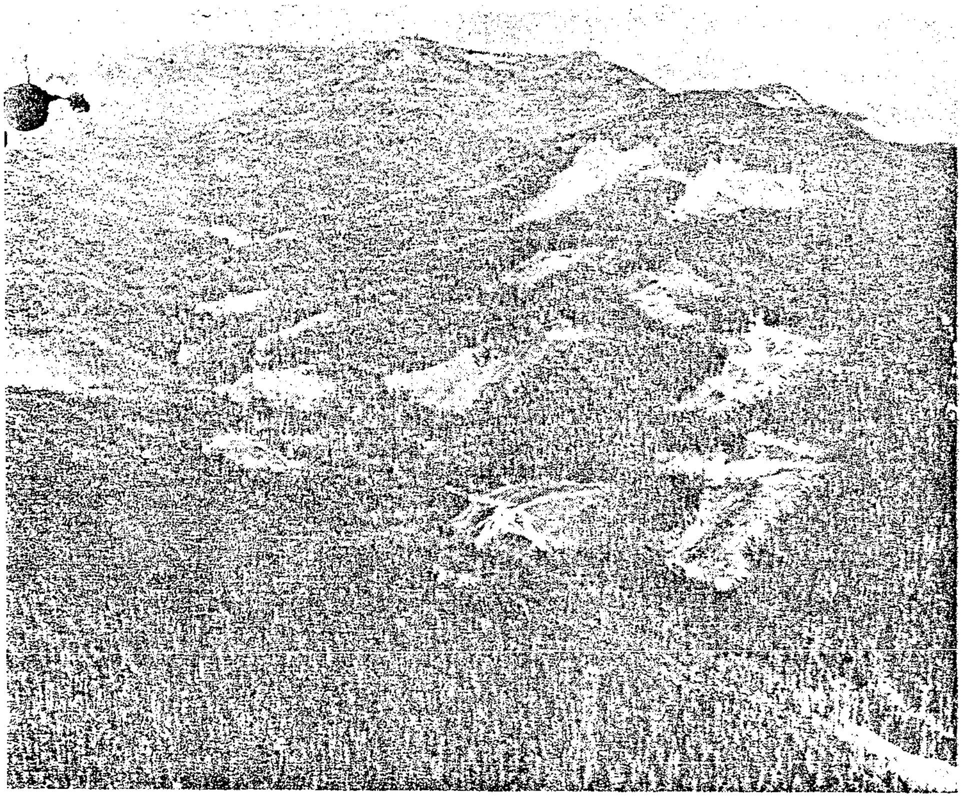

AIR VIEW of the H. J. Andrews Experimental Forest in Oregon, looking eastward toward the sunimit of the Cascade Mountains. General characteristics of road pattern arc shown.

More Efficient Road Patterns for a Douglas Fir Drainage

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IMPROVEMENTS in the pattern and efficiency of roads on the H. J. Andrews Experimental Forest have resulted from the development and application of a few simple principles for reducing road length. This advancement stems from the station's pilot plant studies into the use of complete forestry-logging plans in placing a virgin forest area under management. The beginning of this work is described in Robert Aufderheide's article "Getting Forestry into the Logging Plan" in THE TIMBERMAN, March 1949.

The H. J. Andrews Experimental Forest, established in 1948, includes the entire 15,000-acre drainage of Lookout creek in the Cascade mountains about 50 miles east of Eugene, Ore. In the past five years plans for operations in this old growth Douglas fir forest have been prepared for initial and reserve settings on about 8800 acres, including a road system of 71.6 miles. In the staggered-setting pattern of clear cuts, more than 78 million board feet have been sold; 27 miles of road have been contracted or constructed, and 44 miles of additional road have been located in reserve settings and marked on the ground.

Lookout creek is typical of most drainages in the Oregon Cascades. Stream pattern is complex, and elevations range from 1500 feet at the mouth of the creek to a rim of peaks 2500 to 5200 feet high. Only about one-fifth of the area is in benches and gentle topography. The remainder is steep with occasional rock outcropping. Old lava flows have formed lines of bluffs at some elevations. The drainage is covered mostly with a 400-year-old Douglas fir stand in various states of preservation, but many patches of young growth are found near the ridgetop where crown fires killed the old stand.

Two contrasting road patterns, one random and the other systematic, have been tried in the layout of the forestry-logging plan. The random pattern, including about 29 miles of road, was laid out in 1949 and 1950 for 3273 acres on the south side of Lookout creek, shown in Figure 1. Using the best prevailing practice, road locators took advantage of a very thorough knowledge of the ground and based the plan on economic yarding distances and good watershed management. However, it was a random pattern in the sense that no systematic approach was used; the road system was planned from year to year to meet an annual cut of 20 million board feet. During 1951, in contrast, a systematic pattern was tested in planning the remaining 43 miles of road which included the north side of Lookout creek, illustrated in Figure 2. These two road patterns, then, provided a basis for the comparison reported here.

Principles of Road Planning

A search of American and European literature was of little avail in providing the principles of road planning for mountainous terrain. The way a systematic pattern was developed for the H. J. Andrews Experimental Forest can best be illustrated by considering a very simple forest drainage, as in Figure 3.

A typical road system for this drainage, Figure 3-a, consists of several takeoffs from the main road and many spurs. An improvement over such a pattern has long been demonstrated for flat and uniformly sloping areas; that is, a system of parallel roads spaced at the "economic" interval, the interval at which road and yarding costs balance to give a minimum cost. Applying this idea to our simplified drainage might give a pattern of roads switchbacking at regular intervals, such as Figure 3-b, or one climbing at maximum grades in the same direction as the main road, as in Figure 3-c. But these alternatives result in more road than is needed to log the timber, and most of the roads are on steep gradients.

A pattern that will overcome these objections can be developed by locating most of the roads parallel to the main road and using a single climbing road to join the levels, as Figure 3-d. Thus, the basic principle for a systematic road pattern is: *Reduce the number of roads that climb between levels and increase the proportion of the drainage served by road levels spaced at the economic interval.* The term road level here implies parallel roads of any grade but so far as possible located with gentle favorable grades.

Of course, few drainages are as simple as that in the illustration. Usually, side slopes are cut up by tributary drainages, and distances from stream to ridgetop vary greatly. As a result, the number of road levels on slopes must change from place to place. On the north side of Lookout creek, for example, three road levels are enough northwest of McRae creek, but as many as six are needed elsewhere (see Figure 2). Where the valley is narrow and steep, few levels are required. As the valley widens, more road levels are needed, and a climbing road must be added to start each level. When the valley narrows again, extra levels must end to preserve efficient spacing. By keeping in mind that climbing roads create most of the inefficient mileage, the art of designing an efficient road pattern, then, becomes largely a matter of judgment in starting and ending road levels.

Designing an Efficient Pattern

The 1951 plan for a systematic road pattern on the H. J. Andrews Experimental Forest was prepared on a topographic map for the entire area under management. As a first step we located the theoretical minimum number of road levels required for efficient timber harvesting over a complete rotation. Instead of the usual procedure of trying one lengthy road location after another, we marked short dashes on the map to indicate the best available road location at economic intervals from stream to ridgetop. These marks were made at fairly regular intervals on every main slope, proceeding from the lower end of the drainage to the headwaters.

Control points such as saddles, good stream crossings, critical landing areas, and switchback locations were also designated. When the initial marking was complete, we connected dashed lines of about equal elevation to form a series of road segments that roughly paralleled each other on level or descending grades. The best of several map trials wing this procedure was chosen as a basis for the systematic pattern of the 1951 plan.

Climbing roads were added as a second step. Three techniques were used to minimize the proportion of climbing roads. First, maximum allowable grades generally were used on climbing roads. Second, road levels already on favorable grades were used wherever possible to gain elevation. Lastly, the most gentle topography between road levels was used for climbing roads ; this technique minimized differences in elevation and reduced the length of climbing road required.

The pattern could not be applied inflexibly to every part of the forest. Occasionally other considerations conflicted with the most efficient pattern for logging. Expensive road construction, topographic obstacles, bridge locations, watershed protection, special yarding problems due to topography, the need for good landings, and the need for more direct routes for large timber volumes all sometimes called for more roads than were needed for timber harvesting alone. By using the systematic pattern as a yardstick of minimum road length, however, we could evaluate costs rather precisely in deciding how much extra road to build.

comparison of Old, New Patterns

A good comparison of the two road patterns in many respects is provided by the south and north sides of Lookout Creek. The same men planned both layouts. Similar objectives of forest and watershed management were used. All clear cuts followed the staggered-setting system of cutting and external yarding distances averaged **slightly** less than 700 feet on both areas. Each area ranges in elevation from about 1500 feet to 4500 feet with about equal proportions of difficult roadbuilding topography.

The areas are not strictly comparable in other respects. The south side of Lookout creek has a larger area of high elevations and longer continuous slopes. The north side has a major tributary and more complicated stream pattern. To some extent, these topographic differences are compensating, but they cannot be evaluated. The layout crew's gradual accumulation of experience is another factor which cannot be measured.

No direct cost comparisons are available. But a careful study of the two layouts, Figures 1 and 2, has shown fewer climbing roads, and a higher proportion of well-spaced road levels on the north side. Furthermore, an evaluation of road density, yarding distances, and gradients indicates that real advantages have resulted from a systematic approach.

Probably the greatest gain from this systematic pattern is in total road mileage per square mile of layout — 0.62 mile less road per section than the early layout. A better measure of efficiency is to compare each pattern with the theoretical minimum density of road. On flat land, for example, a quarter-mile spacing would require one road through each 40, or four miles per section. A sampling of 60 external yarding distances over both study areas indicates that the average road spacing is 1268 feet, or nearly one quarter mile. Thus, 4.16 miles per square would be the theoretical mininium. Actually the systematic pattern has 0.81-mile more road than the minimum. The difference is a measure of the extra mileage needed for connecting roads, landing spurs, and all forms of topographic obstncles. The less efficient random pattern required 1.43 miles more road than the minimum.

Amount of road constructed and acreage clear cut, though not yardsticks of road efficiency, indicate initial road development needs in the Cascades. About two miles of road were required per section. This mileage figure was remarkably consistent from sale to sale even though total road mileage snd acreage clear cut per section were reduced in later sales. Acreage clear cut was reduced to leave wider units of green timber between clear-cut settings for fire protection.

Optimum Yarding Distances

Another measure of efficiency is the effect of road pattern on yarding distance. Variation in road spacing from the exact "economic interval" would be a sensitive yardstick but difficult to obtain. Actually good road locations are limited, and of an optimum range of external yarding

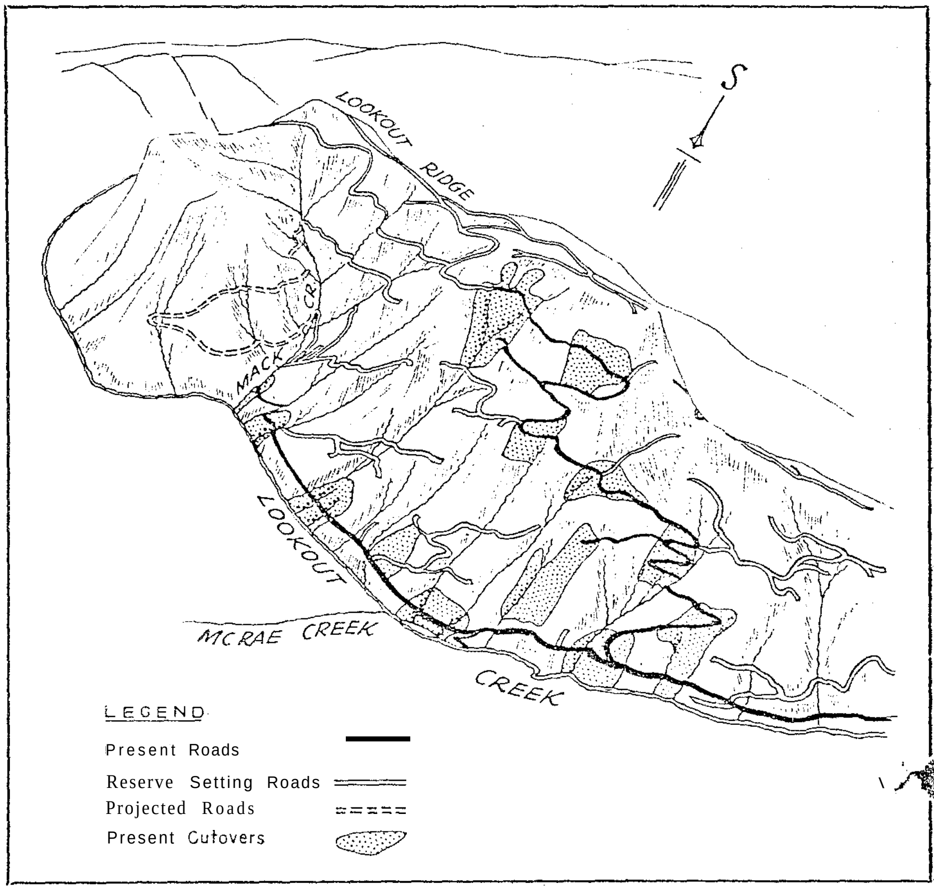

FIGURE 1 — Earlier layout on south side of Lookout Creek used random pattern. Steep grades are prevalent road density higher. yarding coverage poorer than in later pattern.

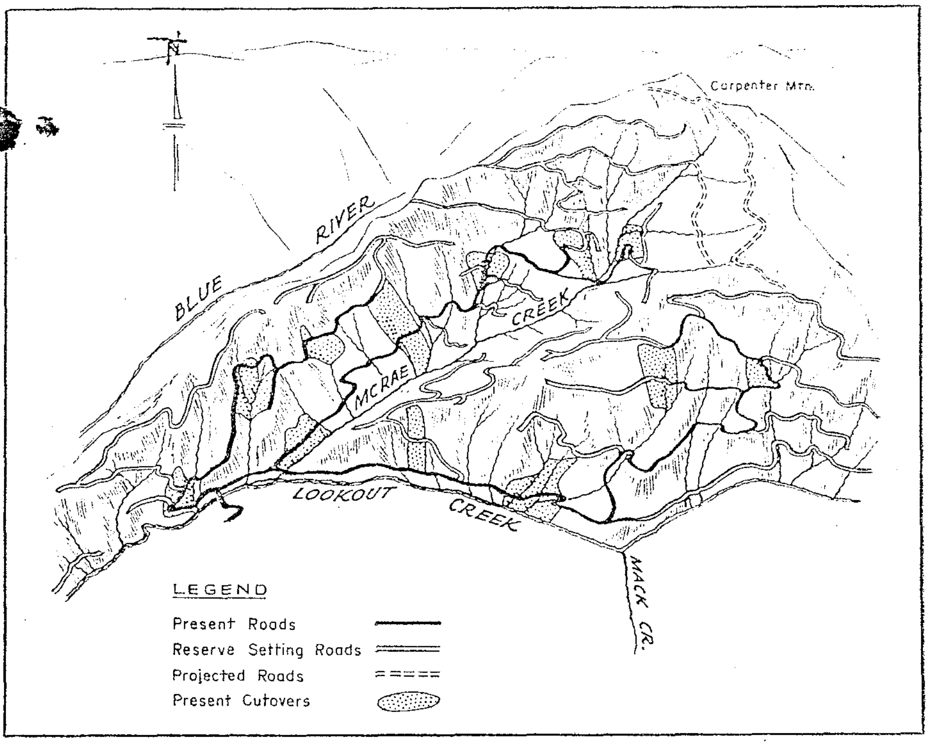

FIGURE 2 — Systematic road pattern was used on north side of Lookout Creek. Road levels are distinct, climbing road minimized. Road density is reduced, yarding improved.

distances as an index of spacing is easier and more practical. Within optimum range, costs are considered normal; outside this range total costs of yarding and road building increase rapidly.

In 1949, we estimated from earlier studies and local experience that this optimum yarding distance ranged between 400 and 900 feet for highlead and 500 and 1400 feet for tractors. These limits have been roughly verified from time to time, using yarding and road costs from the experimental forest. The computations have produced figures for optimum road spacing ranging from 980 to 1600 feet, depending upon equipment, spacing of landings, road costs, and stand volume.

Using 400 to 900 feet as optimum range for yarding, we found that the systematic pattern reduced the area outside optimum by nearly one-half — from 83.4 acres per section to 49.2 acres per section. Most of this reduction was in external yarding distances of less than 400 feet. A primary source of short yarding is to landings along climbing roads, which were greatly restricted in the systematic road pattern. Overly long yarding also was reduced, mainly because improved spacing of roads provided a more uniform spacing of landings.

How would additional reductions in road density affect yarding distance? The only answer available is from a 3700-acre tract in which road densities were reduced to 4.82 miles per section. Here the area requiring external yarding distance more than 900 feet rose again to nearly 20 acres per section. Thus, it appears that under a systematic pattern a reduction of road density to less than five miles per section may only result in longer yarding distances.

A third advantage of the systematic road pattern is a marked reduction in road grades exceeding 8% and a corresponding increase in the 0 to 4% and 4 to 8% gradients. Unfortunately the comparison of road grades between the systematic and random patterns is not as straightforward as other measures of road efficiency. Maximum sustained grade allowed in early layouts was 10%. The regionwide forest service standard was changed in 1951 to 7% sustained maximum. The new standards were followed in the systematic plan so that the new roads would qualify for permanent maintenance. Since climbing roads make up a high share of any road system in steep topography, naturally most roads were in the 8 to 12% gradient class before 1951, and in the 4 to 8% class later.

Still the gradient data indicate a more efficient plan through a systematic approach. First, it provided 10% more of light favorable grades (0 to 4%). Second, less road was required per square mile even though lower grades were used.

This trial has shown among other things that changing maximum grade standards may have relatively little effect on road density. Most of a road pattern in any drainage could conceivably be developed with parallel roads on level or gently descending grades. Such roads are mostly unaffected by changes in grade standard; but climbing roads, which make up a smaller share of the total mileage, are strongly affected. In this trial, climbing roads, those whose purpose is to climb between levels, accounted for only 19.2% of the road system. If a 10% rather than a 7% maximum grade standard had been used for every climbing road, the entire savings would have amounted to only 0.28 miles per section, or 5.7% of the present road system. But not all this possible saving could have been realized. About 49% of the climbing roads are located on steeper than standard maximum grade to avoid obstacles. Others were marked on the only feasible location.

The study also emphasizes the difficulty in eliminating steep favorable and adverse gradients. In spite of the desire to avoid them, 14% of the systematic pattern is in favorable grades in excess of 8% and 9.3% in adverse grades, mostly under 4%. The proportion of adverse grades remained about the same in both the random and systematic layouts.

The Forestry-Logging Plan

One of the more important by-products of systematic development of road patterns has been its usefulness in design of the staggered setting. Earlier work aimed for a somewhat circular setting with a landing in the center to minimize yarding costs. This type of setting often presented problems in finding good fire lines for slash burning. In addition,

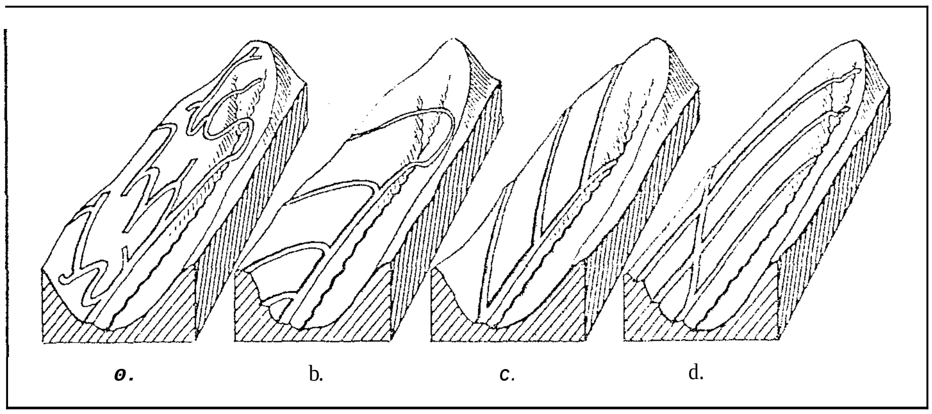

FIGURE 3 — Four road patterns: A—Random development; B—Switchbacks at regular intervals from lowest road; C—Regularly spaced roads climbing in direction of lowest road; D—Single climbing road with others on levels roughly parallel to valley bottom road.

windfall and trees which died on the upper and lower edges could not be efficiently sa1vaged without yarding through the setting and damaging the new crop of young trces

More recent forestry-logging plans with a systematic road pattern have used settings where a strip *or* patch is cut out between road levels. This type of cutting unit permits use of roads for upper and lower boundaries and orients side boundaries at right angles to the contour. All such boundaries make good fire lines. Windfall and mortality losses along the borders either occur along the roads or can be yarded straight up or down the cutting lines without undue disturbance within the setting. Furthermore, all future work, such as planting, thinning, or pruning, is made easier. Men and equipment can be hauled to the top so that ail work can progress downhill.

Extra costs in rigging up are the main disadvantage of this type of setting. Instead of "fuIl trees" to log the entire yarding circle, the newer cutting unit requires rigging "half trees" for yarding either above or below- the road. Also, the new type of unit may require a slightly higher initial road cost per thousand board feet harvested. However, total road mileage per square mile is ap-mately the same for both types of'unit

Thus, besides being more efficient for logging, the systematic road pattern has silvicultural advantages. The pattern has greatly influenced forestry planning on the experimental forest. The general principles may be useful on other forest properties.

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