

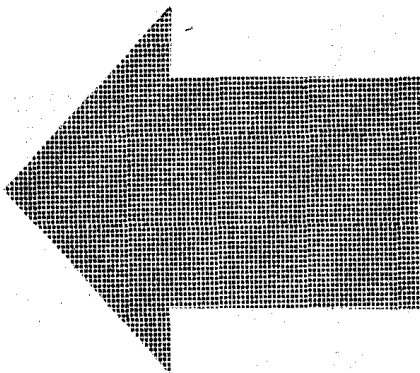
The **FRASER** *Experimental Forest* *.... its Work and Aims*

by L. D. Love, Forester¹

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In 1937 the Fraser Experimental Forest was established in the heart of the Central Rocky Mountains near the Continental Divide 65 miles north and west of Denver. This 36-square-mile outdoor research laboratory is well suited for the study of pressing problems related to water yield from high-elevation forests and alpine areas.

Here in the West, water is a basic resource. It is necessary to the life and livelihood of our people, hence the source of supply is vitally important to all of us. In Colorado the annual yield from the Central Rocky Mountains is about 20 million acre-feet. Eighty-five percent of this water comes from alpine areas and mountain forests. Each acre yields at least 1 acre-foot of water a year, enough to supply the needs of five families.



The relation between the sources in the high country, the elaborate transmountain diversion systems, and the users in the cities and on the irrigated farms is shown by this schematic helicopter view of the countryside surrounding the Fraser Experimental Forest.

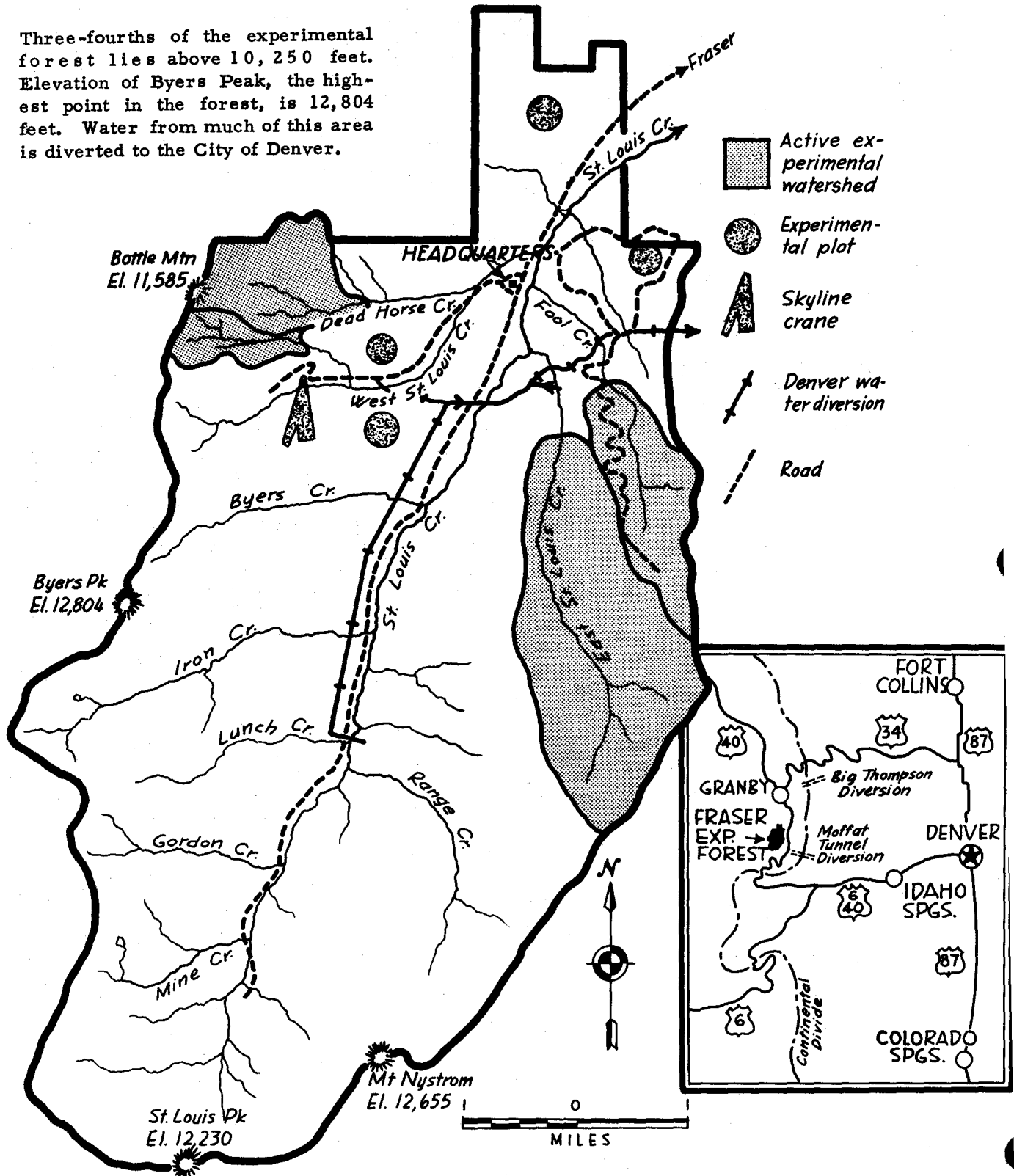
Here, we see the vast Colorado-Big Thompson transmountain diversion that taps the headwaters of the Colorado River and brings its water through a tunnel 9-3/4 feet in diameter and 13 miles long under the Continental Divide to far-off users in eastern Colorado.

Also, we see the Fraser River transmountain diversion constructed by the City of Denver to bring in water from St. Louis and Vasquez Creeks. This diversion passes through the Continental Divide via the pioneer bore of the 6-mile Moffat Tunnel.

¹ Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, with headquarters at Fort Collins, Colorado, in cooperation with Colorado State University.

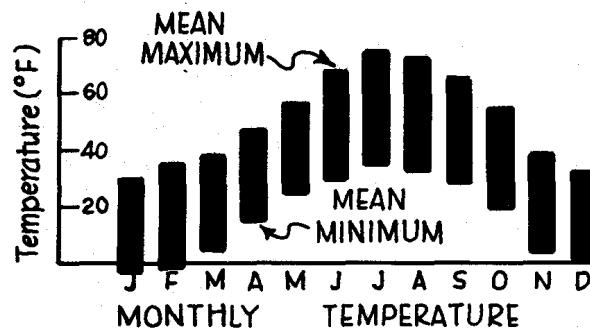
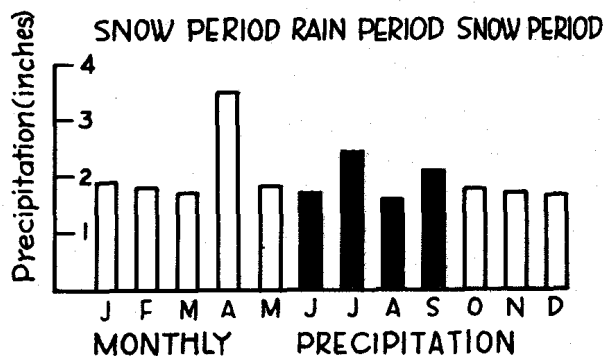
Facts about the Forest...

Three-fourths of the experimental forest lies above 10,250 feet. Elevation of Byers Peak, the highest point in the forest, is 12,804 feet. Water from much of this area is diverted to the City of Denver.



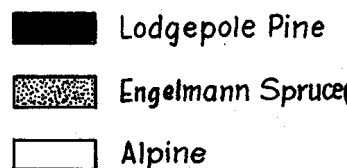
Climate

The climate is cool, with an average yearly temperature of 35°F. Mean monthly temperature for January is 15°F.; for July, 55°F. Growing season is about 75 days; the frost-free period is from mid-June to mid-September. Annual precipitation, two-thirds of which falls as snow, varies from 15 to 30 inches, with an average of 24 inches.



Vegetation

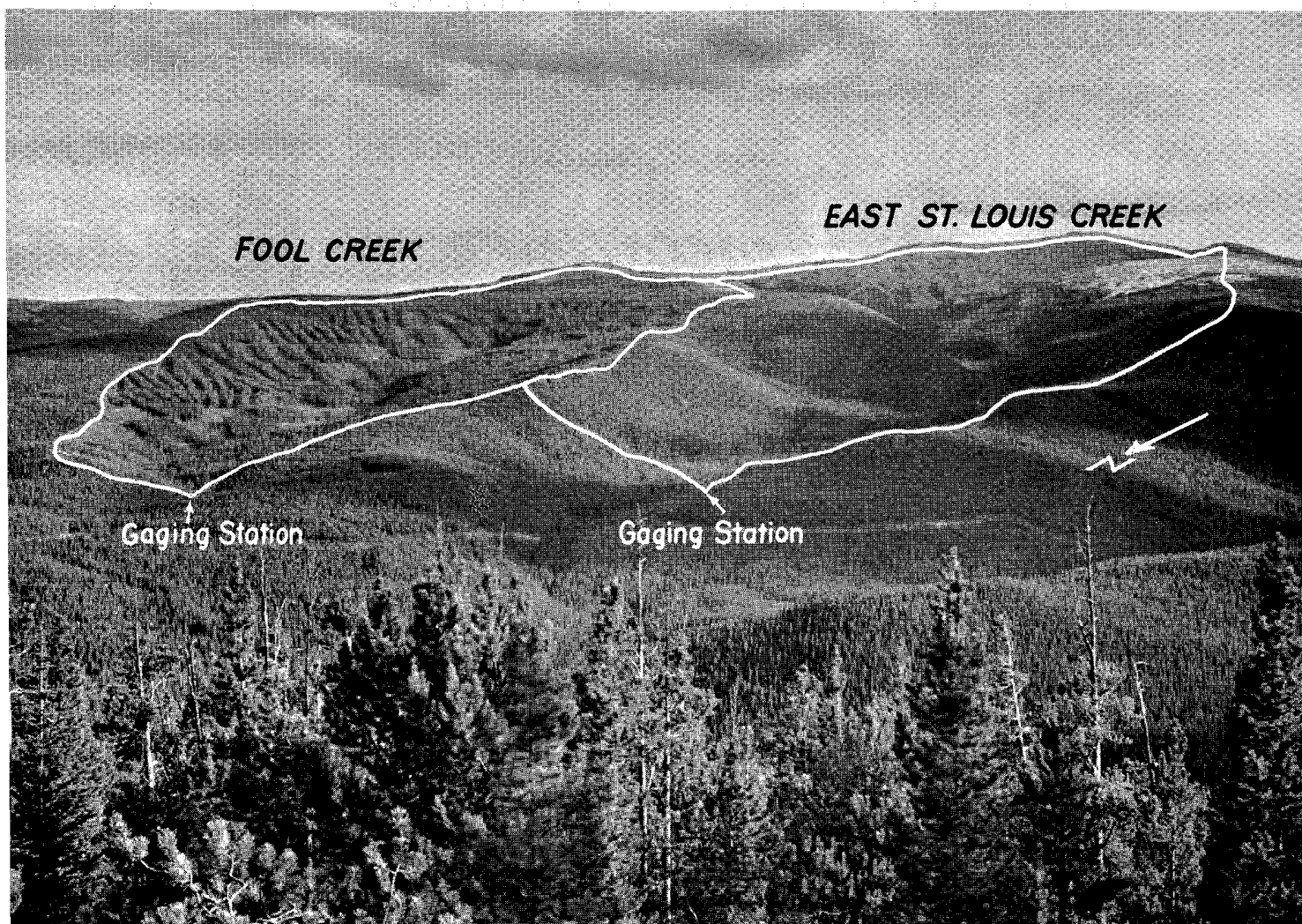
Lodgepole pine, Engelmann spruce, and sub-alpine fir are the important tree species. In virgin stands they commonly reach ages of 200 to 400 years. Quaking aspen grows in the openings left by fire and logging. The forest floor is covered with deep litter and often dense mats of grouse whortleberry. Young pine, spruce, and fir, along with scattered aspen and buffaloberry, also grow beneath the forest canopy. Higher in the alpine areas barren rocks intermix with meadows containing grasses, sedges, weeds, and dwarf willows.



Our Research Program

Most of the research at Fraser is concentrated on watershed management to improve and increase our supply of water. Records show that half of the annual precipitation on the forest becomes streamflow. This amounts to a water yield of 1 to 1.5 acre-feet per acre. About 70 percent of this yield comes from melting snow during April, May, and June.

Snowpacks and surrounding forest areas have been under study since 1937. First came observations in natural stands to see how forest types and canopy patterns affect snow accumulation. Next came plot studies of thinnings and harvest cuttings, and measurements to determine effects of winter accumulation of snow, spring snowfall and rate of snowmelt, summer precipitation, and evapo-transpiration of soil moisture. The final step in this logical sequence was to apply these systems of timber harvesting to whole watersheds then measure the effect on streamflow.



Effects of timber harvest on water yields are being studied on this pair of watersheds at the Fraser Experimental Forest.

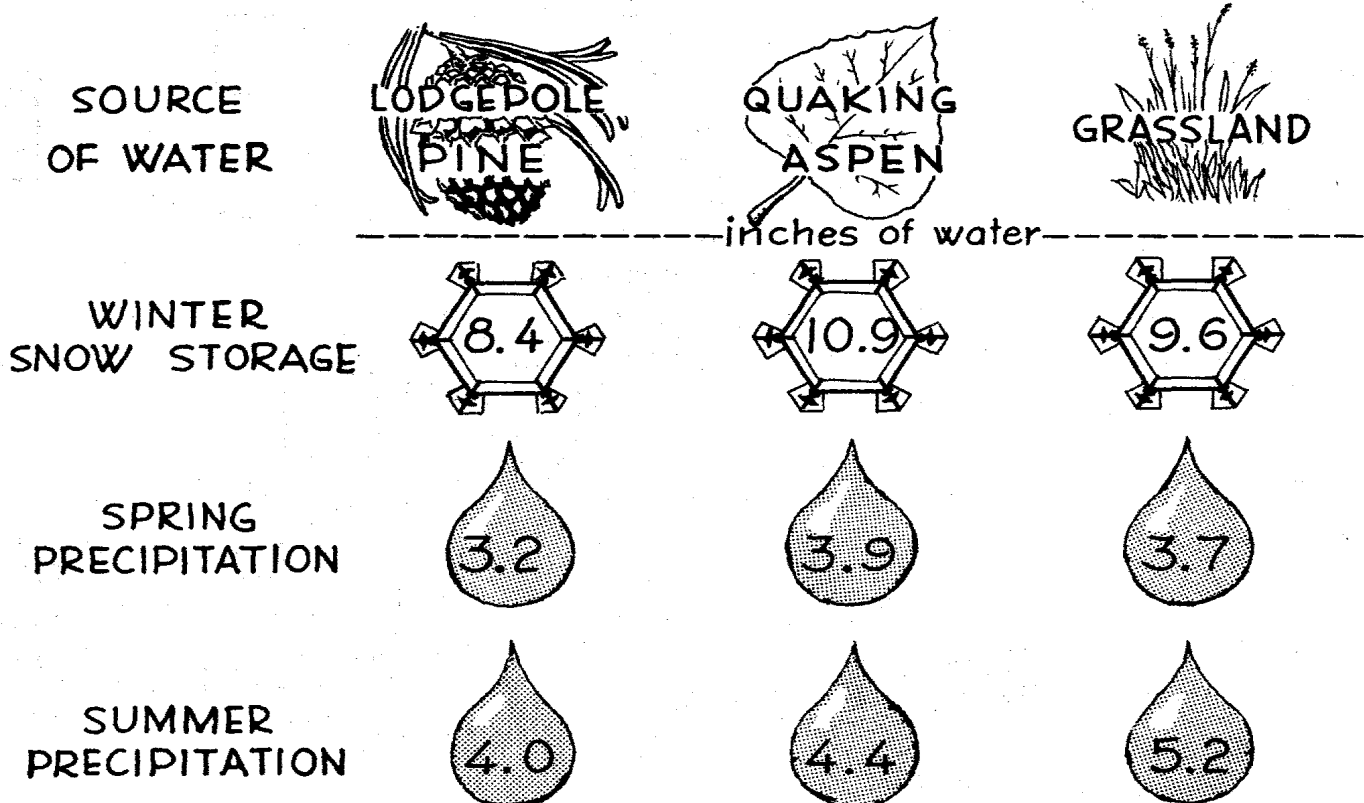
Some of the Highlights . . .

The following explanations, photographs, and diagrams will show briefly the results of our experiments during the past quarter-century.

Effects of Timber Harvesting

Early studies showed that less precipitation reached the ground under dense stands of lodgepole pine than under aspen and grassland. These studies were intended to give clues as to the effects that would be produced when forest stands were harvested for timber or thinned to stimulate tree growth.

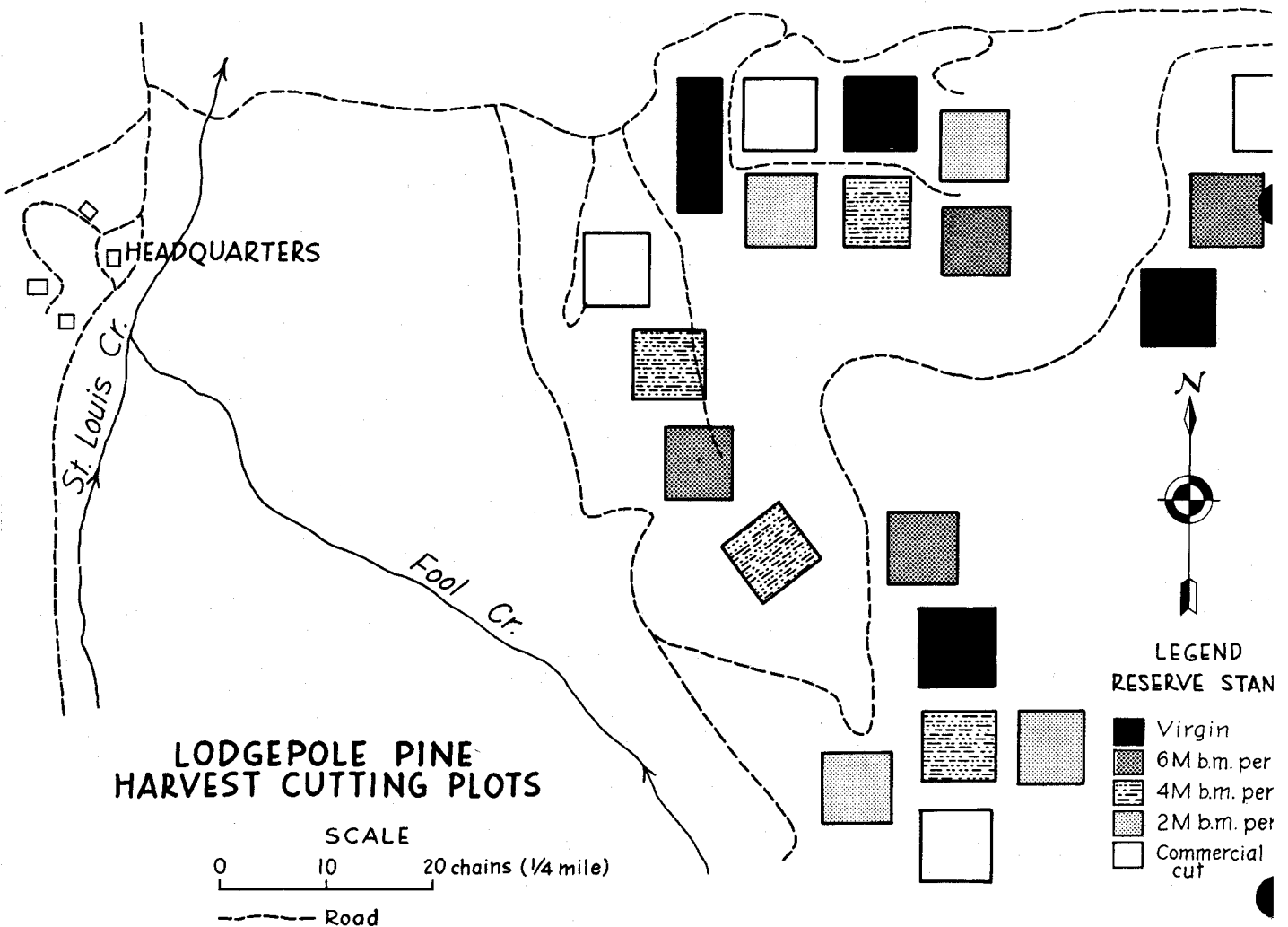
INFLUENCE OF THREE VEGETATIONAL TYPES



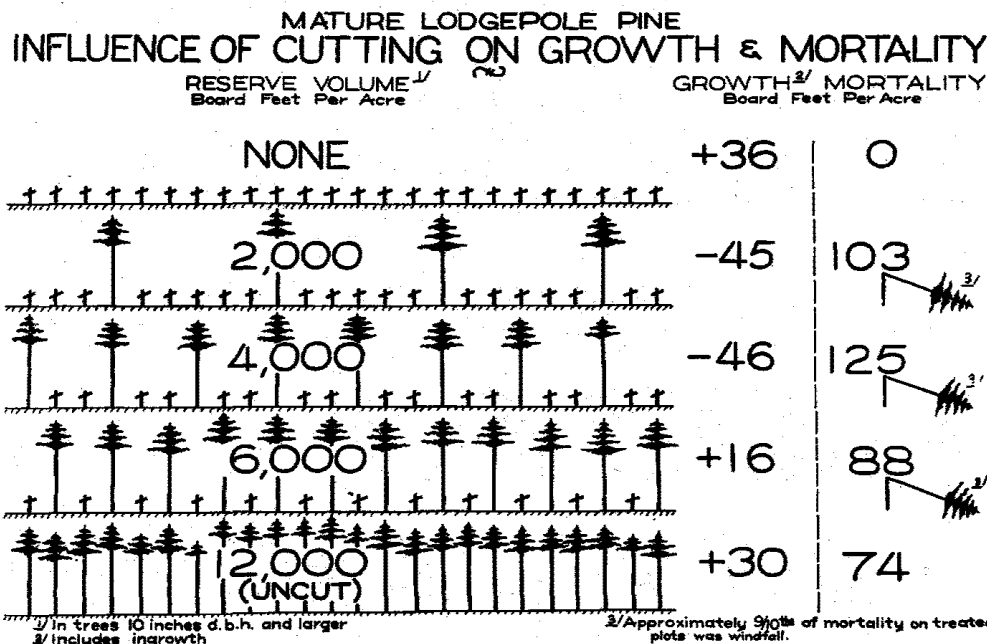
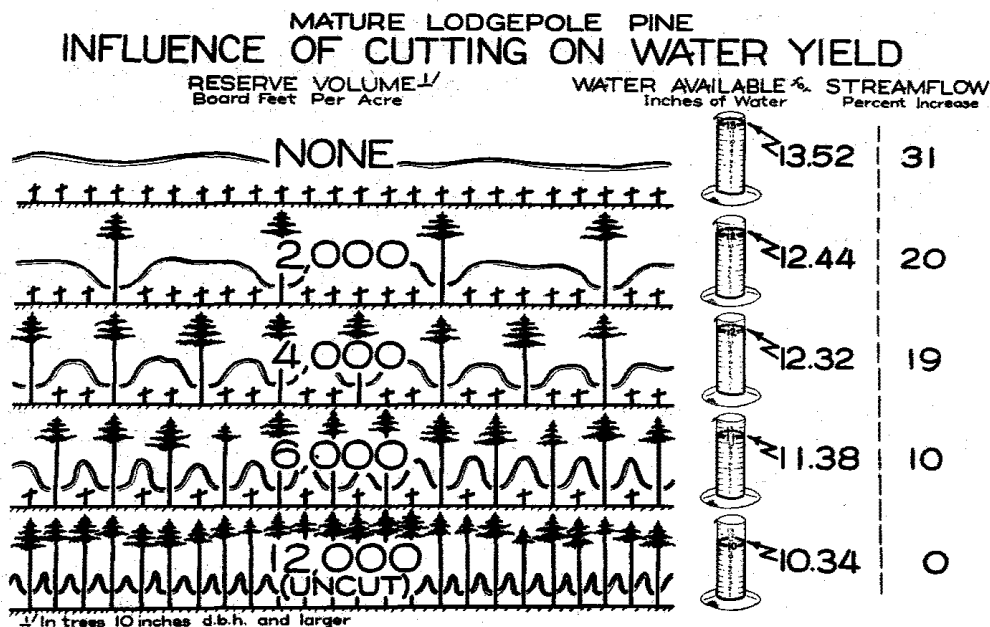


Harvest Cutting in Lodgepole Pine

Twenty 5-acre harvest-cutting plots for forest and watershed management research were laid out in mature lodgepole pine in 1938. In 1940, the plots were logged, ranging from a clear cut of all trees larger than 9.5 inches in diameter to an uncut virgin area. (See map.)



After trees are removed in timber harvesting, more of the winter snow can reach the ground. Here, less of its water content is lost to the air, and so more is available for streamflow. From the lodgepole pine plots an increase in water available for streamflow was as shown here.



Growth and mortality of the residual stand were also measured. Mortality exceeded growth on all of the cut plots except those cleared of all saw-log-sized trees. Principal cause of mortality was windthrow. This result, together with that from the hydrologic measurements, led to the conclusion that clear cutting of mature lodgepole pine is the most desirable method of harvesting.



Harvest Cutting in Spruce-fir

In 1944 an experiment to determine the best method of harvesting spruce-fir was started. The study consists of four 8-acre plots, three of which were treated differently and the fourth left as an uncut control. The treatments used are alternate-strip clear cutting, group-selection cutting, and single-tree selection cutting. In each plot 60 percent of the volume of timber was removed.

Alternate-strip clear cutting removed 50 percent of the volume by cutting all trees larger than 9.5 inches in diameter in alternate strips; an additional 10 percent was removed from the remaining area by cutting overmature trees. Damage to reproduction was moderate on the cut strips.

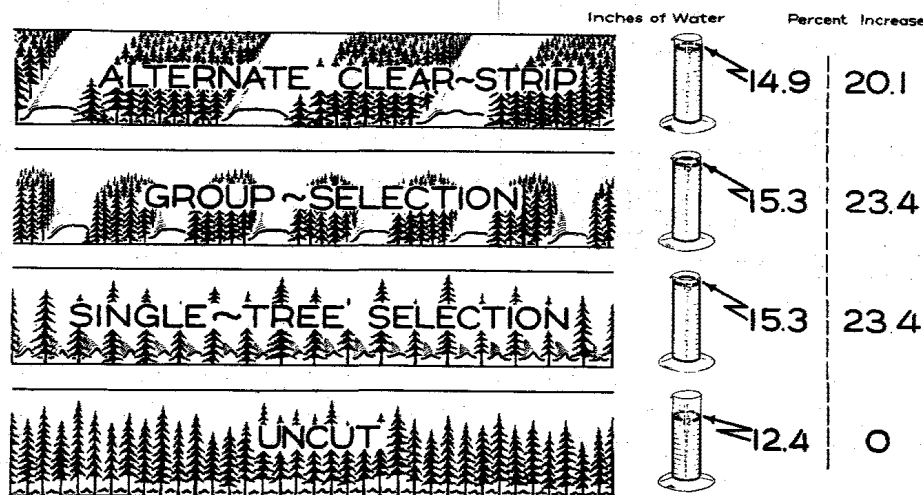
Group-selection cutting removed 50 percent of the volume by cutting all trees larger than 9.5 inches in diameter in small circular clear-cut groups; an additional 10 percent was removed from the remaining area by cutting overmature trees. Damage to reproduction was light in the openings.

Single-tree selection cutting removed 60 percent of the volume by cutting uniformly over the plot. No trees smaller than 9.5 inches in diameter were removed. Damage to reproduction was heavy on the plot.

SNOW STORAGE

Snowfall reaching the ground increased after harvest cuttings in the spruce-fir plots. Measurements in four of the years since logging show that the cut plots have stored an average of 22 percent more water than the uncut. No significant difference in snow accumulation results from variation in cutting. In all three methods, 60 percent of the volume was removed; only the pattern varied.

OLD~GROWTH SPRUCE~FIR INFLUENCE OF HARVESTING METHODS ON SNOW STORAGE



SNOWMELT

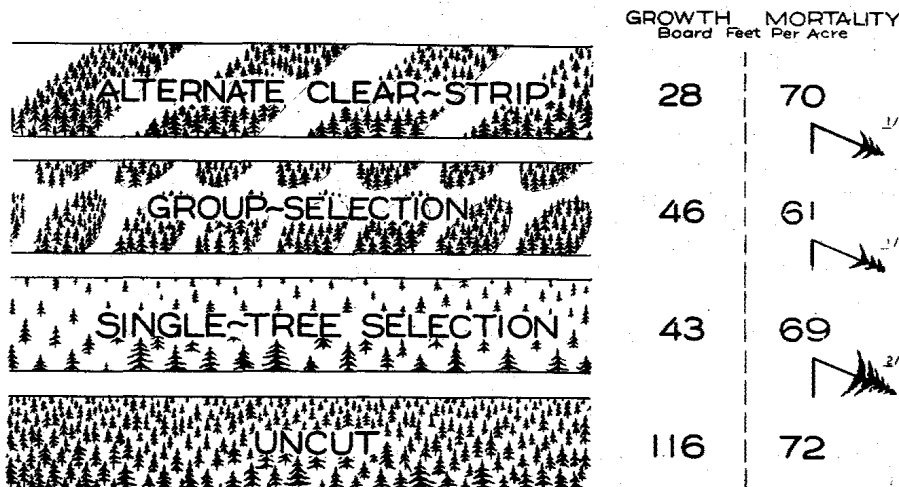
Weekly measurements during the spring showed only slight differences in the rates of melt. Snow melted at the slowest rate in the uncut plot. Effects of the different cutting methods showed:

	<u>Alternate strip</u>	<u>Group selection</u>	<u>Single tree</u>	<u>Uncut</u>
Melt water per day (inches)	0.34	0.31	0.36	0.28

GROWTH AND MORTALITY

Growth and mortality were also measured. These two factors as well as snowmelt were slightly more favorable under the group-selection pattern. However, because of the difficulty of applying the method, alternate-strip clear cutting was chosen for watershed studies at the experimental forest.

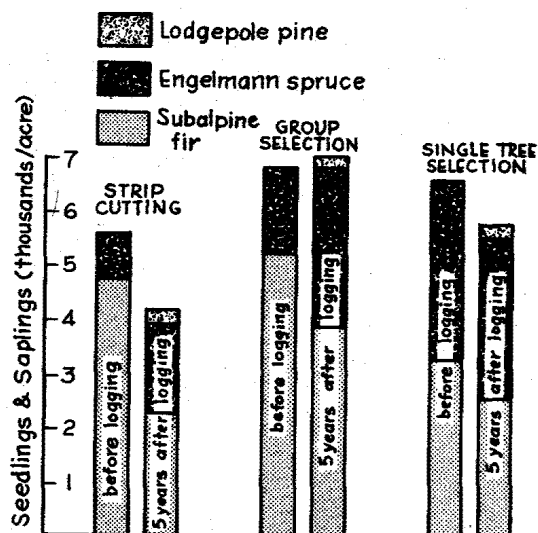
OLD-GROWTH SPRUCE-FIR INFLUENCE OF CUTTING ON GROWTH & MORTALITY



^{1/} 2/3rds of mortality was windfall
^{2/} 9/10ths of mortality was windfall

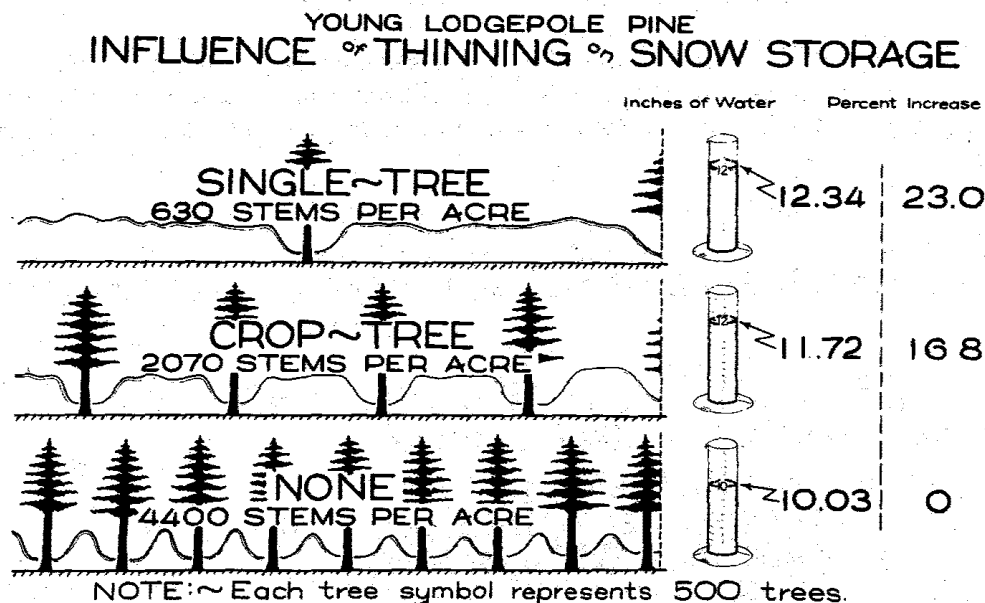
REGENERATION

Regeneration is usually adequate. Prior to cutting, the spruce-fir plots contained 6,344 seedlings and saplings per acre. Logging destroyed 52 percent. Subsequent reproduction raised the count to 4,809 per acre 5 years after logging. The new seedlings are composed of a higher ratio of spruce and some lodgepole pine, indicating that cutting favors these species over subalpine fir.



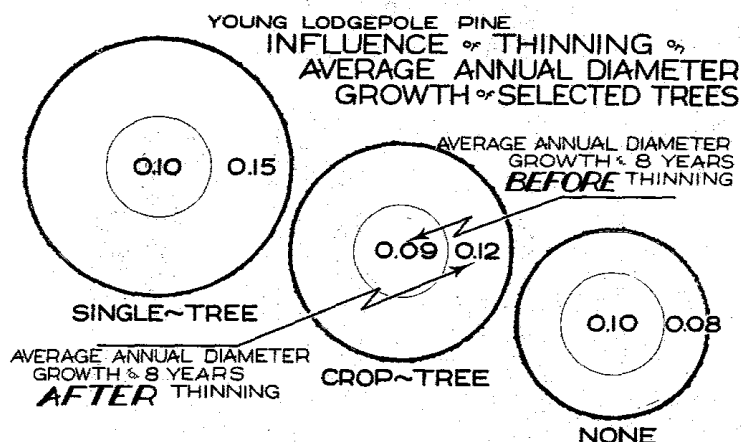
Studies in Young Lodgepole Pine

Two methods of thinning dense stands of 35-year-old lodgepole pine were used to study the effects on snow storage. On six 3/4-acre plots, single-tree thinning left 630 of the better trees per acre spaced 8.5 feet apart. On six other plots, crop-tree thinning consisted of cutting all trees in a 16-foot diameter circle around each of 100 of the best developed trees per acre. No thinning was done on six other plots. Snow storage was measured on all 18 plots. Here are the results:



In 1949 the rates of snowmelt on these plots were as follows:

	Single-tree	Crop-tree	Unthinned
Melt water per day (inches)	0.38	0.36	0.26



Intensive competition for growing space does not permit good development in the dense young stands of lodgepole pine that normally occur after clear cutting or fire. Lodgepole pine, although intolerant, does not thin well naturally. Severe crowding of young trees of the same size results in retarded diameter and height growth; therefore artificial thinning is needed.

[REDACTED]

Cutting timber on small experimental plots has resulted in the accumulation of greater amounts of water, mostly from added volumes of snow. Presumably this water will cause increased streamflow. The assumption is still problematical, however, until similar cutting is done in a forested watershed from which streamflow can be measured. A watershed study has been started to provide the answer.

FOOL CREEK WATERSHED

Fool Creek watershed, a 714-acre drainage, was selected for this study. Streamflow, rainfall, and snow storage have been measured since 1940. Average annual yield of water in streamflow would cover the watershed to a depth of 13 inches. Elevations range from 9,500 to 11,500 feet. About half the 6 million board feet of timber is lodgepole pine and the rest is a mixture of Engelmann spruce and subalpine fir.

EAST ST. LOUIS CREEK WATERSHED

East St. Louis Creek is the companion watershed to Fool Creek. It will not be logged. Since 1943 streamflow and snow storage have been measured on this 1,984-acre drainage. Elevations range from 9,500 to 12,000 feet; the vegetation consists of lodgepole pine, Engelmann spruce, subalpine fir, and alpine turf above timberline. Annual water yield is equivalent to an 18-inch depth over the area. The flow from the two experimental watersheds is well correlated and procedures are available to estimate the flow of Fool Creek from that of East St. Louis Creek.

Streamflow

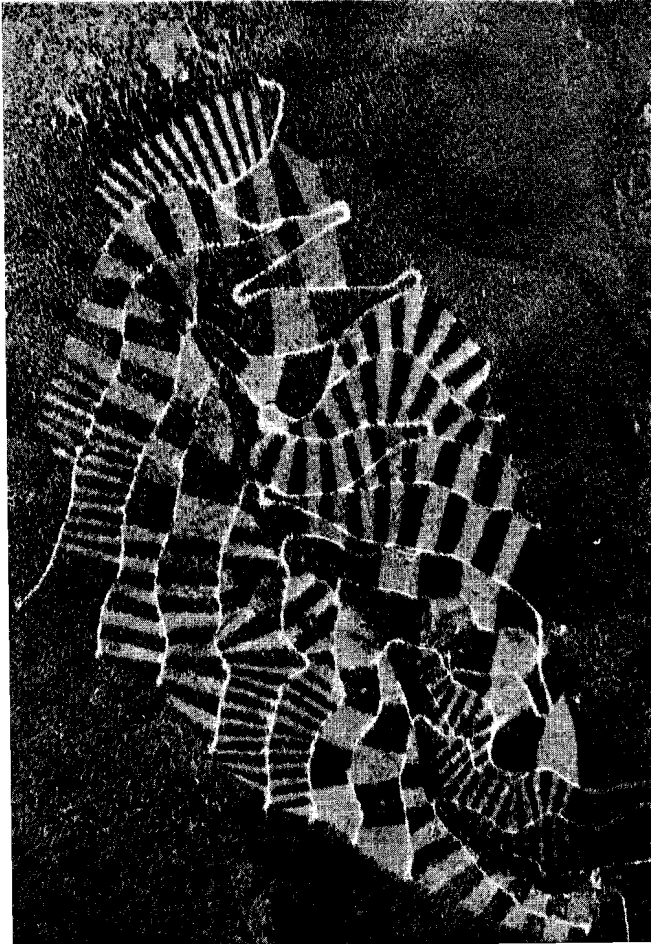
Streamflow is the quantity of surface water flowing past a given point in a stream channel and is measured by means of flumes, weirs, or stabilized channels. It is related to the cross-sectional area of the flume, weir, or channel, and to the velocity of the flowing water. Streamflow is expressed as a rate in cubic feet per second, or as an amount in acre-feet, or inches depth over a known area.

At Fool Creek the gaging station is a combination of a flume and two broadcrested weirs. Streamflow shown here is from snowmelt; water is flowing at the rate of 13 cubic feet per second.



Alternate-strip Cutting

To harvest the timber on Fool Creek watershed, roads (3.3 miles of main access and 8.6 miles of spur) were built in 1950 and 1951. Timber harvest began in 1954 and ended in 1956. Alternate clear-cut strips extending up and down slopes are bounded at the ends by contour roads. Four widths of strip were used: 1, 2, 3, and 6 chains. The slope length of most strips is about 600 feet, the slope distance between spur roads. To minimize damage to the stream course, no timber was cut within 90 feet of the main stream. On the strips designated for cutting, all live trees 4 inches d.b.h. and larger were felled. The tops were lopped and scattered. Merchantable forest covered 550 acres of the total 714 acres in the watershed, with 55 percent in the lodgepole pine type and 45 percent in the spruce-fir type. The stand was 250 to 300 years old.



Watershed area cleared was 278 acres. This includes 35 acres in road system and 243 acres of clear-cut strips, which yielded 3,560 M b.m. of timber in the following products:

	<u>M b.m.</u>	<u>Percent</u>
Saw logs	2,200	62
Poles	1,000	28
Posts	60	2
Pulp	300	8

Water-yield Effects

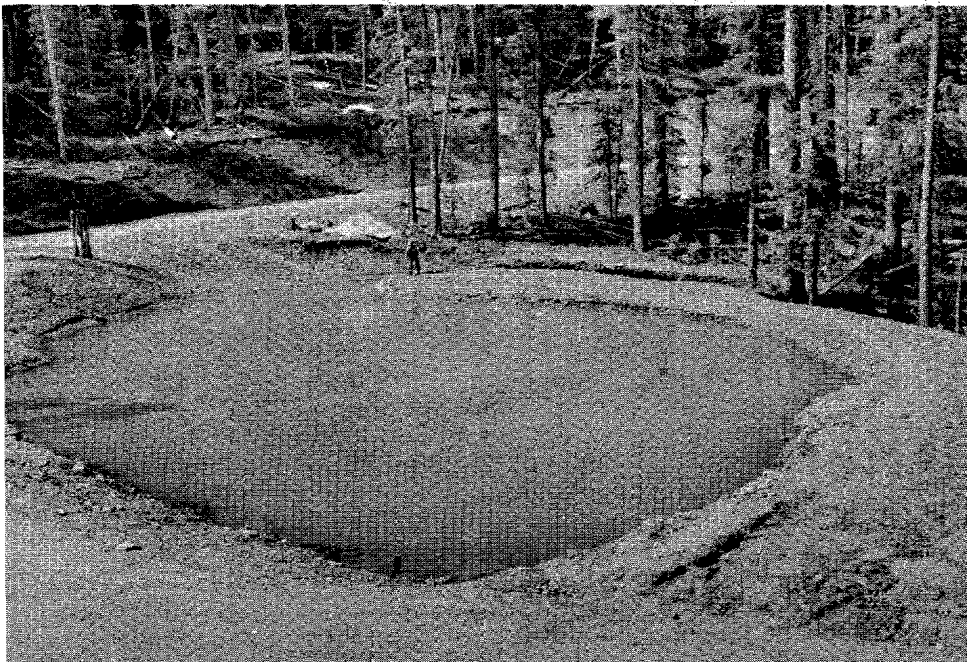
The analysis to determine the effect of the treatment on water yield consists of estimating what the yield of Fool Creek would have been if there had been no treatment, and comparing this estimated value with that recorded. The watershed of East St. Louis Creek has not been disturbed by timber harvest, and so remains as a "control" with its streamflow reflecting only the natural annual variations in climate.

The estimated increase in water yield from the Fool Creek watershed was

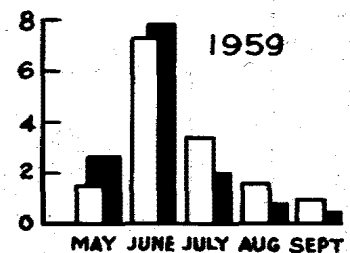
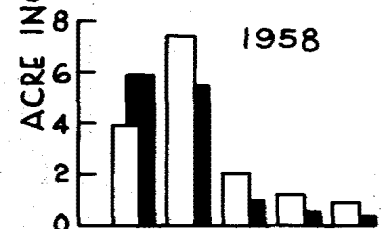
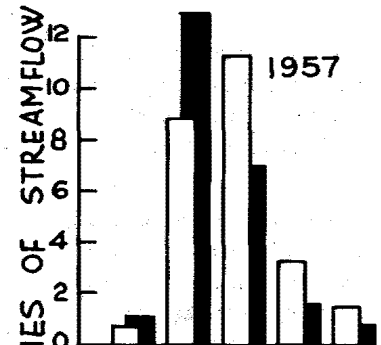
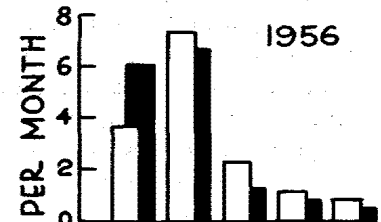
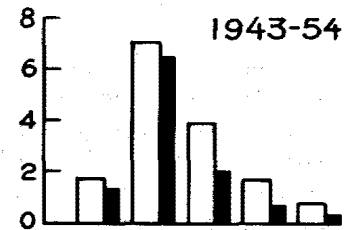
	1956	1957	1958	1959
Acre-feet	254	200	125	186

Sediment yield

The study was not designed to determine the effect of timber harvest and its accompanying road system on sediment yield. However, to confirm the belief that erosion would not be a problem, a sediment basin was constructed in 1951 immediately below the stream-gaging station. Sediment yield has been low and is correlated with discharge. Because measurements were begun after the road system was constructed, no conclusions can be drawn as to the effect of the watershed treatment on sediment yield. However, the annual sediment yield from the watershed following logging averaged only 1.5 cubic feet per acre, wet volume.



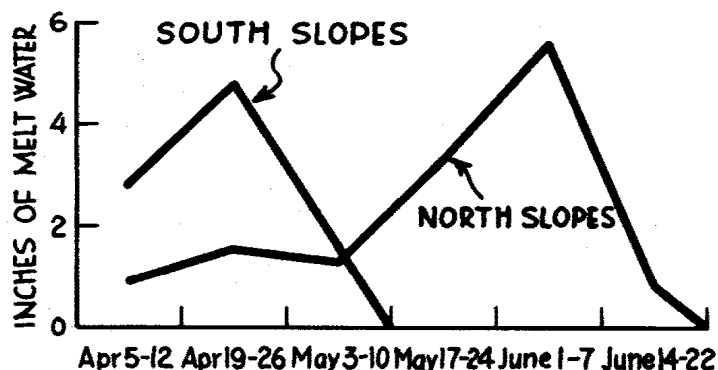
□ East St. Louis Creek
1984 acres
■ Fool Creek 714 acres



Pond of 1/4 acre-foot capacity in which to trap sediment

Snow-cover Disappearance

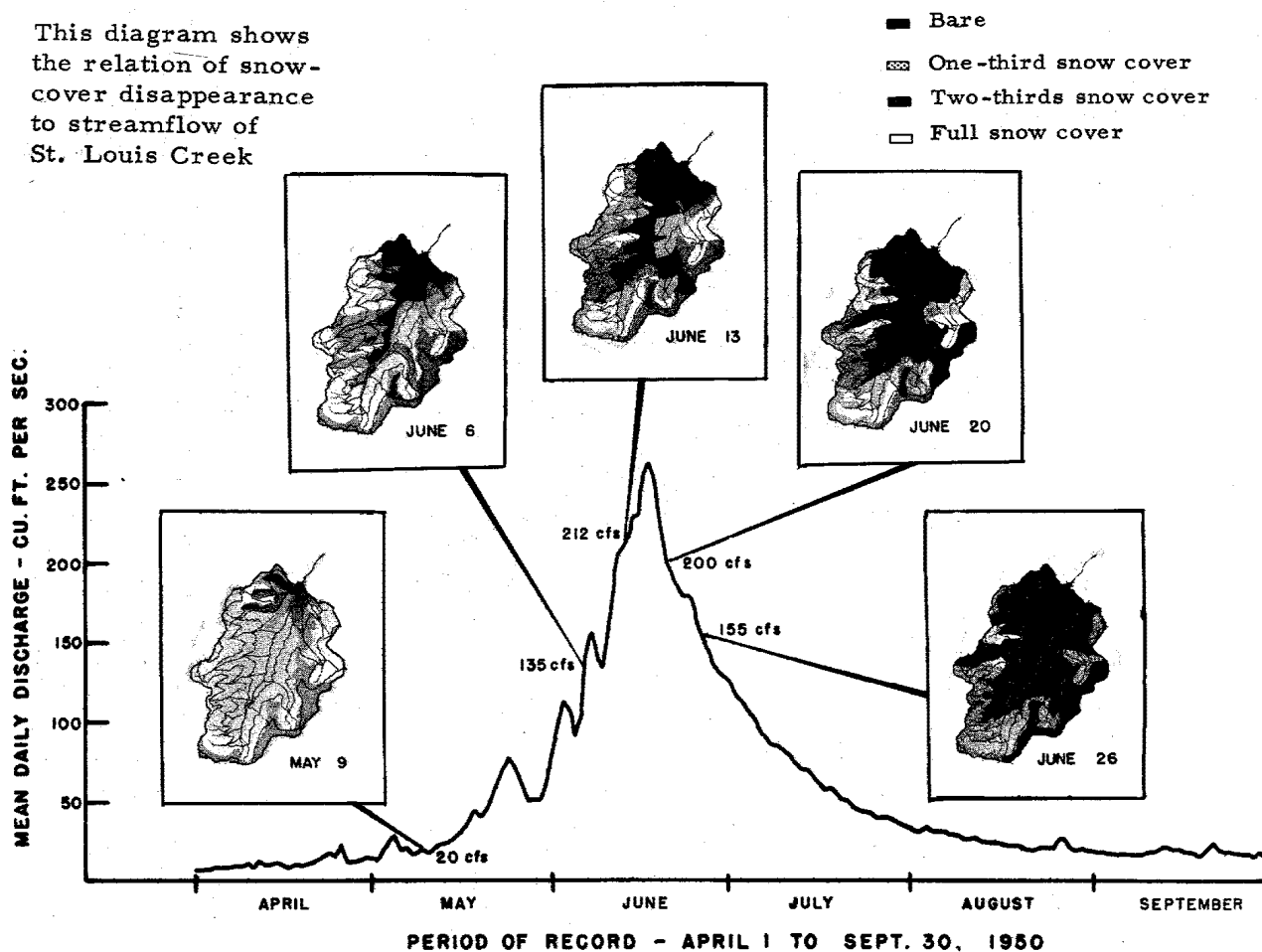
At the end of winter the entire forest is covered with snow. Snow melts and disappears from south slopes about a month before it does from north slopes (see graph). As spring advances, the snow disappears progressively from the lower elevations to the higher. When one-half of the snow has disappeared, the spring peak in streamflow is approached; when 80 percent of the snow is gone the stream is declining in flow.



WEATHER FACTORS

Temperature, humidity, and wind also influence the daily rate of snowmelt which, in turn, governs spring streamflow. Continuous records of these factors are useful in calculating rates of streamflow for the main St. Louis drainage. Cooperative studies with the Bureau of Reclamation have resulted in methods of forecasting daily streamflow.

This diagram shows the relation of snow-cover disappearance to streamflow of St. Louis Creek

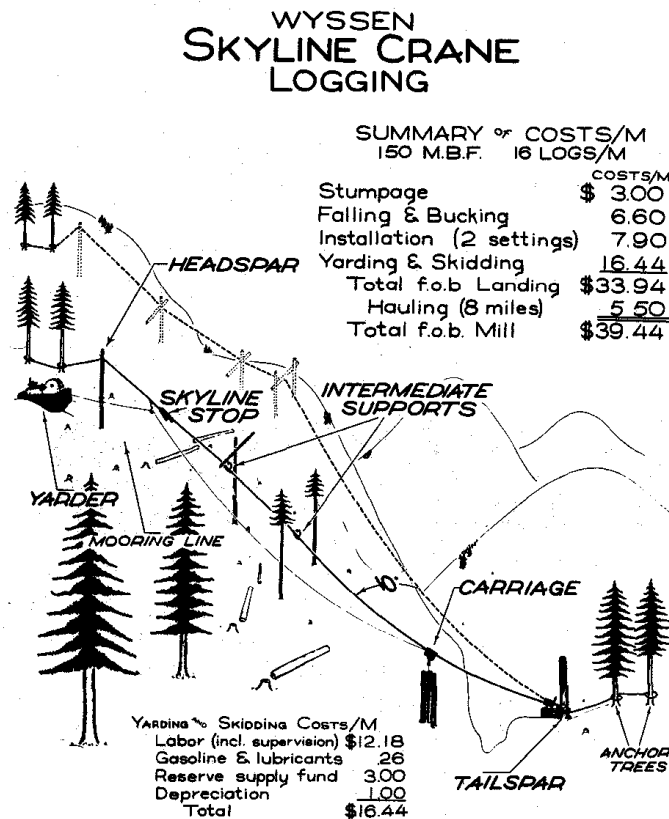


Associated Studies

Other investigations that bear on the main problems of water yields are tests of an overhead cable logging system at the experimental forest and studies of alpine snowfields at Loveland Ski Basin. Both these studies round out efforts to increase water yields from high-elevation forests and alpine areas.

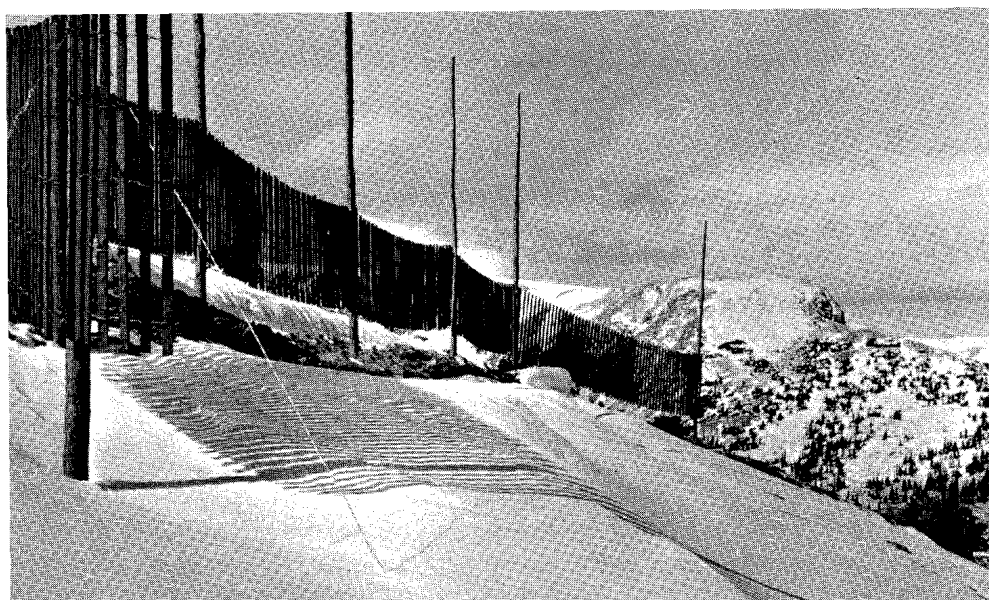
LOGGING METHODS

A skyline-crane is being tested at the Fraser Experimental Forest to determine its advantages in logging timber on slopes too steep to log by tractors and horses and where watershed values must be protected. The essential parts of the skyline-crane are the yarder (winch and power plant) located at top of slope, the skyline, carriage, carriage stop, and intermediate supports. The installation and 1955-56 costs are shown here.



Advantages of the skyline-crane are:

1. It can reach timber that is now inaccessible. Roughly, one-third of the mature timber in Colorado and Wyoming cannot be logged by ordinary methods because of steep slopes, excessive road-building costs, or possible damage to important watersheds.
2. Trees that might otherwise be lost to insects, disease, decay, or old age can be salvaged and used.
3. Logging idle forest stands would increase the snowpack and subsequent water yield by opening up the canopy and letting more snow reach the ground.
4. Since the skyline-crane eliminates most of the road building connected with logging, it would greatly reduce erosion.



Trapping snow in natural catchment basins by artificial or natural barriers will enlarge alpine snowfields so that more water becomes available for late-summer streamflow.

ALPINE SNOWFIELDS

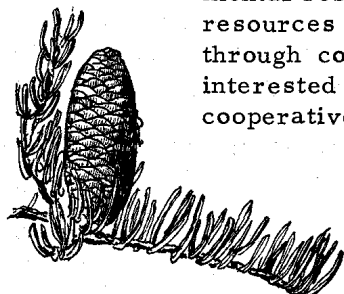
Alpine snowfields contribute to late-summer streamflow. Streamflow records of Middle Boulder Creek, 35.5 square miles in size, and Glacier Creek, 25.2 square miles in size, illustrate the contribution made by alpine snowfields to summer streamflow. The 1953 records show that Glacier Creek had a higher flow during August and September. Aerial photographs revealed 2.5 acres of alpine snow per square mile at the end of September in Glacier Creek drainage compared with 0.8 acre of alpine snow per square mile in Middle Boulder Creek.

Sidelights

The facilities of the Fraser Experimental Forest are used from time to time for training schools, for undergraduate field work, for field meetings of forestry and conservation societies, and for the Foreign Agricultural Service program in forestry. Excellent examples, nearby and on the forest, serve as on-the-ground illustrations of both beneficial and harmful practices in mountain agriculture.



Opportunities for graduate students to undertake fundamental research in the conservation and use of natural resources are excellent. Arrangements may be made through colleges, universities, foundations, or other interested groups, with the U. S. Forest Service, on a cooperative basis.



VISITORS ARE ALWAYS WELCOME. To obtain more detailed published information about the experimental work, ask the resident technicians, or send a request to the Director, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.