AN INVESTIGATION OF LOGGING ROAD PLANNING USING AERIAL PHOTOGRAPHS

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PREFACE

Aerial photographs have been used for many purposes in forestry, including the location of logging roads, but as yet no efforts have gone toward planning logging roads on an economic basis and then applying these findings to location on photos. Whether the location work must be guided more by topographic features than by spacing of these roads must be decided by considering the area for which logging roads are being planned. If it can be shown that aerial photos adapt themselves to the planning of such roads, much may be saved by their use. This thesis is then an investigation into the matter of such use of photos.

The author is indebted to Max Melick, District Forest Ranger of the U. S. Forest Service, and Rheuben Smith, area supervisor aide for the Consolidated Waterpower and Paper Co., for data regarding the actual logging plan studied. The helpful suggestions and comments of John Carow, Assistant Professor of Forest Management, School of Forestry and Conservation, University of Michigan, under whom this problem was taken, are gratefully acknowledged. The author wishes to thank his wife, Ruth, for the encouragment and help in the preparation of the manuscript.

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Introduction:

The determination of economic road spacing on a particular logging chance has been written of in detail in Cost Control in the Logging Industry by the late Donald M. Matthews and has been applied in many areas, particularly where topography does not limit its use. Under certain conditions as found in the Lake States, however, topography has been given as the reason why economic spacing of roads cannot be used. That this latter claim is true cannot be denied, but what is so often forgotten is that the spacing of logging roads as near to the economic spacing as possible will result in the lowest skidding cost and road cost for the chance under consideration.

The integration of economic road spacing with the use of aerial photographs has as yet never been used. If it could be proven that with photos a great deal of effort and time could be saved by not requiring topographic mapping during the cruise or by not requiring an extensive reconnaissance for road location, their future use would be justified. This of course would only be true if the resulting road plan gave a cost estimate for the chance which was equal to or less than the one that was planned by the experienced logging operator.

To investigate the above possibilities an area was selected in parts of Sec. 33 and 34 of T45N, R37W in Iron County, Michigan. This logging operation was handled by

Rheuben Smith, area supervisor aide for the Consolidated Water Power and Paper Co. Mr. Smith sent cost information on two occasions which enabled an approximate economic cost calculation to be made. Since this was a United States Forest Service sale the volume removed from the area was obtained from District Ranger Max Melick. These three letters are to be found in the appendix. This data was used in conjunction with two sets of aerial photographs taken of the same area at different times. The first set of photos was taken in August 1939 as part of the project of nationwide photo coverage by the AAA of the U.S. Dept. of Agriculture. The latest photos were taken in August 1947 as part of the recent National Forest photo doverage program.

The logging operation started before the 1947 pictures were taken but the road plan could be seen on the photos. Since felling of the trees had started before the latest pictures were taken, a type map could not be constructed from them directly. Therefore, the combined use of the two sets of aerial photos with the volume removed from the area would be necessary to determine as accurately as possible the distribution and volume on the various types on the sale area.

Once the type map was obtained a cost estimate of the actual plan could be made. With the cost data available a calculation could be made, using the economic road spacing formula which is discussed later, to show what the most economic spacing is for the various areas of different volume. The economic spacing could be converted into economic road lengths for each separate area of constant volume and then compared with the actualroad length taken from the photos. After a comparison of these two for every area, the ones needing improvement could be noted and corrections attempted in a proposed plan. With the proposed plan completed, a cost estimate of it could be made and compared with the similar estimate of the actual plan. From this work conclusions could be drawn as to the merits and doubtful points in the use of aerial photos in such a way.

The analysis on the above basis is, therefore, followed. Lastly, an illustrative case will be presented to show the mechanics of a possible method in applying the findings of the analysis.

Analysis:

The boundary of the Forest Service sale area was taken from the rough sketch sent by Ranger Max Melick and is shown in the appendix. Lacking adequate ground control and being unable to determine exact section corner locations by reconnaissance, the corners were located according to the above mentioned map.

The first step in the analysis was to make a forest type map and determine the volume per acre on the various types. With the use of the Harvard parallax wedge various measurements of the height of average dominant trees in the stand indicated that for the area under question the height was constant. Since volume of a stand can be measured by considering the two variables, height and crown density,[1] and since the average height was constant, the volume on a given area can be determined by looking at crown density percent in a slightly different way. This other way of expressing crown density might be to say that the crown density percent of a given acre meant that that percent of the acre had a 100% tree cover. With a given crown density percent on a certain acreage, the density percent multiplied by the acreage (hereafter called density factor) would give the theoretical acreage covered by a 100% density stand. On a large area the sum of such multiplications for each crown density variation would give a total which represented the effective total acreage on which a fully stocked stand was located. Then, if the total volume of this fully stocked stand was known, the proportion of the total volume found on a given area would be the ratio of that particular density factor to the total of all density factors multiplied by the total volume. With this as a basis, a type map of crown density of the aspen on the sale area was made from the aerial photos on page 23 and page 24.

The photos on page 23 are the AAA photos taken with panchromatic film while the others are taken with modified infra-red film. The prints from the infra-red film show

1. Stephen H. Spurr, <u>Aerial Photographs in Forestry</u> (New York: The Ronald Press Company., 1948), pp. 296-297.

northern hardwood species light in contrast with the aspen and white birch species. A map was made of the sale area from the panchromatic prints, separating the various areas by crown density percent. Another map was made from the modified infra-red prints outlining the northern hardwood type and including the present road system. These two maps were enlarged to the same scale and then superimposed. The result of this is the map on page 25.

After the map was constructed most of the analysis was done on it. Table I is the result of the study and its construction will be discussed in detail. The various columns in Table I were not calculated in the order in which they are here presented. The columns concerned with the type map and actual logging plan were derived first. Then the calculations for most economic conditions possible were made. Following this work, a comparison was made of the two and used as a guide in attempting to improve the conditions by relocating roads. After the proposed plan was made, calculations exactly like the first ones of the actual plan were made. The columns were then arranged in their present form for ease in comparing changes made between the actual plan and the proposed plan.

Column 1 (Area) gives the symbol applied to each area as shown on the map on page 25. Column 2 (Acreage) was determined for each area by the dot grid method of area determination. Column 3 (Density Factor) was obtained as described previously. The acreage for a particular area times its crown density, as taken from the map on page 25, gave these values. Column 4 (Percent of Volume) was obtained by dividing the Density Factor of the area in question by the total of column 4 and expressing it as a percent. As an example, area A 1 was found by a dot grid to be 27.5 acres. Multiplying this by its crown density of 5.0% gives a density factor of 1.375. The percent of volume on area A 1 was found by dividing the density factor of area A 1 by the total of the density factor column (1.375 ÷ 110.19 = 0.01247 or 1.247%). Column 5 (Volume, cords) was obtained by multiplying the volume removed from the sale area by the percent of volume figure of column 4 (1852 x 0.01247 = 23.1 cords). Column 6 (Volume per acre, cords) was then computed by dividing the values of column 5 by column 2, (23.1 ÷ 27.5 = 0.84 cords per acre).

To determine the correct procedure to follow in calculating road spacing a decision must be made as to the way the operation was done. Mr. Smith in his first letter mentioned skidways but gave no cost of construction. He also estimated the average skidding distance as five chains. Five chains appears to be very near the average direct skidding distance to the nearest road if a correction is made to compensate for actual skidding distances being greater than direct skidding distances. Under stereovision areas A 3 and A 9 on the infra-red prints (page 24) show bare spots along the road which are presumably skidways. These spots are quite close together and would amount to the same as direct skidding to roads. Because of the above factors plus the fact that no special loading or bucking equipment was used which would require landings, the economic road spacing will be the spacing as determined by the direct skidding formula. In this formula, $S = \sqrt{\frac{0.33\ R}{V\ C}}$, S is the economic road spacing expressed in 100 foot stations, R is the road cost in cents per mile, V is the volume in units per acre, and C is the variable skidding cost per unit per 100 foot round trip station.[2]

Since economic spacing, variable skidding cost, fixed skidding cost and similar terms and ideas developed by Professor Matthews may not be completely familiar to those who have not had the opportunity to study his ideas, a brief explanation will be made here. The economic spacing formula shown above was based on three interdependent cost factors which must be balanced for a given situation to give the most economic logging road plan. These cost factors are cost of roads per mile or other distance unit, volume per acre or other area unit, and prehaul (skidding) for the products in terms of a distance unit such as 100 feet or a chain. The prehaul, or skidding, must be broken down into two components; namely, fixed and variable. The term

2. Donald M. Matthews, Cost Control in the Logging Industry (1st ed., imp.; New York: McGraw-Hill Book Company, Inc., 1942) pp. 119-121.

"distance unit" used above implies costs incurred as a result of moving the product or returning for another load. Therefore, the variable skidding component concerns itself with the costs that accumulate as the device used for skidding is actually moving. The fixed skidding component is concerned with such items as hooking, unhooking, and delay time of any kind. Since these fixed factors have no relation to actually moving the product they are not included as a cost when attempting to balance the three above mentioned cost factors. The formula previously mentioned will give the most economic road spacing when the three factors mentioned above are known. A more complete discussion may be found in the reference cited.

To calculate a value for the variable skidding cost (C) a study made by W. S. Bromley was used to obtain average horse efficiency.[3] This study showed that a team could pull a log 100 feet and return at an average time of 1.06 minutes, not counting hooking, unhooking or delays. Since in the operation under consideration pole length timber was skidded with one horse, the above average time would seem to be a conservative estimate. To determine the variable skidding cost, the average load per turn must be estimated. The author constructed a peeled aspen volume table (see appendix) on the area in 1947. His estimate of

3. W. S. Bromley, Ground Skidding With a D-2 Tractor Compared With the Average Team On An Operation In Northern Michigan (U. of Michigan, School of Forestry and Conservation, 1940)p.8.

the average size pole, only one of which would be skidded at a time, is 9.0 inches DBH or 8.6 cubic feet. In determining the number of trees per cord the much used approximation of 90 cubic feet of solid wood per cord of stacked wood was assumed.

The skidding, as Mr. Smith states in his letters , was done with one horse. The rate of production was given as 0.5 cords per man hour for skidding, bucking and piling, or 1.0 cords per man hour for skidding. The cost of skidding a cord of pulpwood was also given as $1.50 plus $0.50 for horse hire. Since the production rate was 1.0 cords per hour for skidding, the total of the above costs gives a machine rate of $2.00 per hour.

With the above information a calculation of the variable skidding cost per cord per 100 foot round trip station can be made as follows:

Average round trip time /100 ft.- 1.06 minutes.
Number of trees / cord= 90 cu.ft./cd. ÷ 8.6 cu.ft./tree=10.5 trees
Variable time /cord /100 ft. round trip station=
    1.06 minutes x 10.5 trees/cd = 11.1 minutes/ cord.
Machine rate / minute=
    $2.00 / hour÷ 60 min./ hour= $0.0334/ min. (3.34¢)
Variable skidding cost / cord / round trip station =
    3.34¢ x 11.1 min. = 37.1¢ / cd. / round trip station (C)

Mr. Smith also supplied the total road construction cost for the operation. This cost was $1096.50. Using the map and photographs taken in 1947 the length of road was measured and found to be 7.8 miles. Some roads were reworked but Mr. Smith stated that these cost as much per mile to construct as did the new roads. The road construction cost per mile (R in the formula) was found to be $140.00, this being computed by dividing the total cost by the total length of road.

Two of the three factors in the economic road spacing formula are then available for use. The third factor is volume per acre which varies for every area. The calculations of the economic road spacing for each area were made by solving the equation and using the volume for each area. The results of these calculations are shown in column 7 (Economic Road Spacing, stations). Column 8 (Acres per chain of road) was found by multiplying the spacing in feet by the feet in a chain and dividing by the number of square feet in an acre. In area A 1 this calculation is $\frac{66 \times 1210}{43,560} = 1.843$. These values are not useful alone but are used to obtain the values of column 9 (Optimum Length of Road per Area, chains). This was obtained by dividing column 2 by column 8.

As a check against the optimum length of road figures of column 9, the actual length of road per area was measured directly from the map on page 25 and is entered in column 10. Similarly, the road length proposed was measured from the map of proposed road lay out and entered in column 11.

The average straight line skidding distances in chains was estimated by inspection by reference to the above mentioned maps and are entered in column 12 and 14. The ocular estimate was made by separating each area into a few nearly rectangular subareas as possible and weighting the average skidding distance per subarea by its percent of total area to get the average skidding distance for the area. An example of this is shown in area A 3 on the map on page 25 and the calculations follow:

a-2/10	x 2.0	chains	=	0.4	chains
b-1/10	x 1.2	"	=	0.12	"
c-1/10	x 2.5	"	=	0.25	"
d-4/10	x 3.3	"	=	0.99	"
e-1/10	x 1.5	"	=	0.15	"
f-1/10	x 1.3	"	=	0.13	"
Totals----------				2.04	"

The values obtained were rounded off to the nearest tenth as further refinement would be inconsistent with the method used to measure and estimate the skidding distances of the subareas.

Under average logging conditions as found in the Lake States, the minor irregularities in topography and occurrence of brushy vegetation in openings in the forest canopy do not permit skidding to be done in a straight line to the nearest road. In many cases the teamster will use a particularly choice skidding trail numerous times and may have skid trails cleared of brush by the piece cutters. In the study by W. S. Bromley previously mentioned he has calculated a correction factor for this item[4] which seems to be applicable to this situation. This factor is 0.77 or expressed in words, for every 100 feet of actual skidding distance only 77 feet is gained in a straight line to the nearest road. With this

4. Ibid., p. 14.

in mind the Corrected Average Skidding Distance, stations (col. 13) and Proposed Average Skidding Distance Corrected, stations (col. 15) columns were computed by multiplying the average straight line skidding distance by 66 (feet in a chain) and dividing by the feet in a station (100) and the correction factor (0.77), e.g. area A 1 column 13 is $\frac{4.0 \times 66}{100 \times 0.77} = 3.4$ stations.

To make a comparison of the average skidding distances for the whole area under both plans, the portion of the average skidding distance applicable to each area was determined. This was done by multiplying the average skidding distance for each area by the percent of volume on that area and adding the values obtained to get the average for the whole sale area. This avoids a lengthy calculation of the variable skidding costs per cord for each area, each of which must then be weighted by its percent of the total volume on that area to get the average variable skidding cost per cord. The actual and proposed weighted average skidding distances are shown in columns 16 and 17 respectively.

By studying the stereoscopic pair of photos set up on page 24 the whole logging chance area may be seen. The overlay outlines the sale boundary and also shows the present road location in black. The topographic features of primary importance are the relatively high ridges on which most of the northern hardwood species are found. The areas of greatest aspen volume per acre seem to border the northern hardwoods and consequently the roads are located on relatively level ground outside of the hardwood area. The road that runs through the northern hardwoods in the northern part of the sale area may have been constructed to remove part of the small proportion of balsam and spruce but was more likely built to facilitate trucking the product to the rail-head. More difficult to explain is the road running along the ridge in the eastern part of the sale area. This area must have contained sufficient volume to justify its location in the eyes of the logging superintendent.

A check of the two sets of stereoscopic pairs of photos also shows that the main haul road was actually reconstructed from a road presumably used in a previous logging job. A very close check will also show that the road branching off the main haul road and running to the eastern part of the area had previously been used but was not in a good condition. The reconstruction of old road would usually cost less than new construction but Mr. Smith stated (see appendix) that due to the frequency of boulders in the old roadbed the reworking operation was as costly as building new roads.

By comparing the values of columns 7 and 13 in Table I, the extent to which roads were properly spaced can be seen. This comparison does not mean, however, that any particular road was improperly located. Rather, in the light of costs that determine economic spacing, it shows which areas have spacing farthest from optimum. In this comparison the road spacing values should be quartered as the average economic skidding distance is one fourth of the economic road spacing or S/4. The check shows that the actual average skidding distance is consistently greater than the optimum and that generally, the difference is larger in the areas of greatest volume, e.g. A 8, A 9, A_3 8, and A_3 9. Since these four areas contain nearly 60% of the total volume a shortening of their average skidding distances would lower the variable skidding component materially.

A comparison of optimum road length and actual road length (columns 9 and 10) shows that the two totals are very similar. Upon looking into the values for the individual areas, however, two large differences between the two columns appear. Area A 1 and the hardwood area would seem to have too much road. Part of the road in A 1 is actually main haul road and must be considered necessary. The hardwood area road, as mentioned above, may have been so located as to facilitate trucking. If it could be eliminated without injury to the hauling operations, however, a cost reduction could be made. The optimum length of road in a given area may be misleading too, unless this length is considered in relation to the economic average skidding distance (S/4). Because of the shape of the area under consideration, economic average skidding distances may not be exactly possible but can be very closely approached. The four areas, as mentioned above, that contain 60% of the total volume have much less road than that considered optimum, which would indicate also that spacing is too great.

In the process of relocating roads on the western part of the sale area, the attempt was made to space them at their economic spacing where topography permitted and to reduce the average skidding distance on major areas where economic spacing was impossible. This work was done on the photographs on page 24 using a pocket stereoscope and an improvised rule made to the scale of the photo, in stations. The relocation was kept on ground comparable to that on which the actual roads were located. This location work was therefore on nearly level land and would eliminate any possibility of increasing road construction cost per unit distance.

The road spacing as calculated for each area (Table I, column 7) shows that for areas with heavy volumes the economic spacing is very small, being about three stations in the case of area A 9. This is of course due to the fact that for this logging chance the road construction cost per miles is very low and the variable skidding cost per cord per station (round trip) is relatively high. Since these costs were provided by the operater, it has been assumed that they are correct and little attempt to justify them will be made. It might be pointed out, however, that low road costs may be due to the relatively level ground on which they were located.

The map of adjusted road location shows the proposed road plan. The overlay on the photos on page 24 also, shows the location in relation to the topography. The road in the northern hardwoods in the north part of the sale area was eliminated as the volume tributary to it is probably very small. The volume in the area could be easily skidded to the ends of roads near its boundary. The average skidding distance would be about 5 chains which would be very nearly correct if the volume averaged 1/2 to 3/4 cords per acre. In the eastern hardwood area the road was eliminated as very little volume would be skidded to it because of its location on top of the hill. Except for the hardwood areas little could be done to improve the road location in the eastern part of the area as topography would not permit a more desireable one, unless contour roads could be constructed for nearly the same cost.

In the western part of the sale area the land was less irregular. Three of the four areas mentioned previously are located here; namely, A 8, A 9, and A_3 8. Any improvement in spacing would result in considerable saving because of the large proportion of the volume located here. In one instance, the average skidding distance in area A 9 was greatly improved at the expense of area A 3 where the distance was increased. This was justified because of the larger percent of total volume present on area A 9. In all of the three areas mentioned above, the relocation resulted in reducing the average skidding distance by one half.

The total improvement in reducing the average skidding distance can be seen by comparing the totals of columns 16 and 17. The reduction amounts to 0.7 of a station and at the same time the road length was reduced by 66.5 chains. A calculation of road costs plus skidding costs for the actual plan and the proposed plan follow:

<u>Actual</u> <u>Plan</u>.

Main haul roads $(7.8 - \frac{366.5}{80})$ \$140 =.....	\$448.00	
Skid roads $(\frac{366.5}{80})$\$140=	644.00	
Total road cost............................		\$1092.00
Variable skidding (2.82x0.37)(1852)=.....	\$1937.20	
Fixed skidding (\$2.00-2.82x0.37)(1852)=..	1766.80	
Total skidding cost........................		3704.00
Total road cost and skidding cost..........		\$4796.00

Proposed Plan.

Main haul roads (as above)...............	$ 448.00	
Skid roads $\left(\frac{300}{80}\right)$\$140....................	525.00	
Total road cost...........................		$ 973.00
Variable skidding (2.11x0.371) 1852=	1429.75	
Fixed skidding (as above)................	1766.80	
Total skidding cost.......................		3196.55
Total road cost and skidding cost.........		$4169.55

The above calculations indicate a total saving of about $627.00. If the roads in the northern hardwood areas were considered necessary to facilitate trucking, this saving would be reduced by the cost of the additional road (57.5/80 x $140 = $100). If this $100 is added to the cost of the skid roads under the proposed plan a comparison of the two will show the results of the relocation of the roads. Since economic spacing is based upon an equalization of road construction cost per unit (for roads to which skidding is done) and variable skidding cost per unit, a ratio of the two should equal one. In the actual plan the ratio of variable skidding cost to skid road construction cost is $\frac{\$1937.20}{644.00} = 3.01/1$ and the same ratio for the proposed plan is $\frac{\$1429.75}{625.00} = 2.29/1$. The reduction of the ratio shows that economic spacing of roads has been approached but that the items involved in the ratio are still out of balance. Topography and shape of areas have combined to keep skidding costs slightly over twice as high as road construction costs.

Although the above savings are the only ones that can be accurately calculated, there are others that might be considered. If a cruise was being made of the tract before submitting a bid for the timber, a contour map would very likely be made to aid in placing future logging roads. This would require the services of one extra man and would increase the cruise cost. If the plan was to locate roads by reconnaissance on the ground considerable extra cost would be added. Time spent in the office making the aerial survey would not amount to more than half a day providing a rough map was all that was required.

Conclusions:

Integrating logging cost control methods with aerial photography has resulted in a proposed alternate logging plan that would have reduced some costs considerably. This in itself would seem to be proof enough that their combined use is feasible. There are other considerations that might arise in other areas, however; and there are also limitations to the use of photographs in this way.

A limitation that must be kept in mind is that the location as determined on the photos may have to be altered slightly due to adverse conditions on the ground that cannot be seen on the photos. Poor drainage, frequent boulders and minor topographic irregularities would be the most important items to consider. In locating roads in dense stands of timber, the limiting conditions would be aggravated.

While minor drainage conditions would pose a problem, the major drainage could be seen and provided for in considering road construction costs. In very swampy tracts photos would enable one to get a clear picture of the entire area much better than a ground survey could. The best location for a road could be found from photos in a very short time whereas ground methods would take much longer. The ability to see the overall picture of the area on photographs would also be very helpful in locating roads where topography is a big factor as saddles between hills or ridges where a crossing would be possible could be seen very easily.

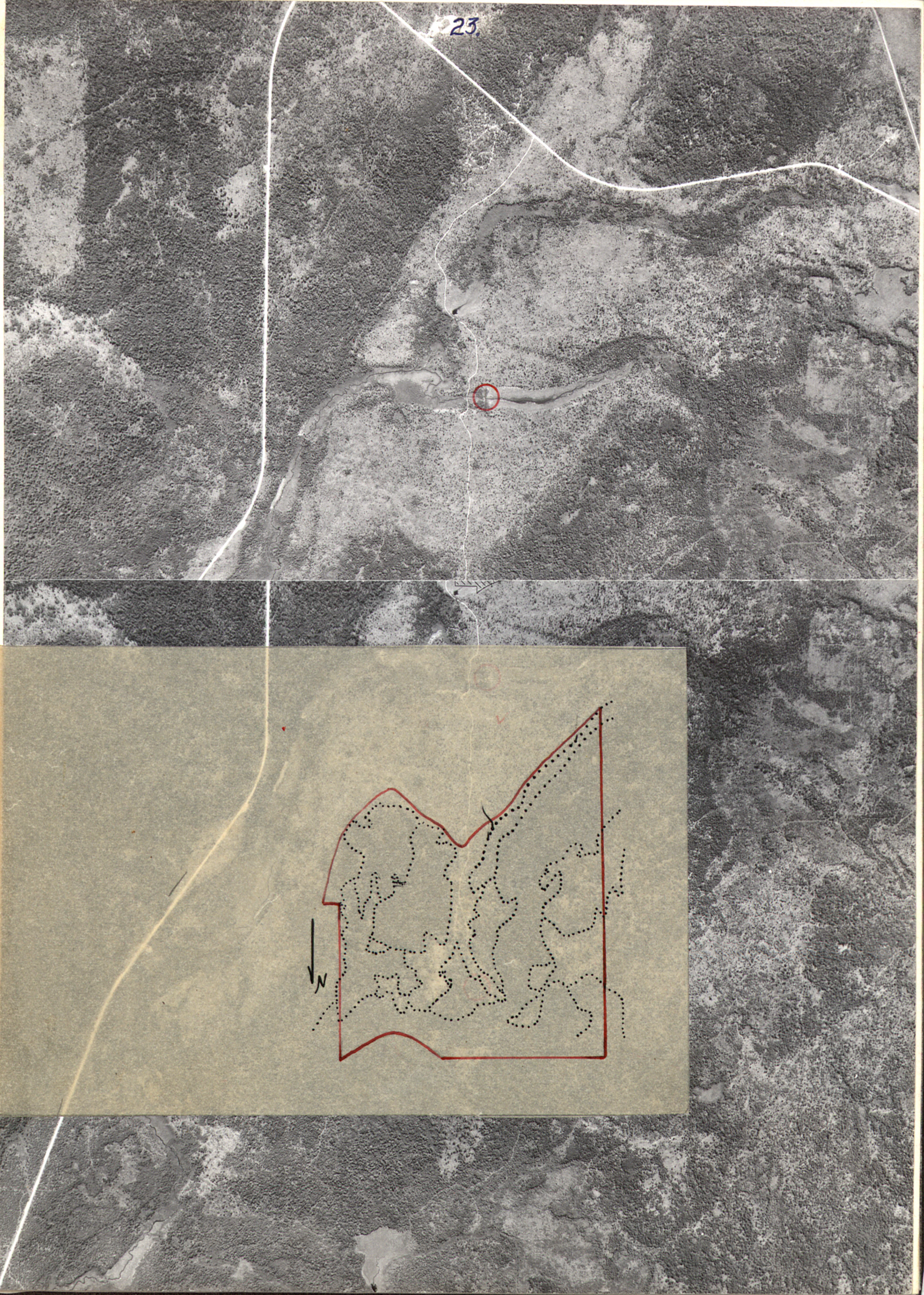
Under most conditions logging cost control involving economic spacing, or attempts to approach economic spacing, could be integrated with aerial photography. Under actual conditions the two factors that limit the use of economic spacing are topography and irregularities in areas of similar volume. Because the first of these factors is unchangeable, roads must be located as near to correct spacing as is possible under existing conditions. The second of these two factors is a problem of adjustment. With many irregular areas containing different volumes per acre, road spacings should be calculated for each one to be very precise. This is obviously impossible unless each area is of considerable size. To adjust these differences a weighted average of volume per acre on the major areas of nearly similar volume should be made. This average volume figure should be increased or decreased slightly if actual volume is less than or greater than the average.

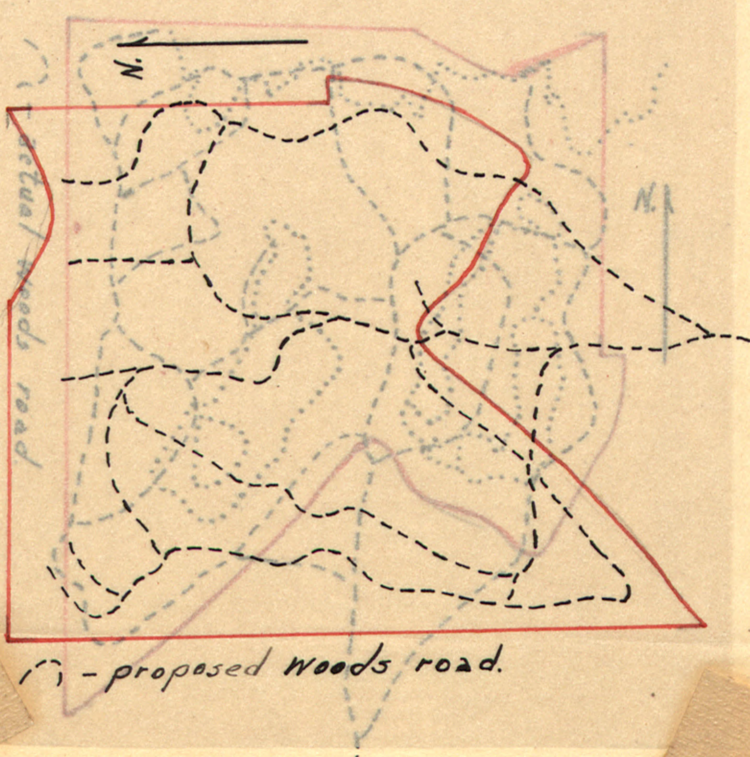
When locating roads on the photographs, variations of volume density within an area of average volume per acre can be seen quite easily. Roads should be built relatively near to these concentrations as this will tend to cut the skidding distance for the area and still keep road construction costs at a minimum.

From the above considerations it may be seen that logging planning could be greatly aided and in many cases improved by considering cost control and applying these finding to photographic methods of map making. With a little practise a forester with some experience should be able to take his place in the field and plan operations just as economically as more experienced men who have no knowledge of this new technique.

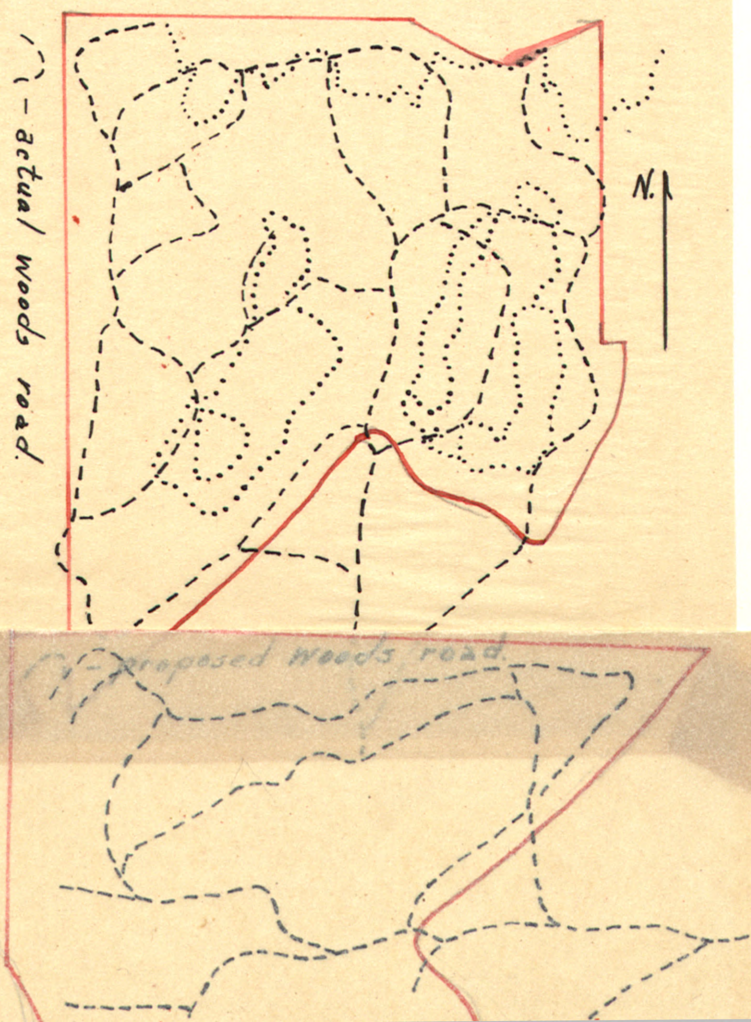
TABLE 1: ANALYSIS OF ACTUAL AND PROPOSED LOGGING PLANS

1. Area	2. Acreage	3. Density Factor (crown density x acreage)	4. Percent of Volume	5. Volume, cords	6. Volume per acre	7. Economic Road Spacing, stations	8. Acres per chain of road	9. Optimum Length of Road per Area, chains.	10. Actual Length of Road, chains	11. Road Length Proposed, chains.	12. Average Straight Line Skid Distance chains	13. Corrected Av. Skid. Distance, stations.	14. Proposed Average Straight Line Skid. Distance, chains.	15. Proposed Av. Skid. Distance (corrected) stations.	16. Weighted Av. Skid. Distance per Area (corrected) stations	17. Weighted Proposed Av. Skid. Distance per area, stations.
A1	27.5	1.375	1.247	23.1	0.84	12.10	1.843	14.9	66.0	52.0	4.0	3.4	4.0	3.4	0.0423	0.0423
A2	22.5	3.375	3.060	56.6	2.51	7.03	1.066	21.7	30.0	18.5	3.0	2.6	3.5	3.0	0.0795	0.0918
A3	7.5	1.874	1.700	31.5	4.20	5.43	0.823	9.1	14.5	3.5	2.0	1.7	3.7	3.2	0.0289	0.0545
A5	13.0	4.550	4.125	76.4	5.88	4.60	0.697	18.6	14.0	14.0	3.0	2.6	3.0	2.6	0.1073	0.1073
A6	9.0	4.055	3.675	68.0	7.55	4.05	0.614	14.7	11.5	11.5	3.5	3.0	3.5	3.0	0.1103	0.1103
A8	24.5	15.960	14.480	268.0	10.95	3.36	0.509	48.1	30.0	45.0	4.0	3.4	2.0	1.7	0.4920	0.2460
A9	14.0	11.900	10.800	200.0	14.30	2.95	0.447	31.3	12.5	22.0	3.0	2.6	1.2	1.0	0.2810	0.1123
$A_2$3	9.5	2.375	2.153	39.8	4.20	5.43	0.823	11.5	10.5	9.0	3.0	2.6	2.7	2.3	0.0559	0.0495
$A_2$5	15.0	5.250	4.760	88.1	5.88	4.60	0.697	21.5	21.5	21.5	3.5	3.0	3.5	3.0	0.1428	0.1428
$A_2$8	6.5	4.225	3.830	70.9	10.95	3.36	0.509	12.8	1.0	0.0	2.0	1.7	2.0	1.7	0.0652	0.0652
$A_2$9	8.0	6.800	6.165	114.2	14.30	2.95	0.447	17.9	5.0	15.5	3.0	2.6	3.0	2.6	0.1603	0.1603
$A_3$3	13.5	3.375	3.060	56.6	4.20	5.43	0.823	16.4	44.5	20.0	2.7	2.3	2.2	1.9	0.0704	0.0582
$A_3$8	33.5	21.800	19.780	366.0	10.95	3.36	0.509	65.8	38.5	55.0	3.4	2.9	1.5	1.3	0.5730	0.2570
$A_3$9	18.0	15.300	13.880	257.0	14.30	2.95	0.447	40.3	6.5	12.5	2.5	2.1	2.5	2.1	0.2912	0.2912
M2/A7	3.0	1.500	1.360	25.2	8.40	3.84	0.582	5.2	0.0	0.0	5.0	4.3	5.0	4.3	0.0585	0.0585
M2/A4	10.5	3.150	2.855	52.8	5.03	4.97	0.753	14.0	0.0	0.0	4.3	3.7	4.3	3.7	0.1057	0.1057
M3/A5	9.5	3.326	3.014	55.8	5.88	4.60	0.697	13.6	3.0	0.0	6.0	5.2	6.0	5.2	0.1568	0.1568
M	78.5	–	–	–	–	–	–	–	57.5	0.0	–		–	–	–	–
S_x	5.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Totals	329.0	110.190	99.944	1850.0				377.6	366.5	300.0					2.8211	2.1097


N

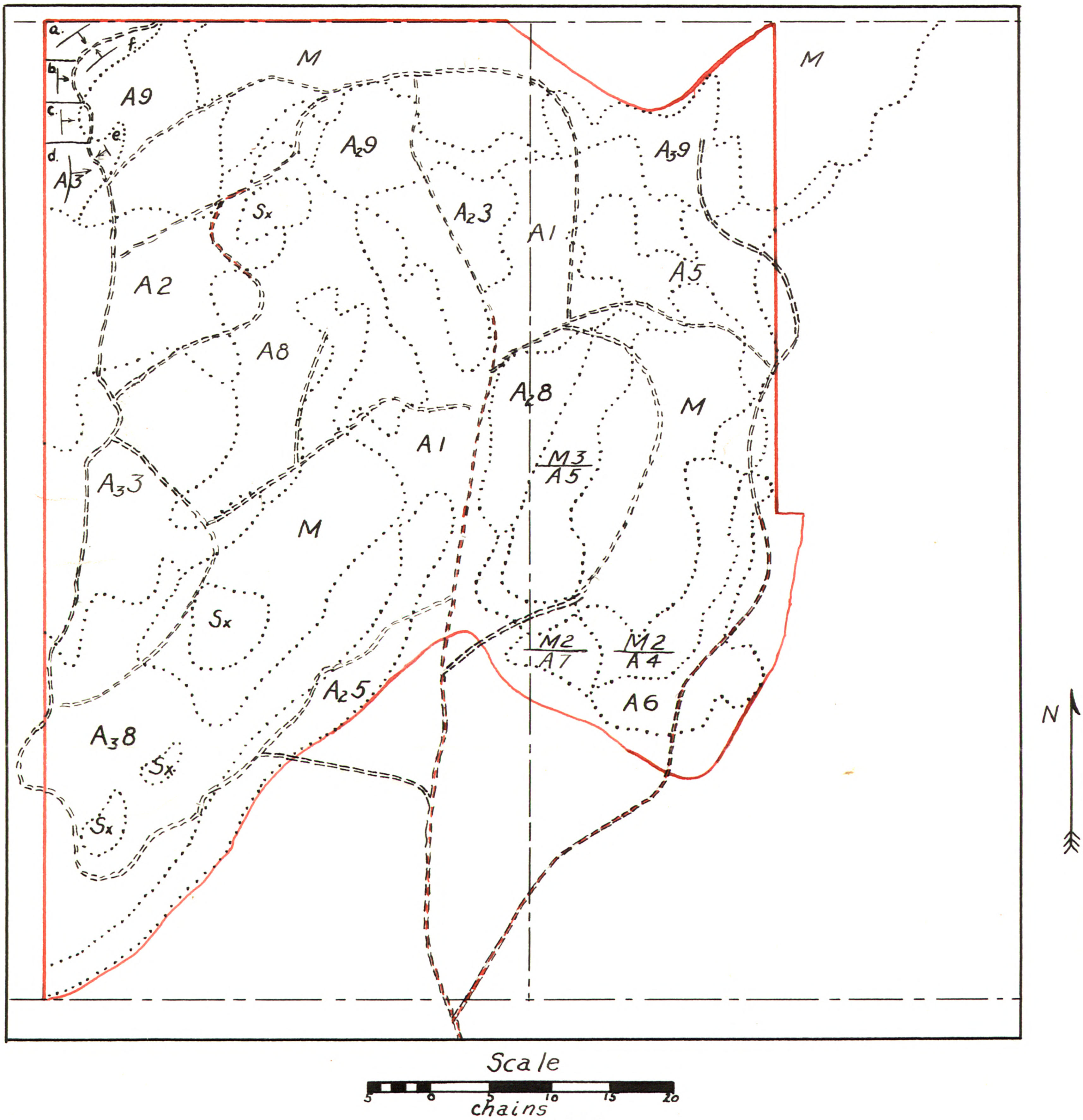


(- proposed woods road.


- actual woods road
N.
- proposed woods road

PLANIMETRIC AND FOREST TYPE MAP OF PARTS OF SEC. 33 & 34, T45N R37W IRON COUNTY. MICH.

PLANIMETRIC AND FOREST TYPE MAP OF PARTS OF SEC. 33 & 34, T45N R37W IRON COUNTY, MICH.



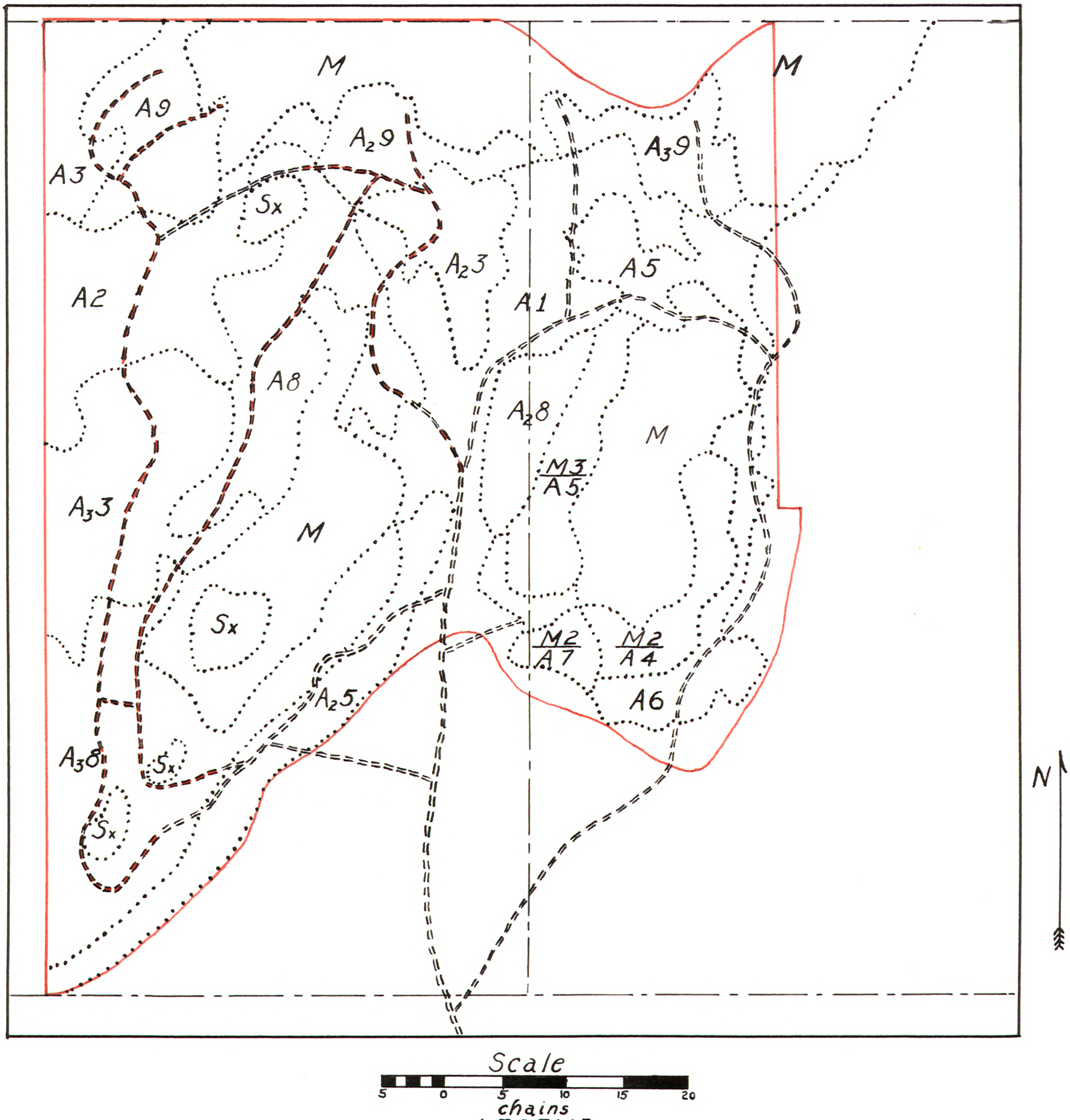
LEGEND

- forest type line	**Crown Density**
- reopened woods road	1 – 5 percent
- new woods road	2 – 15 percent
- section line	3 – 25 percent
- sale boundary	4 – 30 percent
Forest Types	5 – 35 percent
M - northern hardwoods	6 – 45 percent
A - aspen	7 – 50 percent
S_x - bog or swamp	8 – 65 percent
	9 – 85 percent

subscripts separate areas of similar Crown Density

TYPE MAP AND PROPOSED ROAD PLAN OF PARTS OF SEC.33&34, T45N R37W IRON COUNTY MICH

TYPE MAP AND PROPOSED ROAD PLAN OF PARTS OF SEC.33&34, T45N R37W IRON COUNTY, MICH.



LEGEND

- forest type line
- proposed new woods road
- woods road as before
- section line
- sale boundary

Forest Types

M - northern hardwoods

A - aspen

Sx - bog or swamp

Crown Density

1 - 5 percent
2 - 15 percent
3 - 25 percent
4 - 30 percent
5 - 35 percent
6 - 45 percent
7 - 50 percent
8 - 65 percent
9 - 85 percent

subscripts separate areas of similar Crown Density

ILLUSTRATIVE CASE

To illustrate the method of logging road planning by using aerial photographs, an area similar to the one previously studied was taken. This area is the whole of Sec. 24, T45N R37W in Iron County, Michigan. The aerial photographs available for use are those taken by the AAA of the U.S. Dept. of Agriculture on August 15, 1939.

The plan is to log this pulpwood area by skidding the 100 inch sticks on drays which are to be drawn by a team of horses. The hauling will be done with a 1½ ton truck and loading completed by hand or with self loading power-take off units.

Skidding costs and a truck machine rate applicable to the operation as described above were obtained from a study of a pulpwood production problem completed in 1943[5]. These costs follow:

Truck Machine Rate
Standard 1½ ton truck

Fixed cost per hour	$1.20
Operating cost per hour	0.89
Running cost	$2.09

Average load: 3 cords (128 cu. ft. stacked volume)

Horses and Drays Machine Rate.

Fixed cost per cord	$0.40
Variable cost per cord per station	0.05

Road construction costs were obtained for four

5. William P. Yost, Obtaining Lower Costs in Pulpwood Production. (Master's thesis, U. of Michigan, School of Forestry and Conservation, 1943).

standards of roads from a study made in the Upper Peninsula of Michigan by Bruce Spike of the forest consultant firm, George Banzhof and Company, Milwaukee Wis. These classifications are as follows:

Class I (Strip road)- average round trip speed 2 mph, brushed out, stumps cut low, little or no hand grading, rough with no alignment, usually made by piece cutter or trucker. Cost included in the piece rate or trucking rate, estimated at $1.50 per station.

Class II (Poor haul road)- average round trip speed 2-4 mph, brushed out, stumps cut low, hand graded but not smooth. Cost to construct in heavy soil $3.00 per station, cost to construct in sand or gravel- $1.50 per station.

Class III (Fair to good haul road)- average round trip speed 8-10 mph, machine graded, drainage provided for, dirt surface, fair alignment and gradient. Cost to construct in heavy soil $5-$7 per station.

Class IV (Good Haul Road)- comparable to the average township road. Alignment and gradient similar to Class III, smooth and well maintained, dirt surface or lightly gravelled. Cost to construct in heavy soil $7-$9 per station. Maintenance after every 50 truck trips if not gravelled is 25¢ per station.

Table II has been prepared using the above road standard data and skidding and hauling data. The hauling cost per cord per station was calculated from the formula, haul cost / cd / sta $= \frac{2HC}{mph \times 52.8 \times L}$ where HC is the truck machine rate per hour, mph is the average round trip speed, and L is the average load in cords[6]. Calculations for the four standards of roads follow:

Class I: Hauling cost /cd./sta. $= \frac{2 \times \$2.09}{2 \times 3 \times 52.8} = \$0.0132$/cd./sta.

6. Matthews, op. cit., p.170

Class II: Hauling cost /cd./sta.= $\frac{2x\$2.09}{4x3x52.8}$ =\$0.0066/cd./sta.

ClassIII: Hauling cost /cd./sta.= $\frac{2x\$2.09}{8x3x52.8}$= \$0.0033/cd./sta.

Class IV: Hauling cost /cd./sta.= $\frac{2x\$2.09}{18x3x52.8}$=\$0.0015/cd./sta.

Table II. Woods Road Standards.

Road Class	Average Round trip speed-mph	Construction Cost per station	Haul Cost per cord per station
I	2	\$1.50	\$0.0132
II	4	3.00	0.0066
III	8	6.00	0.0033
IV	18	10.00	0.0015

Before proceeding farther with a determination of the standard of road that should be used a photo-cruise must be made to determine the distribution of the stand and its volume per acre. From the aerial photograph BVX-1-101 three relatively bare square corners appear on the east portion. These corners are spaced 3.05 inches apart and are directly in line with each other. This evidence plus the fact that the road system closely resembles that on Sec. 24 on a map of the Ottawa National Forest indicate that the two southern most corners are the northeast and southeast corners of the section in question. The side of a section being one mile on the ground and measuring 3.05 inches on the photograph gives a relationship where by the representative fraction of the photograph can be determined, thus: R.F.= $\frac{3.05}{5280x12}$ and reducing the numerator to one results in R.F.= $\frac{1}{20,775}$.

To use the parallax wedge another calculation must be made to determine the amount of height for every 0.001 inches of parallax difference. To calculate this the formula

$h = \frac{f \times dP}{RF(-dP)}$ [7] where h is height per 0.001 parallox when dP is 0.001 inch, f is focal length of the camera in feet, RF is the representative fraction, and P is the photo base length (average of distance between principal and conjugate points on the two photos) in inches. Therefore, the formula becomes $h = \frac{8.25/12 \times 0.001}{\frac{1}{20{,}775}(2.6-0.001)}$ =5.5 ft. per 0.001 inch parallax difference.

A third calculation is necessary to determine the shadow factor for use with the micrometer wedge on either the Lake States Photo rule or the Harvard Parallax Wedge. The exposure time for photo BVX-1-100 is as follows:

Exposure Time ends of Flight Strip

Print BVX-1-115	12.58 CST
Print BVX-1- 78	12.42 CST
Difference in time	0:16 minutes

Number of prints between 115 and 78 = 37 prints
Number of prints between 100 and 78 = 22 prints.

Time to be added to the exposure time of print 78 is $\frac{X}{16} = \frac{22}{37}$ or X = 9.5 minutes.

Exposure time of BVX-1-100 = 12:42 - 9.5 = 12:51.5CST

To determine the shadow factor (tan x) the following calculations apply:[8]

Greenwich time= 12:51.5 - 6.00= 18:51.5 or 6:51.5
Expressed in degrees 6:51.5 x 15^{o} Longitude=102.9^{o} or 102^{o} 54'
Subtracting "Equation of Time" of 1.0^{o}
Longitude of Sun = 102^{o} 54'-1.0 = 101.54'

7. Spurr, op. cit., p.131.

8. A complete discussion of this type of calculation may be found in Spurr's Aerial Photographs in Forestry, pp. 227-232.

Local hour angle = Longitude Photography- Longitude of Sun
" " " = $88^\circ\ 55' - 101^\circ\ 54' = -13^\circ$

To find the value of X the equation $\sin X = \cos a \cos b \cos c + \sin a \sin b$ is used where a is declination of sun on date of photography ($+ 14.2^\circ$), b is latitude of photography (46° 17 N), and c is the local hour angle.

$$\sin X = \cos 14^\circ 12' \cos 46^\circ 17' \cos 13^\circ \pm \sin 14^\circ 12' \sin 46^\circ 17'$$
$$= (0.97)(0.692)(0.974) - (0.245)(0.722)$$
$$= (0.653) - (0.177)$$
$$= 0.476$$

Therefore $X = 56^\circ\ 6'$ and $\tan X = 1.50$

The overlay on the photographs on page 36 delineate the areas as set up in Table II which shows the results of the photo cruise. The Lake States Photo Rule was used in all estimates with heights being checked by the Harvard Parallax Wedge. The "Volume Class" column was determined by reference to the chart (see appendix) to be used in conjunction with the photo rule. The column,"Volume, cds per acre", was obtained from the U.S. Forest Service classification of stand volume class based on the volume classes cited.

To obtain an estimate of the amount of volume that should be added as growth between the time of photography and the present time an ecological study [9] was used in conjunction with a soils map of Iron County [10]. The soil type

9. Joseph Kittredge. Jr, The Interrelation of Habitat, Growth Rate, and Associated Vegetation in the Aspen Community of Minnesota and Wisconsin, (reprint from "Ecological Monographs", 8:151-246, April, 1938).

10. Z. C. Foster, J. O. Veatch, L. R. Schoenmann; Soil Survey of Iron County, Michigan, (USDA Publication, Series 1930, No. 46).

found on the parts of Section 24 carrying the major portion of the stand is Baraga loam. Using the description of this soil type an average site index of 64 was found to be average based on combined texture-surface formation groups. The average age for site 60 with an average height of dominant tree being 50 ft. is 35 years. From the relationship of volume to age as found in the ecological study, the volume growth between years 35 and 45 was 700 cubic feet (2300 to 3000 cu. ft. per acre) or 7.78 cords, using 90 cu. ft. solid volume per cord. The "Growth 10 yrs., cords" column of Table III was obtained by multiplying crown closure by the growth (7.78 cords) on a well stocked stand (area A_1 growth = 0.8 x 7.78 = 6.22 cords). The total of cruise volume and growth gives the volume present in 1949, unpeeled. Since this is an aspen pulpwood operation sap peeling in the woods would very likely be done. To reduce the reduce unpeeled volume to peeled volume a reduction of 12% was made from the unpeeled volume column.

Table III Photo-cruise Results on Aspen of Section 24

Area	Av. Hgt. feet (nearest 10 ft.)	Crown Closure %	Crown Diameter Scale	Volume Class	Volume cds/acre 1939	Growth 10yrs cords	Volume, cds per acre 1949 (nearest ½ cd)	Volume cds (peeled) per acre 1949 (nearest ½ cd)
A_1	50	80	Pebbly	Good	15	6.22	21.0	18.5
A_2	50	60	Cobbly	Med-Good	13	4.67	17.5	15.5
A_3	50	70	"	Good	15	5.44	20.5	18.0
A_4	50	30	"	Poor-Med	5	2.33	7.5	6.5
A_5	50	60	Pebbly	Med.	10	4.67	14.5	13.0
A_6	50	30	Cobbly	Poor	7	2.33	9.5	8.5
A_7	50	50	"	Med.	10	3.89	14.0	12.0
A_8	50	70	Pebbly	Good	15	5.44	20.5	18.0
A_9	40	60	"	Poor	7	4.67	11.5	10.5
A_{10}	50	50	Cobbly	Med.	10	3.89	14.0	12.5
A_{11}	50	30	"	Poor-Med	5	2.33	7.5	6.5
A_{12}	50	20	"	Poor	4	1.55	5.5	5.0

To make a calculation of the most economic road stand an average volume figure for the major areas must be calculated. This was done by measuring the acreage of the individual areas, as obtained by the dot grid method of area determination, and multiplying by the average volume of that area. The sum of these volumes divided by the total acreage given the average volume per acre. The results of this calculation appear in Table IV below:

Table IV. Volume on Major Areas.

Area	Acreage	Volume per Acre-cds	Total Volume per Area-cds
A_1	18.0	18.5	333
A_2	89.0	15.5	1380
A_5	68.0	13.0	884
A_7	114.0	12.0	1368
A_8	68.0	18.0	1224
Totals	357.0		5189

Average Volume per Acre $= \frac{5189}{357.0} = 14.5$ cds/acre.

Since measurements of skidding distance on photographs must be straight line or direct distances to the nearest woods road a factor must be applied to take care of average skidding conditions where direct straight line skidding is not possible. Bromley,[11] in a study of skidding in the Upper Peninsula of Michigan calculated that a factor of about 0.75 was correct for conditions as found there. Using this factor, the variable skidding cost per cord per station becomes 6.67¢ (5.0¢ ÷ 0.75).

In making comparative cost calculations using different

11. Bromley, op.cit., p.14.

road standards at their economic spacing a calculation using the economic road spacing formula, $S=\sqrt{\frac{17.4\ r}{V\ C}}$, is used.[12]

Standard I $S_1=\sqrt{\frac{17.4x150}{14.5x6.67}}=\sqrt{27.0}=5.19$ sta.

Standard II $S_2=\sqrt{\frac{17.4x300}{14.5x6.67}}=\sqrt{54.0}=7.34$ sta.

StandardIII $S_3=\sqrt{\frac{17.4x600}{14.5x6.67}}=\sqrt{108}=10.37$ sta.

Standard IV $S_4=\sqrt{\frac{17.4x1000}{14.5x6.67}}=\sqrt{180.0}=13.39$ sta.

From an inspection of the photograph the best location of the road leading to the major portion of the timber would be slightly to the left of the center of the section on the forest truck trail going through the southern part of the section. From such a point the average hauling distance, estimated by inspection and considering such items as topography, road grade and center of area in relation to the volume, would be about 35 chains or 23 stations.

The comparative cost calculation to determine the most economic road standard follows and is determined by the formula, Total Cost $= 2C\frac{S}{4} + H\frac{D}{2}$. It takes into consideration the road construction, skidding, and hauling costs per cord.

$TC_1= 2x5¢x\frac{5.19}{4} + 1.32¢ \ x \frac{23}{2} = 28.2¢$ / cd.

$TC_2= 2x5¢x\frac{7.34}{4} + 0.66¢ \ x \frac{23}{2} = 26.0¢$ / cd.

$TC_3= 2x5¢x\frac{10.37}{4} + 0.33 \ x \frac{23}{2} = 29.7¢$ / cd.

$TC_4= 2x5¢x\frac{13.39}{4} + 0.15 \ x \frac{23}{2} = 35.1¢$ / cd.

The above would indicate that a class II road standard

12. Matthews, op.cit., pp.185-188.

spaced at its economic spacing would be the most economical plan. This would give a spacing of 7.34 stations or 11.1 chains ($\frac{734}{66}$ = 11.1). However, as pointed out in the previous summary overskidding should be resorted to where topography or shape of timbered area do not permit roads to be spaced at their proper distance.

Using this spacing figure of 11.1 chains the photos on page 36 were set up and location of roads started. The loop type road was used wherever possible as most operators seem to prefer it. The attempt was made to keep the grade as small as possible and still keep spacing as near as possible to the above figure. Where skidding would have to be done on a slope the roads were so located as to give them a downhill pull as often as possible. The results of this road location work can be seen on the print overlay or on the map on page 38.

After the task was completed an analysis to obtain the average skidding distance for the trial was made so costs for the operation could be estimated. Table V was then constructed in the same manner as Table I with average skidding distances in chains being estimated from the map on page 38 as described on pages 6 and 7. The length of woods road was measured directly from the map and was found to total 453 chains.

Table V: Determination of Average Skidding Distance.

Area	Acreage	Volume per acre (peeled)	Volume per area (peeled)	Percent of Volume	Av. Skid. Dist., chains	Corrected Av. Skid Dist., sta.	Weighted Skid. dist. per area, Stations
A_1	21.0	18.5	388.0	6.45	2.9	2.56	0.1650
A_2	89.0	15.5	1380.0	22.94	2.5	2.20	0.5050
A_3	5.0	18.0	90.0	1.50	2.0	1.76	0.0264
A_4	23.0	6.5	149.5	2.48	6.0	5.28	0.1310
A_5	68.0	13.0	884.0	14.70	2.8	2.46	0.3620
A_6	15.0	8.5	127.5	2.12	5.0	4.40	0.0933
A_7	114.0	12.0	1370.0	22.75	3.3	2.91	0.6620
A_8	68.0	18.0	1225.0	20.35	2.5	2.20	0.4480
A_9	5.0	10.5	52.5	0.87	3.5	3.08	0.0268
A_{10}	16.0	12.5	200.0	3.32	3.8	3.34	0.1110
A_{11}	11.0	6.5	71.5	1.19	3.3	2.91	0.0346
A_{12}	16.0	5.0	80.0	1.33	5.5	4.84	0.0644
LB	145.0	-	-	-	-	-	-
P	18.0	-	-	-	-	-	-
M	21.0	-	-	-	-	-	-
Road	5.0	-	-	-	-	-	-
Totals	640.0		6018.0	100.00			2.6295

From the totals of the above table the variable skidding cost for the tract can be calculated. Road construction cost data is also available.

Estimated Road Construction and Skidding Costs.

Skidding Costs
Fixed cost - \$0.40 x 6018 cds.=------------- \$2407.00
Variable cost - \$0.0667 x 2.63 x 6018 cds.=---1053.00
Total Skidding costs --------------------------------------\$3460.00

Road Construction Cost -(Class II road)
(\$3.00 x 52.8)(453/80)---------------------------------- 896.00
Total Road Construction and Skidding Costs ------------- \$4356.00

The above estimated costs indicate a ratio of variable skidding cost to road construction cost of about 1.18 (\$1053/\$896=1.18). This ratio is very close to the 1.0 ratio obtained under exact economic spacing and is probably as close to the economic spacing as is possible.

After the photographic plan was completed a set of later photos taken in August 1947 (DEU-4-116 and DEU-4-117) were studied. The whole section had been logged and roads were visible. A map of the road system was made from the photos on vellum paper. This system is shown on page 37 and can be compared with the photographic cost control plan map on the following page. A check of one system against the other will not prove that the actual plan is poor because actual logging costs may have been entirely different. However, using the assumed costs on the actual plan will show which is the better plan under the assumed cost conditions. Again average skidding distances were estimated (as on page 6 and 7) from actual road location for every area and incorported into Table VI to get estimated costs.

Table VI

Area	Percent of Volume (Table V)	Av.Skid. Dist., chains	Corrected Av.Skid. Dist.	Weighted Skid.dist. per area, stations
A_1	6.45	4.9	4.32	0.2780
A_2	22.94	5.0	4.40	1.0100
A_3	1.50	1.8	1.58	0.0237
A_4	2.48	3.5	3.08	0.0763
A_5	14.70	2.5	2.20	0.3234
A_6	2.12	6.4	5.63	0.1193
A_7	22.75	9.0	7.92	1.8000
A_8	20.35	3.7	3.26	0.6630
A_9	0.87	18.0	15.80	0.1375
A_{10}	3.32	7.0	6.16	0.2045
A_{11}	1.19	3.3	2.91	0.0346
A_{12}	1.33	4.4	3.87	0.0514
Totals	100.00			4.7217

The total weighted skidding distance figure and the total road length of 382 chains as measured from the map will permit an estimate of costs.

Estimated Road Construction and Skidding Cost under Actual Plan.

Skidding Costs
    Fixed cost $0.40 x 6018.0 cds.=.......$2407.00
    Variable cost $0.0667 x 4.72 x 6018=.. 1894.00
Total Skidding costs=.................................$4301.00

Road construction cost- (class II road)
    ($3.00 x 52.8)(382/80)=.......................... 755.00
Total Road construction and Skidding cost...........$5056.00

In this case the total cost exceeds the previous plan by $700 and the ratio of variable skidding to road construction cost is increased to 2.5. These figures are proof enough that the photographic plan is best under the conditions assumed.

Summary of Illustrative Case:

In checking these later photos of section 24 there are some things that show up that were not visible on the earlier ones. In area A_8 later photos show that the stand was a mixture of northern hardwoods and aspen, whereas on the earlier photographs this differentiation was not readily visible. This same condition existed in the western part of area A_7. Also, roads were not built out to the island of timber on area A_9 even though it apparently contained aspen. In the actual operation this portion of the section was not a part of the sale. From the photos one can see that part of the section to the east of section 24 was logged at the same time. For this reason the actual road pattern would necessarily differ.

Ranger Melick gave some information on this sale which showed another error in construction of the type map from the photos. Part of area A_6 was actually cedar instead of aspen. Although volumes could not be compared directly, it appeared as though the photo-cruise resulted in too large a total volume.

The errors noted after the illustrative case was finished made little difference in showing a method of location logging roads using aerial photos. However, if a more accurate type map and volume estimate had been made the road system might have been changed some. In actual practise purchase of stumpage would be made on the results of a cruise at which time the type map would probably be made. This type map would then be used with the aerial photos to give a more accurate road plan.

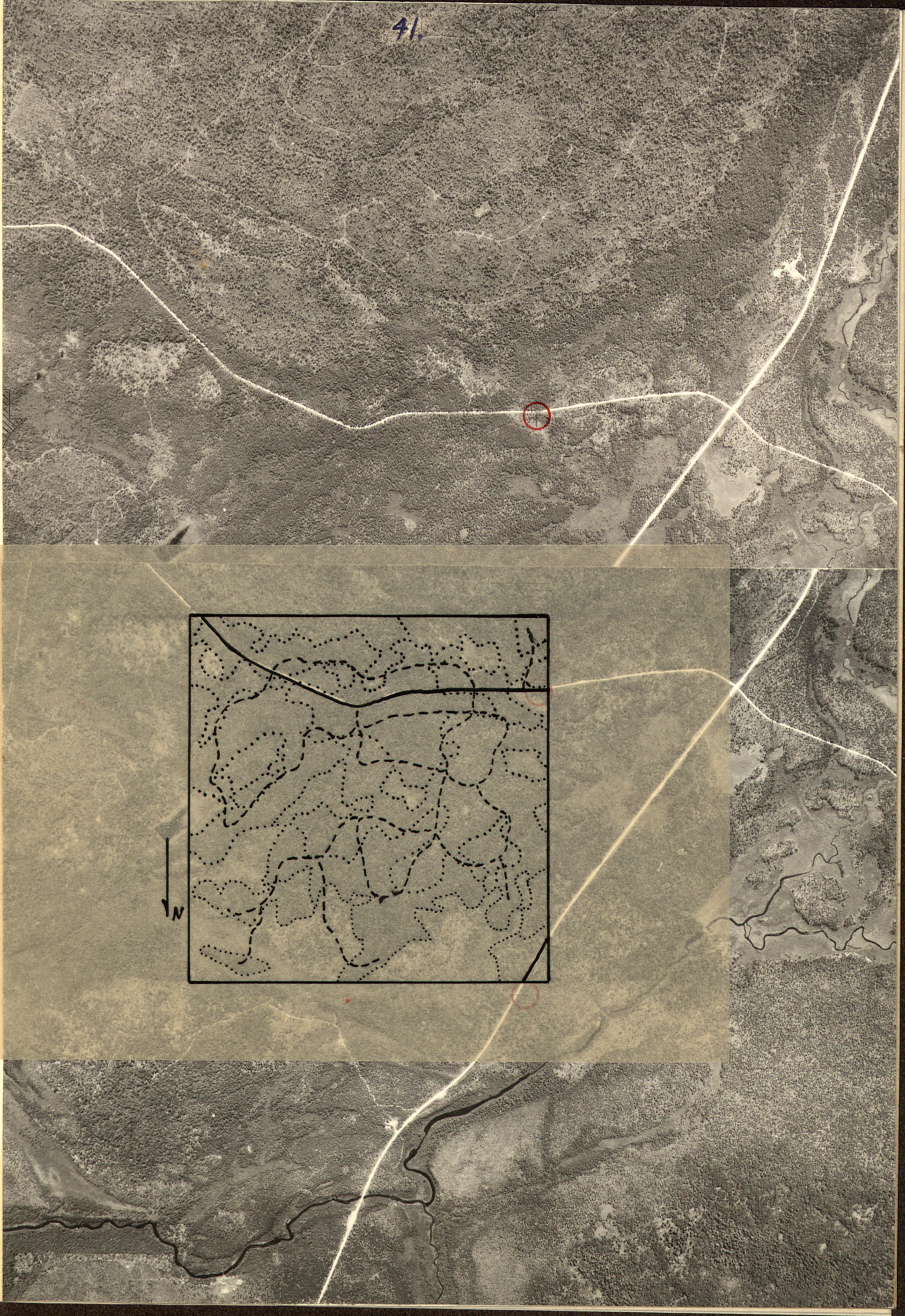
The comparison of the two road plans does not, as has been stated before, indicate a poor actual plan. It only shows that the photo plan is best under the cost conditions assumed. Had the actual costs been used in estimating the road construction and skidding costs, the outcome may have been entirely different. Even with these cost differences the roads compare rather closely in some areas.

From the point of view of forest type determination it can be seen that modified infra-red prints are greatly superior to the panchromatic prints. Also, a photo scale of $3\frac{1}{2}$ inches to the mile (R. F. =1/17,500) is much better than a scale of 3 inches to the mile (R. F. = 1/21,000) as topographic variations can be seen more easily on the former.

A final remark should be a word of caution in the use of photos. Whatever the circumstances, ground checks are necessary in the use of aerial photos. The illustrative case has an area which should have been ground checked. The road leading to areas A_9 and A_{10} was put through on rather low ground. In actual practise such a situation would have called for a ground check or an alternative road plan in that particular location if the ground actually proved too soft.

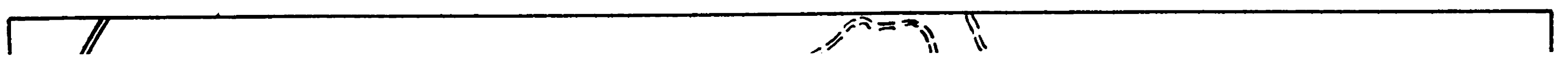
This illustrative case is not presented as the only way in which to go about making such a plan, but it may serve as a foundation to be used by those who are working under conditions similar to those presented here.

41.

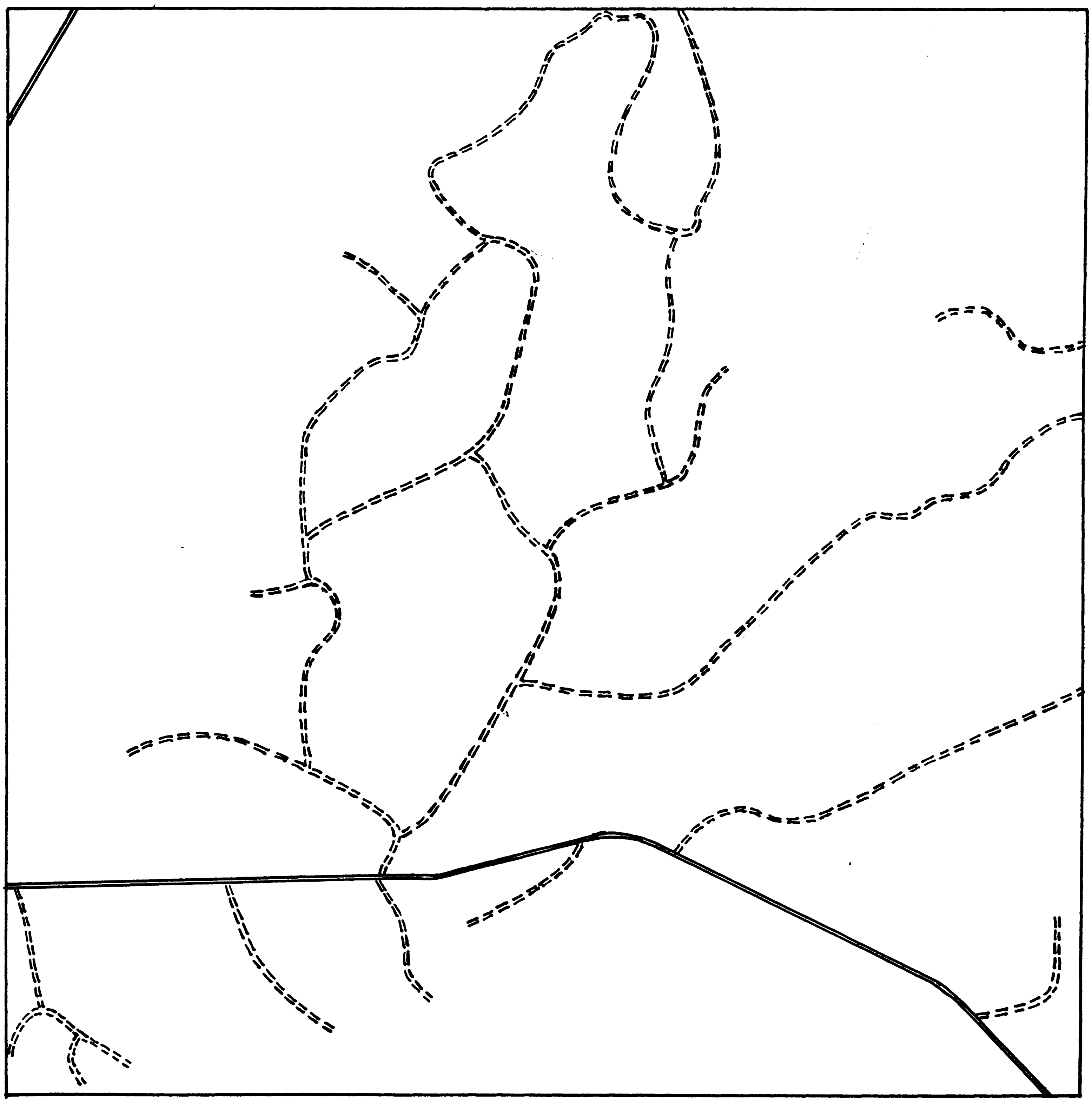


41.

ACTUAL ROAD PLAN
ON SEC. 24 T45N, R37W
IRON COUNTY, MICH.



ACTUAL ROAD PLAN ON SEC. 24 T45N, R37W IRON COUNTY, MICH.

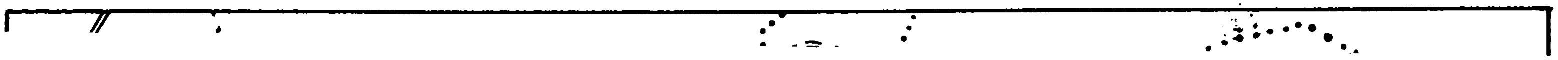


LEGEND

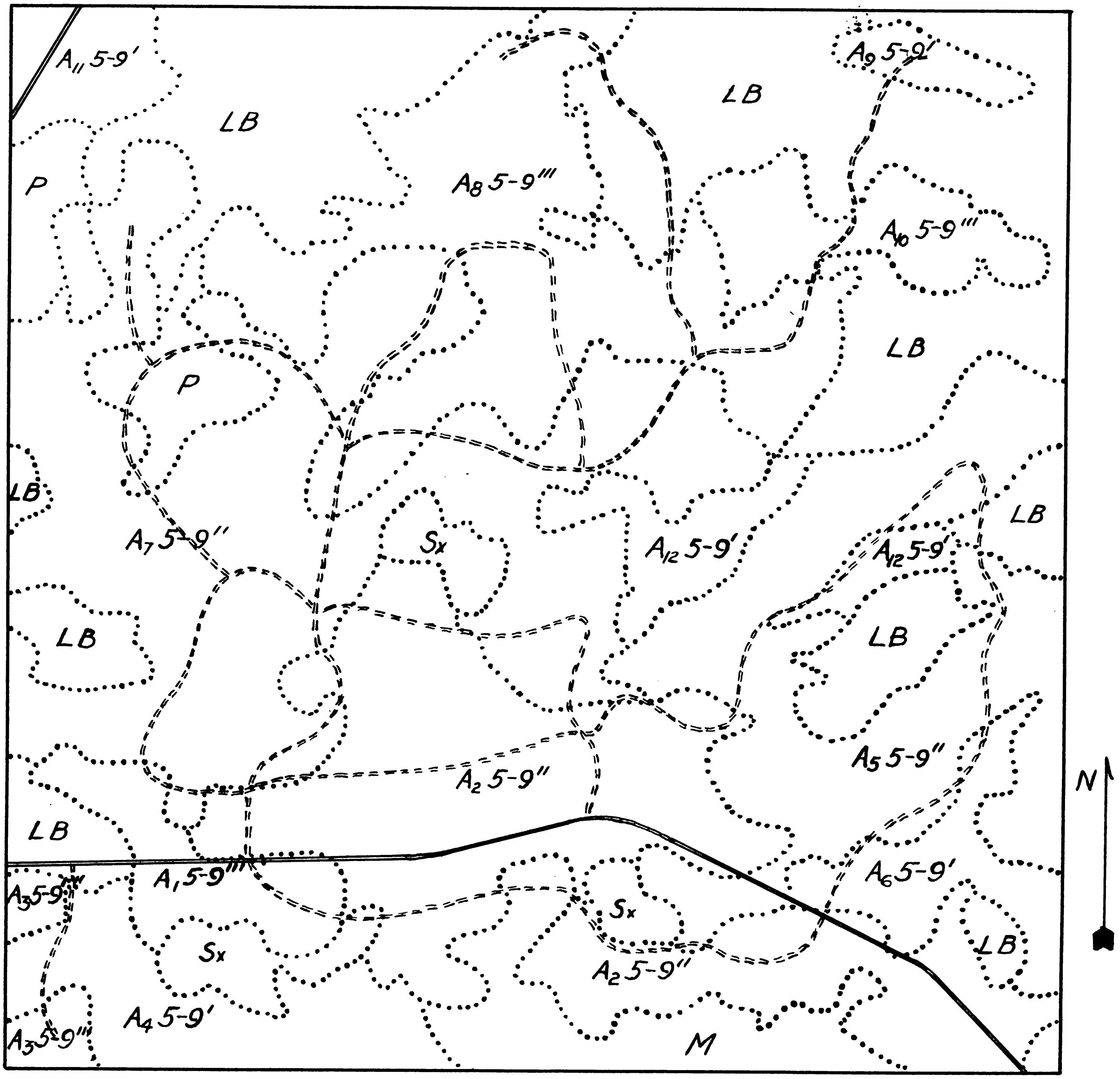
- actual woods road
- forest truck trail

use as overlay on next map

FOREST TYPE MAP AND PROPOSED ROAD PLAN ON SEC. 24 T45N, R37W IRON COUNTY, MICH.



FOREST TYPE MAP AND PROPOSED ROAD PLAN ON SEC. 24 T45N, R37W IRON COUNTY, MICH.



Scale

5 0 5 10 15 20
chains

LEGEND

- type line
- proposed woods road
- forest truck trail

Stand Volume Classes
' - poor - 3-7 cds
" - medium - 7-13 cds
''' - good - 13-20 cds
'''' - very good - 20+ cds
subscripts separate photo-cruise areas

Forest Types
A - aspen
M - northern hardwoods
P - pine
LB - lowland brush
Sx - bog or swamp

Size Classes
5-9 - poles

APPENDIX

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
OTTAWA NATIONAL FOREST

S
COOPERATION
University of Michigan

Iron River, Michigan
February 16, 1949

Prof. John Carow,
School of Forestry & Conservation,
University of Michigan
Ann Arborm Michigan

Dear John:

Your letter of February 14 is received.

Enclosed is a rough plat of the Consolidated W. P. & P. Co. sale in parts of Sec. 33 & 34 which we have called their "Powder House "job (their 7-10-45 sale). Section numbers are placed in centers of the sections. Road locations are approximately as constructed.

Volumes out were 1440 cords (unpeeled volume - peeled volume increased 12%) aspen, 282 cords white birch, 291 cords balsam, 9 cords spruce. Believe piececutters produced 100" peeled sticks which were drayed to roadside piles.

Think they expected to use Drott skid loader and did use it a little but most of it was loaded by hoists mounted on individuals' trucks with power take-off (they contracted most of the hauling and each trucker loaded his own wood by hand or with a power take off if he had one. Don't think all of the wood is out yet - some was hauled in November 1948).

Rheuben Smith, Box 307, Iron River, Michigan is their local woods superintendent. He may have the cost data you want or be able to get it for you or have it sent by their accounting department at Rhinelander, Wisconsin.

Very truly yours,

Max A. Melick

MAX A. MELICK
Forest Ranger

enc.

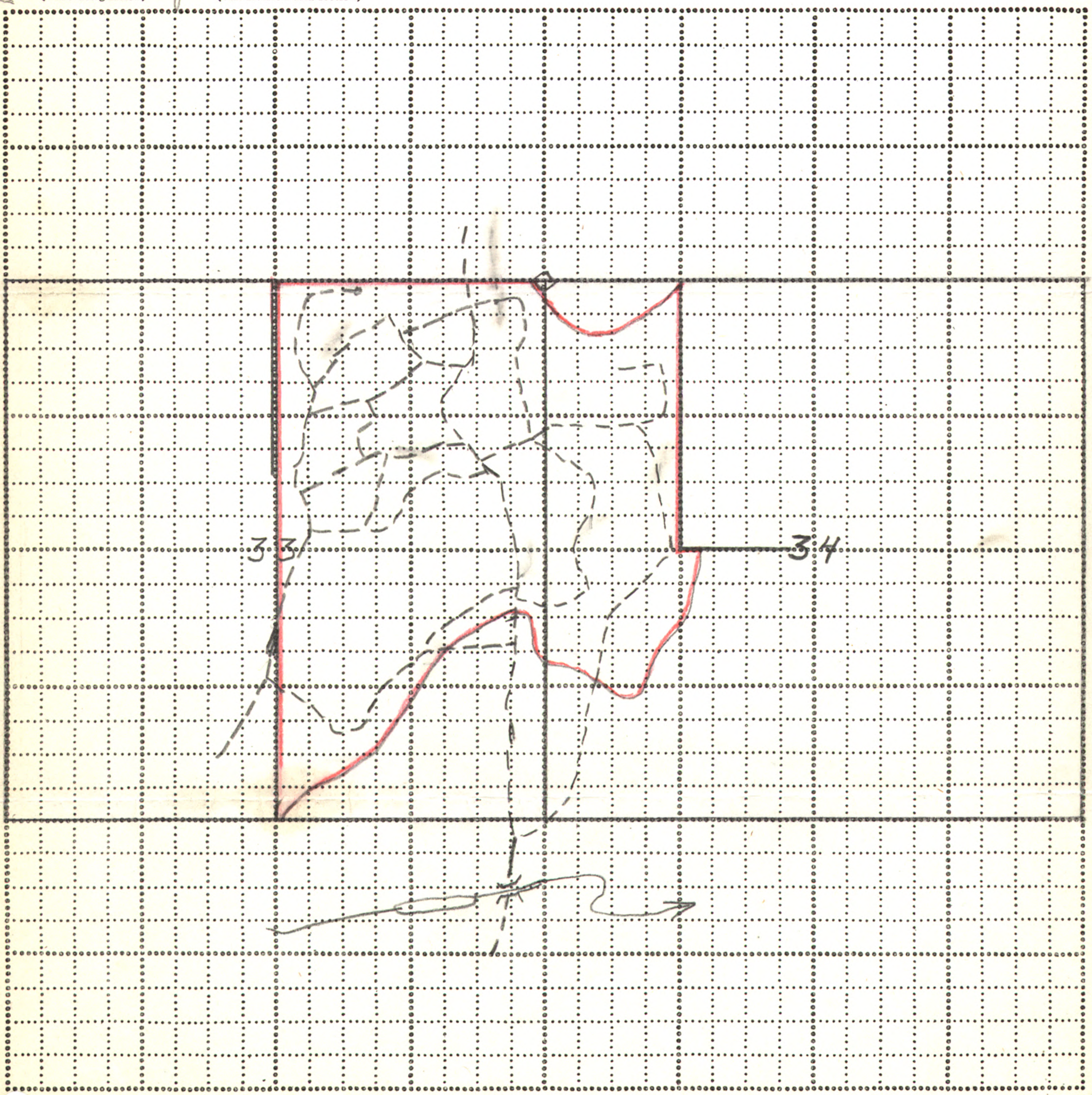
Form 878
(Rev. Feb. 1930)

5
SALES
Consolidated Water Power & Paper Co
7-10-45

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE

________________ Land district. Mag. declin. ________________ Area ________________ acres

________________ (Case designation) Part of Sec 33 & 34 (Subdivision and section) T. 45 N R. 37 W, Mich. Mer. Scale 4 inches=1 mile



Field work by ________________ Date ________________ Platted by ________________

Remarks ________________

Approved ________________, 19____ ________________

U. S. GOVERNMENT PRINTING OFFICE 8—3466

Approving Officer.

Iron River, Michigan
February 25, 1949

Mr. John Carow
Assistant Proffessor of Forest Management
Ann Arbor, Michigan

Dear Mr. Carow:

Reference is made to your letter of February 21 regarding costs on our operation in Sections 33 and 34 T45N-R37W.

We are glad to give you the information you wish and we assume that you are interested only in costs on the points of the pperation as set down under items 1, 2 and three of your letter. Perhaps, in order to give you a more clear understanding of our method of operation, it would be well to cover briefly the different phases of the job from the starting point.

The first item on this job was the location of logging roads. Timber type maps were used to help out on the general location work. The prime factors used to determine the exact location were (a) volume of timber to be cut on a given area (b) skidding distance (5chains average) and (c) terrain. Construction was done by bulldozers following the location work.

Cutting and peeling followed road construction. This timber was cut and peeled in pole lengths, ie. two to four 100 inch pulpwood sticks per pole. This operation was followed by skidding pole length timber and bucking into 100 inch sticks and piling in skidways for hauling.

Skidding was done by crews of two men and one horse each. The cost of this operation was $3.50 per cord including horse hire. Production was at the rate of 0.50 cords per man hour. Trucking costs were $2.50 per cord hauled from the woods to the cars including truck hire. Production on hauling was 1.25 cords per man hour. Average truck load was 4.00 cords. Road construction costs for the whole pperation including skidway or landing construction was $1,096.50. Road costs per cord was $0.59. These costs do not include liability, social security or unemployment insurance.

I am very much interested in the possible use of aerial photos in planning logging operations and will appreciate all the information you can give me on this subject. If we can be of further assistance to you on a like matter please feel free to write to us at any time.

Very truly yours,

Rheuben V. Smith
Area Supervisor Aide

Iron River, Michigan
April 14, 1949

Mr. John Carow
Assistant Professor of Forest Management
Ann Arbor, Michigan

Dear Mr. Carow:

Reference is made to your letter of March 30 in regard to our operation in Sections 33 and 34, T45N-R37W.

The skidding cost of $3.50 per cord includes the bucking and piling of the wood. Most of the wood on this area was peeled in pole lengths of from 2 to 4 100 inch pulpwood sticks. The poles were then skidded out to the landings on the logging roads, bucked into 100 inch lengths and piled in ricks. The skidders were paid at the rate of $3.00 per cord for skidding, bucking and piling. The rate of horse hire is set at 50¢ per cord. The rate for skidding is set at $1.50 per cord for 100 inch rough wood. The rate for bucking and piling after deducting $1.50 for skidding and 50¢ for horse hire from the rate of $3.50 would amount to $1.50 per cord. Bare skidding cost per cord including horse hire is $2.00.

Tractor ownership and operating costs were included in the road costs on this area. Reworking old roads on this job cost as much as the construction of new roads. The cause of this was an unusually large amount of rocks and boulders in the old road beds and a cut on one hill on the main hauling road. The maximum skidding distance on this job was about 400 feet. I do not understand what you mean by an optimum average road spacing of 400 feet. Our roads are spaced nearer to 800 feet thus giving us about 400 feet of skidding distance from each road.

Could you send me a tracing of the roads in this area as taken from the aerial photographs? Please write to me if you need aditional information on this job. The piece-rates for skidding and hauling were set to meet the wage requirements for work in this area or locality but not the requirements of the particular job.

Sincerely yours,

Rheuben Smith

Rheuben V. Smith

C of road construction $1,096.50
Not $1059.00

*

Table For Determining Size and Volume Classes from Aerial Photos.

Total height	Crown		Size class	Volume class			
	Texture	Diameter		Poor	Medium	Good	Very good
Feet	Feet			Crown closure percentage			
100	Coarse	30-	Large saw timber	10-33	33-65	65-90	90-
90	Coarse	30-	Large saw timber	10-40	40-75	75-100	100
80	Coarse	30-	Large saw timber	10-50	50-90	90-	
80	Cobbly	20-30	Large saw timber	10-55	55-		
80	Pebbly	15-20	Small saw timber	10-40	40-70	70-100	100
80	Sandy	10-15	Small saw timber	10-25	25-50	50-75	75-
70	Coarse	30-	Large saw timber	10-70	70-		
70	Cobbly	20-30	Small saw timber	25-40	40-85	85-	
70	Pebbly	15-20	Small saw timber	25-55	55-90	90-	
70	Sandy	10-15	Small saw timber	40-70	70-		
60	Coarse	30-	Small saw timber	25-55	55-90	90-	
60	Cobbly	20-30	Small saw timber	25-55	55-		
60	Pebbly	15-20	Small saw timber	40-70	70-		
60	Sandy	10-15	Pole timber	10-30	30-50	50-75	75-
50	Coarse	30-	Small saw timber	25-55	55-		
50	Cobbly	20-30	Small saw timber	55-			
50	Cobbly	20-30	Pole timber	10-35	35-60	60-90	90-
50	Pebbly	15-20	Pole timber	10-40	40-70	70-	
50	Sandy	10-15	Pole timber	25-50	50-90	90-	
40	Coarse	30-	Small saw timber	40-85	85-		
40	Cobbly	20-30	Pole timber	25-55	55-90	90-	
40	Pebbly	15-20	Pole timber	25-70	70-		
40	Sandy	10-15	Pole timber	55-			
40	Patted	0-10	Restocking	10-50	50-75	75-	
30	Pebbly	15-20	Pole timber	70-			
30	Other classes		Restocking	10-50	50-75	75-	
20	All classes		Restocking	10-50	50-75	75-	
10	All classes		Restocking	10-50	50-75	75-	
5	All classes		Restocking	10-50	50-75	75-	

* Taken from Photo Rule instruction pamphlet.

LOCAL CUBIC FOOT VOLUME TABLE
FOR PEELED ASPEN
Data Taken in T45N R37W
Iron County, Michigan.
June 27, 1947

DBH	VOLUME, cu. ft. (peeled wood)	No. TREES in sample
5.0	1.9	4
6.0	3.0	17
7.0	4.5	19
8.0	6.5	15
9.0	8.6	19
10.0	10.9	17
11.0	13.6	9

Computed by Form Basal Area Method

GLOSSARY OF TERMS

1. Density factor - as it is used here it is the arithmetical product of the crown density on a given area and the acreage of that area.

2. Economic road lengths - the length of road on a given area of similar volume per acre that would result in the lowest total cost when considering road cost and variable skidding cost.

3. Economic road spacing - the spacing of roads that results in the minimum total cost for both road construction and variable skidding.

4. Fixed skidding cost - a cost component of skidding that is independent of distance, including such costs as are involved in hook and unhook time, average time lost due to hang-ups, and miscellaneous delays.

5. Skid roads - as used here it refers to roads to which products are skidded for loading onto trucks.

6. Stereoscope - an optical instrument for blending into one image two pictures of an object from slightly different points of view, so as to produce upon the eye the impression of relief.

7. Stereoscopic pictures - two pictures of an object or taken from slightly dfferent points of view which produce, when viewed under a stereoscope, upon the eye the impression of relief.

8. Variable skidding cost - the cost of moving logs that is proportional to distance; that is, the costs that result from the part of the operation where the product is actually being moved or where the skidding device is returning for another piece.

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