[redacted]

STATEMENT ON EROSION PROBLEMS IN REDWOOD CREEK

by Clyde Wahrhaftig

Member, State Board of Forestry

Jan. 15, 1976

At the December meetings of the Board I promised that I would review the material on streamflow and sediment and come back with a report to the Board. I had also asked the USGS and Winzler and Kelly for some information to clear up some discrepancies, and I promised to report on that. This brief statement is based on a study I have made over Christmas vacation of mainly the USGS and W & K data, reading of other related reports, and conversations with others, mainly at the USGS and at U. C. Berkeley, to clear up questions in the reports.

I will discuss things in the following order: (1) the questions I feel we must try to answer in reaching a decision on Redwood Creek; (2) the relation of natural conditions on Redwood Creek to the land use problems; (3) specific impacts of timber harvest on water and sediment discharge; (4) what has to be known before any action can be recommended; and (5) resolution of the differences.

Questions

It seems to me that we have to know the answers to the following questions before we can reach a fair decision:

(1) How much more water and sediment come from the currently and recently logged parts of Redwood Creek basin than would have come if logging had not taken place?

(2) What changes do these additions (if any) cause on the lower courses of Redwood Creek and its tributaries in Redwood National Park?

(3) How could these changes affect park values?

(4) What measures could be taken to reduce these impacts? (Presumably there is a wide range of measures that could be adopted, with an equally wide range of costs and benefits. We have received recommendations ranging from complete prohibition plus massive rehabilitation to doing nothing. We are looking for the measures that give maximum park protection at minimum economic cost.)

(5) How would each of these measures, if adopted, affect the status of the park?
(6) To what degree do measures the Board has already adopted mitigate the impacts?
(7) What authority does the Board have for any further measures?
(8) What would be the impact of any measure the Board might consider on the economy of Humboldt County and the welfare of the interested parties?
(9) Would such an economic impact have occurred anyway --and when-- because we may be running out of old-growth timber before merchantable second-growth is available to replace it?
(10) If rehabilitative measures are to be considered, what is their cost?
(11) What efforts are being made, or will be made, by other agencies to mitigate the economic impacts of our decisions (Question 8) and pay the costs of any recommended rehabilitation measures (Question 10)?

I think I know the answer to the first three questions: there have been impacts, and I will spell them out below. I could not possibly come up with an answer to the next three questions --what measures, if any, to adopt-- unless I could see the problem at first hand. I was not on the Board at the time of the October field trip. I asked Howard Nakae if I could make such a trip early in January, before this meeting, but he felt I should get that authority from the Board, and I will, later in this report, request that authority. The answers to the remaining five questions are outside my expertise, and I will listen carefully to any testimony on them.

The Natural Environment of Redwood Creek

The basin of Redwood Creek is like other drainage basins in the North Coast Ranges (the Eel, Mad, Mattole, and Van Duzen) in its bedrock geology, geologic history for the last 10--20 million years, the processes that have eroded it, and its response to logging and other land uses. Redwood Creek basin seems unique in only two respects: it has had a larger area cut-over by tractor yarding (about 65 percent) in a 25-year period than any other basin of comparable size; and it has a national park at its lower end. The problems we face in Redwood Creek can be duplicated in many other north coast drainage basins and elsewhere.

The rocks are various units of the Franciscan Assemblage. The west side and some of the east side are underlain mainly by schist; most of the east side is underlain by sandstone and shale. Shear zones, major faults, and belts of crushed and broken rock within the basin are the <u>loci</u> of many landslides. Most of the slopes have light brown stony, not fully developed soils, the Hugo on the sandstone and the Masterson on the schist. On the higher flat upland areas, are thick well developed soils, mainly clay loams, with reddish colors, Melbourne on the sandstone and Orick and Sites on the schist. Atwell and Yorkville soils tend to occur on landslide-prone areas. Judging from places I have seen in southern Oregon and elsewhere, the reddish soils may have taken hundreds of thousands of years of weathering in place to develop to their present condition; the less mature Hugo and Masterson soils took 10,000 years or more to form.

The long valley walls in much of the basin have a local relief and microrelief that indicates that landsliding of some kind or other was the major slope-modifying process: large earthflows and slumps in some places, and debris avalanches in other places. Also, the mantle of surface debris that has moved downslope (colluvium) appears to have been transported in large part by some kind of landslide. We don't know when the landslides occurred, or how fast they delivered sediment to Redwood Creek when they did move; but the presence of an extensive cover of old-growth forest with trees 800 to 1,000 years old, growing on the slopes at the commencement of logging, and the mature soils developed on colluvium, indicate that most of the basin must have been stable (that is, has not been sliding) for at least hundreds or thousands of years. We would have to go back to the lowering of sea-level at the onset of the last glaciation, about 30,000 years ago, to find a geologic event that could be responsible for massive landsliding throughout the basin.

The fact that evidence of landsliding in the past is so prevalant throught the basin means that the slopes of Redwood Creek basin are marginally stable: that is, relatively minor actions, such as undercutting the toes of slopes, increasing the duration of ground saturation; or reducing the soil shear strength by a relatively small amount, could trigger extensive landslides.

The Eel, Mad, and Redwood Creek discharge enormous amounts of suspended sediment per year, five to ten times greater ~~at least~~ per square mile than any other drainage basin of comparable size in the U. S. Their measured suspended sediment discharge, over the last decade or so since these measurements began, is equivalent to an average erosion of the land surface of 3 to 4 feet per 1,000 years.

It has been asserted that this is because the North Coast Ranges have been uplifted in the last few million years, and are being rapidly eroded in consequence. Several years ago I estimated natural erosion rates for the North Coast Ranges for the last 3--20 million years, and they were no more than one-fifth to 1/10 the present rate of sediment discharge. More recently, underwater seismic surveys and offshore drilling have provided information on the volume of sediment that was eroded off the north Coast Ranges and deposited in the adjacent sea-floor. I talked with Prof. Eli Silver of the Earth Science Board at U. C. Santa Cruz, and he confirms that the volume of offshore sediment represents an erosion rate of no more than 1/5 to 1/10 the current rate of sediment discharge. The latest geologic event to have affected Redwood Creek and the rest of the coast was the 400-foot rise in sea-level to its present position that took place between 15,000 and 10,000 years ago; this would have caused the valley slopes to stabilize, for it ponded the lower courses of the streams. Erosion rates today under natural conditions should therefore be much less than the long-term geologic averages, not much more. It appears, therefore, that something has impacted Redwood Creek and the other North Coast drainages to cause the enormous sediment discharges that are now being measured.

Impacts related to timber harvest

The Geological Survey research on Redwood Creek has identified two major impacts from timber harvest: (1) a large increase in runoff; and (2) a large increase in sediment discharge.

Runoff

The increase in runoff is documented in an open-file report by Lee, Kapple, and Dawdy (November, 1975). To do this, they used a method for predicting runoff from rainstorms that was originally developed by the U. S. Weather Bureau. (Kohler and Linsley, 1951). This method predicted the effect of moisture already in the ground (measured by an antecedent precipitation index) and storm rainfall on the volume of runoff. The prediction equation has several constants (or parameters) that have to be determined for each drainage basin from the existing rainfall and runoff records. The weather-bureau method was a graphical method that is time-consuming. Hydrologists of the Tennessee Valley Authority developed a way of calculating the constants with a computer. [illegible]t. This computer model was used to find out what happened to rainfall-runoff relations on

Redwood Creek. I have examined the original papers describing the method, and it looks sound.

Lee, Kapple, and Dawdy first looked at two groups of records, those for the years 1954 through 1958, before extensive logging, and those for the years 1968 through 1972. To determine the constants, they used rainfall records at Prairie Creek and runoff at Orick for the even years '54, '56, and '58; and '68, '70, and '72, getting a set of "before" constants and a set of "after" const ants. They then tested the predictive capabilities of these constants by predicting runoff for the years 1955, 1957, and 1961, 1963, 1965, 1969, and 1971. They found that the "before" constants predicted runoff for the years through 1961 quite well, but underpredicted the seasonal runoff for the years 1963 through 1971 by an average of 22 percent. They found that the "after" constants predicted 1969 and 1971 reasonably well, underpredicted 1963 and 1965, and overpredicted the years 1961 and earlier (seasonal totals) by about 20 percent. Furthermore, they found that under the most common conditions of antecedent precipitation index, the respective under- and over-predictions for individual storms were as much as 50 percent. Thus, at times, Redwood Creek and its tributaries have had 50 percent more water to handle in a single storm than they normally had in the past; the storm most affected was not the rare 1964 flood when rain fell on saturated ground, but the flood with a recurrence interval of 1 to 1½ years. This class of flood has been shown to have a significant impact on width and depth of stream channels and on the sediment load.

This abrupt change in rainfall-runoff relationships is shown even more strikingly in the synoptic studies (Janda and Others, December, 1975). My analysis of peak flood discharges reported in that summary shows that when corrections are made for differences in storm rainfall in the basins, peak flood discharges per square mile for Harry Weir and Miller Creeks, the two logged basins, averaged twice those from Hayes and Little Lost Man Creeks, the two unlogged basins. The range in increase for individual storms was from 1.24 to 5.16 times.

T his should not be unexpeceted. Precisely the same changes were observed in the carefully monitored watersheds in Oregon. The greatest changes in rainfall-runoff relationships observed by the Forest Service and Oregon State Univ. in Oregon were in watersheds where roads and tractor skid trails were around 13 percent of the land surface. The Oregon data (summarized in Harr, 1975) showed that when as little as 13 percent of the area was in roads and skid trials, annual discharges increased from 25 to 70 percent, and storm discharges were also affected. Furthermore, the effect might persist as long as 20 years after logging.

Sediment Discharge

The USGS report that documents sediment discharge is the Graphic and Tabular Summary of Synoptic Storm Sampling (Janda and other, December, 1975). Since some question has been raised about the validity of conclusions that can be drawn from this study, I will discuss this first. The usual method for investigating a land treatment practice (such as road-building or logging) is to select two or three small watersheds (usually contiguous) in a large drainage basin, use one as a control, leaving it untouched, and apply the treatment to the others. The two or three watersheds are monitored for a period of 3--6 years prior to treatment, to see how they differ under natural conditions. This is done because the conclusions are going to rest on samples of one, and you have to be sure that your sample of one works. Sometimes an unexpected event such as a landslide in the control watershed, may confuse the results.

The USGS could not do this because logging was already going on in every watershed likely to be "treated", and there was no chance for a preliminary calibration program. They solved this problem by increasing the size of the sample. Instead of one unlogged watershed, they had two: Little Lost Man and Hayes Creeks; and two "treated" watersheds as well: Harry Wier and Miller Creeks. They had also two watershed that had been logged years ago and are now nearly fully recovered: Lost Man and Geneva Creeks.

I checked the figures and methodology in the summary by drawing my own flood and sediment "hydrographs" from the basic data report (Iwatsubo and other, Oct., 1975) for a flood on Harry Wier, one on Miller, and two on Hayes Creek, and came up with figures very close to those reported by Janda and others (Dec., 1975). The calculations are all right, and from information I shall report later, I think the original measurements are all right.

Summarizing the calculations, the quantity of suspended sediment discharged per square mile during a storm from Miller and Harry Wier Creeks ranges from 6 to 47 times that discharged from Little Lost Man and Hayes Creeks. The average was about 20 times. The variations within the two groups (logged vs. unlogged) is much less than than the differences between them, so the differences are real. There is no doubt that logging has greatly increased suspended sediment from these watersheds. There has probably been an equal change in bedload, inasmuch as the same slides, rills, and gullies that are contributing suspended sediment are also contributing bedload. Janda and others, (Oct. 1975, p. 80-81) describe aggradation and filling of pools with bedload on tributaries of Redwood Creek down-stream from logged areas.

In spite of this great increase in suspended sediment, these small tributaries on the east side of the stretch of Redwood Creek in the park have a negligible impact on the suspended sediment load of Redwood Creek itself. On a per-square-mile basis, Redwood Creek commonly carried from 2 to 20 times the suspended sediment than did Harry Wier or Miller Creeks. So regulations on the the lands immediately east of the Park will only protect park values on the slopes and in the tributaries, and will not have any effect on Redwood Creek. Regulation of watersheds of west-side tributaries such as Bridge and Tom MacDonald Creeks, could very well protect Park values along Redwood Creek, for these streams appear to cast considerable amounts of gravel into the main stream.

This increase in sediment load in logged drainage basins of Redwood Creek, as a result of logging, is not unusual; a large literature exists on the impact of logging and road-building and has been summarized in some recent papers (Janda and others, Oct., 1975; Swanson and Dyrness, 1975; Youngberg and others, 1971) and in the erosion report submitted to this Board in December. These studies show that where logging and road-building are undertaken on landslide-prone soils or formations, such as make up the basin of Redwood Creek, landslides and other forms of soil erosion, and resulting sediment discharge are increased on the order of 5 times. The effect of roads in the Oregon studies is ten times that of cable yarding, per unit area disturbed. This indicates that tractor yarding, with its large area in roads and skid trails, will produce many more landslides and far more sediment, than cable yarding.

Secondary impacts of increased water and sediment load

Redwood Creek and its tributaries have had to accomodate increased discharges of water, and increased suspended sediment and bedload. They can handle these increases by either (1) increasing their slope, and thereby the velocity and transporting power of the water, or (2) by increasing the width and depth of the channel. The slope can be increased only by aggrading the stream bed, and this seems to have happened over considerable reaches of the main channel and its tributaries; but the slope, over-all, can be increased very little by aggradation. Furthermore, a stream responds to an increase in the quantity of bedload by developing a broad braided channel, because of a peculiar difference between the relation between transporting and eroding velocities of bedload and suspended sediment. The greater the quantity of bedload, the wider the channel has to be to accomodate it.

Thus, the major secondary impact of timber harvest and other activities is that the streams erode their banks. Widening the banks, in turn, removes, the toes of marginally stable slopes and triggers landslides, and this seems to be what has happened in Redwood Creek at an increasing rate for the last two decades. Janda and others, 1975 (Oct.) and Colman (1973) document a steady increase in the number of landslides along the banks of Redwood Creek and its tributaries. Some of this may be due to the 1964 storm. However, equally large floods in the 19th century did not create the havoc on Redwood Creek that the 1964 flood did; and small tributaries that were not logged in 1964 did not erode their banks as they are doing now. It is hard to predict how long it will take these reactivated slopes to achieve stability; and it is certainly hard to make any recommendation (certainly without seeing them) as to how they might be stabilized.

Many of these slides may grow into gullies. They greatly increase the bedload and suspended sediment Redwood Creek is now carrying, and judging from the differences between the suspended sediment of Redwood and Harry Weir and Miller Creeks, these, together stream bank erosion, may now be the source of 3/4 of the sediment coming down Redwood Creek.

This, also, is not unique to Redwood Creek. A recent study made by the State Department of Water Resources for the Division of Fish and Game (Denton, 1974) documents exactly the same changes on the Mattole River, as a result of logging in the upper reaches of that stream. This report also carries a record of a great decline in spawning runs of salmon and steelhead trout in the north coast rivers, a decline that seems to be caused by the fact that accumulations of gravel on the stream beds, impregnated and somewhat cemented by silt, have rendered many of these streams far less suitable than before for fish spawning.

The interagency River Basin Study (USDA, 1970) showed that most of the stream sediment in the Eel and Mad Rivers was coming from streambank erosion and landslides, before the 1964 flood as well as afterward. This streambank erosion cannot have been going on for many years, for these rivers flow mostly in the bottoms of narrow canyons. Clearly land use patterns in the last century have had an impact on them. This impact seems to be a combination of sediment from many sources on land and the increase in storm runoff, that caused the streams to erode their banks and in turn to trigger more landslides and further increase the sediment discharge.

What is to be done?

I cannot answer that question with what I know now, and from here. I would have to see Redwood Creek basin itself, the logged lands around the Park, and some of the streams in the park, before I could come up with any suggestion, or could rationally consider anyone elses suggestions. And since a few days is too short a time to understand fully on one's own a problem as complex as Redwood Creek, I would like to see the problem in company with some people who are really familiar with it. The people I would like to have with me are Mr. Jerry Ficklin of Winzler and Kelly, one or two other experts the timber companies may wish to select (possibly Dr. Orme), Dr. Richard J. Janda of the USGS, Dr. Marvin Dodge and Mr. James Denny of the Division of Forestry--because I am impressed by some data in the erosion study that indicates that sound erosion-control practices can greatly reduce sediment discharge, and also because Dr. Dodge has developed a way of measuring what is going on at the site--- and either Dr. Rice or Dr. Ziemer of the U. S. Forest Service Experiment Station at Eureka, if they would be willing to attend. I would welcome the company of one or two more Board members, but I don't want any more board members because I don't want this trip to be overwhelmed by crowds of people as the October field trip was. I want to see if a few experts, knowledgeable about the problem from all points of view can come to some agreement on what erosion-control measures would give the greatest benefits to the park at the least economic cost. If the board could authorize this, and I believe that Sec. 4611 of the Z'berg-Nejedly act gives us some authority for making such a trip, I would like to make it on Monday Jan 26 through Thursday Jan. 29. We would try to come up with some alternative recommendations and a short report, hopefully writing the first draft on the spot, and get them into everyone's hands well before the next board meeting.

Resolution of Differences

Now, for the answers to the questions I asked in November. I received the data from the Geological Survey on about Dec. 11, and the data from Winzler and Kelly on January 6. The three disputed points involve water discharge, instantaneous sediment discharge, and total storm sediment yield at Orick, and near Highway 299, in February and March, 1974 (Mainly the period March 27-30, 1974.

I cannot resolve the question of water discharge, because the measurements near Highway 299 were taken on bridges some distance apart, and Winzler and Kelly did not send me their current-meter measurements for Orick.

The Geological Survey, in answering my request, decided to make final calculations for the data I asked (the final computations are what appear in the annual summaries of water-resources data). I discovered that the values reported by Dr. Janda Din his memo to Dr. Curry of the Park Service were preliminary estimates of instantaneous sediment discharge, made by the st aff of the Eureka office of the USGS, by reading the probable instantaneous suspended sediment concentration from logarithmic graphic plot of all suspended sediment concentrations against gage height or water discharge. The final determinations were made by constructing a graph showing the variation in sediment discharge for the storm plotted against time. Since the particular instantaneous sediment discharges in question at Highway 299 occurred during the falling stage of the storm, when suspended sediment concentration is lower than normal, the instantaneous suspended sediment figures reported in Janda's memorandum were too high. The corrected and final figures for instantaneous discharge agree well with the Winzler and Kelly figures. These corrections, however, do not affect the total sediment load discharged during the storm, because they are balanced by higher than average suspended sediment early in the storm. However, the revised final storm discharge figures for Orick increased from 116,000 to 142,000 tons. See attached sheet.

The really puzzling difference to me was an eight-fold difference between the total suspended sediment discharge for the storm of March 27-30, 1974. I have finally been able to resolve this difference. It is the result of three factors. First, as everyone recognizes, the Winzler and Kelly suspended concentrations are likely to be low because their samples were taken from near the surface, whereas the USGS samples are depth-integrated. Correcting for this would increase the W & K values by about 50 percent. The second factor, which I did not discover until I had the field notes from Winzler and Kelly, is that W&K reported only the period from 1730 March 27 to 0230 March 30, whereas the USGS period was 1200 March 27--1200 March 30. The flood actually peaked at or shortly after 2:30 am March 30, and half the suspended sediment of the storm passed Orick between 2:30 and 12 noon on Marych 30. So the W & K figure should be doubled by this factor. The third factor is that the W & K calculations, in applying the standard formula

$$Q_w \text{ (in cfs) } \times C_s \text{ (in mg/l) } \times 0.0027 = Q_s \text{ (in tons/day)}$$

forgot to multiply the average suspended seidment discharge for the period of 57 hours by the number of days. The suspended sediment discharge they reported should further be multiplied therefore, by the number 2 & 3/8. When these factors are multiplied together, the W & K and USGS figures for Orick agree quite well. W & K did not send me their calculations for Chezem bridge, but since the error appears to be in the method, I assume the same factors apply there. So I consider this matter closed.

I might add in closing that I see nothing in the Winzler and Kelly report that really contradicts the conclusions of the USGS reports. I asked Dr. Isaac Barshad, an expert in clay mineralogy in our soils department,to read the section on clay mineralogy, and it was his opinion that the method would not definitively show that there was no significant contribution from the upland soils. His letter is attached.

I will have the bibliography for this report at the next Board meeting

SELECTED BIBLIOGRAPHY

Betson, Roger P., Tucker, Russell L., and Haller, Faye M., 1969, Using Analytical Methods to develop a Surface-Runoff Model; Water Resources Research, vol. 5, No. 1, p. 103-111.

Brown, George W., and Krygier, James T., 1971, Clear-cut Logging and Sediment Production in the Oregon Coast Range; Water Resources Research, vol. 7, No. 5, p. 1189-1198.

Colman, Steven M., 1973, The History of Mass-movement Processes in the Redwood Creek Basin, Humboldt County, California; Thesis in Geology submitted for the Degree of Master of Science, Pennsylvania State University, Department of Geosciences, Dec. 1973, 180 p.

Dawdy, David R., Lichty, Robert W., and Bergmann, James M., 1972, A Rainfall-Runoff Simulation Model for Estimation of Flood Peaks for small Drainage Basins; U. S. Geological Survey Professional Paper 506-B, p. B-1--B-28.

Denton, Douglas N., 1974, Water Management for Fishery Enhancement on North Coastal Streams; Calif. Department of Water Resources, Northern District, 68 p.

Fredriksen, R. L., 1970, Erosion and Sedimentation following Road Construction and Timber Harvest on Unstable Soils in three small Western Oregon Watersheds; U. S. Dept. Agri. Forest Service, Research Paper PNW-104, 15 p.

Harr, R. Dennis, 1975, Forest Practices and Streamflow in Western Oregon; Paper presented at the Symposium on Watershed Management, Logan, Utah, Aug. 11-13, 1975, 16 p., 3 tables, 8 figs. (mss).

Hoskins, Ernest G., and Griffiths, John, 1971, Hydrocarbon Potential of Northern and Central California Offshore; American Association of Petroleum Geologists Memoir 15, vol. 1, p. 212-228.

Iwatsubo, Rick T., Nolan, K. Michael, Harden, Deborah R., and Glysson, G. Douglas, Oct., 1975, Redwood National Park Studies, Data Release No. 1, Redwood Creek, Humboldt County, California, Sept. 1, 1973--April 10, 1974; U. S. Geological Survey Open File Report, Menlo Park, Calif., 123 p.

Janda, Richard J., Nolan, K. Michael, and Harden, Deborah R., Dec., 1975, Graphic and Tabular Summaries of Water and Suspended-Sediment Discharge during Eight Periods of Synoptic Storm Sampling in the Lower Drainage Basin of Redwood Creek, Humboldt County, California; U. S. Geological Survey Open-file Report, Menlo Park, Calif., 10 tables, 8 fig.s, 2 plates (22 p.)

Janda, Richard J., Nolan, K. Michael, Harden, Deborah R., and Colman, Steven M., Oct., 1975, Watershed Conditions in the Drainage Basin of Redwood Creek, Humboldt County, California, as of 1973; U. S. Geological Survey Open-file Report 75-568, Menlo Park, California, 257 p., bibliography, map.

Kohler, M. A., and Linsley, R. K., 1951, Predicting the Runoff from Storm Rainfall; U. S. Weather Bureau Research Paper No. 34, 9 p.

Lee, K. W., Kapple, G. W., and Dawdy, D. R., Nov., 1975, Rainfall-Runoff Relation for Redwood Creek above Orick, California; U. S. Geological Survey Open-file Report, Menlo Park, Calif., 14 p.

Swanson, F. J., and Dyrness, C. T., 1975, Impact of clear-cutting and road construction on soil erosion by landslides in the western Cascade Range, Oregon; Geology, vol. 3, no. 7, p. 393-396.

U. S. Department of Agriculture, River Basin Planning Staff (SES-FS), 1970, Water, Land, and Related Resources, North Coastal Areas of California and Portions of Southern Oregon; Appendix No. 1, Sediment Yield and Land Treatment, Eel and Mad River Basins, 143 p. (Portland, Oregon).

Wahrhaftig, C., and Curry, Robert R., 1967, Geologic implications of sediment discharge records from northern Coast Ranges, California, in Man's Effect on California Watersheds, sec. 3, Institute of Ecology, University of California, Davis; Published for the Assembly Subcommittee on Forest Practices and Watershed Management, p. 35-58.

Winzler and Kelly, Engineers, Water Laboratory, 1975, 1973-1974 Redwood Creek Sediment Study, 44 p., 23 figs., Eureka, Calif.

Youngberg, C. T., Harwood, M. E., Simonson, G. H., Rai, D., Klingeman, P. C., Larson, D. W., Phinney, H. K., and Bell, J. R., 1971, Hills Creek Reservoir Turbidity Study; Water Resources Research Institute, Oregon State University, Corvallis, Oregon, WRRI-14, Dec. 1971, 252 p.

TABLE 1.--*Water and sediment discharge for Redwood Creek at Orick and Redwood Creek near Blue Lake*

Date and time	Source	Water discharge, in cubic feet per second	Suspended-sediment load, in tons
		Redwood Creek near Blue Lake	
2-27-74	USGS (final)	455	209
1800 hours	USGS (Janda memo 6-20-75)	455	379
	Winzler & Kelley (April 1975)	860	450
2-28-74	USGS	2,020	12,700
1920 hours	USGS (Janda)	2,040	18,400
	Winzler & Kelley	3,300	11,900
3-1-74	USGS	1,670	7,390
0130 hours	USGS (Janda)	1,670	14,400
	Winzler & Kelley	3,200	9,100
3-29-74	USGS	3,460	46,700
2100 hours	USGS (Janda)	3,460	64,460
	Winzler & Kelley	4,100	36,200
		Redwood Creek at Orick	
3-30-74	USGS	13,100	238,000
0225 hours	USGS (Janda)	13,000	170,240
	Winzler & Kelley	20,100	145,000

Total suspended-sediment load, in tons, from 3-27-74 (1200 hours) through 3-30-74 (1200 hours)

Station	USGS (final)	USGS (Janda memo 6-20-75)	Winzler & Kelley
Redwood Creek near Blue Lake	40,600	42,000	7,750
Redwood Creek at Orick	142,000	116,000	19,500

WATER AND SEDIMENT DISCHARGE DATA FOR REDWOOD CREEK AT ORICK AND NEAR BLUE LAKE FOR THE PERIODS, FEBRUARY 27 TO MARCH 1, AND MARCH 27 to 30, 1974

Table 1 lists the water- and sediment-discharge data for both sites for the periods of concern. The suspended-sediment loads listed in Dr. Janda's June 20, 1975, memo were obtained by use of a preliminary plot of instantaneous suspended-sediment concentration versus instantaneous water discharge. This technique is often used for estimating sediment discharge when a temporal concentration curve has not been drawn. The final suspended-sediment loads have been determined by use of the temporal concentration curve and have been put through standard USGS review procedures. A discussion of the techniques used in collecting the field data and computing the water and sediment discharge follows:

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DEPARTMENT OF SOILS AND PLANT NUTRITION

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January 13, 1976

Dr. Clyde Wahrhaftig
Department of Geology and Geophysics
University of California, Berkeley

Dear Dr. Wahrhaftig,

At your request, I have examined the section on clay mineralogy of the Redwood Creek Sediment Study by Winzler and Kelley, Engineers, of Eureka. I am familiar with the soils of Redwood Creek, having made the mineralogic analyses for the soil-vegetation surveys of Humboldt County.

My judgment is that the data presented are inadequate to differentiate among the clay minerals actually present in these soils. In the clay-size fraction of these soils, the higher-order spacings of the clay minerals and the larger-angle spacings that identify quartz, feldspar, and gibbsite are essential for identifying the clay sources. Likewise, organic matter content in the clay fraction can identify the A and B horizons of the soils.

Consequently, I find that the material presented in the Winzler and Kelly report is inadequate to recognize sediment sources in the Redwood Creek watershed.

Sincerely yours

Isaac Barshad

Isaac Barshad
Lecturer and Soil Chemist

Duplicate copy

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by Clyde Wahrhaftig

Member, State Board of Forestry

Jan. 15, 1976

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I will discuss things in the following order: (1) the questions I feel we must try to answer in reaching a decision on Redwood Creek; (2) the relation of natural conditions on Redwood Creek to the land use problems; (3) specific impacts of timber harvest on water and sediment discharge; (4) what has to be known before any action can be recommended; and (5) resolution of the differences.

Questions

It seems to me that we have to know the answers to the following questions before we can reach a fair decision:

(1) How much more water and sediment come from the currently and recently logged parts of Redwood Creek basin than would have come if logging had not taken place?

(2) What changes do these additions (if any) cause on the lower courses of Redwood Creek and its tributaries in Redwood National Park?

(3) How could these changes affect park values?

(4) What measures could be taken to reduce these impacts? (Presumably there is a wide range of measures that could be adopted, with an equally wide range of costs and benefits. We have received recommendations ranging from complete prohibition plus massive rehabilitation to doing nothing. We are looking for the measures that give maximum park protection at minimum economic cost.)

(5) How would each of these measures, if adopted, affect the status of the park?
(6) To what degree do measures the Board has already adopted mitigate the impacts?
(7) What authority does the Board have for any further measures?
(8) What would be the impact of any measure the Board might consider on the economy of Humboldt County and the welfare of the interested parties?
(9) Would such an economic impact have occurred anyway --and when-- because we may be running out of old-growth timber before merchantable second-growth is available to replace it?
(10) If rehabilitative measures are to be considered, what is their cost?
(11) What efforts are being made, or will be made, by other agencies to mitigate the economic impacts of our decisions (Question 8) and pay the costs of any recommended rehabilitation measures (Question 10)?

I think I know the answer to the first three questions: there have been impacts, and I will spell them out below. I could not possibly come up with an answer to the next three questions --what measures, if any, to adopt-- unless I could see the problem at first hand. I was not on the Board at the time of the October field trip. I asked Howard Nakae if I could make such a trip early in January, before this meeting, but he felt I should get that authority from the Board, and I will, later in this report, request that authority. The answers to the remaining five questions are outside my expertise, and I will listen carefully to any testimony on them.

The Natural Environment of Redwood Creek

The basin of Redwood Creek is like other drainage basins in the North Coast Ranges (the Eel, Mad, Mattole, and Van Duzen) in its bedrock geology, geologic history for the last 10--20 million years, the processes that have eroded it, and its response to logging and other land uses. Redwood Creek basin seems unique in only two respects: it has had a larger area cut-over by tractor yarding (about 65 percent) in a 25-year period than any other basin of comparable size; and it has a national park at its lower end. The problems we face in Redwood Creek can be duplicated in many other north coast drainage basins and elsewhere.

The rocks are various units of the Franciscan Assemblage. The west side and some of the east side are underlain mainly by schist; most of the east side is underlain by sandstone and shale. Shear zones, major faults, and belts of crushed and broken rock within the basin are the loci of many landslides. Most of the slopes have light brown stony, not fully developed soils, the Hugo on the sandstone and the Masterson on the schist. On the higher flat upland areas, are thick well developed soils, mainly clay loams, with reddish colors, Melbourne on the sandstone and Orick and Sites on the schist. Atwell and Yorkville soils tend to occur on landslide-prone areas. Judging from places I have seen in southern Oregon and elsewhere, the reddish soils may have taken hundreds of thousands of years of weathering in place to develop to their present condition; the less mature Hugo and Masterson soils took 10,000 years or more to form.

The long valley walls in much of the basin have a local relief and microrelief that indicates that landsliding of some kind or other was the major slope-modifying process: large earthflows and slumps in some places, and debris avalanches in other places. Also, the mantle of surface debris that has moved downslope (colluvium) appears to have been transported in large part by some kind of landslide. We don't know when the landslides occurred, or how fast they delivered sediment to Redwood Creek when they did move; but the presence of an extensive cover of old-growth forest with trees 800 to 1,000 years old, growing on the slopes at the commencement of logging, and the mature soils developed on colluvium, indicate that most of the basin must have been stable (that is, has not been sliding) for at least hundreds or thousands of years. We would have to go back to the lowering of sea-level at the onset of the last glaciation, about 30,000 years ago, to find a geologic event that could be responsible for massive landsliding throughout the basin.

The fact that evidence of landsliding in the past is so prevalant throught the basin means that the slopes of Redwood Creek basin are marginally stable: that is, relatively minor actions, such as undercutting the toes of slopes, increasing the duration of ground saturation; or reducing the soil shear strength by a relatively small amount, could trigger extensive landslides.

The Eel, Mad, and Redwood Creek discharge enormous amounts of suspended sediment per year, five to ten times greater per square mile ~~at least~~ than any other drainage basin of comparable size in the U. S. Their measured suspended sediment discharge, over the last decade or so since these measurements began, is equivalent to an average erosion of the land surface of 3 to 4 feet per 1,000 years.

It has been asserted that this is because the North Coast Ranges have been uplifted in the last few million years, and are being rapidly eroded in consequence. Several years ago I estimated natural erosion rates for the North Coast Ranges for the last 5--20 million years, and they were no more than one-fifth to 1/10 the present rate of sediment discharge. More recently, underwater seismic surveys and offshore drilling have provided information on the volume of sediment that was eroded off the north Coast Ranges and deposited in the adjacent sea-floor. I talked with Prof. Eli Silver of the Earth Science Board at U. C. Santa Cruz, and he confirms that the volume of offshore sediment represents an erosion rate of no more than 1/5 to 1/10 the current rate of sediment discharge. The latest geologic event to have affected Redwood Creek and the rest of the coast was the 400-foot rise in sea-level to its present position that took place between 15,000 and 10,000 years ago; this would have caused the valley slopes to stabilize, for it ponded the lower courses of the streams. Erosion rates today under natural conditions should therefore be much less than the long-term geologic averages, not much more. It appears, therefore, that something has impacted Redwood Creek and the other North Coast drainages to cause the enormous sediment discharges that are now being measured.

Impacts related to timber harvest

The Geological Survey research on Redwood Creek has identified two major impacts from timber harvest: (1) a large increase in runoff; and (2) a large increase in sediment discharge.

Runoff

The increase in runoff is documented in an open-file report by Lee, Kapple, and Dawdy (November, 1975). To do this, they used a method for predicting runoff from rainstorms that was originally developed by the U. S. Weather Bureau. (Kohler and Linsley, 1951). This method predicted the effect of moisture already in the ground (measured by an antecedent precipitation index) and storm rainfall on the volume of runoff. The prediction equation has several constants (or parameters) that have to be determined for each drainage basin from the existing rainfall and runoff records. The weather-bureau method was a graphical method that is time-consuming. Hydrologists of the Tennessee Valley Authority developed a way of calculating the constants with a computer, [redacted]. This computer model was used to find out what happened to rainfall-runoff relations on

Redwood Creek. I have examined the original papers describing the method, and it looks sound.

Lee, Kapple, and Dawdy first looked at two groups of records, those for the years 1954 through 1958, before extensive logging, and those for the years 1968 through 1972. To determine the constants, they used rainfall records at Prairie Creek and runoff at Orick for the even years '54, '56, and '58; and '68, '70, and '72, getting a set of "before" constants and a set of "after" const ants. They then tested the predictive capabilities of these constants by predicting runoff for the years 1955, 1957, and 1961, 1963, 1965, 1969, and 1971. They found that the "before" constants predicted runoff for the years through 1961 quite well, but underpredicted the seasonal runoff for the years 1963 through 1971 by an average of 22 percent. They found that the "after" constants predicted 1969 and 1971 reasonably well, underpredicted 1963 and 1965, and overpredicted the years 1961 and earlier (seasonal totals) by about 20 percent. Furthermore, they found that under the most common conditions of antecedent precipitation index, the respective under- and over-predictions for individual storms were as much as 50 percent. Thus, at times, Redwood Creek and its tributaries have had 50 percent more water to handle in a single storm than they normally had in the past; the storm most affected was not the rare 1964 flood when rain fell on saturated ground, but the flood with a recurrence interval of 1 to 1½ years. This class of flood has been shown to have a significant impact on width and depth of stream channels and on the sediment load.

This abrupt change in rainfall-runoff relationships is shown even more strikingly in the synoptic studies (Janda and Others, December, 1975). My analysis of peak flood discharges reported in that summary shows that when corrections are made for differences in storm rainfall in the basins, peak flood discharges per square mile for Harry Weir and Miller Creeks, the two logged basins, averaged twice those from Hayes and Little Lost Man Creeks, the two unlogged basins. The range in increase for individual storms was from 1.24 to 5.16 times.

T his should not be unexpeceted. Precisely the same changes were observed in the carefully monitored watersheds in Oregon. The greatest changes in rainfall-runoff relationships observed by the Forest Service and Oregon State Univ. in Oregon were in watersheds where roads and tractor skid trails were around 13 percent of the land surface. The Oregon data (summarized in Harr, 1975) showed that when as little as 13 percent of the area was in roads and skid triails, annual discharges increased from 25 to 70 percent, and storm discharges were also affected. Furthermore, the effect might persist as long as 20 years after logging.

Sediment Discharge

The USGS report that documents sediment discharge is the Graphic and Tabular Summary of Synoptic Storm Sampling (Janda and other, December, 1975). Since some question has been raised about the validity of conclusions that can be drawn from this study, I will discuss this first. The usual method for investigating a land treatment practice (such as road-building or logging) is to select two or three small watersheds (usually contiguous) in a large drainage basin, use one as a control, leaving it untouched, and apply the treatment to the others. The two or three watersheds are monitored for a period of 3--6 years prior to treatment, to see how they differ under natural conditions. This is done because the conclusions are going to rest on samples of one, and you have to be sure that your sample of one works. Sometimes an unexpected event such as a landslide in the control watershed, may confuse the results.

The USGS could not do this because logging was already going on in every watershed likely to be "treated", and there was no chance for a preliminary calibration program. They solved this problem by increasing the size of the sample. Instead of one unlogged watershed, they had two: Little Lost Man and Hayes Creeks; and two "treated" watersheds as well: Harry Wier and Miller Creeks. They had also two watershed that had been logged years ago and are now nearly fully recovered: Lost Man and Geneva Creeks.

I checked the figures and methodology in the summary by drawing my own flood and sediment "hydrographs" from the basic data report (Iwatsubo and other, Oct., 1975) for a flood on Harry Wier, one on Miller, and two on Hayes Creek, and came up with figures very close to those reported by Janda and others (Dec., 1975). The calculations are all right, and from information I shall report later, I think the original measurements are all right.

Summarizing the calculations, the quantity of suspended sediment discharged per square mile during a storm from Miller and Harry Wier Creeks ranges from 6 to 47 times that discharged from Little Lost Man and Hayes Creeks. The average was about 20 times. The variations within the two groups (logged vs. unlogged) is much less than than the differences between them, so the differences are real. There is no doubt that logging has greatly increased suspended sediment from these watersheds. There has probably been an equal change in bedload, inasmuch as the same slides, rills, and gullies that are contributing suspended sediment are also contributing bedload. Janda and others, (Oct. 1975, p. 80-81) describe aggradation and filling of pools with bedload on tributaries of Redwood Creek down-stream from logged areas.

In spite of this great increase in suspended sediment, these small tributaries on the east side of the stretch of Redwood Creek in the park have a negligible impact on the suspended sediment load of Redwood Creek itself. On a per-square-mile basis, Redwood Creek commonly carried from 2 to 20 times the suspended sediment than did Harry Wier or Miller Creeks. So regulations on the the lands immediately east of the Park will only protect park values on the slopes and in the tributaries, and will not have any effect on Redwood Creek. Regulation of watersheds of west-side tributaries such as Bridge and Tom MacDonald Creeks, could very well protect Park values along Redwood Creek, for these streams appear to cast considerable amounts of gravel into the main stream.

This increase in sediment load in logged drainage basins of Redwood Creek, as a result of logging, is not unusual; a large literature exists on the impact of logging and road-building and has been summarized in some recent papers (Janda and others, Oct., 1975; Swanson and Dyrness, 1975; Youngberg and others, 1971) and in the erosion report submitted to this Board in December.These studies show that where logging and road-building are undertaken on landslide-prone soils or formations, such as make up the basin of Redwood Creek, landslides and other forms of soil erosion, and resulting sediment discharge are increased on the order of 5 times. The effect of roads in the Oregon studies is ten times that of cable yarding, per unit area disturbed. This indicates that tractor yarding, with its large area in roads and skid trails, will produce many more landslides and far more sediment, than cable yarding.

Secondary impacts of increased water and sediment load

Redwood Creek and its tributaries have had to accomodate increased discharges of water, and increased suspended sediment and bedload. They can handle these increases by either (1) increasing their slope, and thereby the velocity and transporting power of the water, or (2) by increasing the width and depth of the channel. The slope can be increased only by aggrading the stream bed, and this seems to have happened over considerable reaches of the main channel and its tributaries; but the slope, over-all, can be increased very little by aggradation. Furthermore, a stream responds to an increase in the quantity of bedload by developing a broad braided channel, because of a peculiar difference between the relation between transporting and eroding velocities of bedload and suspended sediment. The greater the quantity of bedload, the wider the channel has to be to accomodate it.

Thus, the major secondary impact of timber harvest and other activities is that the streams erode their banks. Widening the banks, in turn, removes, the toes of marginally stable slopes and triggers landslides, and this seems to be what has happened in Redwood Creek at an increasing rate for the last two decades. Janda and others, 1975 (Oct.) and Colman (1973) document a steady increase in the number of landslides along the banks of Redwood Creek and its tributaries. Some of this may be due to the 1964 storm. However, equally large floods in the 19th century did not create the havoc on Redwood Creek that the 1964 flood did; and small tributaries that were not logged in 1964 did not erode their banks as they are doing now. It is hard to predict how long it will take these reactivated slopes to achieve stability; and it is certainly hard to make any recommendation (certainly without seeing them) as to how they might be stabilized.

Many of these slides may grow into gullies. They greatly increase the bedload and suspended sediment Redwood Creek is now carrying, and judging from the differences between the suspended sediment of Redwood and Harry Weir and Miller Creeks, these togeth with stream bank erosion may now be the source of 3/4 of the sediment coming down Redwood Creek.

This, also, is not unique to Redwood Creek. A recent study made by the State Department of Water Resources for the Division of Fish and Game (Denton, 1974) documents exactly the same changes on the Mattole River, as a result of logging in the upper reaches of that stream. This report also carries a record of a great decline in spawning runs of salmon and steelhead trout in the north coast rivers, a decline that seems to be caused by the fact that accumulations of gravel on the stream beds, impregnated and somewhat cemented by silt, have rendered many of these streams far less suitable than before for fish spawning.

The Interagency River Basin Study (USDA, 1970) showed that most of the stream sediment in the Eel and Mad Rivers was coming from streambank erosion and landslides, before the 1964 flood as well as afterward. This streambank erosion cannot have been going on for many years, for these rivers flow mostly in the bottoms of narrow canyons. Clearly land use patterns in the last century have had an impact on them. This impact seems to be a combination of sediment from many sources on land and the increase in storm runoff, that caused the streams to erode their banks and in turn to trigger more landslides and further increase the sediment discharge.

What is to be done?

I cannot answer that question with what I know now, and from here. I would have to see Redwood Creek basin itself, the logged lands around the Park, and some of the streams in the park, before I could come up with any suggestion, or could rationally consider anyone elses suggestions. And since a few days is too short a time to understand fully on one's own a problem as complex as Redwood Creek, I would like to see the problem in company with some people who are really familiar with it. The people I would like to have with me are Mr. Jerry Ficklin of Winzler and Kelly, one or two other experts the timber companies may wish to select (possibly Dr. Orme), Dr. Richard J. Janda of the USGS, Dr. Marvin Dodge and Mr. James Denny of the Division of Forestry--because I am impressed by some data in the erosion study that indicates that sound erosion-control practices can greatly reduce sediment discharge, and also because Dr. Dodge has developed a way of measuring what is going on at the site--- and either Dr. Rice or Dr. Ziemer of the U. S. Forest Service Experiment Station at Eureka, if they would be willing to attend. I would welcome the company of one or two more Board members, but I don't want any more board members because I don't want this trip to be overwhelmed by crowds of people as the October field trip was. I want to see if a few experts, knowledgeable about the problem from all points of view can come to some agreement on what erosion-control measures would give the greatest benefits to the park at the least economic cost. If the board could authorize this, and I believe that Sec. 4611 of the Z'berg-Nejedly act gives us some authority for making such a trip, I would like to make it on Monday Jan 26 through Thursday Jan. 29. We would try to come up with some alternative recommendations and a short report, hopefully writing the first draft on the spot, and get them into everyone's hands well before the next board meeting.

Resolution of Differences

Now, for the answers to the questions I asked in November. I received the data from the Geological Survey on about Dec. 11, and the data from Winzler and Kelly on January 6. The three disputed points involve water discharge, instantaneous sediment discharge, and total storm sediment yield at Orick, and near Highway 299, in February and March, 1974 (Mainly the period March 27-30, 1974.

I cannot resolve the question of water discharge, because the measurements near Highway 299 were taken on bridges some distance apart, and Winzler and Kelly did not send me their current-meter measurements for Orick.

The Geological Survey, in answering my request, decided to make final calculations for the data I asked (the final computations are what appear in the annual summaries of water-resources data). I discovered that the values reported by Dr. Janda Din his memo to Dr. Curry of the Park Service were preliminary estimates of instantaneous sediment discharge, made by the st aff of the Eureka office of the USGS, by reading the probable instantaneous suspended sediment concentration from logarithmic graphic plot of all suspended sediment concentrations against gage height or water discharge. The final determinations were made by constructing a graph showing the variation in sediment discharge for the storm plotted against time. Since the particular instantaneous sediment discharges in question at Highway 299 occurred during the falling stage of the storm, when suspended sediment concentration is lower than normal, the instantaneous suspended sediment figures reported in Janda's memorandum were too high. The corrected and final figures for instantaneous discharge agree well with the Winzler and Kelly figures. These corrections, however, do not affect the total sediment load discharged during the storm, because they are balanced by higher than average suspended sediment early in the storm. However, the revised final storm discharge figures for Orick increased from 116,000 to 142,000 tons. See attached sheet.

The really pizzling difference to me was an eight-fold difference between the total suspended sediment discharge for the storm of March 27-30, 1974. I have finally been able to resolve this difference. It is the result of three factors. First, as everyone recognizes, the Winzler and Kelly suspended concentrations are likely to be low because their samples were taken from near the surface, whereas the USGS samples are depth-integrated. Correcting for this would increase the W & K values by about 50 percent. The second factor, which I did not discover until I had the field notes from Winzler and Kelly, is that W&K reported only the period from 1730 March 27 to 0230 March 30, whereas the USGS period was 1200 March 27--1200 March 30. The flood actually peaked at or shortly after 2:30 am March 30, and half the suspended sediment of the storm passed Orick between 2:30 and 12 noon on Marych 30. So the W & K figure should be doubled by this factor. The third factor is that the W & K calculations, in applying the standard formula

$$Q_w \text{ (in cfs) } \times C_s \text{ (in mg/l) } \times 0.0027 = Q_s \text{ (in tons/day)}$$

forgot to multiply the average suspended seidment discharge for the period of 57 hours by the number of days. The suspended sediment discharge they reported should further be multiplied therefore, by the number 2 & 3/8. When these factors are multiplied together, the W & K and USGS figures for Orick agree quite well. W & K did not send me their calculations for Chezem bridge, but since the error appears to be in the method, I assume the same factors apply there. So I consider this matter closed.

I might add in closing that I see nothing in the Winzler and Kelly report that really contradicts the conclusions of the USGS reports. I asked Dr. Isaac Barshad, an expert in clay mineralogy in our soils department,to read the section on clay mineralogy, and it was his opinion that the method would not definitively show that there was no significant contribution from the upland soils. His letter is attached.

I will have the bibliography for this report at the next Board meeting

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COLLEGE OF NATURAL RESOURCES
DEPARTMENT OF SOILS AND PLANT NUTRITION

HILGARD HALL
BERKELEY, CALIFORNIA 94720

January 13, 1976

Dr. Clyde Wahrhaftig
Department of Geology and Geophysics
University of California, Berkeley

Dear Dr. Wahrhaftig,

At your request, I have examined the section on clay mineralogy of the Redwood Creek Sediment Study by Winzler and Kelley, Engineers, of Eureka. I am familiar with the soils of Redwood Creek, having made the mineralogic analyses for the soil-vegetation surveys of Humboldt County.

My judgment is that the data presented are inadequate to differentiate among the clay minerals actually present in these soils. In the clay-size fraction of these soils, the higher-order spacings of the clay minerals and the larger-angle spacings that identify quartz, feldspar, and gibbsite are essential for identifying the clay sources. Likewise, organic matter content in the clay fraction can identify the A and B horizons of the soils.

Consequently, I find that the material presented in the Winzler and Kelly report is inadequate to recognize sediment sources in the Redwood Creek watershed.

Sincerely yours

Isaac Barshad

Isaac Barshad
Lecturer and Soil Chemist

WATER AND SEDIMENT DISCHARGE DATA FOR REDWOOD CREEK AT ORICK AND NEAR BLUE LAKE FOR THE PERIODS, FEBRUARY 27 TO MARCH 1, AND MARCH 27 to 30, 1974

Table 1 lists the water- and sediment-discharge data for both sites for the periods of concern. The suspended-sediment loads listed in Dr. Janda's June 20, 1975, memo were obtained by use of a preliminary plot of instantaneous suspended-sediment concentration versus instantaneous water discharge. This technique is often used for estimating sediment discharge when a temporal concentration curve has not been drawn. The final suspended-sediment loads have been determined by use of the temporal concentration curve and have been put through standard USGS review procedures. A discussion of the techniques used in collecting the field data and computing the water and sediment discharge follows:

TABLE 1.--*Water and sediment discharge for Redwood Creek at Orick and Redwood Creek near Blue Lake*

Date and time	Source	Water discharge, in cubic feet per second	Suspended-sediment load, in tons
	Redwood Creek near Blue Lake		
2-27-74	USGS (final)	455	209
1800 hours	USGS (Janda memo 6-20-75)	455	379
	Winzler & Kelley (April 1975)	860	450
2-28-74	USGS	2,020	12,700
1920 hours	USGS (Janda)	2,040	18,400
	Winzler & Kelley	3,300	11,900
3-1-74	USGS	1,670	7,390
0130 hours	USGS (Janda)	1,670	14,400
	Winzler & Kelley	3,200	9,100
3-29-74	USGS	3,460	46,700
2100 hours	USGS (Janda)	3,460	64,460
	Winzler & Kelley	4,100	36,200
	Redwood Creek at Orick		
3-30-74	USGS	13,100	238,000
0225 hours	USGS (Janda)	13,000	170,240
	Winzler & Kelley	20,100	145,000

Total suspended-sediment load, in tons, from 3-27-74 (1200 hours) through 3-30-74 (1200 hours)

Station	USGS (final)	USGS (Janda memo 6-20-75)	Winzler & Kelley
Redwood Creek near Blue Lake	40,600	42,000	7,750
Redwood Creek at Orick	142,000	116,000	19,500