A STUDY OF SOME WATER QUALITY CHARACTERISTICS AND POSSIBLE LOGGING INFLUENCES ON A SMALL STREAM ON THE NORTH COAST OF CALIFORNIA

BY

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AN ABSTRACT OF A THESIS

A Study of Some Water Quality Characteristics and Possible Logging Influences on a Small Stream on the North Coast of California

by

William N. Johnson

Master of Science Graduate Program
in Watershed Management,
Humboldt State College, June, 1972.
Dr. Dean Freeland, Chairman

Several important water quality parameters were measured on the North Coast stream of Jacoby Creek, in order to study the effects of past and present logging practices on the stream environment and down stream uses. The Jacoby Creek watershed comprises 14.7 square miles, and drains into Humboldt Bay. The wide variety of logging and road construction activities that have taken place within the basin make it ideally suited for this study.

Recording instruments (two-probe thermograph,

pyrheliometer, and hygro-thermograph) were used to determine the impact of solar radiation on stream temperatures in clear-cut blocks and old growth timber stands. The instruments were equipped with eight-day clocks and recorded their parameters on graphs. The instruments were placed at the base of a stand of old growth timber and below a clear-cut block on a tributary of Jacoby Creek. Data were collected over a two week period. Temperature increases of 7.9 degrees F in May were measured after the stream traveled through the clear-cut block. Stream temperatures were 1.5 to 5.7 degrees F higher in the clear-cut block than in the unlogged control stream. The temperature fluctuated 7.9 degrees F in the logged area as compared with a 5.3 degree F fluctuation in the old growth stand. Stream temperatures were accurately predicted by use of Brown's formula within an average of 1.3 degrees F. The shading effect of trees and low growing vegetation in the old growth timber stand are important factors in maintaining stream temperatures adequate for fish survival and production.

Dissolved oxygen, pH, total hardness, turbidity, temperature and flow were monitored on three different aged logged areas and an unlogged control stream. The four sub-watersheds monitored were similar in geologic and soil characteristics. Water samples collected from the streams were analyzed by the use of a Hach Portable Engineering Laboratory and flow measurements were taken with a standard

Price Current Meter. Dissolved oxygen levels as low as seven parts per million were recorded in the partially logged areas as compared with 12 parts per million in the unlogged control stream. pH showed minor variations between streams. Total hardness in the streams of the partially logged watershed averaged from 26 to 79 parts per million higher than those in the unlogged control stream and turbidity averaged from 18 to 33 Jackson Turbidity Units higher. Temperatures were similar on the four streams monitored, with the exception of one day in which the unlogged control stream was four degrees F lower than the three partially logged areas.

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CHAPTER I

INTRODUCTION

The purpose and objective of this thesis are (1) to study some important water quality parameters on a North Coast stream; (2) to study the ranges in which these parameters may vary over a brief period; and (3) to study the way these parameters may vary in relation to logging as a land use.

Specific areas of concern in the research are the measurements of water quality parameters (dissolved oxygen, stream and air temperature, flow, total hardness, pH, turbidity and solar radiation) and the correlation of these parameters with different aged logged areas.

The Jacoby Creek drainage was chosen because of the wide variety of logging and road construction activities that have taken place within the watershed and the lack of research that has been performed on water quality parameters and their relationships to these activities.

I hope to bring out information and recommendations that can be valuable in land use planning and to prevent or lessen many of the disastrous mistakes that have been made through the manipulation of our environment by improper logging and road construction practices.

DESCRIPTION OF STUDY AREA

The Jacoby Creek watershed is located southeast of the city of Arcata. The northeast boundary of the watershed is Fickle Hill Road and the southwest boundary is a portion of the Kneeland Road. The town of Bayside is located on the lower boundary and the town of Kneeland is on the upper boundary.

The watershed is somewhat rectangular in shape, comprising 14.7 square miles (9,404 acres). A map of the watershed can be found on pages 7 and 8. The mean elevation is 1,134 feet ranging from a low of 40 feet to a high of 2,388 feet at Boynton Prairie.[1,2]

Jacoby Creek flows into Humboldt Bay with a northwest basin aspect. The stream is approximately 11 miles long with a main channel slope of 220 feet per mile (see maps pp. 4-5). Additional hydrologic data can be found in the appendix.

WATER YIELD, CONSUMPTION AND CLIMATOLOGICAL DATA

The watershed has a mean annual precipitation of 60.65 inches and a mean annual temperature of 51.9 degrees

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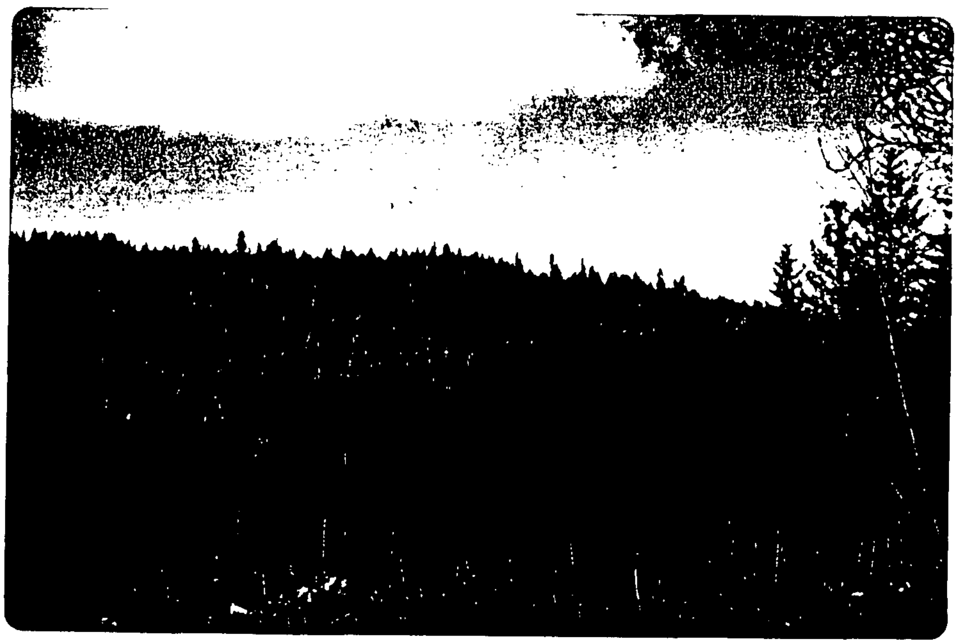
[1] U.S. Geological Survey, Blue Lake Quadrangle, (Washington, D.C., 1951).

[2] U.S. Geological Survey, Eureka Quadrangle, (Washington, D.C., 1959).

F.[3] From 1955-1964 the U.S. Geological Survey operated a stream gauging station on Jacoby Creek which received runoff from the upper 6.07 square miles of the watershed. The average discharge for nine years was 15.1 cfs (10,930 acre feet per year).[4]

From the above figures the following data have been



PHOTOGRAPH NO. 1

SECOND GROWTH TIMBER IN JACOBY CREEK DRAINAGE

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[3]U.S. Weather Bureau. The Climate of Humboldt and Del Norte Counties (Calif.: Agricultural Extension Service, 1964).

[4]LaRue, Jerry, U.S. Geological Survey (Post Office Building, Eureka, California, 1968).

derived for the 6.07 square miles above the gauging station.

Average evaporation	5.6	inches/year
Average transpiration	30.0+	inches/year
Average runoff	34.8	inches/year

Prior to 1964, the city of Arcata utilized Jacoby Creek for its water supply. After 1964, they switched to wells on the Mad River.

HISTORY

Man's activities first began in the Jacoby Creek area in the late 1800's. A railroad was built running up into the headwaters of the drainage. This railroad served two functions. Primarily it was used for logging. The train hauled shingles from two small shingle mills as well as logs, that were skidded to the tracks by oxen. Its second purpose was to haul rock from two quarries for construction of the jetty. The railroad was removed in 1926, but pilings from the trestles are still visible along the creek.[5]

By 1946, most of the watershed had been logged and was coming back in second growth: redwood (Sequoia sempervirens), Douglas fir (Pseudotsuga menziesii), incense-cedar

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[5]Humboldt County Tax Assessor's Office (Humboldt County Court House, Eureka, Calif.).

(Libocedrus decurrens), sitka spruce (Picea sitchensis), grand fir (Abies grandis), and Western Hemlock (Tsuga heterophylla) (see page 3, photograph No. 1). Logging continues today, but most of the timber cut is second growth, with the exception of a few small clumps of old growth timber in the upper reaches of the watershed.[6]

SOCIAL AND ECONOMIC DEVELOPMENT

The Jacoby Creek watershed has contributed to the economy of the redwood region since the turn of the century with the production of logs, shingles, rock and water for domestic and industrial use.

Today timber is still a major resource of the watershed. The broad, flat alluvial plains near the mouth of Jacoby Creek are being used for agricultural purposes with an ever increasing number of residences being constructed, gradually pushing their way into the upper portion of the watershed. Because of this, the ownership pattern at the lower end of the watershed is broken into small parcels.[7]

RECREATION

Recreational activities do not have a major impact on the Jacoby Creek drainage. Access to the upper portion

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[6] Ibid. [7] Ibid.

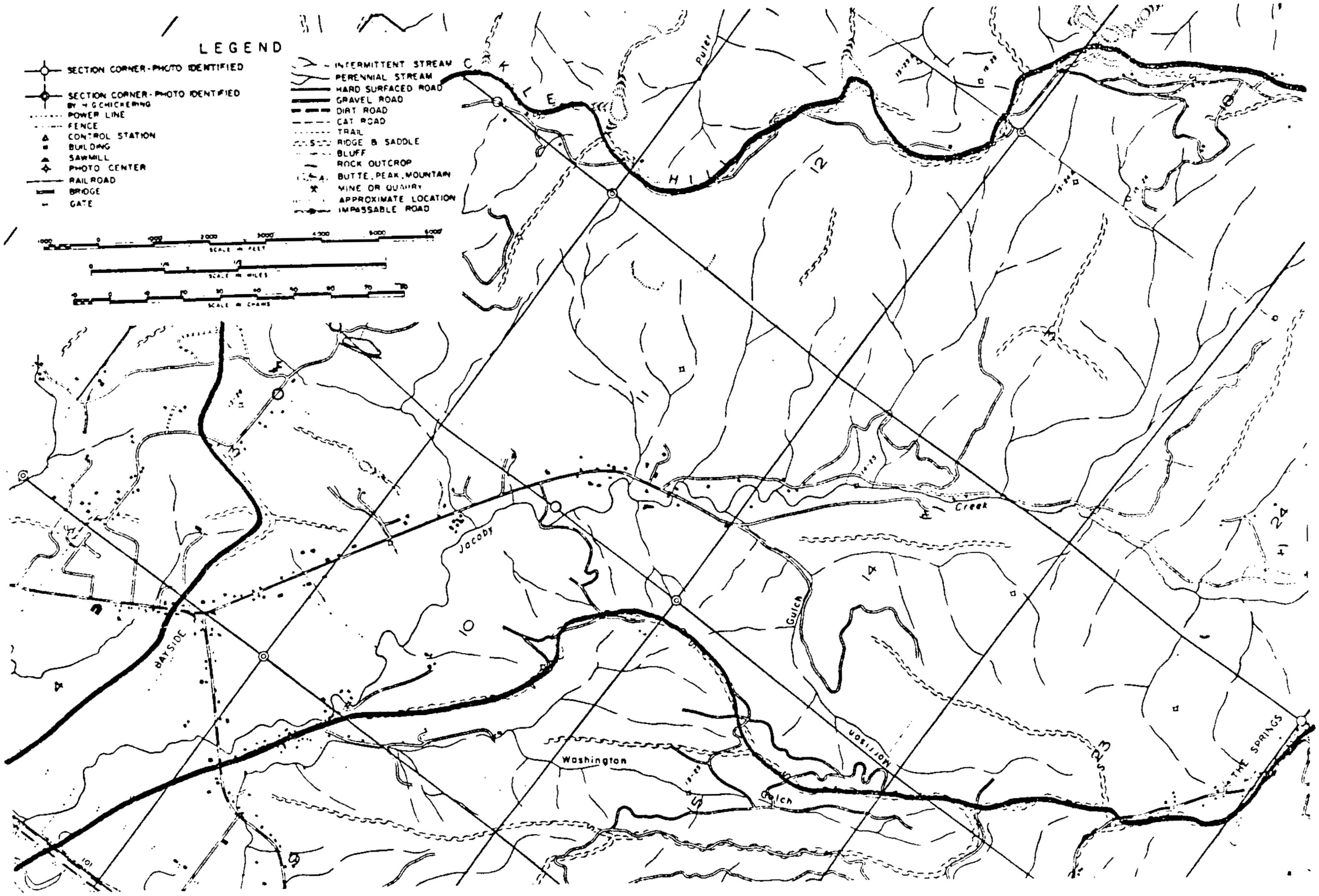
of the watershed is restricted and large parcels are fenced off for grazing and farming throughout the area. According to the California Department of Fish and Game, some big game hunting and fishing is carried on within the drainage. Other recreational activities observed include hiking, motorcycle riding and horseback riding, most of which are carried on by local residents.

FISH AND WILDLIFE

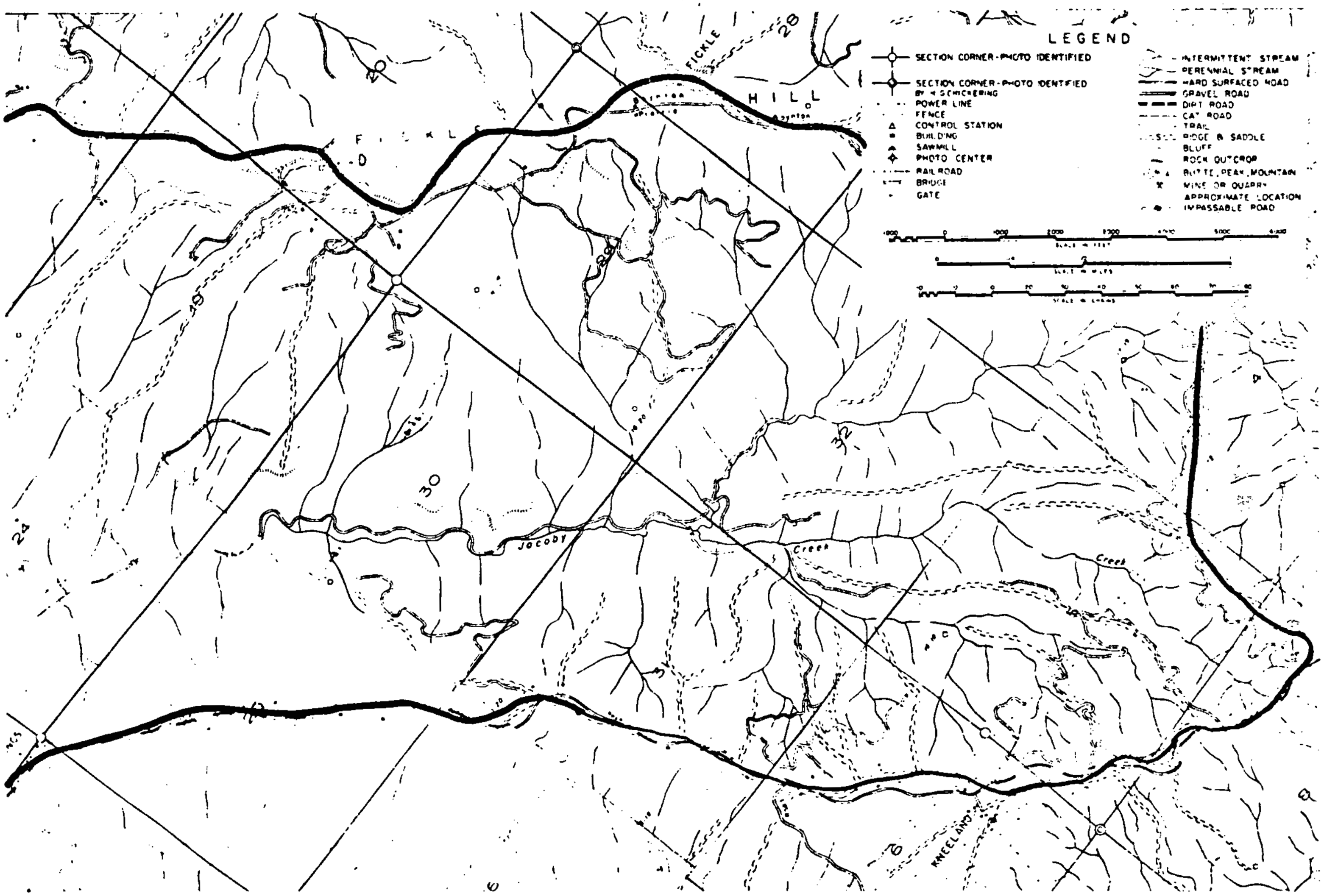
The California Department of Fish and Game report the following species of wildlife can be found in the Jacoby Creek drainage: black-tailed deer, Odocoileus hemionus columbianus; black bear, Euarctos americanus; ring-tailed cat, Bassariscus astutus; raccoon, Procyon loter; bobcat, Lynx rufus; coyote, Canus latrans; gray fox, Urocyon cinereorgenteus; brush rabbit, Sylvilagus bachmani; gray squirrel, Sciurus griseus; skunk, Mephitis spp.; mountain quail, Orertyx picta; band-tailed pigeon, Columba fasciata fasciata; and, mourning dove, Cinclus mexicanus. The California Department of Fish and Game reported that the annual kill for deer in the Humboldt drainage, in which Jacoby Creek is located, was 80 animals in 1970. This is a rather low number for Humboldt County which has one of the highest deer kills in California.

Jacoby Creek supports a population of steelhead and cutthroat trout. It has been stocked with cutthroat trout in the past, starting in 1962.

MAP NO.1
JACOBY CREEK



MAP NO. 2
JACOBY CREEK.



CHAPTER II

A COMPARISON OF STREAM TEMPERATURES IN LOGGED AND UNLOGGED AREAS

A portion of the Jacoby Creek watershed was studied to determine the effects of vegetative cover and its removal upon stream temperatures. By way of field comparisons, the relationships of these factors to and effects upon stream temperatures will be evaluated.

This study will provide data directly relating to the hypothesis that removal of vegetative cover along stream banks, exposing the stream channel to direct solar radiation, has affects on the biological communities supported by the stream and will cause thermal pollution.

This research project primarily utilized the comparison of graphs obtained from the various recording instruments (hygro-thermograph, two-probe thermograph and pyrheliometer) that were placed in or near the stream within the study area. Through analyzing these graphs, conclusions may be drawn regarding stream temperature and the factors that affect it.

DESCRIPTION OF AREA

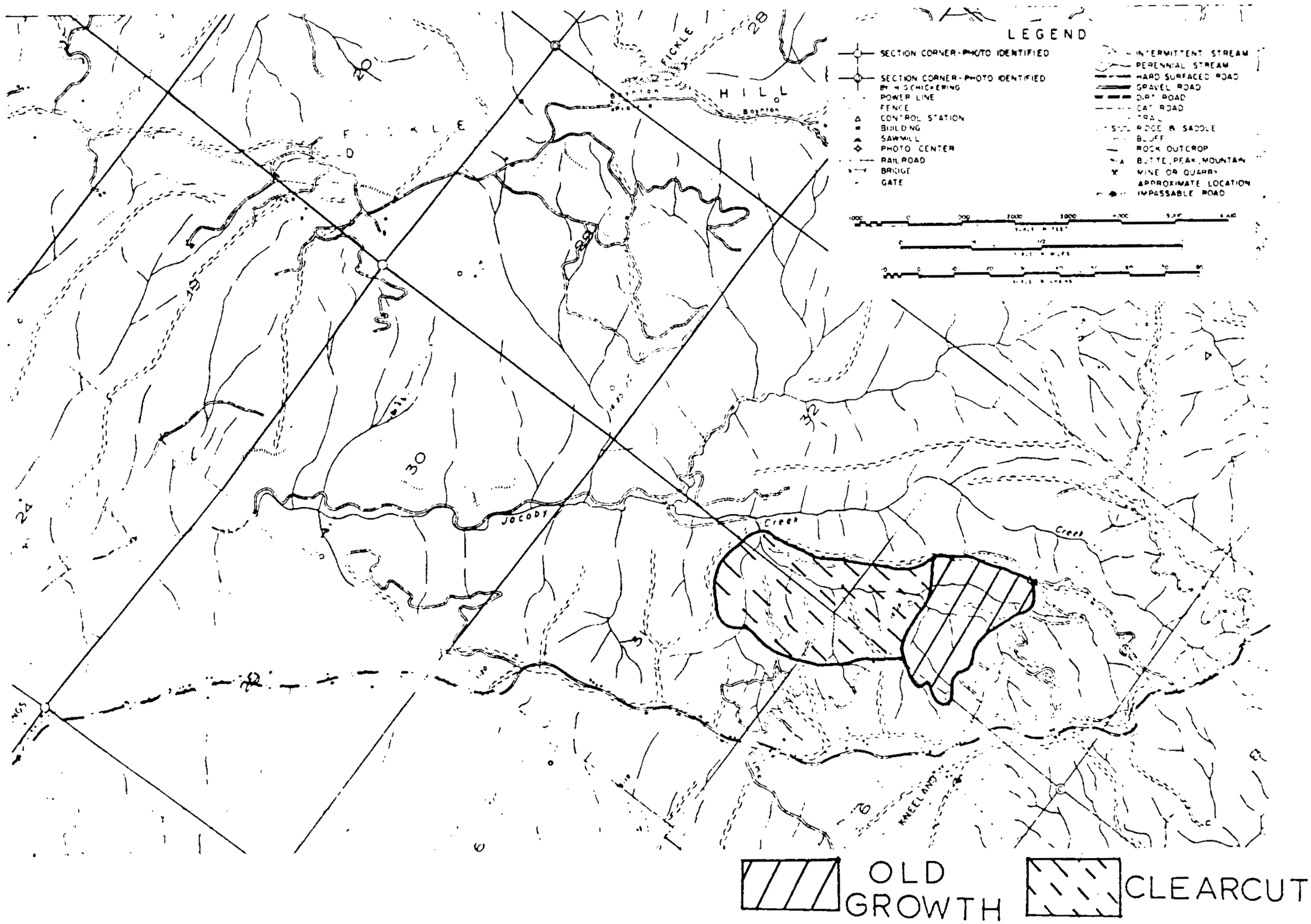
The area studied was a small sub-watershed in the upper reaches of the Jacoby Creek basin. The upper portion of the area is old growth redwood and Douglas-fir with scattered cedar and western hemlock. The lower area was clearcut in 1967, leaving approximately one-quarter mile of stream fully exposed and one-half mile of the stream partially exposed. The exact location is indicated on map No. 3, page 11.

The stream channel runs primarily in a north-south direction with west and east facing slopes. The canyon sides are very steep, ranging upwards to 80% in the clearcut area, as can be seen in photograph No. 2.

PHOTOGRAPH NO. 2

EXPOSED STREAM CHANNEL AT LOWER PORTION OF CLEARCUT BLOCK

MAP NO. 3
STREAM TEMPERATURE STUDY AREA



PROCEDURE AND INSTRUMENTATION

Two major sites were chosen for the placement of the instruments. The first location was just below a section of old growth timber, representing a completely shaded stream. The second location was at the base of the clear-cut block, representing exposed stream channel conditions. Exact locations are indicated on map No. 3, page 11.

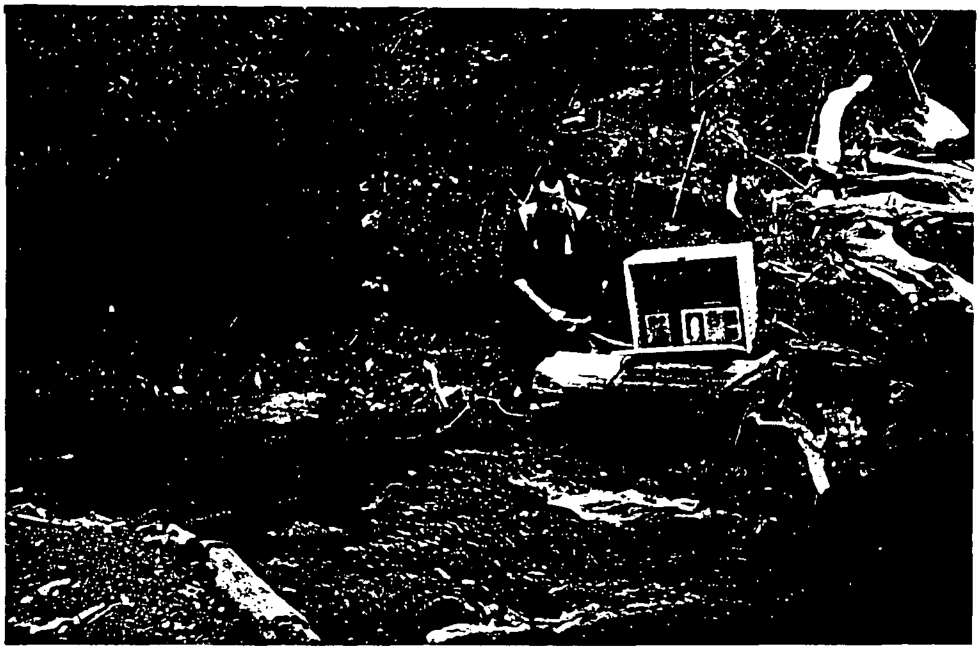
An important aspect of this project was the selection of the appropriate equipment and operation procedures to facilitate a meaningful, accurate study. The project procedure was set up to take full advantage of the instruments' strong points and to extract data from the stream in the most efficient and representative manner.

The instruments were tested and standardized at the weather station on the roof of the forestry building at Humboldt State College. It was found that one of the two-probe thermographs read four degrees high, so this had to be considered in the calculations.

All instruments utilized in this study were equipped with eight-day clocks and their data recorded on graphs. The following is a list of these instruments and how they were used in this research project.

<u>Hygro-Thermograph</u>

This instrument was used to record the daily fluctuations in the air temperature, and in the correlation of stream temperature and air temperature. This instrument was placed in a vented weather station box so it was shaded from the direct rays of the sun as can be seen in photographs 3 and 4.



PHOTOGRAPH NO. 3

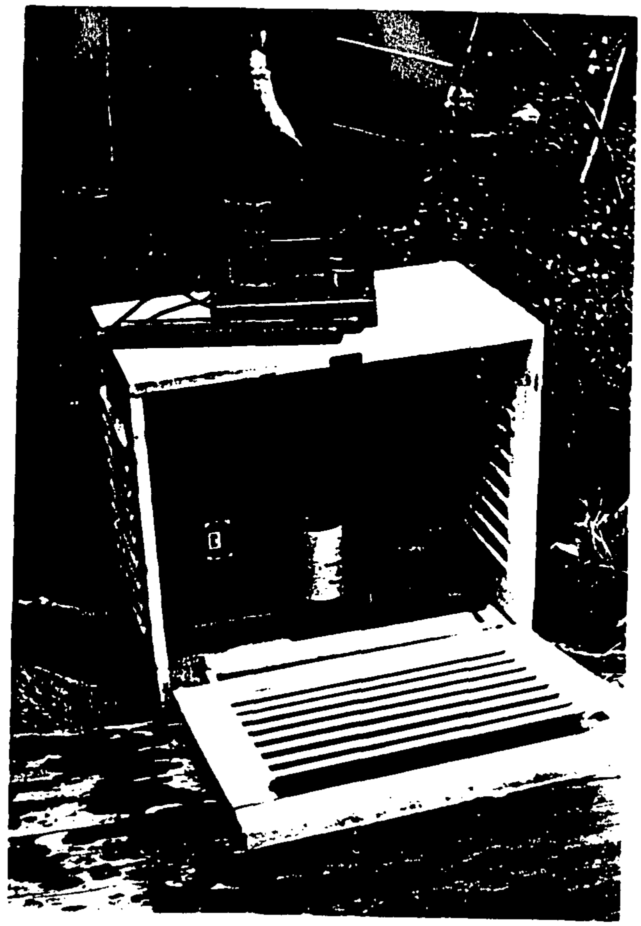
LOWER STREAM STATION IN CLEARCUT BLOCK
(Note cables of thermograph leading into stream, exposed slopes, and debris in channel.)

Two-Probe Thermograph

Two of these instruments were used in this study, one at the main weather station on the lower part of the stream, below the clearcut block, and the other upstream at the base of the control area of old growth redwood and Douglas fir. Each instrument has two temperature-sensitive probes, that could be placed in different locations to record the 24-hour temperature fluctuations of the stream.

PHOTOGRAPH NO. 4

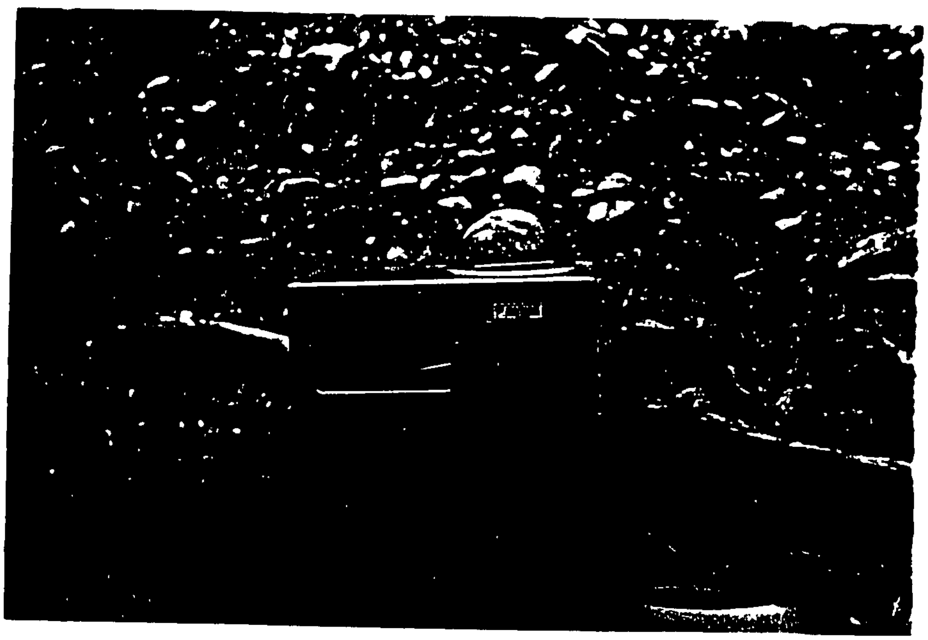
LOWER STREAM STATION SHOWING THE WEATHER STATION BOX, TWO-PROBE THERMOGRAPH, AND HYGRO-THERMOGRAPH.



In both cases the two probes of each thermograph were placed on bedrock in the stream channel and under two to six inches of water. One probe of each thermograph was located in the main channel and one near the edge. In analyzing the graph, there was no significant temperature difference between the two probes of each instrument, so they were considered as one.

Pyrheliometer

The pyrheliometer was used to measure and record the solar radiation received by the stream. The instrument measures solar radiation in the form of a langley (gram calorie per square centimeter per minute). This instrument was placed about 50 yards above the lower station in an exposed area to receive maximum solar radiation consistent with that received by the stream.



PHOTOGRAPH NO. 5

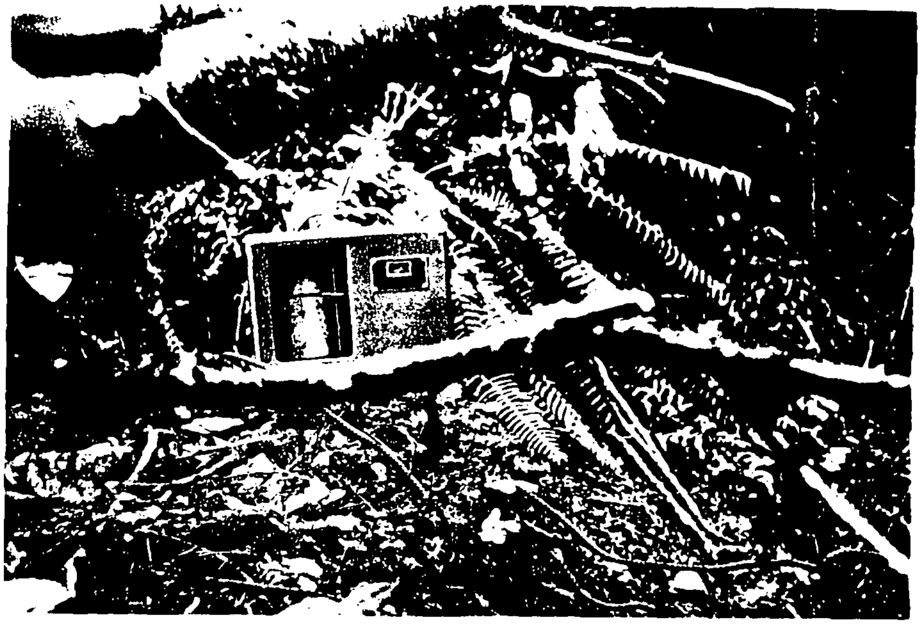
PYRHELIOMETER LOCATED NEAR LOWER STATION
(Note exposed slope!)

The pyrheliometer is very important to the project. By measuring solar radiation that is received by the stream and the subsequent stream temperature, a relationship with amount of exposed slope and vegetative cover can be made.

With a comparison of stream temperatures at the lower exposed station and the upper control area, the effects of solar radiation on stream temperature as a function of exposure and stream conditions can be determined.

The upper station within the control area represents the stream under natural, undisturbed conditions. The only instrument placed there was a two-probe thermograph to measure stream temperatures. The lower station consisted of a hygro-thermograph, two-probe thermograph, housed in a vented weather station box, and a pyrheliometer placed about 50 feet upstream from the box as can be seen in photographs Nos. 3, 4 and 5. These instruments were placed in the disturbed portion of the study area so that the effect of clear-cut (regeneration) logging on thermal pollution could be determined.

The instruments were left in the field for one week, at which time they were checked and the graphs were changed. It was decided to leave the instruments in the field another week in hopes of receiving better weather with higher solar radiation intensities and air temperatures. The instruments were retrieved after two weeks and photographs were taken of the area.



PHOTOGRAPH NO. 6

TWO-PROBE THERMOGRAPH AT UPPER STATION
(Note lush vegetation and shading of trees.)

PHOTOGRAPH NO. 7

PORTION OF OLD GROWTH TIMBER IN CONTROL BLOCK

GRAPHS

Stream temperature, solar radiation and air temperature were recorded for a period of two weeks, from April 24, 1969 to May 10, 1969. Five representative days have been selected and the following variables plotted on graph paper: solar radiation in gram calories per cm^2 per minute, stream temperature in degrees F, and air temperature in degrees F. Colored overlays have been used for air temperature and solar radiation so that direct comparisons can be made to determine their effect on stream temperature.

Three of the days graphed are of high temperature and solar radiation intensity. In these, the stream temperature in the clearcut area ranged two to six degrees F higher than those in the old growth timber as is shown on graph No. 3 and 4. Total temperature fluctuation in the clearcut area was 7.9 degrees F in a five-hour period on May 6, 1969, and 7.4 degrees F in a five-hour period on May 5, 1969. The peak time of stream temperature generally coincided with the peak time of air temperature; however, the peak time of solar radiation was about one-and-one-half hours to two hours earlier than that of air and water temperature.

Two other days were chosen and the results of their parameters were graphed. They were days of fluctuating solar radiation intensity. Temperature differences between the two stream stretches ran from a low of 1.5 degrees F to a high of 5.7 degrees F.

The following table shows maximum and minimum stream temperature differences between the two stream stretches:

TABLE I

STREAM TEMPERATURE INCREASES IN THE UNSHADED CHANNEL OVER THOSE OF THE SHADED CHANNEL

Date	Maximum Temperature Difference Degrees F	Minimum Temperature Difference Degrees F
4/27/69	+ 4.8	+ 2.0
4/28/69	+ 4.0	+ 2.7
5/05/69	+ 5.7	+ 2.3
5/06/69	+ 4.4	+ 1.5
5/07/69	+ 5.4	+ 2.5
Average:	+ 4.9	+ 2.2

THE EFFECT OF INCREASING STREAM TEMPERATURES ON THE STREAM ENVIRONMENT

Temperature is an important water quality parameter. It has a tremendous influence on levels of dissolved oxygen, contributing to decreased oxygen capacity and increased oxygen demand.[8] Higher stream temperatures diminish the

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[8] Jack Edward McKee and Harold W. Wolf, Water Quality Criteria (second edition; Publication No. 3-A. California: State Water Quality Control Board 1963) pp. 283-284.

capacity for dissolved oxygen and thus decrease the availability of this essential gas. Oxygen demand, metabolism and respiration of fish and aquatic insects increases as water temperature increases, creating an increased demand for oxygen, even though the total oxygen supply has been lowered.[9]

Algal blooms and noxious nuisance growths of aquatic plants are induced under increased stream temperatures, creating adverse changes in taste, odor and color of the water. Warm water is also conducive to the growth of aquatic bacteria, such as the parasite columnaris (disease). An increase in these populations may cause fish mortality.[10]

Trout, salmon and many other species of fish are adversely affected by increases in stream temperatures, especially during their embryonic stages of development. Trout prefer temperatures between 45 degrees F and 64 degrees F, with 78 degrees F being lethal for many trout and salmon. The maximum and minimum temperatures these species can withstand prior to spawning is 56 degrees F and 42 degrees F.[11] Direct solar radiation as a factor in increasing stream temperatures is more important in smaller streams, especially

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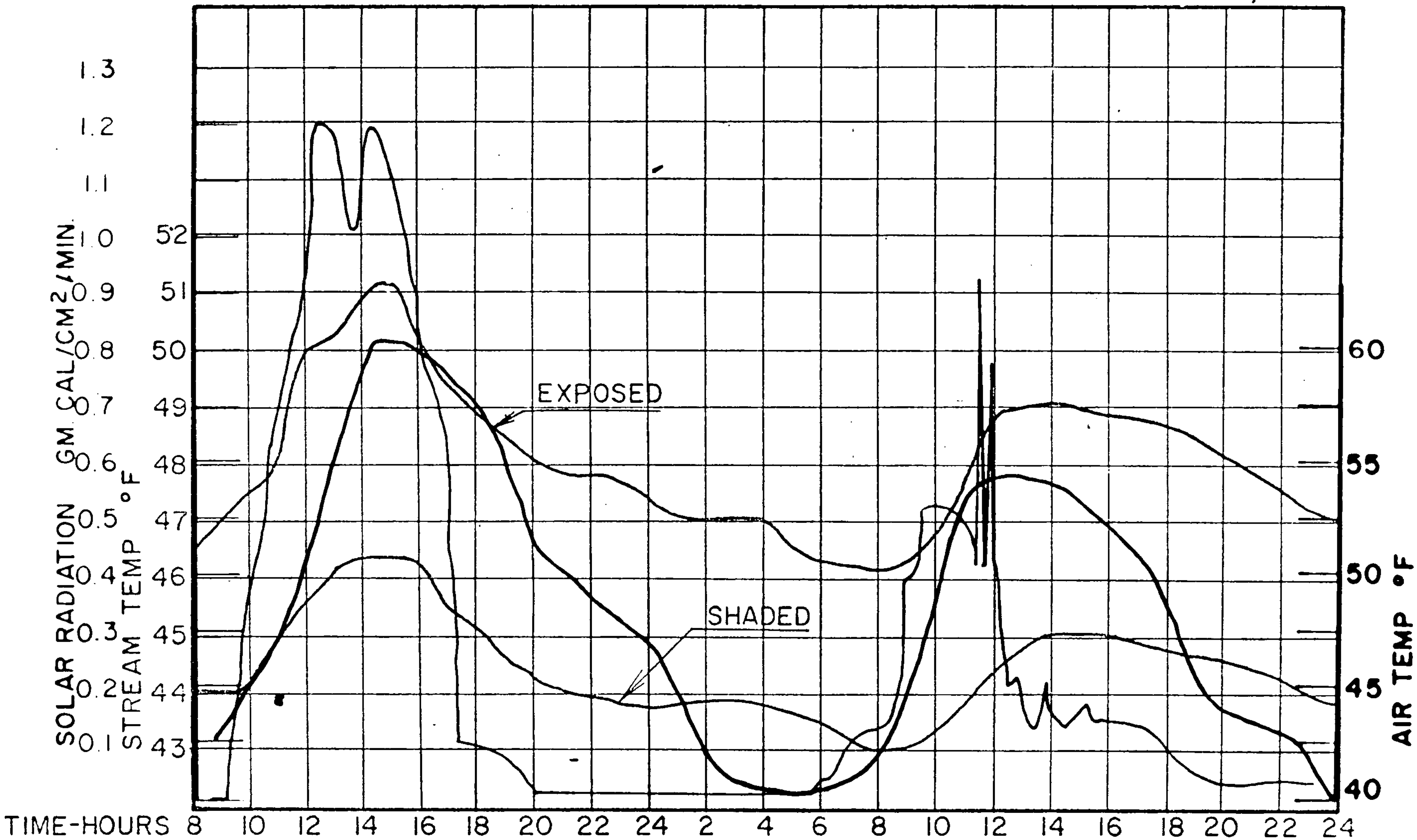
[9] Ibid.

[10] George W. Brown, "Effects of Clearcutting on Stream Temperature," Water Resources Abstract, Vol. 6, No. 4 (August 1970) pp. 1138-1139.

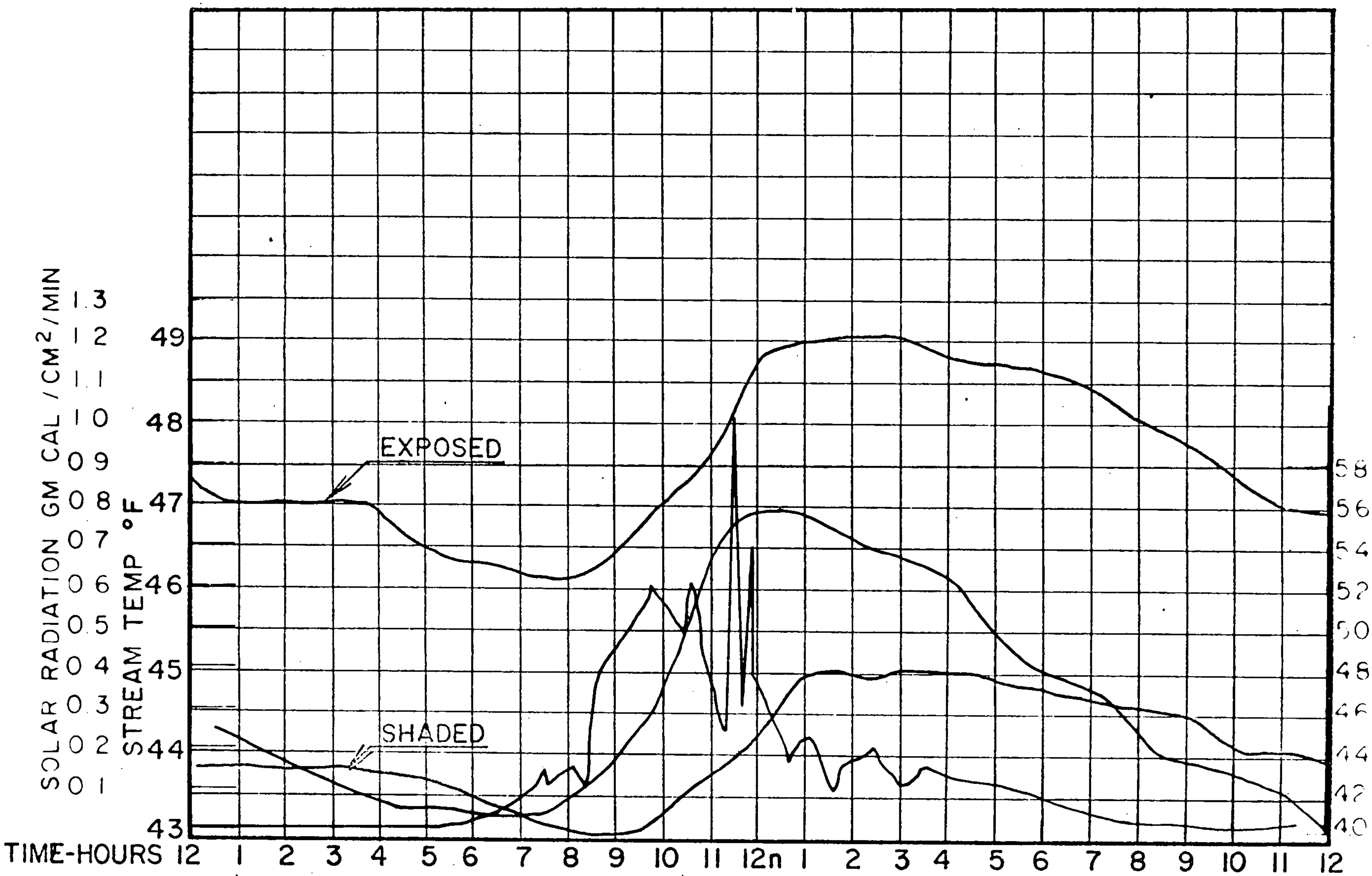
[11] McKee, op cit., pp. 284-285.

GRAPH No. 1
A GRAPH OF THE STREAM TEMPERATURE FOR THE SHADED AND EXPOSED STRETCHES OF JACOBY CREEK FOR APRIL 27-28, 1969

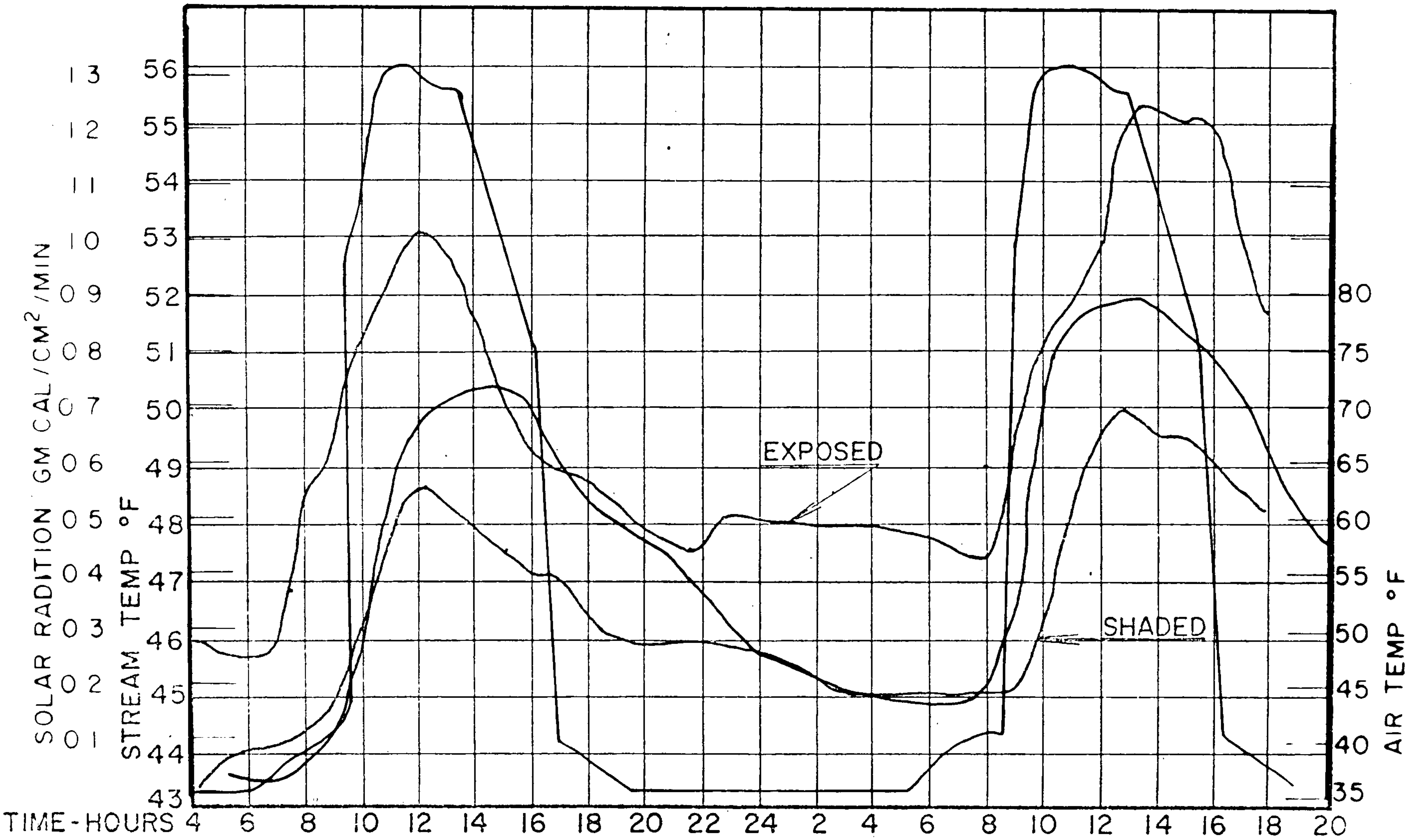


GRAPH N-.2

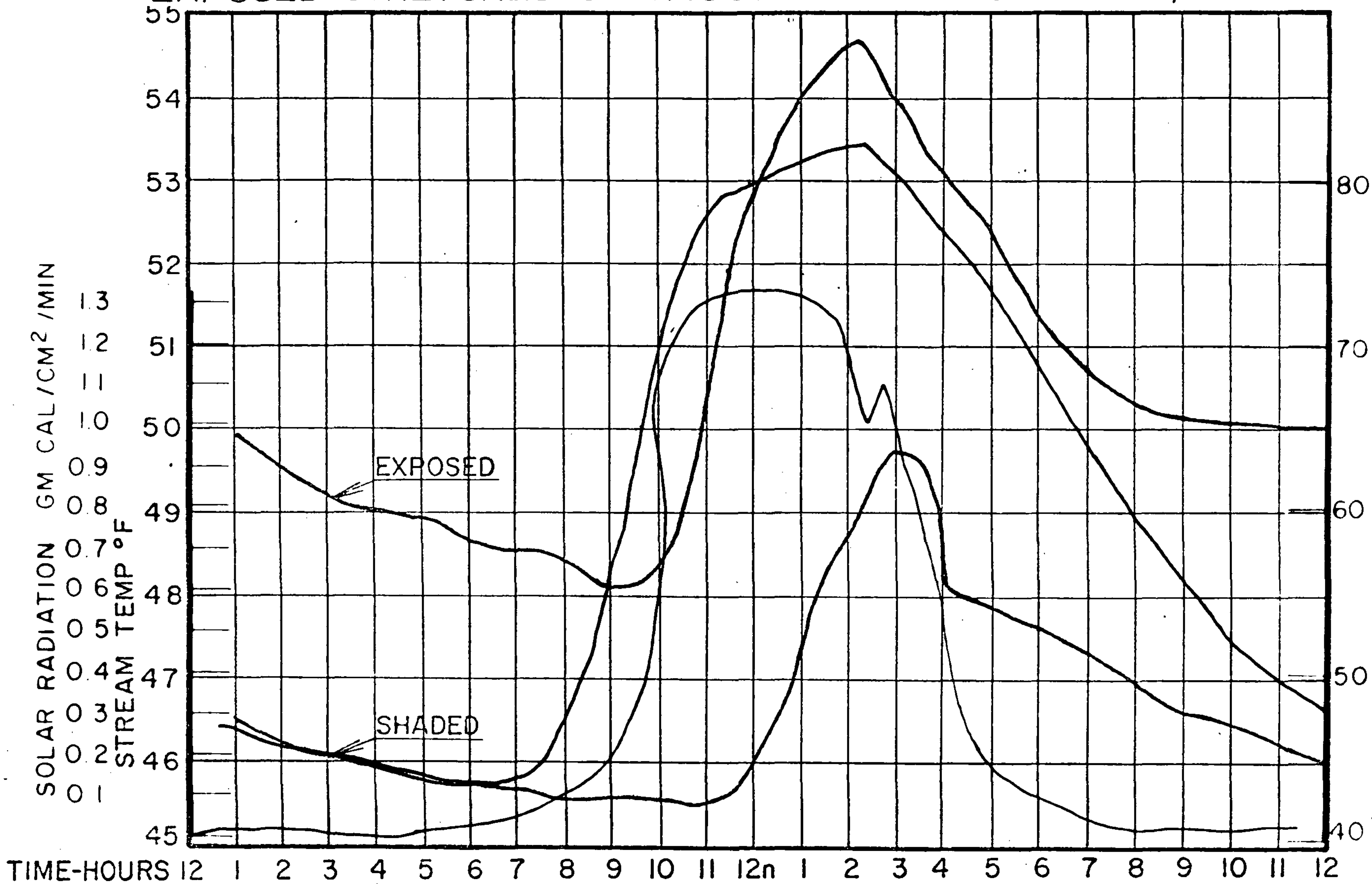
A GRAPH OF THE STREAM TEMPERATURE FOR THE SHADED AND EXPOSED STRETCHES OF JACOBY CREEK FOR APRIL 28,1969



GRAPH No. 3
A GRAPH OF THE STREAM TEMPERATURE FOR THE SHADED AND EXPOSED STRETCHES OF JACOBY CREEK FOR MAY 5-6, 1969



GRAPH No. 4
A GRAPH OF THE STREAM TEMPERATURE FOR THE SHADED AND EXPOSED STRETCHES OF JACOBY CREEK FOR MAY 7, 1969



those in cloud-and fog-free areas.[12]

TABLE II

OPTIMUM OR PREFERRED TEMPERATURES FOR FISH

Common Name	Optimum or Preferred Temperature	
Rainbow Trout	13.0°C	55.3°F
Chum Salmon	13.5°C	56.3°F
Sockeye	15.0°C	59.0°F
Coho Salmon	20.0°C	68.0°F
Lake Trout	15-17°C	59.0-62.0°F

*Table II, Ibid.

Besides its effect on stream temperatures, the removal of vegetative cover along the streams banks may result in the following:

1. Create an increase in algae production and a decrease in organic debris supplies to the stream by the forest canopy. In some cases these two factors may offset themselves.[13]

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[12] George W. Brown, "Predicting the Effect of Clear-cutting on Stream Temperature," Journal of Soil and Water Conservation, Vol. 25, No. 1 (Jan.-Feb. 1970) pp. 1-3.

[13] John W. DeWitt, "Streamside Vegetation and Small Coastal Salmon Streams" (paper read at Forum on Pollution in Janeau, Alaska, Feb. 8, 1968) pp. 5-7.

2. The decrease in vegetative cover will bring about a rapid decline in aquatic insects that serve as food for trout and salmon. This is due to the removal of the plant material upon which the insects feed. Aquatic insects have been known to make up 5-66 percent of the diet of some trout and salmon in some streams.[14]

3. Reduce fish protection (cover) from predators and disturbance by other animals.[15]

4. Increase evaporation and decrease transpiration, creating an overall increase in flow during summer months. This factor is favorable for the production of salmonid populations due to an increase in living area (Chapman, 1962).[16]

5. Reduce interception of rain, snow, fog, and clouds.

6. Reduce protection of the stream banks from the erosive effects of rainfall impact and streamflow.

7. Allow no protection of the stream banks against erosion by overland flow of water, and of the stream against debris carried by overland flow.

8. Reduce forest floor litter for soil protection and for facilitating water infiltration into the soil.

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[14] Ibid.

[15] Ibid., p.2.

[16] Ibid., p.6.

9. Reduce interception of toxic materials from spraying, dusting, and seeding operations.[17]

PREDICTING CHANGES IN STREAM TEMPERATURE

The temperature change that occurs between two points on a stream is directly proportional to the surface area of the stream and the heat load applied between these points. It is inversely proportional to the flow.[18] Solar radiation accounts for 95 percent of the heat input on small streams. Air temperature and the cooling effect on evaporation are much less important.[19]

The following formula developed by Brown[18] was employed to predict the temperature increases in the clearcut portion of the study area:

$$\Delta T = \frac{A \times H}{D} \times 0.000267$$ [20]

T = Predicted temperature change.

A = Surface area of the stream exposed by clear cutting.

H = Rate of heat absorbed by the stream, in British thermal units per square foot per minute.

D = Discharge in cubic feet per second.

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[17]Ibid., p.2.

[18]Brown, *loc. cit.*

[19]*Ibid.*

[20]*Ibid.*

The constant, 0.000267, converts discharge in cubic feet per second to pounds of water per minute.

The discharge was averaged from several flow measurements taken on April 27, 1969. One tributary discharges into the clearcut area and some vegetation remained in the partially clearcut portion of the stream channel. These two factors will affect the accuracy of the prediction.

The average stream discharge was 2.21 cubic feet per second and the surface area of the stream exposed to solar radiation was 15,500 square feet. The stream length was 4,000 feet with 2,500 feet totally exposed by clearcut and the rest partially logged. Solar radiation intensities ranged from a maximum of 4.9 British Thermal Units per square foot per minute to a low of 2.8 British Thermal Units per square foot per minute.

Example:

$$\frac{(16{,}000 \text{ sq.ft.})\ (4.42 \text{ BTU's/ft.}^2\text{/min.})\ .000267}{2.14 \text{ cubic feet per second}} =$$

$$= 8.83 \text{ degrees F}$$

Table III on page 29 shows the results of these computations in comparison with observed data.

All predicted temperatures were high. The average deviation was +1.3 degrees F. The reason the predicted temperatures were high is probably due to the 1,500 feet of channel that was only partially logged. Some shading of the stream surface occurred in this area, decreasing the amount

TABLE III

COMPARISON OF PREDICTED AND MEASURED STREAM TEMPERATURES

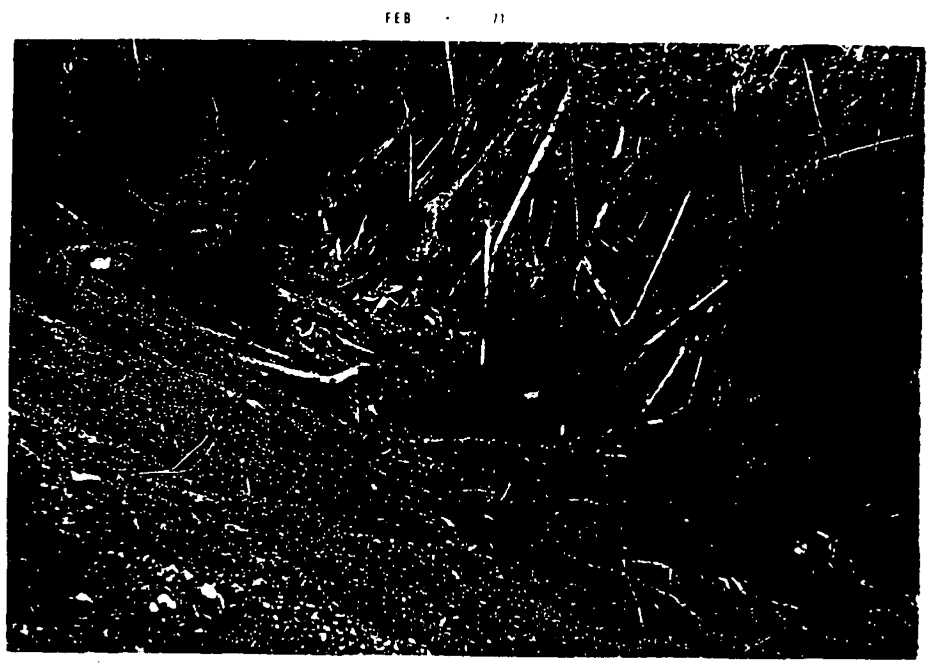
Date	Predicted temp. change degrees F	Measured temp. change degrees F	Deviation
4/27/69	6.9	5.2	+1.7
4/28/69	3.4	3.0	+ .4
5/05/69	8.6	7.4	+1.2
5/06/69	8.9	7.9	+1.0
5/07/69	8.9	6.6	+2.3
		Average:	+1.3°F

of solar radiation actually received by the stream surface. Brown (1970) used his method on two Oregon streams bound by clearcuttings. Temperature changes of 16 degrees F were predicted within one degree F.[21] This method enables prediction of stream temperatures within three degrees F. An example of the shading that occurs in the stream channel can be seen in the left side of the photograph on page 30 (No. 8). This method is ideal for predicting temperature changes in small drainages of low volume that do not have

[21]Brown, loc. cit.

a large interchange with ground water. These streams are usually low in volume and are greatly affected by direct solar radiation.

Predicting stream temperatures is an important way to determine the effect of clearcutting on the total stream environment. It also has applications in attempts to increase the productivity of forested streams with suboptimal temperature regimes.



PHOTOGRAPH NO. 8

MASS MOVEMENT TRIGGERED BY LOGGING AND ROAD CONSTRUCTION ON EXTREMELY STEEP SLOPES BLOCK STREAMS, INCREASING SURFACE AREA, CAUSING INCREASED TEMPERATURES AND SEDIMENTATION

CONCLUSION

This study shows the effects of direct solar radiation upon the net thermal radiation for a small stream and the resultant changes in the stream temperature regime. The channel, which is bedrock in many places, acts as an energy sink during the high temperatures of the day and an energy source at other times. This condition keeps the stream in the clearcut section at a higher temperature than the shaded section even during the night hours.[22]

The maximum stream fluctuation in temperature was 7.9 degrees F in a five-hour period in the exposed stream channel. Much higher temperature increases would be expected later in the summer. This demonstrates the effects which removal of vegetation has on increasing stream temperature.

The effect of increased stream temperature and of greater temperature fluctuations can be lethal to trout and salmon, especially to their eggs and young fry. Aquatic insect populations change, the bad odor, taste and color associated with warm water algae blooms becomes a serious problem. Man's activities may have a critical effect on the total aquatic ecosystem. These problems can be overcome. It will cost money, but it will protect the stream

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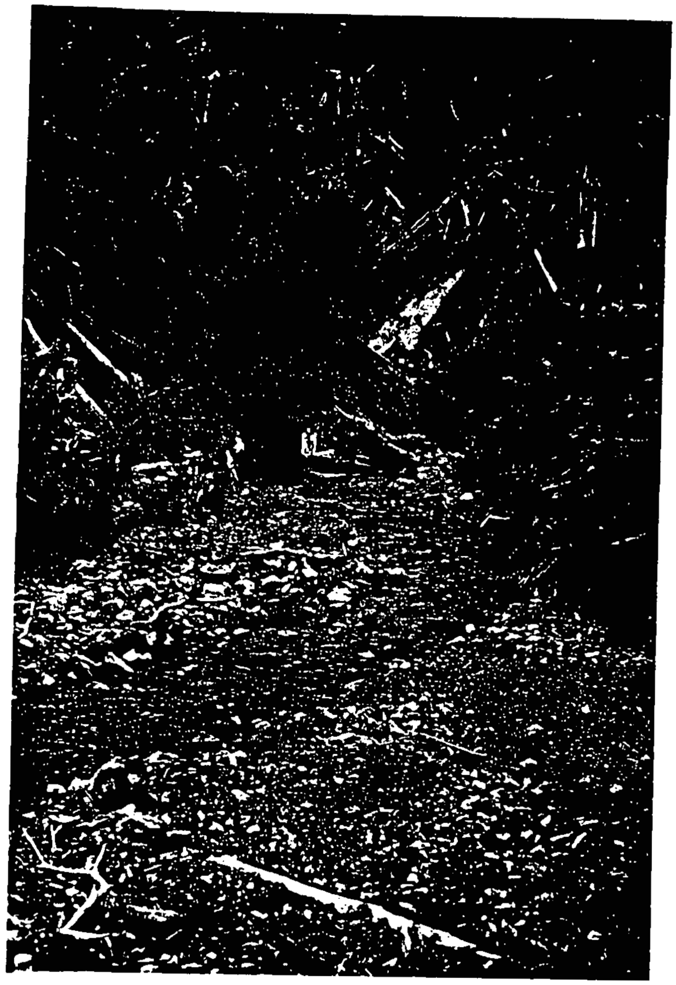
[22] George W. Brown, "Predicting Temperatures of Small Streams, "Water Resources Research, Vol. 5, No. 1, (Feb, 1969) p. 74.

environment. This study provides data supporting the importance of protective buffer strips of high or low growing vegetation in maintaining adequate stream temperatures for fish survival.

PHOTOGRAPH NO. 9

LOCATION OF EQUIPMENT
IN OLD GROWTH TIMBER



PHOTOGRAPH NO. 10

LOCATION OF EQUIPMENT
IN CLEARCUT AREA

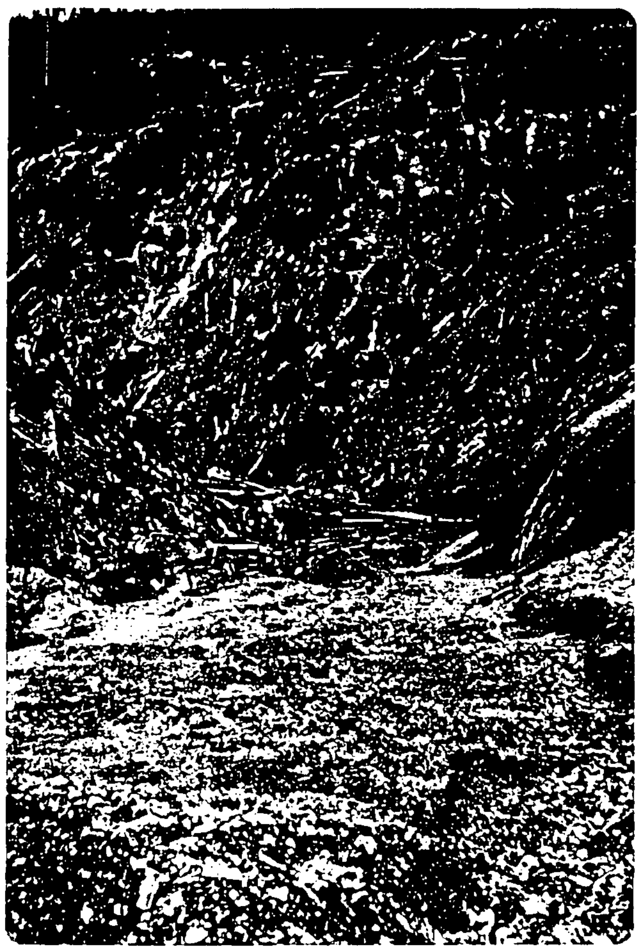
CHAPTER III

A CRITICAL ANALYSIS OF ROADS AND LOGGING ON A PORTION OF THE WATERSHED

Since 1964, the upper reaches of the Jacoby Creek watershed have been intensively logged. In this study a large portion of this logged area was surveyed and analyzed from the standpoint of road construction and logging techniques. The area is located one mile northeast of Kneeland, and was clearcut in 1967. The location of this area and its road system is indicated on map No. 3, page 11.

In the bottom one-third of the study area is a large landing constructed in the stream channel where the two forks of Jacoby Creek meet. Rather than build a bridge or install a culvert over the creek, cull logs were piled across the channel and the water was allowed to flow between them. Dirt was filled in over the top for logging trucks to cross. This section of the road, shown in photograph No. 11, was washed out during the 1968-69 winter.

From the landing there is a logging road about three-fourths of a mile in length. The first 400 yards of the road rises at a 24% slope in a southwest direction with a 80-83% side slope. This section of the road is pictured in photograph No. 11. The road then turns in a south direction, running for about 300 yards at a ten percent grade. At this point the west side of the clearcut area is visible, as shown in photograph No. 12.



PHOTOGRAPH NO. 11

LANDING IN STREAM CHANNEL AND ROAD WASHOUT

PHOTOGRAPH NO. 12

WEST SIDE OF CLEARCUT BLOCK

Photograph No. 12 shows a skid road going up the hill at a slope of 39% and a series of switch backs that have almost completely slid out. The side slope on which these roads were constructed was 85%. This is the same clearcut block in which stream temperatures were measured.

Photograph No. 13 shows another view of the main road. It can be seen that the road has almost entirely slumped into the stream channel. Removal of vegetation which holds soil in place on steep slopes may set the scene for disaster. Underground water and surface runoff then saturate fill material and soil. The soil can no longer support the weight of the water it is holding, and mass movement occurs. This phenomenon may occur without removing vegetation.

PHOTOGRAPH NO. 13

SLUMPED OUT PORTION OF MAIN ROAD

Photograph No. 14 shows an excellent example of gullying and channel aggradation. Also, material has slid across the creek blocking it and causing a backing up of water. In time, the water will cut through the fill material and wash it farther down stream, scouring the stream channel. This material gradually works its way down into Humboldt Bay.

Photograph No. 15 shows where the road continues at a 23% grade in a southeast direction and again levels off

PHOTOGRAPH NO. 14

GULLYING AND
BLOCKED STREAM

PHOTOGRAPH NO. 15

SLUMP ON MAIN ROAD

to a 10% grade in a south ten degrees west direction with a 79% side slope. Along the road are numerous slumps completely blocking it.

PHOTOGRAPH NO. 16

TREES BEING PUSHED OVER BY SOIL MOVEMENT

Photograph No. 16 shows the end of the road where it gives way to a mass of leaning trees, gradually being pushed over by the slumping road. The road crosses the creek one more time before it ends. Again, rather than install culverts, large tree stumps were pushed into the stream channel and the water was allowed to cut its way through them.

This area shows many disturbances due to logging and the roads built for the logging. Perhaps high-lead, balloon or helicopter logging systems could have reduced watershed disturbances in comparison to the present tractor system.

Because of the steep slopes and constantly slipping soil, the area probably will not support good stands of timber again for several centuries, at least. Why has such a tremendous amount of damage occurred here?

1. The area is underlaid by an unconsolidated unstable formation (Franciscan Formation).

2. The soils are shallow and prone to slipping, even before being disturbed.

3. High, seasonal precipitation, causing saturation of the soil and a decreased frictional resistance and adhesion.

4. Extremely steep slopes.

5. Removal of rooting systems which increases the opportunity for mass movement.

From the tremendous amount of damage that has occurred in this area, one can see that a better set of guidelines and laws must be passed to regulate logging and road building on private and public lands.

CHAPTER IV

WATER QUALITY VERSUS LOGGING AND ROAD CONSTRUCTION

In this portion of the study water quality parameters (pH, turbidity, dissolved oxygen, total hardness, temperature and flow) were evaluated on four sub-watersheds in the Jacoby Creek drainage. Three of the sub-watersheds were partially logged and the fourth was a control stream in a small block of old growth timber.

The first three streams will be given names corresponding to the year they were logged (1968, 1966, and 1964) and the control stream will be referred to as Old Growth.

DESCRIPTION OF DRAINAGES

The four drainages are all within the Franciscan Formation and contain similar soils. The 1964, 1966, and 1968 watersheds are indicated on Map No. 4, page 42, the Old Growth watershed on Map No. 3, page 11 and the areas logged are identified on the Timber Map of the Jacoby Creek Watershed in the appendix.

Table IV summarizes the sizes and logging data of these four drainages.

Drainage and logged areas were computed by use of a dot grid.

MAP NO. 4
WATER QUALITY STUDY AREAS

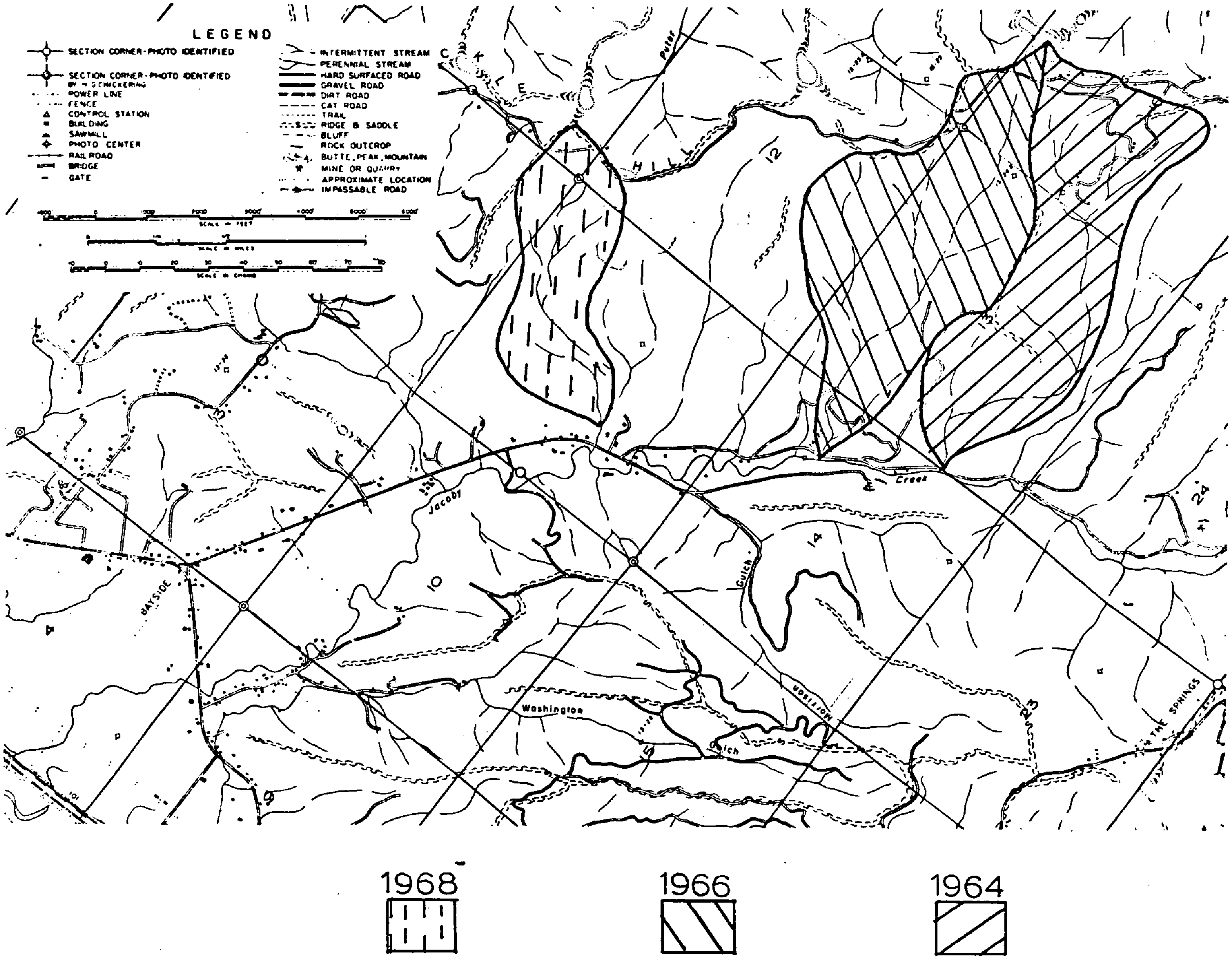


TABLE IV

SUB-WATERSHED AREAS STUDIED FOR

WATER QUALITY

Year Drainage Was Logged	Drainage Area Acres	Area Logged Acres	Percent Logged
1964	369	95	19.4
1966	447	127	28.4
1968	143	21	14.6
Control stream*	127		

*The upper portion of the control stream is mature second growth timber and the lower portion is old growth timber.

INSTRUMENTATION AND SAMPLE COLLECTION

A Hach Portable Engineering Laboratory was used to measure pH, dissolved oxygen, turbidity, total hardness and temperature. Flow measurements were taken with a standard Price Current Meter. All parameters were measured as close to 12:00 p.m. as possible. Turbidity samples were collected in a home-made sediment sampler which worked on the same principle as the Depth Integrated Sediment Sampler. The reason for this was to obtain a statistically sound sample. All samples were analyzed in the field due to fluctuations of specific parameters which might occur during transport and storage, i.e., dissolved oxygen and pH.

WATER QUALITY PARAMETERS AND RESULTS

Six water quality parameters have been measured on each drainage: pH, dissolved oxygen, total hardness, turbidity, flow and temperature. Tables V and VI (pages 45 and 46) show the comparisons which have been made by the use of graphs between the different drainages and specific parameters: turbidity and total hardness. The Old Growth stream was inaccessible during my high flow measurements of the three partially logged drainages and so these data are not available for comparison.

pH Hydrogen-ion Activity

The symbol pH is used to designate the logarithm (base 10) of the reciprocal of the hydrogen-ion concentration in moles per liter.[23] The pH of most natural water ranges from 6.5 to 8.5. Some diurnal fluctation may occur when aquatic organisms, during photosynthesis, take up dissolved carbon dioxide.[24]

Water with a pH of seven is required for brewing and

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[23] American Public Health Association, Standard Methods of the Examination of Water and Wastewater, Including Bottom Sediments and Sludges (twelfth ed., N.Y. American Public Health Association, Inc., 1969). pp. 225-226.

[24] John D. Hem, Study and Interpretation of the Chemical Characteristics of Natural Water (Geological Survey Water-Supply Paper 1473, Washington Government Printing Office, 1970). pp. 93-94.

TABLE V

PARAMETERS MEASURED FOR SUB-WATERSHEDS

Parameter Measured	Stream (Year Logged)	Date 2/29/69	Date 3/01/69	Date 3/12/69	Date 3/18/69	Date 4/05/69	Date 4/27/69	Date 5/15/69
Flow (in	1968	0.59	0.54	0.19	0.22	0.75		0.03
cubic feet	1966	4.33	3.71	1.21	1.47	2.63		0.03
per second)	1964	5.78	4.94	1.53	2.05	3.97		0.18
	Old Growth			1.28			0.30	0.15
Temperature	1968	44		44	45.5	47		48
Degrees	1966	44		43	45.0	47		48
Farenheit	1964	44		43	45.5	47		48
	Old Growth			43			44	44
Dissolved	1968	12.0	12.0	7.0	10.0	9.5		8.0
Oxygen	1966	10.0	10.0	9.5	11.0	11.5		8.0
Parts per	1964	11.0	11.0	7.0	10.5	11.5		8.0
Million	Old Growth						11.5	11.5
Total	1968			85	100	100		135
Hardness	1966			50	60	60		90
Parts per	1964			47	50	50		75
Million as $CaCO_3$	Old Growth			25	30		25	25
pH	1968	8.2	8.2	8.4	8.3	8.5		8.25
Hydrogen	1966	8.2	8.0	8.3	8.2	8.4		8.3
ION	1964		8.3	8.3	8.4	8.2		8.3
Activity	Old Growth			8.2	8.2		8.2	8.2
Turbidity	1968	60	60	13	30	63		8
Jackson	1966	35	35	10	52	78		8
Turbidity	1964	19	19	7	25	64		10
Units	Old Growth			2	8		5	5

TABLE VI

AVERAGE PARAMETERS MEASURED ON TRIBUTARIES

TO JACOBY CREEK

Stream (Year Logged)	Flow (C.F.S.)	Temperature Degrees F	Dissolved Oxygen (ppm)	Total Hardness (ppm) as $CaCO_3$	pH	Turbidity (JTU)
1968	0.34	45.7	9.7	105	8.3	39
1966	2.25	45.4	10.0	65	8.2	36
1964	3.07	45.5	9.8	55	8.3	24
Old Growth	0.58	43.7	11.7	26	8.2	6

is also a good pH for chlorine to have its maximum killing power.[25] From the standpoint of production, aquatic insects do best at a pH range from 6.5 to 8.2, but can survive from 5.0 to 9.5. Trout have survived in waters with pH ranges from 3.3 to 10.7 without adverse effects, although algae generally are unable to survive in natural waters with a pH of 8.5 or higher.[26]

The pH values of the waters measured in this study ranged from 8.0 to 8.5. There was no specific difference in pH between streams in the logged areas. The pH values were rather high. This can be partially explained by the high amounts of calcium available in the parent material (Franciscan Formation) and aquatic activity.

There appeared to be a slight increase in pH value with a decrease in flow, but it was not significant. It was probably due to greater interchanges of ground water with the stream and photosynthetic activity concentrated in a lower volume of water.

Turbidity

The American Public Health Association Standard Methods defines turbidity as "an expression of the optical property of a sample which causes light to be scattered and

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[25] McKee, op. cit., pp. 235-236.

[26] Ibid.

absorbed rather than transmitted in a straight line through a sample."[27] The standard unit of measurement is the Jackson Turbidity Unit (JTU). This scale is not interchangeable with parts per million (ppm).

The Hach Turbidimeter, used for turbidity measurements in this paper, is an absorptometer which measures the amount of light passing directly through a sample. A weak point of this machine is that it is not sensitive to low turbidities.[28] Graph 5, page 49, summarizes the relations found between turbidity and volume of flow for the three logged watersheds.

Photograph No. 17 shows debris deposited at the base of a slope. One week after this photograph was taken, the gully was completely filled in by debris. This is a continuing process by which alluvial material is deposited at the base of slopes or in drainages by low intensity storms and finally scoured from the channel and deposited on the flood plain or in Humboldt Bay by high intensity rainfall.

Turbidity is caused by suspended particles in water, such as clay, silt, organic matter, plankton and other microscopic organisms. From the standpoint of domestic use, water should not have rapid fluctuations in turbidity which would

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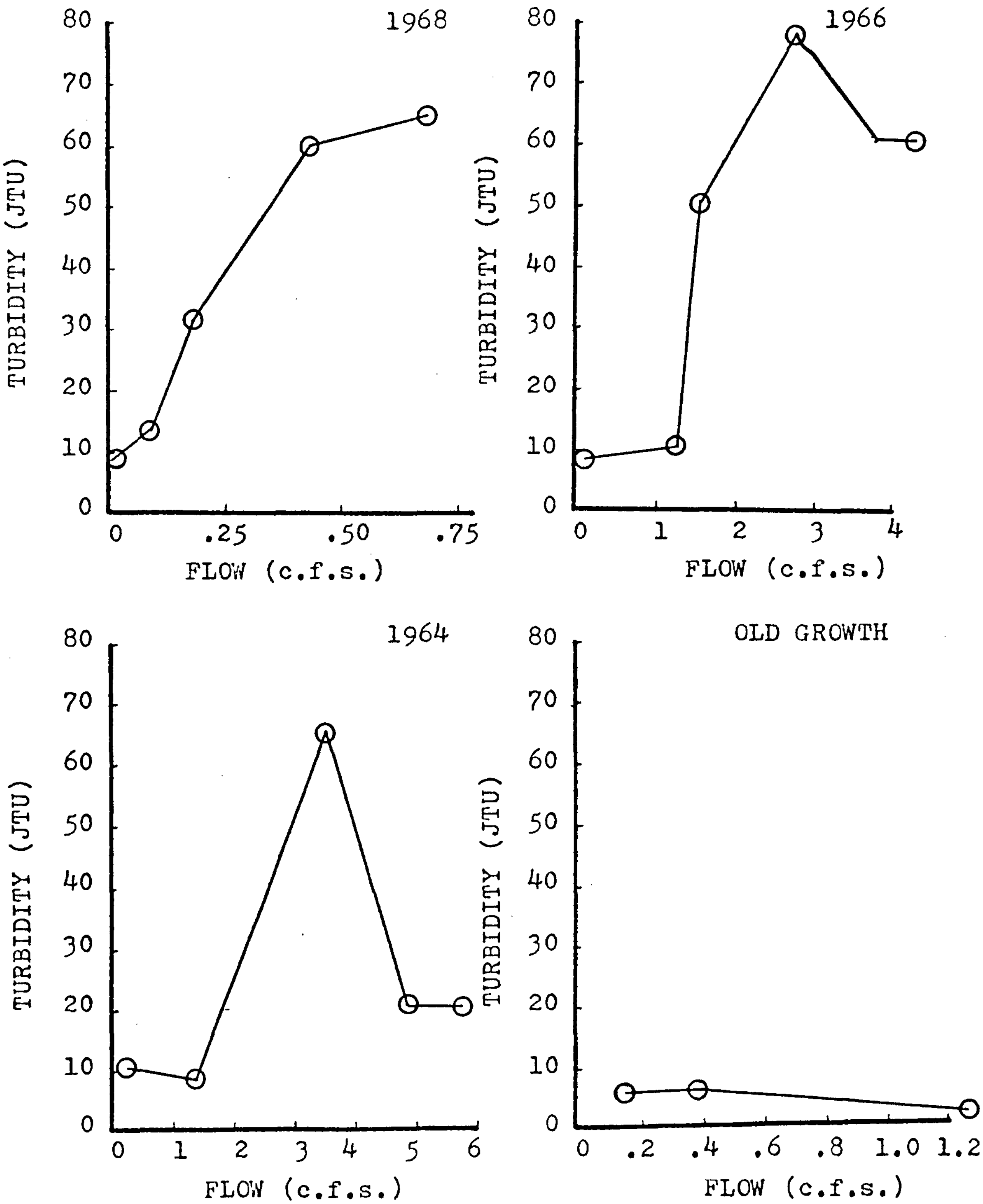
[27]American Public Health Association, op. cit. pp. 312-313.

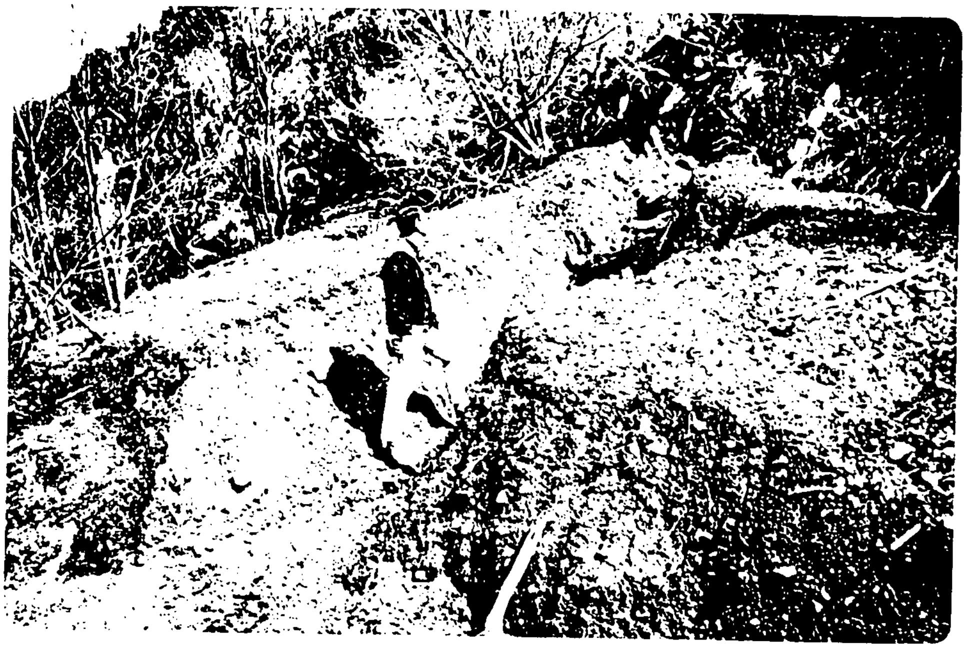
[28]Clifford C. Hach, Introduction to Turbidity Measurement (Ames, Iowa). pp. 1-2.

GRAPH NO. 5

A GRAPH OF TURBIDITY AND STREAMFLOW FOR

SELECTED TRIBUTARIES OF JACOBY CREEK





PHOTOGRAPH NO. 17

DEBRIS CONTRIBUTING TO TURBIDITY. MATERIAL IS WASHED OUT AND PILED IN DEBRIS CONES AT THE BASE OF SLOPES. THIS MATERIAL IS EVENTUALLY WASHED INTO JACOBY CREEK.

upset the water treatment plant processing.[29] The 1962 United States Public Health Service drinking water standards set five Jackson Turbidity Units as a maximum.[30] Higher turbidities only increase the cost of treatment.

The turbid waters of our north coastal streams pose a serious threat to anadromous fish production. Turbidity reduces light penetration, in turn reducing algae production

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[29]Water Pollution Control Administration, Water Quality Criteria (Report of the National Technical Advisory Committee to the Secretary of the Interior. Washington U.S. Government Printing Office, April, 1968). p. 21.

[30]McKee, op. cit. p. 290.

and visibility of fish for feeding. The abrasive effect of silt on the gills of fish and the grinding action on benthic algae and aquatic insects is directly harmful to the fish and indirectly harmful by reducing available food.[31] The siltation of gravel beds is another indirect detrimental effect of turbid waters. Siltation decreases the exchange of oxygen between surface waters and ground water. Groups of coho salmon and steelhead embryos suffered almost complete mortality at dissolved oxygen levels of seven mg/l in a silted gravel bed.[32] Silting in of eggs by shifting gravel beds, reduction of protective cover for young and the decrease in spawning during periods of turbid water all decrease production of salmon and trout.[33]

Turbidity measurements in the logged areas registered much higher than those in the old growth control stream. (See Graph No. 5.) The turbidity measurements in the 1968 drainage fell below those of the 1966 drainage for low and medium flows. The turbidities increased with increased flow as was expected. The lower flows and turbidities of the 1968 drainage could have been due to its smaller size (143 acres) compared with the other drainages. The turbidities of the 1964 drainage were below

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[31] D. W. Chapman, "Effects of Logging upon Fish Resources of the West Coast," Journal of Forestry, Vol. 60, No. 8 (August 1962). pp. 534-535.

[32] Ibid. [33] Ibid.

those of the 1966 drainage. During two periods of high flow, turbidities ranged from 60 JTU in the 1968 drainage to 35 JTU in the 1966 drainage to 20 JTU in the 1964 drainage.

Dissolved Oxygen

Dissolved oxygen in water is primarily a function of temperature, dissolved solids and pressure.[34] Dissolved oxygen (DO) is not actually a primary pollutant but a corollary pollutant brought about by adverse changes in other water quality parameters. DO in natural waters is very seldom at equilibrium because of changing water temperatures, and because physical, chemical, bio-chemical or biological activities are constantly liberating or utilization oxygen.[35]

Dissolved oxygen levels in the waters of logged areas can be lowered by: increased water temperatures, decomposition of slash by aerobic bacteria and by decreases in interchanges of ground and surface waters by siltation. Coho salmon and steelhead embryos showed almost complete mortality in a stream gravel environment with DO levels of seven mg/l.[36]

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[34] Hem, op. cit., p. 221.

[35] McKee, op. cit., pp. 181-182.

[36] D. W. Chapman, "Effects of Logging upon Fish Resources of the West Coast," Journal of Forestry, Vol. 60, No. 6, (August 1962). p. 534.

In spawning areas DO levels should not be below seven mg/l at any time. For optimal growth of salmon and trout, DO concentrations should not be below six mg/l, although they can survive minimum levels between five and six mg/l for short periods of time providing water quality is favorable and that daily and seasonal fluctuations occur.[37]

Dissolved oxygen levels measured on the different logged areas showed a broad scattering of DO levels during moderate and high flows. No correlation could be made between them. However, during low flows, dissolved oxygen levels were lower in the partially logged watersheds than in the Old Growth control stream.

Dissolved oxygen levels in the partially logged areas ranged from seven to 9.5 mg/l and from 11.5 to 12 mg/l in the Old Growth control stream. In lower flows, there is less dissolved oxygen present.

Total Hardness as $CaCO_3$

Hardness is generally referred to as the soap neutralizing power of a water. Any substance that forms an unsoluble curd with soap causes hardness.[38] The two most common cations causing hardness are calcium and magnesium and so total

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[37] Federal Water Pollution Control Administration, *op. cit.*, pp. 43-44.

[38] McKee, *op. cit.*, pp. 195-196.

hardness is sometimes referred to as calcium plus magnesium hardness. Hem uses the following classification for hardness:

TABLE VII

HARDNESS CLASSIFICATIONS[39]

Hardness range mg/l $CaCO_3$	Description
0-60	Soft
61-120	Moderately Hard
121-180	Hard
180+	Very Hard

Hardness generally becomes objectionable, from the standpoint of domestic use, at levels above 100 mg/l.

Excessive hardness can cause these results: excessive soap consumption; formation of scum and curd in laundries, homes and textile mills; toughen vegetables cooked in hard water; and form scales in pipes, hot water heaters and boilers.[40] Increased use of detergents in hard water directly contributes to pollution by adding increased quantities of nutrients to the water.

The effect of hardness on aquatic life depends on

[39]Hem, op. cit., p. 225.

[40]McKee, loc. cit.

the specific cation involved. Generally Ca and Mg contribute to productivity, but some of the other elements are toxic and reduce biological productivity. Because of this, hardness should be avoided in dealing with water quality requirements for aquatic life. From the standpoint of domestic and industrial use, it is an important water quality parameter.

The high total hardness found in the streams monitored in this study was derived from calcium carbonate dissolved from the geologic parent material (Franciscan Formation).

From Graph No. 6, it can be seen that the greatest total hardness was measured in the most recently logged area. Maximum readings reached 135 parts per million (ppm). The 1966 drainage ranged from 35-42 ppm below the 1968 drainage and the 1964 drainage ran from 2-10 ppm below the 1966 drainage. The Old Growth control stream had the lowest total hardness measurements, ranging from 45-105 ppm below those of the logged drainages.

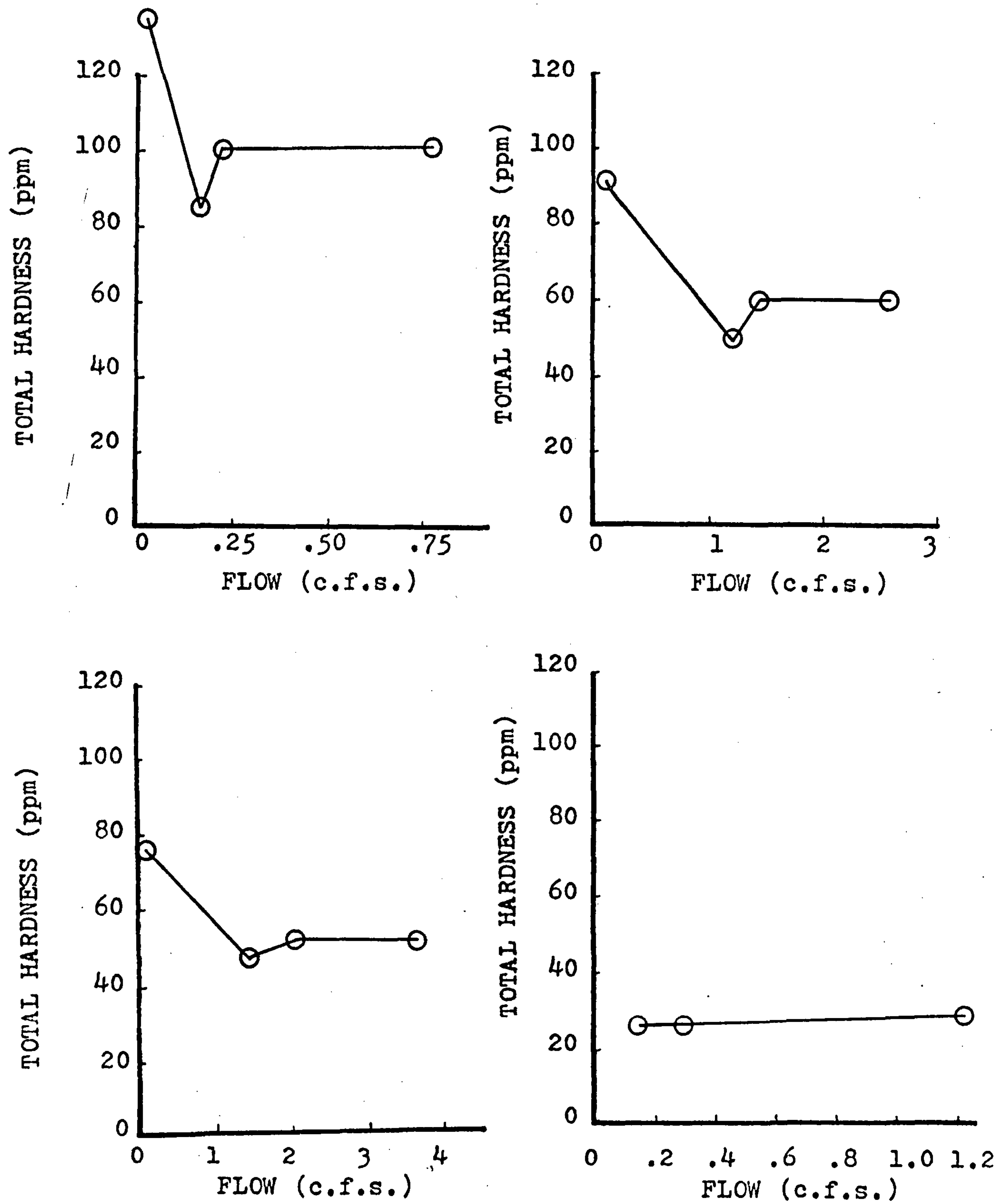
<u>Temperature</u>

Stream temperatures remained fairly constant throughout the three logged areas. I feel this was due to a considerable length of shaded channel below all of the logged areas. Although on a day of higher stream temperatures (5/15/69) the Old Growth control stream was

GRAPH NO. 6

A GRAPH OF TOTAL HARDNESS AND STREAMFLOW FOR

SELECTED TRIBUTARIES OF JACOBY CREEK



four degrees lower in temperature than the three other streams measured. Data showing stream temperatures can be found on page 45, Table V.

Stream side vegetation provides shade to the stream channel, in turn lowering the stream temperatures below clearcut blocks. Temperature drops as much as 12 degrees F have been recorded after a non-forested stream meandered through 400 feet of forest and brush cover.[41] Even with this return of stream temperature to a near normal condition, a thermal barrier to migrating fish may be created by such a temperature change over a short distance.[42]

Flow

As was mentioned before, the city of Arcata used Jacoby Creek as a source of domestic water prior to 1964. The U.S. Geological Survey operated a stream gauging station in the upper portion of the drainage until 1964 when it was damaged by the flooding. After that time, the upper reaches of the watershed were intensively logged. I repaired the old gauging station, shown on page 58, Photo. No. 18 and 19, with the help of Jerry LaRue of the U.S. Geological Survey and Dr. Dean Freeland, Associate Professor of Watershed

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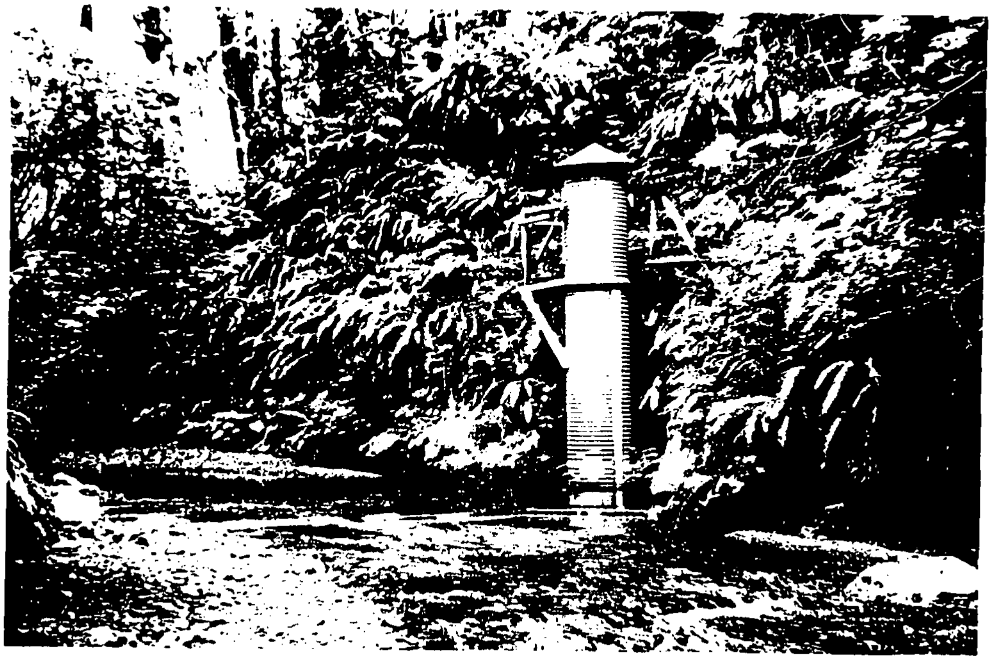
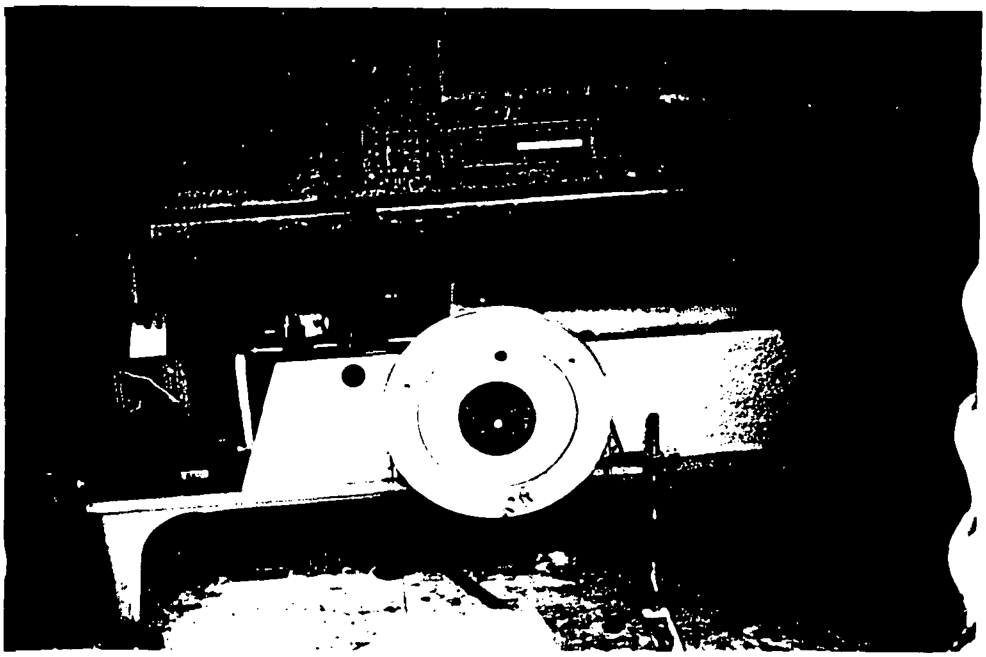
[41]Al Levano, "Increases in Maximum Stream Temperatures after Logging in Old Growth Douglas Fir Watersheds (PNW Research Note -65, Oct. 1966). p. 9.

[42]McKee, op. cit., p. 285.



PHOTOGRAPH NO. 18

STREAM GAUGING STATION



PHOTOGRAPH NO. 19

STAGE RECORDER INSTALLED IN STREAM GAUGE

Management at Humboldt State College. A stream recorder was installed and the stilling basin behind the weir was cleaned out. A series of flow measurements were taken and a rating curve was derived for the station. My hopes were to measure any changes in water yield over the old flow records which could have been due to the intensive logging that had occurred in the upper portion of the watershed. As it turned out, I did not have enough high flow measurements to accurately determine the total flow. I operated the station from March 21, 1969 to June 5, 1969.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The effects of logging and road building practices on the stream environment and downstream resources are many. Stream temperature increases measured in the clear-cut block in this study ran up to 7.9 degrees F. The highest stream temperature recorded was 55.4 degrees F on May 6, 1969. Stream temperatures were 1.5 to 5.7 degrees F higher at the base of the clear cut block than in the Old Growth control stream. Levano (1967) showed similar temperature increases for the month of May in the clearcut blocks on the H. J. Andrews experimental forest. On June 14, 1966, he measured temperatures of 77 degrees F on the same stream. After flowing through 700 feet of undisturbed canopy the temperature was reduced to 69 degrees F.[43] Stream temperatures were accurately estimated by use of Brown's formula within an average of 1.3 degrees F. Predicting stream temperatures is an important way to determine the effect of vegetative removal on the total stream environment.

The removal of the vegetation that shades the stream can have a drastic effect on the stream environment. How

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[43] Levano, loc. cit.

can this problem be solved? The answer may lie in leaving a protective buffer strip of vegetation along the stream for shading purposes. In some areas a buffer strip of timber 100 feet on both sides of the stream is the answer. Other drainages which may have steeper sides or be more subject to windthrow would have to be treated in another way.

Road construction in and near stream channels removes additional canopy, valuable for shading the stream. Cable logging from roads built along ridge tops could eliminate this problem. Trees susceptible to windthrow could be removed without damage to the riparian vegetation in the stream channel, which could then be left for shade. This brings up an important point. Trees are not the only form of vegetation that can be used to shade the stream channel. Low growing shrubs, such as willow, vine maple, salmon berry, maple, dogwood, alder, blackberry, etc., can be just as effective.

Dissolved oxygen levels of seven mg/l were recorded on March 12, 1969, in the 1968 and 1964 logged areas while the DO levels were 12 mg/l in the Old Growth drainage. Total hardness in the streams of the logged watersheds averaged 26 to 79 parts per million higher than those in the Old Growth control stream with a maximum difference of 110 parts per million recorded on May 15, 1969. No specific correlation could be made between pH and watershed disturbance. The pH of the various streams monitored ranged from 8.0 to 8.5. Turbidities averaged 18 to 33 Jackson Turbidity Units higher in the logged watersheds than those in the Old Growth control stream. Increased sediment yields, total hardness and low dissolved oxygen levels also have a definite impact on downstream resources, fisheries and domestic use, not to mention the loss of valuable soil on the watershed.

The results of the various water quality parameters measured show that logging may pose a serious threat to water quality if not regulated properly. Some of the parameters measured might have been more striking if they had been taken during the critical summer months when dissolved oxygen levels were low and stream temperatures were high, or during peak flows when turbidities were high.

Sadler did an economic analysis between timber and fisheries that could be lost after logging. His economic evaluation showed, "that from an economic standpoint, the fishery values can equal or exceed the timber values."[44]

The Eel and Mad River Basins dump 9,258 acre feet of sediment a year into our oceans and bays.[45] Jacoby

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[44] Ronald R. Sadler, Buffer Strips A Possible Application of Decision Theory. (Technical Note, Bureau of Land Management, U.S. Dept. of Interior, Oregon, Oct. 28, 1970). pp. 1-11.

[45] U.S. Dept. of Agriculture, Water, Land, and Related Resources (Appendix No. 1, Portland, Oregon, 1970).

Creek situated between the two, is a major contributor to the siltation of Humboldt Bay.

The following is a list of recommendations for logging and road construction in the north coastal area. Some have been mentioned before by other people, but I will list those I feel to be most significant.

1. Keep road gradients to 15% or less.

2. Install culverts and bridges of sufficient size to handle peak discharge and maintain them or remove them after the logging operation.

3. Always provide a protective buffer strip of vegetation between the stream and any logging, landings, roads, and skid trails.

4. Install drainage bars in roads immediately after logging.

5. Install all overside drains and water bars so that they drain into vegetation or rock energy dissipaters.

6. Keep stream channels free of obstructions.

7. Compact fills during construction.

8. Never push fill for roads or landing over vegetation.

9. Restrict the use of dirt roads during the wet season.

10. Provide adequate drainage for surface and subsurface water on permanent roads.

11. Exercise greater consideration in road location with respect to unstable land forms and soil.

12. Avoid building roads on steep slopes because they are expensive, increase erosion, leave permanent scars and require the whole hillside for the side cuts and back-slope.

13. Do not tractor-log on steep slopes.

14. Use logging systems that minimize soil disturbances and road construction in steep areas, such as skyline, balloon, and helicopter logging.

15. Log from the ridge tops and keep roads out of stream channels.

16. Do not log in the wet season.

17. Provide for an adequate maintenance program for road drainage, cuts and fills.

18. Surfaced roads only should be used in the winter months.[46]

19. Keep landings out of live streams.

20. Keep overcast material out of drainages.

21. Keep heavy equipment out of streams.

22. Fall trees away from stream channels.

23. Plant or seed all disturbed areas.

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[46]U.S. Dept. of Agriculture, *op. cit.*, pp. 31-32.

24. Outslope temporary roads wherever possible.[47]

25. Install dips at the down grade approach so that in case of peak flows or plugged culverts the water may flow over the road.

26. Use low water crossings for drainages with high debris loads.[48]

27. Provide for fish passage through culverts.

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[47]Federal Water Pollution Control Administration. Industrial Waste Guide Logging Practices. (Portland, Oregon, 1970).

[48]*Ibid.*

APPENDIX

HYDROLOGIC ANALYSIS DATA FOR JACOBY CREEK

WATERSHED CHARACTERISTICS

Drainage Pattern

Jacoby Creek has a dendritic drainage pattern. A large flood plain is present in the lower portion of the drainage where the stream meanders through it to Humboldt Bay. Active downcutting is still occurring in the upper reaches of the drainage adding sediment to the flood plain and Humboldt Bay.

Area

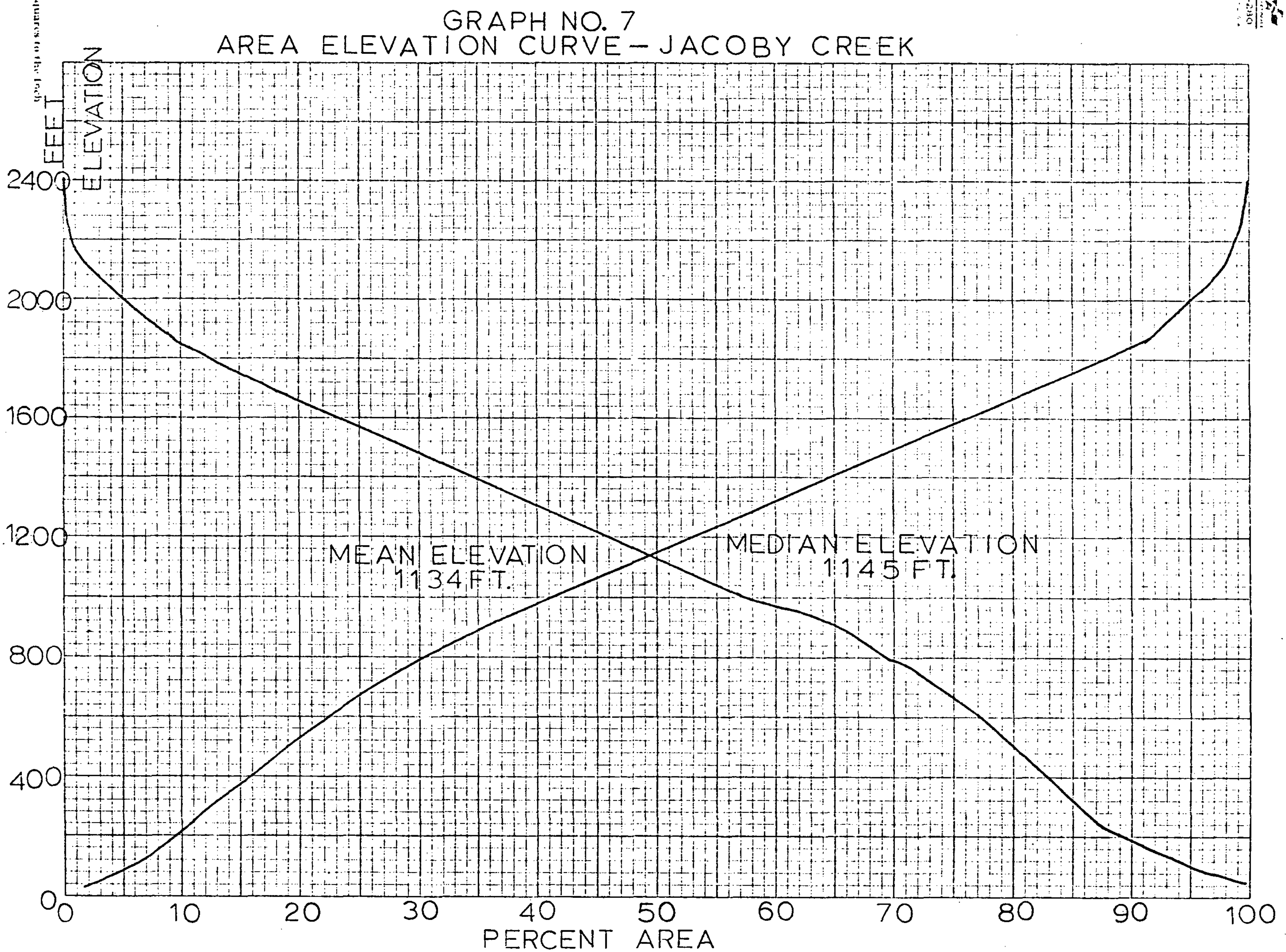
The area of the drainage is 14.70 square miles (9,409.8 acres).

Aspect

The aspect of the main drainage basin is northwest.

Area Elevation Distribution

The area elevation distribution has been displayed by plotting elevation against percentage of area on the graph on page 69.



GRAPH NO. 7
AREA ELEVATION CURVE — JACOBY CREEK
ELEVATION FEET
2400
2000
1600
1200
800
400
0
MEAN ELEVATION 1134 FT.
MEDIAN ELEVATION 1145 FT.
0
10
20
30
40
50
60
70
80
90
100
PERCENT AREA

Elevation in feet	Tally	% area below this elevation	% area above this elevation	Mean Elevation	Mean Zonal Elev.
60	7	1.8	98.2	50	350
240	54	11.0	88.0	150	8100
480	50	19.4	80.6	360	18000
720	44	26.9	73.1	600	26400
960	63	37.5	62.5	840	52920
1200	93	53.3	46.7	1080	100440
1440	77	66.4	33.6	1320	101640
1680	85	80.8	19.2	1560	132600
1920	30	92.7	7.3	1800	126000
2160	36	98.8	1.2	2040	73440
2388	6	100.0	.0	2274	13680
	585		100.0		663570

$$\frac{663570}{585} = 1134.3 \text{ feet}$$

Maximum elevation = 2388 Feet

Minimum elevation = 40 Feet

Mean elevation = 1134.3 Feet

Median elevation of the watershed:

See area elevation curve.

Median elevation = 1145 Feet

Area elevation data are important in comparing the elevation distribution in basins of different sizes. From the area elevation data of Jacoby Creek, the slope is rather uniform and steep. The uniform slope will cause a rather uniform overland flow. The steepness of the watershed will cause the stream to have high velocities and the overland flow to be turbulent at times. The median elevation also can be used as an indicator of mean temperature and climate.

Total relief on the watershed (basin relief):

Maximum elevation: 2388 Feet

Minimum elevation: 40 Feet

Total relief: 2348 Feet

The total relief of the watershed is small when compared to the length of the watershed, which is about 5.15 miles in length. The total relief of a watershed given an indication of the steepness.

The Basin altitude index:

The basin altitude index is computed as the average of the altitude of the points 10 and 85 percent of the distance along the main channel upstream from the lower boundary of our watershed.

Elevation at 10% = 238.8 Feet

Elevation at 85% = 2029.8 Feet

$$\frac{2268.6}{2} = 1134.3 \text{ Feet}$$

Basin altitude index = 1134.3 Feet

The basin altitude index gives a better altitude index for the main body of the stream because at the lower end of the watershed it is quite flat as compared to the main slope. The top of the watershed is quite steep as compared to the rest of the stream gradient. By eliminating these two ends of the stream, a more uniform basin altitude index can be computed.

The main-channel slope index in feet per mile and percent.

28.55 In. X .379 Miles/In. = 10.72 Miles

Length of main channel = 10.72 Miles

Length of main channel at 10%:

2.855 In. X .379 Miles/In. = 1.072 Miles

Length of main channel at 85%:

24.27 In. X .379 Miles/In = 9.198 Miles

Distance in miles between points at 10% and 85% on the main channel:

$$\begin{array}{rl} & 9.198 \text{ Miles} \\ - & \underline{1.072} \text{ Miles} \\ & 8.126 \text{ Miles} \end{array}$$

Elevation at 10% of main stream channel = 238.8 Feet

Elevation at 85% of main stream channel = 2029.8 Feet

Difference in elevation at 10% and 85%

$$\begin{array}{rl} & 2029.8 \text{ Feet} \\ - & \underline{238.8} \text{ Feet} \\ & 1791.0 \text{ Feet} \end{array}$$

Main channel slope = $\frac{1791.0 \text{ Ft.}}{8.126 \text{ Miles}}$ = 220.4 Ft/Mile

<u>Main channel slope = 220.4 Ft/Mile</u>

Main channel slope index in terms of percent:

Difference in altitude at 10% and 85% = 1791.0 Feet

Length of channel in feet between 10% and 85%

19.42 In. X 2000 Ft/In. = 38860 Feet

$\frac{1791.0 \text{ Ft.}}{38860 \text{ Ft.}}$ = .046 X 100 = 4.6%

Main channel slope index in percent = 4.6%

The main channel slope index is moderately steep allowing runoff to be quite rapid. From the location of the stream at the higher elevation where the most precipitation will occur, the runoff will probably be later in the storm due to the distance of that area from the mouth of the main stream.

Mean slope of main channel, fall in feet per mile:

195.8 Ft/Mi.

Mean slope of the main channel in percent:

3.7%

See stream profile Graph page 74.

The mean slope is not uniform. There is a series of steep and gradual slopes. There is a still noticeable curve in the stream profile. This depicts a mature basin. Downcutting is still persistent in the head waters.

Drainage density

$$\text{Drainage Density} = \frac{L}{A}$$

L = Length of stream (all classes) in miles

A = Area of basin in square miles

Total length of permanent streams:

70.0 In. X .379 Mi./In. = 26.5 Miles

Total length of intermittent streams:

131.4 In. X .379 Mi./In. = 49.8 Miles

26.5 Miles
49.8 Miles
76.3 Miles = Total length of streams.

$$\text{Drainage density} = \frac{76.3 \text{ Miles}}{14.70 \text{ Sq.Mi.}} = 5.19 \text{ Miles of stream/Sq.Mi.}$$

Drainage density 5.19 miles of stream per square mile of watershed

This watershed has an exceptionally well-drained basin. The number of streams per unit area is greater in the steeper upper reaches of the watershed. During the rain periods, the watershed probably receives a high amount at one time. At high intensities this will cause a lot of runoff after the initial infiltration and interception.

Compactness coefficient:

The compactness coefficient is an indication of the shape of a watershed, a compactness coefficient of one (1) means that the runoff from a watershed would tend to reach the main channel all at once. The compactness coefficient we received for Jacoby Creek was 1.875. This would indicate a rather linear watershed rather than circular as would be indicated by a compactness coefficient of one.

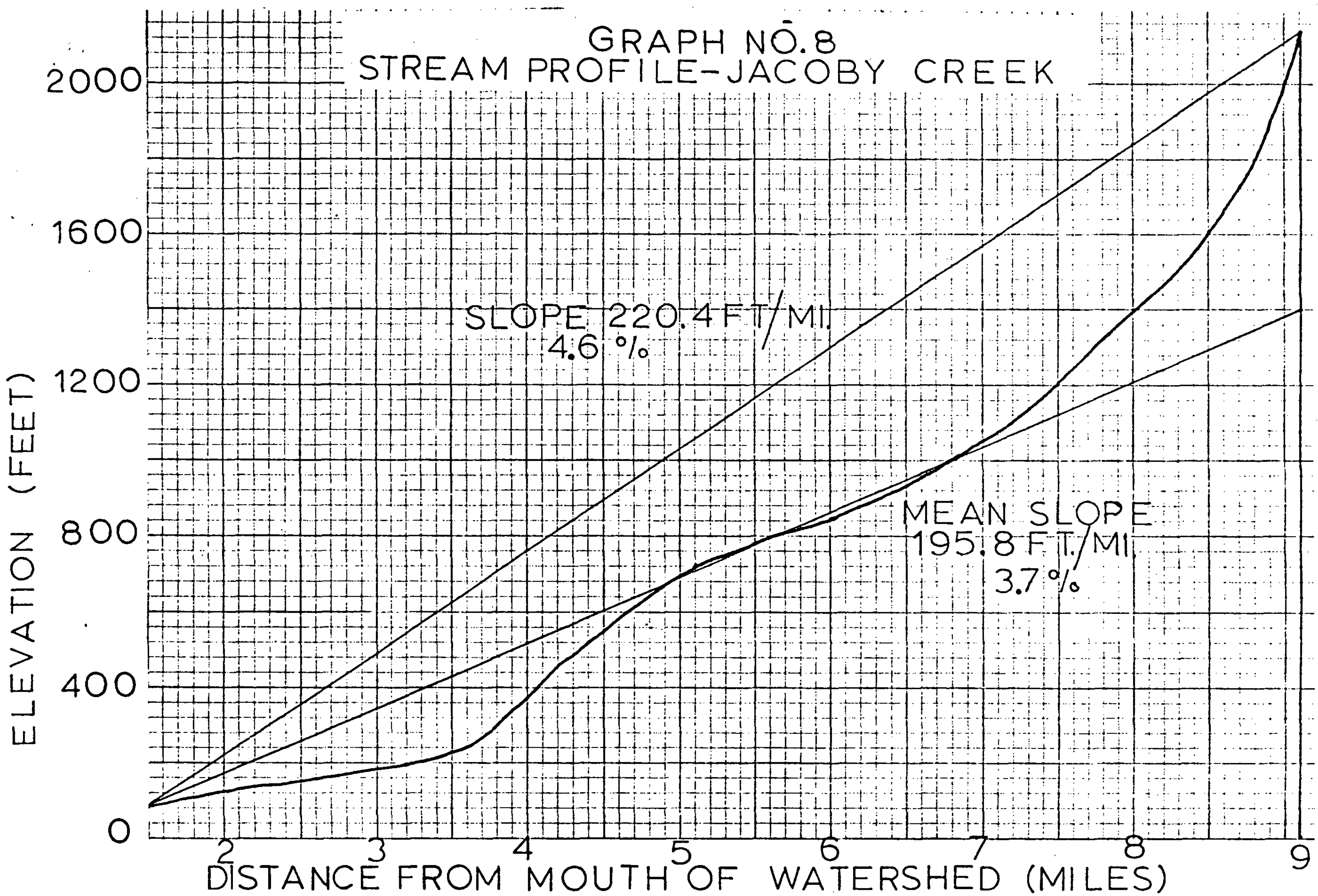
P perimeter in miles.

A area in square miles.

Perimeter in miles: 70.2 In. X .379 Mi/In. = 26.6 Miles/In.

Area in square miles: 14.70 Sq. Mi.

Square root of area: 3.83 Miles


GRAPH NO. 8
STREAM PROFILE-JACOBY CREEK
SLOPE 220.4 FT/MI
4.6 %
MEAN SLOPE
195.8 FT./MI
3.7 %
ELEVATION (FEET)
0
400
800
1200
1600
2000
DISTANCE FROM MOUTH OF WATERSHED (MILES)
2
3
4
5
6
7
8
9

$$.28 \times \frac{26.6 \text{ Mi.}}{3.83 \text{ Mi.}} = 1.875$$

Compactness coefficient = 1.875

Mean slope of the watershed

Mean slope of the watershed = $\frac{D\ L}{A}$

D = contour interval in feet (240)

L = total length of the contours measured in feet

A = area of basin in square feet

Length of odd contour intervals in feet.

720 ft.	8.9 in.
960 ft.	11.8 in.
1920 ft.	8.2 in.
2160 ft.	2.9 in.
Total	31.8 in.

31.8 In. X 2000 Ft/In. = 163600 Ft.

Length of even contour intervals in feet.

60 ft.	1.8 in.
240 ft.	9.5 in.
480 ft.	7.4 in.
1200 ft.	14.0 in.
1440 ft.	13.3 in.
1680 ft.	12.8 in.
Total	65.8 in.

65.8 In. X 2000 Ft/In. = 131,600 Ft.

Area in square feet:

9409.8 acres X 43560 Sq. Ft./acre = 409890888 Sq. Ft.

14.70 Sq. Mi. X 27878400 Sq. Ft/Mi. = 409862480 Sq. Ft.

409890888 Sq. Ft.
409862480 Sq. Ft.
819753368 Sq. Ft. ÷ 2 = 409876684 Sq. Ft.

Mean slope of watershed, even contour:

$$\frac{(240)\ (131600)}{409876684} = \frac{31584000}{409876684} = .775 \text{ X } 100 = 77.5\%$$

Mean slope of watershed, odd contour:

$$\frac{(240)\ (63600)}{409876684} = \frac{15264000}{409876684} = .35 \text{ X } 100 = 35.0\%$$

$$\begin{array}{r} 77.5\% \\ \underline{35.0\%} \\ 112.5\% \end{array} \quad 2 = 56.25\%$$

<u>Mean slope of the watershed = 56.25%</u>

The mean slope of 56.25% is an average computed from the length of both even and odd contour intervals. The mean slope on this watershed is steep, a lot of water is lost to runoff that could be infiltrated on a less steep watershed. Overland flow is very rapid, and in cases turbulent. The wetness of the watershed and the low growing vegetation and cutting of timber in the upper reaches creates a great potential for erosion. Any disturbance on this watershed might result in a great loss of material that can be carried by runoff, in the event of large amounts of rainfall.

Geology

The primary geologic formation found in the upper two-thirds of the watershed, the part with which this report deals, is the Franciscan Formation.

The Franciscan formation is an eugeosynclinal accumulation of detrital sedimentary rocks, chemical sedimentary rocks, and volcanic rocks. These include mainly, massive graywacke and minor amounts of platy, dark-gray shale, thin bedded chert, greenstone where undifferentiated, and minor amounts of glaucophone schist. Generally the rocks of the Franciscan Formation are sheared, deformed, and dislocated, and are intruded widely by mafic and ultra-mafic rocks. The Franciscan is often characterized by shear zones. These zones collect water and have numerous slumps and slips. For this reason, much of the Franciscan Formation is considered a poor formation for road-building.[49]

Soils

The primary soils found in the watershed are the Atwell (823), Hugo (812), Melbourne (814), and the Larabee (914) soil series. The Atwell and Hugo series are the primary soils found along the creek areas and in sections of the watershed where roads are located. The Atwell soil is dark grayish brown to pale brown on the surface. It is composed of clay loam and gravelly clay loam with the parent material being sandstone and shale. The topography and slope classes found in the watershed are hilly to very steep. Permeability of this series is slow and the general drainage is imperfect. Erosion hazard is considered to

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[49] Division of mines and Geology, Geologic man of California, (San Francisco, California.

be moderate. This series is very poor for road building, usually considered to be slide prone even before logging.[50]

The Hugo series is composed of loam and gravelly clay loam. The soil depth range is between 30-60 inches with the parent material being sandstone and shale. Slopes range from 30 to 70%. Permeability is moderate and drainage is good. Estimated use of the soil for timber production are high to very high with erosion hazard being moderate.[51]

The depth range of the Larabee soil series is 40 to 70 inches. Texture of the surface is loam with sub-soil composed of clay loam. Parent material is soft sedimentary rock. Slopes of this soil in the watershed range from less than 30 to 70%. Permeability is moderate with general drainage being good. Erosion hazard of this soil series is high.[52]

Boomer (7118), Kinman (855), Mendocino (915), Yorkville (752), and Orick (813), soil series are also present but only in very local areas and are not of much significance to the watershed as a whole.[53]

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[50]Peter E. Black, A Guide to the Soil Vegetation Maps of Humboldt County, Calif. (Humboldt State College, Arcata, Calif., 1964). pp. 1-14.

[51]Ibid.

[52]Ibid.

[53]Ibid.

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