REPORT OF THE SURVEY OF SEDIMENT BELOW STREAM GAGING SITES 1, 2 AND 3 IN THE H. J. ANDREWS EXPERIMENTAL FOREST WATER YEARS 1974-1979

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SITE HISTORY

Experimental timber harvest on Watersheds 1, 2, and 3 was an early forest research project in the H. J. Andrews Experimental Forest after its establishment in 1952. Watershed 2 was designed as the undisturbed control. Road building was completed in Watershed 3 during 1959 and after 3 years of monitoring for road building influences on the watershed, logging took place in 1962 and 1963. Approximately 30% of the watershed is in clearcut and road. Extensive road repairs were made in the summer of 1968. Logging in Watershed 1 was accomplished without road building. Cutting continued from 1962-1966, when the entire watershed had been clearcut and slash burning had been completed. No other major management activities have occurred within the watersheds.
Large mass movements have been important in the production of bedload in the study watersheds. Swanson (unpublished data) has done a field reconnaissance study of mass movement features and the watershed project field crew have made observations that have generated a partial history of recent mass-movement events in the basins. Dyrness (1967 and unpublished data) and Fredriksen (1963, 1965) have also documented failures in the study watersheds (see fig. 1).

Roadfill failures have frequently delivered sediment to the stream channel in Watershed 3. Such a failure in WY 1962 (S29, fig. 1) entered the channel and eroded 3000 feet of tributary and mainstream. The debris torrent did not reach the gaging station or settling pond (Dyrness, 1967).

In December 1964, heavy rain and melting snow triggered three large (volumes over 500 yd^3) road fill failures (D39 A&B, D40) in Watershed 3. The resulting debris torrents buried the gaging station and sediment basin under tons of mud and debris. Mass movement resulting from road failures also occurred in Watershed 3 in WY 1968 and 1972 (S30, S101).

Storms of WY 1965 also triggered four substantial slides in Watershed 1 (D44, D45, D46, D47). In WY 1968 two large slides (S99, S100) related to earthflow activity began delivering sediment to the stream in Watershed 1. This area continues to be active. Heavy rainfall in 1972 triggered two slides (S97, S98) on the south slope, low in the watershed that continued to be a source of bedload material. Mass movement in Watershed 2 has been rare during the length of the study.

Figure 1 - Mass Movement Reference Map

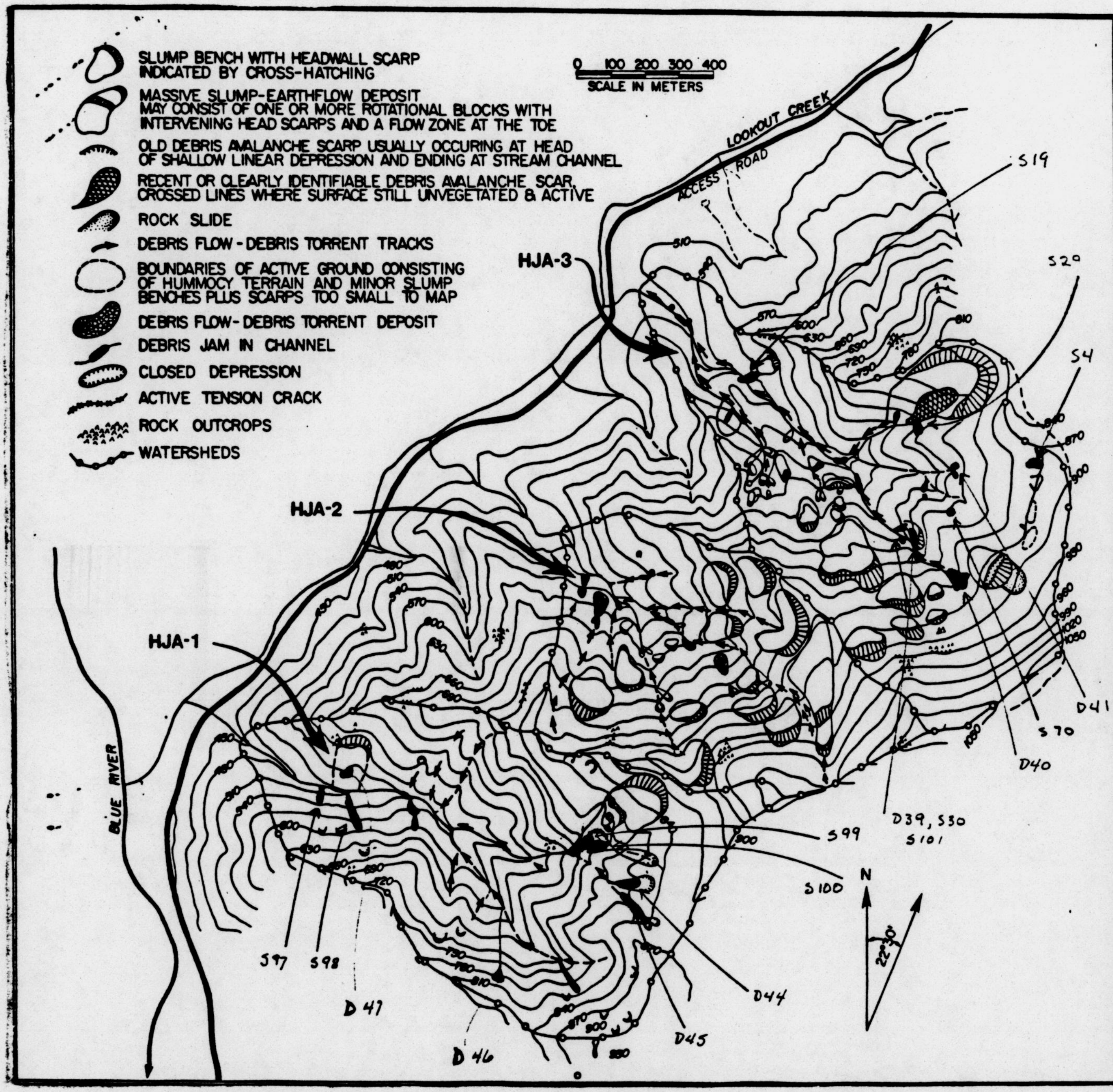

Figure 1 - Unpublished map of mass movements in HJA 1, 2, and 3 (Fredriksen, personal communication). Colored areas indicate mass movement contributing to bedload (Dyrness, 1967; F. J. Swanson, unpublished data).

MEASUREMENTS

Basin surveys have been designed to determine a change in average bottom elevation between annual surveys. Monumented cross sections are spaced at regular intervals along a primary control line, which runs the length of the basin dam. Survey points are spaced at intervals along the cross section lines, three-foot intervals at Watershed 1 and Watershed 2 and two-foot intervals at Watershed 3.

The survey is conducted using a level or a transit, a tape, and a leveling rod. The tape is run between cross section end posts and the rod is placed on the basin bottom at each of the prescribed survey points. At each point a level reading is made with the surveying instrument and recorded.

Permanent bench marks have been established near all three gage houses and in 1977 auxiliary bench marks (1/4 bolts set in concrete) were established near each catchment basin. These new bench marks replace nails or spikes driven into stumps or trees as reference points. annual checks, monitoring elevational distance between bench marks and reference points, showed unexpected changes. The reference point on the Watershed 3 dam was actually sinking, while at Watershed 1 and Watershed 2 stumps containing the reference spikes were deteriorating and reliable measurements became increasingly difficult. The elevational difference between auxiliary bench marks and permanent bench marks continues to be monitored.
As part of the sediment basin survey, a check on the auxiliary bench mark elevation is made at the end of alternate cross-section transects. This procedure reveals any change in the elevation or level of the surveying instrument.

When catchment basins near or reach capacity, they are emptied. Local contractors are employed and usually a front-end loader or clam-shovel is used to clean the basin. After emptying, the basin is resurveyed--this survey being used as the baseline for comparison.

Following debris torrents and subsequent burial of the gaging station and sediment basin at Watershed 3 (see 1965 report), the catchment basin was remodeled in December of 1965. Details can be found in the 1966 report. A new survey was made in that month, but further modification was done in April 1966, followed by a new base survey in August 1966.

In 1976, the channel between the flume and the sediment basin at Watershed 2 was excavated to reduce the entrainment of bedload material in this seciton. In order to detect any accumulation or degradation in the channel several survey lines were extended.

CALCULATIONS

The determination of sediment accumulation is based on the average change in bottom elevation between two annual surveys. This is accomplished by comparing the change for the same survey points between any two surveys. Originally all points between cross section end posts were included in the calculations, but in years of little or no bedload accumulation small errors began to compound and led to negative values for bedload accumulations. Errors in rod placement or instrument readings are difficult to quantify, however some potential errors can be eliminated. One such potential error is rod placement on steep slopes at the edges of the sediment basin. These slopes accumulate virtually no sediment and may provide some very misleading rod readings. The entire cross section line is surveyed to monitor bank slumping. However, during years of low sediment yield, in an attempt to hold errors to a minimum only points on the bottom are used in calculations--slope points are eliminated. When slope points have been eliminated, the area they represented is less than 10 percent of the sediment basin area.

The number of points included in any calculation is variable, depending on the amount of filling. The catchment basins often fill to, and sometimes beyond, capacity. When a basin is filled near capacity, points on the bottom may have been on a steep slope in a previous survey and are included in the calculations. Therefore, all points along the survey line must be recorded.
Rod measurements for survey points used are totaled and averaged; yielding an average rod reading. A line of sight is determined by adding the mean of the bench mark readings to the elevation of the auxiliary bench mark (designated as 100.000 feet) and adjusting further by any change in the elevational difference between the permanent bench mark and the auxiliary bench mark. The average rod reading subtracted from the line of sight provides an average bottom elevation. By subtracting the previous bottom elevation from the current value and multiplying by sediment basin area, the volume of sediment accumulation is determined. This volume divided by watershed area determines yield of bedload per unit area of watershed.

Example

$$\frac{\text{rod readings}}{\text{\# of points}} = \text{average rod reading}$$

Elevation of auxiliary bench mark + $\bar{X}$ bench mark reading +correction value = line of sight

Line of sight - average rod reading = average bottom elevation

Current average bottom elevation - previous bottom elevation = change in bottom elevation

% Bottom elevation x sediment basin area = accumulation

Accumulation ÷ watershed area = accumulation/unit Watershed area

SEDIMENT BASIN SUMMARY - WY 1974

Removal of the WY 1973 bedload accumulation in Watershed 1 was completed on September 22, 1973. During the operation streamflow was too high for successful diversion and the sediment basin could not be completely emptied. Bedload material remaining was an estimated 50 yd^3. Basins at Watershed 2 and Watershed 3 were not emptied this year.

Due to the late date of cleanout, Watershed 1 basin was initially surveyed on October 3, 1973. The annual surveys at Watershed 1 and Watershed 3 were made on July 9, 1974 and on July 10, 1974 at Watershed 2. Vandals apparently removed several cross-section endposts at Watershed 2 and repositioning of new posts was, at best, approximate. Survey points that were obviously in error were eliminated from the calculations.

The storm season of WY 1974 (October through April) was the wettest on record. Precipitation was 144% of the 22 year mean for the storm period at the study site (Table 1). Peak flows exceeded the 0.6 foot level at Watershed 2 during four storms, but none were of extreme intensity (Table 2).

Although the first storm of the water year (November 8 to 14) sent streams to a moderate stage, nearly 8 inches of precipitation fell during that period. Intense rainfall, abrupt stream rise and a partially cleaned basin at Watershed 1 combined to nearly fill the catchment basin. During moderate storms early in the storm season, streams often produce large amounts of bedload. The transported material has accumulated over the summer in the channel and is moved during the first storm. Subsequent storms, which undoubtedly moved bedload material, transported it through the basin and little of it accumulated. The measured value for bedload accumulation in Watershed 1 is an estimate of the actual amount produced.

Observations throughout the storm season of the Watershed 3 basin showed approximately one foot of material had accumulated by the end of the storm of January 15, 1974. In this storm pulses of red-colored sediment were noted during suspended sediment grab sampling. No change was observed in the Watershed 2 basin during WY 1974. Slides which had occurred in Watershed 1 in earlier years continued to contribute material to the stream. Stakes at slide head scarps on the lower south slope of the watershed showed that headward erosion had not occurred. Streamside slumps in the lower portion of the watershed also contributed material.

A formation bearing smooth spherical red pebbles occurs in the upper eastern portion of the watershed (near D44, D45), and abundance of these pebbles in the sediment basin along with field examination of the site indicates that activity in this area provided bedload in WY 1974.

SEDIMENT BASIN SUMMARY - WY 1975

The Watershed 1 bedload accumulation of the previous year was removed on August 14, 1974 and surveyed September 6, 1974 and again on August 5, 1975. Watershed 2 and 3 were not emptied and were surveyed on August 4, 1975.

Precipitation during the storm season (October through April) was near normal: 106% of the 22 year mean (Table 1). Two major storms occurred during the period (Table 2), one of which, on December 20, 1974, was quite intense.

Observations of sediment basin accumulation were sparse and timing of bedload movement is an approximation. Based on extreme bedload transport at Watershed 10, we have assumed that the bulk of material in the catchment basin at Watershed 1 was delivered during a week-long series of storms culminating on December 20, 1974. A second storm on January 5, 1975 probably deposited more material; however, the basin was likely near capacity before the storm and much bedload material was therefore not trapped.

The same storms apparently deposited the bulk of bedload accumulation in Watershed 2 and Watershed 3. Observations on February 6, 1975 report material in Watershed 3 basin to fill the basin a third. The lack of observed accumulation in the Watershed 2 basin may be due to the small amount of material delivered to the basin.

No major mass movements influencing sediment production were reported during WY 1975.

SEDIMENT BASIN SUMMARY - WY 1976

In preparation for the accumulation of bedload material in WY 1976 the Watershed 1 catchment basin was emptied on September 6, 1975 and the initial survey made on September 12, 1975. The second survey was made on June 23, 1976. Basins at Watershed 2 and Watershed 3 were not emptied this year and both were surveyed on June 22, 1976.

Precipitation during the storm season (October through April) was slightly greater than the 22 year mean (see Table 1). Three storms were intense enough to be considered major events, the storm of January 8, 1976 being the largest.

The catchment basin at Watershed 1 filled to near capacity during WY 1976. Observations show that storms of December 1, 1975 and January 8, 1976 had deposited at least 100 yd^3 of bedload material in the catchment basin. A third storm on January 14, 1976 contributed at least another 25 yd^3. An undetermined amount of bedload material is assumed to have passed through the basin, uncollected, as the basin approached filling capacity.

At Watershed 3 observations show that by December 19, 1975 5 yd^3 of bedload had accumulated in the catchment basin. This material can probably be attributed to the storm of December 1, 1975. Observations made on January 16, 1976 indicate that an additional 20 yd^3 of bedload material were deposited in the sediment basin by storms of January 8 and January 14, 1976.

Although field observations make no mention of accumulation of material at Watershed 2 basin, the measured amount of material in the basin was the highest since 1965 (see fig. 2). Some of this material was probably generated by a small slide associated with the storm of January 8, 1976. The slide occurred approximately 200 m upstream at the confluence of two forks (L1, fig. 1).

No other major mass movements were reported for WY 1976, but raw areas along channels of Watershed 1 and Watershed 3 continue to ravel and contribute sediment to the stream.

SEDIMENT BASIN SURVEY - WY 1977

WY 1977 was a drought year in the western United States, and the H. J. Andrews Experimental Forest was no exception. Precipitation during the usual storm season (October through April) was less than half of normal (see Table 1). Low streamflow reflected the fact that no major storms came through the area during the entire water year.

The accumulated material from the previous year was removed from Watershed 1 basin on August 11, 1976 and basins at Watershed 2 and Watershed 3 were cleaned on August 12. At this time the channel between the flume and sediment basin at Watershed 2 was also excavated. Initial surveys were made August 18 at Watershed 1, August 19 at Watershed 2 and August 20 at Watershed 3. Final surveys were done August 16, 1977 on Watershed 2 and Watershed 3 and August 17 on Watershed 1.

During the summer of 1977 it was determined that auxiliary benchmarks at all three watersheds were losing their reliability. At Watershed 3 the benchmark was on the dam, which was actually sinking. At Watershed 2 and Watershed 1 the benchmarks were spikes driven into stumps. The stumps were deteriorating and the spikes were becoming loose. New auxiliary benchmarks (a bolt embedded in a concrete footing) were constructed near each basin.

Bedload production was minimal during this year and no mass movements were reported.

SEDIMENT BASIN SUMMARY - WY 1978

Since very little material accumulated in the sediment basins during WY 1977, no basins were cleaned. Surveys to determine the 1978 accumulation were made on August 29, 1978 at Watershed 2 and on August 30 at Watershed 1 and Watershed 3.

In terms of precipitation during the storm season, WY 1978 could be called a normal year (see Table 1). Three major storms occurred--all before Christmas 1977. All were of high intensity.

Field observations show that 15 to 20% of the annual bedload accumulation in the Watershed 1 sediment basin was delivered during a storm on November 25, 1977. Following the storms of December 13 and 14, 1977 field reports show at least 100 yd^3 of material had collected in the basin. More material probably accumulated during subsequent high discharge events (not rated as major storms); but since the basin was nearing capacity some material likely passed through the basin.

At Watershed 2 observations indicate that the bulk of the material deposited in the catchment basins was roughly equally distributed between the storms of November 25 and December 13 and 14. At Watershed 3 the November storm produced some 20% of the year's accumulation, while the December storms accounted for most of the remainder. In each basin, of course, material continued to accumulate as a result of subsequent less intense storms.

No new mass movements were reported in the study area during WY 1978, but slide tracks in Watershed 1 and Watershed 3 continue to deliver sediment to the stream.

SEDIMENT BASIN SUMMARY - WY 1979

Accumulated sediment from water years 1977 and 1978 was removed from the Watershed 1 catchment basin on September 19, 1978. The intial survey was completed on September 21. Basin cleaning was not done at Watershed 2 or Watershed 3. Surveys to determine bedload accumulation were conducted on July 31, 1979 at Watershed 2 and Watershed 3 and on August 1 at Watershed 1.

The storm season (October through April) of WY 1979 may be described as relatively dry. The study watersheds received approximately 80% normal precipitation during the period (see Table 1). Two major storms occurred in WY 1979. On December 3 and 4, 1978 a rainstorm flushed channels of debris and some sediment that had accumulated over the summer and fall. Observers report that this storm delivered an estimated 35 yd^3 to Watershed 1 basin and approximately 6 yd^3 to Watershed 3. No accumulation was noted at Watershed 2.

A period of prolonged cold in January was followed by snowfall and accumulation February 3 to 6, 1979 and warm rain February 6 and 7. Nearly a foot of snow was on the ground at the Watershed 1 gagehouse on February 6. The ensuing rain melted this accumulation and produced high peak streamflows (Table 2). Field observations indicate that probably another 60 to 70 yd^3 were deposited in the Watershed 1 basin by this storm and some 15 to 20 yd^3 in the Watershed 3 settling pond. Little change was noted in the Watershed 2 basin.

In April a large boulder apparently dislodged from an upslope position by freeze/thaw activity, rolled into the stream channel at Watershed 3 and came to rest about 12 feet upstream from the flume. The boulder, about 3-1/2 feet in diameter, had little effect on sediment transport during this water year. However, in subsequent years the trapping efficiency of this obstruction should be monitored.

DISCUSSION

Figure 2 is a histogram of bedload production since the beginning of the study. This figure will serve as a basis for discussion of the results of WY 1974 to WY 1979.

Bedload production in Watershed 1 remains high. With the exception of WY 1977, the basin was filled near capacity every year and an undetermined volume of bedload material may have been carried through the sediment basin. The source of material appears to be slides in the upper areas of the watershed associated with earthflow terrain (S99, S100) and an area (D47) on a southeast branch in the upper section that typically produces sediments containing spherical red gravel. Another source lower in the watershed are two slides on the southwest slope (S97, S98). No actual sliding has taken place in these areas since 1972, but ravel and surface wash, as well as streamside slumps associated with earthflow, contribute material to bedload.

Surface, bank and channel erosion processes appear to have made the most significant contribution of bedload material during the years of this report. Prolonged cold periods, typical in recent winters, encourage the growth of needle ice and the mechanical erosion of freeze/thaw cycles. Rain melting accumulated snow raises the stream level rapidly, transporting sediment stored in the channel and destabilizing bank areas. Small (<5 m^3) streamside slumps may result, introducing more material to the stream channel. In Watershed 2 bedload production remains quite low. The values of recent years remain consistent with past production. However, the treetops that entered the stream just above the gaging station in 1974 are having an effect on bedload production. Observation and measurement indicate that by 1977 as much as 20 m^3 of bedload material may have been trapped among and behind this debris. As the organic debris begins to deteriorate, bedload production should show an increase.

The excavation of the channel between the gagehouse and the sediment basin has also complicated the calculated values of bedload production. The determination of the contribution the connecting channel makes to bedload production has been impossible, because the extended transect lines do not provide adequate coverage for accurate monitoring. A new grid is planned to monitor the channel in future surveys.

Bedload production in Watershed 3 has been relatively low through the study period. The exact influence of the massive debris torrents of

WY 1965 on later bedload production is unclear. The 200 m section immediately above the gaging station is part of the depositional zone of the debris torrents and undoubtedly a large proportion of bedload material trapped in the settling basin has its origin in this section. Of the actual contribution of the rest of the watershed, most is probably trapped within the depositional section. Assuming that the usual noncatastrophic fluvial processes are depositing and transporting material in the lower 200 m of the stream; annual values calculated for bedload production in Watershed 3 should parallel the actual amount of production.

LITERATURE CITED

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Table 1 Storm Season (October through April) Precipitation

Water Year	PPT (mm)	PPT (in)	# Major* Storms	% of Storm Season $\overline{x}$
1974	2850	112.20	4	144
1975	2100	82.68	2	106
1976	2302	90.63	3	116
1977	860	33.86	0	43
1978	1996	78.58	3	101
1979	1588	62.52	2	80

Mean of storm season precipitation 1958-1979
$\overline{x}$ = 1983 mm
* = A storm during which the discharge at Watershed 2 exceeds 7.6 cfs

Table 2 Major storms for WY 1974 - WY 1979, peak flow

WY	Date	Watershed 1 (ft)	Watershed 1 (cfsm)	Watershed 2 (ft)	Watershed 2 (cfsm)	Watershed 3 (ft)	Watershed 3 (cfsm)
1974	12-7-73	1.012	68.68	.642	37.56	.879	42.45
	12-29-73	.885	48.92	.606	33.50	.812	36.75
	1-15-74	1.167	91.50	.681	42.08	.925	46.52
	3-15-74	.915	56.07	.620	34.95	.801	35.85
1975	12-20-74	1.225	100.89	.839	63.57	1.029	56.53
	1-5-75	1.041	72.70	.675	41.35	.91	45.85
1976	12-1-75	1.292	112.30	.872	68.61	1.155	69.75
	1-8-76	1.447	141.07	1.100	108.62	1.351	92.75
	1-14-76	.918	56.44	.606	33.50	.785	34.56
1977							
1978	11-25-77	1.239	103.22	.914	77.27	1.274	83.36
	12-13-77	1.239	103.22	.962	83.32	1.248	80.30
	12-14-77	1.103	81.68	.866	67.68	1.117	65.63
1979	12-4-78	1.089	79.61	.643	37.56	.85	40.28
	2-7-79	1.245	103.72	.780	55.04	1.125	66.49

Figure 2 - Annual Bedload Accumulations in Sediment Basins WS 1,2, & 3 H. J. Andrews

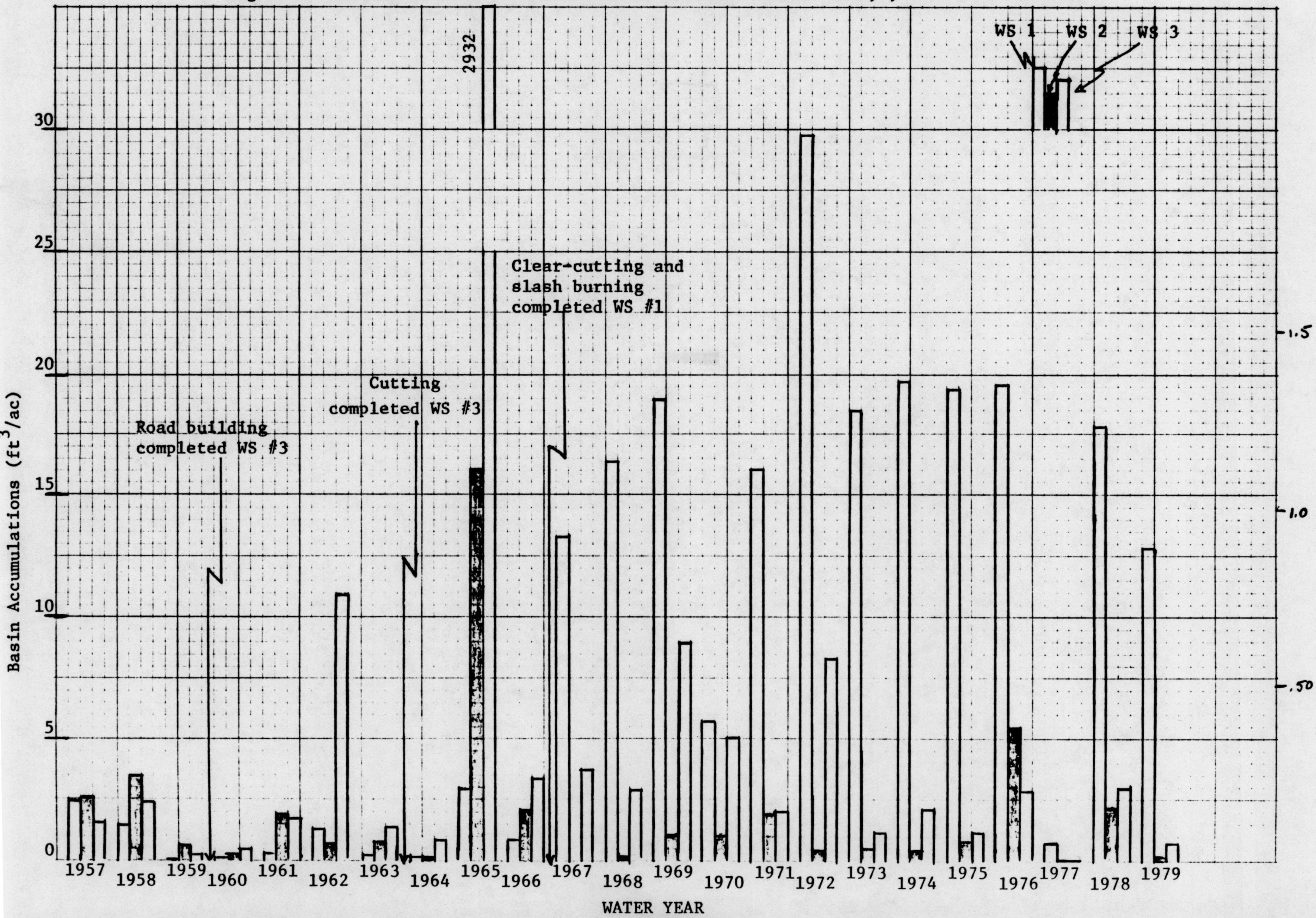

Table 3 Sediment Accumulation WY 1974 - WY 1976

Site	Year	Number of points	Line of sight (ft)	Average rod reading (ft)	Average bottom elev. (ft)	Δ bottom elev. (ft)	Total accum. (ft^3)	Total accum. (yd^3)	Production ft^3/ac	ratio
WS 1	1973	261	114.291	7.626	106.665					
	1974	261	114.026	5.188	108.838	2.173	4635.009	171.67	19.56	67.45
WS 2	1973	190	105.250	7.896	97.354					
	1974	190	105.425	8.048	97.377	0.023	43.40	1.61	.29	
WS 3	1973	225	105.645	8.686	96.959					
	1974	225	105.653	8.120	97.533	.574	510.86	18.92	2.04	7.03
WS 1	1974	266	114.506	9.134	105.372					
	1975	266	114.150	6.634	107.516	2.144	4573.15	169.38	19.30	27.18
WS 2	1974	190	105.425	8.048	97.377					
	1975	190	105.055	7.622	97.433	0.056	105.672	3.91	.71	
WS 3	1974	225	105.653	8.120	97.533					
	1975	225	105.137	7.296	97.844	0.311	276.79	10.25	1.11	1.56
WS 1	1975	280	114.080	8.520	105.560					
	1976	280	114.083	6.354	107.729	2.169	4626.48	171.35	19.52	3.64
WS 2	1975	195	107.864	7.587	100.270					
	1976	195	107.770	7.070	100.700	0.423	798.20	29.56	5.36	
WS 3	1975	225	105.137	7.296	97.844					
	1976	225	105.449	6.847	98.601	0.757	673.37	24.94	2.55	0.48

	WS 1	WS 2	WS 3
Watershed area (ac)	237	149	250
Sediment basin area (ft^2)	2133	1887	890

Table 4 Sediment Accumulation WY 1977 - WY 1979

Site	Year	Number of points	Line of sight (ft)	Average rod reading (ft)	Average bottom elev. (ft)	Δ bottom elev. (ft)	Total accum. (ft^3)	Total accum. (yd^3)	Production ft^3/ac	ratio
WS 1	1976	171	101.760	11.10	90.66					
	1977	171	101.280	10.55	90.73	.070	107.73	3.99	.45	
WS 2	1976	203	107.951	8.118	99.833					
	1977	203	109.205	9.380	99.825	-.008				
WS 3	1976	223	105.449	9.713	95.736					
	1977	223	105.691	10.010	95.681	-.055				
WS 1	1977	211	103.285	9.97	93.315					
	1978	211	104.378	9.09	95.288	1.973	3746.73	138.77	15.81	6.90
WS 2	1977	226	109.205	8.82	100.389					
	1978	226	109.997	9.44	100.557	0.168	341.71	12.66	2.29	
WS 3	1977	223	100.358	10.01	90.348					
	1978	223	100.511	9.26	91.251	0.903	803.67	29.77	3.21	1.40
WS 1	1978	168	104.189	10.90	93.287					
	1979	168	103.580	8.89	94.693	1.406	2125.87	78.74	8.97	56.06
WS 2	1978	219	106.494	10.01	96.486					
	1979	219	105.860	9.362	96.498	0.012	23.65	.88	.16	
WS 3	1978	223	100.511	9.256	91.255					
	1979	223	100.600	9.169	91.431	0.176	156.95	5.81	0.63	3.94

	WS 1	WS 2	WS 3
Watershed area (ac)	237	149	250
Sediment basin area (ft^2)	2133	1887	890