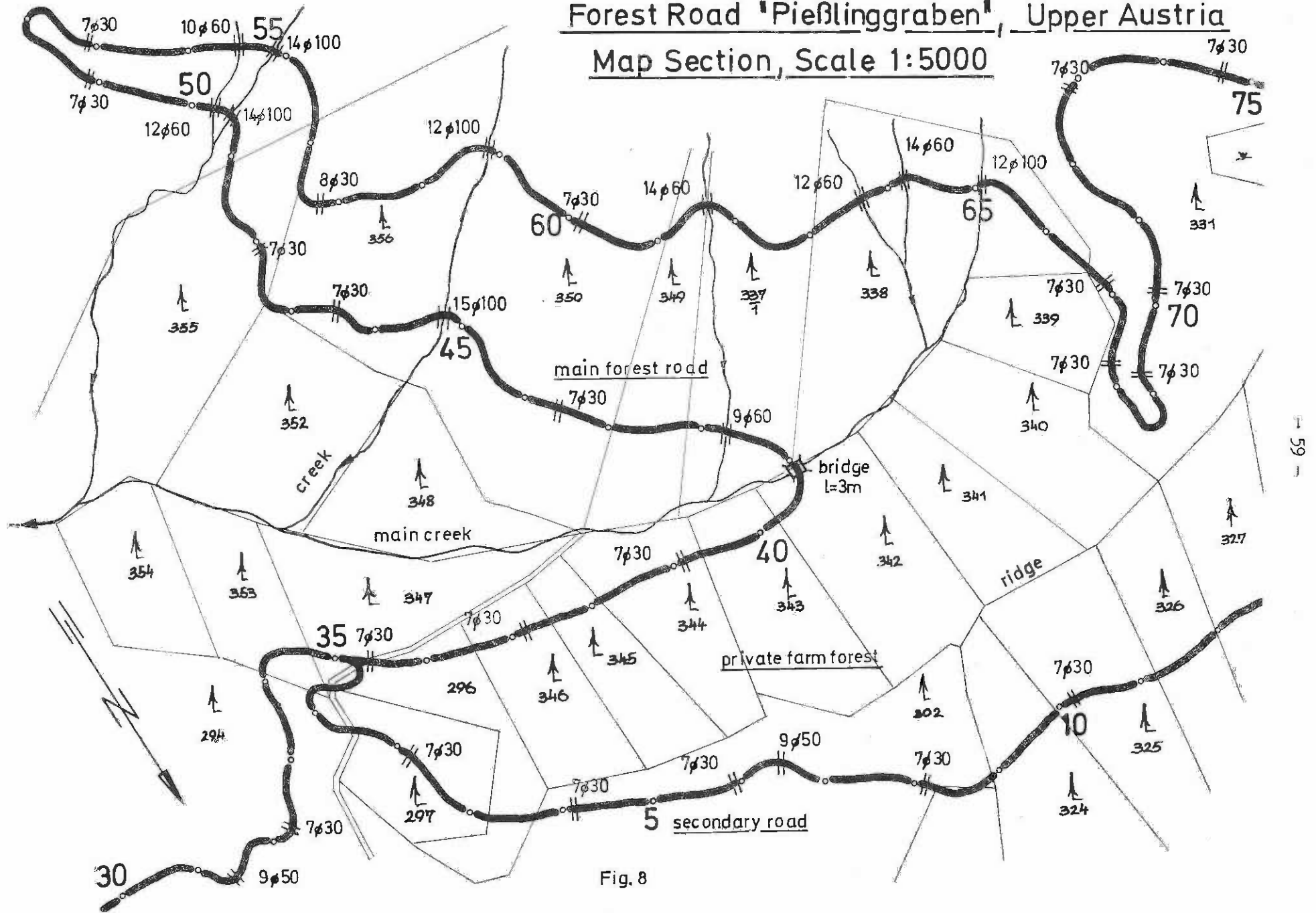
The layout of the detailed project of a forest road usually resembles the general one. It consists both of graphic plans and a written section containing the technical report and the cost estimates.

3.1 Plans

A survey map (scale 1:50 000 to 1:25 000; or one inch to a mile, to one inch to half a mile) shows the situation of the planned forest road within the transport system already existing.

Forest Road 'Pießlinggraben', Upper Austria

Map Section, Scale 1:5000

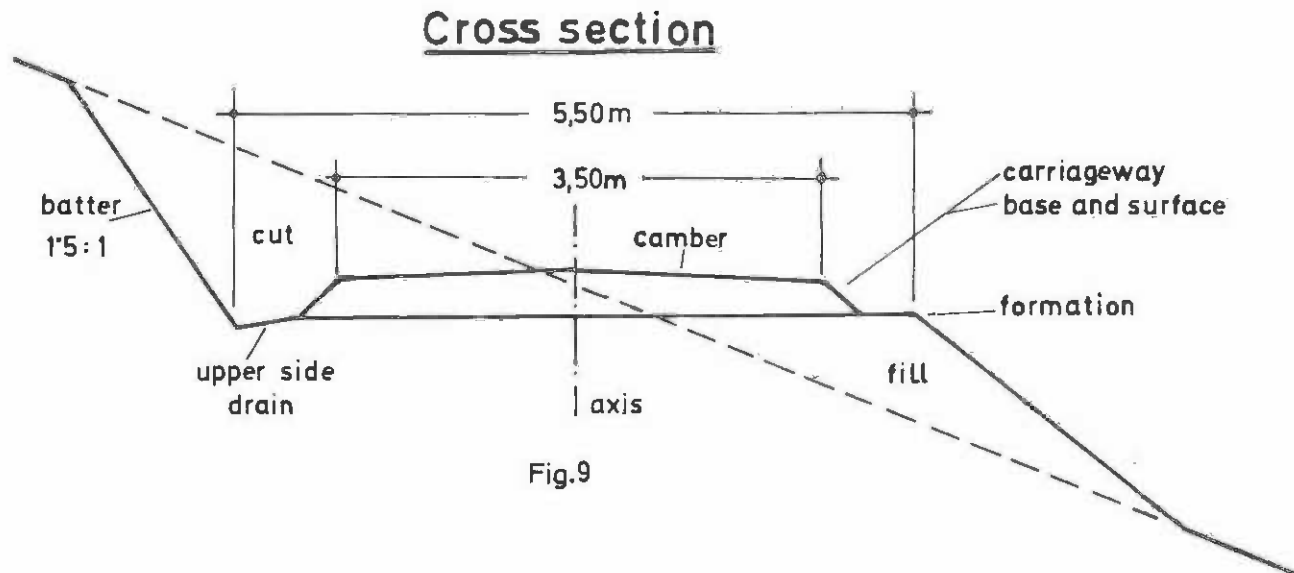


The map section scale is 1:1 000 to 1:5 000; or one inch to 100 feet, to one inch to 400 feet.

The surveyed zero-line polygon is transferred on to transparent paper by means of a protractor and rounded with the help of the centre-line. By fitting the checking points this line is transferred to the map and subdivided into sections of 100 m (or 100 yds) each.

All concrete culverts, construction works (e.g. walls or bridges), landings and peculiarities of the terrain (rocky or sliding terrain) are marked on the map with simple symbols.

If required, general cross-sections of the planned road (which are different for earth and rock) have to be elaborated (scale 1:50 or one inch to four feet; see Fig. 9).



A drawn longitudinal profile of the forest road is usually not prepared. A table listing the longitudinal and gradient conditions is sufficient (written longitudinal profile, see Fig.10).

3.2 Written part of the detailed project

3.2.1 Technical report

This should give the following information:

- description of the area (situation, geological conditions, shape of the terrain, area, forestry conditions and so on);
- existing conditions (logging methods, transport, costs);
- proposed management after opening-up (methods of logging and silviculture, advantages);
- description of the system planned;

- construction (machinery equipment, methods and organization);
- list of distances and gradients (for major projects several roads are contained in a table);
- written longitudinal profile

Peg	Station (hm)	Distance d (m)	Gradient g (%)	Remarks

Fig. 10

3.2.2 Cost estimates

In spite of big differences among the various forest areas of the world, the costs for mechanized forest road construction are fairly similar. Within certain limits, the costs for mechanized earth movement and transport are therefore comparable.

The question of profitability is however different for different working methods. In countries with low wage costs (daily earnings between US\$ 1 and 5) and underemployment, modern construction machines are relatively expensive. In such countries it is economic to carry out minor earth movement by hand and leave only heavy and major works to machines. This combined working method was formerly also applied in Austria. Big stumps must be preblasted to save machine time. Batters can be constructed manually.

Preparatory work

Clear-cutting the route

If the timber can be used, the cost of clear-cutting should not be allocated to construction expenses. Before angledozers are employed, all branches and bushes have to be removed from the route and deposited at the downhill edge of the road bed.

Stump blasting

If explosives are available it is economic to clear the zero-line area by blasting stumps with a diameter of more than 50 cm.

Costs according to diameter: US\$ 3 - 5 per stump.

Drains

In wet areas these should be excavated before employing machines.

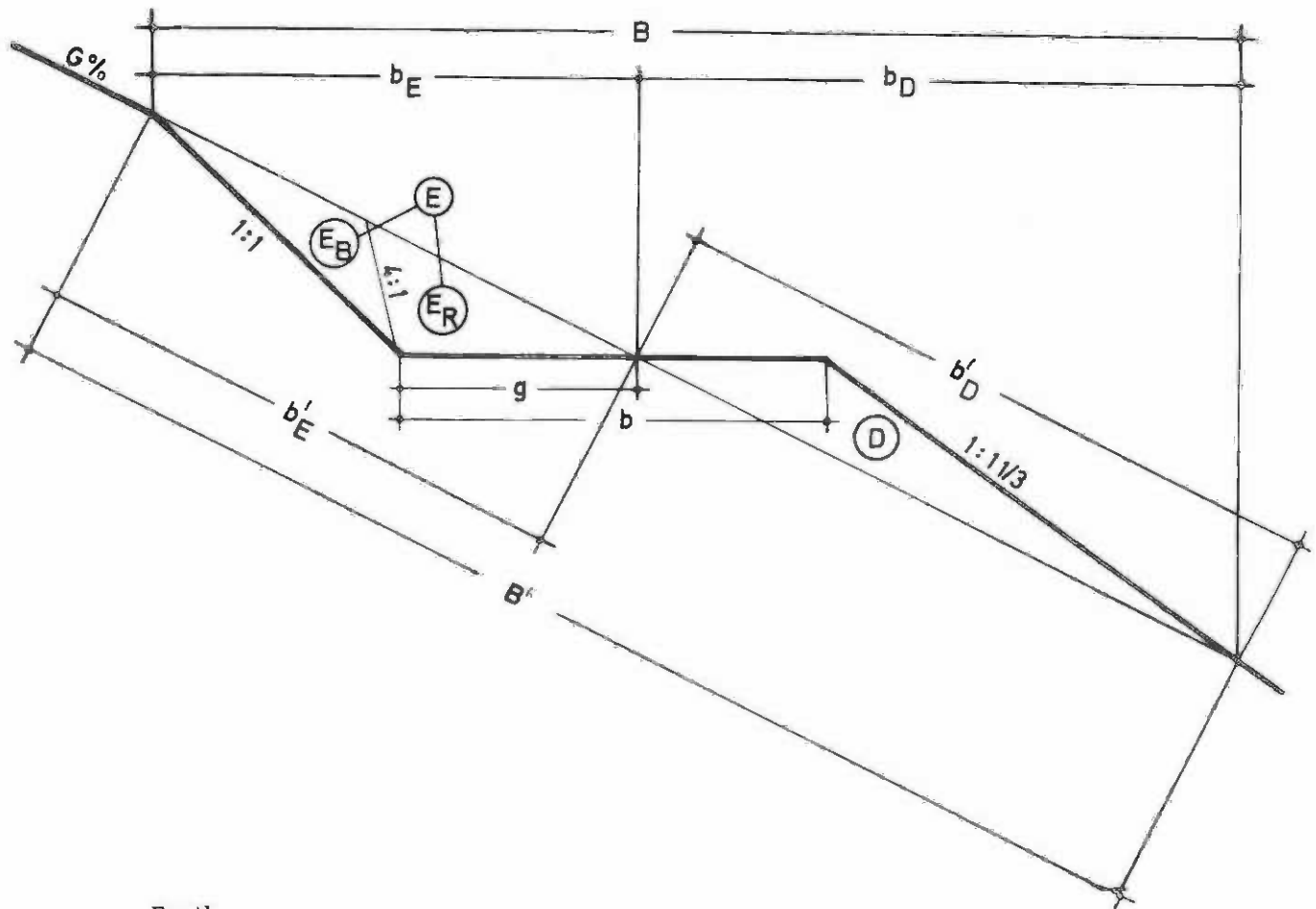
Costs depending on sizes range from about US\$ 0.5 to 1.5 per meter of drain.

Earth movement

The bulldozer (equipped with A or S blade) is the most important machine in forest road construction. Costs are calculated according to various methods:

- a) by calculating the cut volume from gradients and cross-sections. Cross-section profiles are easy to determine for various road widths and gradients. Examples according to Hafner (see Figs. 11 and 12). Costs of earth movement are calculated on the basis of the total volume produced and the costs per unit (m^3 or cubic yards);

Cross section (slope profile) - Earth
Example for $b = 4$ m, (acc. to HAFNER)

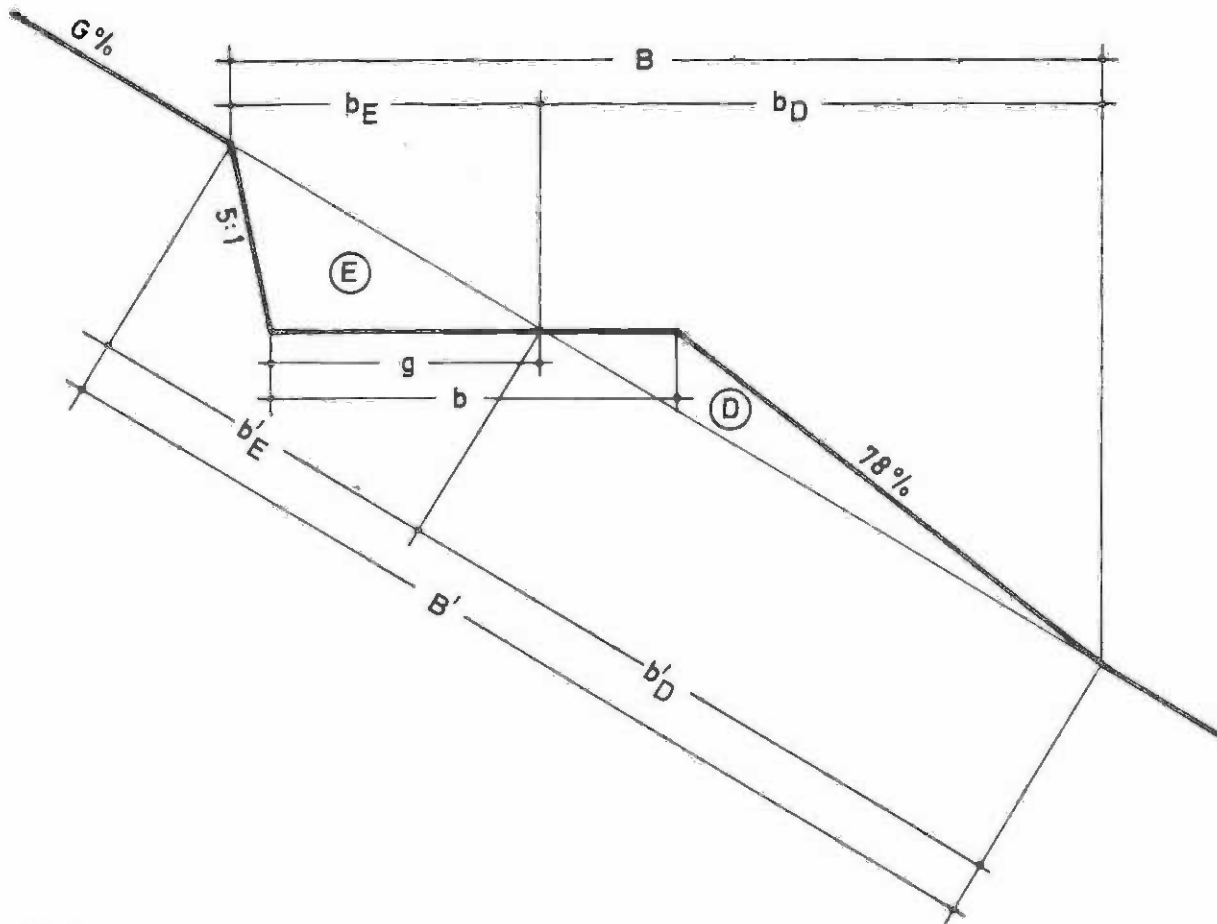


Earth

G %	g m	b m	E m ³ /m	E_R m ³ /m	E_B m ³ /m	b_E b'_E m	b_D b'_D m	B B' m
20	2.70	5.30	0.91	0.77	0.14	3.35 3.40	3.65 3.70	7.00 7.10
30	2.70	5.30	1.56	1.18	0.38	3.85 4.05	4.30 4.50	8.15 8.55
40	2.30	4.40	1.76	1.17	0.59	3.85 4.15	4.50 4.85	8.30 9.00
50	2.30	4.20	2.64	1.51	1.13	4.60 5.15	5.80 6.50	10.40 11.70
60	2.40	4.10	4.32	2.03	2.29	6.00 7.00	8.75 10.20	14.80 17.20
70	2.70	4.00	8.50	3.09	5.41	9.00 11.00	19.70 24.00	28.70 35.00

Fig.11 - Calculation of Soil Mass

Cross section (slope profile) - Rock
 Example for $b = 4$ m, (acc. to HAFNER)



Rock

G %	g m	b m	E m ³ /m	$\frac{b_E}{b'_E}$ m	$\frac{b_D}{b'_D}$ m	$\frac{B}{B'}$ m
40	2.50	4.50	1.36	2.70 2.95	4.00 4.35	6.75 7.30
50	2.50	4.20	1.74	2.80 3.10	4.75 5.30	7.55 8.40
60	2.60	4.00	2.30	2.95 3.45	6.20 7.25	9.20 10.70
70	3.00	4.10	3.66	3.50 4.25	10.90 13.30	14.40 17.60
80	4.00	4.00	7.62	4.80 6.10	00	5 + 6.5 +
90	4.00	4.00	8.78	4.90 6.60	00	5 + 7 +
100	4.00	4.00	10.00	5.00 7.10	00	5 + 7.5

Fig. 12

- b) by estimating the average soil or rock mass per unit of distance (m^3/m or cubic yards per yard) according to the average sloping ground.
- c) by estimating the machine costs per unit of distance (m or yards) on the basis of local empirical data.

Average production and cost of medium angledozers (weight 12-16 t) constructing a secondary forest road in Austria

Machine cost per productive hour US\$ 27-33

Terrain conditions	simple	medium	difficult
Average slope of terrain in %	30	50	70
Output (m/h)	12-15	9-12	6-9
Cost per m in US\$	2-2.5	2.5-3.5	3.5-5
Cost per m^3 in US\$	1	0.9	0.7

The motor grader has a total weight of 10 to 14 tons. It is a profitable machine for draining, shaping and battering on suitable soils. Its output depends on the gradient, the volume of earth and amount of work, and amounts to approximately 50 - 100 m per hour.

Costs amount to about US\$ 0.4 to 0.7 for each linear metre of earth movement.

Rock blasting

Drilling is done by drilling machines or hand-carried, compressor-powered machines. Various methods and machines are available.

The rock component is estimated as a percentage of the individual slope profiles in routing and calculated as part of the overall volume. The costs of rock blasting depend on gradients, the type of rock and rock component, and the method chosen. Costs come to about US\$ 3-5/ m^3 .

Drainage

Forest roads with a gradient of up to 9 percent are drained by means of drains on the upper side of the route and by concrete culverts. In industrial countries prefabricated concrete pipes are available at relatively low prices and are transported to the construction sites by lorry.

If prefabricated concrete pipes are not available, concrete culverts can be made at the construction site. Even old barrels welded together can be used. If culverts cannot be fabricated the upper side ditch must be drained by simple surface water bars.

These are made of timber, concrete or steel, and protect the road against surface erosion. In subtropical and tropical forest areas with high annual rainfall, drainage has to be particularly careful to avoid erosion and destruction of the base.

The following weights and prices apply for concrete culverts produced in Austria:

Diameter (cm) Length 1 m	Concrete pipes for culverts Weight (kg/m)	Cost on the road (US\$/m)
30	100	5.-
50	270	11.-
60 heavy load	610	32.-
80 heavy load	1 000	45.-
100 heavy load	1 700	65.-

In Europe, concrete culverts are usually laid by hydraulic excavators; costs depend on diameter and terrain conditions. Costs for the well and apron of a concrete culvert amount to about US\$ 20 - 30 per piece on an average.

Prefabricated concrete culverts are usually produced up to a diameter of only 1 metre. A compromise solution between culverts and bridges is the use of prefabricated corrugated steel sheets. These are produced in various sizes for different cross-sections and are fitted together at the construction site. Costs are relatively high; in Austria they amount to about US\$200-500 per linear m for culvert diameters of 1.5 - 3m.

Base

On loam and clay soils with low bearing capacity, the expenses for the base material may be up to 60 percent of the total road construction costs. The amount of base material depends on the bearing capacity of the soil, the road width, and the quality of the base material itself.

The following data were empirically determined for Austrian conditions:

Requirement for base material if b = 3.50 m

Subgrade soil	clay/loam	loam/sand	sand/stone
Bearing capacity	low	medium	high
Base-material (m ³ /m)	2.0 - 2.5	1.5	0.5 - 1.0

It is important to obtain the base material from places as close to the construction site as possible, since transport accounts for the biggest percentage of total base construction costs. If a gravel pit is found along the road to be constructed, construction costs can be significantly reduced. The material is loaded onto heavy lorries by traxcavators.

Average loading output is about 40 - 50 m³ per hour and costs come to about US\$ 0.5 - 0.8/m³.

Normal loading capacity of two or three-axle lorries is 6 - 10 m³ per lorry. Transport costs in Austria presently amount to about US\$ 0.4 - 0.5 per m³ and km for distances of between 10 and 20 km.

The base material is dumped on the road bed and shaped by means of small angledozers or motor-graders. The costs are about US\$ 0.4 - 0.5 per m³.

Final grading and compacting of the base and surface is done with motor-graders and vibro-drums.

Machine	Output (m/h)	Cost (US\$/m)
Grader	150 - 250	0.2 - 0.3
Roller	80 - 100	0.3 - 0.4
	Total	0.5 - 0.7

Other costs

Bridges, big culverts and other constructions are calculated separately. Planning and supervision account for 5 percent of total costs. Unforeseen costs should be allocated 10 percent of the total costs.

Form of cost estimate

	Items	Units	Price per unit	Costs
1	Preparation (felling and clearing, blasting of stumps, ditches for drainage)			
2	Formation			
3	Rock blasting			
4	Drainage (Culverts, waterbars)			
5	Construction of the base (Gravelling, grading and compacting)			
6	Structures (Bridges, retaining walls)			
7	Planning and supervision			
8	Unforeseen expenses			

Fig. 13

Summary of forest road costs in Austria

(Average data derived from experience in
US\$ per m)

Type of road	Bearing capacity of subgrade		
	low	medium	high
A. main road	18-22	12-14	8-10
B. subsidiary road	15-18	10-12	5-7
C. skidding road	1-3		

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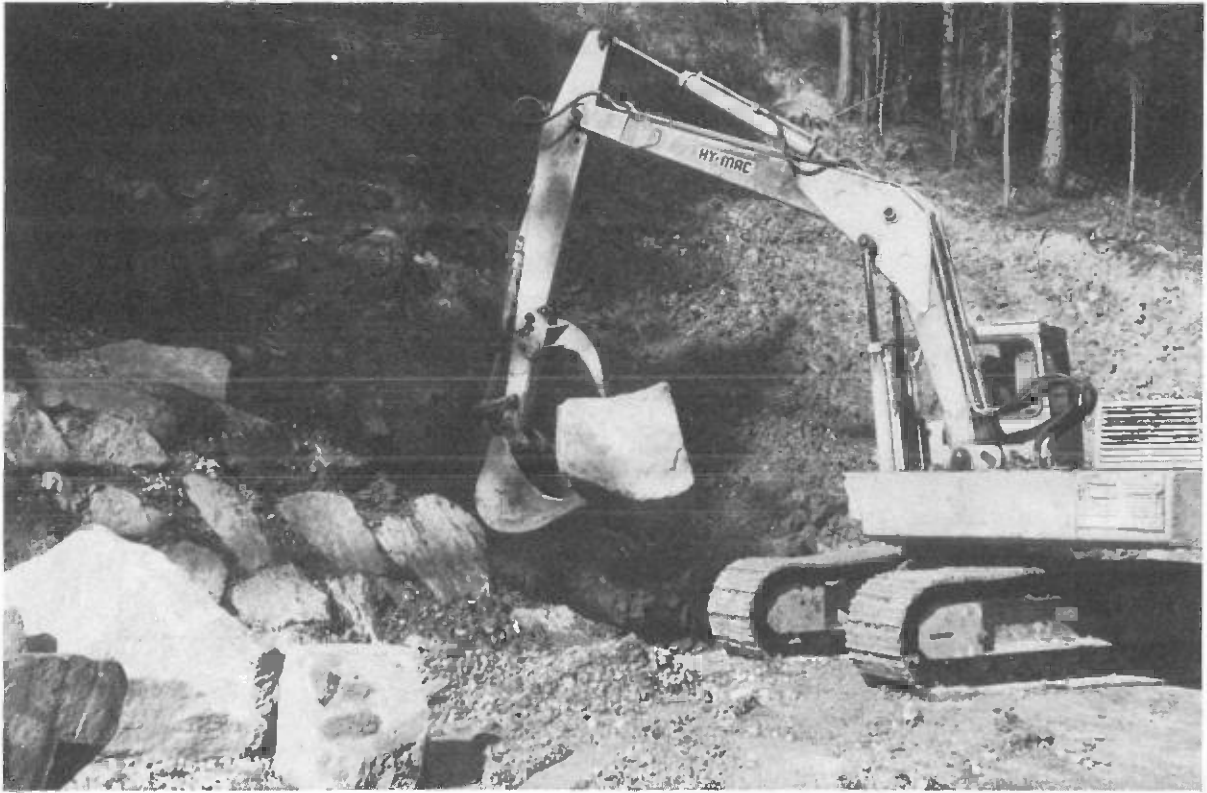
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Construction of a dry stone retaining wall by means of an excavator.
(Photo O. Sedlak)



Cleaning a mountainside drain and regrading an existing forest road.
(Photo R. Heinrich)

MACHINE INPUT IN FOREST ROAD CONSTRUCTION
IN MOUNTAINOUS AREAS

by

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1. INTRODUCTION

Modern forest road construction by the Chamber of Agriculture started nearly 23 years ago in the province of Lower Austria, which is the largest federal province in the north-east of Austria. These roads were built mostly to serve the owners of small private forests (up to 400 ha) on hillsides and in mountainous areas. Since those times, machine input has permanently and considerably changed. In the beginning modern forest road construction became possible initially with the advent of angledozer. These machines were military angledozer left over from the second world war period. Austrian foresters saw the advantages of these machines for opening up the forests by mechanized road construction and developed new methods of planning, appropriate for the enormous construction capacity of these angledozer.

2. DEVELOPMENT OF FOREST ROAD CONSTRUCTION

At first, small or medium-sized angledozer (from 8 - 10 t) were used for road formation, for excavation of the gravel needed for road basing and for rough shaping. Battering, constructing culverts, digging drains, and loading basing material for the road bed required manpower. Basing material had to be moved by horse-drawn carts or farm tractors. The equipment and road construction crew consisted of an angledozer and driver, up to 20 unskilled workers, a number of carts and farm tractors and in rocky terrain one or two compressors operating pneumatic drills. Nowadays economic considerations require more rapid opening up of forests. With the advance into increasingly difficult terrain, lack of manual labour, caused by migration to industrial zones, a high degree of mechanization in road construction methods, the share of equipment costs has now gone from about 50 percent to about 95 percent of the total road construction costs.

3. PRESENT SITUATION

At present different kinds of road construction equipment are used depending on the terrain and geological factors:

Situation A

Terrain conditions not difficult, slopes not too steep and with a low rock component:

Angledozer	16 t, 120 kw	formation, battering
Light excavator	7 t, 50 kw	roadside drains, small culverts
Grader	12 t, 100 kw	drains (V-section), shaping
Foreman or skilled worker	1	managing work and equipment, blasting operations
Unskilled workers	1 - 2	drilling, assisting operators

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If necessary:

Compressor, operating 1-2 pneumatic drills; air output 2-2.5 m³/min; 5.9-7.8 bar

0.8 t, 20 kw minor blasting operations

Heavy excavator

18 t, 50 kw big culverts, protective constructions consisting of large rocks

Situation B

Difficult terrain, steep and rocky slopes, hairpin bends required:

Heavy traxcavator

17 t, 110 kw formation, battering, filling and depositing blasted debris

Light excavator

7 t, 50 kw roadside drains, small culverts

Grader

12 t, 100 kw drains (V-section), shaping

Heavy excavator

18 t, 50 kw hairpin bends

Rock drill mounted on crawler tractor; air output 8.5 m³/min.; 9.8-14.7 bar

15 t, 95 kw major blasting operations

Foreman

1

managing work

Skilled workers

1 - 2

blasting, protective constructions

Unskilled workers

2 - 3

drilling, assisting operators

Situation C

For basing and surfacing of the forest road:

Heavy traxcavator or

(17 t, 110 kw) loading and spreading rock

Heavy excavator

(18 t, 50 kw) and gravel

Heavy trucks (3-axle)

25 t, 110 kw transporting

Traxcavator

11 t, 65 kw grading the base

Grader

10 t, 70 kw grading the surface

Vibratory roller

9 t, 95 kw achieving high-degree compaction of the road

4. ESTIMATING ROAD CONSTRUCTION OUTPUT AND COSTS

For rough cost estimates, a few examples are given below:

Situation A

With a construction output of 80-200 m per working day (10 hours) the cost would amount to about US\$4 700 - US\$16 700 per km; averaging US\$6 700.

Situation B

With a construction output of 30-80 m per working day (10 hours) the cost would amount to about US\$16 700 - US\$33 300 per km; averaging US\$23 300.

Situation C

With a construction output of 170-250 m per working day (10 hours) the cost would amount to about US\$7 300 to US\$16 700 per km; averaging US\$10 700.

CONCLUSIONS AND RECOMMENDATIONS

The use of heavy traxcavators and excavators instead of angledozers in forest road construction has proved to be of great advantage. If terrain conditions are difficult, filling and depositing of blasted debris can be done by these machines carefully enough to avoid damaging the environment below the forest roads. It should be stressed that the same forester should be responsible for the planning and supervision of forest road construction.

Forest road construction will be both economical and protective for the landscape if the crew consisting of a foreman, operators, skilled workers and the forester become a well trained and experienced team.

The permanent training of this crew should be one of the main tasks of the responsible forester. High efficiency and working speed naturally may create a great temptation for the forester and his crew to disturb the landscape and seriously damage natural resources. Therefore, they should always bear in mind that road construction is no end in itself. Its purpose, on the contrary, is to support good forestry practice.

6. SUMMARY

Ideally, instead of one all-purpose machine, a combination of more specialized machines should be used to construct forest roads. This fact will require efficient planning, good supervision and a constantly well trained crew.



On dangerous construction sites, enterprises prefer to employ drills mounted on wheeled tractors because damage caused by falling rocks is cheaper to repair on these than on more costly crawler tractors. (Photo E. Pestal)



The revolving drill method was originally applied in mining. Except for granites and gneisses containing quartz, the method is the quickest and cheapest. (Photo E. Pestal)



These machines are gaining in importance because they are careful excavators. (Photo E. Pestal)

NEW METHODS OF ROCK DRILLING IN AUSTRIA

by

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There are two facts which justify a paper on rock drilling in Austria:

- 1) Whereas road locating, excavation and base construction are different from country to country, rock drilling is basically similar in all mountainous countries of the world.
- 2) In Austria there are almost all types of rocks, from sandstone, limestone, dolomite, to the hardest gneisses and granites which are rich in quartz. All drilling methods (with the exception of manual drilling) are extensively applied. In order to make drilling easier and more rapid, firms like Böhler, Leobersdorfer and others have developed excellent compressors and drilling equipment.

While mentioning these positive aspects of the subject I cannot hide my serious concern. Our modern rock-drilling methods permit access to remote forests which 15 years ago nobody even dreamt of opening up. We receive more and more news from many parts of the world that the opening-up of forests is immediately followed by their destruction. If this happens in flat and hilly terrain it is sad enough, but for mountainous areas it can mean disaster.

In applying modern rock-drilling methods let me warn you not to let road construction machines be followed inconsiderately by wood harvesting machines, with the result that remaining forests are burnt and turned into pastureland.

Our rock-drilling methods are best classified by their development. My description will therefore follow a chronological order.

1. HAND-OPERATED HAMMER DRILLS

In the first decade, mechanical road construction was carried out mainly in favourable terrain. Roads had to be located around topographical obstacles; projects which would have required major rock removal were avoided. Drilling machines and blasting material were used mainly to eliminate individual opposing rock blocks or rock ribs. Hand-operated external hammer drills were quite sufficient. The standard Austrian device was the Jenbach diesel compressor IW 20 K, which drove a big hand-operated hammer drill with a power of 15 kw by compressing 2 m³ of air to 6-7 bar a minute. Today almost all of the Jenbach compressors acquired over two decades are still in use, but they are employed only to remove ribs left over from deep-hole drilling and big-hole blasting, or to shape and level the road bed.

For big rock-drilling projects, hand-operated hammer drills are too expensive and too slow, and there are not enough operators. Nevertheless, they continue to be useful in two particular cases:

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a) Locating in terrain with a low rock component

If the route runs along terrain which can be excavated and there is only a small rock component at the height of the mountainside ditch, drilling can be done by hand-operated external hammer drills. The time required does not impair the progress of construction, since work with construction machines can be continued without having to wait for blasting and drilling.

b) Locating in nature reserves

Apart from timber production mountainous forests serve increasingly for recreation and tourism. In recreational areas it would be intolerable to disfigure rocky slopes with large dumps of blasting spoil. The use of the hand-operated hammer drill is still the most appropriate method in these areas because the large number of low-charged drilling holes leaves a well-crushed spoil which will not roll far. This helps to keep damage to remaining stands to a tolerable level.

2. MOUNTED ROCK DRILLS

The major part of all the road to be constructed in rocky terrain is drilled by mounted rock drills. The most rapid and cheapest method consists in combining these with deep-hole hammer drills.

Mounted rock drills were developed from other drill supports which had long been used for horizontal and inclined drilling. By shifting the hammer drill operation from man to machine, an essential increase in performance was achieved.

2.1 Drill-carrying vehicle

According to the kind of drilling carrier the following kinds of mounted rock drills are distinguished:

a) Drills mounted on crawler tractors

Because of the crawler tractor's heavy weight, the drilling column can be accurately placed thus very rarely getting stuck. Transporting the crawler tractor is very expensive; therefore, its use is profitable only if the distance of road construction is long enough.

The same problem arises if the crawler tractor is damaged by rocks falling from the upper batter. Repairs take a long time and are expensive, because flat-bed trailers are required for transport.

For these reasons several road construction companies have changed over to rock drills mounted on wheeled tractors.

b) Drills mounted on wheeled tractors

By mounting the drill on a wheeled tractor easier manoeuvring is achieved. The unit can be economically used also for smaller construction projects in rocky terrain. If the tractor is damaged by falling rocks it can be repaired much more quickly and cheaply than the crawler tractor.

c) Drilling trailer

Particularly with rock layers running parallel to the slope rocks will fall from the upper batter. In such cases the drilling trailer is placed on the drilling site and is connected to a compressor by an air hose of 30 to 40 m. Here, the operating personnel is less exposed to danger because the drilling column points toward the mountain; the operator stands on the valley side of the trace, and can jump away in moments of danger.

2.2 Drilling methods

Drilling can be carried out according to three basic methods; each of these is a method in its own right and methods cannot be interchanged.

All deep-hole hammer drills use sole drilling: the hole is drilled at the height of the mountainside road ditch, just under the planned road-bed, along the axis of the road.

a) External hammer drill

In principle this resembles a large hand-operated hammer drill. The whole drilling column performs the hammering and revolving motions of the drilling bit.

Drilling of holes up to 6 m in depth is quite satisfactory, but if holes exceed this depth, power loss due to friction becomes too great. The power demand is extraordinarily high; if the diameter of the hole is too big, the drive of the crawler tractor is too weak; a separate drive must be added for the compressor. For an air supply of 20 m³/min, a power of 150 kW is required. Even if the carrier vehicle's performance is high enough it is advisable to provide a separate compressor drive in order to avoid excessive wear on the carrier vehicle's engine.

Depending on the diameter of the drill bit and the type of rock, the drilling speed ranges between 10 to 50 cm/min. For granites and gneisses containing quartz, the external hammer drill is virtually the only method that can be used.

b) Internal hammer drill

Whereas the whole drilling column of external hammer drills hammers and revolves, the internal hammer drill hammers just with the drilling head and bit. The drilling column merely performs the revolving motion. Much less power is required for a drilling speed of 6 to 20 cm/min and a drilling-hole diameter of 85 mm, the air supply is calculated at 7 m³/min, which require a motor drive of 50 to 60 kW. Internal hammer drills are used for all sedimentation rocks, for dolomites and for marble. These drills are the most frequently used in Austria; they are sometimes even used for granites and gneisses. In the latter case, however, performance is lower and drilling bits wear very quickly.

c) Revolving drill

This method was taken over from tunnel construction. Instead of hammering, it works with a revolving bit which is driven into the rock under enormous pressure. Air is used only for blowing out the spoil. The power requirement is small: in sedimentations the speed is 40 to 70 cm/min for a hole diameter of around 80 mm and a power supply of 50 kW; in soft limestone it is 1 m/min. Dust production is correspondingly high. For granites and gneisses containing quartz the revolving drill is not advisable. In order to reach the driving force of 50 to 60 kN, a crawler tractor is required as a carrier vehicle.

3. BLASTING AND DETONATION MATERIAL

Of all blasting materials, gelatine-donarite I is preferable because of its water-resistance. It is very powerful, however, and produces coarse blasting spoil which may lead subsequently to damage of the lower slope. A less detrimental blasting agent is donarite II in powder form which was formerly blown into drilling holes. Nowadays it is filled into plastic bags for protection against humidity, and used like gelatine donarite. If doses are correctly chosen, most of the blasting spoil remains on the road-bed.

Damage to the lower slope is even smaller when lambrate is used. This was originally applied in mining. Its effect is a mainly driving one and structures of surrounding rock layers are hardly affected. Although the method is more careful, it requires twice the amount of other blasting agents.

For smaller blastings the black firing cord (1 cm/sec) is still used, for deep-hole blasting the yellow detonation cord or dynamite cord (7 000 m/sec). Electrical detonation is necessary where millisecond detonation is required; it is also used in combination with the detonation cord.

4. EXCAVATION WORKS IN ROCK DRILLING

Depending on whether rolling rocks present a problem or not, angledozers, traxcavators or excavators are employed. Operation with angledozers is the cheapest. They push the spoil material down the lower batter, which is possible only if the gradient does not exceed 40 percent. For gradients of over 60 percent this method requires expensive construction works. Angledozers are now no longer used so much for road construction because they cause severe damage on the lower slope. In the Tyrol angledozers have already been outlawed.

Traxcavators are increasingly employed, not only because they cause less damage but also because they are widely used multi-purpose machines which are used not only in forest road construction but also for other earth moving work, including gravel production. Therefore, they are sometimes economically preferable to angledozers, although their excavating performance may be smaller.

Higher slopes can be better reached and battered by traxcavators than by angledozers. The material is not laterally excavated but transported over distances of up to 100 m along the road-bed and deposited wherever required. Skilful operators even know how to form a dry wall with the spoil material, which can otherwise be done only with excavators.

Traxcavators are sometimes also used as loaders. Unfortunately, turning on the spot requires high power and causes excessive wear on the tracks, so that it is not advisable to use them for regular loading of excavated material.

Excavators are the most careful road construction machines. They are used mainly with their shovels in the down position, even if working on the upper slope. They move the spoil to the lower slope, thereby supporting the dry wall from below; they load excessive spoil onto trucks and clean the higher slope up to a height which could not be reached by either angledozers or traxcavators. Excavators help save blasting material since they are strong enough to pull loosened material out of the ground. Costs per linear metre, however, are three to five times higher than for angledozers.

For road construction in rocky terrain, environmentalists call for increasing use of excavators, even in cases where traxcavators would cause tolerable damage for forestry. There is no agreement yet on who is to bear the additional costs incurred.

5. WORK ORGANIZATION

a) Personnel

Theoretically one person is enough to work on a construction site in rocky terrain, if he knows how to operate drill and traxcavator or excavator, but since it is much too dangerous to carry out this type of work on one's own, a second operator is required. One person works as a minelayer, the other one as a traxcavator or excavator operator. In emergency situations, construction sites have frequently been managed by a single person without any substantial effects on performance.

Workers usually live in heated caravans near the construction site.

b) Weather influence

Rock drilling is largely independent of the weather. In winter, in periods of frost and rain, other types of road construction work must be interrupted, whereas as a rule rock drilling is continued.

6. AVOIDING DAMAGE TO THE LOWER SLOPE

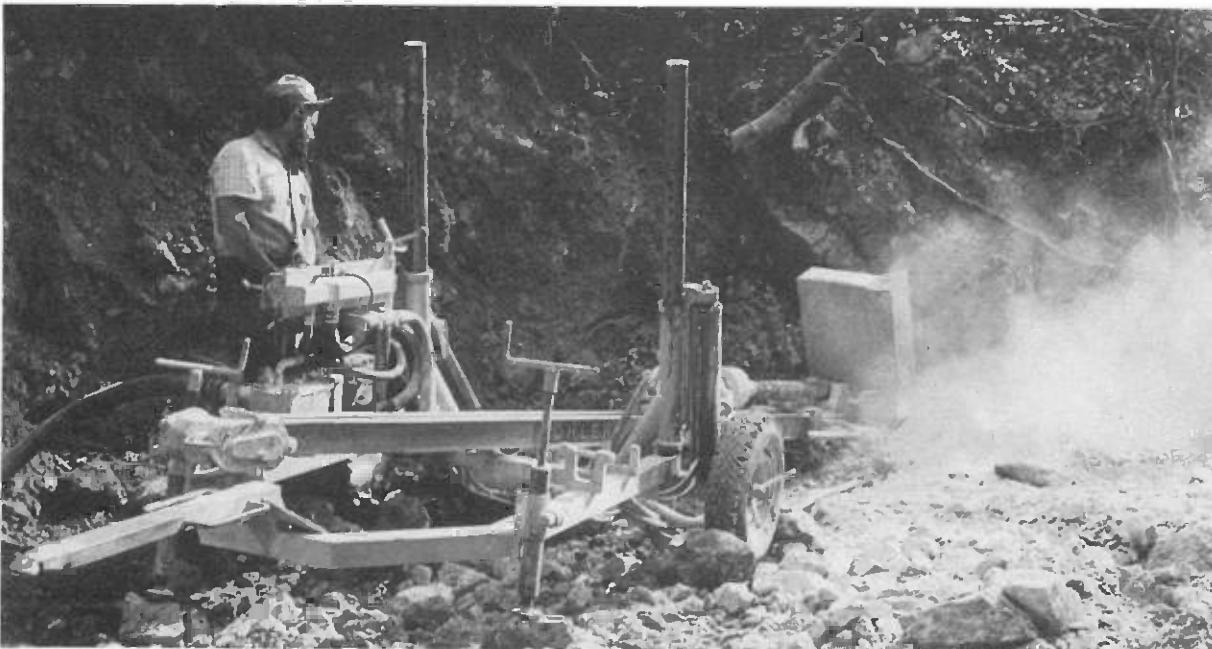
Roads could be constructed without damaging the lower slope. The material should be broken off the higher slope and deposited on the lower as dry walls. This method was applied for the crossing of Raxstrasse (an Austrian mountain road) and the main Vienna water supply pipe. However, costs per linear metre were 20 times higher than for blasting.

Usually one must be content with keeping damage by blasting and rolling spoil to a minimum. For this purpose the following measures are recommended:

- choosing the right amount of charge: if it is too high the spoil is coarse and rolls far.
- setting up catching devices: (rows of rough trees, tops and branches) for rolling spoil.
- carrying work out in deep snow: snow keeps the spoil from rolling; as it melts away, the spoil "settles" naturally.
- encouraging the greening of the batter: during construction earth material is dumped over the blasting spoil. It has proved advantageous to deposit straw litter, hay and hay flowers.

Bark waste hampers greening because it contains tannin.

The most careful road construction in rocky terrain is forward excavation by hydraulic excavators. Longitudinal transport of the excavated material is by means of trucks. It is desirable and possible to achieve the optimum mass balance with this method. Relatively little material rolls down on the lower slope. Costs per linear metre are considerably higher, however, compared to conventional methods of using angledozers and traxcavators.



A drilling trailer in action connected to the compressor by a 40 metre hose.
(Photo E. Pestal)



In areas with low volumes of rock or for final shaping and levelling, compressors and hand-operated rock drills are used in Austria (Photo E. Pestal)



For larger rock volumes rock hammer drills mounted on tractors are often preferred (Photo E. Pestal)

PROTECTION OF FOREST ROADS USING BIOLOGICAL AND ENGINEERING METHODS

by

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1. INTRODUCTION

The basic requirements for modern forest management, especially wood harvesting, are well planned and designed forest road networks. Careful attention has to be paid when planning and locating roads, especially in steep terrain, to avoid or minimise the erosional impact of roads on the environment.

Areas particularly susceptible to erosion problems such as very steep slopes with easily erodable soils and rock strata dipping towards the slope should be avoided as much as possible.

Erosion caused by road construction and soil disturbance can be avoided by using biological means and/or engineering structures. Slope and gully erosion adjacent to the road is very often a result of over-grazing and denudation of hills which exposes the soil to wind and rain and endangers the road structure. Erosion often occurs on the cuts and embankments as well as on the outlets of cross drains, water flows and on the surface of the road itself.

This paper describes briefly how to plan and survey forest roads efficiently to meet technical standards, keeping soil disturbance to a minimum by fills and cuts, in order to make the least possible erosional impact when constructing forest roads.

Revegetation practices are presented in detail to demonstrate how mass slope failures can be controlled. Simple and inexpensive types of engineering structures are also presented.

2. ROAD PLANNING, SURVEYING AND DESIGN

To plan the road alignment good topographical maps, preferably with a scale not larger than 1:10 000, are necessary. The main points to be opened up by the forest road should be determined and marked on the map. If no good contour maps are available, then extensive field work is required to measure all main points barometrically and to record detailed terrain features. For low-cost roads such as forest roads the survey method differs significantly from the classical engineering surveying methods. In a reconnaissance survey the main points which have first been marked on the map should be traced in the field height measurements taken and recorded. The survey of the road itself consists of taking measurements in between the polygon points determined by the geometrical requirements of the road, which are dependent on the standard of the roads. Distances, vertical and horizontal angles are measured at each point by means of tape measures, clinometers and hand compass. It is advisable to measure the road line back and forth in order to have a control measurement and to exclude errors in measurement readings. This simple surveying method has proved to be very efficient and sufficiently accurate for low-cost roads.

Especially in steep and difficult terrain it is a great advantage to use the surveying method, as it would be quite costly and time-consuming to survey with a theodolite. When surveying forest roads it should be borne in mind that road excavation volumes and fills should be balanced, thereby achieving minimum soil disturbance. On slopes steeper than 70 percent it is advisable to construct full bench roads. It may often be necessary to construct retaining walls made of rock masonry, logs or gabions to further reduce cut and fill soil disturbances, especially on steep and unstable slopes.

On such slopes, mid-slope locations of roads should be avoided. In general, road gradients should not be more than 10 percent. Only in exceptional cases, and over short distances, 12 percent may be acceptable. In areas with high precipitation, water run-off on soil surfaces is considerable and on roads with steep gradients precautionary measures with adequate drainage facilities are required, such as pitched ditches, open top culverts, frequent and sufficiently wide culverts, fords and bridges.

In addition, under certain conditions it is advisable to slope the road surface about 3 percent towards the downhill slope. They are best applied on full bench construction roads. Outward sloping of the road surface has the advantage that precipitation of road surface water drains off laterally, therefore the quantity of water accumulated in cross drains, open top culverts and sub-base culverts will be less, and risk of erosion reduced. However, outward sloping should not be applied on clayey road surfaces as they become extremely slippery when wet, and where slope fills occur, especially if they are not protected by vegetative cover.

On inward sloping roads, the road surface water drains off towards the slope, where a mountainside ditch, preferably paved, drains off the water to culverts which bring the water to the downhill side of the road.

Culverts should be protected by head walls; they should be sufficient in number to prevent the water causing erosion problems in the ditches as well as in the area below the culvert outlet. They should be placed safely in the road sub-base. (The compacted layer above the culvert should be equal to the diameter of the culvert, but at least 50 cm in order that they are not destroyed by traffic).

Depending on the amount of debris material, normally 30-60 cm diameter of precast concrete culverts give satisfactory results. If larger diameter culverts are required, corrugated steel culverts should be used; they are easily transported and set up at the construction site - but they are more expensive. Another way to avoid larger diameter cross culverts would be to install two parallel pipes, forming a culvert.

The gradient of the piped culvert should not be less than 3 percent and not more than 6 percent because too low and quick running water has a negative effect on the protective structures of culverts.

Special attention should be paid to the surfacing of the road. A favourable soil mixture to be used as carriage way and surfacing material should consist of sieving grain and sedimentation grain sizes that as few spaces as possible are between the large grains.

3. SLOPE PROTECTION AND STABILIZATION

First of all it is most important to determine the source of factors influencing slope instability in order to be able to design appropriate control and rehabilitation measures. Very often a single measure may achieve the desired results but sometimes it may be necessary to combine measures to restore the stability of the slopes. For instance, on a seepage

slope it may be only necessary to drain off the water with open ditches or stone filled drains. On other occasions, it may however be necessary in addition to revegetate the slope in order to fix the slope surface because vegetation would not come back at all or it would take too long a time, and a retaining wall would be required. In a mountain road project in the USA (Idaho) it was noted that 80 percent of the surface erosion occurred within one year on the disturbed slopes; thus it is important to stabilise slopes along or shortly after the construction of a road.

3.1 Slope drainage

The simplest method to safely drain off springs and surface water is by means of an open ditch or a system of open ditches. The main ditch is located in the direction of the slope gradient; secondary or lateral ditches are located in a fishbone pattern. Water should be collected as closely as possible from where it originates and be channelled safely to the road ditch, culvert or any other nearby water flow. In areas with steep gradients and a large amount of water run-off pitched ditches may be required. The excavation of the ditches should start at their lowest point in order that the accumulating water may drain off immediately. A very effective method to drain off the sub-surface water is by means of so-called "covered drains". On cut slopes the drains may at the same time act as a kind of retaining structure, if made in a "Y" or arch shape, thus further increasing slope stability. The most common types are stone or gravel filled drains with or without pipes.

To check the efficiency of the drains and for maintenance purposes, it is advisable to have a standing pipe at the junction of the main drain and secondary drain. Pipes may be made of concrete, brick or PVC material. The excavation of the drains should start at the lowest point, the lining of pipes, however, be started at the top. The pipes should be placed as tightly as possible, one to each other, and they should be located in water-tight soils in order that maximum water drainage can be achieved. Piped drains are the most efficient and their effectiveness is long-lasting; however, they are more expensive, or even not available. Normal stone drains may silt up after some time; therefore it is advisable to form a drainage channel of stones at the bottom of the drain, or to put in a bundle of brush wood at the bottom of the drain. The top of the drain may be covered with a layer of grass in order to prevent the siltation of the drain more effectively.

Besides using them effectively to stabilise fill and cut slopes, drains may be very useful behind retaining walls.

3.2 Revegetation of road embankment and slopes

Revegetation measures for stabilization of cut and fill slopes of roads which are well known may be grouped as follows:

- i) Seeding, grass turfing and mulching to obtain a grass cover;
- ii) Contour wattling, wicker work fencing, contour planting and fascines to obtain shrub vegetation;
- iii) Reforestation with pioneer plants.

3.2.1 Seeding

Very often before sowing grass seeds on barren slopes, soil and site preparation such as shaping the slope, spreading humus and application of fertilizer may be required. The seeds may be either sown on the entire area, in rows or in certain places only. To seed an area of 100 m², about 3 kg grass seeds will be needed. It is an advantage to have legume seeds mixed with grass seeds as they are especially nitrogen fixers. It will take $\frac{1}{2}$ - 1 working hour to seed 100 m². A mixture of deep-rooted and flat-rooted strong, quick-growing pioneer grasses will give the best results in fixing the soil.

3.2.2 Grass turfing

To regenerate successful vegetation through placement of grass sods, it should be borne in mind that grass sods would need to be placed on the slope when the surface is wet and during the vegetation period. Depending on the availability of grass sods, slopes may be entirely covered by them or only in strips. The latter application would require additional seeding. On very steep slopes fixation of the grass sods may be necessary to get a firm hold on the slope surface. This could be done by means of sticks prepared from tree branches, twigs, or bamboo, when available.

3.2.3 Mulching

This is a very quick method of regaining grass cover on sterile, bare soils. This method of revegetation requires a layer of straw, wood fibre or other organic material which is spread on to the soil. Seeds and fertilizers are added and finally the layer of mulching is fixed by spraying cold asphalt suspension. The advantage of mulching is that the grass cover comes up after a relatively short time because through this method favourable micro-climate and conditions are created; it reduces water losses from soil, surface temperature and soil crust formation as well as prevents seeds from rolling down the hill, and it also preserves the fertilizer. In the USA and Japan machines (hydro-seeders) have been developed which can spray the mixture of mulching material mixed with water and an adhesive as well as seeds and fertilizer on to the slope in one operation.

In Middle Europe in the alpine region revegetation by mulching techniques has been successfully used with the following method of application: The slope is covered by a layer of straw (2-4 tons/ha), which is spread by hand, by utilizing a ladder which is placed on the slope. Seeding and fertilizing is carried out by spreading seeds and fertilizer by hand, again utilizing ladders. Seeds and fertilizer fall through the straw layer onto the ground. For the fixation of the straw layer on to the slope surface, an asphalt suspension of 50 per cent asphalt in water, is watered to a 25 percent solution which is applied on to the straw by means of a portable rucksack type sprayer. About 0.5 litre of asphalt suspension per m² is applied. Spraying cannot be carried out during heavy rain and wind. Normally 2 to 3 hours are required after spraying the suspension to fix the mulching material. In general by the time the asphalt suspension covering the straw layer has disintegrated the grass vegetation is well established.

3.2.4 Contour wattling

Contour wattling, also called "wattling and staking", is one method of achieving a brush vegetation on steep slopes to be applied where a grass cover would not be strong enough to stabilize the soil of the slope. The idea is to sub-divide the slope with dense brush rows and if necessary in-between the rows, grass seeding could be applied for additional soil fixation. Before starting with the wattling and staking, slope preparatory work should be carried out, such as levelling of small gullies or removing such obstacles as big loose boulders and branches. Then stakes should be driven in along the contours at certain distances from each other within the contour line as well as from row to row. It is desirable to have every fourth stake as a sproutable stake. Staking should be started from the lowest part of the slope, moving uphill. Trenches should be dug just above the stakes and wattling consisting of sproutable twigs and branches be put in the trench, overlapping each other. Part of the twigs and branches should be above the surface to prevent soil from moving down the slope. The soil dug out is used to cover the lower contour wattling. Some technical data are given below, as well as production data of an example of contour wattling carried out in Jamaica under the supervision of Mr Sheng, FAO Watershed Management Officer. Stakes sharpened at the bottom ends 1 - 1.2 m long and with a diameter of about 5 cm with a row interval of 1.2 m and 0.50 m from each other were driven into the soil, leaving about 15 cm of the stake above the soil surface. Thus a hectare would require about 17 000 stakes. Contour trenches 20 cm wide and 25 cm deep were dug and bundles of wattling 13 cm in diameter and 3 m long laid in the trench. A ten-man crew may be able to carry out contour wattling work up to about 250 m² per day. Within the working crew, six labourers carried out staking, two labourers trenching and covering wattles, and two labourers for transporting and other duties.

Another example where several species to be used as cuttings have been tested by Mr Tautscher, FAO, was in Nepal. Those found to be most suitable for cuttings are Salix tetrasperma, Salix vallichiana and Viburnum.

3.2.5 Wicker work fencing

The system is similar to the one mentioned above and is widely used in the alpine region in Middle Europe. The difference is that the sproutable material is not put in bundles into the soil, but is put around the stakes like a fence and the ends of the sproutable twigs are put into the soil.

The rows must not necessarily follow the contour lines; very good results have been achieved with rows placed at an angle of 45° forming rhomb shapes with 1.5 - 4 m long sides. The stakes are driven into the soil with a spacing of 40-50 cm, having a length of 1-2 m and diameters of 5-10 cm. The stakes should be driven into the soil three-quarters to two-thirds of their length. The spacing of the wattle rows very much depends on the gradient of the slope and soil. Normally they are 1-4 m apart, laid out in parallel rows. In alpine regions good results have been achieved using Salix spp. and Alnus spp. as sproutable fencing material.

3.2.6 Contour planting (cordons)

Sproutable plant material of 0.9 to 1.5 m length is placed in horizontal cross layers into the contour terraces. Terrace digging starts from the bottom of the slope proceeding to the top. The lower cross layers of sprouting material are covered with soil gained from the excavation of the upper terrace. The spacing of the terraces depends on the gradient and the soil; it may be up to 3 m. The width of the terrace should be 0.5 - 0.6 m. Cordon layers may either continuously follow the contour line or have a certain length, say 5 m, and overlap each other. With the indicated spacing of contour planted rows, 3 500 to 5 000 cordons per hectare would be required for the rehabilitation of the eroded slopes.

3.2.7 Fascines

The technique is similar to the one used in contour planting. It differs in that instead of putting cross layers in the contour terraces, brushwood is laid in. This can be mixed with cuttings to achieve a green brush row. In between the brush rows, shoots are put or seedlings are planted. Terraces should have a gradient of 20 to 25 percent towards the slope having a width of 0.6 - 1.2 m. The brushwood and cuttings should be about 20 cm longer than the width of the terrace.

3.2.8 Reforestation

Revegetation work should be carried out with pioneer plants to stabilize slopes subject to landslides, or as a preventative erosion control measure on severely degraded slopes. In alpine regions pioneer plants such as Alnus, Betula, Fraxinus and Prunus have proven to be most successful as far as their survival rate on eroded slopes is concerned. When considering plants for use as slope stabilizers it should be borne in mind that they have strong, deep roots to bind as much soil as possible. Wherever possible it would be desirable to select species for afforestation on bare slopes which could be used as fodder or fuelwood trees, since there is a desperate need for such trees in many developing countries.

4. STABILIZATION OF DRAINAGE WAYS

Unprotected drainage ways crossing the roads are very often the source of major erosion problems. Erosion mainly occurs on unprotected outlets of the drainage way where runoff water frequently develops gullies through its erosive force, which in some cases even causes landslides and damage to the road structure. Protection of water drainage outlets and channels can best be done by pitching the soil surface with dry stones or cement-bonded stones. In channels with steep gradients, it is advisable to have some stones cemented along the channels which are above the bed of the cement stone channel, thus reducing water velocity and its destructive erosion forces.



Erosion caused by water flow on poorly covered and overgrazed slopes, culminating in a landslide. (Nepal) (Photo FAO).



Water flow with pitched stones and revegetation cover on both sides of the water flow (Austria). (Photo FAO)

A cheaper way of stabilizing channels and outlets of water crossings is to provide rock rip rap which in many cases gives satisfactory results.

For the protection of bridges, culverts and fords, structures such as rock rip rap, dry stone or cement stone retaining walls, or where applicable wooden protection structures, may suffice. Very often revegetation treatment on the slopes of cross-water drainage ways already gives satisfactory protection.

5. SLOPE PROTECTION WITH ENGINEERING STRUCTURES

Simple engineering works for forest road construction such as dry stone structures, gabions, log crib revetments, timber retaining walls, etc., have proved very useful in many countries. They are inexpensive and easy to be constructed at the required sites with local material. As cement is often difficult to get or is not available in remote areas of developing countries, transport costs are high and skilled masonry labourers scarce. In this paper main emphasis has been put on dry stone structures and timber construction works.

5.1 Stone arches

Stones are placed in the form of arches into the soil of cut slopes. The width of such arches may be 0.60 to 1.20 m and they may be up to 1 m in depth. In between the arches and above them, cuttings of salix spp. may be planted to achieve additional stabilization.

5.2 Dry stone retaining walls

Stones with sizes of 20 to 30 cm are placed next to each other into the surface of the slope. For the setting of stones into the soil surface 2.5 - 4 m² per man/day may be achieved and in addition provisions for obtaining and transporting the stones will have to be made.

5.3 Gabions

Gabions are structures made of stones which are normally set up by hand labour and covered with wire mesh to keep them together.

The advantages of gabions are:

- i) their construction is simple; with proper supervision, unskilled labourers can set up these structures;
- ii) they are cheap;
- iii) stone material which is available in many places at the construction site can be used;
- iv) only wire mesh or wire needs to be purchased and transported to the construction site;
- v) their construction time is short;
- vi) they are very durable; in comparison to cement masonry walls, they are more resistant against mass movement without breaking, because they are flexible;
- vii) water drains off easily, thus increasing the shear strength of the soil and reducing the erosion hazard of the slope to be protected;
- viii) in between the stones grass grows sooner or later, thus making the gabions even more stable and integrating them well in the environment.



Wooden open top box culvert for road surface water drainage.
(Photo: Federal Forestry Research Institute)

Based on information collected in Nepal the costs per m³ gabion amounted to around 140 Rupees or US\$ 11.24.

Basic data used in the cost estimate are as follows:

Labour wages on average	= 12 Rupees per working day
Income of foreman	= 500 Rupees per month

Average construction output per m³ gabion = 1.9 man days which comprises preparation of wire mesh, collecting stones near the construction site, transport and setting up the stones, forming the construction, as well as rock fill.

Cost of wire per m ³ gabion, including transport and tax	= 110 Rupees
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Direct cost per m³ gabion (in Rupees)

Labourers (1.9 man/days)	22.8
Supervision	4.0
Hand tools	2.0
Wire	<u>110.0</u>
Total	138.8

5.4 Log crib revetments

These structures may be of use where wood is easily available and where there is no adequate stone material or where the construction costs of stone structures are excessively high because of long transport distances for the stones. Log crib revetments are made of roundwood, consisting of logs laid parallel to the slope and crosslayers, which fix the structures with the sub-soil of the slope. The crosslayers should be put at a spacing of 1 - 2 m. In between the log layers, placed parallel to the road, stone filling and additional sprutable material may be placed, protecting the road of stone and earth material. Log layers and the ends of the cross logs must be fixed either by nails or cut to fit each other. In severely sliding areas, it is advisable to construct log crib revetments consisting of front, back and cross layers of logs, which would form a cage and would be thus more resistant to the gravity force of the slope material. The advantage of log crib revetments are that they can be set up in a short time, they are cheap, local tree species could be used and they are more resistant to slope movements than inflexible masonry constructions. Their disadvantage is that they have a limited lifetime, generally 10 - 15 years. However by that time it is expected that the treated slopes are stabilized.

5.5 Timber retaining walls

To protect slopes from erosion hazards, this simple type of structure may be built. It is composed of stakes driven into the sub-surface of the slope and of timber nailed on to them from the mountainside. They are placed near the road and if necessary higher up on the slope along the contour lines of the cut slope.

5.6 Precast concrete crib revetment

These structures have been developed for areas where neither stone nor timber is economically available. Concrete beams of 250 cm x 12.5 cm x 12.5 cm weighing about 90 kg and crossbeams of 125 cm x 12.5 cm x 12.5 cm weighing about 45 kg are used for this type of structure. This example is only mentioned to give a more complete picture of the development in this sector of construction. At present their application may not be economically feasible in many developing countries, except for locations close to a source of cement.



Revegetation of a fill slope by mulching (Photo FAO)



Fill of a gully by traxcavator, concrete culvert and supporting roundwood construction to guarantee natural waterflow. (Photo: FAO)

6. PROTECTION OF ROAD EMBANKMENTS AGAINST TORRENTIAL WATERFLOWS

The damage to roads caused by torrential waterflows may occur when the roads are located along or crossing the torrents. Erosion caused by the running force of water may endanger or destroy the banks or embankments of roads or the road itself by its scouring effect and erosion of the toe of torrent banks. When crossing torrents or gullies, the road may be blocked by sedimentation material or destroyed by downhill mass movements. Necessary rehabilitation measures in controlling erosion caused by torrents are to reduce the velocity of water by engineering structures and rehabilitating slopes of the gully or torrent banks. Thus, a combination of biological and structural bank stabilization, as well as putting in check dams, or sills and check dams may be required to fully protect the road from erosion and sedimentation caused by torrential waterflows.

6.1 Embankments

Embankments may be constructed with different materials. The most common type is made of rocks. Stones protecting the toe and bottom of the channel should have a diameter of at least 0.5 m and those protecting the banks should be of 0.3 m and above. If only smaller stones are available, paving with stones covered by a wire mesh is very effective.

A very quick method of stabilizing embankments is by putting boulders on the banks of the torrents - these structures are called "rip rap". In torrential flows with big hazards of bed erosion and scouring, the paved toe may be protected additionally by placing boulders on it.

A combination of layers of boulders and layers of fascines with sproutable material may give very good results, as the water velocity is reduced by the fascines on one side and the embankments are made more stable because of the vegetative cover. The cuttings should be put about two-thirds of their length into the sub-soil.

Boulders in combination with grass turfing, or grass turfing and planting of brushes and trees on the embankments, may provide good results in stabilizing embankments.

In areas where wood is available, log crib revetments with stone fillings in between the logs may be constructed. At the bottom of the timber crib revetment a layer of logs should be placed to prevent the filling material from being washed out from the structure.

Bank revetments and training walls made of concrete are very effective - however, they are more costly than the structures mentioned above.

7. ROAD SURFACE PROTECTION

7.1 Open top culverts

An effective way to control road surface erosion will be to put in open top culverts or simply earth cross-drains, which will lead off the surface water from the road. Open top culverts can be made of steel, concrete, timber, round wood, or only earth debris. Open top culverts need to be placed into the road with a certain cross gradient in order that they will be self-clearing, and normally a cross-gradient of 6 - 7% is sufficient.

The effectiveness of open top culverts depends very much on the correct spacing and maintenance work (clearing of soil particles, leaves and twigs, etc.) in order to keep them functioning effectively all the time. The spacing of open top culverts depends mainly on the gradient of the road, amount of precipitation, steepness of terrain and soil conditions. In a watershed forest in steep terrain with high rainfall, Sessions (1974) proposed an open top culvert spacing in metres derived by $800/\text{gradient}$ in percent. However, in areas with heavy rainfall and large catchment areas, a shorter spacing (20 - 40 m), especially on roads with 9% or a higher gradient, may be required. The correct spacing of open top culverts may be worked out through experience in the respective areas; the table below should serve as a guideline.

Spacing of open top culverts in metres

<u>Road gradient in percent</u>	<u>800/gradient in percent</u>	<u>Suggested spacing in steep terrain with heavy rainfalls</u>
5	160	80
6	130	65
7	114	55
8	100	45
9	88	40
10	80	35
11	72	30
12	66	20 - 30

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Roadbase and retaining wall destroyed by landslide;
road fixed by gabion. (Nepal)
(Photo FAO)

PROTECTIVE CONSTRUCTIONS FOR FOREST ROADS IN ENDANGERED AREAS

by

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1. INTRODUCTION

In the mountains the roadbuilder must always consider the possibility of destruction and damage of parts of the roadnet work and installations (bridges, culverts, etcetera), due to torrents and the effects of water on unstable slopes.

This paper aims at giving a short survey of the following:

- the characteristics and effects of torrents;
- the possibilities of reducing or preventing damage caused by torrents;
- the work analysis of torrent control in connection with forest road design;
- the various parts of a small project for local torrent control;
- an example of protective structures designed for a forest road crossing a torrent.

The appendix gives some data for project design.

2. CHARACTERISTICS OF A TORRENT AND ITS EFFECTS

A torrent can be described as a natural channel or waterway with a small catchment; steep and irregular sections; extreme variations of the runoff with high flood peaks, mostly caused by rainstorms; and more or less intensive erosion, high bed load transport and sedimentation.

The principal effects of most torrents are the following:

- erosion of all known forms (sheet, rill, gully, bed and lateral or bank erosion);
- sedimentation (in the torrent channel and in the neighbouring areas);
- inundations (frequently as a result of, or intensified by, sedimentation in the torrent channel).

Damage to and destruction of forest roads as a result of the effects mentioned above can occur when a forest road leads along or cuts across a torrent channel.

The main causes of damage and destruction by torrents are as follows:

- a) Lateral or bank erosion. In this case the running water destroys the bank and road embankments. The intensity of erosion increases with the depth and speed of the running water. Therefore the toes of the banks and road embankments as well as the toes of stream bank - protective structures - (training walls, bank revetments, rip-raps and so forth), are particularly exposed to danger.
- b) Bed or channel erosion. In this case the running water deepens the bed of the channel. It endangers and destroys the toes of banks, road embankments and the base of stream bank-protective structures, which is often accompanied by lateral

1/ Federal Ministry of Agriculture and Forestry, Austria

erosion. The abutments of a bridge are frequently endangered. The narrow span of the bridge also increases the velocity and the depth of water during heavy flows. As a result the pull of the water and bed erosion are increased.

- c) Scouring at the downstream end of a paved ford and of culverts.
- d) Erosion of the road surface or of the entire road. This occurs when the cross-section of the channel is too small and floods overflow parts of the road. Frequently, the reduction of the cross-section is an artificial one. Two main cases: the first, a consequence of road construction along a torrent channel, when the valley is narrow and the slopes are steep. Here, a part of the embankment is often in the torrent channel. The second occurs when the span of a bridge or the diameter of a culvert is too small for flood peaks, bed loads, branches, trunks and so on, brought down during the flood.

The greatest damage and destruction to forest roads is caused by erosion. Therefore, the most important purpose of protective measures is to combat erosion.

Damage caused by landslides:

- a) the road moves along with the sliding slope;
- b) the moving masses of soil bury the road.

3. PROTECTIVE MEASURES.

To prevent or reduce damage or destruction caused by torrents or unstable slopes the roadbuilder may take two protective measures:

- a) He may avoid the dangerous zones whenever it is possible to construct the endangered parts of the road network or installations (bridges, culverts, side walls) outside of these zones (passive protection);
- b) He may protect the road and installations by application of torrent control measures and slope stabilization (active protection).

4. WORK ANALYSIS OF PRELIMINARY STEPS

The final design of a forest road must be arrived at by having executed a number of preparatory steps. A checklist or work analysis of these steps is given in Figure 1.

4.1 Presence of torrents and landslides

After the preliminary design of the forest road network has been made, it is necessary to check whether there are critical zones or points such as torrents and unstable slopes. Endangered sites exist mainly where the road crosses or leads along the channel of a torrent. Unstable slopes are often characterized by wet spongy spots with indicator plants proving that the soil is wet. Other characteristics are irregularities of the slope (small mounds and ridges, for instance) and inclined trees which indicate slow movement of the soil (like soil "creeping").

4.2 Surveys before construction

The next step is to examine the catchments of the torrents and to determine the hydrological circumstances on the basis of a detailed inventory. The accuracy of the estimation or calculation depends largely on the extent of the surveys. The extent and cost of the survey should also be determined by the value and importance of the forest road. On the basis of the hydrological data and field surveys the extent of floods and debris flows are estimated or calculated. (For estimating the run-off for simple cases the FAO Conservation Guide Number 2 - Some Simple Hydrological Techniques for

Reconnaissance Work in Watershed Management - is a good basis). These data must be available before bridges and culverts can be designed.

4.3 Identifying endangered zones

The inundation, sedimentation and erosion (bank erosion) zones and their intensity and frequency should be established. The following are mainly used as a basis for such evaluation:

- a) estimation or calculation of run-off and debris flows;
- b) geomorphological and hydromorphological forms;
- c) reports and other information (interviews).

4.4 Estimating extent and cost of damage

This step includes estimating the extent of the damage (length of the section of road destroyed, for instance). The main question is what damage may be caused by the intensity and frequency of floods or debris flows estimated in the preceding step.

The costs which would result from damage consist of:

- a) cost of reconstruction of the destroyed sections of road;
- b) cost of clearance (removing debris, etcetera);
- c) cost due to interruption of the traffic.

If costs are estimated to be low, the effects small, and the possibility of damage infrequent, the roadbuilder may gamble and disregard protective measures. If he believes that the cost of damage will be high, protective measures should be considered and a cost/benefit analysis made.

4.5 Designing preliminary protective measures and studying their feasibility

This step includes considering the cost and benefits to be derived from protective measures. The purpose is to give the roadbuilder a basis for final design. The formal results of these considerations may range from a simple study if there are local problems to a preliminary project in the case of an important forest road, which may have a major impact on the environment. The main parts of the study should include the following:

- a) collection of the necessary physical and socio-economic data (as a result of the preceding steps);
- b) possible protective measures;
- c) a rough estimate of costs;
- d) feasibility or a feasibility study.

Consideration of feasibility should include the following:

- a) conditions and resources needed to provide protective measures;
- b) the cost of different protective measures and structures;
- c) the cost of possible future damage;
- d) comparison of costs of different protective measures;
- e) conclusions.

The most important conditions and resources are as follows:

- a) Financing. Protective measures and structures will nearly always be included in the overall financing of the forest road.

- b) Personnel. If complicated construction work is planned (such as of reinforced concrete construction work) the workers should be specialized in this field.
- c) Machinery. The same machines should be used for construction of forest roads and protective installations.
- d) Material. Costs of transporting material should be borne in mind. For instance, rip-rapping is advisable only if suitable rock is available in the vicinity, otherwise another form of protection should be considered.
- e) Available sites. You should not plan a route without being sure of your access rights.
- f) As a rule the costs of different protective structures will be calculated on the basis of a rough estimate.

The conclusions drawn depend on cost comparisons as well as on feasibility and profitability studies.

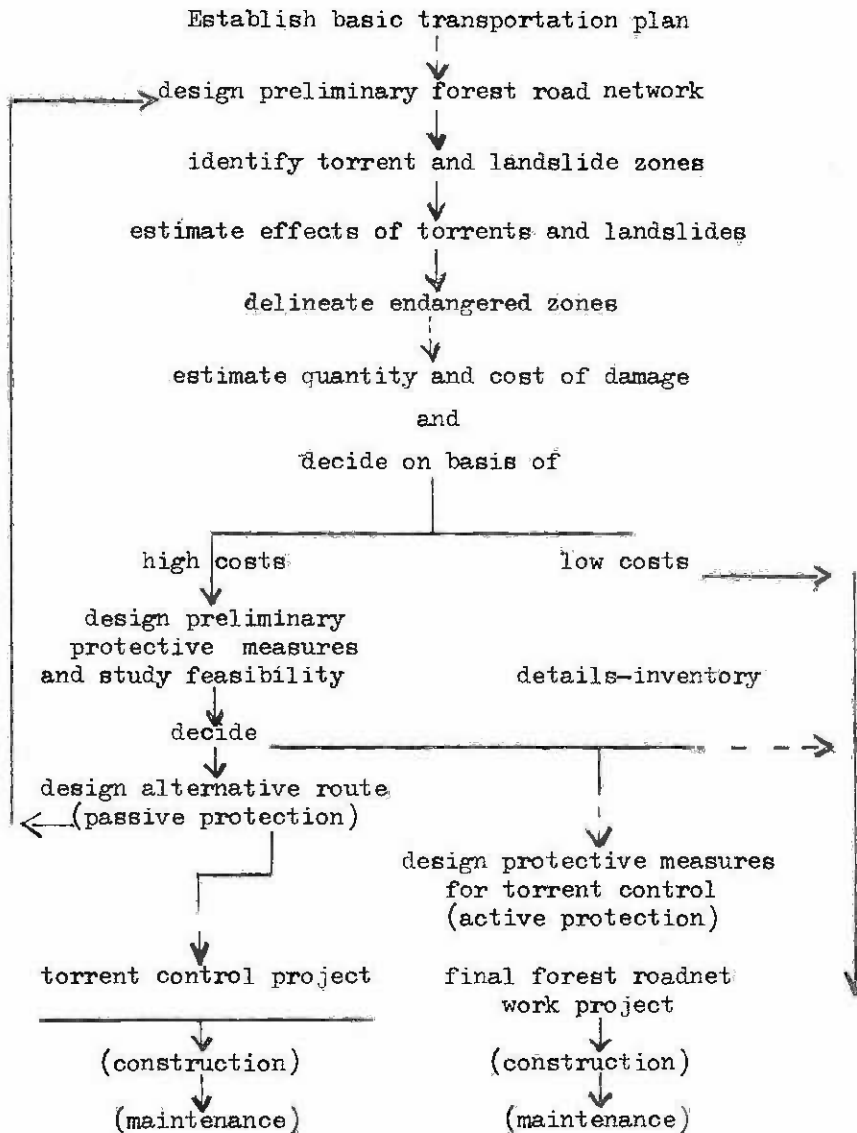
Below are three alternatives:

1. Another route is designed for the endangered sections of the preliminary forest road (passive protection), considering its safety from torrents and landslides. This alternative is mainly for going around landslide areas.
2. The forest road (or a certain section) and installations are protected by torrent control structures (active protection). This is the solution most frequently chosen, particularly when a) reconstruction of the destroyed part of the road or bridge and the interruption of traffic is more expensive than the preventive protective works; b) passive protection is not economical and/or cannot be employed.
3. In the third case, protective measures may not be economical or cannot be put into practice under the given circumstances. For instance, it may be cheaper to repair a destroyed bridge every 20 years than to construct the protective works that would be necessary to prevent the damage.

The extent and the accuracy of the study or preliminary project depend on the importance and the size of the endangered parts of the forest road. It may be a very simple study - as in many cases - or a preliminary project. The main steps in elaborating it are generally the same as those used for a detailed project and are given in the section entitled torrent-control project (sec. 5).

Fig. 1

Work analysis of preliminary steps



5. TORRENT CONTROL PROJECT

5.1 Main steps

The first formal step in the design of a project can be an order or directive to a department within the same administration or institution or a contract to a private firm. Then the project is designed, using and completing the data, maps and information collected up to that date.

For the design of the torrent control project the following main steps are recommended:

- a) Collation and study of data on the areas concerned, using the results of the preceding steps (see Fig. 1);

The necessary documents include:

- i) maps and aerial photographs;
 - ii) physical data (topographical, climatic, hydrological and geological information about soils and vegetation);
 - iii) socio-economic data (always in connection with the purpose of the project);
 - iv) data on damage and danger caused by floods, mud flows, erosion and landslides.
- b) Field trips and engineering surveys to check, correct and complete all available information and data. At this stage the results of the reconnaissance survey which has already been carried out are used as well;
- c) Determination of possible future damage, identification of the endangered zones;
- d) Determination of the general concept and the basic ideas for the protective measures;
- e) Detailed survey and mapping;
- f) Determination of the kind of the protective structures needed and their locations;
- g) Determination of the programme for putting the plan into practice;
- h) Elaboration of all project sections.

5.2 Project sections

The various sections of the project depend mainly on the purpose of the project, the extent and the importance of the forest road network which is to be protected, as well as on the physical and socio-economic circumstances existing in the project area.

According to the purpose of the project and the importance of the protective measures, the investigations, surveys and calculations will be more or less accurate.

As an example, the various sections of two different kinds of projects are given below:

- A. A simple project for local protective works should include the following:

- technical report
- project estimate
- site plan
- longitudinal section (profile map)
- types and cross sections of the protective measures.

B. A detailed project plan for carrying out important protective measures should include the following:

- technical report
- calculations (hydraulics, statics, etcetera)
- quantity survey
- schedule of unit prices
- project estimate
- cost-benefit analysis
- general map
- aerial photographs
- land registry map
- site plan
- longitudinal sections
- cross sections
- types of protective structures
- details of protective structures.

The technical report should include the following:

- an order to execute the project;
- description of the physical and socio-economic circumstances in the catchment area;
- protective structures already in existence;
- type and extent of damage or danger;
- results of investigations and surveys;
- basic concept of the protective measures;
- description of the protective measures;
- costs and economic considerations (including cost-benefit analysis);
- schedule of programme to carry out the project.

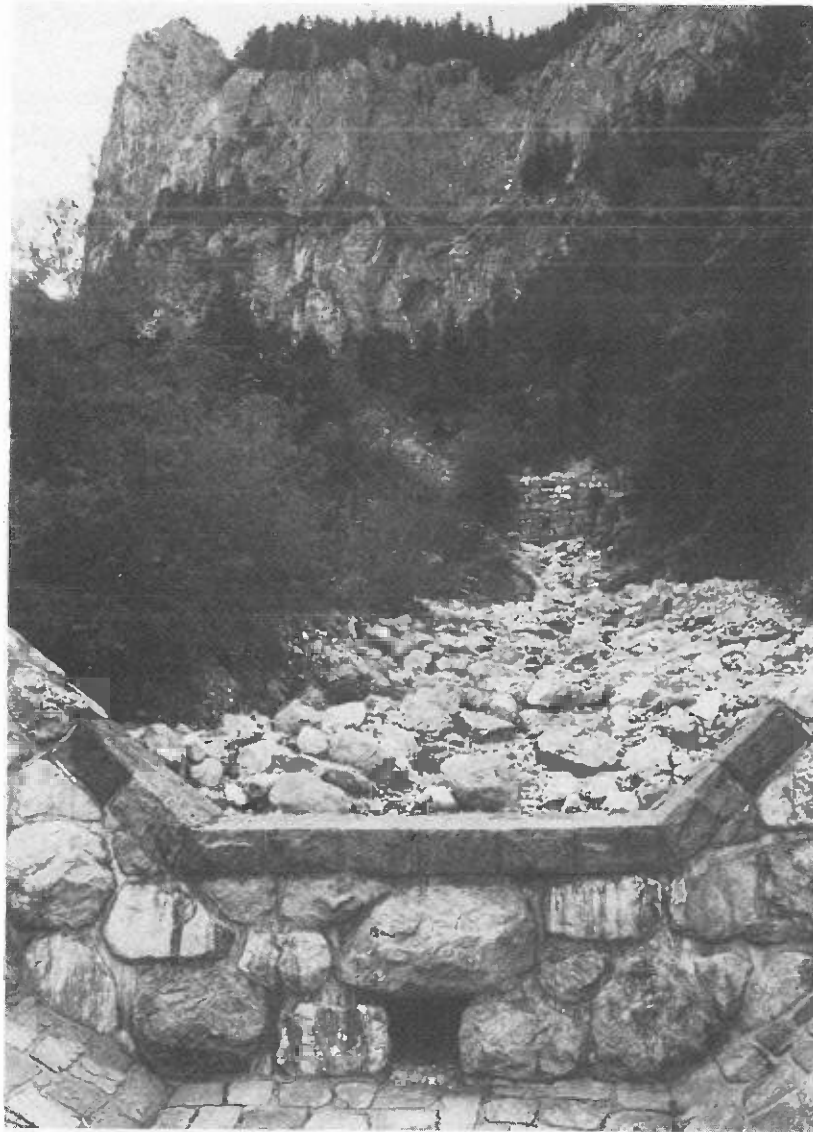
5.3 Types of protection

The main types of protective structures used for forest roads are the following:

- check-dams and sills
- rip-rapping
- bank revetments
- training-walls
- paved channels.

Characteristics, design and application of the simple types are described in the FAO Conservation Guide Number 2 (Torrent Control in the Mountains with Reference to the Tropics, by H. Hattinger).

Standards for cost estimates are given in the attached annex.



Masonry check dams to retain debris material. (Photo T. Pasca)

6. EXAMPLE: THE WEISSE RIESE TORRENT CONTROL PROJECT

This is an example of a small and simple project.

Content:

Technical report

Estimate of costs

Site plan

Longitudinal section

Cross sections and types of structures

6.1 Technical report

6.1.1 Geographical situation

The Weisse Riese torrent is situated near the town of Gmunden on the western slopes of Trauntstein mountain.

6.1.2 Catchment

It comprises an area of 0.2 km^2 . The highest point of the channel is at approximately 1 000 m, the lowest point at 422 m, where the torrent discharges into the Traunsee. Near this point, the gradient of the channel is 20 percent and rises to more than 40 percent. The forest cover is poor.

Climate: Influenced by the Mediterranean climate zone to the south. High rates of precipitation. The average annual precipitation is about 2 000 mm.

Geology: The bedrock formation consists of dolomitic limestone, which produces a considerable quantity of debris through weathering.

Hydrological considerations: It is difficult to estimate the maximum flood for this very small catchment. Because of the high precipitation in relation to the small catchment there is a high specific flood discharge. Past debris flows are known; but it is nearly impossible to determine exactly the volume of the maximum debris flow. The basic principle of the hydraulic design is to approximate the cross sections of the structures to those of the torrent channel.

6.1.3 Necessity for protective measures

The important "Lainaustrasse" forest road project is designed to cross the Weisse Riese torrent. Former investigations have shown that it would not be possible to choose another route which could by-pass the torrent. Therefore a bridge must be built. Because of the torrent this structure must be protected; it may be endangered & could be destroyed by bed erosion downstream of the bridge and between the abutments. Sedimentation of the channel-bed upstream of the bridge is possible. The resulting inundation could damage or destroy parts of the road next to the bridge every year and the bridge itself on an average of about every five years.

6.1.4 Purpose and basic concept of the protective works

The purpose is to protect the bridge and the connecting parts of the road against erosion and inundation caused by sedimentation. The bed of the channel must be stabilized and the flood run-off improved upstream of the bridge and between the abutments.

6.1.5 Protective structures

For the above-mentioned purposes the following structures are planned:

- a) Three check-dams downstream of the bridge to avoid bed erosion
- b) Paving between the abutments to protect the bed against erosion
- c) Paving and lateral walls to improve the run-off and to improve the transportation effect by increasing the speed of the water
- d) One check-dam as a final protective structure upstream of the bridge,
(Diagrams and details of the structures are given pp. 104 to 108).

6.1.6 Costs

The total cost of all structures would be 950 000 schillings (US\$ 63 000 approx.), broken down as follows:

<u>Structure</u>	<u>Size</u>	<u>Volume of material</u>	<u>Cost in Austrian Schillings</u>
hm 0.65 and hm 0.80			
1. <u>Two concrete check-dams</u>			
1 check-dam requires:			
excavation (by hand and machine)	57 m ² x 2.0 m	114 m ³	at 200 = 22 800
concrete (compressive strength 250 N)	50 m ² x 1.2 m	53 m ³	at 1 700 = 90 100
paving of the overflow section	7.02 m ² x 1.1 m	7.7 m ³	at 2 000 = 15 400
backfill (by hand and machine)	30 m ² x 1.0 m	30 m ³	at 30 = 900
		Total	= 129 200
		Total for 2 check-dams	= <u>258 400</u>
hm 0.95			
2. <u>One check-dam (concrete)</u>			
excavation (by hand and machine)	32 m ² x 2.0 m	64 m ³	at 200 = 12 800
concrete (compressive strength 250 N)	32 m ² x 1.5 m	48 m ³	at 1 700 = 81 600
paving of the overflow section	6.4 m x 1.1 m	7 m ³	at 2 000 = 14 000
backfill	16 m ² x 1.0 m	16 m ³	at 30 = 480
		Total	= <u>108 880</u>

<u>Structure</u>	<u>Size</u>	<u>Volume of material</u>	<u>Cost in Austrian Schillings</u>
hm 0.96 - 1.02			
3. <u>Paving between the abutments of the bridge (6.0)</u>			
excavation (by hand and machine)	6.0m x 6.0m x 0.5m	18 m3	at 200 = 3 600
paving (concrete)	(4.0m+2 x 1.3m) x 6m	44 m3	at 1 200 = 52 800
			Total = 56 400 =====
hm 1.02 - 1.10			
4. <u>Paved channel</u>			
excavation	4 m2 x 8 m	32 m3	at 200 = 6 400
(by hand and machine)	5 m2 x 8 m	40 m3	at 200 = 8 000
concrete (compressive strength 250 N)	2x0.8m x1.2mx8m +2 x 2.0m x0.4m	28 m3	at 1 700 = 47 600
	5m x 0.3mx8m		
paving	9.6 m x 8 m	77 m3	at 1 200 = 92 400
backfill	15 m2 x 8	120 m3	at 30 = 3 600
			Total = 158 000 =====
hm 1.10			
5. <u>Concrete check-dam</u> (as in item 1)			Total = 129 200 =====
6. <u>Site installations</u>	lump sum		49 120
Total of items 1 - 6	(net costs)		760 000
25% of the net costs for general costs and contingency reserve.			190 000
TOTAL			950 000 =====



Construction of dry stone training wall to protect river banks. In the background, check dams protect bridge. (Photo T. Pasca)



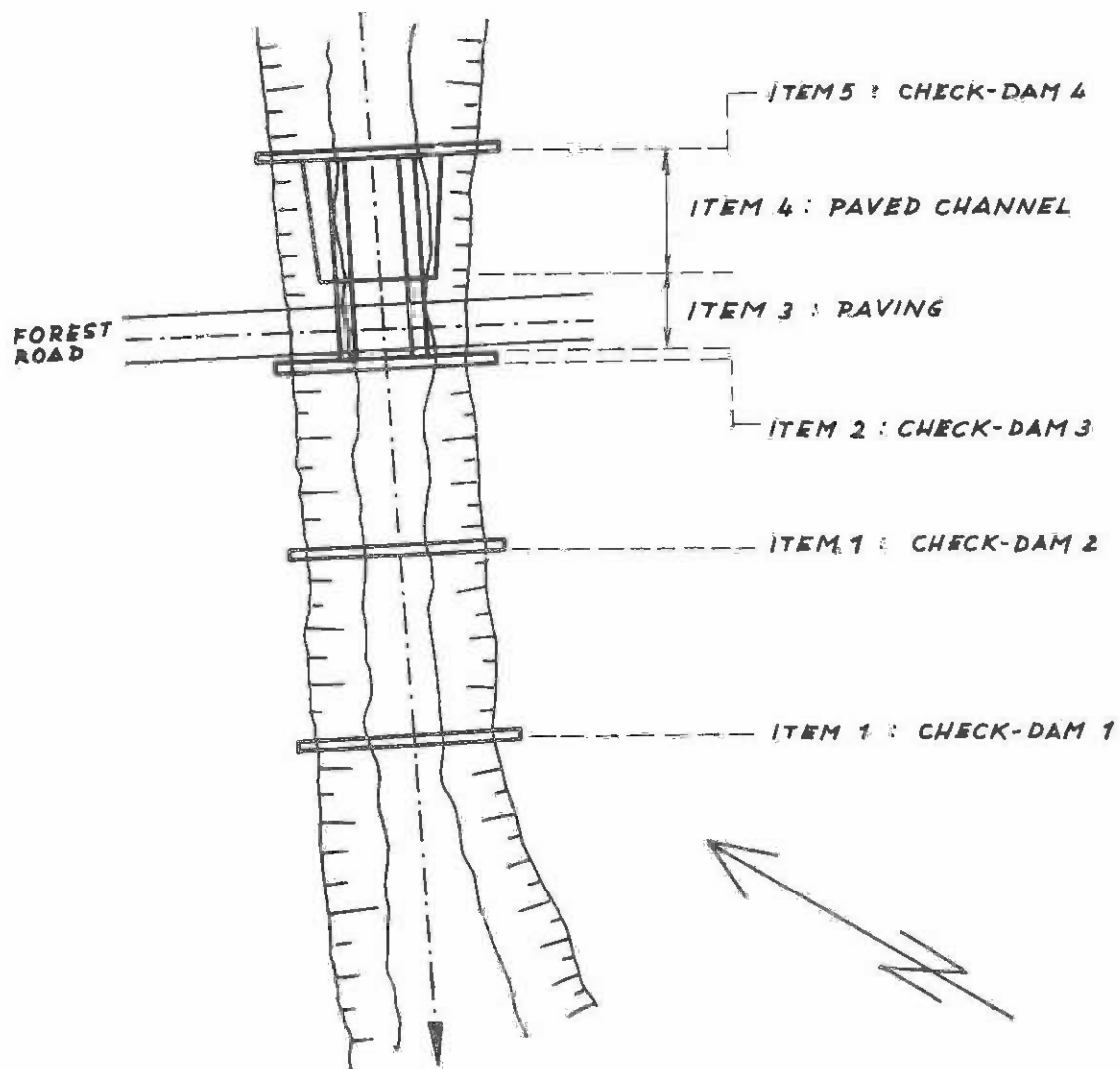
Corrugated steel sheet culvert used as form to replace a conventional bridge. (Photo T. Pasca)

TORRENT CONTROL PROJECT

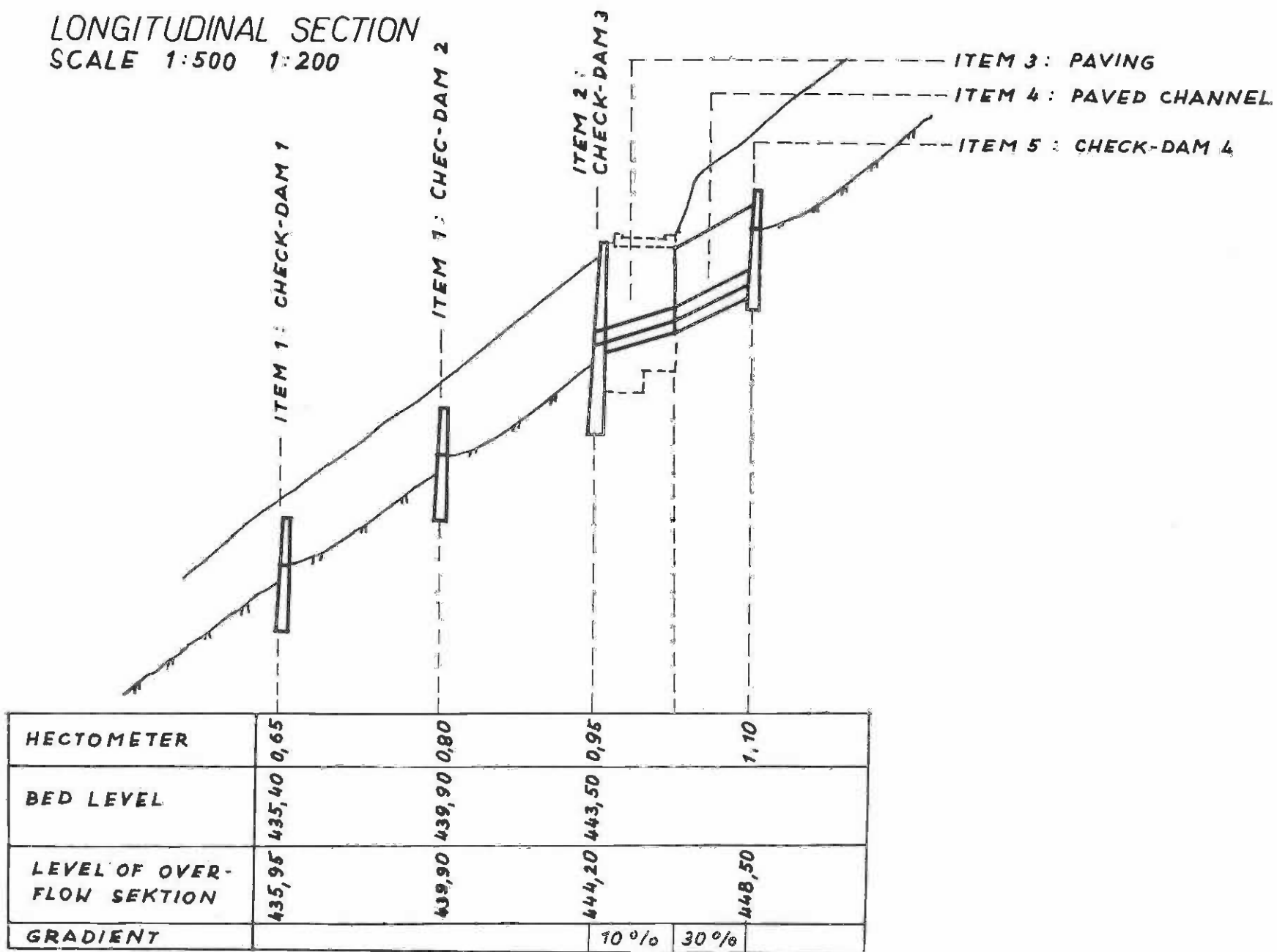
'WEISSE RIESE'

SITE PLAN

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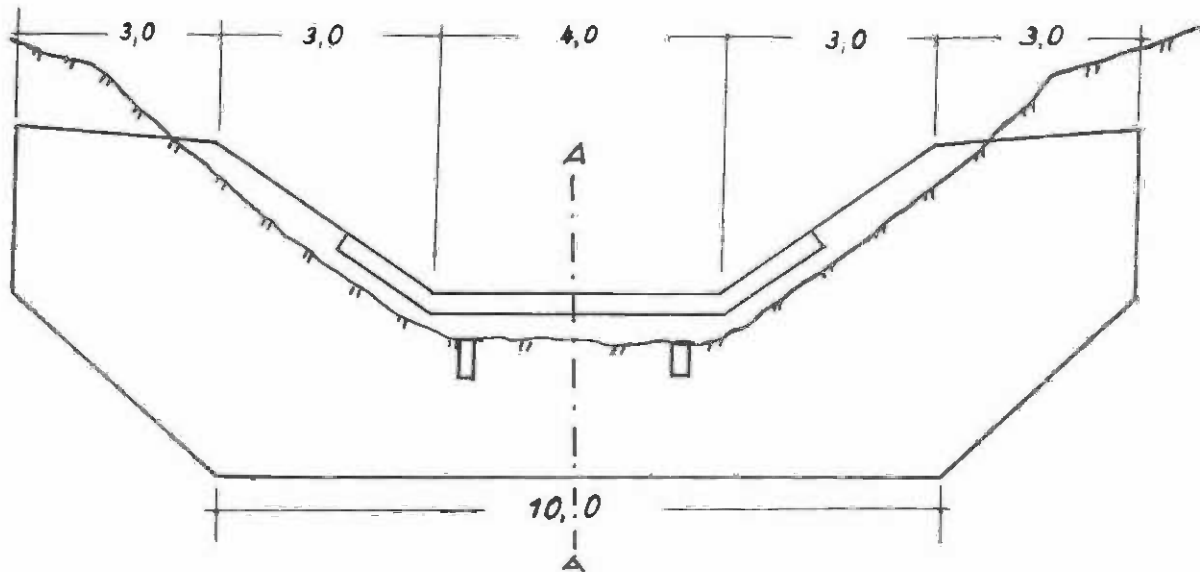
LONGITUDINAL SECTION
SCALE 1:500 1:200



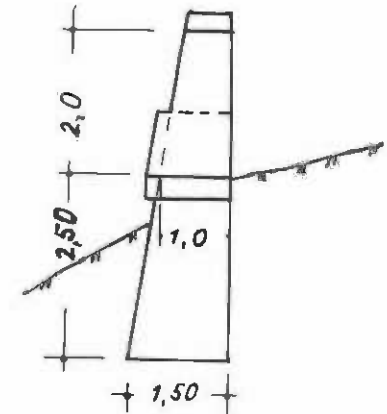
CROSS SECTIONS

SCALE 1:100

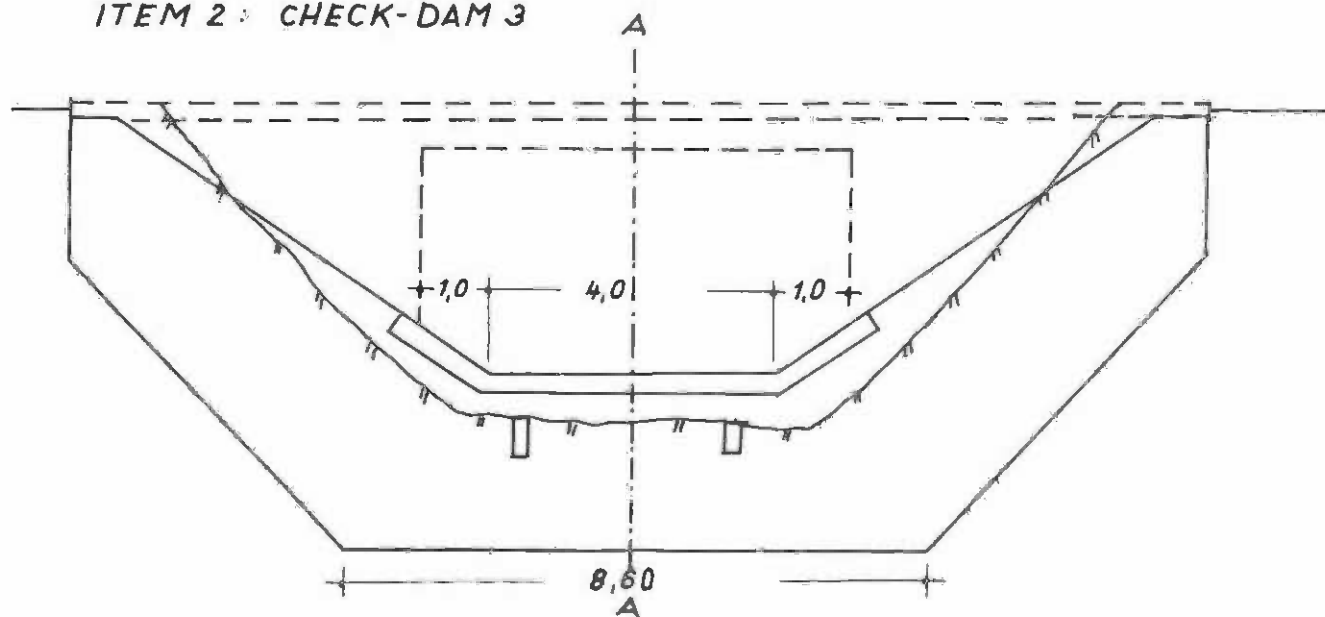
ITEM 1 : CHECK-DAM 1 AND 2



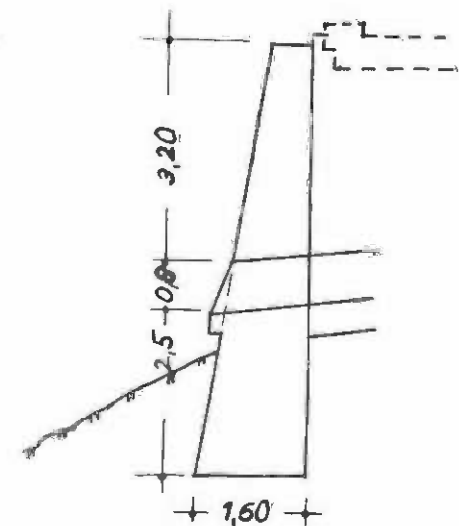
SECTION A-A



ITEM 2 : CHECK-DAM 3

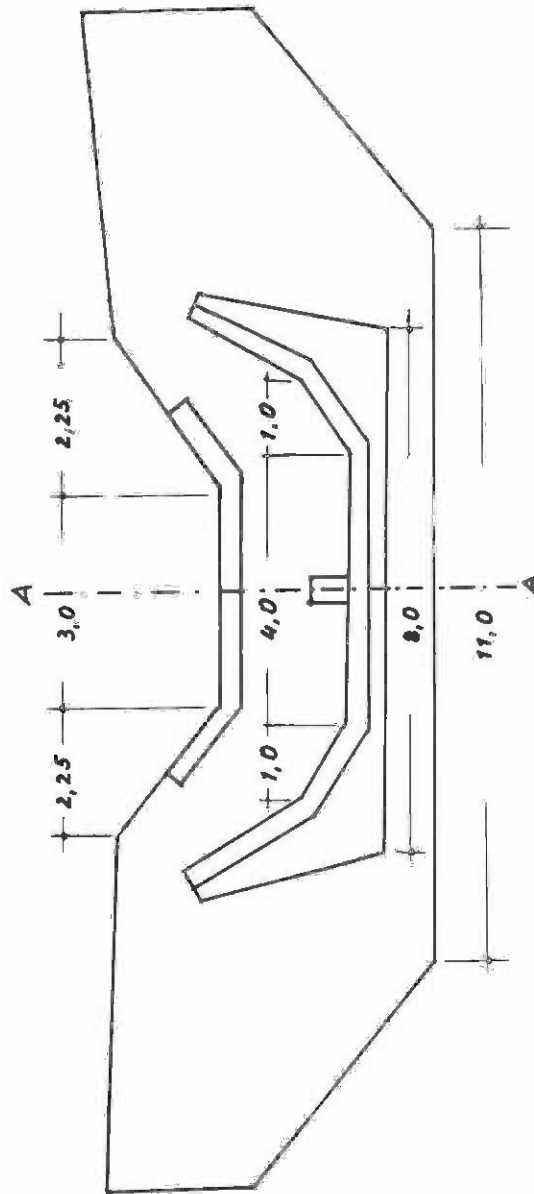
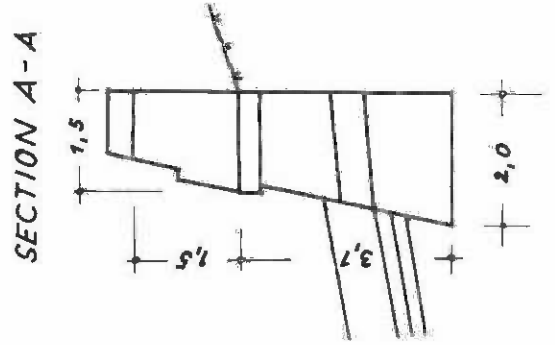


SECTION A-A



CROSS SECTION SCALE 1 : 100

ITEM 5 : CHECK-DAM 4



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ANNEX 1

Works used for torrent control

<u>Description</u>		<u>Elements</u>
Rip-rapping with payloader or bulldozer (with shovel)	1.5 t	quarry stones
1 m3	0.1 h	payloader
	0.1	supervision
Rip-rapping with dredger	2.0 t	quarry stones
1 m3	0.1 - 0.3 h	dredger
	0.1 - 0.2 h	unskilled labourer
	0.1 - 0.2 h	supervision
Gabions	2.0 - 3.0 m2	wire mesh
1 m3	1.2 m3	gravel
	1.0 - 2.0 h	skilled labourer
	3.0 - 6.0 h	unskilled labourer
Paving (thickness 0.3 m - 0.4 m) with quarry stones	0.5 - 0.9 t	quarry stones
1 m2	0.2 - 0.25 m3	concrete
	3 to 8 kg	steel mat
	1 h - 4 h	skilled labourer for preparing stones
	2 h - 4 h	skilled labourer for paving
Mulching		
1 m2	0.3 kg	straw
	0.05 - 0.1 kg	fertilizer
	0.05 kg	seeds
	0.5 l	asphalt suspension
	0.1 - 0.2 h	unskilled labourer
	0.1 h	supervision
Contour planting (excluding excavation)	20	willow slips or cuttings
1 m	0.8 - 1.5 h	unskilled labourer
	0.2	supervision
Gravel drain with pipe 1 m deep (excluding excavation)		
1 m	0.8 m3	gravel
	1 m	pipe
	0.3 h	skilled labourer
	0.5 h	unskilled labourer



Crib type retaining wall made of roundwood to stop erosion by water flow.
(Photo O. Sedlak)



Torrent controlled with a series of check dams. (Photo T. Pasca)



Protective structures for forest roads (Photos R. Heinrich)

THE APPLICATION OF SOIL TESTING METHODS IN FOREST ROAD CONSTRUCTION

by

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INTRODUCTION

Forest roads, in order to serve their purpose, have to carry timber loads at the required times and the appropriate speeds.

On main roads, which may have one or two lanes, timber loads of 500-5 000 m³ a year are transported at speeds of up to 40 km/h. These roads are also intended for opening-up recreational woodlands. Therefore, they also serve private traffic moving at speeds of up to 60 km/h. The axle loads to be expected may be as much as 16 tons, since these roads are also used by truck, tractor-trailer units having a total weight of 38 tons.

Feeder roads have to carry wood volume loads of up to 500 m³ a year at a speed of up to 20 km/h and serve only opening-up purposes. Nevertheless, they must be regarded in elaborating construction plans. Skidding roads are accessible only for cross-country vehicles, sledges, horse-drawn carts, and the like, and are used periodically.

If the local road construction material has a low bearing capacity, reinforcing layers of screened or natural material, gravel or sand, mixed with binders (bitumen, cement) would be necessary. Feeder roads may be poorly reinforced but accessible all year round, or not reinforced and only temporarily accessible. The second type (fine-weather roads) can carry trucks only when the surface is dry or frozen.

Forest roads must be sufficiently resistant to mechanical, climatic and bacteriological influences. Appropriate construction methods and traffic safety can be guaranteed only if data are supplied by soil testing methods which help determine the quality and stability of a road. Such control data will decisively influence the excavation methods used in a certain project. There are simple procedures that permit soil testing without special devices, and laborious and complicated methods that give an exact description of soils and their qualities by reference data or curves. Most methods are standardized processes. Tests should always be carried out by experts to give reliable data.

Since there is such a large number of soil testing methods only the most important ones are mentioned in this paper, and the individual steps are not described in detail. Furthermore, only mechanical stabilization methods are described since these are most frequently used in forest road construction. Stabilization with lime, bitumen, cement, and chemical substances is of minor importance. Mechanical stabilization consists in increasing the internal friction by better distribution of soil grain sizes and compaction.

At the construction site a soil mechanics expert visually classifies the soils according to their properties. In field testing the soil is analyzed and its properties described.

^{1/} Federal Forestry Research Institute

However, although such a rough analysis is important it is not sufficient for an exact evaluation. Reliable data can be obtained only from mechanical tests. For an accurate evaluation of the test results it is important to know whether the test samples consisted of natural and undisturbed soil, of more or less disturbed soil, or of kneaded material. Tests are carried out either in a field laboratory at the building site, or in a normal laboratory.

2. ROUGH CLASSIFICATION OF SOIL PROPERTIES

Visual and manual methods serve as a rough classification.

2.1 Visual methods

Grain sizes, weights and percentages are estimated and colours recorded by means of visual methods.

(a) Soil fractions

Soil samples are picked up in the hand or spread on a suitable surface. Then the particles are compared with a reference table or objects in everyday use. The following categories are used:

Stones: grains bigger than a hen's egg.

Gravel: smaller than a hen's egg, bigger than the head of a match

Coarse sands: smaller than the head of a match down to grains just visible to the eye.

Fine sands: silt and clay are not visible to the eye; therefore, manual testing is necessary.

(b) Colour

The true colour of the soil can be determined only in full daylight and if freshly excavated. Changes in colour resulting from exposure to the air should be recorded. Dark colour of the soil is significant in that it indicates the presence of organic particles.

2.2 Manual methods

By means of simple hand and finger tests coarse and fine grain fractions as well as plasticity of the soil can be determined.

2.2.1 Dry-state stability

Sun, air or oven-dried samples show varying resistance to finger pressure; this clearly indicates the dry-state stability of the soil. There is none at all if the sample crumbles at a slight touch. Dry-state stability is high if the sample can be broken only between the fingers.

2.2.2 Shaking test

By means of this method the reaction of soils to shaking particularly of silty ones, is determined.

The sample should be nut-sized and moistened. It is shaken in the hollow of the hand. When water appears on the surface the sample becomes shiny. Under finger pressure the water disappears again; with increasing pressure the sample starts to crumble. Upon further shaking the particles again cohere and the test can be repeated. The time it takes for the water to appear on the surface and to disappear under pressure is a soil property indicator.

2.2.3 Kneading test

By means of kneading, the plasticity of a soil and its silt and clay content can be determined.

A soft but not sticky piece of soil is rolled on a smooth surface into a bar with a diameter of 3 mm. It is then kneaded to a lump again. Rolling and kneading cause a loss of water. The soil has:

- (a) low plasticity, if a cohesive lump cannot be kneaded from the bar;
- (b) medium plasticity, if the lump crumbles under finger pressure;
- (c) high plasticity, if the lump can be kneaded without crumbling.

2.2.4 Rubbing test

This method serves to estimate the proportion of sand, silt and clay.

A small sample is rubbed between the fingers, sometimes under water. The proportion of sand grains can be estimated by the degree of coarseness, crunchiness and scratchiness. Clay soils feel greasy and stick to the fingers; when dry they will not come off without washing. Silty soils feel soft and floury and can be blown off when dry.

2.2.5 Cutting test

In this test a moist soil sample is cut with a knife; if the cut surface is shiny the clay content is high. A dull surface indicates silt or clay-sandy silt with low plasticity.

To investigate the organic elements of a soil and the degree of decomposition of organic particles it must be smelt and squeezed by an experienced tester.

3. EXACT TESTING

3.1 Determining water content

The water content determines the quality of a soil and decisively influences its characteristics such as compacting ability, its carrying capacity and resistance to frost. The water content is expressed by the weight of pore water as a proportion of the particle weight after drying at 105° C.

$$\text{Water content}_u = \frac{M_u - M_d}{M_d} \times 100$$

M_u = mass of the sample undried

M_d = mass of the sample kiln-dried

3.1.1 Oven drying

Drying soil in an oven is the most reliable method and therefore the most frequently used. The sample is dried till its weight remains constant and then cooled down to room temperature in an exsiccator. The next step is weighing. The scales should be accurate to 0.1% of the sample weight and the maximum permissible weight difference of 0.05 gramme.

Large samples cannot be weighed on precision scales and are too big for the exsiccator. Therefore, simpler scales are employed and the dry weight is determined while the sample is still warm, weighing errors being tolerated up to ± 10 gramme.

The sample size chosen depends on the type of soil to be tested and should be in the 10 - 10 000 gramme range for silt, coarse sand and gravels.

3.1.2 Calcium carbide test

Smaller samples are examined for their water content at the construction site. The accurately weighed sample is put into a steel bottle and an ampoule with a certain amount of calcium carbide, and several steel balls are added. The lid of the bottle carries a manometer. Violent shaking breaks the ampoule, the calcium carbide mixes with the soil sample thus generating an acetylene - air mixture. When the gas mixture is stable the pressure is recorded and the water content determined by means of a table. Other methods to determine water content use air pycnometers and submersion weighing. Rare methods are heating by infra red radiation and burning of small samples.

3.1.3 Petrol test

This method is employed for testing coarse-grained soils such as coarse sand and sand. The fresh sample is weighed and spread in a metal basin. Then petrol is poured over the sample, and the mixture is stirred with an iron bar. The combustion heat dries up the sample; the dried sample is then weighed and on the basis of weight difference, the water content is determined.

3.2 Determining the state of the soil

The Atterberg soil limits which are indices for coherent soils are important control data for assessing the plasticity and compacting ability of soils. These limits indicate the points at which transitions from one state to another takes place and are expressed in percent of water content.

Liquid limit w_f : transition from the liquid to the plastic state

rolling limit w_a : transition from the plastic to the semi-solid state

shrinking limit : transition from the semi-solid to the solid state

Below this limit a decrease in water content does not cause a significant change of volume.

Plasticity w_{fa} indicates the state in which the soil is kneadable. The plasticity index is expressed as a percentage and indicates the difference between liquid limit and rolling limit ($w_{fa} = w_f - w_a$). The state of a soil depends on its natural water content (w_n) and can be calculated with the aid of an index (k_w) as follows:

$$k_w = \frac{w_f - w_n}{w_{fa}}$$

k_w - states:

< 0	.....	liquid
0	.....	liquid limit
0 - 0.50	...	viscous
0.50 - 0.75		soft
0.75 - 1.00		stiff
1.00	.....	rolling limit
> 1.00	.....	semi-solid/ solid

In order to find the plasticity limits of a soil the values of the liquid limit and the plasticity index are plotted into a chart as devised by A. Casagrande.

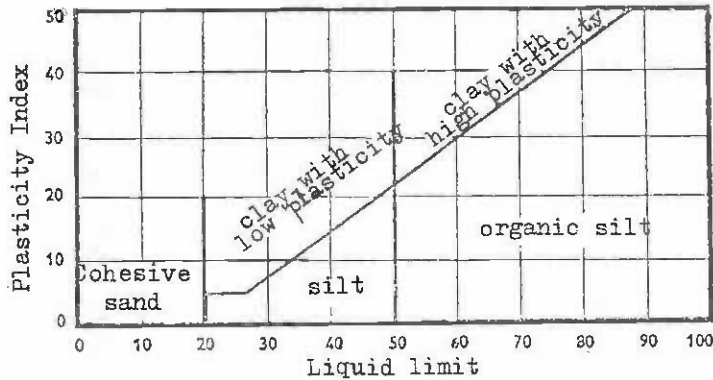


Fig. 1 - PLASTICITY CHART

From the calculated values and the graphic representation the plasticity of the soil type can be examined and its compacting ability easily determined. In practice the liquid limit is found by means of a method devised by Casagrande. Samples with grain sizes of < 0.4 mm and varying moisture contents are filled into cups. Then a small furrow is drawn in the samples. The cups are hung in a device operated by a handle, which is turned. The cups strike the ground till the furrow closes. The number of strikes and water content are entered on a record sheet. The resulting four to six values are combined and the water content after 25 strikes is expressed as a percentage.

The samples are rolled on a water-absorbent surface to a thickness of 3 mm (rolling limit). The process is repeated till the sample starts to crumble, and the water content of the particles is determined.

3.3 Determining grain size composition

The grain size is calculated by the diameter of a sphere which can pass through the same sieve as the grains and has the same sedimentation speed in water. The value for grain distribution indicates the proportion of various grain sizes existing in a particular soil. Grain distribution is graphically represented by a curve.

This mechanical analysis is used for determining the composition of a natural soil or base material. The sample is put through a series of screens and thus fractionated.

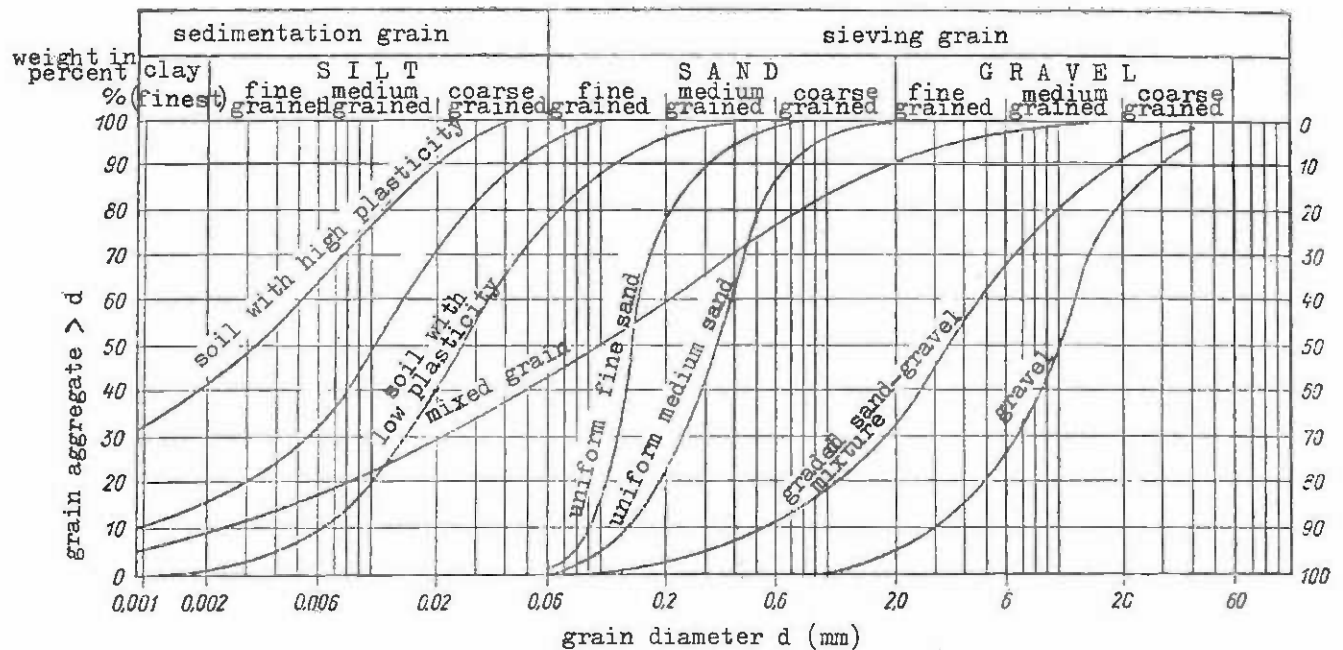


Fig. 2. CHARACTERISTIC GRAIN DISTRIBUTION CURVES

There are two main groups:

- (a) Sedimentation grains with clay particles of < 0.002 mm and silt with a diameter of $0.002 - 0.06$ mm. Grain size and distribution are determined by analysis of water sedimentation.
- (b) Sieving grains with a sand grain size of $0.06 - 2.0$ mm and a gravel grain size of $2.0 - 60$ mm. Grain size and distribution are determined by dry sieving.

A mixed grain structure contains sieving grain and sedimentation grain sizes. Examinations are carried out by sieving to a grain size of 0.063 mm and subsequently analysing the sedimentation. In a soil mixture the grains should be distributed in such a way that the spaces between the large grains are filled with fine grains; there should be as few void spaces as possible. The grain distribution curve of favourable road material is represented by a quadratic parabola. If p is the percentage of material falling through the sieve with the mesh size d , and if d_o is the smallest grain and D the largest one, the equation reads as follows:

$$p = \frac{d^m - d_o^m}{D^m - d_o^m} \times 100$$

The parabolic exponent for useful mixtures is $0.40 < m < 0.55$.

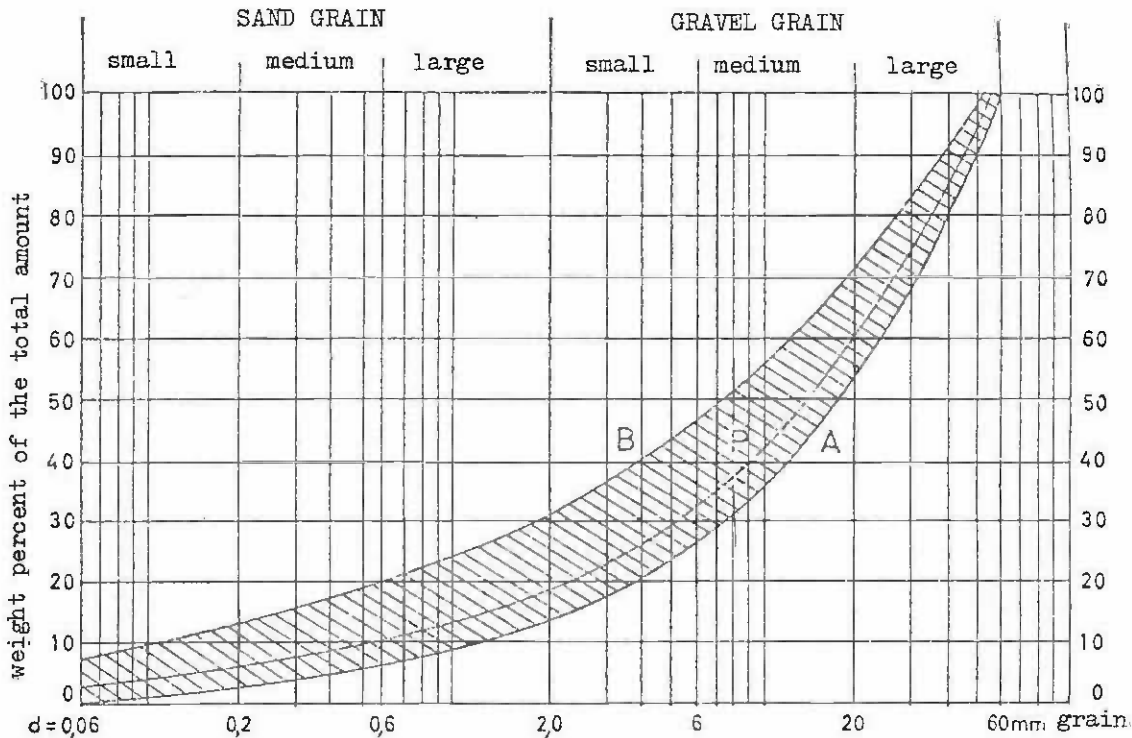


Fig. 3 GRAIN DISTRIBUTION CURVE OF A BROKEN MINERAL MIXTURE
A,B marginal sieve lines
P quadratic parabola

3.4 Determining the Proctor density

Cohesive and non-cohesive soils have an optimum density. This can be determined in the laboratory by means of the Proctor test and is called simple (100 percent) Proctor compaction. This is the compaction a soil type can reach when its moisture content is most favourable for construction, and is called the dry volume weight. In this context a differentiation is made between soils that are difficult or easy to compact. In the first group are all cohesive soil types, uniformly grained non-cohesive or slightly cohesive soils with a non-uniformity of $U = 1.5 - 3$, and light and heavy rock. Soils that are easy to compact are well-graded sands or sand and gravel mixtures, and non-cohesive or slightly cohesive soils with $U = > 7.0$. Non-cohesive or slightly cohesive soils with $U = 3 - 7$ require intensive compaction.

The standard of non-uniformity is $U = \frac{d_{60}}{d_{10}}$. In this formula d_{60} and d_{10} are the grain sizes that correspond to the ordinates 60 percent and 10 percent of the grain distribution curve. Soils with $U \leq 5$ are called uniform and soils with $U \geq 5$ are called non-uniform.

Test description

To an air-dried sample having a grain size < 7 mm, water is added until the water content is approximately 5-6% below the estimated optimum water percentage. The thoroughly mixed material is introduced into a standardized cylinder in 3 layers. Each layer is compacted by 25 strokes (gravity weight). Both the cylinder and the compacted sample are dried. Then the dry volume weight is determined. A small quantity of material is extracted from the centre of the sample and its water content determined. The same process is repeated for samples with 2-3% higher water contents, until the moist volume weight decreases. All the values are then plotted into a chart and the resulting curve is the Proctor curve. The dry volume weight at the top of the curve is the highest value that can be achieved under the given test conditions. The volume of the compacted soil sample must always be recorded in order to find the dry weight difference between the construction site sample and the laboratory sample with a Proctor density of 100 percent. If the latter has a dry volume weight of 1.80 g/cm^3 and the former 1.71 g/cm^3 this means that a Proctor density of 95 percent was achieved.

If during compaction only 90 percent of the Proctor density is achieved, settlement of the road material after construction is to be expected under traffic conditions. It is therefore important to check the water content of soil with a certain grain distribution during excavation by means of the Proctor test. There must be optimum moisture content to guarantee good compaction.

3.5 Determining deformation

The plate bearing test is employed when other compaction tests cannot be applied, as for example in the case of large rubble hills.

The plate bearing test serves to find the degree of deformation (E_v) or the bedding index (k) of the non-bituminous, non-cement bound base of gravelled roads. Furthermore, it indicates compacting ability, load capacity and density of a soil. It is applied in all cases in which other compaction tests fail, that is for coarse-grained, stony and rocky material.

Since the plate bearing test can be carried out only at the construction site and costs in time, equipment and material are high, it is only rarely used in the construction of forest roads.

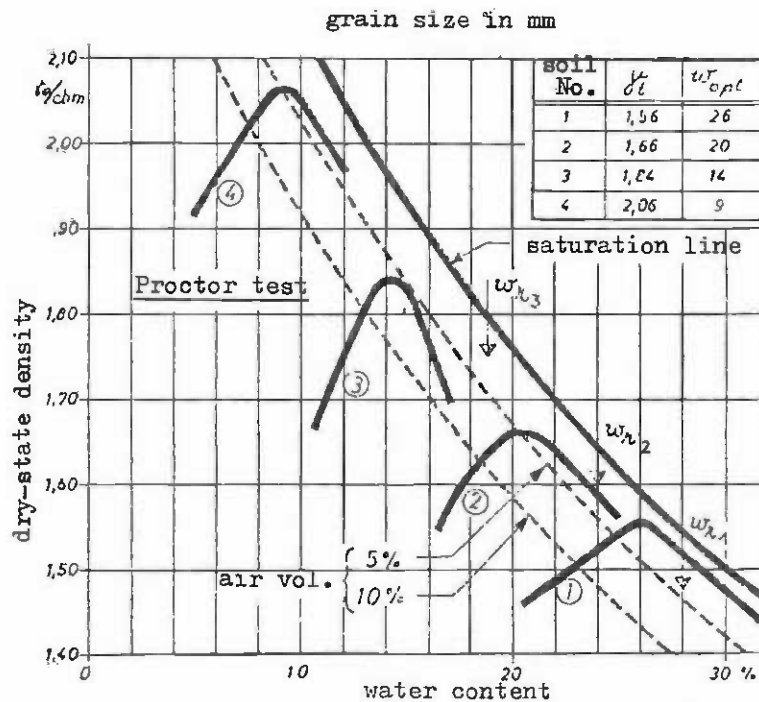
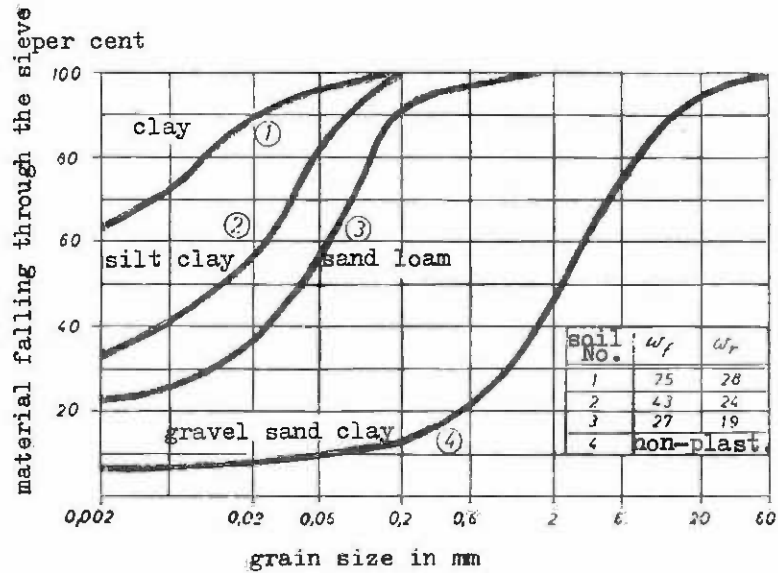
More important than the above-described method is the CBR test (California bearing ratio) which is used extensively in non-European countries. This test is an empirical method for determining the relative bearing capacity of the sub-soil. The method, which was developed in the USA, is standardized. The deformation resistance of a soil which was first compacted in the laboratory is determined by means of an indenter. Deformation resistance is defined as the compaction a soil must have to allow indentation of 1.25 mm/min .

The compaction of the sample is compared with a standard sample (graded, crushed rock) compacted under the same conditions and over the same indenter path. The compaction ratio between the samples is expressed in percent. CBR-values in the range of 15-40%, 40-100% indicate good, and values between 70-100% excellent soil characteristics.

3.6 Determination of water capillarity

It is important to know the capillary height of sands and fine gravels if they are to be used as frost protection material. The capillary height must lie below the frost protection layer. In general, a soil is sensitive to frost if it has a degree of non-uniformity of $U < 5$ and more than 10 percent of grains under 0.02 mm , or if the values are $U \geq 15$ and more than 3 percent of the grains are under 0.02 mm . During the freezing process such a soil draws water into the frost area (groundwater, drainage water) which is deposited in layers of ice. When they thaw, the soil becomes saturated and soft and loses its load-bearing capacity.

Fig. 4 - COMPACTION CURVE FOR
DIFFERENT SOIL TYPES



A soil exposed to frost can be protected by the addition of material with a grain size of >0.02 mm. Addition of individual big stones is not very useful; a good grading of the sieve curve is more important.

The simplest device to determine capillary height up to 1 m is the so-called ascending tube, a calibrated cylinder of glass or clear plastic with a finely meshed lower edge. The soil is oven-dried, filled into the cylinder and compressed with a wooden pestle. The cylinder is then put into a container of water and the capillary limit (indicated by a change in colour of the soil from light to dark) can be read. The sample size depends on the size of the cylinder and ranges from 4 - 15 kg. The diameter of the largest grain should not exceed a fifth of the diameter of the cylinder.

4. EXTRACTION AND TREATMENT OF SAMPLES

Test samples have to be extracted at points which are representative of the average particle distribution in nature. To examine the soil types in an existing road, samples are extracted from all its layers. The number of samples to be sent to the laboratory depends mainly on the diameter of the largest grain (as indicated for some methods), individual samples are combined to give a good representative sample for determining the soil type.

The individual samples are blended, thoroughly mixed, heaped and divided until the required test quantity is obtained.

The consistency of cohesive soils may need to be determined. In this case the samples have to be kept in vacuum containers till they are tested. To test the density of a sample - in order, for example, to determine compaction - individual samples instead of a mixture are used. These are taken with special tools in order not to disturb the sample. The extraction data should be carefully entered on a record sheet.



Participants listening to the lecture on soil tests. (Photo T. Pasca)

THE WORLD FOOD PROGRAMME ASSISTANCE TO FOREST ROAD CONSTRUCTION
IN DEVELOPING COUNTRIES

by

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1. INTRODUCTION

The World Food Programme (WFP), set up jointly by the United Nations and FAO, began operations in 1963. Its purposes are:

- to meet emergency food needs and emergency inherent in chronic malnutrition; and
- to assist in the implementation of projects for economic and social development, using food as an aid.

These government development projects supported by WFP assistance fall conveniently into three categories, one of them being for directly producing projects, including those in the agricultural and forestry sectors.

Governments often find it difficult, for budgetary reasons, to engage in projects that require a substantial labour force, the cooperation of a large number of producers or the training of large numbers of people. Furthermore, whilst these indispensable projects (such as erosion control, watershed management, forest plantations) usually have to be implemented in socially or economically marginal areas, they have a relatively long-term return and, therefore, hardly attract the traditional investors. WFP food aid, in the form of grains, meat, fish, dairy products, oils, sugar, etc. can help governments meet such costs; the food rations being given either as part payment of wages or distributed as an incentive to participation in self-help projects. In several instances, the contribution of WFP has proved to be the decisive factor in a government's decision to undertake the project.

Forty-three approved WFP projects, for a total cost to the Programme of approximately US\$173 million, aiming at the integrated development of natural resources and the employment of people in low-income rural areas through reforestation, soil conservation, watershed management, forest road construction, man-power training and related activities, are presently under way or should become operational in about 30 developing countries.

2. WFP AND OTHER COMPLEMENTARY FORMS OF AID

The emphasis in UNDP projects is mostly given to pre-investments. Assistance includes expert advice, equipment and training. FAO has major responsibility for executing such projects in the field of agriculture (including forestry) which are operated by FAO personnel working closely with the responsible government agencies.

The WFP assistance, on the other hand, is a capital input in the form of food support of government projects, the government being responsible for their execution and for the handling, storage, transportation, distribution and use of the WFP commodities after they are delivered at the port of entry. The government is also responsible for the technical aspect of the project, the WFP field officers assisting the government authorities concerned with the logistic aspect of food aid.

One should say that UNDP and WFP assistances are complementary in a two way process: WFP projects assisting the implementation of the recommendations formulated by a UNDP/FAO pre-investment project or a WFP project showing the need for some pre-investment studies in order to achieve better results. In many cases UNDP/FAO and WFP projects are closely associated.

Most of these projects could not have been launched without WFP grant-in-kind aid. However, many other projects of similar nature cannot be undertaken particularly in the 25 least developed countries because they lack the technical expertise and funds (often required in hard currency) to meet the cost of non-food inputs such as equipment, materials and supplies as well as the technical know-how which are indispensable for the support of forestry development and watershed management projects.

With the present arrangements, the required non-food inputs cannot be supplied by the WFP aid, and in several instances, in order to assist the governmental executing agencies, one or more technical assistance projects of non-UNDP origin have been developed (FFHC/Action for Development; Trust Funds provided through FAO Cooperative Programme with Governments or bilateral assistance) and special efforts are being made to increase the non-food items component to the WFP projects.

The recently established FAO Technical Cooperation Programme (TCP) already provides a substantial assistance to several projects and complements WFP aid.

3. WFP ASSISTANCE TO CREATION OF EMPLOYMENT AND TO FOREST ROAD CONSTRUCTION

As already mentioned, the WFP food rations may constitute a part payment of the wages which in some cases may generate savings. These savings could either permit increase of the labour force or be re-invested in the necessary equipment or tools. In several countries where regulations do not envisage supplements for skilled or hard work or for workers having to stay in remote areas, food assistance may help to solve this problem. Also, when no cash wages are paid or could be paid, the food rations may represent an incentive to local population working on road construction for communal forests or even when roads, in addition to their role in wood extraction from state-owned forests, would have a social role linking villages and areas previously isolated.

Food assistance may help considerably in creating employment in low-income areas where unemployment and under-employment represent generally serious socio-economic problems; sometimes it may also help to avoid unnecessary mechanization. It should also be stressed that apart from the fact that forestry workers throughout the world and especially in the developing countries, usually get low reward in terms of wages, security and stability in employment, their living and working conditions are among the poorest; their diet could be

improved with food assistance and their productivity increased. Usually, daily rations distributed per day of work are calculated on the basis of five beneficiaries: the worker and four dependents.

As forestry road construction is a part of forestry development works, it is mentioned in the title of the WFP-assisted forestry projects only in a few cases, like for instance, WFP project Syria/268 "Construction of Forest Roads and Afforestation in Selected Areas". Also, the construction of forest roads "per se" not always justifies the approval of a specific WFP project but is rather associated with other forestry activities. As an illustration, objectives of a project are given below:

Indonesia 2343 "Social and Economic Development in Java through Forestry Activities"

The main purpose of the project is to open forest areas to which access is presently extremely difficult. Among other objectives is the plantation of 2 500 ha, mostly with Pinus merkusii and teak. The project will last five years and the WFP contribution to the performance of some 7.4 million man-days of labour is estimated to amount to about US\$5 608 000. Approximately 89 percent of the WFP contribution will be for forest road construction or rehabilitation.

Activities will consist of:

	<u>Targets</u>	<u>Man-days</u>
Forest road construction	352 km	6 560 000
Forest road rehabilitation	22 km	110 000
Reforestation	2 500 ha	420 000
Check dams/irrigation dams	6 unit	300 000
		<hr/> 7 390 000 <hr/>

It is to be noted that, in addition to the technical and economic requirements which sometimes may be somewhat neglected, the main problems encountered when formulating, and later on, evaluating the achievement of forest road construction schemes undertaken with WFP assistance are:

- The accuracy in the establishment of work-norms and therefore, in estimating the total man-days of work required. Revision of work-norms in labour-intensive projects because they were originally set too high or too low (mistakes are easy to make until experience has been gained with the work) is often a necessity.
- Forestry officers, when designing forest roads, have in many cases to take into consideration the competing needs of the local population whose villages are devoid of any public roads. Therefore, the road may well not be properly designed either for logging needs or for public use and it needs to be completely rebuilt later on.

4. PREPARATION AND PRESENTATION OF REQUESTS FOR WFP ASSISTANCE

The UNDP Representative in a country is also the representative of WFP. In addition, WFP project officers and FAO Country Representatives are stationed in the majority of the developing countries served by FAO. Ideas for possible food aid should be discussed with them, and upon their advice, the appropriate government agency may formulate the request in English, French or Spanish according to the proforma for WFP project requests.

Further information may be requested from the UNDP/WFP Offices in the various countries or from the Forestry Department Liaison Officer with WFP, FAO, Via delle Terme di Caracalla, Rome, Italy.



Labour-intensive road construction in a food-for-work project in Peru.
(WFP/FAO Photo).

THE FOREST ROAD NETWORK
AS A BASIS OF MODERN TIMBER HARVESTING

by

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I. INTRODUCTION

Forest road construction in its modern sense was started in Europe in the last century, when timber was still transported over long distances by floating and rafting.

At that time road construction was hard manual work, costs were high, and progress was slow. A forest road was just an alternative to many other possible ways of transport, such as forest railways, waterways or cableways.

This situation underwent a marked change when after the second world war earth-moving machines of US origin started to be employed in Europe. Austrian foresters were pioneers in mechanized road construction in mountainous areas.

In Austria, the productive forest land comprises about 3 230 000 ha. Between 1950 and 1977 a road network of about 46 000 km was constructed which replaced the old ways of transport. Annual cuttings amount to roughly between 10 and 12 million m³ of timber, of which 85 percent is transported by road, about 11 percent by animals, sledges and the like, and only 4 percent is extracted by cableways.

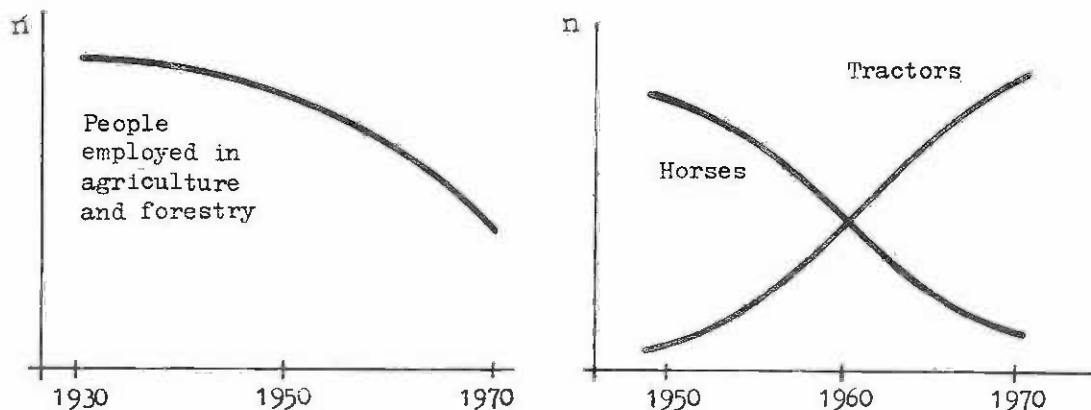
What were the causes for the development of forest roads?

- lower construction costs and faster progress of road construction works by the application of modern machinery;
- economic advantages to be gained by use of the forest road network;
- increasing timber demand;
- shortage of labour and high wage costs in forestry, the need for mechanization of forest work.

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The following figure shows the Austrian trends in the employment of people, horses and tractors.

Fig. 1



The experience gained in Europe can be only partly applied to non-European forests. The forest road network in tropical and subtropical forests cannot be planned according to the same density objectives since biological, economic and technological prerequisites are different.

2. FUNCTIONS OF THE FOREST ROAD NETWORK

A forest road network is the only long-term means to open up a forest area and to integrate it into the economy of a country and into the international market. This approach offers many advantages but also entails many disadvantages.

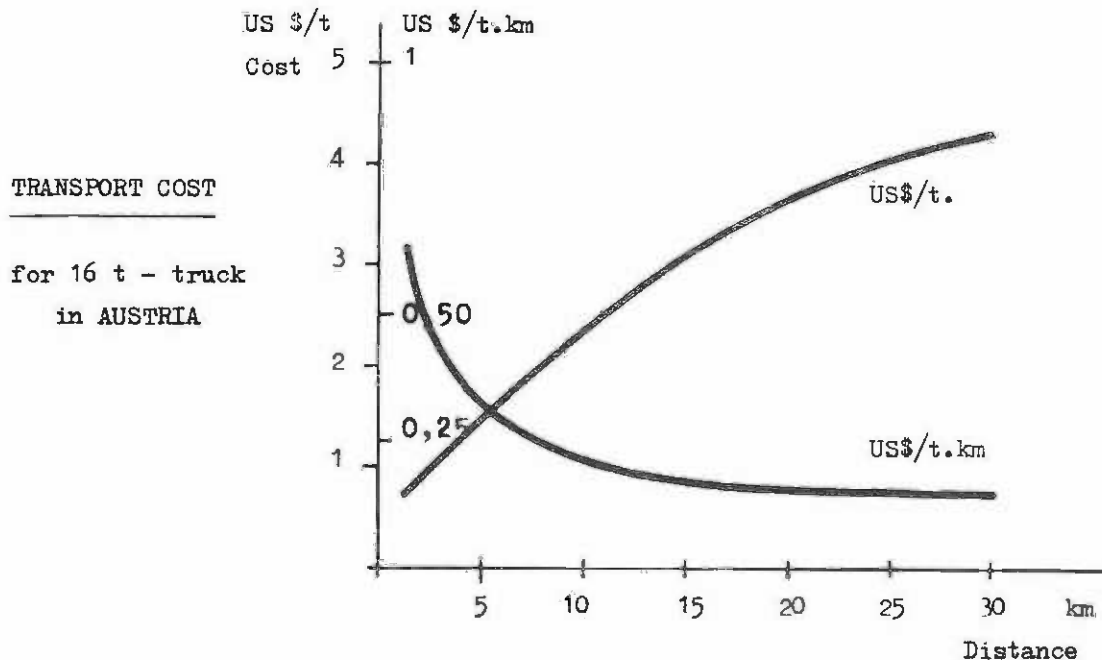
2.1 The main advantages of a forest road network

a) Low transport costs

Just like coal or iron ore, timber is a mass commodity with an unfavourable price-weight ratio; it is "transport-cost sensitive". All over the world the heavy lorry has become the best means to transport timber over short and medium distances. Railways are competitive only over long distances, the economic distance margins depending on the individual economic conditions of a country. Figure 2 shows the cost curve in US\$/t and US\$/t x km. The costs per ton and kilometre are relatively high for small distances of 5-10 km; they decrease with longer distances.

It is only by lorry that timber can be transported from the forest directly to the consumer. Compared with other interrupted ways of transport, such as lorry-railway-lorry or lorry-ship-lorry, loading and manipulation costs are considerably lower. This is why the forest road network should be suitable for heavy vehicles.

Fig. 2



b) Improved economics

It is interesting to note that the road networks in Central European forests are used for timber transport at the rate of a mere 20-25 percent a year. About 75-80 percent is made up by passenger traffic and transport of machinery and material into the forest. The forest road network influences the ecological, economic and social aspects of management. Small extraction distances mean lower extraction costs and help to avoid damage to soil, stand and extracted timber. Smaller timber cuttings and low-quality assortments prove also worth extracting. Since little time is required to transport the timber from the felling site to the consumer, fungi and insects cannot affect its value. The capital required is not tied up for as long a time as it was formerly.

Skidding machines can be employed most favourably in an opened-up forest area. Supply of petrol and spare parts is no problem. The forest road frequently serves as a work site, and a place for machinery, and also as a landing, mainly for timber extracted from steep terrain.

The road divides a forest area into permanent units, thereby dividing the terrain for planning, silviculture and production.

Working conditions for forestry workers and administrative personnel are improved because working sites can be reached quickly and without fatigue. In case of accidents help can be provided quickly. If distances are not too long workers can return to their families after work, which is important because food and housing are seldom adequate at the work site.

For reasons of economy it is possible to meet the ecological requirements for small cutting areas and decentralized cutting sites only in opened-up forests. Forest protection, such as prevention of fires and pests, is greatly improved.

In many subtropical and tropical forests the infrastructure is improved by a forest road network. Dispersed settlements are connected.

Forest road networks not only contribute to the permanent cultivation and preservation of a forest, they also improve conditions for people who work and live there. Therefore, road networks are a justified investment for the future.

2.2 Disadvantages of a forest road network

In planning a forest road network one should be aware of its disadvantages and try to keep these to a minimum.

Constructing a forest road means interfering with the ecological system. Inaccurate planning and construction will result in damage from erosion and landslides.

Even under normal conditions with accurate planning, the erosion rate will increase after road construction. This is particularly likely in mountainous areas. Löffler gives the following data on the opening-up of a mountainous forest in the USA which has a deep soil layer, 1 500 mm of annual precipitation, and a forest road network of 40 m/ha:

<u>Condition</u>	<u>Annual erosion rate</u>
Before road construction	0.02 - 0.03 t/ha
During and after road construction	2 - 4 t/ha
After consolidation of batters	0.1 - 0.15 t/ha

During road construction, therefore, the erosion rate was 100 times higher than before starting, and after consolidation of batters it was still 5 times higher than it would have been in undisturbed terrain.

Road construction in rocky and steep terrain will cause heavy damage to the forest by sliding excavation material.

A general requirement can therefore be formulated: the planners of forest roads should take great care to keep the unavoidable damage to soil and forest which will be caused by road construction to a minimum. This requirement can be met with the help of modern machinery and construction methods.

The loss of productive forest area through the construction of a forest road is considerable, as shown by the following example:

Forest area 1 000 ha, road network density 20 m/ha

	<u>Europe</u>	<u>Tropical forest</u>
Average width of clearing	10 m	20 m
Area required	20 ha	40 ha
Percentage of area	2 %	4 %

Studies in Germany have shown, however, that the loss of trees is partly compensated by a higher increment of trees located at the edges of the clearings of the roads.

Forest road construction may also affect forestry negatively in overpopulated areas with primitive kinds of agriculture (shifting cultivation). A forest road network may lead to inconsiderate exploitation and therefore to destruction of the forest. These problems are not to be blamed on forestry but on the economic and political forces in a country.

3. FOREST ROADS AS LIFELINES OF MODERN FORESTRY

3.1 Extraction methods in Europe

Wherever forestry is up-to-date, a road network is the basis of modern timber harvesting. The density and condition of the road network can be adjusted to the different economic and technological standards. Road construction as a means of opening up forests has found worldwide recognition.

In the same way, the system of timber extraction can be adjusted to local conditions. There is therefore no single system which can be called the best. But costs for machinery employed in road construction and timber extraction tend to be similar all over the world and therefore comparable; timber extraction problems show common worldwide trends.

Timber extraction has been widely mechanized in European countries having a high percentage of forest land because wages are high and labour is scarce. The degree of mechanization varies in individual countries because of terrain and wage level differences.

For more than 20 years the machine most frequently used by the forest worker has been the power saw. Its introduction was one of the most effective measures of rationalization in forest work. Extensive working with the power saws however, will damage the health of workers. For physiological reasons the axe should be employed at least for delimbing.

In flat and hilly areas the articulated wheeled skidder is unrivalled for wood extraction. In such areas a road network density of around 15-20 m/ha is sufficient. Favourable terrain conditions will enhance the trend towards full mechanization; for example, the application of fellers, bunchers and processors.

In Europe the system chosen for timber extraction depends upon the size of the holding. In small forests owned by farmers, full mechanization is neither feasible nor required because farmers can work economically by extracting their timber with the help of available labour and farm machinery.

In mountainous areas, wood harvesting is much more difficult and expensive. Even in industrialized countries, mechanization will very soon arrive at its economic limits.

For slope gradients of up to 40 percent articulated wheeled skidders can be used for downhill extraction; on steep slopes timber is most rationally skidded by the gravity method which has been applied in Alpine countries for centuries.

Since this method involves heavy work and labour is scarce in Europe it is important to shorten the average skidding distances to 100-150 m by roads dividing the slope into sections. Plastic chutes, the newly-developed "log-lines", have opened up new perspectives for gravity skidding of smallwood.

In bigger forest enterprises extraction by cable is an integral part of the logging system. The steeper and more difficult the terrain, the more important the various cable systems.

In Austria, 50 percent of the timber is skidded manually by gravity, and about 40 percent by wheeled tractor or cable. About 10 percent is transported to the forest roads by animals.

In Central European mountainous regions a high road network density of 25-50 m/ha is required. Road density depends for the most part on the type and size of forest holdings.

3.2 Extraction methods in tropical and sub-tropical forests

In subtropical and tropical forests wage costs are low and sometimes the demand for work is very high. Therefore there is no need for full mechanization. Under the specific climatic conditions it is essential to make work easier for the worker and to increase his performance and so his income. By simply introducing modern tools and training forest workers, conditions can be considerably improved. The power saw is indispensable for work with heavy logs.

Since generally the amount of commercial timber per hectare extracted from tropical forests is much smaller than from Central European forests, the cost of road construction becomes disproportionately high. This is why in flat and hilly areas a forest road network with a density of 10-15 m/ha must be sufficient. Wheeled skidders, crawler tractors and animals are employed and sometimes various skidding methods are combined.

In mountainous tropical forests skidding is problematic. Gravity skidding is hardly feasible because logs are too heavy and the method is hardly known in this area. In less precipitous terrain logs are extracted by articulated wheeled skidder or crawler tractor, in precipitous terrain by cable systems. A minimum road network density of about 20 m/ha is required.

4. PERSPECTIVES AND TRENDS

World demand for timber will increase with economic growth and rising population. Even if other raw materials become scarce and economic development slackens, the demand for timber will hardly decrease but rather to a certain extent increase.

Timber is a naturally growing raw material which will always be at man's disposal if forests are wisely managed. The forest areas still existing in this world must therefore be protected and managed in such a way as to guarantee an uninterrupted flow of wood production of steady quality.

Unfortunately, this principle is frequently not observed in practice. In many parts of the world forests are endangered by ruthless exploitation. In past centuries, the danger of their destruction was also present in Alpine countries. As a consequence, stringent Forestry Acts were passed and the forest service was founded.

Work objectives have not greatly changed. Timber harvesting is compatible with the concept of forest protection only if the forest road is accurately planned and carefully constructed. The road network will serve as a basis for long-term and well managed forestry.

The present trend towards mechanization in timber harvesting in industrialized countries will soon reach its limits. Rising energy costs will set lower and lower economic limits to highly mechanized systems; a tendency which can already be observed. But a forest road network is the permanent element in the opening-up of forests and if carefully planned it can be used for all methods of timber extraction.

Finally, people in developing countries cannot become forest-conscious as quickly as technology is advancing. The reasons are not only economic but also social. The machines obtainable nowadays permit exploitation and destruction of relatively big areas in short periods of time. Population pressure and demand for land which is then cultivated by primitive methods are the main reasons for heavy losses of forest land.

Therefore, before opening-up forests, production limits and protective silvicultural measures should be determined and their application be followed. This objective is already beyond the narrow range of forest technology and requires a consistent forest policy.

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Uphill ground skidding by farm tractor with bogie. (Photo Steyr Werke)



Delimber-debarker-bucker processing saw logs. (Photo R. Heinrich)



Loading of trailer and truck by truck-mounted grapple loader at the log landing. (Photo E. Pestal)

NEW TRENDS IN WOOD HARVESTING

by

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Even though wood harvesting varies greatly from country to country, its objectives are the same everywhere:

1. to increase wood production in order to meet the demand of an ever growing population
2. to avoid losses in quality and quantity by improving felling operations, haulage and storage
3. to reduce the physical stress of forest workers during wood harvesting operations
4. to use machinery and techniques which will not damage the productive capacity of the forest.

Permit me to start my presentation with Item 4, because this is commonly underestimated in many wood producing countries.

"A bigger biomass" is the slogan which has led to the devastation of forests in some countries. When whole-tree logging is used, the forest is deprived of its biological substance, its nutrient circulation is interrupted, and wood harvesting results in the gradual devastation of the forest. The harvesting of wood only is the least harmful for the forest. The bark, which contains many immunising substances and antitoxins, ranging from antibiotics to growth inhibitors, may be dispensable, but the forest is certainly allergic to the deprivation of branches, brushwood, leaves and needles. If on top of it large areas are also deprived of their root substance, the forest as a living community will finally collapse. Therefore, all efforts aiming at the total technological exploitation of the tree, including its roots, should be rejected. The delusion will soon pass, but the feeling of remorse will last, and in mountainous forests the consequences are simply unforeseeable.

Furthermore, large machinery should not be used. On account of their high purchasing costs and high daily production capacities they can only be employed for exploitation. Some years ago we witnessed the attempt to introduce fully mechanized harvesters into the forestry of Central Europe. Meanwhile, they have disappeared again.

Today we criticize those foresters who introduced the theory of highest revenue 150 years ago. But they did not cause that much damage to the forest because they did not have the machines. Today the machinery is available which, if abused, could have a ruinous effect on forest resources. Therefore, the use of machines should be kept within reasonable limits, for otherwise future generations will severely criticize us.

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This Training Course shows modern, labour-saving, economical but moderate methods of wood harvesting which aim at the preservation and improvement of the productive potential of the forest. In Austria we can offer a wide range of possible solutions. Some of 250 000 wood owners carry the wood on their backs out of the forest because they do not have a horse for skidding. On the other hand we employ the articulated four-wheel drive skidder with a capacity of up to 10 tons. In areas so remote that eagles nest there, helicopters have been used for the transport of timber. The big difference in the size of holdings, topography, wages and population density are the reasons why primitive as well as partially or highly mechanized methods of timber harvesting are used throughout Austria.

1. WOOD HARVESTING AS A PROBLEM OF TRANSPORT

When man was a hunter he used to draw the wood for his hut and his fire with his hands for thousands of years before he succeeded in taming the urus. Suddenly the payload increased fivefold to a hitherto unsurpassed degree of rationalisation. We have thus defined the most important correlation of wood harvesting "the unit mass law".

The fewer individual units to a certain mass, the cheaper its transport. A pulpwood length of 2 m, which was introduced in Germany, is more economical than the previously used length of 1 m. In Sweden pulpwood usually has a length of 3 m, which is even better. In Austria efforts are under way to have a length of 4 m and if feasible even a length of 6 m or in rare cases, of 7 m.

The limits of the unit mass law become evident when full-length trees are to be skidded. In this case the damage done in the course of thinning may reach such an extent that this can no longer be considered a tending operation. The same holds true for the skidding of long logs or whole trees (including branches and crown in the course of thinning).

The unit mass law is not a law of nature but an empirical economic law. It has its limits and allowance should be made for exceptions. If there are enough local contractors available for short timber transport and if a special company would have to be hired for long timber, the transport of short assortments could be more profitable for both the wood producer and the wood processor.

In general, the basic economic goal is to gradually increase the size of unit masses, while skidding equipment, forest roads, loading facilities and means of transport have to be adapted correspondingly. In Austria about 50 years passed between the development of the 6 ton capacity truck and the tree-axle-truck with minimum payload capacities of 25 tons. Most of the public bridges do, however, not permit further increase in payload capacity.

2. WOOD HARVESTING AS AN ECONOMIC PROBLEM

On the average, the costs of felling, skidding and transport add up to more than half the total expenditure of forest enterprises. Any improvement in this sector makes itself immediately felt; however, this also holds true for planning errors. For this reason some basic rules for a useful mechanization are listed below:

If mechanization is rejected and no new techniques are introduced, operations will become inefficient and workers will gradually leave. If the level of mechanization chosen is too high, if the machines bought are too expensive, the operation of the forest enterprise will not be profitable either. Over-mechanization is even more dangerous: under-mechanization can be gradually made up for, but over-mechanization cannot be undone without heavy losses. Moreover, the use of big machinery results in wage increases which can hardly be decreased when it becomes evident that they present too heavy a burden for the enterprise.

The same type of mechanization cannot be applied everywhere. Each enterprise has to decide for itself which course it will follow. It would be wrong to believe that the mere purchase of machines guarantees profits. The adaption of working techniques to new machinery is at least as important. There are enterprises which buy the right machines for their workers but which are nevertheless unable to increase their profits. The foresters have not taken care of proper work organization. The workers have used them in the wrong way or ruined them altogether.

The right type of machinery and their well-planned use are the basis for profitable forest operations.

Mechanization can only be successful if the worker never believes that he could be replaced by any machine. Therefore, mechanization should be pursued particularly in areas where there is not a sufficiently large labour force available. The prime purpose of machines should not be to help save labour but to fill gaps in human labour. It would also be problematic to use large machines for wood harvesting, which is finally promising, and to leave only the less profitable tending operations to the workers. This would merely make them hostile to machines.

3. ORGANIZATION OF WORK

The easiest way to learn how to organize work is in your own enterprise; in the beginning all you need is to be present at the work site. You will soon learn about difficulties when you watch operations constantly. In this connection the first principle of any manager should be to praise positive achievements and to refrain from criticizing failures. It is enough to be aware of them. Mistakes are repeated only if nobody takes the trouble of noticing them. On the other hand good achievements will not continue if the manager does not take note of them. Frequent presence at the work site is therefore the first step towards an active and well-planned organization of work.

After the period of observation enough results should have been gathered to be able to start the coordination of the different operations. Every day in the evening one should review the different work elements such as employees, work sites, equipment, means of transport for personnel and equipment. One should work out two versions for each day: one for good weather and one for bad. Thus one automatically has weekly and monthly work programmes.

We can no longer expect too much of innovations in the machinery sector because the introduction of various new designs would impair the productive capacity of the forest. However, as far as the organization of work is concerned, there remains much to be done. The main problem is that most forestry people love nature and therefore take a sceptical or outright negative attitude towards technology.

It will probably take years or even decades until a change in attitude can be expected. Such a change is, however, necessary, since otherwise wood harvesting may become the exclusive domain of technocrats, while the work of foresters will be confined to afforestation and tending.

4. RESULTS OF THE TESTING OF NEW TECHNIQUES

Since the First International FAO Training Course on Forest Roads and Wood Harvesting, in 1975, new results have mainly been obtained in the fields described below:

4.1 Whole tree extraction

Whole tree skidding, i.e. the skidding of full-length trees with branches is a precondition for delimbing by processor in the forest and has meanwhile been tested in various areas in Austria. Even if the trees are topped and the tops remain at the felling site, this method constitutes a loss for the forest soil. Dust clouds in dry weather and mud streams after heavy rain clearly indicate that this method should not be used in mountainous terrain.

The use of processors permits reduction in the number of forest workers to a minimum, thus greatly facilitating management. However, the question remains as to whether the use of processors can be justified at a time when there is the danger of unemployment. A comparison with manual delimbing, or delimbing with power saw shows that the use of processors has resulted in strikingly low profits.

4.2 Debarking at wood industries sites

Debarking of almost two-thirds of the total wood volume felled in Austria is now carried out at the site of the forest industries because debarking has shifted from the forest to the processing firm. The profits obtained are shared by the wood producer and the wood industry. In some cases, the secondary advantages such as rapid transport, preservation of quality and prevention of drying out are more important than the financial advantages.

4.3 Piece work by farmers

Since suitable forms of mechanization have also been found for farm forests, farmers have become a valuable supplement to professional forest workers or commercial felling companies. A piece-work farmer enjoys the same tax reliefs and social welfare benefits as the farmer. Owning forests in this way, even large enterprises stand a chance of getting at least a small share of the cake of agricultural subsidies.

Piece-rate work as subsidiary earnings help the mountain farmers survive. For forest enterprises piece-work by farmers is a cost-reducing factor. Piece-rate work, due to its high flexibility, is especially important when huge volumes of wood have to be processed within a short time span, e.g. after a disaster.

4.4 Thinning and utilization of small sized wood

The utilization of small wood is still one of the weakest points of mechanization. In Austria harvesting of small-sized timber by means of large machines will never be profitable. But even the partial mechanization of thinning operations will involve losses, since the forest enterprise has to bear the full burden of taxes and social charges.

Small processors can only be used in flat and hilly terrain. We hope that piece-work farmers and their small machines - wheeled tractors with one drum logging winch, and horses - will prove to be a favourable solution in mountainous terrain.

5. SUMMARY

In the three years since the last International FAO Training Course further progress has been achieved in all fields of wood harvesting. In certain sectors a limit in mechanization has been reached which should not be exceeded for reasons of forest protection.

In the future special attention should be paid to the preservation of timber quality. The time interval between felling and processing should be shortened. In cases where it is not possible to accelerate skidding and transport the drying out of wood should be prevented right at the log landings by means of long-distance sprinklers. The timber should also be protected from fungus and insect attacks. In the log yards of the wood processing companies sprinkling of stored timber should also become a matter of course.



Power saw winches are useful when clearing forest roads.
(Photo E. Pestal)



The MB-Trac fills the gap between a farm tractor and a skidder. Its cable equipment and a comfortable two-man cabin make it increasingly popular. (Photo E. Pestal)



A logging winch attached to an agricultural tractor is often used for wood extraction in farm wood lots. (Photo E. Pestal)

PRINCIPLES OF GENERAL PLANNING OF WOOD HARVESTING METHODS
IN MOUNTAINOUS REGIONS

by

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Generally speaking, the work system to be chosen for timber harvesting is determined by the size of the operation.

The interrelationship of the various elements in the system have important influences on the work to be performed and the final results.

Planning of work must be preceded by an analysis of the significance of the individual elements of the system. On the basis of these findings, the limits of each element can be determined.

Fig. 1 - Order of working stages

Objectives of work planning (Determination of the limits)	
Measures to be taken	Results
Opening-up Road network Work procedures Forest machinery	Increased output from forest
Personnel Number - qualifications	Performance, Efficiency, Safety
Basic training Further training	Environmental protection
Wages	Economic output

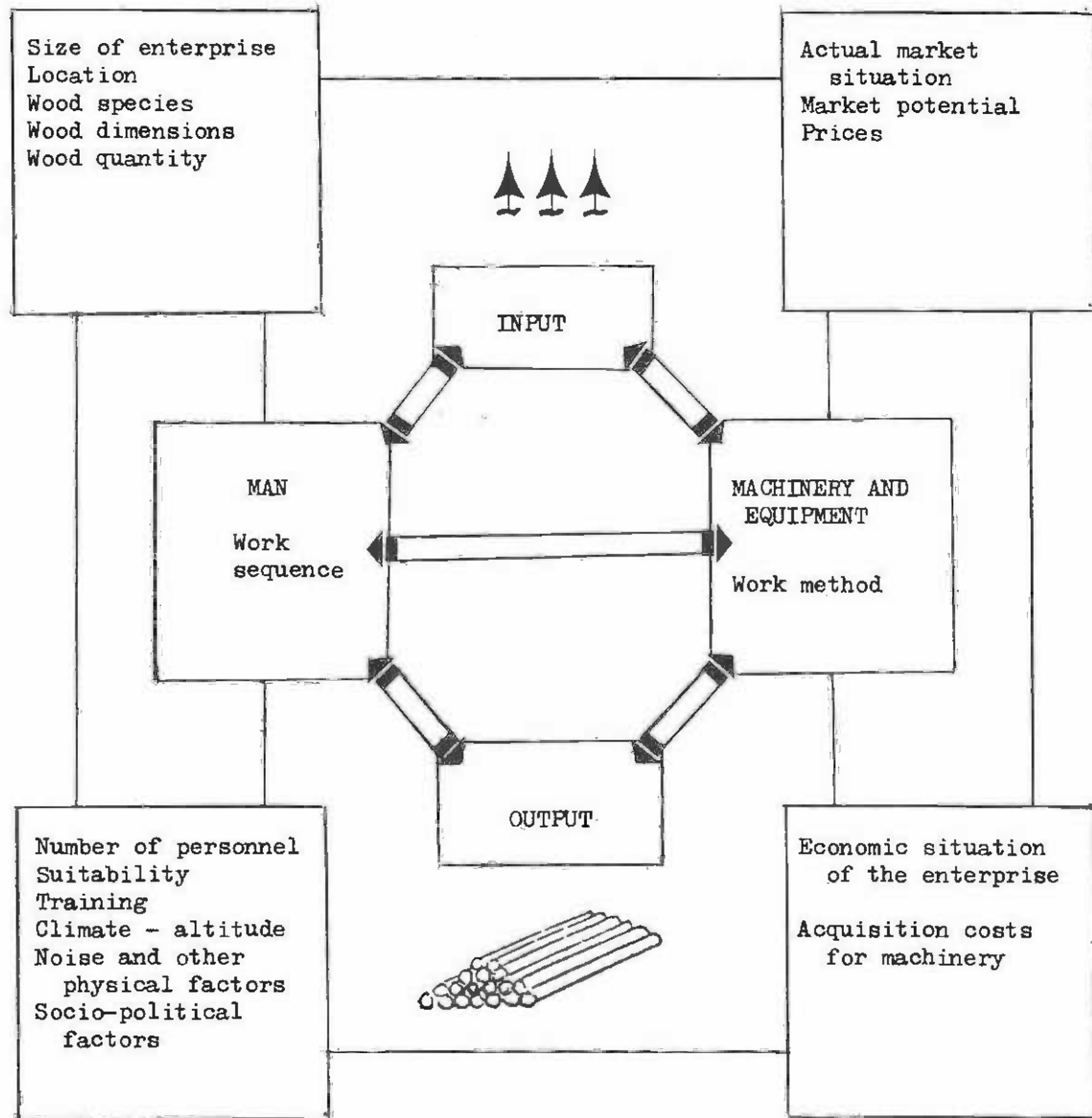
The first measure to be taken in work planning is aimed at an optimum opening-up of the forest area by means of a good road network.

In planning the road network it is important to consider the forest machinery to be used. (See "The Forest Road Network as a Basis for Modern Timber Harvesting, by Dr. Sedlak, page 127). The kind of machinery and systems to be used determine the routing of minor skidding trails.

If opening-up is planned with a view to potential mechanization the advantages will include lower production costs, a lower workload for the forest workers and less danger of accidents.

^{1/} Forestry Training Centre, Ort, Austria

Fig. 2 - Work system for wood harvesting



The work system consists of an outer and an inner circle. The outer circle, in which the elements include size of enterprise, its economic situation and social conditions, is usually beyond the planner's influence. Nevertheless, he has to take it into account in determining the inner circle - the way he will work - which includes his input and output.

It is a further substantial objective of work planning to choose methods of wood harvesting which are suitable for the given conditions and guarantee safe operation. The three factors of production - forest, man and machine - are the basis for choosing a biologically, socially and economically justifiable wood harvesting method. It is obvious that work, safety and maintaining the health of the forest's condition must also be taken into consideration.

Every planner should try to make use of mechanization insofar as it makes work easier, safer and more economic. He must not, however, ignore the social conditions and the need to create employment, and not unemployment.

Based on such deliberations, the work methods and the necessary forest machinery are chosen.

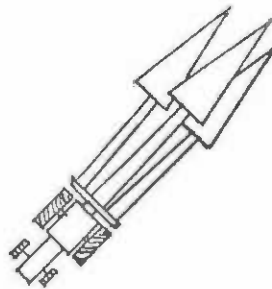
The planner may choose between three methods:

- The whole-tree method
- The full-length method
- The assortment method

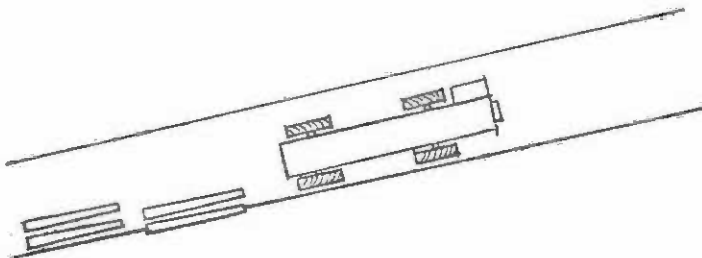
Fig. 3 - Whole tree method



1. Felling



2. Skidding



3. Either employment of mobile processor or transport to timberyard and final processing at the mill.

Fig. 4 - Full-length method

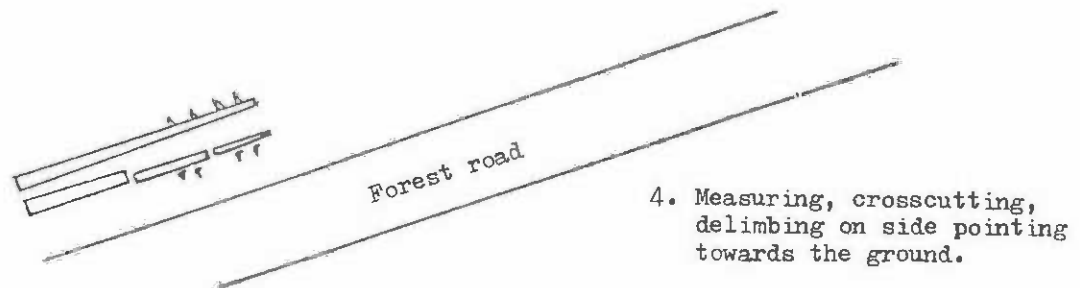
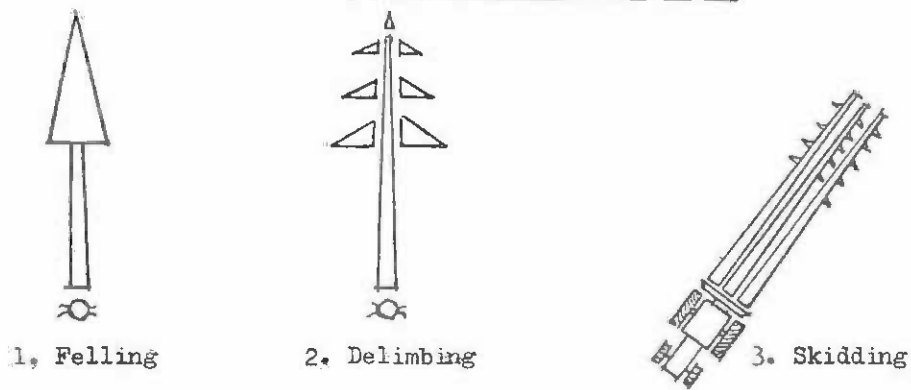
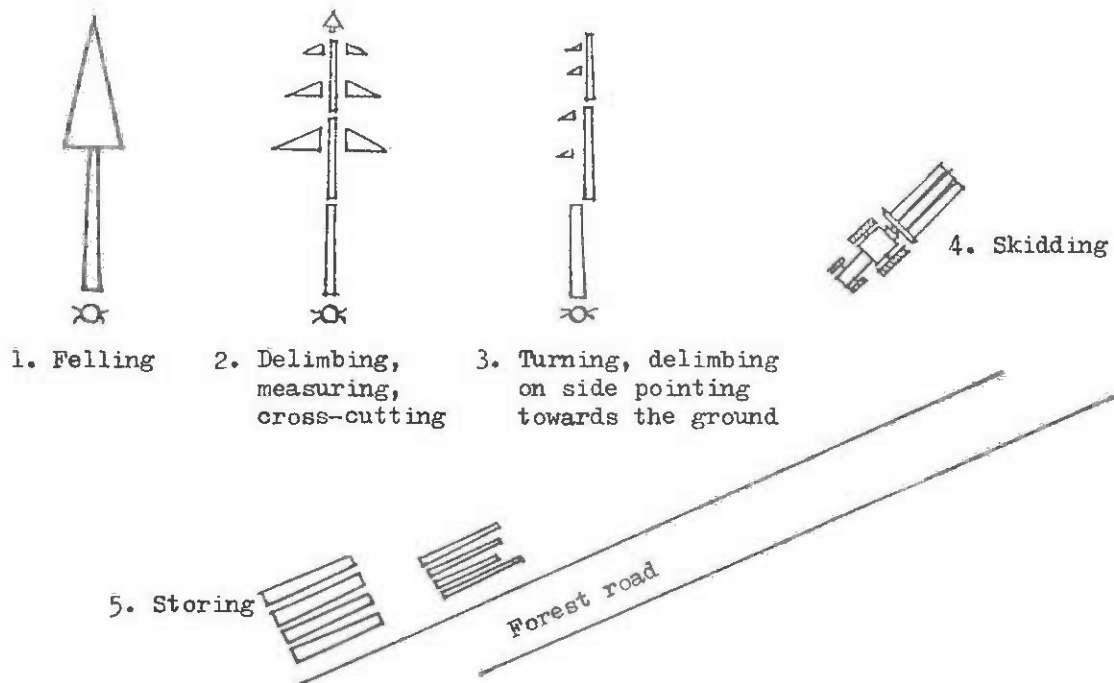


Fig. 5 - Assortment method



There are variants for each individual method. These figures are intended only to outline the main characteristics.

Each of the methods described above may be appropriate in different circumstances.

It is not true that in any event the most highly mechanized method is also the best one. In order to arrive at a correct decision and to avoid adverse consequences it is vital to consider not only the costs but also the environmental influences on man and forest, and to take the impact of the outer circle of the system into consideration.

Generally speaking, the assortment method (logs and double-length logs, or cross-cut poles of a maximum length of 12 m) is preferable in selective harvesting because major damage to the remaining stand is avoided.

The assortment method is also most appropriate when small volumes are to be cut per felling area (up to about 150 m³ final cuttings) or when short skidding distances (up to about 250 m) are involved. If landings and terrain are extremely difficult the assortment method is also advisable.

Large quantities of timber, long skidding distances and clear-cuttings with negligible preparatory cuts are factors which would justify the full-length method. Prerequisites are appropriate landings and suitable skidding machinery. Here, it is common practice to complete the entire harvesting operation once begun in order to reduce indirect expenses and to use the machines to their full capacities (in terms of time and load per trip). For thinnings it is important to calculate the costs for optimum preparation on special landings, in particular expenses of time and machinery incurred. Also, comparison between potential proceeds and expenses should be made.

The whole-tree method requires a careful study of questions such as the amount of timber to be harvested, transport and skidding alternatives. Cost accounting is a valuable source of information in the decision-making process (See "Comparative Cost Calculations for Various Wood Harvesting Methods" by H. Tauer, page 201).

The machines chosen for the various harvesting methods are selected to meet the requirements of the individual project (work, workers, performance, economics).

A machine can be suitable only if it has been designed for the particular type of terrain and work process (cross-country mobility, a favourable weight-performance ratio etc.). Ideally, a machine designed for a specific operation should be adaptable to various other uses as well. Damage to the remaining stand, to the timber produced, to the forest floor and the road has to be kept to a minimum.

A machine can be adequate to the worker only if it corresponds to ergonomic principles and requirements. Its design and safety features must be such as to guarantee easy, convenient and safe operation (these are prerequisites for the worker's sustained performance).

Machines can be efficient only if, apart from the above-mentioned criteria, they permit safe and reliable operation under normal conditions. Before purchasing a machine, its specifications should be studied in relation to the work required of it. Of course, profitability is another factor that comes into play here. It will be profitable if the purchasing price is reasonable or low, if it can be employed at capacity and if costs for its operation and repair are low. If it is used to 60 - 70 percent of its capacity satisfactory results can be obtained. Acquisition costs should always be related to the unit (m³) of production.

Today, reliable economic and ergonomic data are available. It is advisable to consult these data before buying a forest machine. The data can also be used for determining positive and negative characteristics of machines already in use.

Work methods and machines are fully effective only if operators are efficient and specially trained.

Work planning includes choosing sufficient well-trained personnel.

It would be completely wrong to believe that planning consists merely in the acquisition of machinery and the intention to apply a certain work method.

Wages for a particular job should be determined by planners. Trained and experienced workers operating under a normal workload should receive adequate compensation. If, however, the worker receives a higher payment in compensation for the strain of additional work he may offer to perform, his life and work may be endangered, wear and tear on the machine may be excessive and the remaining stands may be damaged.

Wages may be either in the form of time wages, piece-rate wages or bonus payments. It is up to the planner to choose the right kind of payment for each job.

Bonus payments are advisable when the work process is a combination of manual work and machine operation.

Production, protection and a healthy ecology of the forest are not in the hands of just the forest worker. Any person who has a share in the work process is concerned. The challenge is particularly high for the planner. Planners must be conscious of their responsibility and act accordingly.



STEYR-USA processor 705 at work, delimbing and bucking. (Photo E. Pestal)

ORGANIZATION OF WORK

by

Othmar Frauenholz
Forstliche Ausbildungsstätte Ort ^{1/}

The purpose of work organization is to plan the best use of available labour, machinery and techniques in production in accordance with the specific task assigned.

Measures

Effects

Detailed planning	- Optimum use of machinery and equipment
Felling sequence	- Safe and efficient work
Determination of the size of the work crew	- Economic efficiency
Making work sites safe	- Lower work load
Organization of working hours	- Qualified work and high efficiency
Arrangement of work breaks	- Mutual satisfaction of employer and employee
Positive follow-up	- Valuable for future projects

The purpose of planning and the opening-up of a site in detail is to develop working conditions which guarantee the best use of labour and equipment on the one hand and the careful treatment of the growing stock on the other.

For the employee, detailed planning means organization and control of the work to be performed, which in turn results in safe working conditions, minimum physical stress, and efficient work.

A further advantage of detailed planning is that it results in the efficient use of the machinery and equipment provided for opening up the site. It also means that the operations will not entail additional dangers to man, machinery and equipment, and the forest itself.

Factors in opening up a site which should be carefully planned are the following: skidding trails and tracks, skidding tracks in connection with cable routes and cable crane corridors.

Skidding trails

These are earth roads which can be constructed at minimum cost. The layout and width of this type of road, which has no surfacing, are determined by the skidding equipment used. Heavy equipment (high horsepower rating) permits the laying out of steep skidding trails. The decisive factor when planning skidding trails is its erosional impact. The use of light skidding equipment requires routing over flat terrain. If agricultural tractors are used, the gradient should not exceed 25 percent.

^{1/} Forestry Training Centre Ort, Austria.

Minimum width of skidding trails

Skidding trails should have a minimum width of 2.5 - 3.0 m (safety, log gathering, fast transport). Planned as supplementary roads of the forest road network, skidding trails and tracks should provide for skidding on wide slopes which are accessible by truck. The logs are transported to the skidding trail either via the track, by means of uphill cable logging, or downhill by means of the alpine peavie.

Spacing of skidding trails

Depending on terrain conditions, the spacing of the skidding trails should range from 100 to 200 m.

Skidding tracks

These are natural corridors leading through the stand. Their use is restricted to certain forest vehicles. It is usually necessary to remove individual trees in order to render the track accessible. The forest floor serves as the road surface.

When tracks are selected, the topographical conditions should be taken into account. Good accessibility should be the final goal.

Width of tracks

Therefore, tracks should usually be laid out as straight as possible. The average width ranges from 2.5 to 3.0 m (vehicle width plus 1 m).

Gradient

On sloping terrain the track runs with the gradient. Cross-inclinations of the roadway should be avoided. If necessary, bends should be adjusted to the maximum length of timber to be skidded.

Skidding tracks should join the forest roads or landings at the most acute angle possible. Planners must take into account the space that skidding vehicles require for turning.

Spacing of tracks

On account of the working techniques applied the spacing of tracks should be as narrow as possible. In young stands the tracks should be planned at a distance of 15-20 m. Depending on terrain conditions the distance may vary by a few metres. It should not be determined without taking into account natural conditions.

Tracks in connection with cable routes

If the site is exposed to wind, if late thinnings are carried out in old stands or if the forest floor is hardly accessible, the track distance may vary depending on terrain conditions. In special cases it may come to as much as 100 m. However, if the track spacing is as wide as this, the remaining areas will have to be opened up by cable. In this case the economic utilization of the forest may be reduced for the benefit of stand protection. The full economic potential cannot be reached when the forest is hardly accessible (swamp, big rocks).

Spacing of cable routes

In such cases the spacing of cable routes may range from 5 to 10 m. The direction of the cable is determined by the topography of the terrain, the machine used for cable logging, the sequence of operations, and the type of cross-cutting required.

Cable routes

As a rule, in steep terrain the cable line runs with the gradient until it joins a skidding trail or forest road at an angle of 90°. If the gradient is smaller, individual cables may radiate from a suitable landing, which may be highly advantageous. Depending on the length of timber to be extracted and its further handling, the cable will run either in a direction vertical to the track (with skidding and crosscutting of logs at the track) or at an acute angle to it, if longer assortments or whole trees are required.

Cable corridors

The shape, length and spacing of cable corridors are determined by the terrain, the equipment used and the working technique selected.

When cable corridors are planned it is especially important that the entire sequence of wood harvesting operations is kept in mind and that a clear decision is made on the measures relating to the protection and best economic utilization of the forest.

Detailed plan for opening up

1. Determination of the section to be opened up (on the map and in the field).
2. Determination of the direction of timber extraction.
3. Provisional determination of extraction limits (starting and end points).
4. Repeated reconnaissance of the area to be opened up and choice of the best means for the most complete extraction with due regard for existing roads.
5. Determination of the extraction method to be used (skidding trails, tracks, cable routes and corridors).
6. Locating landings and processing sites.
7. Marking of tracks, cable routes, etcetera (marking of the trees to be felled or used).
8. Decision on whether the butt ends or the tops of the log should face the direction of extraction.
9. Determination of the felling direction.

Considerations for optimum skidding

1. Damage to the stand should be kept to a minimum.
2. Skidding should not cause subsequent erosion damage.
3. The workers should not be subjected to excessive stress or exposed to special dangers in the course of skidding operations.
4. Skidding should be possible at any time of the year. The condition of the timber (bark or branch stubs in contact with the ground) should not hamper skidding.
5. When the skidding system is selected, the size of logs required is a determining factor.
6. Skidding costs should be kept as low as possible; however these have to be considered in relation to total logging costs.

Felling sequence

The felling sequence should be chosen with consideration to efficiency and human factors. In addition, it should also cause the least possible damage to the forest.

Determination of the felling sequence and required measures

Consideration of the direction of skidding, determination of the felling direction, determination of the sequence of operations (beginning and continuation of operations).

Furthermore, the felling sequence includes determining the time and place of wood harvesting operations (whether felling and skidding constitute one work cycle or whether all stump area operations are completed before skidding starts, and so on). The sequence of individual operations ranging from felling to crosscutting is certainly not always the same, and should be arranged in such a way as to ensure safety, efficiency, and protection of the forest. When the felling sequence is determined, these factors should be taken into account.

In general, the selection of the correct size of the work crew is a key decision in the organization of work. The bigger the crew, the greater the danger of personality clashes, and the greater the mutual exposure to danger. With work safety and increased performance in view, the organizers should try to make sure that the crews are as small as possible, that is, that if possible they consist of one man only.

Reduced idle times, less stress for the individual worker, reasonable running periods of power saws, more diversified and dynamic work, and increased safety are the obvious results of such a measure.

By one-man work we mean that the stump area operations are carried out by one man only. The next worker does the same work at a safe distance. The minimum permissible distance is one and a half tree lengths, while the maximum distance is just within earshot. The sequence of operations on the tree is of special economic and ergonomic significance, which should not be ignored by those organizing work. Moreover, the creation of a safe working place, the organization of working time and the arrangement of breaks that take into account the stress to which the worker is exposed contribute toward both more safety of the individual worker and a higher performance level over long periods. Work can be done effectively only for a certain period. According to studies by Professor Lehmann the best average performance is achieved with a working time of five to seven hours including delay time and short breaks. If wood harvesting lasts eight hours a day the work results are still satisfactory; if the working time is longer, the average performance is considerably reduced due to increasing fatigue. At the same time the work may be done carelessly and with less concentration, which in turn considerably increases the danger of accidents. It has been known for some time that the workload can be considerably reduced and accidents avoided if work is interrupted by short breaks (two to five minutes).

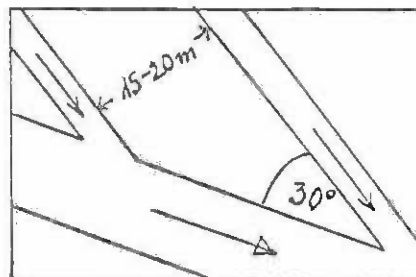
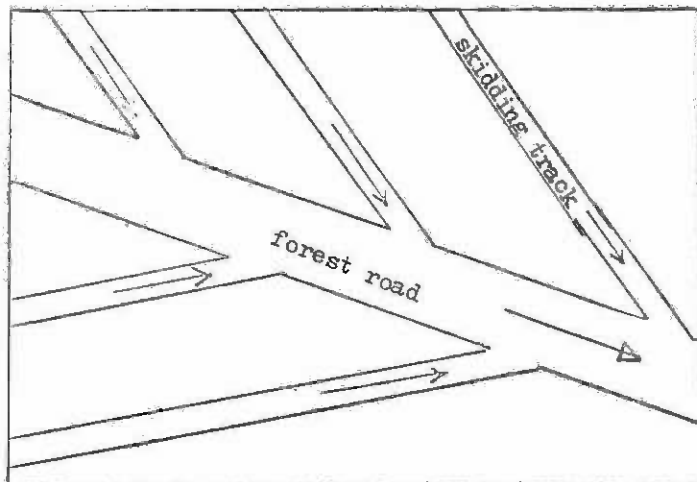
Positive follow-up, permanent training and the provision of suitable tools and equipment should be a permanent concern for those organizing work.

Measures aimed at organizing forest work contribute to increased safety and performance in wood harvesting and are an essential factor in the conservation of the forest and the prevention of stand damage.

ANNEX I

SKIDDING TRACKS

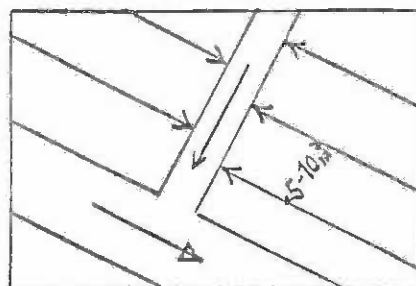
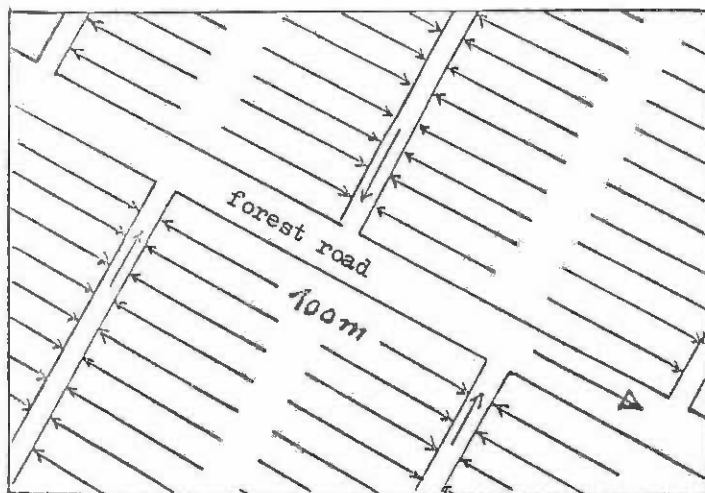
in terrain accessible by wheeled skidder



Skidding tracks join the skidding trails or forest roads at an angle of about 30°. Optimum spacing of skidding tracks is 20 m.

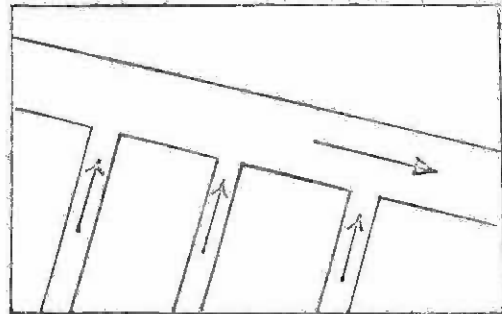
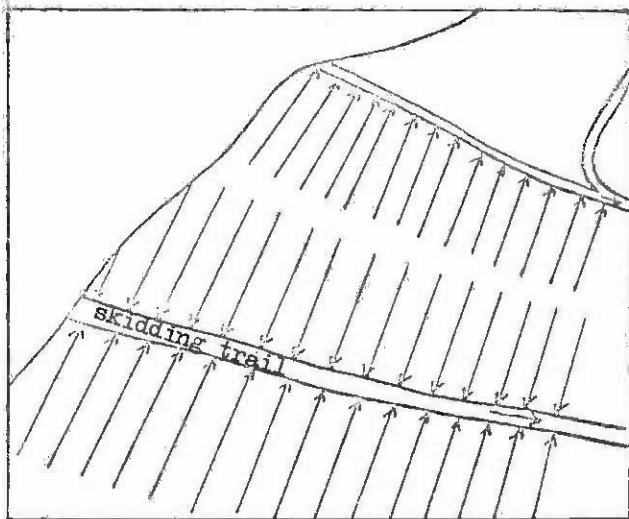
SKIDDING TRACKS

in combination with cable routes

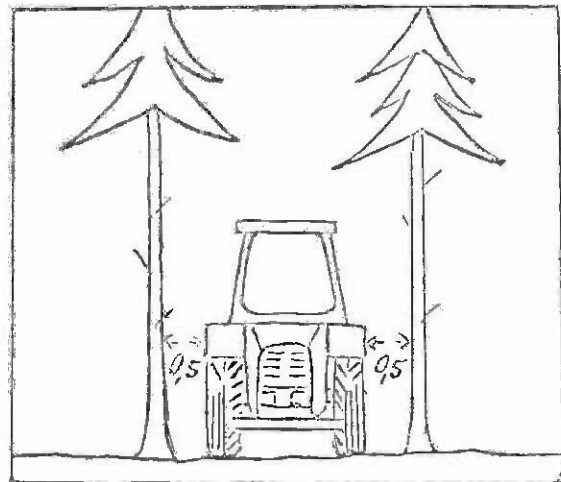
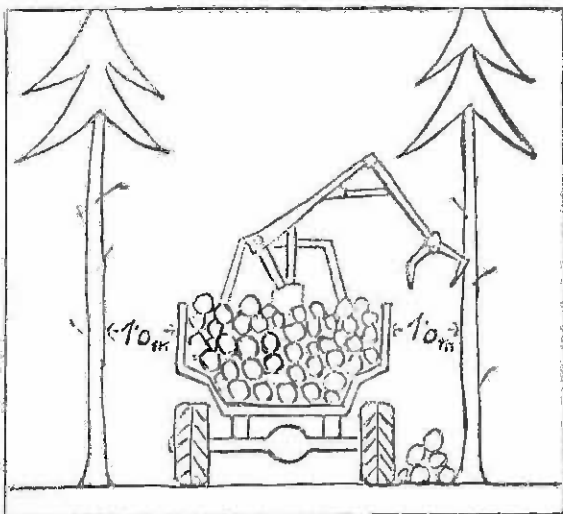


- Spacing of skidding tracks max. 100 m.
- Width of skidding track max. 4 m.
- Spacing of cable routes 5 - 10 m.
- Direction of cable routes / straight

SKIDDING TRAILS in combination with cable routes



- Skidding trails are earth roads constructed at minimum cost
- Spacing of skidding trails 50 to 100 and 200 m.
- Spacing of cable routes about 8 m.
- Width of lateral skidding tracks about 2 m.

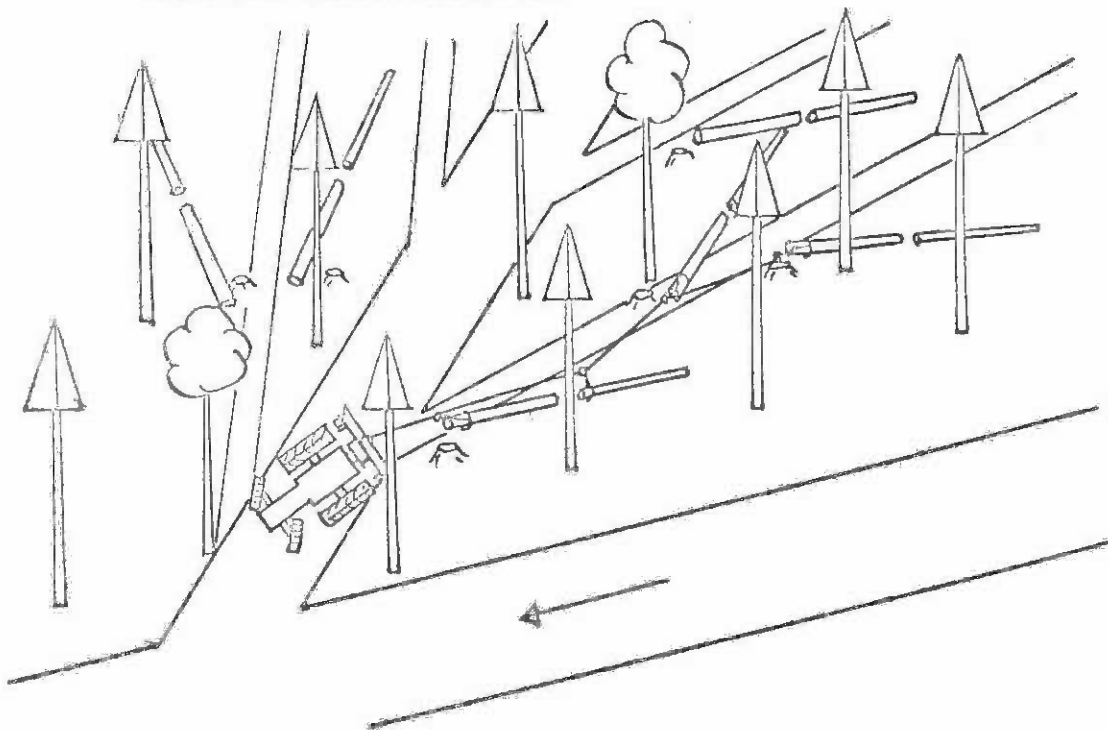


- Width of skidding track: width of vehicle + 1m
- If possible, tracks should run with the gradient

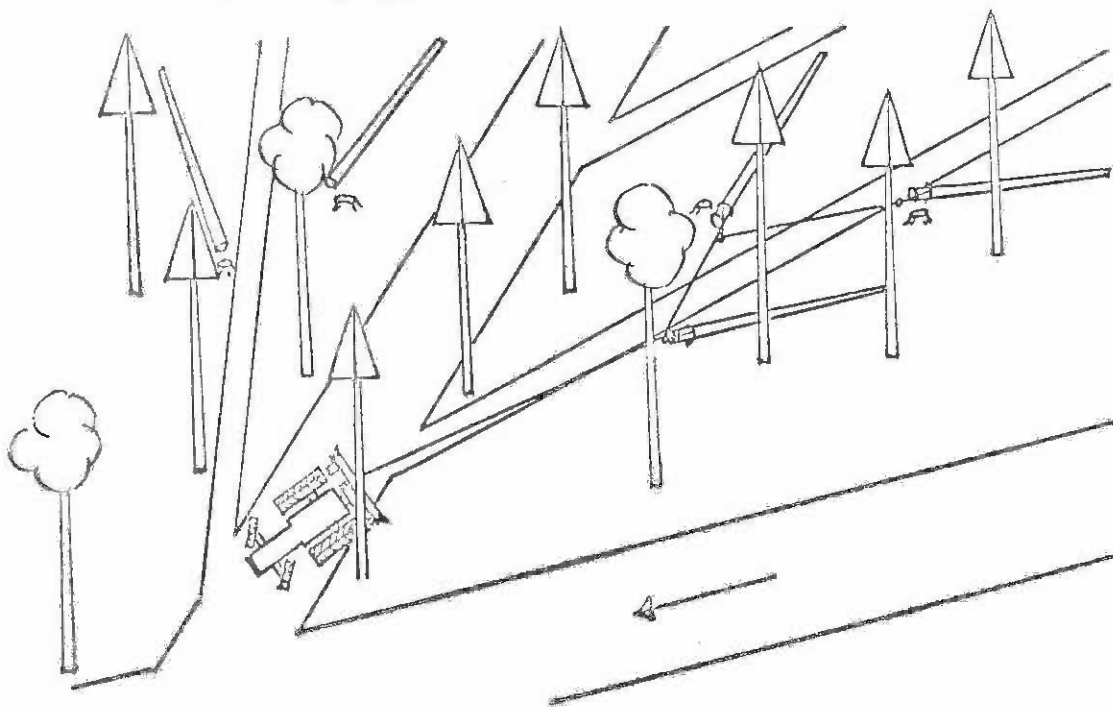
- Width of skidding track for forwarder operations: vehicle width + 2 m.

FELLING SEQUENCE FOR SINGLE TREE FELLING

Downhill operation using the assortment method with skidder on skidding track (low sloping gradient).

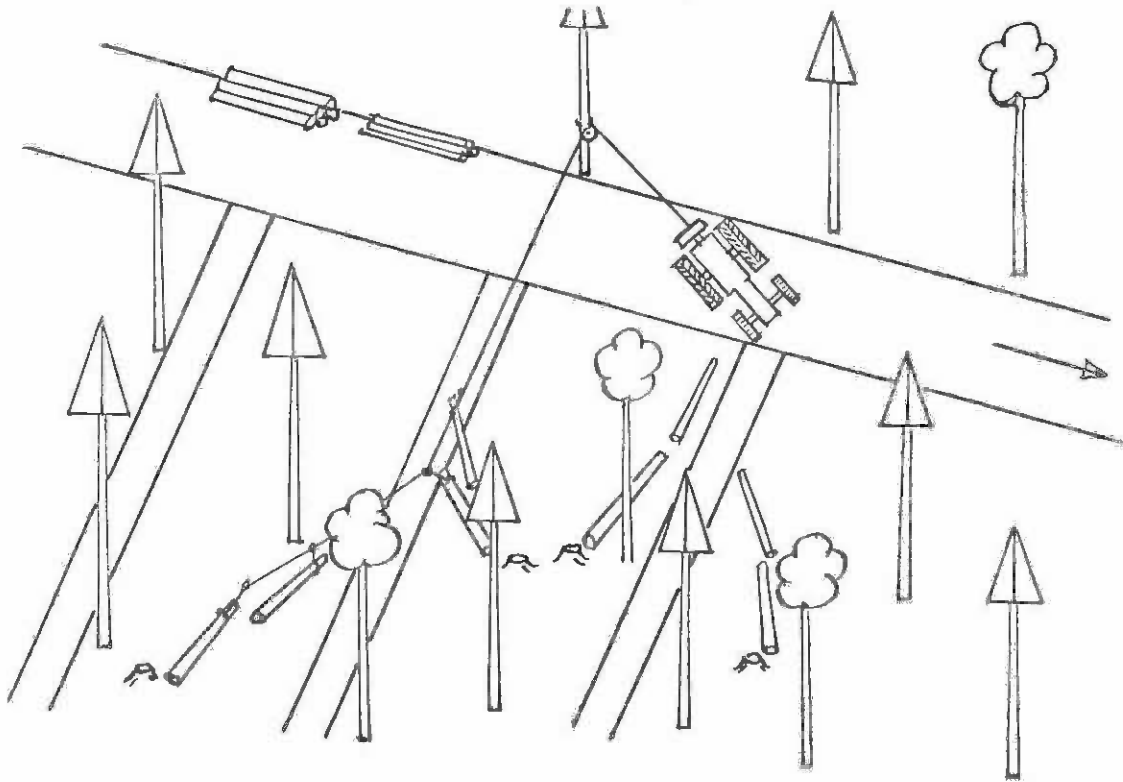


Downhill operation for full-length method with skidder on skidding track (low sloping gradient).

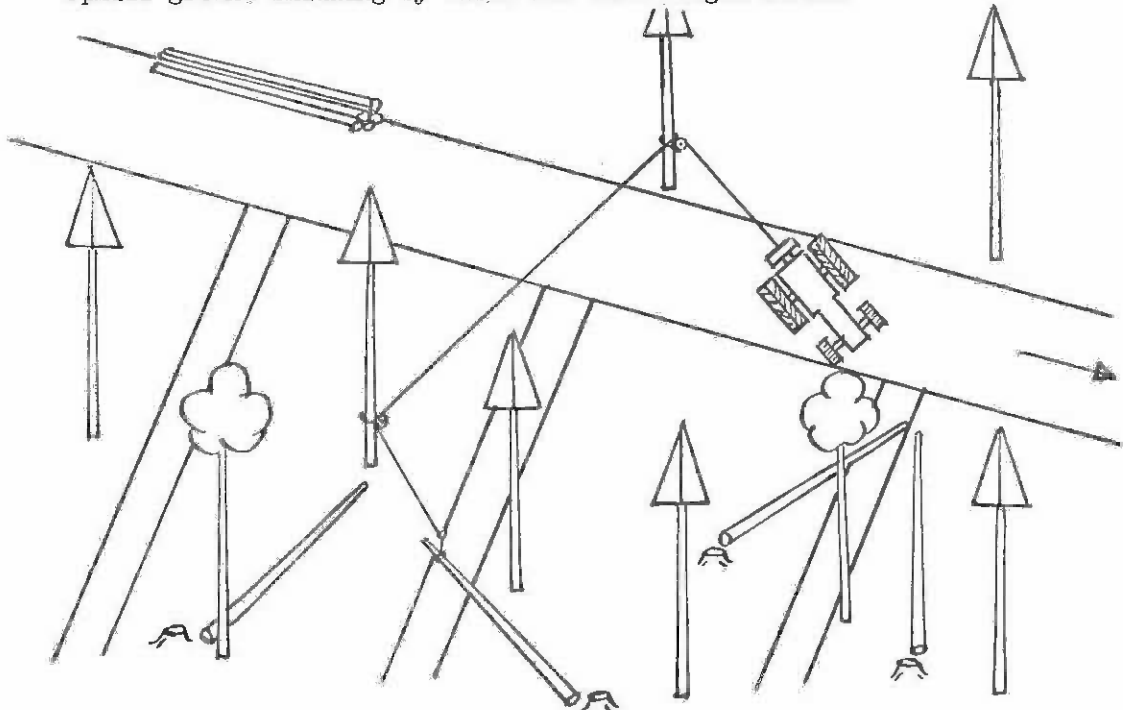


FELLING SEQUENCE FOR SINGLE TREE FELLING

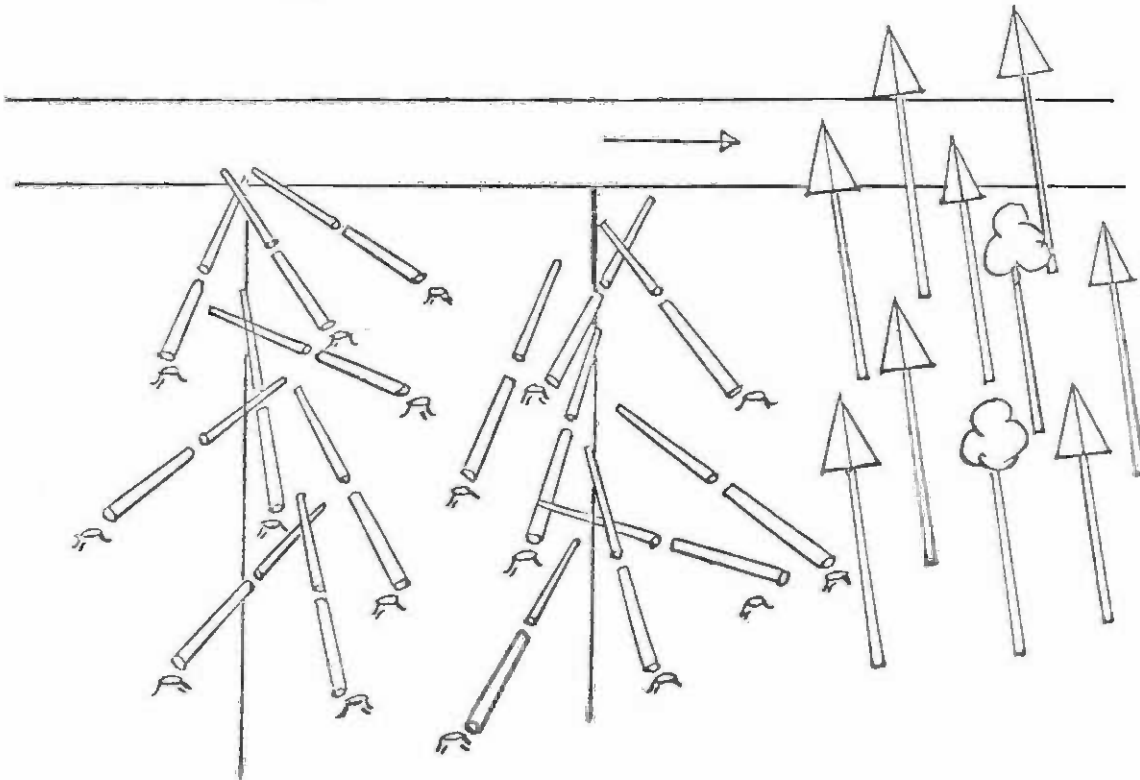
Uphill ground skidding by cable for assortment method.



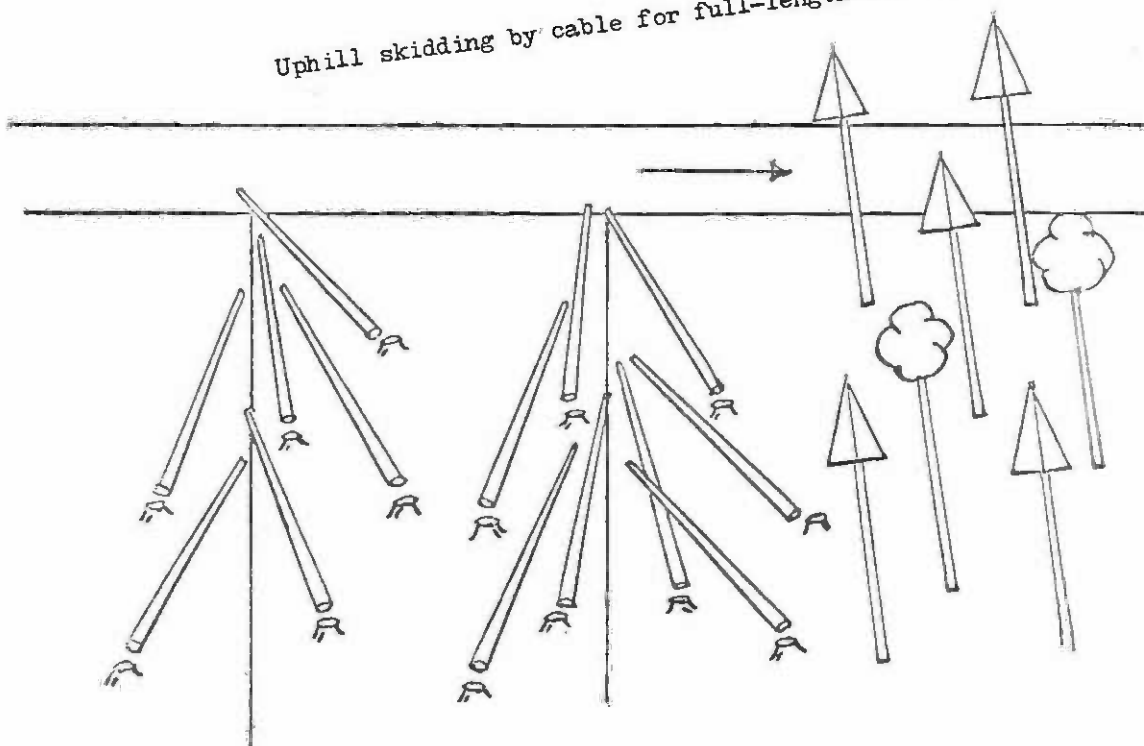
Uphill ground skidding by cable for full length method



FELLING SEQUENCE FOR STRIP FELLING
Uphill skidding by cable for assortment method

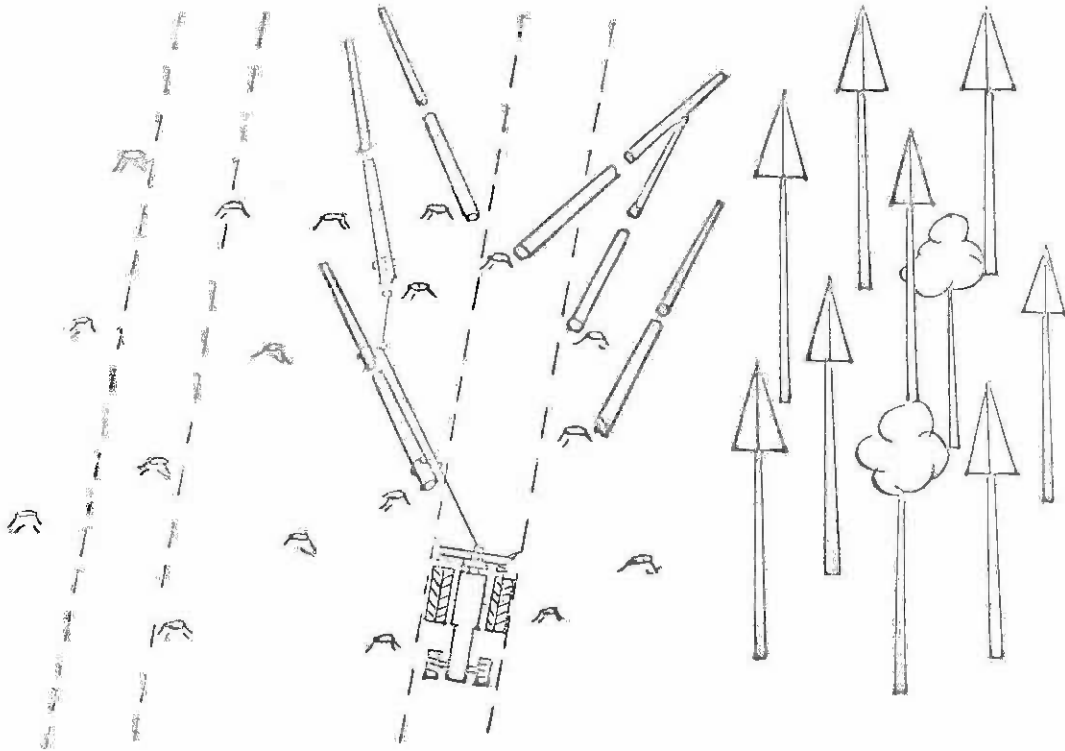


Uphill skidding by cable for full-length method

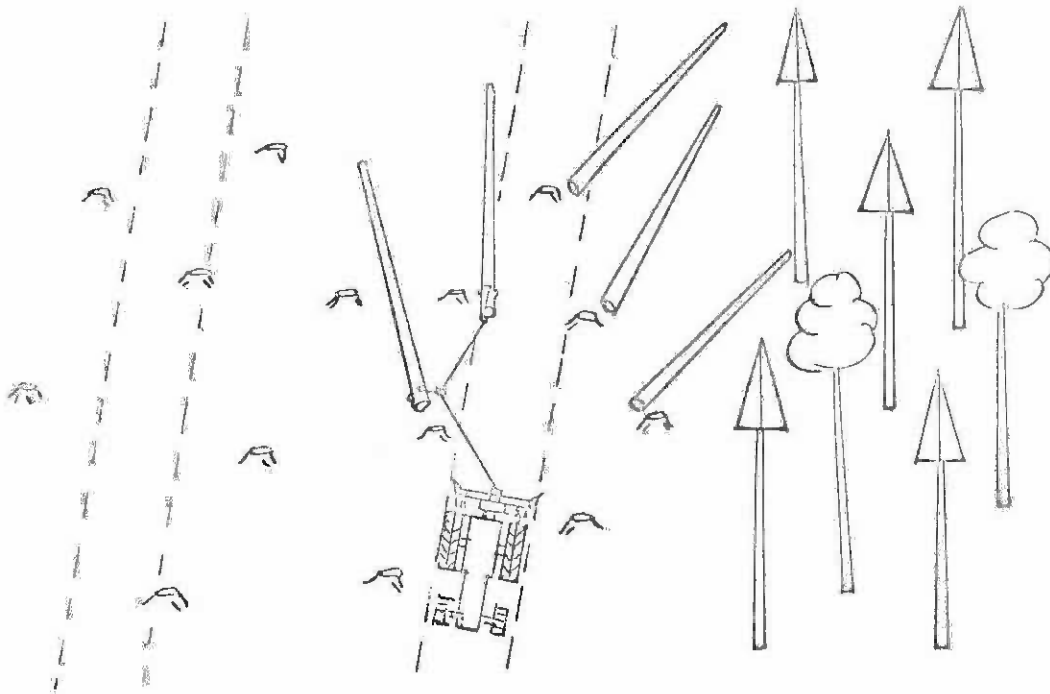


FELLING SEQUENCE FOR STRIP FELLING

Downhill operation by wheeled skidder for assortment method



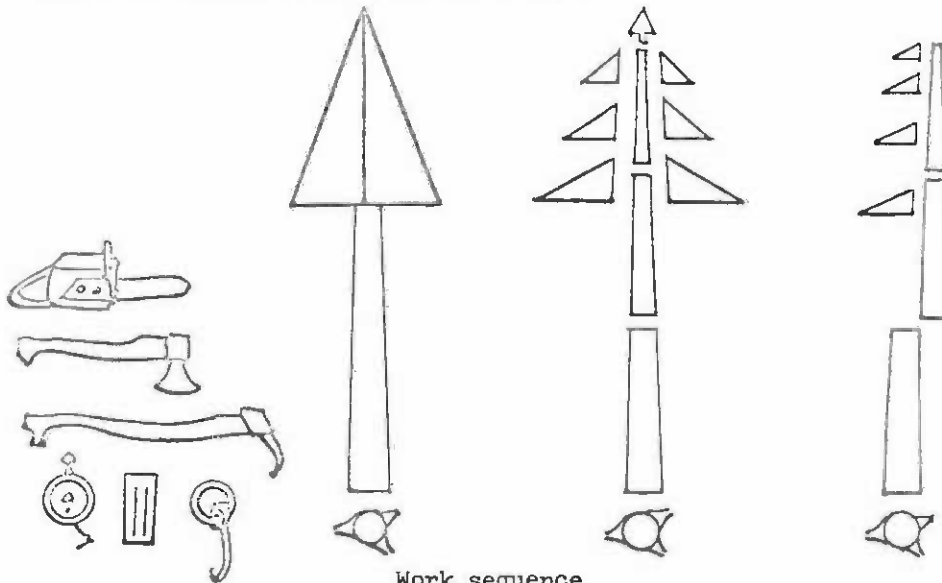
Downhill operation by wheeled skidder for full-length method



ASSORTMENT METHOD

(Heavy timber)

One worker working on onetree (power saw delimbing)



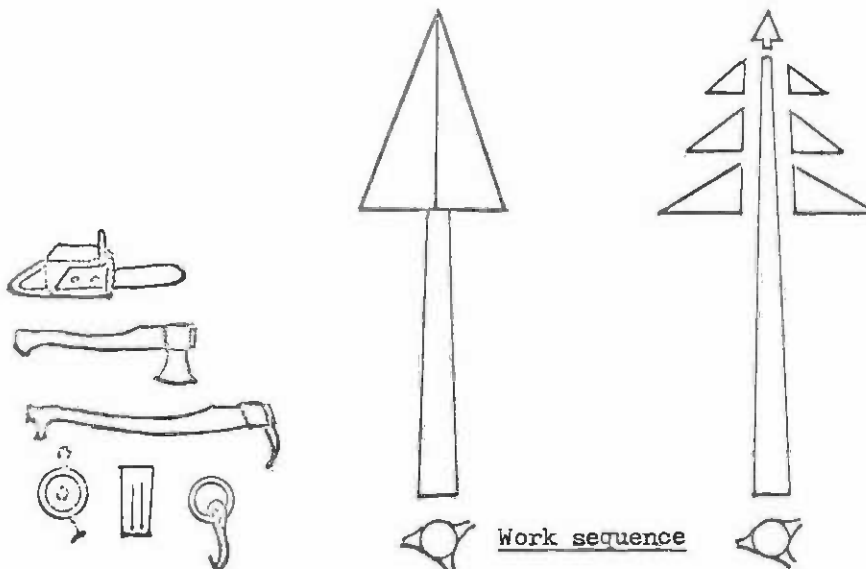
Work sequence

- Tools: Power saw; axe; 1. Felling 2. Delimbing on upper side, measuring, sorting 3. Turning, delimbing on lower side
- alpine peavie;
rewinding loggers tape;
wedge; turning hook

FULL-LENGTH METHOD

(Heavy timber)

One worker working on onetree (power saw delimbing)



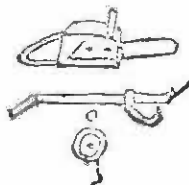
Work sequence

- Tools: Power saw; axe; 1. Felling 2. Delimbing on upper side, measuring, topping
- alpine peavie;
rewinding loggers tape;
wedge; turning hook

ASSORTMENT METHOD

(Small diameter wood)

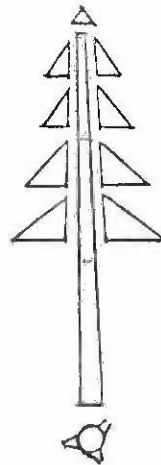
One worker working on one log (delimbing with power saw).



Tools: Power saw,
cant hook,
rewinding
logger's tape.



1. Pruning,
felling



Work sequence

2. Delimbing on upper
side, marking of
assortment length

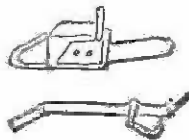


3. Turning,
delimbing on
lower side,
crosscutting

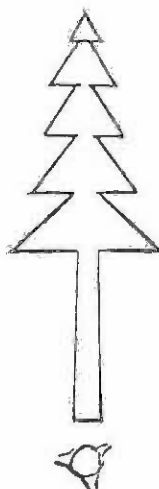
FULL-LENGTH METHOD

(Small diameter wood)

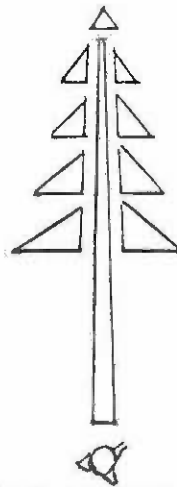
One worker working on one log (delimbing with power saw).



Tools: power saw,
cant hook



1. Felling



Work sequence

2. Delimbing on upper
side, topping

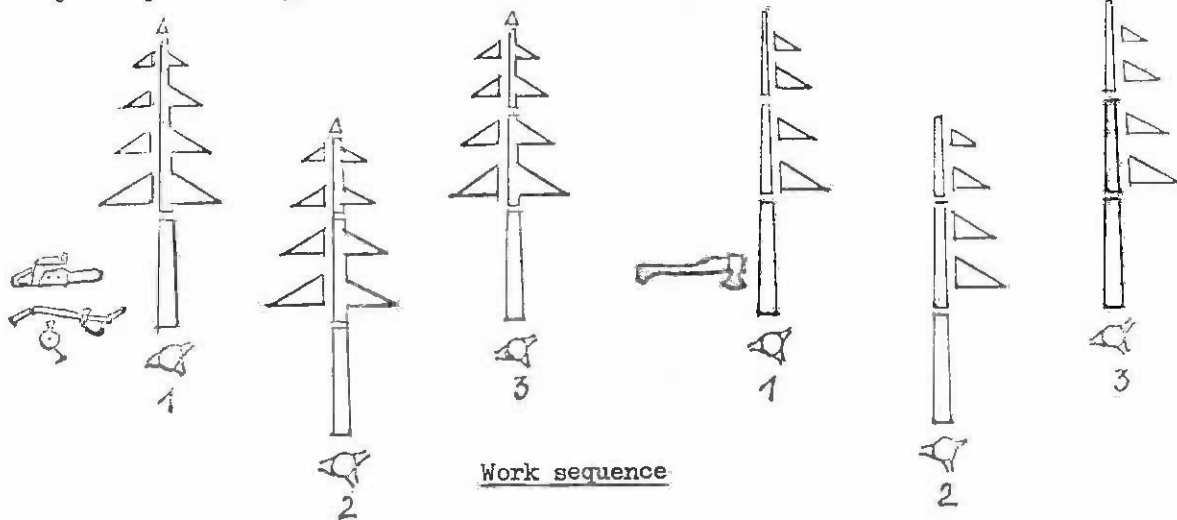


3. Turning, delimbing
on lower side

ASSORTMENT METHOD

(Small diameter wood)

One-man cycle operation (power-saw and axe-delimbing)



Tools: power saw,
rewinding loggers
tape; cant hook

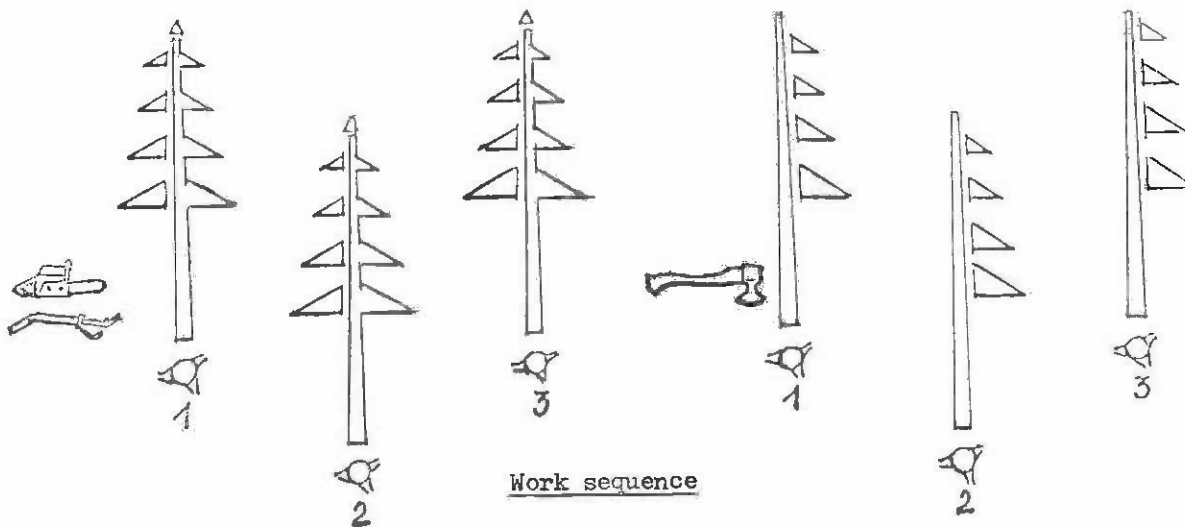
Log 1 - 3 Felling,
delimbing on left
side, measuring,
crosscutting

Log 1 - 3
final delimbing by axe

FULL-LENGTH METHOD

(Small diameter wood)

One-man cycle operation (power-saw and axe-delimbing)

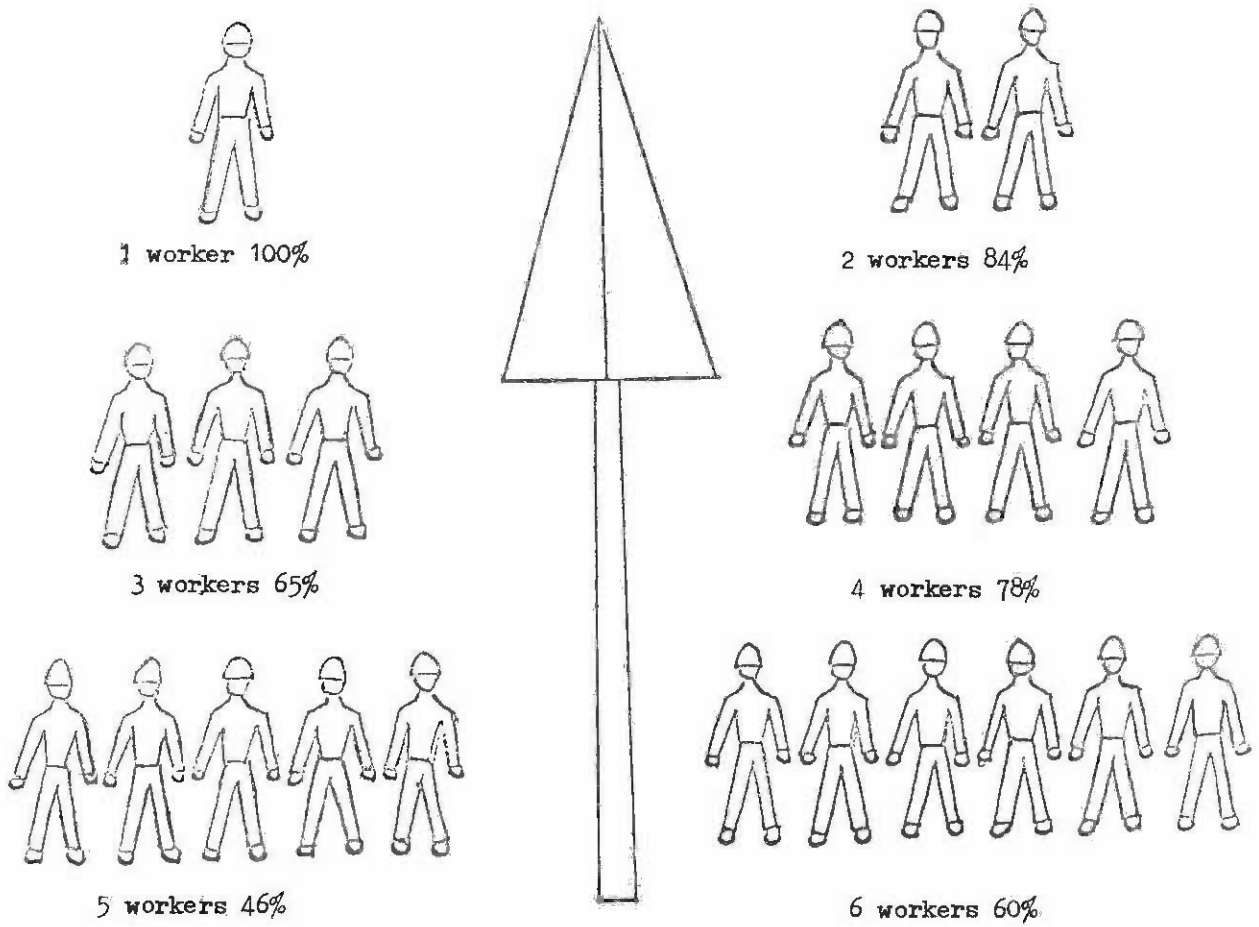


Tools: power saw;
axe, cant
hook

Log 1 - 3 felling,
delimbing on left
side, topping

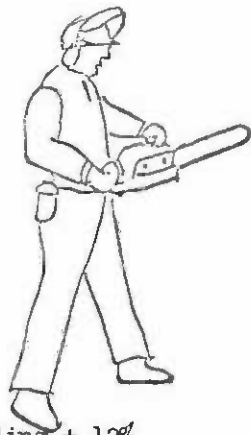
Log 1 - 3
final delimbing by axe

EFFICIENCY OF GROUP WORK

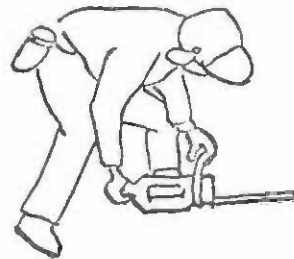


BODY POSITION

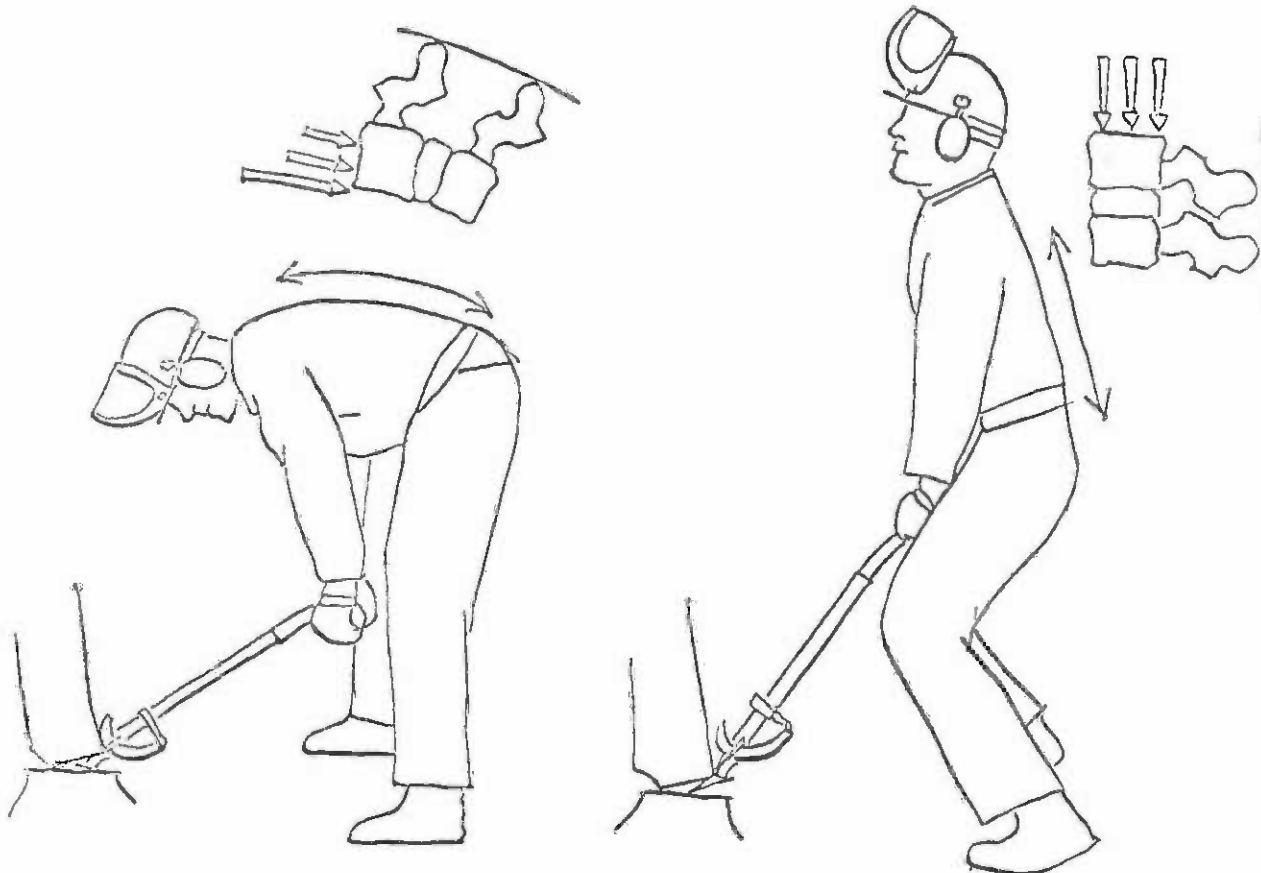
Energy consumption in lying-down position = 100%



Standing + 12%



Bending down + 55%



Vibration caused by power-saw operation in bent-forward position and exposure to heavy workload in lifting with the dorsal spine twisted lead to damage of backbone.



Delimber-bucker machines of the Austrian Federal Forest Enterprise have proved useful in processing wind-damaged timber (Photo E. Pestal).



Forwarders have been used successfully in areas with wind-damaged timber and for the transport of small quantities of timber in farm forests. (Photo E. Pestal)

NEW METHODS FOR FELLING AND LOGGING SMALL DIAMETER WOOD IN AUSTRIA'S MOUNTAINOUS FORESTS

by

Anton Trzesniowski
Forstliche Ausbildungsstätte, Ossiach^{1/}

A sufficiently dense road network is a prerequisite for thinning in mountainous areas. The optimum road spacing is between 200 and 350 m, depending on individual terrain conditions.

Apart from silviculture and forest protection, economic questions must also be considered. The main problem of harvesting small diameter wood derived from thinnings arises from uncertain selling prospects and timber prices which often fail to cover operational costs. Forest workers are not always motivated to work in thinnings because this type of work has to be carried out more carefully and earnings are lower than in final cuts. The mechanization of thinnings in mountainous areas is technically and often also economically, limited. Highly mechanized harvesting units can be used only on forest roads or landings. For the above reasons, mechanization in thinnings in difficult terrain has its limits. The emphasis is rather on replacing heavy manual work by light, mobile machines and devices which have proved expedient for operations in mountainous areas. Moreover, Austrian forests are, for the most part, divided into smallholdings owned by farmers, and therefore methods and systems must be devised to provide earnings for them.

Methods and machines used in state-owned forests and private enterprises are generally known. The present paper will focus on simple and cheap devices, machines and methods which have been successfully used in Austria for some time.

1. FELLING METHODS IN THINNINGS

Before felling is started, all phases of the operation must be carefully planned and organized. In mountainous areas it is particularly important to decide on the logging method before felling is started. Past experience has shown that skidding corridors are useful in most cases. The operational sequence should be as follows:

- 1 - choice of skidding corridors in the terrain
- 2 - clearing of skidding corridors
- 3 - marking of the trees to be cut
- 4 - felling the marked trees and extracting them to the skidding corridors
- 5 - skidding the trees to the forest road

With this operational sequence, the crown cover is kept intact and damage to the remaining stand is reduced to a minimum. The skidding corridors must be spaced in such a way that the cut tree falls either directly into these corridors or into their vicinity. Forest workers should be instructed to observe the required felling direction (which depends on the skidding method) and move the trees to the corridors either manually or with the aid of simple auxiliary equipment.

In very dense stands the most difficult task consists in getting the trees down.

To facilitate downhill extraction a special plastic "shoe" was developed by the Ossiach Forestry Training Centre. With this shoe the tree slides downhill automatically or can be easily moved into the desired position. The cut trees are either immediately delimbed, cross-cut and placed in the skidding corridor, or skidded to the forest road where mechanical delimbing and cross-cutting to assortments (processor) is done.

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1.1 Downhill skidding of small diameter wood

The majority of small diameter roundwood cut in Austria is ground-skidded to the road. Here, the hooker^{1/} is the most important auxiliary tool. For some time the so-called "log line" has been increasingly used for skidding small size wood.

The "log line" is a chute which consists of pipe-shaped sections. Each section is 5 m long and weighs 25 kg. Its wall thickness is 5 mm and its diameter 35 cm. The sections are made of polyethylene and are connected by rapid-action clamps to a chute of any length which can be laid over rough terrain. The sections may be assembled in the terrain or on the forest road. The entire chute of 150 to 200 m length is pulled uphill by means of a small cable winch. With gradients above 15 percent, unbarked trees with a maximum diameter of 32 cm and a length of up to 6 m can be slid downhill.

Due to the high elasticity of polyethylene, easy and rapid sliding of the trees is achieved. Even in winter, the "log line" can be employed without problems. Some experience is required for assembling the log line correctly, avoiding sharp bends and adjusting the gradient of the chute to weather and terrain conditions. At gradients of between 25 and 35 percent a three-man crew can skid 5 - 6 m³ of unbarked logs over a distance of 100 m within one hour.

1.2 Uphill logging of small diameter wood

Of the various methods employing wheeled tractors and cable installations only three are described in the present paper:

- 1 - ground skidding with "sledge winch"
- 2 - logging with small cable crane
- 3 - logging with "Mini-Urus"

2. GROUND SKIDDING WITH SLEDGE WINCHES

The sledge winch is a small unit which operates over a distance of 120 m. A winch, a power-saw drive and a gear box are mounted on a sledge. The mainline is fastened to a tree and the winch is pulled up along the line by an operator. In theory the tractive power is 700 kg; however, in practice only about 0.3 m³ are skidded per trip. With normal terrain conditions and tree diameters, one worker can log 8 to 12 m³ of small diameter wood a day (8 working hours). Cross-cut logs are logged in small bunches; the operator stands on the load and travels with the winch. Muscular strength is sufficient to pull the winch downhill to the logs.

Whole trees, either delimbed or with their branches on, are logged according to the "two-man" method. The winch is fastened to a tree and operated by one worker. The second worker pulls the mainline to the tree and fixes it. The mainline runs parallel to the tree and is attached to the top by means of a wire rope. The second worker holds this wire rope and travels with the load to the forest road. On the road the rope is detached and the tree is pulled up and deposited parallel to the forest road. This method offers the advantage that full-length trees can be extracted. This means that trees with their branches on can be deposited on the road for processor conversion.

3. LOGGING WITH SMALL CABLE CRANES

For distances of up to 300 m, three workers can set up the entire system within a mere 30 minutes. In such installations the well-known principle of gravity cable cranes is employed. The time required for setting up and dismantling the cable crane is extremely short.

Any winch of approximately 15 HP may be used as a cable winch. The drum capacity must be for a wire rope of 8 mm in diameter and 350 m in length and a skyline of the same

^{1/} In Austria known as the "mountain peavie".

length and 12 mm in diameter.

The required saddles are fixed to the tree by means of special devices. The skyline is tensioned with a 3-ton pulley block. For dismantling the installation, first the skyline and then the mainline are wound on to the same winch drum. All three men of the working crew must be skilled and capable of working independently.

In practice, cable corridors for thinnings are laid out at distances of between 10 and 15 m. The width of such corridors is 1.0 to 1.3 m. Logging of 10 m³ of timber per corridor is profitable.

4. LOGGING WITH MINI-URUS

The Mini-Urus is a small trailer-mounted cable crane with a collapsible tower. In addition to the usual equipment required for gravity cranes, the Mini-Urus has three drums (for skyline, mainline and haulback line), and can therefore be used for any cable crane operation in smallwood forests, independent of the terrain configuration.

A three-man working crew can log up to 30 m³ a day. Since this unit is highly mobile and setting up and dismantling can be carried out rapidly, extraction costs for small diameter wood are low.



A pan used to pull down hang-ups when felling for thinnings. (Photo T. Pasca)



Plastic chute for extraction of thinnings. (Photo O. Sedlak)

AN INTRODUCTION TO CABLE EQUIPMENT USED FOR WOOD EXTRACTION

by

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The equipment used in forestry for cable logging is divided into cableways and cable cranes.

1. CABLEWAYS

Mostly semi-stationary, cableways may also be stationary if required. They permit the transport of timber, and to a limited extent also that of other goods, between two fixed points, the loading and the unloading stations. Under certain conditions further intermediate stations may be added, but outside the stations loading and unloading is not possible. Therefore, cableways are particularly suited for logging from inaccessible plateaux, and from terrain where loading along the route is not necessary. The timber to be transported by cableway has to be taken to the loading station by other means.

Some types of cableways may be used as gravity systems (without an engine) provided that the skyline has the minimum gradient required (e.g. types 3.1.1; 3.1.2; 3.1.2.B). Others provide downhill transport by means of gravity but the return trip of the unloaded carriage requires an engine (e.g. type 3.1.2.A). Finally, there are cableway systems that need an engine for all operations. This is also true of any kind of uphill transport, of transport along corridors with insufficient skyline gradient, as well as of transport along counter slopes.

As the opening up of forests advances through road construction, the importance of cableways for logging in intensively managed mountainous areas has considerably declined. Nowadays they are used only in special cases. The relatively high consumption of time and the costs for setting up and dismantling cableways are responsible for their decline in countries with a high wage level and scarce labour force. In areas with a low wage level, a sufficient labour force and forests that provide difficult access to vehicles, technological and economic considerations justify the use of cableways for logging even today.

2. CABLE CRANES

Cable cranes are logging devices that thanks to their construction and design can easily be transported, set up and dismantled. They are suitable for uphill and downhill transport of timber, loading and unloading being possible at any desired spot along the route (skyline). In addition, a direct lateral dragging of timber by means of the mainline from areas adjoining the route (in a range of 50 m on both sides) is feasible during an uphill or downhill operation. Thus, a cable crane allows almost continuous removal of timber from the cutting site. Logging with cable cranes causes minimal damage to the soil and stand; therefore, it is also advisable for critical slopes as an alternative to skidding.

Only cable cranes with the required skyline gradient can use gravity (without an engine) in downhill logging. For all other operations, including dragging loads to the carriage, engine power is necessary. Therefore, all cable cranes have to be equipped with a sufficiently strong engine.

^{1/} Forestry Research Institute, Austria.

According to their use cable cranes may be divided into two groups:

Short distance cranes are employed for distances of up to 500 m mainly for uphill and downhill logging. The time used for setting up and dismantling is relatively short with a low-mounted skyline, simple supports and by using efficient rigging methods. The time used for setting up accounts for only 15-20 percent of total logging time. Timber transport by short distance cable cranes is mainly tree-length transport under the "raised-head" method, that is, the stems are roped and raised at one end only. The other end trails along the ground. By this means even heavy loads of timber may be carried from the felling site to the road.

Long distance cranes are used in Central Europe for strips between 500 and 1 500 m long, mainly for downhill logging. The timber must be freely suspended for the equipment to operate smoothly, the skyline must be high above the ground. Therefore, setting up is not as simple as in the case of short distance cranes and takes longer. It accounts for between 40 and 50 percent of total logging time.

The maximum load that may be transported is limited by the load capacity of the cable equipment. In Central Europe most frequently cable cranes with a load capacity of 2.5t are used.

3. CLASSIFICATION AND DESCRIPTION OF THE MOST IMPORTANT CABLEWAYS AND CABLE CRANES USED IN FORESTRY

3.1 Cableways

3.1.1 With Suspended Wires

Description:

- 1 skyline (wire or steel rope)
- A variety of hooks for attaching the load (wooden hooks, simple hooks, hooks mounted on pulleys, etcetera.
- Gravity drive only
- Direction of transport: downhill only
- Minimum skyline gradient: about 18 percent
- Maximum skyline length: about 1 200 m
- Performance: depends upon the length of the cable
- Application: logging of timber assortments 1 m long, bark, etcetera, up to a weight of 50 kg

3.1.2 Pendulum Cableways

A. Mono-track pendulum cableways

- With open-end mainline

Description:

- 1 skyline - 1 open-end mainline
- 1 carriage (fastened to the mainline)
- 1 yarder (cable winch)
- Position of the yarder: on the mountain
- Direction of transport: mainly downhill, uphill possible
- Minimum skyline gradient: about 20 percent
- Maximum skyline length: about 1 500 m in theory, over 1 000 m not advisable
- Performance: depends on corridor length

- With endless mainline

Description:

1 skyline - 1 endless mainline
1 carriage (fastened to the mainline)
1 yarder (with parabolic pulley)
Position of the yarder: landing at road side
Direction of transport: mainly downhill, uphill possible
Operation: independent of skyline gradient (also possible on flat strips or over counter slopes)
Maximum skyline length: about 2 500 m in theory, over 1 500 m not advisable
Performance: depends on corridor length

- Serial Cableways (variant of the above)

Description:

1 skyline - 1 endless mainline
Several carriages (about 5) detachable from the mainline
1 yarder (with parabolic pulley)
Performance: depends on the skyline length. Because of more carriages it gives better output than the type with one carriage; skyline lengths of up to about 2 500 m are possible
All other features similar to the one-carriage type

B. Two-track Pendulum Cableways

Description:

2 skylines- 1 endless mainline
2 carriages (fastened to the mainline)
1 braking station (for gravity drive) or
1 yarder (for engine operation)

- With engineless gravity drive

Position of braking station: on the mountain
Direction of transport: downhill
Minimum skyline gradient: about 20 percent
Maximum skyline length: about 2 500 in theory, over 1 500 not advisable
Performance: depends on skyline length

- With engine drive

Position of yarder: on the mountain or in the valley
Direction of transport: mainly downhill, uphill possible
Operation: independent of skyline gradient
(also possible over flat strips or counter slopes)
Maximum skyline length: about 2 500 m in theory, over 2 000 m not advisable
Performance: depends on skyline length

3.1.3 Round Cable

Description:

2 skylines - 1 endless mainline
Numerous detachable carriages (their number depends on skyline length)
1 braking station (for gravity drive)
1 yarder (for engine operation)

- With engineless gravity drive

Position of the braking station: on the mountain.
Direction of transport: downhill
Minimum skyline gradient: about 15 percent
Maximum skyline length: technically not limited, may amount to several km (the longer the corridor the more carriages may be used)

- With engine drive

Position of the yarder: on the mountain or in the valley
Direction of transport: mainly downhill, uphill possible
Operation: independent of skyline gradient (also possible along flat strips or counter slopes)
All other features: similar to gravity drive

3.1.4 Lasso Cable: (special form) (with endless cable similar to chair lifts)

Description:

1 endless circulating cable
A number of pulleys (to lead the cable over the changing terrain gradients of the corridor)
A number of detachable hooks: specially shaped (for attachment of the load to the cable)
1 yarder with cable tensioning device
Position of the yarder: next to the road (landing)
Operation: up to a slope gradient of about 35 percent
Cable length: up to 2 000 m
Loading and unloading: all along the endless cable (cable about 1 - 2 m above the ground)
Performance: independent of cable length (the longer the cable the more loads can be attached to it)
Application: logging of timber assortments with a length of 1 m and with a maximum weight of 80 kg with single suspension and of timber assortments with a maximum length of 4 m and a maximum weight of 500 kg (with double suspension)

3.2 Cable Cranes

3.2.1 Long Distance

(In most cases freely suspended loads and skyline high above the ground are necessary)

- With open-ended mainline

Description:

A skyline - 1 open-ended mainline
1 carriage (with or without stopping devices)
1 yarder (motor driven sledge winch)
Position of the yarder: on the mountain
Direction of transport: mainly downhill, uphill possible
Minimum skyline gradient: about 20 percent
Maximum skyline length: about 2 000 - 2 500 m in theory, over 1 500 m
not advisable
Performance: independent of corridor length

- With endless mainline

Description:

1 skyline - 1 endless mainline
(1 lifting cable for various carriage models)
1 carriage (with or without stopping devices)
1 cable yarder (with parabolic pulley)
Position of the yarder: advisable at the landing next to the road
Direction of transport: both ways possible
Operation: independent of skyline gradient (also possible along
flat strips and over counter slopes)
Maximum skyline length: about 2 500 m in theory, over 1 500 m not
advisable in practice
Performance: depends on corridor length

3.2.2 Short Distance

(with "raised-head" logging and skyline close to the ground)

- With skyline and open-end mainline

Description:

1 skyline - 1 open-ended mainline
1 carriage (mostly with lifting block) - 2 stopping devices
1 yarder - (motor driven sledge or self-propelled winch, also
tractor winch)
Position of the yarder: on the mountain next to the road (landing)
Direction of transport: uphill only
Minimum skyline gradient: about 30 percent
Maximum skyline length: about 300 m
Performance: depends on the corridor length

- With skyline, mainline and haulback line

Description:

1 skyline - 1 open-end mainline - 1 open-end haulback line
(1 lifting cable for various carriage models)
1 carriage (with or without stopping devices)
1 yarder with 2 winch drums; mostly combined with a tower of
6-12 m and a skyline tensioning device mounted on a truck or
Unimog (mobile cable crane unit)
Position of the yarder: always next to the road (landing)
Direction of transport: mainly uphill, downhill possible
Operation: independent of skyline gradient
Maximum skyline length: about 500 m
Performance: depends on skyline length

3.2.3 High Lead System

(short distance cable operation without skyline: mainly "raised-head"
transport of timber)

Description:

1 open-end mainline - 1 open-end haulback line
(1 lifting cable for various carriage models)
1 simple carriage
1 yarder with 2 winch drums (independent unit or mounted on a tractor)
1 tower for lifting mainline and haulback line mostly mounted on a
winch or tractor
Position of the yarder: always next to the road (landing)
Direction of transport: mainly uphill, downhill possible
Operation: independent of gradient
Maximum length: about 250 m
Performance: depends on cable length
Footnote: haulback line takes over function of the skyline.

INTRODUCTION TO WOOD EXTRACTION METHODS BY WHEELED TRACTORS

by

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1. INTRODUCTION

In well organized forest enterprises skidding operations are required after thinnings, selective and clear-cutting. Depending on the size of the forest enterprise and the available machinery and equipment skidding may be performed under one of the following systems:

- assortment method
- full-length method
- whole-tree method

The assortment method is preferred by smaller forest enterprises if their agricultural tractors have a low tractive power. The full-length method requires more powerful machinery and suitable bucking sites, while the whole-tree method should only be used in those cases where timber harvesting is fully mechanized.

2. LAYOUT OF SKIDDING CORRIDORS

The distance between skidding corridors should be about twice the tree length. Taking full advantage of topographical conditions, the distance will range from about 30 to 60 m. While in young stands all skidding corridors should be accessible to tractors, only every second skidding trail is used by tractors once the trees have reached a certain size. The skidding corridors should run as close to the gravity line as possible, but should not be geometrically straight. Depending on log length a large bend should be planned at junctions. For precipitous slopes or other steep inclinations special skidding corridors should be planned for unloaded uphill travel. Such corridors would be accessible in both directions, while several corridors should be planned for downhill extraction only. It is not the average gradient of a skidding corridor but its steepest spot that matters. The width of a skidding corridor is determined by the width of the vehicle. Therefore, the distance between trees will range from 3.5 to 4.0 m (width of vehicle and an additional 0.75 m on both sides). If the radii in bends of the skidding corridor are too small, the border trees will be damaged. They should be left on the border as long as possible to protect the trees behind them, and should only be felled after their decay. If skidding corridors are laid out parallel to the slope, excavating for levelling will be indispensable, otherwise skidders would turn over easily. Tree stumps in the skidding corridor should be level with the ground.

3. BUCKING SITES

Sufficiently wide sections of the forest road may be used as bucking sites. When planning forest roads, these sites should be considered. If batters are too steep, special ramps should be built for skidders. The optimum length of bucking sites should correspond to about two logs lengths.

4. SELECTION OF SKIDDING MACHINERY

Smaller forest enterprises prefer wheeled tractors suitable for a wide range of operations. Agricultural tractors with or without four-wheel drive, having as attachments cable winches, skidding bogies or skidding tongs will in many cases be profitable and

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technologically adequate. Agricultural tractors are of particular advantage for forests owned by farmers, since a better utilization of machinery is thus obtained and the farmer can make some extra money. Bigger forest enterprises which have an annual skidding capacity of 5 000 m³ per machine or which have an annual record of more than 1 000 machine hours prefer articulated four-wheel drive skidders. Articulated four-wheel drive skidders are special skidding machines and outperform all other machines even in harvesting small wood. In those places where ordinary wheeled tractors already require non-skid chains, articulated four-wheel drive skidders can be driven without chains, thus causing no damage to roots or the forest soil. Up to a gradient of about 30% articulated four-wheel drive skidders do not need chains for uphill and downhill extraction provided that the soil is solid. No previous preparations are required if articulated four-wheel drive skidders are employed with chains for slopes with a gradient of up to about 50%. For steeper terrain skidding corridors must be laid out.

5. CHOICE OF ATTACHMENTS

When tractors are employed for skidding, we may choose among different types of attachments. Choker cables and chains have proved especially useful. For larger logs cables are better suited, while smaller logs which are usually skidded in bunches should be fastened by means of choker chains. Now already for some time high-strength chains with square links have been on the market and have proved satisfactory. For skidding over longer distances, chains are better suited than steel cables because they are highly resistant to wear and tear. The load has to be fastened in such a way as to guarantee a continuous skidding operation and safe trailing under the raised-head method.

A load is properly attached if the choker cable or chain binds the timber in such a way as to assure the below indicated sequence of operations:

- binding of the load
- pulling the load towards the tractor
- lifting the load onto the tractor

6. SEQUENCE OF OPERATIONS: FELLING - SKIDDING - BUCKING

Felling of small wood is very time-consuming; therefore, the so-called "interrupted sequence of operations" is used for this purpose. The first step is to fell the wood quantity that is reasonable from the viewpoint of forest protection and that justifies the use of a wheeled tractor for several days. When this tractor is available, skidding, bucking, and subsequent sorting should be carried out in one operation, by the same crew that performed the felling. The "interrupted" as well as the "continuous sequence of operations" can be applied to large-sized logs after selective or clear cutting. Many forest enterprises prefer the interrupted sequence because planning and organization are easier. On the other hand, the continuous sequence requires a much better organization, high-performance machinery, and highly trained personnel. If the full-length method is applied, the sequence of operations is the following: depending on the species, the trees are felled and de-limbed by two or three forest workers. Immediately after felling the logs are skidded by the articulated four-wheel drive skidder to the conversion site, where final de-limbing and cross-cutting are performed by one or two forest workers.

7. DETAILED PLANNING AND ORGANIZATION OF THINNINGS

Before marking the trees which are to be felled in the course of thinning it is important to consider the skidding operation itself and to observe the below described procedure:

- laying-out of skidding corridors in the terrain; the corridors are clearly indicated by a series of trees marked with coloured paint or plastic tape;
- marking of the trees to be thinned;

- clear-cutting of corridors: starting from the top, the trees growing in the corridor should be felled, branches and tops should be deposited along these corridors. After skidding they may be deposited in the corridor to protect the soil against erosion.

- felling operations in the course of thinning: the trees should be felled at an acute angle to fall in a fish-bone pattern with the tops pointing uphill, since downhill skidding is the accepted type of skidding by tractor. Depending on tree length, either full-length trees or logs will be skidded. After small-sized trees have been felled, their butt ends are laid across a log.

- felling corridor by corridor: all trees that are to fall within corridors should be felled and moved towards the corridor so that one corridor after the other can be extracted by the skidder.

8. ONE-MAN SKIDDING

If wheeled tractors are used, skidding can be performed by one man only; this results in a very high output in comparison with cable crane operation which requires at least three operators. Once the small wood has been pulled towards the corridor and deposited on a base log, the driver can choke the load and start skidding. In this process the driver has to get off the vehicle again and again, which is desirable from the ergonomic point of view, for noise-induced damage or damage to intervertebral discs is a frequently observed occupational hazard for tractor drivers. For safety reasons it is advisable to have some workers work in the vicinity of the vehicle, i.e. on the conversion site where they can therefore be of assistance in case of need. The driver is also responsible for detaching the load after skidding but he may be assisted by other workers.

If corridors are steep, provision should be made for the safe turning of the vehicle. It has also proved useful to cut the stumps in the corridor level with the ground in order to make sure that the tractor does not get stuck on soft soil or that entangled loads are avoided. When skidding uphill, it is especially important for the driver to know the performance limits of his vehicle.

Stopping on the slope or having to reduce the load is dangerous and time-consuming. In downhill skidding the loads may be twice as high as in uphill skidding, however, the danger of a heavy load downhill going out of control should not be underrated.

9. TWO-MEN SKIDDING

If the timber is distributed over the stand because it is too heavy to be moved manually, it has to be pulled mechanically to the vehicle. For the choking operation a helper is absolutely necessary. Sometimes the felling crew may be able to help. In general, the helper will mount the chokers while the driver is skidding a load. If the logs to be skidded are very small and the skidding distance is short, the helper is usually overburdened, whereas if the corridors are too long or large-sized logs have to be skidded he may be underemployed.

10. DETACHING THE LOAD

For this operation base logs should be prepared which are either fixed to the ground or are pushed under the load immediately before it is lowered.

Using logs as a base for the log loads will facilitate the use of choker chains or wire ropes. In addition, bucking can be performed more easily because the worker need not bend continually. This also reduces the wear on the chain of the power saw. Cross-cutting of small wood may be immediately followed by sorting, which is usually done manually. If small wood is sorted in the course of loading operations, sorting is carried out mechanically.

11. SAFETY REGULATIONS

Before using wheeled tractors in forests, drivers should receive the best possible technical training; also the best suited model should be employed. With regard to the driver let me point out here that special training and suitable work clothes are the determining factors for safety and working performance. A good safety helmet, work gloves and solid shoes with a skid-proof sole should form part of the necessary personal equipment of a wheeled tractor driver working in the forest.

The wheeled tractor itself has to meet the following requirements:

1. Roll-over protection cab

An approved roll-over cab is indispensable for off-road use and can be life-saving.

2. Wheeled tractors with branch guards and front shields

Not yet in common use, these safety features are, however, indispensable for the protection of the exhaust pipe (which should extend above the cab) and the windscreen.

3. Four-wheel drive wheeled tractors which have big front wheels and high load capacities are better suited to forestry than other agricultural tractors.

4. The tyres should be skid-proof, throw out earth and snow easily, and offer optimum road grip.

5. Anti-skid chains (most suitable are disc-type chains) should be mounted on all wheels if operations have to be carried out on rather steep slopes and, of course, in winter. Be careful to make sure that the chains are neither too tight nor too loose and that they throw off material which may get stuck immediately.

6. The brakes must be 100% reliable and act evenly on all four wheels.

7. Protective screens for all lamps, indicator and roof lamps save repair costs.

8. A plate for the whole of the bottom of the vehicle will protect the axles and the engine from below. The engine block should also be protected on both sides.

9. Power-assisted steering with a steering wheel knob facilitates off-road travel.

10. The hydraulic system of agricultural tractors must be such as to permit rapid mounting of attaching equipment such as cable winch, bogie, trailer, grader, afforestation machinery.

The individual attachments cannot be presented in detail in this paper. It is, however, important that all attachments meet the specific requirements. Brakes, clutches, trailer devices, drive shafts, etc., must always be in good working condition. Attachments such as cable winches or bogies must be easy to operate from the tractor.

BASIC CONSIDERATIONS ON THE PLANNING OF CABLE CRANES

by

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1. INTRODUCTION

Economic and technological considerations are essential for the planning of cable crane installations. A cable crane installation is well planned if an optimum compromise is found between technological and economic aspects. For basic planning the timber transport system has to be studied in its total length, from the felling site to the landing. A cable crane installation has to be harmoniously integrated into this transport chain. Finally, planning has to eliminate manual work as far as possible and keep transport costs low as compared to other logging systems. If the employment of a cable crane does not help to save costs, there should be other rationalization effects to justify its use. Generally speaking the construction and operation of cable crane systems is very expensive thus all methods of timber transport should be studied. Particularly forest roads have to be considered as an alternative, mainly if thinking of long-term planning and forest operations. According to up-to-date findings, cable crane installations should not replace forest roads, but complement them.

2. ECONOMIC CONSIDERATIONS

Since overall transport costs determine the profitability of timber transport, they are the first to be fixed. By comparing several timber transport methods and costs, the profitability of a method can be determined. Cable logging taken individually may be expensive within a certain transport chain, but it can still be profitable if other costs such as, for example, long timber-storage periods are saved.

For the determination of cable corridors it is important to follow the principle of logging roundwood always downhill and of keeping manual work to a minimum. When felling is planned it is important to determine the cable corridors before felling work starts. Forest personnel has to be well instructed as to how the timber is going to be extracted and in what direction trees have to be felled.

Since lateral dragging is rather time consuming and increases extraction costs, trees have to be felled towards the cable corridor. Timber may only be pulled uphill or to the cable line. Lateral dragging distances must not be too long. It is most favourable if all logs come to lie within a lateral range of about 30 m on both sides of the cable. The steeper the terrain the longer the lateral dragging distance, since the logs cannot be pulled to the skyline.

If logs roll down laterally or get stuck by obstacles, this is always due to incorrect lateral dragging to the skyline. If the cable corridor crosses a ditch, it is advisable to drag the log manually to the ditch and to have the cable crane pick it up from there. In such cases extraction output is very high, but the timber itself, the soil and the remaining stand are likely to be heavily damaged. Lateral dragging is advisable when the cable corridor leads along the ridge of a mountain: any manual dragging is eliminated and logs are in the right position to be extracted from both slopes. Extraction output is somewhat lower but is carried out with least detriment to the forest and the logs.

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The mountain top winch should be installed above the endmast, so that safe anchoring of the skyline is possible.

For reasons of safety the winch platform must never be under the skyline but at an angle above the highest landing. The distance between winch and pulley (or endmast) should be 20 times the drum width to enable smooth winding up of the mainline.

Mobile cranes with a collapsible tower can rarely be installed laterally. This is why special safety measures are necessary for such devices (safe anchoring of the tower, tightened guylines, safety cab).

The landing should be large enough to permit storage of at least the daily output of extracted timber. If the landing is situated on a slight elevation, manual work is saved in storing the logs.

The anchoring point in the valley should be situated as far away as possible from the foot of the slope or even on the opposite slope to achieve higher skyline heights and to reduce the number of supports.

Systematic opening-up of the forests consists in a combination of parallel and radial cable corridors. The spacing of parallel corridors is 80 to 120 m depending on the amount of extracted timber and skyline height. Radial cable corridors prevail in valley basins.

A landing is a prerequisite for work centralization by which transport costs can be lowered. As experience increases, there seems to be a trend towards radial opening-up of forests. Far-off forests will sometimes require sidelines, although double cable transport increases costs. One main corridor and several radial side corridors can open up a forest area very efficiently.

Plans for short distance cable cranes do not include ground anchors. This is why suitable anchor trees have to be used. More and more cable cranes with collapsible towers are used for short distances; the distance between the individual cable lines may be smaller (between 10 and 30 m).

3. TECHNICAL CONSIDERATIONS

In planning the cable line from a bird's-eye view it is important to remember that cable cranes in practice always require a straight line. Material and setting up expenses are very high if the skyline has to lead around horizontal bends and, furthermore, operation is not sufficiently safe.

There are several vertical profile alternatives for cable lines. The best one has no supports at all. Good profiles have supports on slight elevations. Generally speaking, few supports with low support pressure and span-distances of equal length are advisable.

Slopes with uniform gradients require many supports. Since they are all equally high and regularly spaced, material and setting up expenses are higher, but operation itself is no problem.

On convex terrain, cable lines are most problematic to construct because supports have to be higher and more densely arranged. Buckling angles, support pressure and friction within the cable shoes are high.

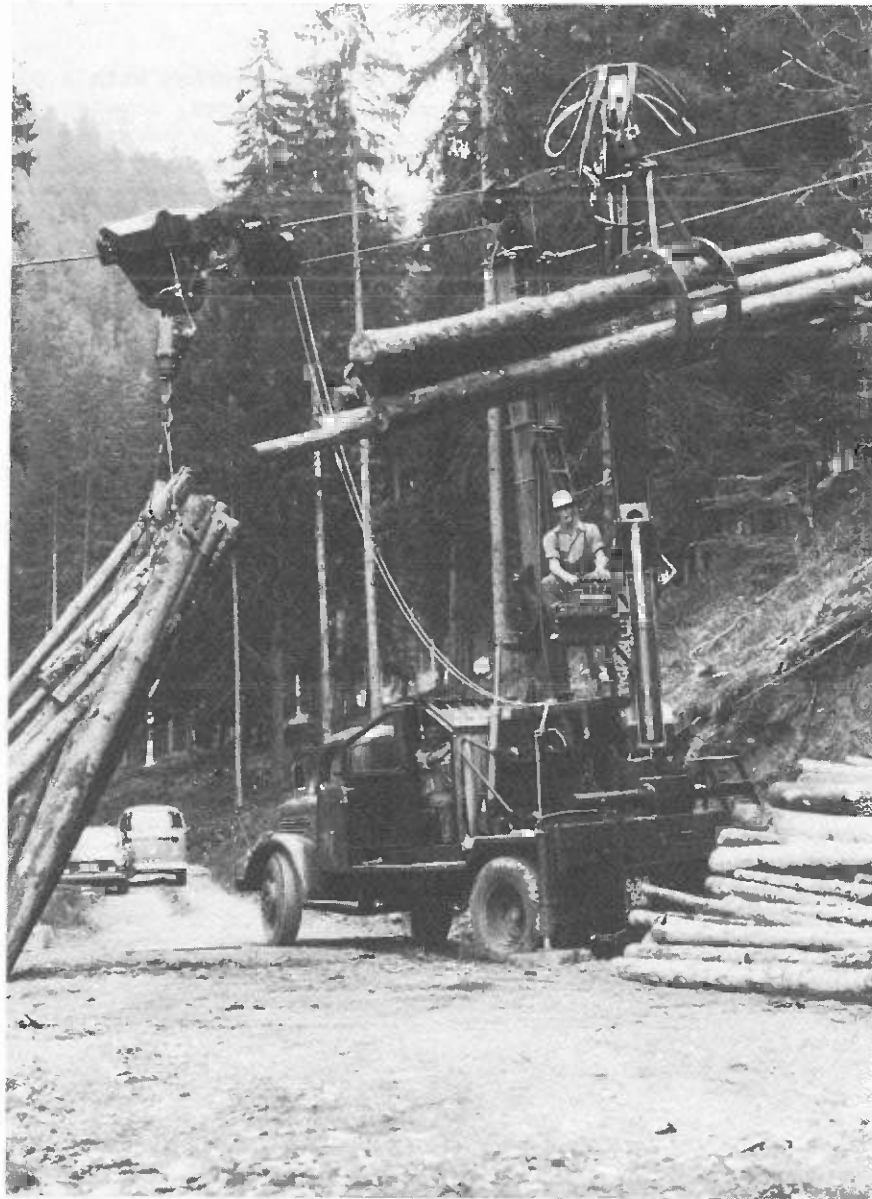
Slightly concave terrain sometimes makes construction of a cable crane impossible, because the supports would have to be too high for the unloaded cable, and the loaded skyline without supports would run too close to the ground.

The gradients required for the various cable crane systems have to be such as to guarantee smooth operation. Minimum gradients are specified by cable producers (about 22 percent). Maximum gradients are limited by carriage designs and amount to 100 to 140 percent.

Counter-slopes can only be surmounted by cable crane systems with a closed mainline. For cable cranes with an open mainline a second winch is required, counter-slopes can only be small, however. The terrain is studied on maps and aerial photographs, and the main points of the cable line are determined. Only after determining the ideal line, staking it out in nature, and drawing and calculating the most important details can the cable corridors be clear-cut and setting-up authorised.



Conventional cable crane in operation. (Photo R. Hinteregger)



Combined mobile cable crane and loader. Note the two operators. (Photo R. Hinteregger)

SPECIAL SAFETY MEASURES FOR SETTING UP
AND OPERATING CABLE CRANES

by

Anton Trzesniowski
Forstliche Ausbildungsstätte Ossiach 1/

1. INTRODUCTION

It was only after the second world war that Austrian forestry changed over from traditional logging methods with manual tools and draught animals to modern methods with properly trained forest workers equipped with power saws and wheel tractors. Although stationary cableways have been in use in Austria and other alpine countries for many years, modern cable cranes have been used for only about 20 years. Quite recently mobile cable installations and wheeled skidders started gaining unexpected importance, following the transfer of a large proportion of forest work from the forest to lower landings. This change of equipment and working method was accompanied by changes and improvements in safety conditions in forestry work.

From 1960 to 1970 accidents in forestry work decreased as follows:

	<u>1960</u>	<u>1970</u>
Total number of forestry accidents	7 459	5 501
Accidents leading to compensation for permanent, partial or total disability	605	438
Fatal accidents	46	28

This decrease of accidents was caused by the diminishing number of forestry workers but also by improved training and increased mechanization. The influence of training on accident prevention can be seen in the following table containing average figures for the years 1966 to 1970. It shows clearly that professional forest workers who have all undergone formal training have fewer accidents than seasonally or occasionally employed workers, who are as a rule untrained.

1/ Forestry Training Centre Ossiach, Austria

Table 1

INFLUENCE OF TRAINING ON PREVENTION OF ACCIDENTS

Occupation	Professional workers		Other workers employed in forestry (farmers, agricultural workers, seasonal workers)		All Workers	
	Total	%	Total	%	Total	%
Tree felling	Total 353 Fatalities 4.0	14 53	633 10.8	20 46	986 14.8	18 48
Conversion	Total 1 145 Fatalities 1.6	47 21	1 255 2.8	41 12	2 400 4.4	44 14
Cable crane transport	Total 500 Fatalities 0.8	21 10	433 3.6	14 16	933 4.4	17 14
Other off-road transport (skidding)	Total 44 Fatalities 0.2	2 3	31 1.0	1 4	75 1.2	1 4
Piling and loading	Total 384 Fatalities 1.0	15 13	605 1.4	20 6	989 2.4	18 8
Road transport	Total 17 Fatalities -	1 0	109 3.6	4 16	126 3.6	2 12
Total	2 443 = 100% 7.6 = 100%		3 066 = 100% 23.2 = 100%		5 509 = 100% 30.8 = 100%	

According to this table 62 percent of all accidents occur during felling and conversion. For cable transport, skidding and road transport the numbers are lower because these operations require special knowledge, and safety regulations and training are, therefore, more readily accepted.

As a precaution against accidents it is common practice to issue working instructions for each cable crane installation in the enterprise and for large-scale wheeled skidder operations. These instructions, of which examples are given in Annexes 1 and 2, deal with correct and safe work procedures and with maintenance and servicing requirements. The supervisor of the operation (forester, foreman) is responsible for fully informing each worker on the cable crane or wheeled skidder operation of the contents and importance of the working instructions.

All persons engaged in the installation and operation of cable installations are required by law to affirm with their signature that they have been informed of the relevant working instructions and that they fully understand them. As regards wheeled skidders the workers' signatures are not yet required by law, but this is strongly recommended.

2. SPECIAL REGULATIONS CONCERNING CABLE INSTALLATIONS

At the Forestry Training Centre in Ossiach, Carinthia, 150 cable crane installations have been set up since 1960, of which a large number have been checked and approved by the responsible authorities. The experiences gained during this work and the relevant instructions have been collected systematically for teaching purposes.

3. LEGAL REQUIREMENTS

The following legal prescriptions must be wholly or partly taken into account when cable equipment is installed and operated:

- (1) Forestry law No. 222/1962 (in which distinction is made between cable installations which should be reported to or approved by the authorities concerned);
- (2) General safety regulations of the individual province;
- (3) The Austrian regulations governing electrical installations (with regard to distances from and crossing of power lines);
- (4) Civil aviation: special permission is required for installations which are higher than 100 m above surface level. In Carinthia all obstacles to aviation must be reported which are more than 30 m high and which are situated on elevated places exceeding the surroundings by more than 100 m;
- (5) Radio and telephone: for the use of radio and telephone permission is required from the telecommunications administration;
- (6) All other cases in which cable installations might interfere with the public interest (mining, roads, military installations) also require permission.

4. APPROVAL BY COMPETENT AUTHORITY

For cable crane installations which are subject to formal approval an application must be sent to the competent local authority (Bezirkshauptmannschaft) together with the following documents:

- (1) Map showing the corridor of the cable crane ;
- (2) Longitudinal section with location of supports, sag of cable with and without load, minimum and maximum height of cable above the ground, loading stations, bending angle of cable at the supports and other data.
- (3) Technical description of the whole cable installation especially power source and transmission and braking device; distance from or crossing of railway lines, power lines, telephone lines, public and other roads, terrain belonging to other owners, rivers, torrents; timber storage areas near torrents and so on;

- (4) Certificates for skylines and mainlines (provided by the suppliers of wire ropes) stating the diameter of the cable, the number and strength of wires, the breaking strength and the manufacturer of the cable. Calculation of the load to which the cable will be exposed in relation to the actual strength of the cable;
- (5) List of all landowners within the area of the cable installation declaring their agreement with it;
- (6) Working instructions for the cable installation guaranteeing its safe operation and maintenance;

The legal requirements concerning cable installations of more than 30 or 100 m above ground level should be considered.

5. FURTHER TECHNICAL REQUIREMENTS

In addition to the requirements which must be fulfilled in order to obtain approval of cable installations from the competent authorities, the following technical standards must be met:

- (1) Skylines, mainlines and the motor unit must be earthed (at both ends of the skyline a cable for lightning protection should be dug into the ground about 30cm deep over a distance of 15-20 m);
- (2) At crossings with public roads, working signs must be put up on both sides at a distance of at least 50 m with the inscription "Attention ! Cable Crane" In special cases gates must be constructed which are opened only when the cable crane is not working;
- (3) If cable installations lead on to areas used by public traffic, these must be adequately protected by barriers against sliding or rolling logs. If possible cable installations should not be set up in the vicinity of railway lines, public roads exposed to heavy traffic, and other such places;
- (4) All moving parts of engines and transmissions such as driving belts, chains and sprockets, axle shafts and air brakes must be safely enclosed or adequately guarded against being accidentally touched. The platform of the winch and other working places situated more than 1 m above ground level must be properly fenced. Safety devices must be maintained in good condition.

ANNEX 1

MODEL OF WORKING INSTRUCTIONS FOR
CABLE INSTALLATIONS (INCLUDING SAFETY REGULATIONS)

For the cable crane.....
cable trace..... No.....
installed by.....
instruction of team carried out by.....
operated by.....

1. The cable crane shall be used only for the transport of wood and other materials. Transport of persons is prohibited.
2. The forest enterprise responsible for the operation is
3. The supervisor responsible for the operation is Mr.....
His instructions must be carried out under all circumstances. (Persons responsible for the work must also be appointed at all other working places such as intermediate or lower landings.)
4. All persons engaged in the installation and operation of cable installations must be fully informed of these working instructions before beginning their work. They must certify this with their signature.
5. The maximum load ism³ orkg (The maximum load must under no circumstances be exceeded in order to maintain a safety factor of five for the mainline).
6. Transport must not exceed a speed of m/sec or approximately min for the transport of one load. (Air fan brakes ensure constant speed).
7. Mobile installations must be so installed that they will not change their position or be turned over by the load or other influences. At a distance corresponding to the width of the winch drum multiplied by 20 and at an angle of 90° in relation to the axis of the winch a pulley should be securely fixed so as to ensure continuous feeding of the mainline on to the drum. Guiding or touching of moving cables with the hands is prohibited.
8. The operation shall begin only when reliable communications have been established between the different stations. (Visual signalling is permissible for small and clearly arranged installations up to a distance of about 100 m. In all other cases telephone or radio communications are necessary).
9. During the operation of cable winches the winch operator shall not leave his working place at the winch (brake).

10. Signalling shall be done as follows:

Line stop - one long sound (or light signal)
Line slack - two short sounds (or light signal)
Line ahead - three short sounds (or light signal)

(When radio or telephone is used, these signals should be marked on the apparatus). Signalling by means of shouting is allowable only if the cable installation is not working (this should also be marked on the signalling apparatus). All signals must be explained and demonstrated by the responsible supervisor and tried out by the workers before the operation begins.

11. When loads are attached by means of chokers, these must be fitted lightly. Under no circumstances should loads be able to get loose by themselves.
12. When loads are moved or stopped, the brakes should be released or pressed gently (jerky braking can result in dropping of the load). When the operation is finished all brakes must be tightened and the carriage so secured that no unauthorized person can set the cable crane in motion.
13. Transport must stop at once in any one of the following circumstances:
- (a) If the signal "stop" is given;
 - (b) If telephone or radio communications have broken down;
 - (c) In dense fog if visual signals are used;
 - (d) If an unusual resistance is noticed;
 - (e) If there are strong winds or thunderstorms within a distance of less than 3 km;
 - (f) If the mainline gets caught by the skyline.
14. The responsible supervisor must make sure that sufficient supplies of lubricants, tools and spare parts are available.
15. In a control book all inspections, repairs and other incidents as well as the daily volume of timber transported must be entered.
16. Safe distances must be kept between workers and lines running on the ground. (If lines which are under tension are caught by obstacles they may suddenly whip back). When loads are lifted workers must keep a safe distance from the skyline.
17. No worker should stand in the bight of a line or under a suspended load.
18. At the landings a first aid kit must be available. The working instructions should be put up on a notice board together with the following notices:
- Access prohibited to persons not engaged in the operation
 - Transport of persons prohibited
 - Authorized load..... kg
19. At the winch station a fuel supply sufficient only for a day's operation may be stored.
20. Work exposed to wire ropes is permitted only if gloves are worn. (Safety helmets are urgently recommended as well as felt boots to be worn by the winch operator during winter.)

21. Guylines of wooden constructions must be inspected and screws joining wooden constructions must be regularly retightened.
22. Persons subject to giddiness or having physical defects are not permitted to climb supports or supporting trees. Tree climbers should be equipped with climbing irons and certified safety belts fitted with two ropes or chains. (It is safer and more practicable to use chains instead of ropes. Chains can be better adjusted to different tree diameters and are not damaged by cutting tools used during cable installation work).
23. Daily lubrication and maintenance of winches and engines should be carried out according to the instructions of the manufacturer.
24. Maintenance work, repairs, inspections and all other work carried out to keep cable installations in good working order are permitted only if the cable operation has been halted, while at the winch a notice board has been put up with the following text: "Attention! Work in progress on the cable system. Do not set winch in motion".
25. The brakes must be kept in such condition that one brake will suffice to stop the cable. Brake linings should never be excessively worn.
26. Cable saddles must be lubricated once a week. At the same time a check must be made on whether they fit properly, whether the skyline has sufficient play and whether suppressing saddles properly fulfil their function.
27. Snatch blocks and blocks supporting the mainline must be lubricated daily and guiding devices must also be adjusted if necessary. The pulleys of the carriage must be lubricated twice a week. On these occasions the carriage must be inspected and safety devices checked.
28. Prior to installation, skylines and mainlines must be inspected for defects, kinks, broken wires and excessive wear. Defects must at once be removed. If the wires at the outer side of the cable are worn down for more than 50 percent of the diameter, the cable should be discarded. Defective sections (more than four broken wires over a length of 1 m) must at once be removed and the cable ends joined by splicing. The length of the splice must correspond to the diameter of the cable multiplied by 1 000 (e.g. for a diameter of 9.5 mm the splice must have a length of 9.5 m).
29. The fitting of loading hooks to the mainline must be inspected at least once a day. At the same time the mainline must be inspected for wear near the loading hook.
30. Skylines should be tensioned only to a limit guaranteeing a safety factor of 3 to 3.5. The tensioned cable must be inspected once a day by walking along the trace.
31. Riding on cable installations is permitted only upon special orders given by the supervisor.
32. Skylines and mainlines must be treated from time to time with non-acid lubricants (for the mainline use cable varnish).

ANNEX 1

Certificate

The above working instructions have been brought to the attention of:

1. The forest enterprise (paragraph 2):

.....
(Signature)

2. The supervisor of the cable installation
(paragraph 3):

.....
(Signature)

3. The supervisors of the different
working places:

.....
.....
(Signatures)

4. The workers engaged in the operation:

.....
.....
(Signatures)

These persons certify by their signature that they have been fully informed of the working instructions and that they fully understand them (Paragraph 4).

ANNEX 2

MODEL OF WORKING INSTRUCTIONS
FOR WHEELED SKIDDERS

Type of wheeled skidder:

Site of operation:.....

Person responsible for local
operation (e.g. forestry official):.....

Operated by (forest enterprise,
private undertaking):.....

Competent forest administration
(forest manager):.....

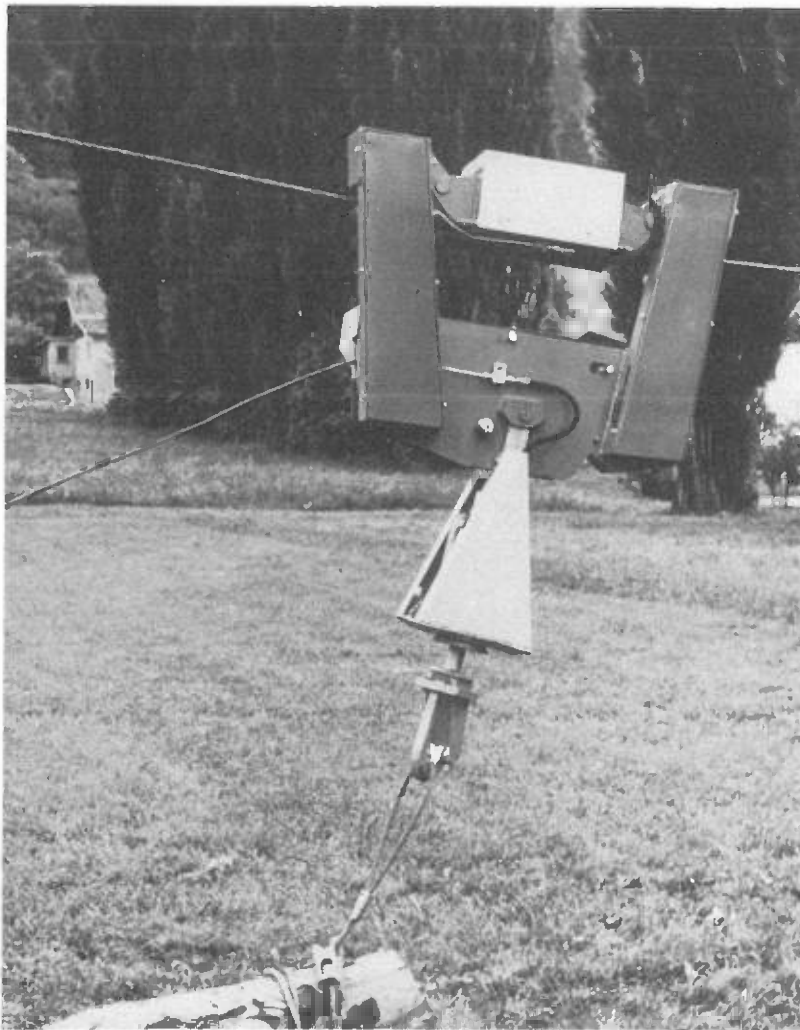
At each working place (felling, skidding, piling) a responsible supervisor must
be appointed.

1. For proper operation and maintenance of the wheeled skidder the following operator
is responsible:
Mr.
2. The wheeled skidder shall be used only for the transport of wood and other materials.
Riding on the machine by persons other than the operator is strictly prohibited
(one man machine).
3. The maximum load ism³ (The maximum load must be determined by consider-
ation of slope, weather conditions, ground surface conditions, strength of traction
cable and choker, capacity of clutch and winch, and so on).
4. The operator must not leave the tractor while the engine is working and winching is
in progress.
5. Cables and cable slings must be regularly checked for defects, kinks, broken wires,
excessive wear and fittings of chokers. Defects must at once be removed.
6. The operator is responsible for the availability of lubricants, tools and if
necessary spare parts in sufficient supply. An adequate safety kit with sterile
dressings must be kept on the machine.
7. The machine must be equipped with a fire extinguisher ready for use (according to
the relevant regulations).
8. The skidder must be properly maintained and serviced according to the operating
manual (daily, weekly and monthly inspections). It is forbidden to touch moving
parts of the machine.
9. It is urgently recommended that safety helmets and working gloves be used.
10. In a control book all inspections, repairs and other incidents as well as the daily
volume of wood skidded must be entered.

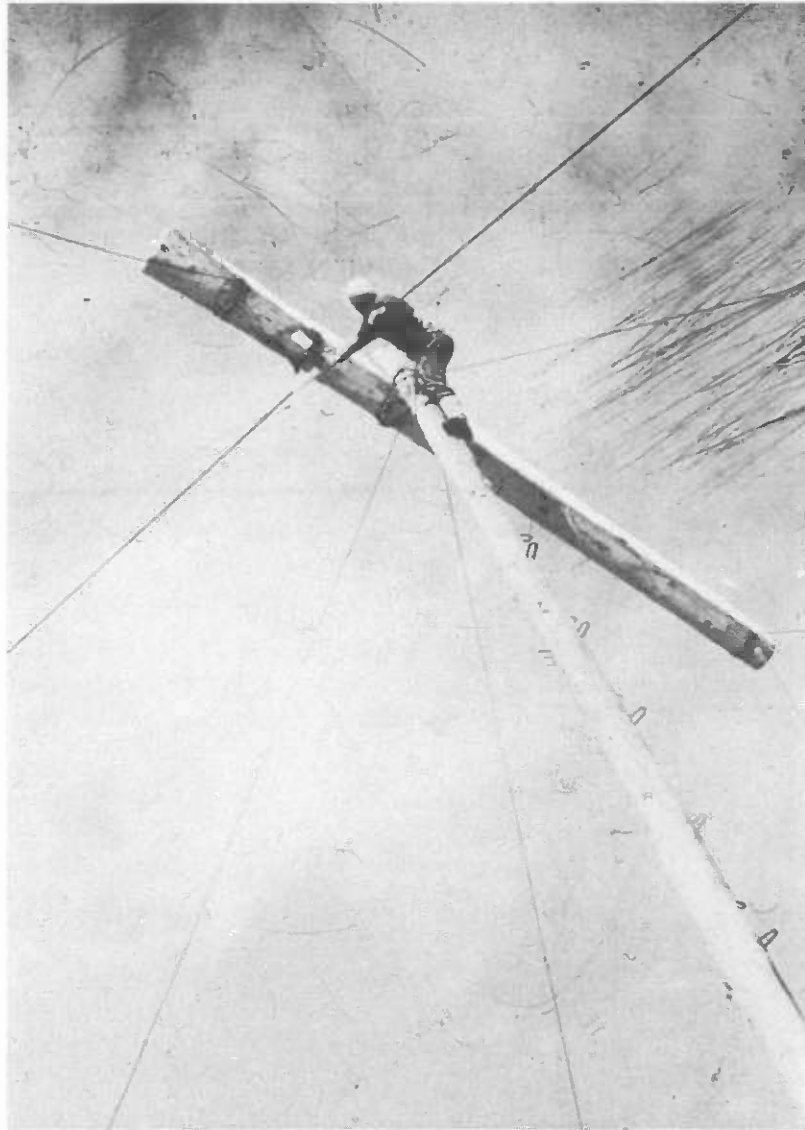
11. The cable and choker slings should not be dragged empty behind the skidder.
12. It is forbidden to touch the moving cable or to guide it with the hands.
13. Winching of a load toward the skidder should begin only after a clear exchange of signals between the operator and the helper. Visual signals must be determined in advance for this purpose.
14. The skidder or the winch should be set in motion only after helpers have withdrawn from dangerous places.
15. Avoid lateral winching at an excessive angle. The rear wheels should be in line with the direction of winching.
16. When the load is attached slings should fit tightly. Under no circumstances should the load get loose by itself.
17. Before being driven off, the load should be winched up close to the skidder so that the front end of the load is lifted up.
18. Safe distances must be kept between workers and the cable moving on the ground.
19. No worker should stand in the bight of the line.
20. When a long tree is winched uphill on a steep slope, there is a danger that the tree might roll laterally especially if the cable is attached to the top end of the tree. Depending on the specific situation trees must, therefore, be cross-cut and attached at the middle or at the butt end. Standing trees may be used as supports to guide the skidding of logs to the road.
21. The skidder should be set slowly and gently in motion (to avoid ruptures of the cable or of chokers).
22. The blade at the front of the skidder must be raised high during travelling. When the driver is going downhill in steep terrain the blade should be lowered so that it can be quickly released to the ground in case the skidder slips.
23. During off-road driving the appropriate gear should always be selected especially when going downhill. Moderate speed should be maintained and excessive braking avoided.
24. When the skidder passes close to persons, it should be ascertained that wood, branches or stones lying around are not thrown up by the machine or by the load.
25. When backing up, the operator must look backward.
26. When the vehicle is turned on slopes, there is a danger of its overturning. Therefore, turning should be so done that the two axles of the tractor pointing downhill form an angle of less than 90° and the centre of gravity is thus not excessively displaced to the downhill side.
27. If the skidder turns over, the operator should keep a tight grip on the available handles and not jump off.

28. After termination of work the blade at the front of the skidder must be lowered to the ground, the machine put into the lowest gear, the brakes tightened and adequate precautions taken to avoid the engine being started by unauthorized persons.
29. All persons participating in a wheeled skidder operation (felling, skidding, conversion at the landing, lorry loading, debarking, etcetera) must have been fully informed of these working instructions before the operation begins.

Further special regulations:



Koller automatic carriage designed for use in gravity system. (Photo FAO)



Fixing the skyline on the cross beam. (Photo Forestry Training Centre Ossiach)

TIME STUDIES FOR SKIDDING OPERATIONS

by

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1. INTRODUCTION

Time studies for skidding have three functions: planning, execution and evaluation with the main emphasis on the first two. Evaluation is a process of simple calculation dictated by the purpose of the time study. Time studies should be carried out only by trained people.

2. PLANNING

2.1 Purpose

Time studies for skidding performance data (time required per unit). From this data the rate of utilization (frequency) and economic return of a machine as well as labour productivity, can be determined. They also form the basis for calculating the cost of skidding therefore good planning of skidding operations. The purpose of time studies should be clearly specified.

2.2 Requirements

Before time studies are started, there should be a basic agreement between management and employees that they are needed.

Skidding personnel should be trained; they should be familiar with their tools and machines.

The conditions of tools and machines should be checked first of all, and possible defects eliminated to guarantee smooth operation and to prevent accidents.

2.3 Preparatory work

Both the work process in general, and individual skidding operations should be surveyed. The scope and limits of individual operations should be determined so that the proper time required for each operation can be estimated.

The characteristics of the terrain are identified and classified according to slope gradient, topography, soil conditions, stand density, and so on. The time taken to drive equal distances in differently shaped terrain is measured.

The timing method to be used for work units should be selected and time sheets prepared.

3. EXECUTION

Since human labour, mechanical tools and machines will be observed, whole-day studies are advisable. The duration of the observations depends on the purpose of the study; it may last for a week or longer.

^{1/} Federal Forestry Research Institute, Austria

The number of people carrying out time studies is dependent on the timing method chosen and the type of units to be observed (people, tools, machines). They should have all that they need, such as stop watches, time sheets, forms, etc.). Short test studies are carried out, after which necessary adjustments are made, and the study can start properly.

3.1 Methods of timing

There are various methods used in conducting time studies for skidding.

3.1.1 Cumulative timing

This method is particularly suited to illustrate the working process, since the time required for each work unit or group is recorded and the time of day. With the help of such a record it is easy to discover periods when machines are idle or people are waiting, situations that usually occur when several work groups are combined. Necessary adjustments in work can thus be made.

3.1.2 Partial operation timing

This method is applied when a chronological recording of the work process is not necessary.

The absolute times required for each work unit or group are recorded on the form. These entries are already made under their respective headings so that they can easily be summed up and evaluated. This method requires a profound knowledge of the work process.

Both the above methods require a relatively large number of timers, usually one timer per worker.

3.1.3 Observation ratio method

In this method 11 operations carried out by a worker are coded with a symbol and recorded at certain intervals (usually once a minute). Although the resulting values are not absolute, the accuracy of the time requirement for each operation unit is sufficient if enough recordings are made. Evaluation is carried out by summing up equal symbols. The total time requirement of an operation unit is usually expressed as a percentage.

It is an advantage of this method that one timer can observe several workers or machines within the chosen interval.

3.2 Determination of volumes and special working conditions

In order to determine the time requirement per unit of wood volume, it is necessary to find out the amount of timber that is skidded. This is done by measuring the logs (diameter and length) and sometimes also by judging their quality. In the case of animal skidding, mechanized skidding and cable extraction, the volume of timber is measured for each individual load so that comparative values can be determined.

As in difficult terrain lateral skidding to the main track is rather time-consuming, distances and terrain characteristics have to be recorded either in average values or individually for each skidding operation. It is also important to know the weather conditions and changes that influence the time required.

4. EVALUATION

Evaluation may be by calculation or computerized analysis if a sufficient amount of data is recorded. If a computer is to be used, this factor should be taken into account at the planning stage to avoid wasting time in making appropriate adjustments to the data recordings later on.

PRINCIPLES OF A COST CALCULATION FOR FOREST MACHINES

by

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Forstliche Ausbildungsstätte Ossiach^{1/}

1. INTRODUCTION

In 1956 the FAO/ECE/ILO Joint Committee on Forest Working Techniques produced a set of guidelines (TIM/LOG 36 Geneva 1956) for the calculation of machine running costs. Following this scheme the Kuratorium für Waldarbeit und Forsttechnik - KWF - (Board for Forest Work and Forestry Techniques) of the Federal Republic of Germany, has worked out rules for the calculation of machine costs (Mitteilungen des KWF, Vol.XII, 1971). The aim of these cost calculations is to achieve better planning and control of machine utilization. On the basis of cost calculations, decisions can be taken on

- replacement of manual labour by machines
- replacement of old machines by new ones
- the introduction of new work systems
- intervention of entrepreneur
- the cost of work not contracted out

Cost calculations should be as accurate, but also as simple as possible. On the basis of such calculations comparisons can be made between various work methods and periods required to carry out work. For these reasons the application of standardized guidelines is appropriate.

2. DEFINITIONS

2.1 For calculating machine costs "precalculations", "interim calculations" and "re-calculations" may be used.

Precalculations (determination of target cost figures) are rough estimates based on experience. These are used for planning purposes only.

Interim calculations take into account expenditure actually incurred (e.g. fuel consumption) as well as the precalculated values (e.g. repair costs). These are used for checking the first estimates.

Re-calculations (ex post-facto determination of expenditure) are possible only after the machine has been used up or sold. Here only costs and expenses that have actually been incurred are considered.

2.2 Standard

The standard used for determining the operating costs of forestry machines is the "operating hour". This is defined as one hour during which the motor is running, independently of whether the machine is running idle or working at full capacity. Down time and waiting time during which the motor is not running are not included. Time required for starting up or closing down the engine, on the other hand, is included in the operating hours. The actual number of operating hours can be most accurately determined by using a tachograph, or a similar device, on the machine.

^{1/} Forestry Training Centre, Ossiach, Austria

2.3 Variable, semi-variable and fixed costs

The cost structure of manual labour differs from that of machinery. With regard to manual labour only variable costs are incurred, which result from the length of time worked. With regard to machines, in addition to variable costs annual fixed costs (overheads) are to be considered.

Breakdown of machine costs

A. Capital costs

- a) fixed costs, e.g. interest, insurance, taxes, garaging
- b) semi-variable costs, e.g. depreciation, repairs
- c) variable costs, e.g. fuel, tyres, chains, cables

B. Labour costs

Variable costs: It is necessary to compute costs for wages (including social security contributions and the like) for manning the machine, for its maintenance and, in some cases, separation allowances for workers.

The category of semi-variable costs may be considered as fully variable costs if the normal degree of utilization of the machine is achieved during its useful life. If a machine is used below capacity, semi-variable costs should be regarded as fixed costs.

Depreciation per hour of operation thus increases in line with the number of hours of use per year. The repair costs go down as the number of operating hours decreases. These relationships must be taken into account when expensive machines are used or when they are utilized only to a limited extent.

3. DERIVATION OF COSTS

3.1 Capital costs

3.1.1 Fixed costs. Amortization is calculated annually on the basis of the number of operating hours per year.

Interest is paid off under the straight line depreciation method, currently amounting to 8% of half the purchase price.

Insurance includes all annual premiums.

Taxes e.g. vehicle tax, etc.

Garaging e.g. rentals for parking

3.1.2 Semi-variable costs

Depreciation and repair costs may be added up for the machine and all auxiliary equipment. In many cases, however, separate calculations are preferable in order to distinguish between varying degrees of wear and tear (e.g. on motor chain saws, tractor tyres etc.).

Here the following factors should be taken into account:

a) Purchase costs (An)

Cost of purchasing the machine, including freight.

b) Useful life (H)

This is the period over which the machine operates at the lowest average costs.

c) Obsolescence time (N)

This is the period until the machine is superseded by a more efficient machine, irrespective of whether it has been utilized or not.

d) Annual utilization (J)

This is based on the actual number of hours during which the machine was utilized in a year.

e) Marginal utilization (Sw)

This is derived from the ratio between its useful life (H) and obsolescence (N).

$$Sw = \frac{H}{N}$$

This value is compared with the annual utilization (J) of the machine. If J is greater than Sw the machine will be written off before obsolescence has been reached. If J is smaller than Sw the machine will not be used to full capacity.

f) Repair cost factor (r)

This value corresponds to a certain portion of the purchase price, e.g.:

- for motor saws	$r = 0.6$
- for articulated wheeled skidders	$r = 0.8$
- for winches	$r = 0.5$

These estimated values were suggested by the FAO/ECE Study Group.

g) Depreciation (Ab)

This is obtained by dividing the purchase price (An) by the hours of operation. To calculate depreciation there are two possibilities:

$$\text{if } J \text{ is greater than } Sw \text{ then } Ab = \frac{An}{H} \text{ (in US\$/operating hour)}$$

$$\text{if } J \text{ is less than } Sw \text{ then } Ab = \frac{An}{J} N \text{ (in US\$/operating hour)}$$

3.1.3 Variable costs = utilization costs

Fuel, (petrol, diesel oil) for the precalculation figures can be taken from tables, or estimates may be used;

Lubricants (motor and gear oil, grease), are generally taken as 20% of fuel costs;

Tyres and tracks;

Cables for winches;

Chains for motor-driven chainsaws.

3.2 Labour costs

These include wages, social security contribution, etc., for machine operators. In Austria the social security costs currently account for as much as 80 to 100% of wages.

Machine operation

Machine operators

Assistants

Machine maintenance

The figure is estimated at 15% of hourly wages including social security paid to machine operators.

4. SUMMARY OF DATA REQUIRED FOR CALCULATION

In determining machine costs the necessary calculation data should be entered on a form in order to give an overall picture (additional summaries may be made for auxiliary equipment as required, broken down according to number and type):

1. Initial cost (An) of the machine (with or without accessories and auxiliary equipment) US\$
 - Accessories US\$
 - US\$
 - Auxiliary equipment US\$
 - US\$
2. Interest factor (p) percent
3. Insurance premiums US\$ p.a.
- US\$ p.a.
- US\$ p.a.
4. Taxes US\$ p.a.
- US\$ p.a.
- US\$ p.a.
5. Garaging US\$ p.a.
6. Useful life (H)
 - of the machine op. h.
 - of accessories op. h.
 - of auxiliary equipment op. h.
7. Obsolescence (N)
 - of the machine years
 - of auxiliary equipment years

8. Annual utilization (J)

- of the machine	..... o.p. h/year
- of auxiliary equipment	..... o.p. h/year
	..... o.p. h/year

9. Marginal utilization ($Sw = \frac{H}{N}$)

- of the machine	..... o.p. h/year
- of auxiliary equipment	..... o.p. h/year
 o.p. h/year

10. Repair cost factor (r)

- of the machine	.....
- of auxiliary equipment	.....

11. Fuel costs (consumption litres/op. h;
price US\$/litre)

..... US\$/op.h

12. Lubricant costs (.....% of 11)

..... US\$/op.h

13. Wages (excluding social security, etc.)

- of the machine operator (inc. ...% extras)	..... US\$/op.h
- of assistants, per man (inc. ...% of extras)	..... US\$/op.h

14. Social security contributions, etc.

..... percent

15. Number of assistants

.....

16. Maintenance costs per operating hour including pro-
rata share of wages and social security costs per
machine operator

..... percent

5. COST CALCULATION MODEL

Using the cost calculation model in which cost factors can easily be entered, costs per operating hour can readily be determined for each machine. Furthermore, the model indicates the relative importance of the individual cost factors.

A. Capital costs	US\$/year	US\$/op.h	Percent
a) Fixed costs			
interest		
insurance premiums		
taxes		
garaging		

b) Semi-variable costs			
depreciation:			
- of the machine
- of auxiliary equipment

repair costs	US\$/year	US\$/op.h.	Percent
- of the machine
- of auxiliary equipment
	<u>.....</u>	<u>.....</u>	<u>.....</u>

c) Variable costs

fuel	.....	.....
lubricants	.....	.....
tyres	.....	.....
wear on cables	.....	.....
wear on chains	.....	.....
	<u>.....</u>	<u>.....</u>

TOTAL A.

B. Wage costs

a) Machine operation

machine operator (hourly wage including social security etc.)	.....	.....
assistants (hourly wage including social security etc.)	.....	.....

b) Maintenance

.....

TOTAL B.

OVERALL TOTAL

COMPARATIVE COST CALCULATIONS FOR VARIOUS METHODS OF TIMBER HARVESTING

by

Horst Tauer
Forstliche Ausbildungsstätte Ort 1/

1. COST CALCULATION AS A FACTOR IN WORK PLANNING

Precalculation involves estimating the costs of a given timber harvesting method and it is the basis of profitability studies.

Recalculation determines and confirms the costs of machinery and work procedures, it serves to show whether cost estimates were correct. The data obtained are useful in subsequent cost calculations.

Profitability Studies and Comparative Cost Calculation. The costs of various working methods and machines are compared. This comparison is valuable for determining the following:

- investments (choice of suitable machinery)
- changes in organization and method of work
- selection of the best timber harvesting method
- whether to do the work oneself or to contract it out

The calculation of costs is an important factor in work planning but it does not provide the only criteria for the selection of a particular method.

2. BASIC PRINCIPLES

Costs are defined by the capital input in monetary systems required to achieve a particular performance goal. Costs are determined either for a period of time (month, year) or for a production unit in quantitative terms (m^3 , metre, operating hour).

In cost accounting various factors are distinguished:

Cost categories. What types of costs were incurred? (materials, wages, salaries, depreciation, interest, energy, repairs).

Cost centres. Where were the costs incurred? (road building, timber harvesting, silviculture, machinery, administration).

Cost units. On what basis are the costs apportioned? (m^3 , metres, operating hours).

Variable costs - quantity-related costs. These depend on the amount of timber produced or on the number of operating hours (fuel for machinery, repairs, wages, costs of material).

Fixed costs - time-related costs. These occur within certain period. (month, year); (depreciation, interest, salaries, rentals, etc.).

Combined costs. These include elements of time-related and quantity-related costs (fuel, maintenance). Before considering them for comparative cost calculations, these must be analyzed.

Overhead costs. All costs incurred must be broken down and apportioned to individual cost items and cost units. This method, applied mainly in recalculations, results in the most exact data.

Sectional costing. Calculation of cover ratio. Only the quantity-related costs are determined. The cover ratio equals proceeds minus quantity-related costs. This type of calculation allows a comparison of methods if the time-related costs remain roughly the same.

3. COST COMPARISON FOR VARIOUS METHODS OF TIMBER HARVESTING

Comparative cost calculations are arithmetical comparisons of various working methods, machinery, and devices in order to find out which are the most economic for a certain method of timber harvesting. In most cases various degrees of mechanization are compared:

	<u>Highly-mechanized work</u>	<u>Labour-intensive work</u>
Fixed costs (time-related)	high	low
Variable costs (quantity-related)	low	high
Repairs	high	low
Fuel	high	low
Wages	low	high
<u>Output</u>	high	low

By employing profitability studies, the work planner can answer the following questions:

- What is the cheapest method for harvesting a given number of units (m^3 per area or year)?
- What quantity has to be produced per period or area in order to guarantee profitability of the most highly mechanized or the most costly work method?
- At which distance will an expensive skidding device begin to become profitable?

4. STAGES OF COMPARATIVE CALCULATIONS + PROFITABILITY STUDIES

Obtaining the basic data:

- cost of machinery and equipment for various timber harvesting methods (see Mr. Trzesniowski's paper on "Cost Calculation for Machines")
- calculation of preparatory costs such as transport of machines, setting-up, dismantling
- planning costs
- costs for auxiliary installations such as landings, skidding roads, housing, service stations
- personnel costs, wages and salaries including social costs.

Estimating the capacity and efficiency of harvesting methods.

It is important to know the capacity of each harvesting method in order to determine its profitability. Empirical data obtained from recalculations, specifications and operational reports are valuable sources of information. If equipment is expensive, the annual rate of utilization (i.e. the ratio between actual capacity and potential capacity) has a marked influence on variable costs.

Cost analysis:

For comparative calculations cost elements have to be analyzed and broken down into fixed- and variable costs.

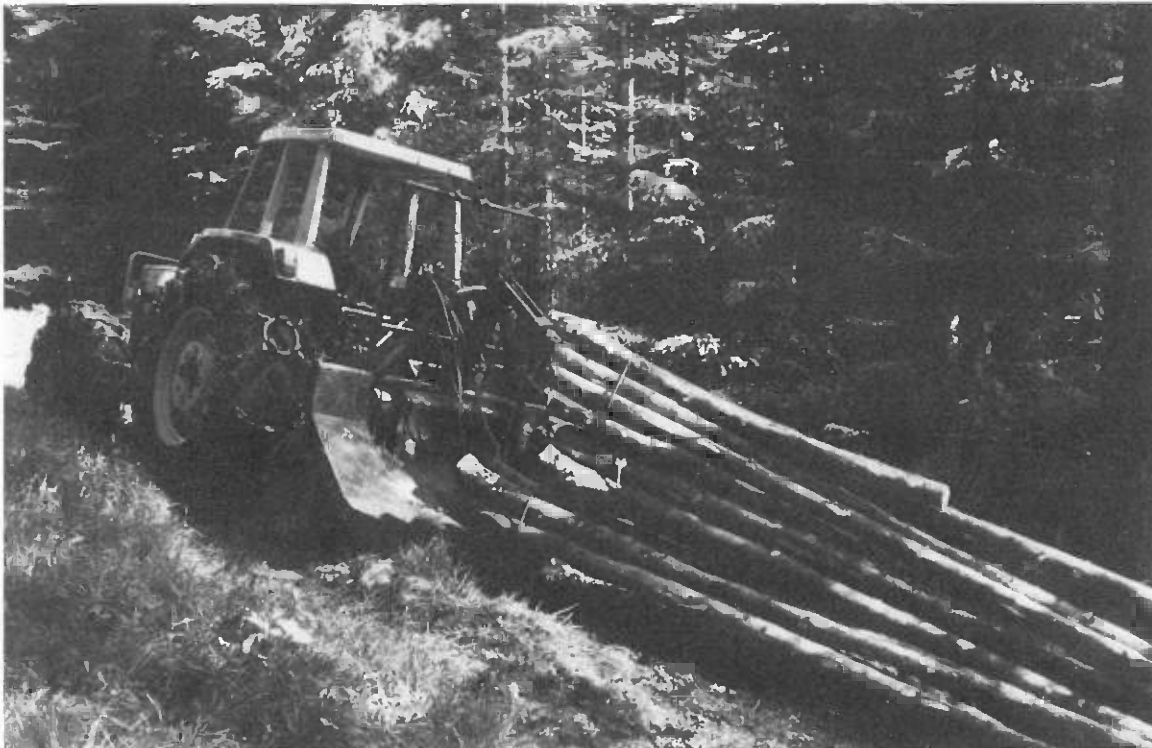
Comparative calculations:

By comparative calculation the critical number of units is projected either arithmetically or graphically. This is to say that the break-even point of two methods can be determined.

	<u>Fixed costs</u> (Time-related costs)	<u>Variable costs</u> (Quantity-related costs)
Method A	lower	higher
Method B	higher	lower

Calculation:

$$\text{Critical number of units} = \frac{\frac{(\text{fixed costs})}{\text{time related costs method B}} - \frac{(\text{fixed costs})}{\text{time related costs method A}}}{\frac{\text{quantity related costs method A}}{(\text{variable costs})} - \frac{\text{quantity related costs method B}}{(\text{variable costs})}}$$



Farm tractor with bogie skidding the load. (Photo O. Sedlak)



In 1977 logging by helicopter from remote mountain regions was used in three areas affected by storm damage, where this logging method proved profitable. (Photo E. Pestal)

EXAMPLE OF A TIME STUDY FOR SKIDDING OPERATIONS

by

Alfred Bernhard
Forstliche Bundesversuchsanstalt ^{1/}

1. OPERATION

Whole-tree skidding by means of articulated wheeled skidder (58 kw) from the felling site to the road (accessible by truck). Storage of trees on the valley side of the road.

2. WORKING SEQUENCE

This consists of the following: unloaded travel on forest road - unloaded travel on skidding track - arrival at the felling site - pulling out the cable and attaching the load - skidding by winch - loaded travel on skidding track - loaded travel on forest road - detaching load - depositing trees. Repetition of operation.

3. DETERMINING THE WORK ELEMENTS FOR TIME RECORDING

Individual work elements are determined and coded with symbols.

3.1 Work elements and their symbols

Unloaded travel on forest road	L
Unloaded travel on skidding track	L1
Pulling and attaching load manually	H1
Skidding by winch	S
Loaded travel on skidding track	V1
Loaded travel on forest road	V
Detaching load	H
Depositing trees	LM
Rest period	P
Time allowance for repair of cable & chokers	RS

4. TIMING

Cumulative timing is particularly suitable for this type of time study. Cumulative timing and other timing methods, as well as their applications, have already been described by Hauska ^{2/}. Cumulative timing is based on a chronological recording of the time of day, the element of work performed, and its respective symbol. The time study sheet may be evaluated arithmetically or by means of a computer.

As a rule, one timer observes one worker. For timing a simple stop-watch with 1/100-minute scale and a second-, minute-, and also hour-scale is used. If no special chronometric instrument is available, a wrist-watch or pocket watch will be sufficient.

^{1/} Federal Forestry Research Institute, Austria

^{2/} "Time Studies for Skidding Operations", pp. 193 - 194.

4.1 Reference data

Reference data should be recorded separately for each cycle. These are: diameter measured at breast height (DBH), mean diameter, tree length, number of trees on each load, travel distances for each section, direction of travel and gradients for cable operations: skidding distances, skidding directions, and gradients.

4.2 Working conditions

Qualified driver, articulated wheeled skidder 58 kw, temperature 22°C, sunny, no travel obstacles.

5. EVALUATION OF TIME STUDY

The time study is evaluated by determining the respective differences of time entries. There are exact time control data for each cycle or each time sheet, which serve as criteria for the evaluation of the recorded times. For human labour, differences between recorded time and control time must not exceed ± 3 percent; for machine operation they must not exceed ± 5 percent.

5.1 Results

Time for the individual work elements:

<u>Symbol</u>	<u>Minutes</u>	<u>Percent</u>
L	11.4	10.2
L1	5.0	4.5
H1	18.6	16.7
S	13.7	12.3
V1	10.1	9.1
V	13.4	12.0
H	5.0	4.5
LM	9.2	8.3
P	18.3	16.4
RS	6.6	6.0
Total	111.3	100.0

Total time required for each cycle in minutes:

Cycle 1	24.3
Cycle 2	55.9
Cycle 3	31.3

Average time requirement for one cycle: 37.1 minutes. Cable repair work and rest allowance account for the long time needed for cycle 2.

Time study evaluations allow an assessment on the average time required for each trip over given distances as well as reference data for performance.

Results may also be assessed on the basis of work elements showing common characteristics (see 3.1). Depending on whether human labour or machine operation predominates, work elements fall into two categories, as follows:

<u>Human labour</u>	<u>Minutes</u>	<u>Percent</u>
Main activity (symbols L, Ll, Hl, S, Vl, V, H, LM)	86.4	77.6
Additional activity MZ (symbol RS)	6.6	6.0
Resting ME (symbol P)	<u>18.3</u>	<u>16.4</u>
	111.3	100.0
<u>Machine</u>		
Main utilization BH (symbols L, Ll, S, Vl, V, LM)	62.8	56.4
Secondary utilization BN (symbols Hl, H)	23.6	21.2
Down-time due to defect BS (symbol RS)	6.6	6.0
Interruptions for rest BE (symbol P)	<u>18.3</u>	<u>16.4</u>
	111.3	100.0

This kind of classification also indicates the extent to which the capacity of the machine is utilized, and gives a useful indication as to rationalization and engineering methods.

Engineering methods may require the following adjustments: employment of a more powerful (in terms of kw) skidder to improve uphill travel (Vl); depositing several trees (two or three loads) in one single operation.

Adjustments should be checked for reference data and by additional time studies under very similar or identical working conditions.

Time studies, particularly if used for the calculation of allowed times, are in fact documents and must be carried out accurately. For more comprehensive studies it is advisable to elaborate separate sheets for time recording, reference data and working conditions, and to adjust these to the time study objective.



Small skidder in operation (Photo: Forestry Research Institute, Vienna)



Front-end loader feeding a log processor at the forest landing (Photo: FAO)

COST CALCULATION FOR AN ARTICULATED WHEELED SKIDDER
AND A CABLE CRANE

by

Peter W. Bauernfried
Forstliche Ausbildungsstätte Ossiach ^{1/}

To calculate the costs of a logging operation, equipment and labour costs must be taken into account. An example is given of how total expenditure for a logging operation with articulated wheeled skidder and a cable crane is calculated.

Cost calculation of a cable crane for a transport distance of 1 500 m
and a payload capacity of 2.5 t

<u>Equipment</u>	<u>Price in Austrian Schillings</u> ^{2/}
1 winch, traction force 25 000 N, with fan brake, air-cooled engine, power approx. 38 kW, mounted on a steel sledge	255 000
1 carriage, fully automatic, 2.5-t transport capacity	88 700
3 skyline jacks for the intermediate supports (A.S. 4 100 each)	12 300
1 tail shoe with double pulley	1 800
1 pulley block (8 pulleys) with ball bearings	14 400
2 mainline pulleys, 3 t (A.S. 2 400 each)	4 800
2 ground pulleys for mainline protection (A.S. 1 900 each)	3 800
2 blocks with tackle "Tirfor TU 16" (A.S. 5 940 each)	11 880
2 mainline pulleys 2 t (A.S. 1 430 each)	2 860
1 "Lug-all" guyline tensioner 1.7 t	3 400
2 wedge clamps, various sizes	3 450
1 communication set, consisting of 3 units and 2 000 m of wire	18 800
2 safety belts with Manila rope (25 m) (A.S. 950 each)	1 900
3 cable shears, 3 sizes for 7 mm, 12 mm and 16 mm, together	3 010
1 skyline, 1 600 m long, 28 mm diameter, 114 wires	115 000
1 mainline, 1 800 m long, 12 mm diameter, seale type with 114 wires	28 000
1 guyline, similar to the mainline, 1 000 m long	15 500

1/ Forestry Training Centre Ossiach, Austria

2/ US\$ 1 = A.S. (Austrian Schilling) 14.00 (September 1978)

<u>Equipment</u>	<u>Price in Austrian Schillings</u>
1 winch drive cable, 150 m long, 16 mm diameter, 216 wires	3 800
1 mounting cable, 1 800 m long, 7 mm diameter	8 600
various cables for tail shoe, anchor, pulley block, etcetera	8 000
various pieces of equipment like climbing irons, U-clamps, bulldog clips, lightning protection cable, choker cables (36), tools, cable drum sledge, etcetera	35 000
Total A.S.	<u>640 000</u> =====



One tree (leaning) skyline support (Photo R. Heinrich)

1/

✓ Σ_2 Formula valid for $j < \frac{H}{N}$, if $j > \frac{H}{N}$ then take $\frac{A}{H} \frac{r}{r}$

It is assumed that per working hour approx. $4 - 5 \text{ m}^3$ are transported, which means transport costs of A.S. 50.58/m³ for 1 000 hours/year

<u>Timber transport costs</u>	<u>Cost in Austrian schillings</u>
Setting-up	
117 hours at A.S. 90.70*	10 611.90
transport (vehicle)	<u>170.00</u>
	10 781.90
Dismantling	
40 % of setting-up costs	4 312.76
setting-up and dismantling costs for 400 m ³ timber	15 094.66
	<u>37.74/m³</u>
Transport	
4 workers, 9 hours/day at A. S. 90.70/hour	3 265.20
average transport output 45 m ³ /day	<u>72.56/m³</u>
Total transport costs per m ³	
machinery	50.58
setting-up + dismantling	37.74
transport	<u>72.56</u>
Total	<u>160.88</u>
	=====

* The hourly wage is A.S. 49.03 + 85 % for social welfare.

Operating costs for a medium-sized articulated wheeled skidder ^{1/}

1. Basic information		Price in	Assumed lifetime		
		Austr. schillings	in hours (H)		
1.1	Purchase price - machine w/o tyres, wheel chains, hauling line, chokers (A)	894 000	7 000		
	- 4 tyres	41 400	3 500		
	- 4 wheel chains	33 000	6 000		
	- 1 hauling line	4 800	500		
	- 1 set chokers (i.e. 10)	3 600	200		
		976 800			
1.2	Time of depreciation (- machine) (N)		6 years		
1.3	Repair factor (r)		0.8		
1.4	Interest (p)		9.5 %		
1.5	Hourly wage of operator (incl. social welfare) in A. S.		95.39		
2.	Cost calculation		Annual working hours (j)		
			800	1 000	1 200
2.1	Interest (half usual rate)				
	$\frac{A}{100} \frac{p}{2} = \frac{976\ 800}{100} \frac{9.5}{2} = \text{A. S. } 46\ 398$	58.00	46.40	38.66	
2.2	Rent of storage A. S. 4 000/year	5.00	4.00	3.33	
2.3	Insurance (liability)	-	-	-	
2.4	Depreciation				
	- machine $\frac{A}{N} \frac{x_1}{j} = \frac{894\ 000}{6} \frac{1}{800}$	186.25	149.00	127.71	
	- tyres $\frac{A}{H} = \frac{41\ 400}{3\ 500}$	11.83	11.83	11.83	
	- wheel chains $\frac{A}{H} = \frac{33\ 000}{6\ 000}$	5.50	5.50	5.50	
	- hauling line $\frac{A}{H} = \frac{4\ 800}{500}$	9.60	9.60	9.60	
	- chokers $\frac{A}{H} = \frac{3\ 600}{200}$	18.00	18.00	18.00	
2.5	Repairs $\frac{A}{H} \frac{N}{H} \frac{j}{r} x_2 = \frac{894\ 000}{7\ 000} \frac{6}{7\ 000} \frac{800}{0.8}$	70.06	87.58	102.17	
2.6	Fuel (7 l/h at A.S.5.60 per litre)	39.20	39.20	39.20	
2.7	Lubricants (20 % of 2.6)	7.84	7.84	7.84	
	Total machine hour costs A. S.	411.28	378.95	363.84	

^{1/} According to FAO/ECE/LOG/58 TIM/LOG/36

* Formula valid for $j < \frac{H}{N}$, if $j > \frac{H}{N}$ then take $\frac{A}{H}$

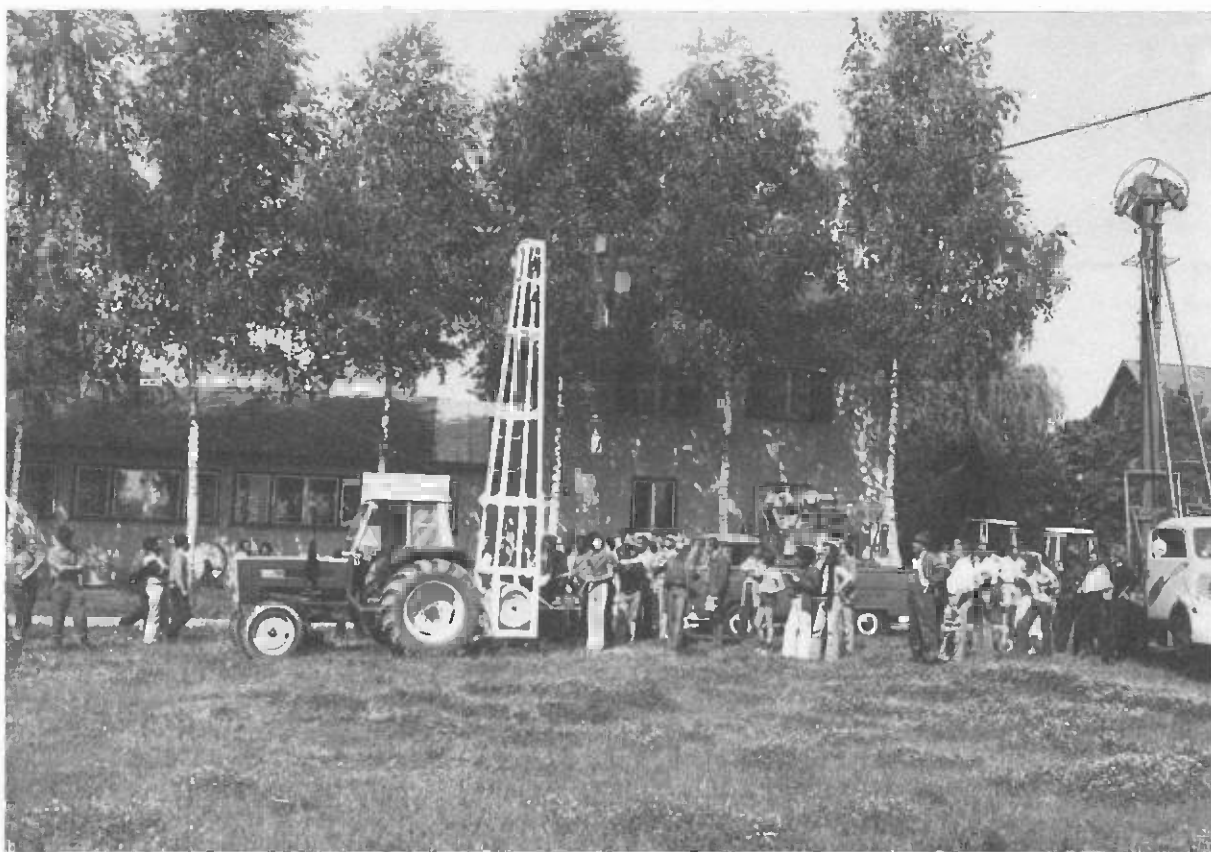
✓ Formula valid for $j < \frac{H}{N}$, if $j > \frac{H}{N}$ then take $\frac{A}{H} \frac{r}{H}$

To find the total costs of a logging operation with mechanized equipment, the labour costs must be added to the machine costs.

Transport costs for one day of work :

6.5 hours of machine work at A. S.	363.84/h	=	A. S.	2 364.96
8 hours of operator's work at A.S.	95.39/h*	=	A.S.	<u>763.12</u>
Total				= A. S. 3 128.08
=====				

The average daily output of one articulated skidder (without a helper) is approximately 45 m³. This figure would of course depend on terrain conditions and timber size and also whether transport was uphill or downhill. With this average daily output transport costs per m³ would be A.S. 69.51.



New development of simple cable crane equipment as attachment for farm tractor.
(Photo T. Pasca)

* The hourly wage is A. S. 51.56 + 85 % for social welfare,

APPENDIX

Setting-up time for a cable crane near the
Forestry Training Centre Ossiach

Working crew:

3 men

		<u>Hours</u>
Staking out the cable line	2 x 4 hours	8
Planning	1 x 5 h	5
Transporting equipment	3 x 4 h	12
Winch drive to the upper station	3 x 4 h	12
Preparing the winch station	2 x 2 h	4
Pulling the skyline and fixing	3 x 3 h	9
Endmast	2 x 3 h	6
Support	3 x 8 h	24
Endmast	2 x 3 h	6
Fixing the carriage	3 x 1 h	3
Pulling the mainline	2 x 1 h	2
Installing the pulley block	3 x 2 h	6
Fixing the telephone line	2 x 1 h	2
Tensioning the skyline	3 x 3 h	9
Checking the installation	3 x 3 h	<u>9</u>
Total		117 hours =====



Sledge winch used in extraction of thinnings, and positioning of plastic chute (Photo R. Heinrich)

BASIC PRINCIPLES OF ERGONOMICS

by

Josef Wenzl,
Forstliche Bundesversuchsanstalt^{1/}

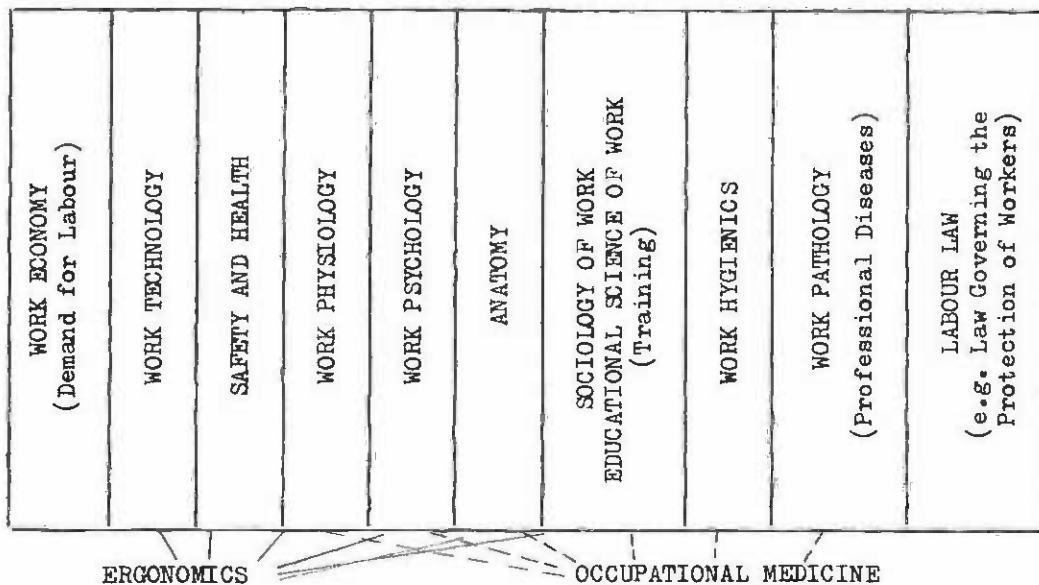
1. ORGANIZING FOREST OPERATIONS ACCORDING TO ERGONOMIC MEASUREMENTS

Ergonomics aims at studying and scientifically analyzing the relationships between man and work. Ergonomics is based on experience gained in the most varied disciplines of science. It is a main objective of ergonomics to adapt work to man. In most cases this can be achieved only with the help of ergonomic studies.

In order to adapt work (tools and equipment) to man, the working capacity and energy limit of the worker have to be known. Therefore it is necessary to measure work load, individual physical strain and environmental influences.

2. BASIC PRINCIPLES OF ERGONOMICS (according to Köck)

Terms - Branches of Work Science



^{1/} Federal Forestry Research Institute, Austria

Definitions

ANATOMY:	theory of the structure of the human body and its parts;
ERGONOMICS:	theory of adapting work to man; man is considered as a component element of a working system;
SAFETY & HEALTH MEASURES:	precautionary measures for the safety of man and material goods
SOCIOLOGY OF WORK:	theory of the interrelationships between work and man on the one hand, and his state of health on the other;
OCCUPATIONAL MEDICINE:	theory of interrelation between work and occupation on the one hand, and man and health on the other hand;
WORK PHYSIOLOGY:	theory of the functions of the human body and its organs during work;
WORK PSYCHOLOGY:	theory of mental and emotional strain in man resulting from work;
WORK SCIENCE:	theory dealing with different kinds of human work, their interdependence and optimum organization;
WORK TECHNOLOGY:	theory of working techniques (e.g. work studies).

3. SYSTEMIZING THE ADAPTATION OF WORK TO MAN

Working positions

sitting, standing,
bending or other

M A N

Types of Work

muscular work
(static, dynamic load)
work under time pressure
(assembly line, piece-rate, etc.)
concentrated work

Environmental Influences

artificial and natural lighting,
colouring, noise, vibration, indoor
climate (hot, cold), exhaust gas,
dust, smoke, vapours, etc.

At the work site man is exposed to the influences of his working position and of his type of work, the atmosphere and environment. In addition, psychological and socio-logical factors come into play.

4. MEASURING WORK LOAD AND PHYSICAL STRAIN

It is the objective of ergonomic measurements to determine the work load of various operations at the work site. The determination of individually tolerable physical strain is of paramount importance. Physical strain on man can be determined through energy expenditure and heart-rate measurements. This is why apart from proper work load studies personal data have to be recorded and special tests (e.g. electrocardiographic measurements) have to be carried out.

Environmental factors exert a substantial influence on the work load. For any ergonomic work evaluation they have to be accurately studied. Since forest work may be carried out under extreme climatic conditions, climate and weather are factors to be studied as well. For wood harvesting in mountainous forests slope gradient and accessibility are two main determinants of work load and work organization. Further determining factors to be examined are work methods, tools and equipment, and protective devices.

All ergonomic research is based on time studies. For accurate results whole-day studies are indispensable.

Mechanization of wood harvesting has created new work load factors which may have a negative effect on the work situation. Here we are concerned with local disturbances (e.g. noise, vibration). Strain induced by exhaust fumes from power saws may under certain conditions (weather, gradient) be aggravated.

Only a comprehensive study of all these impacts on the worker permits an ergonomic evaluation and organization of wood harvesting.

In view of the above considerations all ergonomic studies are carried out on the following principles: (see Basic Principles of Ergonomics, FAO-Austria Training Course, Ossiach, 1975).

4.1 Obtaining personal data

They include data such as age, weight, size, family status, professional qualifications, medical case history, past accidents and other factors.

4.2 Measuring the circulatory functions

These tests are applied to examine the individual physical strain capacity by means of bicycle ergometers which can be adjusted to different work load rates (PWC 170). The relation between work load and physical strain provides a unit for the individual working capacity.

4.3 Measuring climatic factors

To determine the climatic influences various measurements are necessary. For field studies it is sufficient to measure the wet and dry temperatures by means of aspiration-psychrometers according to Assmann and the wind velocity with an anemometer. The effective temperature is calculated from the values for wet temperature and dry temperature and wind velocity on the basis of a nomogram developed by Yaglou.

4.4 Describing work site, work method, tools and equipment

All factors determining the work method, such as altitude, stand density, stand height, mean diameter, slope gradient, surface conditions, undergrowth and so on, are recorded. For an ergonomic evaluation it is also necessary to study the type of operation (one-man or group work, manual or partly mechanical work, purely mechanical work) and to record and describe the tools and equipment (working and protective).

4.5 Time studies

Our experience has shown that time studies performed under the cumulative timing method have yielded the best results.

4.6 Measuring energy expenditure

Energy consumption is measured with a respirometer or with the Douglas bag. Two different metabolic rates are distinguished, the basic metabolic rate and the metabolic rate of work. To calculate the metabolic rate the amount of oxygen consumed by the worker is measured. This is done with oxygen-analysers.

4.7 Measuring the heart rate

4.7.1 Manual measurement

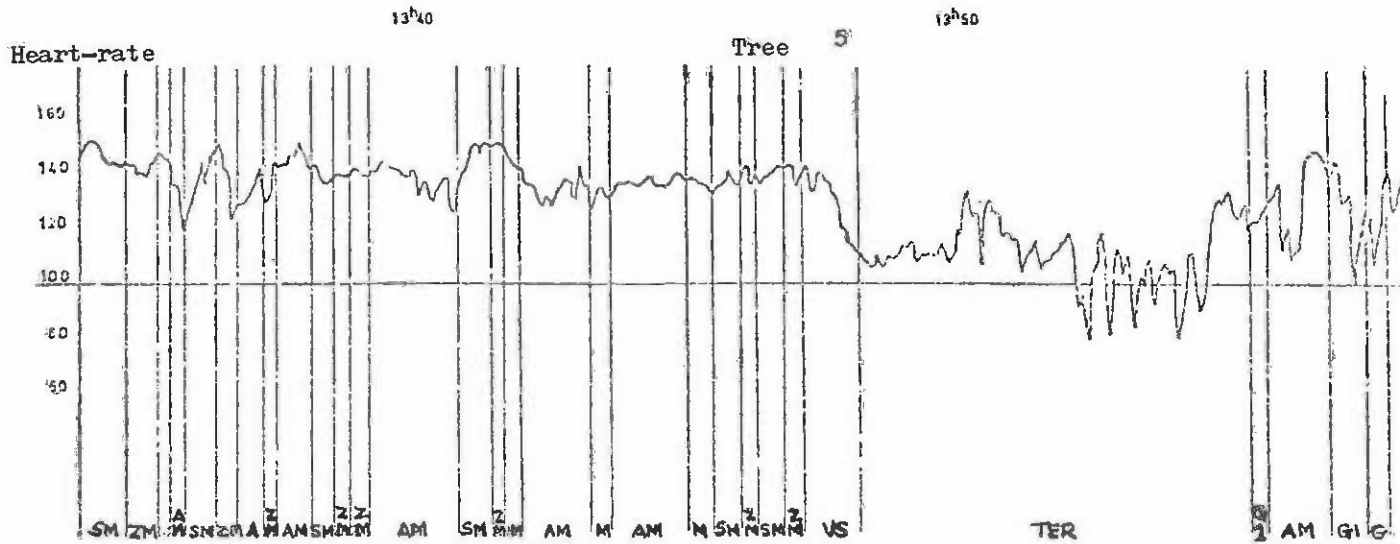
Measurement of the heart-rate by hand - feeling the pulse or the carotid artery is carried out by finding the time taken for 10 beats and calculating the heart-rate per minute with a stop watch or a special heart-rate recording stop watch.

4.7.2 Telemetric measurement

In recent years telemetric recording of the heart-rate has rapidly increased. The heart-rate pick-ups may be via selenium cells at the ear or chest electrodes (electrocardiogram). The telemetric device consists of a mini-transmitter that is in wireless contact with an automatically recording receiver. This device permits direct counting of the heart beats and also long-term recording of the heart rate diagram (tape or graphic recorder). Scientists at the Max Planck Institute employ the increase of the heart-rate during work over the heart-rate at rest (initial level) as a criterion of evaluation, whereas Christensen (1953) elaborated a schematic classification of absolute heart-rate values.

Tolerable Heart-rate Values

<u>Heart-rate absolute</u>	<u>Physiological load</u>	<u>Increase above initial rate</u>
0 - 75/min.	very low	
75 - 100/min.	low	standing 30 heart-rate/min.
100 - 125/min.	moderate	sitting 35 " " "
125 - 150/min.	high	lying 40 " " "
150 - 175/min.	very high	
175/min. +	extremely high	



Section of a whole-day heart-rate diagram of a forest worker when felling with power saw.

- AM delimbing with power saw
- ZM pointing with power saw (sniping)
- SM cross-cutting with power saw
- AH delimbing with axe
- A depositing branches by hand in rows
- ZH pointing with axe (sniping)
- W turning logs
- M measuring logs
- G walking without power saw
- G1 walking with power saw
- TER rest period
- VS operational allowance
- VP personal allowance

4.8 Measuring the vibration influence

4.8.1 Noise

The effects of noise are determined by sound pressure, exposure time, frequency distribution, time phases, and individual disposition. Permanent exposure to a marginal noise level of 85 dB (A) may result in impaired hearing. A distinction is made between permanent noise level of constant vibrations and a so-called evaluation level of intermittent vibrations. The term "evaluation level" takes vibration differences as well as pauses in the noise into account.

Noise levels of 85 to 100 dB(A) cause physical and mental impairments and even irreversible damage to hearing (noise-induced deafness). Above noise level of 120 dB(A) the sound pressure affects not only the ear but also circulation, blood supply, autonomic nervous system, etcetera.

Since nearly all forest machines produce noise levels above the tolerable limit, noise protection in mechanized wood harvesting is particularly important. Active noise protection at the source of noise is sometimes not feasible, particularly in case of mobile machines. In this type of forestry work major emphasis, therefore, lies on the passive kind (ear protection).

Noise measurements carried out in the open cab of various skidders and other logging machines have yielded the following data for loaded and unloaded trips.

	Unloaded trip dB(A)	Loaded trip dB(A)	Frequency range of maximum noise level in Hertz
Wheeled skidder			
- 50	78 - 84	97 - 100	63 - 125
51 - 80	79 - 85	94 - 101	63 - 250
+ 80	80 - 90	97 - 100	250
Articulated wheeled skidder			
- 50	78 - 85	96 - 100	250
51 - 80	79 - 86	97 - 102	125
81 - 110	79 - 88	93 - 100	125
Mobile cable crane with collapsible tower (closed cab)	66 - 78	88 - 98	500 - 1000
Other cable crane installations	88 - 92	102 - 130 (fan brake)	300

Determining the quantity of exhaust gas is carried out with gas detectors. Gas is absorbed by a suction pump and passes through a filtering tube. The gas concentration in the tube is indicated by a colour spectrum.

5. WORK LOAD STUDIES

(Measuring the heart-rate during timber harvesting in the mountains).

5.1 Felling

New working methods have substantially influenced felling in coniferous forests. In recent years debarking has been increasingly transferred from the forest to industrial plants. Since debarking is no longer always included in the felling operation, one-man forest operations are becoming the rule, and the share of power saw operation time in the overall working time has become much bigger. An ergonomic study of a one-man debarking operation developed by Frauenholz yielded exact data on work load intensity and on power saw operation time for various mean diameters.

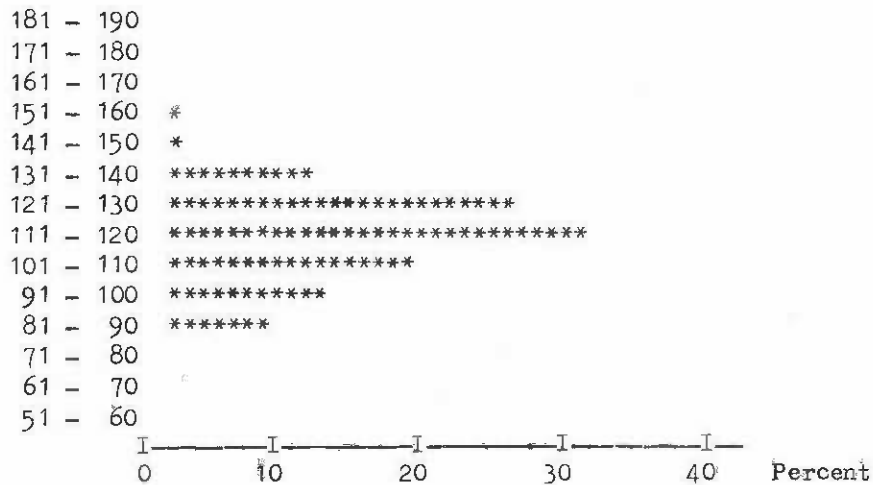


Diagram of the distribution of heart-rate frequency (absolute) in the operation of delimbing with a power saw. Average values taken from all diameter classes (mean diameter 9 to 40 cm and above) and four workers (28.7 percent of working time).



Telemetric heart-rate measurement in wood harvesting
(Photo: Federal Forestry Research Institute)

Heart-rate increase (absolute) in individual work phases and for various mean diameters

	Up to 19.9 cm diameter measured at breast height			Above 40.0 cm diameter measured at breast height			All diameters measured at breast height		
	time share	heart-rate		time share	heart-rate		time share	heart-rate	
		maximum	average value		maximum	average value		maximum	average value
<u>Felling</u>									
by hand (FH)	3.52	140	112	2.05	152	114	2.70	152	111
power saw (FM)	5.33	135	111	8.08	162	120	6.73	162	114
inserting wedges (FK)	1.58	139	111	3.19	157	134	2.03	160	123
bringing tree down (FA)	4.92	141	117	0.10	155	119	2.20	155	118
<u>Delimbing</u> axe (AH)	44.60	144	117	7.51	150	122	24.00	156	117
power saw (AM)	14.47	144	115	37.45	153	116	28.57	153	115
<u>Pointing</u> axe (ZH) (sniping)	1.45	145	114	1.02	154	120	1.24	162	116
power saw (ZM)	1.23	143	114	4.27	153	118	2.86	153	116
<u>Placement of branches</u> (A)	5.83	144	114	12.81	151	118	9.69	151	116
<u>Turning</u> (W)	1.33	142	117	5.33	152	121	2.98	162	119
<u>Cross-cutting</u> measuring (M)	1.67	142	115	2.36	155	118	2.17	155	115
cutting support (SH)	0.14	143	123	0.52	150	120	0.30	150	118
power saw (SM)	2.23	144	113	7.66	154	117	4.54	154	115
<u>Walking</u> without power saw (G)	3.87	145	112	3.15	154	115	3.15	160	112
with power saw (G1)	7.65	144	112	3.95	149	113	6.44	156	113
<u>Preparing working site</u> (VA)	0.18	138	115	0.55	139	121	0.40	148	115
<u>Working time</u> (TG)	100.00	145	115	100.00	162	118	100.0	162	116

Pointing: simple one-side pointing

Placement of branches: piling in heaps

Overall survey of average day values

	Mean diameter			
	up to 19.9	up to 29.9	up to 39.9	above 40.0
<u>Pure working time (TG)</u>				
minutes per m ³	58.2	27.3	16.3	14.4
hours TG per day	5.1	4.3	4.5	4.4
<u>Work with power saw</u>				
percentage share of TG	23.1	48.8	53.9	57.5
hours of power saw work per day	1.2	2.1	2.4	2.5
heart-rate increase above sitting heart-rate, related to TG	42	41	42	47
<u>Allowance percentages (values related to TG)</u>				
operational allowance (TS)	3.4	5.6	8.5	8.9
personal allowance (TP)	1.3	0.8	1.1	1.0
delay time due to work (TW)	1.0	3.8	4.5	2.0
preparation for work (TR)	2.2	2.2	2.7	3.2
rest time (TER)	20.8	24.1	20.7	23.4
Sum of allowances in %	28.7	36.5	37.5	38.5
hours of TG+sum of allowances TG	6.5	5.8	6.2	6.0
heart-rate increase above sitting heart-rate, related to TG	37	35	36	42
share of dead time in TG (dead time= delay due to weather, transport or machine failure) in %	8.5	8.8	4.2	7.1
share of lunch rests in TG	18.4	20.2	22.1	20.7
total allowances' share in TG in %	55.6	65.5	63.8	66.3
total work day in hours (TOTAL)	7.9	7.0	7.4	7.3
heart-rate increase above sitting heart-rate, related to TOTAL	32	30	31	36
<u>Sum of allowance percents</u>				
without lunch rest allowance to TG	37.2	45.3	41.7	45.6
hours without lunch rest	7.0	6.2	6.4	6.4

5.2 Wood extraction with skidders

Heart-rate values measured during skidding operations with skidders in difficult terrain have shown peak work load values for the operator. Substantial heart-rate increases were also recorded when storing and stacking operations were carried out with these machines on landings and forest roads (concentration strain). Line-pulling in ground skidding also implies high work load values.

Ergonomic study of extraction by skidder

Symbol	Work cycle	Time min.	Pulse average	Increase in heartbeats/min above initial level
L	Driving without load	2.8	113	32
H	Hooking up	1.5	115	34
LZ	Pulling the load to the skidder	4.8	130	49
V	Driving with load	2.2	124	43
LM	Storing by skidder	1.5	127	46
LH	Storing by hand	1.0	130	49
H2	Unhooking	2.3	128	47
SM	Handling of the cable	2.4	123	42
P	Personal allowance	2.0	85	4
VS	Allowance (other than personal)	1.5	121	40
		22.0	120	39

5.3 Cable crane operations

Heart-rate values were recorded during the mounting operation of a cable crane and during various other individual cable crane operations. A marked difference was noted in work load values on cable winch operators and on workers at the felling site and landing.

Of all setting-up operations the most strenuous were climbing up supports, pulling the skyline and setting up the end mast. Winch operation, controlling activity during logging, observing activity, and signalling are below the physiological limit of continuous performance but require high concentration and are affected by noise and sometimes by exhaust gases from the drive unit. Extreme work load values were also found during tensioning of the mainline, when apart from the basic work load, factors of the terrain condition and slope had to be observed. For activities at the landing and during dismantling of the equipment the heart-rate increase was negligible.

Work load study of cable-pulling in different terrain conditions

Place	Cable length and diameter	Slope gradient in %	Accessibility	Traction power	Heart-rate max.	Increase in heart beats/min. above initial level
Road	30 m/11.5 mm	flat	very good	150-250	140	48
Road	" "	10% uphill	very good	180-400	148	62
Terrain	" "	42% downhill	holes, twigs & brushwood -bad	150-350	144	50
Road	70 m/9 mm	flat	very good	140-400	168	83

6. INTRODUCTION TO ERGONOMIC CHECKLISTS

Ergonomic checklists help to evaluate working systems and to organize work. In recent years checklists have been compiled by various countries for different applications. Some of them are very general, some serve a detailed purpose.

All checklists are intended as questionnaires based on ergonomic principles and yielding analyses which describe working situations systematically and as completely as possible. Their informative value depends on the questions' scope and precision and on the ergonomic knowledge of the user. A quick ergonomic evaluation is a substantial function of ergonomic checklists.

General remarks on ergonomic checklists

(Quoted from "Checklist for the Ergonomic Evaluation of Forest Machines" compiled by Dr. Rehschuh and Dr. Tzschöckel, Mitteilung des KWF* - volume XIX, 1977).

The checklist is intended for an ergonomic evaluation of forest machines and was elaborated and compiled by the work-economic department of the KWF (Board of Forestry Works and Techniques, FRG). It is based on experience gained in applying the first and second drafts and other domestic and foreign checklists and it was discussed with various authorities. Application of the present checklist requires ergonomic knowledge; it is recommended for use by institutions such as testing stations for forest machines, by supervisors of forest machine and forest-technology centres, by designers of forest machines as well as for educational purposes.

The checklist is designed for the evaluation of forest machines - with the exception of portable power devices - and consists of a questionnaire and explanations. The explanations are meant to make answering easier and to allow general standards to be applied to the answers. International standards are included as far as they are known and applicable.

* Board of Forestry Works and Techniques, Federal Republic of Germany.

Since only some evaluation items are standardized the explanations contain reference values which are taken from publications in technical literature. These values are related to standards and regulations applied in the Federal Republic of Germany and must be adjusted for use in other countries. The values given correspond to the present state of work study findings and updating is necessary.

The checklist is divided into three parts:

Part A is intended as a general description and includes checking and description of the machine, and technical data.

Part B is the main part and contains the individual questions for the ergonomic evaluation. The appropriate column is checked off (+, 0, -). If the question does not apply, this has to be indicated by the entry "not applicable".

Plus answers to the questions in Part B lead to the assumption that the solution is ergonomically favourable; minus answers indicate an ergonomically unfavourable judgement. The questions are not listed according to importance.

Part C contains a summary and recommendations. If the ergonomic utility of a machine is to be judged (for example for comparison with other machines) it may in some cases be enough to answer the questions in part C, which should, therefore, be carefully completed.



Heart-rate measurement by hand, with stop-watch.
(Photo: Federal Forestry Research Institute)



Measuring the concentration of gas with a gas detector
(Photo: Federal Forestry Research Institute)

INTRODUCTION TO THE TRAINING ACTIVITIES
OF THE FORESTRY TRAINING CENTRE, OSSIACH

by

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Twenty five years have passed since the Forestry Training Centre at Ossiach started its endeavours to make all people who take an interest in forestry acquainted with the scientific and practical knowledge gathered in this field. Thus far about 38 000 people have participated in a total of 1 750 courses offering information on a variety of forestry problems. Always with an eye to the practical, we have attempted to focus on the work science of forestry.

In view of the forest ownership structure in Austria it is impossible to concentrate on certain technical requirements and standards while disregarding the others. The great number of farmers who own woods, the state-owned and private forest enterprises, and the numerous sawmills employing their own forest workers require flexible curricula adapted to the specific needs of these. Cooperation between the private sector and the public authorities is excellent. The Federal Ministry of Agriculture and Forestry provides the Training Centre with adequate funds and also helps with the tuition of needy course participants. The Provincial Labour Office, the Federal Forestry Research Institute, the Austrian Federal Forest Enterprise, the Federal Province of Carinthia, the Chamber of Agriculture and Forestry, the Chamber of Agricultural Workers, the Business Promotion Institute as well as the Forestry Association of Carinthia all give support to forestry training at Ossiach. In many cases the forestry enterprises themselves make a valuable contribution by continuing paying wages during the training programmes and by reimbursing their staff for travel and other expenses.

Tasks of the Federal Forestry Training Centre, Ossiach

The Training Centre performs the following tasks:

1. Training of forest guards and other personnel who protect the forests (under the Forest Law, Federal Law 440/1975). Duration of course: 500 hours, or 3 months.
2. Vocational training of the forest workers of Carinthia (under the Vocational Training Act of 1965 and 1977). Duration of course: approximately 240 hours or six weeks, sandwiched over a period of three years. These are for apprentices who want to become skilled forest workers.
3. Training courses for compulsory technical schools (if required). These are organized jointly with the Provincial Government of Carinthia. Duration of course: 480 hours or two courses of six weeks each.
4. Forestry training of students becoming technicians in agricultural extension work (under the Agriculture and Forestry Vocational Training Act). Duration of course: 40 hours or one week.

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5. In-service training of forest workers (offered on a voluntary basis during unemployment in winter; courses are modelled after the ones offered under the Vocational Training Act for Forest Workers). Duration of course: 80 hours or two weeks distributed over a period of two years.
6. Training of blasting experts (as defined in the regulations governing blasting operations, Federal Law 77, 1954, and in cooperation with the Business Promotion Institute). Duration of course: 80 hours or two weeks.
7. Further training courses covering the entire scope of forestry working techniques: afforestation, tending of young stands, thinning, the use of power saws, cable logging, articulated four-wheel-drive skidders, maintenance of equipment and other subject matter as required. Duration of course: from 20 to 120 hours or from two days to three weeks.
8. Further training of forest personnel in management: seminars on public speaking, management, ergonomics, fire control, the use of herbicides, etc. Duration of course: 8 - 24 hours.
9. Practical course on forest work for six-semester students enrolled at the University of Agriculture and Forestry. Duration of course: 40 hours.
10. Organization of international courses for developing countries focused on road construction and timber harvesting. Duration of course: 1 month.
11. Short training courses for forest farmers, by agreement with forest farmers in different places and local communities of Carinthia. At present there are training courses on afforestation in mountainous terrain in the spring, demonstrations and training courses on protection against damage by game, and thinning in the autumn, and courses on the maintenance of power saws in winter. Duration of course: 8 - 10 hours.
12. Consultation of forest enterprises with regard to practical work and working techniques (including demonstrations and tests carried out in different forest enterprises).

At present the focal points are: construction and operation of cable cranes, the use of skidding equipment, especially articulated four-wheel-drive skidders, tending of young stands by chemical and mechanical means, and different tests and trials.
13. Courses on the operation of cableways for the engineer troops of the Federal Army. Duration of course: 40 - 100 hours.
14. Participation in programmes devoted to problems of forestry in the form of lectures, seminars, symposia, demonstration of machinery and equipment, presentation of pictures and slides, organization of exhibitions and contests for the Association of Young Farmers, excursions which are also organized for outsiders (e.g. for high-school graduates) to promote forest-mindedness and a sense of responsibility toward the environment.

The Federal Forestry Training Centre employs two forest engineers who have also taken a test on pedagogics, four teachers who are trained foresters, five teachers who are trained forest rangers and three skilled forest workers. Experts who have practical experience because they work in a forest enterprise are also brought in as lecturers for certain courses.

FOREST MANAGEMENT TECHNIQUES IN MOUNTAINOUS TERRAIN

by

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The general aim of silviculture is to create ecologically sound forests with stands of stable structure. The sustained production of maximum quantities of high-quality timber and the optimum preservation of the protective and social functions of the forest in such a way as to meet economic requirements and assure the rational use of capital and labour are at the centre of the economic objectives pursued.

On account of the long production periods silviculturists have to adjust the growing stock and regeneration objectives to satisfy 21st century needs. The increasing demand for timber as a sustained source of raw material, the rising need for high-quality timber and the growing importance of the forest's protective and social functions constitute responsibilities which foresters will have to meet in the future.

The development of natural forests is characterized by clearly differentiated stages. Starting from the initial stage when the wood is still young, the cycle of development moves on first to the stage of their productive prime, then to the stage of decay, and finally to the stage of disintegration. The cycle is closed by the stage of regeneration. The natural life cycle of a forest is also characterized by different stages of development: young growth, thickening of stands, stands usable for polewood, and mature timber. At each stage the stand is tended in a different way.

The purpose of stand improvement is to control the development of individual trees and entire stands by means of selective silvicultural measures and appropriate tending operations in such a way as to assure attainment of the economic objective. Planning should be aimed at this objective. In forest regeneration the planting of a sufficient quantity and quality of suitable species of wood is of decisive and far-reaching importance. The question of the spacing of plants and thus the number of plants per ha has to be considered in each case individually. Even today spruce plantations are often regenerated at high costs, and their later thinning is even more expensive. The more mature the seedlings, the better their quality, the more careful their handling and planting and the more suitable their provenance, the wider the distance between the individual plants could be. An impairment in spruce quality must be expected if the number of plants per ha is less than 2500. The tending and protection of young trees as well as the selection and tending of the most valuable trees at the expense of undesirable low-quality trees can be easily achieved by mechanical means in widely spaced plantations.

The carefully planned lay-out of tending corridors has proved to be an extremely suitable measure or even precondition for the rationalization of tending operations. These corridors subdivide wide areas into distinct sections. As soon as there is wood from thinnings that can be further used, such corridors may serve as logging trails. However, if these corridors are only laid out in thickets or "small-diameter" stands the danger of damage by snow arises especially in mountainous terrain. Tending corridors facilitate the passage of equipment and vehicles already in young forests. Silviculture and forest technology should not pursue antagonistic objectives but must be aimed at the common goal of preserving productive, sound, and healthy stands.

^{1/} Forestry Training Centre Ossiach, Austria

1. OUTLINE OF IMPORTANT TENDING MEASURES

1.1 Tending of young stands

Attainment of the thicket stage of the desired species should be the primary goal (decision on mixture of different species). The radical cutting of undesired trees may impair the development of the stand. It is sufficient to specifically promote the development of desirable trees. Instead of resulting in advantages, thoughtless "thinning" will do a lot of harm. The growth of grass is stimulated; certain species of trees and bushes which are also regenerated and which belong to the herbaceous layer are eradicated. In most cases it is sufficient to make sure before the beginning of autumn/winter that the species and qualities desired are encouraged to grow with desired spacings. Brush-like growth should not be schematically thinned. Here too, the development of the desired material should be furthered by assuring sufficient space between the trees (about 1.0 - 1.5 m). This is achieved by the removal of the undesired material in the immediate vicinity of the desired trees. In this way less tending will be required.

1.2 Tending of thickets

The most important decisions have to be taken during this stage of development. The question of positive or negative selection may be decided on the basis of the following characteristics:

Negative selection is advisable if there is replacement for medium-sized trees, if good quality desired for the future cannot or can hardly be seen (oak, linden tree, elm tree); if, due to external factors, the quality cannot be determined, e.g. in spruce thickets. The poorest of the dominant trees should be eliminated with a desired spacing.

Positive selection is advisable if either decision would be possible; if the number of trees is low; if there are not enough trees of the desired quality or species.

1.3 Tending of small sized wood

This stage of development marks the beginning of thinning by positive selection, which aims at increasing the value of the individual tree, e.g. selective thinning in a spruce stand

- Goals:
- reliability of operations
 - a better organization of all forest operations
 - a higher degree of mechanization of all forest operations
 - wood production of larger-diameter assortments and better quality
 - additional yield as a result of thinning

Selective thinning should start in stands where there are about 3000 trees per ha with a dominant height of approximately 12-15 m, i.e. when the dry branch zone is at least 6 m above the ground. It should be finished when the dominant height of the trees is between 23 and 25 m, i.e. when the trees have reached half their rotation age. This may be followed by one or two early thinnings.

1.3.1 Time of thinning

Since the growing space requirement of a tree depends on its height, the time of thinning is determined by the dominant height of the stand and the number of trees per unit area. The thinning cycle is determined by the height development and not by age. In this way thinning can be better adjusted to the growth of the stand. If one takes into consideration that in young stands a second thinning should be carried out

after the trees have grown another 3 m in height, it follows that thinnings in young stands are more frequent than thinnings in older stands, which have a lower height increment.

Desired Final Number of Trees According
to Locality Class and Rotation Periods

Rotation period in years	Average total increment in m ³ of the standing wood volume over bark				
	6	8	10	12	14
60	—	—	—	750	550
80	—	—	570	470	400
100	—	570	450	400	400
120	700	470	400	400	—
140	550	400	400	—	—

Basically, the desired final number of spruce trees is 400 per hectare. Since thinnings are more or less useless when they are performed in the last years before final cutting, the final number of trees will be higher if the rotation periods are shorter or if the locality class is poorer.

1.3.2 Selection of elite trees

Since the growing space requirement of a spruce in a final stand rises to at least 25 m², the maximum number of elite trees selected must not exceed 400, regardless of the desired final number of trees. However, these elite trees need not be distributed over the area according to a strictly geometric pattern. In order to avoid a one-sided crown formation, the minimum space between 2 elite trees should not be less than 4 m. If the space between two elite trees reaches this minimum, the distance between these two elite trees and the other elite trees should be considerably larger in order to make sure that the elite tree which has already limited space on one side gets sufficient total space.

Elite trees must not stand along skidding trails. Their selection is determined by the following criteria listed in the order of priority:

- (i) vitality (health, crown formation)
- (ii) quality (mainly stem form, favourable height/diameter ratio)
- (iii) distribution (a maximum of 400 elite trees, minimum spacings of trees, 4 m)

The above order of priority clearly indicates that only vital trees with a suitable stem form may be selected as elite trees. If the distance between these elite trees is not below the minimum requirement, the trees may be marked as such. It is thus vitality and quality, and not distribution that is of primary concern.

It is better to restrict the number of elite trees to 300 vital trees than to select an additional 100 which are of dubious quality. So far, experience has shown that a high number of elite trees makes it difficult to select elite trees and to provide them with enough growing space. As a rule, the number of elite trees should therefore be below that of the desired total number of trees in the final stand. The difference between these two figures is made up by trees which may reach the final stand but the development of which is not furthered as selectively as that of elite trees. It is better to have a 20% deficit of elite trees than a 10% surplus.

Elite trees are only selected once in the life of a stand. Therefore, they should be carefully selected by a forester assisted by two helpers. The selection of elite trees by two people or one person only should be confined to small stands. Occasional check measurements of the tree stand are recommended. In order to make sure that the maximum number of elite trees is not exceeded it is advisable to count the trees again after selection. This method permits further control because the assistants can give their opinion on the selection of the elite trees (stem and branches, form, possible damage). In dense stands the selection of elite trees may be preceded by a limited degree of early thinnings (preferably to be carried out by persons interested in receiving wood without paying for it) which facilitates selection considerably.

For marking elite trees, plastic tapes may be used; to avoid damage by skidding these are removed only after thinning or when the elite trees are pruned. In general, elite trees have to be liberated to such an extent that even unpruned trees can be easily recognized as elite trees when the next thinning operation is performed. If the marks have to be kept on the tree for several years because the trees are neither pruned nor liberated the marking should be inconspicuous (e.g. blue colour dots).

1.3.3 Liberation of elite trees

Elite trees are liberated by removal of their strongest competitors. As a rule, in dense young stands (number of trees over 3000 spruces/ha) the liberated spacing of elite trees and their competitors should, as a rule, have a radius of 2 m.

If the desired final number of trees is not reached through liberating elite trees and marking damaged trees, the remainder is marked in the course of early thinning. Early thinning may be postponed if the market situation is unfavourable.

1.3.4 The Height/Diameter ratio and its significance (H/D ratio)

The H/D ratio is an indicator for the stability of the stem. It can easily be calculated on the basis of the height of the tree in meters (H) divided by the diameter at breast height of the tree in meters (D)

e.g.	tree height	=	20 m,	20 m,	20 m
	D.b.h.	=	0.25 m,	0.20 m,	0.16 m
	H/D ratio	=	20 : 0.25 = 80		
	H/D ratio	=	20 : 0.20 = 100		
	H/D ratio	=	20 : 0.16 = 125		

The H/D ratio has a strong influence on the safety conditions of tree stands. Trees having an H/D ratio of over 90 can easily be broken by storm and snow. Trees having an H/D ratio of around or below 80 are hardly affected by storm and snow. Elite trees must have a high chance of survival. The lower the H/D ratio of elite trees, the higher their chance of survival. When selecting future elite trees, the employee of the forest enterprise has to consider stability of the stand on the one hand and tree form (taper) on the other. Priority is given to stability.

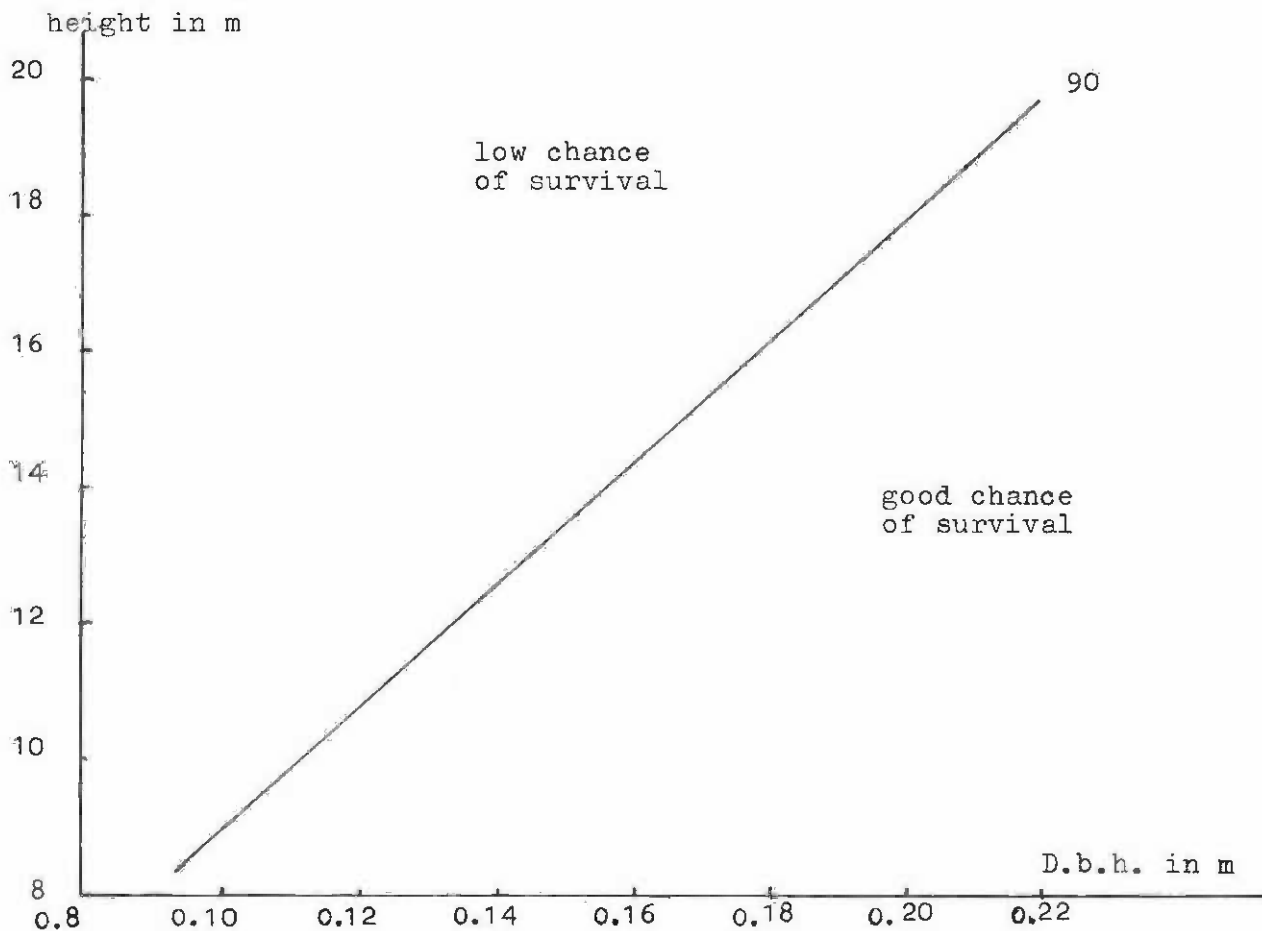
Trees having an H/D ratio of over 90 have a low chance of survival.

Trees having an H/D ratio of below 90 have a good chance of survival.

As a matter of course, the chance of survival also depends on the site and the environmental conditions.

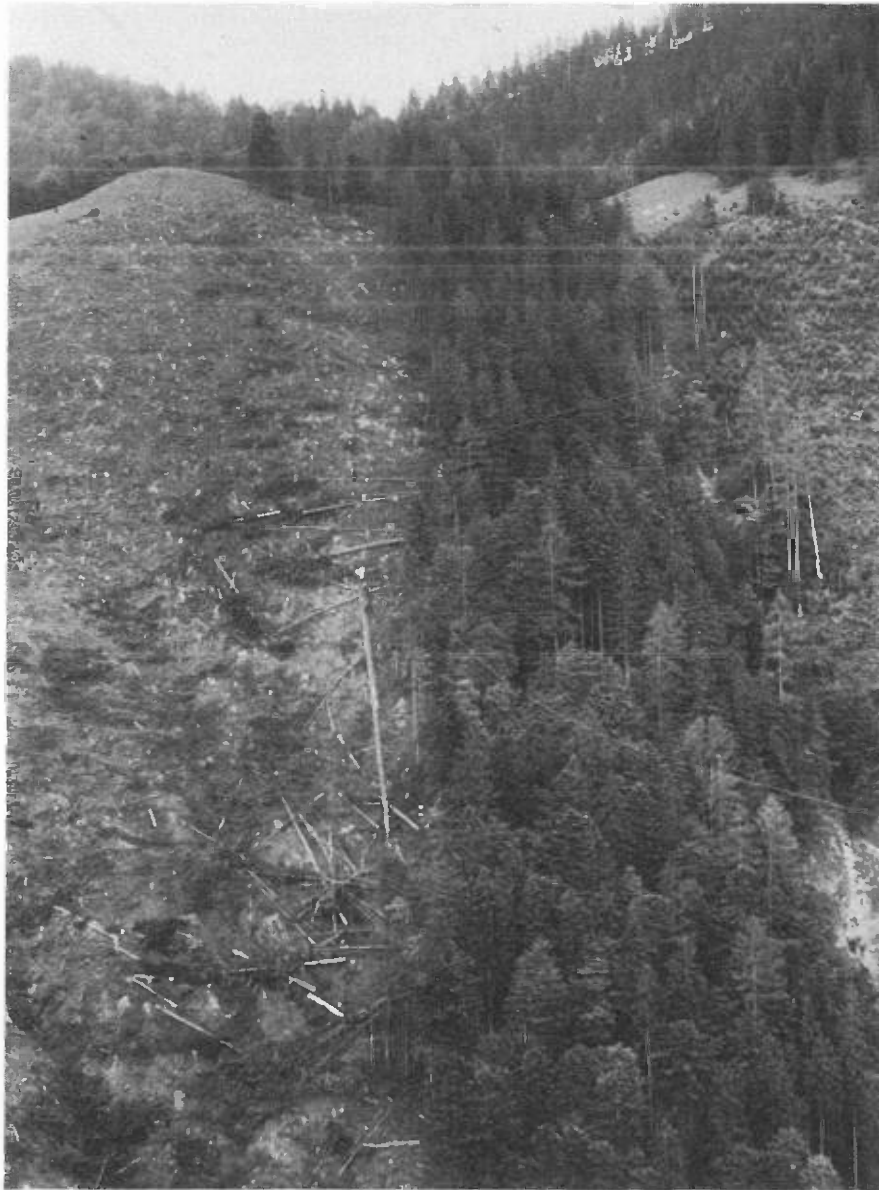
If the H/D ratio of elite trees is over 90, not more than 40% of the total number of trees should be removed in each thinning intervention.

H/D Ratio - Chance of Survival



1.4 Tending of the Growing Stock

Tending of the growing stock and increase in the value increment. Artificial regeneration. Today's forest owners may choose among numerous methods of treatment. The sweeping economic and technological changes of the past decades have created a situation where only partial aspects of silviculture are taken into account and long-term objectives are not consistently pursued. A certain lack of planning in silvicultural practice such as the tending of stands must be admitted. Today the tending of forests requires thorough preparation and careful evaluation of individual silvicultural measures. The determination of tending objectives and the concentration on important questions is a basic requirement. Profound knowledge, personal commitment, interest and enthusiasm are the basis of a successful work. The long-term evaluation of the measures taken is of special importance, since successful results are not immediately visible. The desirable rationalization of tending may be achieved by careful planning, a deliberate and flexible organization, the labour-saving implementation of work (a good forester knows when to leave work to nature), good training, careful instruction, and supervision of workers.



Three phases in forest management, from left to right: logged area; dense stand; regenerated area. Note skyline with a log being brought in. (Photo R. Heinrich)

LOG CROSS CUTTING FOR HIGH MILL RECOVERY WITH EMPHASIS ON MOUNTAINOUS AREAS

by

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FAO Forestry Department

1. INTRODUCTION

The first decision determining the economic or the volume recovery from a tree occurs when it is being cross-cut into logs. Bad and inexperienced cross-cutting can cause more losses in quality, quantity and financial return than any other operation in the processing chain from felling to the finished product emerging from the sawmill, veneer mill or plywood mill. It is a job which requires more knowledge, skill and judgement than the actual felling operation. Therefore, the ideal situation is one in which bucking can be carried out in the mill yard where adequate equipment and trained staff are available and in cases of doubt advice can be sought from management. Unfortunately, due to a number of reasons, wood very often has to be transported to the mill in finished log sizes or in multiples of the individual log length. This is mostly the case in mountainous forests where road conditions do not permit tree-length transportation or where the individual tree is too heavy to be extracted or transported in one piece. Then cross-cutting to length must by necessity be done in the forest and by forest workers.

Results of deficient cross-cutting may go undetected for a long time or forever, particularly where forest ownership and mill ownership is in one hand. Otherwise, industry usually stipulates quality and dimensions. This serves to alleviate the problem for the buyer (who then gets the raw material the way he wants it) but not necessarily for the forest owner, since a lot of wood may be wasted, causing serious loss of overall revenue.

2. RECOVERY

Recovery is a term which, when used in connection with forest industries, particularly with sawmilling and veneer and plywood production, usually denotes the physical volume of the usable or commercial end-product which is obtained from a given volume of raw material in log form under bark. It is expressed in percent of the gross volume of the raw material. In other words:

$$\text{physical recovery} = \frac{\text{usable output}}{\text{u.b. volume input}} \quad (100)$$

This percentage figure is of crucial importance to any operation. Recovery figures give a broad indication of the overall efficiency of the industry. If, for example, recovery in a tropical hardwood drops below 40 percent, the reasons, among others may be:

- a) bad tree form or heavy defects;
- b) wrong bucking methods;
- c) bad processing (milling);
- d) gaps in marketing of lower grades.

However, recovery figures also indicate the reverse; that is what is left of the tree as "waste". This is of extreme importance in the case of an integrated industry which may require the "waste" as raw material for production of such commodities as pulp and paper, particleboard, fibreboard or blockboard. Even in the case of less sophisticated processes, the use of waste as fuel must be considered as a form of integration. In planning as well as in operating a mill producing its own steam, heat and power this figure must be accurately known.

While in many instances the physical recovery in a mill may be high, the economic recovery can be low. In this event, the forest owner suffers even more than the mill owner if, as is often the case, low economic recovery can be traced to bad bucking practices or deficient log grading systems. A typical example here would be the sale of veneer logs as saw logs. This, of course, does not hurt the economic recovery of the mill owner, but it does harm the profitability of the forest operation. However, less easily traceable is the loss of volumetric as well as economic recovery from plantation forests through bad bucking and log grading systems.

3. BUCKING CRITERIA

The "bucker" (cross-cutter), whether he operates in the forest or in a mill yard, must have substantial knowledge of the end product which may come out of a tree. This should enable him to buck according to the following criteria:

- a) grade;
- b) top-end diameter;
- c) length;
- d) incidence of defects.

a) Grade

Recognized log grading rules are essential for this. These should also indicate relative monetary values. It is in this area that the forest owner may sustain high losses through bad bucking techniques. The principal rule here should be to take the highest grades out of the log first and then proceed down to the subsequent grades. Even if grading rules do not exist the sequence should be:

- Veneer logs (slicers - peelers)
- Saw logs of high quality
- Saw logs of lower quality
- Pulpwood

The quality of slicer and peeler (veneer) logs is often difficult to determine. In such cases it may well be advisable to cut "ahead" of the obvious veneer log and make additional cuts "back" until veneer quality is reached. The loss of volume is usually compensated by increased economic recovery.

b) Top-end diameter

Bucking for the best top-end diameter of the log applies mainly to saw logs from plantations. The thought behind this is that the maximum recovery of the intended end product is achieved if its dimensions fit into an inscribed square at the top end of a log.

Example: The end products are boards, 100 mm wide, 25 mm thick. The minimum top-end of a log to achieve maximum recovery would therefore be the hypotenuse of the square formed by the width of the board and 4 boards (25 mm x 4 = 100) plus the thickness of 3 sawkerfs = 9 mm

$$= \sqrt{100^2 + 109^2} = 148 \text{ mm}$$

For practical purposes logs of 15 to 18 cm in diameter would be considered for this end product. The top-end diameter would have to be further increased if the log were not straight, if it were not round or contained other defects which might influence recovery. The next suitable top-end diameter for high recovery of the same end-product dimension would then be:

$$\begin{array}{rcl}
 & 200 \text{ mm (2 board widths)} &) \text{ one side approximate} \\
 \text{plus} & 3 \text{ mm (sawkerf)} &) \text{ of the square} \\
 \\
 & 200 \text{ mm (8 board thicknesses)} & \\
 \text{plus} & 21 \text{ mm (7 sawkerfs)} & \\
 \\
 = & \sqrt{203^2 + 221^2} = 300 \text{ mm} & 31 \text{ to } 34 \text{ cm}
 \end{array}$$

In normal sawmill practice logs are bucked and sorted in 2 cm or 3 cm classes and then used accordingly. However, in order to avoid wrong bucking the principle behind maximum recovery should be understood by the operators.

The system described above refers mainly to conversion of coniferous species into construction lumber. Different criteria apply where high grade recovery is the aim or with plantation grown Eucalyptus in which case allowance may have to be made for spring.

c) Length

Bucking to length in the forest depends on:

- the length which can be transported on existing roads;
- the grading system;
- defects.

While the first two points are self-explanatory, a few words have to be said on defects.

Taper: excessive taper requires shorter log lengths for higher volume recovery.

Sweep: logs with sweep should be cut in the sweep. If the sweep is on two planes the log is suitable for pulp only. This seems obvious but it is amazing how many logs with double sweep arrive at the sawmill when the bucking is done in the forest.

Other considerations: The branches must be cut flush with the log. Otherwise they are a costly and time-consuming hindrance in preparing the log for de-barking and sawing, particularly in frame saw operations.

Incidence of defects: Defects have to be taken into consideration as they occur. This is the subject of a paper on its own.



Proper arrangement of logs awaiting final crosscutting
prior to conversion (Photo T. Pasca)

ANNEX I

COURSE PROGRAMME

- Saturday, 3 June Arrival in Vienna
- Sunday, 4 June Bus trip from Vienna to Melk
Visit of the Monastery, Melk, and lunch in the "Stiftskeller Melk"
Bus trip from Melk to Ort
- Monday, 5 June General information at the Information Desk in the club-room of
the Forestry Training Centre Ort
Official opening of the Training Course in the Court Hall,
Forestry Training Centre Ort
Welcoming speech and introduction to the Course by H. Redl, Head
of the International Division, Federal Ministry of Agriculture and
Forestry
Welcome address by N. Hamml, Chief of Upper Austrian Forest Service
Keynote speech by A. Leslie, Director, Forest Industries Division,
FAO Forestry Department
Opening lecture: The Impact of Forest Road Construction on Long-
Term Forest Policy, by E. Plattner, Head of Forestry Department,
Federal Ministry of Agriculture and Forestry
Excursion to Grünberg; multiple functions of mountain forestry.
O. Sedlak, O. Moser, O. Frauenholz
Key address by F. Eggl, Director-General of the Austrian Federal
Forestry Enterprise
Reception in the Court Hall of the Forestry Training Centre Ort
- Tuesday, 6 June Information on the Course Programme, formation of Working Groups,
election of Group Leaders, Rapporteurs and Drafting Committee,
distribution of lecture papers (R. Heinrich)
Forestry and Ecology in the Mountains of Central Europe, by
E. Tüchy
Austria's Forests and her Future-oriented Forest Research, by
H. Egger
The Forest Road Inventory Project and its Effect on Financing and
Planning Measures, by E. Neuberger
Excursion to the Federal Forest District Traunstein and to Farm
Forest Holdings St. Konrad
Demonstration of examples of forest road networks in difficult
rocky terrain and in soft soil areas. E. Duschek, O. Sedlak,
O. Frauenholz

- Wednesday, 7 June Principles of General Planning of Wood Harvesting Methods in Mountainous Regions, by O. Frauenholz
The Forest Road Network as a Basis for Modern Timber Harvesting, by O. Sedlak
General Principles for the Planning of a Forest Road Network, by O. Sedlak
Organization of Work, by O. Frauenholz
Demonstration of modern forestry handtools. O. Frauenholz, in cooperation with the staff of the Training Centre Ort
- Thursday, 8 June Practical Planning and Layout of Forest Roads; Instruments for Road Alignment and Auxiliary Equipment; Introduction to the Working Papers. O. Sedlak
Demonstration of surveying equipment in the terrain, modern felling, bucking and delimbing techniques in final cuts. O. Sedlak and O. Frauenholz
- Friday, 9 June Practical training; surveying and staking of the road alignment and additional necessary surveys for a forest road in steep terrain. O. Sedlak, R. Heinrich and staff of Training Centre Ort
- Saturday, 10 June Sightseeing in Gmunden
Excursion to the Abbey of Kremsmünster
- Sunday, 11 June No official programme. Church visit. Excursion to Salzburg, sightseeing tour, return trip via St. Gilgen-Wolfgangsee, Bad Ischl - Gmunden
- Monday, 12 June Elaboration of the forest road project from the survey data by the participants; general introduction to construction methods of forest roads. O. Sedlak
- Tuesday, 13 June Machine Input in Forest Road Construction in Mountainous Areas, by W. Blaha
Comparative Cost Calculations for Various Methods of Timber Harvesting, by H. Tauer
New Methods of Rock Drilling in Austria, by E. Pestal
Excursion to Reichraming; forest roads under construction. F. Auböck
- Wednesday, 14 June Protection of Forest Roads using Biological and Engineering Methods, by R. Heinrich
The Application of Soil Testing Methods on Forest Roads, by J. Eisbacher
Excursion to Chemiefaser Lenzing AG. Visit of pulpmill and wood yard. H. Czypionka
- Thursday, 15 June Protective Constructions for Forest Roads in Endangered Areas, by H. Hattinger
Excursion, planning of skidding corridors and felling organization. Demonstration of felling operations in selective cutting. O. Frauenholz

Friday, 16 June Excursion to Gosau and Bad Goisern; example of landslide, protective constructions for forest roads, checkdam under construction. H. Hattinger, R. Heinrich, H. Flachberger

Saturday, 17 June Free. No official programme
Party in the Forestry Training Centre Ort

Sunday, 18 June Transfer by bus from the Forestry Training Centre Ort to the Training Centre Ossiach. Ort - Salzburg - Kuchl - Katschberg - Millstatt - Kleinkirchheim - Ossiach. H. Hattinger, R. Görtler

Monday, 19 June General information in the Lecture Hall of the Training Centre Ossiach. R. Heinrich

Welcoming speech by H. Hauser, International Division, Federal Ministry of Agriculture and Forestry

Introduction to the Training Activities at the Forestry Training Centre Ossiach, by A. Trzesniowski

Exhibition and demonstration of forestry equipment. A. Trzesniowski and the staff of the Training Centre Ossiach

Picnic in the forest of the Ossiacher Tauern

Tuesday, 20 June New Trends in Wood Harvesting; presentation of film and discussion, by E. Pestal

An Introduction to Cable Equipment used for Wood Extraction, by R. Meyr

Introduction to Wood Extraction Methods by Wheeled Tractors, by A. Trzesniowski

Forest Management Techniques in Mountainous Terrain, by G. Sonneleitner

Wednesday, 21 June Basic Considerations on the Planning of Cable Cranes, by A. Trzesniowski

Demonstration of Surveying Equipment for Cable Crane Installations, by P. Bauernfried

Survey of a Cable Crane Line (Groupwork). A. Trzesniowski and staff

Thursday, 22 June Excursion to Hessa-Domäne, Wolfsberg. Logging demonstration by wheeled skidder and mobile cable crane, visit to sawmill and timber yard. F. v. Roten, W. Brabeck

Friday, 23 June Design of setting-up plan for a cable crane from data surveyed. A. Trzesniowski, P. Bauernfried

Demonstration of setting-up, operation and dismantling of a simple short-distance cable crane in thinnings. Staff of Forestry Training Centre Ossiach

Saturday, 24 June Visit to Villach

Sunday, 25 June No official programme. Church visit. Concert. Swimming.

Monday, 26 June Continuation of design of setting-up plan for a cable crane.
A. Trzesniowski, P. Bauernfried
Special Safety Measures for Setting-up and Operating Cable Cranes,
by A. Trzesniowski
Demonstration of setting-up of the cable crane according to the
data surveyed. A. Trzesniowski and staff

Tuesday, 27 June Principles of a Cost Calculation for Forest Machines, by A.
Trzesniowski
Cost Calculations for an Articulated Wheeled Skidder and a Cable
Crane, by P. Bauernfried
Continuation of the demonstration of cable crane operation;
demonstration of skidding tree-length logs. Staff of Forestry
Training Centre Ossiach

Wednesday, 28 June Excursion to the forestry enterprise Dr Aripbrand Graf Thurn
Valsassina, Eisenkappel
Logging demonstration by wheeled skidder and gravity cable crane;
visit of wood yard and sawmill. A. Thurn-Valsassina, J.
Mihaljevic

Thursday, 29 June Basic Principles of Ergonomics, by J. Wencel
Ergonomics, measurement methods. J. Wencel
Demonstration of instruments for ergonomic measurements.
Application of ergonomics in wood harvesting operations. J. Wencel,
W. Wenter, M. Horst, A. Lenger, J. Lugmayr

Friday, 30 June Example of a time study for skidding operations. A. Lenger, J. Lugmayr
Evaluation of the Training Course; drafting of Conclusions and
Recommendations, final discussions and adoption of the draft
report. R. Heinrich, A. Trzesniowski
Farewell speech by H. Redl, Head of the International Division,
Federal Ministry of Agriculture and Forestry
Farewell party at the Forestry Training Centre Ossiach.

Saturday, 1 July Return trip by bus from Ossiach - Gumpoldskirchen - Vienna
Final reception by J. Wencel, Mayor of Gumpoldskirchen

Sunday, 2 July Transfer to Vienna-Schwechat Airport

ANNEX II

LIST OF COURSE PARTICIPANTS

<u>Country</u>	<u>Name</u>	<u>Address</u>
AFGHANISTAN	Said Ehsanuddin ABEDY	Kunar Forestry and Sawmilling Development Authority c/o UNDP, P.O. Box 5 Kabul
BHUTAN	Chenco TSHERING	Forestry Development Project in Bhutan c/o Forest Department Thimphu
	Laiki DORJI	Forestry Development in Selected Areas of Western Bhutan c/o UNDP, P.O. Box 136 New Delhi-110001, India
	Tshering WANGDI	Forestry Development in Selected Areas of Western Bhutan c/o UNDP, P.O. Box 136 New Delhi-110001, India
BELIZE	Lucillo SOSA	Forest Industry Development Project c/o Forest Department Belmopan
BRAZIL	Perminio Pascoal COSTA FILHO	Emorada - Empresa Brasileira de Pesquisa Agropecuaria C. P.A.T.U. Belém - Para
CYPRUS	G. PATTICHIS	Cyprus Forestry College Prodromos
GERMANY (Fed. Rep. of)	Manfred FALLER	German Agency for Technical Cooperation, D-6236 Eschborn
	Gero HECKER	Institut für Forstbenutzung u. Forstliche Arbeitswissenschaft Holzmarkt 4 D-78 Freiburg
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<u>Country</u>	<u>Name</u>	<u>Address</u>
GUINEA	Modi Amadou TRAORE	Centre forestier de Sérédou B.P. 31, Macenta
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	Wankupar WARJRI	Garo Hills, Tura Meghalaya
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	Benjamin RAHARJO	Forestry and Forest Products Development c/o UNDP, P.O. Box 2338 Jakarta
	Oesman JOESOEP	Directorate-General of Forestry Jl. Ir. H. Juanda 100 Bogor
	Judi Djaenudin MALIK	Directorate-General of Forestry, Jl. Ir. H. Juanda 100 Bogor
	Dedi Ruchyadi PRAWIRAATMADJA	Directorate-General of Forestry Jl. Salemba Raya 9 Jakarta
IRAN	Boris MADJNOUNIAN	Natural Resources Faculty Karadj
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KENYA	Humphrey Mwaniki NGIBUINI	Forest Training School P.O. Box 8 Londiani
MALAYSIA	Mohamed Ramli Bin MANSOR	State Forest Department Pehang

<u>Country</u>	<u>Name</u>	<u>Address</u>
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MEXICO	Arno BURKHOLDER CATZIN	Subsecretaría Forestal y de Fauna Secretaría de Agricultura y Recursos Hidráulicos Avenida Insurgentes Sur No. 476-12 ^o Piso México 7, D.F.
	Juan Carlos PINA-TINAJERO	Providencia 631 Col. del Valle z. P. 12 México, D.F.
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	Abodunrin Charles OMOLUABI	High Forest Development Project c/o Federal Department of Forestry P.M.B. 5011 Ibadan
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ANNEX III

LIST OF COURSE STAFF AND LECTURERS

a) Austrian Organizing Committee

DÜRR Hubert, Dipl. Ing. Dr. Ministerialrat	Leiter der Abt. VA5, Bundesministerium für Land-und Forstwirtschaft, Stubenring 1, A-1011 Wien
FRAUENHOLZ Othmar, Dipl. Ing. Direktor	Leiter der Forstlichen, Ausbildungsstätte Ort, A-4815 Ort b. Gmunden
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NEUBERGER Erich, Dipl. Ing. Dr. Ministerialrat	Leiter der Gruppe VA und der Abt. VA3, Bundesministerium für Land-und Forstwirtschaft, Stubenring 1, A-1011 Wien
PERNERSDORFER Josef, Dipl. Ing. Sektionsrat	Bundeskanzleramt, Abt. IVA10, Hohenstaufengasse 3, 1011 Wien
PLATTNER Edwin, Dipl. Ing. Ministerialrat	Leiter der Sektion V, Bundesministerium für Land-und Forstwirtschaft, Stubenring 1, A-1011 Wien
PUHANE Karl, Dipl. Ing. Dr. Ministerialrat	Leiter der Abt. VA2, Bundesministerium für Land-und Forstwirtschaft, Stubenring 1, A-1011 Wien
REDL Hermann, Dkfm. Dr. Ministerialrat	Leiter der Abt. IIIA3, Bundesministerium für Land-und Forstwirtschaft, Stubenring 1, A-1011 Wien
TRZESNIEWSKI Anton, Dipl. Ing. Direktor	Leiter der Forstlichen Ausbildungsstätte Ossiach, A-9570 Ossiach

b) Course Directors

FRAUENHOLZ Othmar, Dipl. Ing. Direktor	Leiter der Forstlichen Ausbildungsstätte Ort, A-4815 Ort b. Gmunden
HEINRICH Rudolf, Dipl. Ing. Forestry Officer	Forest Logging and Transport Branch, Food and Agriculture Organization of the United Nations, (FAO), I-00100 Rome, Italy
TRZESNIEWSKI Anton, Dipl. Ing. Direktor	Leiter der Forstlichen Ausbildungsstätte Ossiach, A-9570 Ossiach

c) Administrative, Secretarial and Technical Personnel

BASEL Elvira, Mag.	Bartensteingasse 13, A-1010 Wien
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WOLF Friedrich	Forstliche Ausbildungsstätte Ort, A-4815 Ort b. Gmunden

d) Lecturers and Speakers

In addition to the alphabetical list of speakers and lecturers, O. Frauenholz, R. Heinrich, E. Neuberger, E. Plattner and A. Trzesniowski gave lectures during the Training Course.

BAUERNFRIED Peter, Ing. Fachlehrer	Forstliche Ausbildungsstätte Ossiach A-9570 Ossiach
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EISBACHER Johann, Dipl. Ing. Rat	Forstliche Bundesversuchsanstalt Institut für Forsttechnik Schönbrunn, Tirolergarten A-1131 Wien
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PESTAL Ernst, o.Prof. Dipl. Ing. Dr.	Vorstand des Institutes für Forstliches Bauingenieurwesen und Waldarbeit Universität für Bodenkultur Peter-Jordan-Straße 82 A-1190 Wien
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TAUER Horst, Dipl. Ing. Professor	Forstliche Ausbildungsstätte Ort A-4815 Ort b. Gmunden
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e) Personnel involved in Excursions

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THURN-VALSASSINA Aripbrand, Dr.

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