Gravel Bed Composition in Oregon Coastal Streams[1]

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The amount of fine sediments (generally <1 mm in diameter) in gravel bedded streams is often used as an indicator of habitat quality and also as a measure of the impact from accelerated sedimentation resulting from land disturbance. Five streams in the Oregon Coast Range were studied to evaluate temporal and spatial variability of streambed composition, as well as the factors affecting the amount of fine sediment within the bed. The amount of fine sediments (<1 mm) contained in frozen streambed cores and expressed as a percentage (by weight) of the total sample proved highly variable in time and space. During a 19-mo sampling period, temporal variability was caused by an occasional flushing of fines from the gravel beds during high flows. Percent fines also varied greatly between streams, between locations in the same stream, and between locations in the same riffle. Streams on 21 Coast Range watersheds were sampled during summer low flow. The amount of fines averaged 19.4% for all watersheds and ranged from 10.6 to 29.4% for streams on undisturbed watersheds. Regression analysis indicated that the watershed slope, area, relief, and land use influenced the amount of fine sediment in the bed. Bed composition varied greatly between locations in the same stream with about 75% of the within-stream comparisons indicating a significant ($\alpha = 0.05$) difference. Within a single stream, gravel bed composition correlated significantly with channel sinuosity and bank-full stage. Regression analysis and field observations suggested that road construction and logging operations can increase the amount of fines; however, such increases may be temporary if high flows flush the gravels

Key words: bed sediments, forest harvesting, Oregon Coast Range, sedimentation, spawning gravels, stream channels, water quality

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La quantité de fins sédiments (généralement de diamètre inférieur à 1 mm) dans les cours d'eau à fonds de gravier est souvent utilisée comme indicateur de la qualité de l'habitat et aussi comme mesure des répercussions d'une sédimentation accélérée résultant du dérangement de la terre. Cinq cours d'eau de la chaîne côtière de l'Orégon ont été étudiés dans le but d'évaluer la variabilité temporelle et spatiale de la composition du lit, de même que les facteurs affectant la quantité de sédiments dans le lit. La quantité de fins sédiments (<1 mm) présente dans des carottes congelés du lit, exprimée en pourcentage (en poids) de l'échantillon total s'avère hautement variable, dans le temps et dans l'espace. Au cours d'une période d'échantillonnage de 19 mois, la chasse occasionnelle de fines particules des lits de gravier au moment des forts débits est responsable de la variabilité temporelle. Le pourcentage de fins sédiments varie grandement aussi entre cours d'eau, entre sites du même cours d'eau et entre sites d'un même radier. Pendant la période d'étiage d'été, les cours d'eau de 21 bassins hydrographiques de la chaîne côtière ont été échantillonnés. Les quantités de fins sédiments sont en moyenne de 19,4% pour tous les bassins et sont situées entre 10,6 et 29,4% dans les cours d'eau des bassins non dérangés. L'analyse de régression indique que la pente, la superficie et le relief du bassin, ainsi que l'utilisation des terres influent sur la quantité de fins sédiments dans le lit. La composition du lit varie grandement d'un endroit à l'autre du même cours d'eau, environ 75% des comparaisons dans un même cours d'eau montrant une différence significative (α = 0,05). Dans un unique cours d'eau, on observe une corrélation significative entre la composition du lit de gravier, d'une part, et la sinuosité du chenal et le niveau de pleins-bords, d'autre part. L'analyse de régression et les observations sur le terrain laissent penser que la construction de routes et les opérations forestières peuvent accroître la quantité de fins sédiments; cependant, de telles augmentations peuvent être temporaires si les grands débits nettoient le gravier.

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THE size distribution of sediment in small mountain streams significantly affects anadromous and resident fish species, as well as other stream biota (Gibbons and Salo 1973). Forest harvesting activities (road construction, yarding, and slash disposal) in steep terrain can also increase sediment in streams (Fredriksen 1970; Brown 1972; Swanson and Dyrness 1975). However, in general, increased rates of erosion and sedimentation eventually recover to preharvest levels (Megahan 1974; Beschta 1978).

Forest harvesting can temporarily increase levels of intergravel fines, sediment less than ~1.0 mm in diameter (Burns 1972; Moring and Lantz 1974; Moring 1975). Apparently, even small increases in intergravel fines may be detrimental to aquatic resources (Cordone and Kelley 1961). Increased levels of fine sediment within the stream bed may depress fish reproduction and survival (Moring and Lantz 1974; Moring 1975; Iwamoto et al. 1978) while fine sediments can adhere to or abrade the chorion of salmon ova incubating in streambed gravels (Phillips 1971). The exchange of dissolved oxygen between stream water and intergravel water, critical to alevins and incubating ova (Sheridan 1962), can be restricted by fines (Vaux 1962; McNeil and Ahnell 1964; Cooper 1965). Finally, accumulated fines may barricade alevins within the gravel (Dill and Northcote 1970; Koski 1972), reduce living space and escape cover (Saunders and Smith 1965; Bjornn et al. 1977), and decrease species diversity and abundance of aquatic insects and benthic organisms (Nuttal 1972).

In-channel measurements of bed composition have been suggested for rating the reproductive capacity for fish as well as for monitoring the effects of land-use activities (Platts et al. 1979). The percentage, by weight, of fine sediment in the streambed also has been suggested as a stream quality criterion (Bjornn et al. 1977; Iwamoto et al. 1978). Recently, Alaska adopted a water-quality standard based on fine sediments in spawning gravels (Alaska Department of Environmental Conservation 1979). These measures require more knowledge of factors influencing the composition of stream gravels than is currently available. We therefore measured the temporal and spatial variability in gravel composition and evaluated factors affecting fine sediment levels in streambeds. Although this study evaluated only streams in western Oregon, the results may well be applicable to other gravel bedded streams.

Methods and Materials

Five streams in the Oregon Coast Range between the Yaquina and Siuslaw rivers were intensively studied from winter 1977 through spring 1979. Four of these streams (Needle Branch, Deer Creek, Flynn Creek, and Meadow Creek) are 16 km south of Toledo, Oregon. The first three streams were the site of the Alsea Watershed study (Moring 1975). Green Creek is 16 km southwest of Alsea, Oregon. Table 1 lists selected watershed and land-use characteristics for the five streams.

Monthly and immediately after storm events, streambeds were sampled at a total of 13 plots located in riffle areas and designated by two cross-section stakes, one in each stream bank. Samples were limited to the area within 1 m above or below each cross section. A liquid carbon dioxide sampler (Walkotten 1976) froze streambed cores to a depth of 25 cm, the approximate depth anadromous fish bury their eggs. Two samples from each plot were combined for analysis. We recorded the location of each sample to avoid repeated sampling of the same location within any given plot.

We profiled all streambeds monthly to document any scour and fill of the gravel bed. Continuous streamflow records from Flynn Creek were used to index the size and sequence of storms on all five streams. Because Green Creek is apart from the others, a crest gauge was installed there to verify the applicability of the Flynn Creek discharges.

During summer 1978 we sampled additional streams for a total of 21 Coast Range watersheds, both disturbed and undisturbed, ranging from 23 to 537 ha. Three streambed cores from each stream were frozen with liquid nitrogen (Hess 1977). Seven cores were collected from Flynn Creek, an easily accessible, undisturbed drainage. Although the diameter of the liquid nitrogen cores is about twice that of the carbon dioxide cores (20 cm vs. 10 cm), the techniques resulted in similar estimates (paired t-test, $\alpha = 0.05$) of fine sediment (Adams 1980). The 40-cm nitrogen cores were stratified into depths of 0–10, 10–25, and 25–40 cm. The mean fines content was calculated for the 0- to 25-cm depth for the three samples on each stream. For each of the 21 streams we recorded 21 independent variables (Table 2) believed to influence the size composition of the gravel bed. These included channel, watershed geomorphic, and land-use characteristics. All 21 variables were analyzed by multiple linear regression to quantify the data set.

TABLE 1. Selected characteristics of study streams and associated watersheds.

Stream	No. of sample plots	Watershed area (ha)	Area harvested (ha)	Year cut	Logging roads (km)	Avg. side slope (%)	Main stem channel length (m)	Avg. stream gradient at plots (%)
Flynn	4	225	0	—	0	28	1700	0.9
Deer	2	304	82	1966	6.0	41	2500	2.0
			30	1977				
Needle	1	75	62	1966	2.4	37	1300	1.0
Meadow	1	138	51	1963	1.2	29	1500	1.2
Green	5	56	15	1955	1.1	35	1000	1.6

TABLE 2. Dependent and independent variables for Coast Range watersheds.

	Description
	Dependent
1	Percent fines (<1.0 mm, excluding rocks larger than 50.8 mm)
2	" " (<1.0 mm, including rocks larger than 50.8 mm)
3	" " (<2.0 mm, excluding rocks larger than 50.8 mm)
4	" " (<2.0 mm, including rocks larger than 50.8 mm)
5	" " (<0.84 mm, excluding rocks larger than 50.8 mm)
	Independent
6	Stream order[a]
7	Watershed area (ha)
8	Bank-full stage (m)
9	Stream cross-sectional area at bank-full stage (m^2)
10	Width–depth ratio at bank-full stage (m/m)
11	Stream gradient (%)
12	Sinuosity (m/m)[b]
13	Watershed relief ratio (m/m)
14	Average watershed slope (%)
15	Watershed sediment yield ranking[c]
16	Road density (km/km^2)
17	Amount of watershed harvested (%)
18	Land-use factor (%)
19	Direct stream disturbance (%)[d]
20	Armor layer, average diameter (cm)
21	Armor layer, geometric mean diameter (cm)
22	Channel stability rating[e]
23	Basalt present in stream (yes = 1, no = 0)
24	Large-scale mass movements present in watershed (yes = 1, no = 0)
25	Private ownership (yes = 1, no = 0)
26	Index of uniformity (mm/mm)[f]

[a]Stream orders classified according to Strahler's (1957) method.
[b]Stream sinuosity is the ratio of actual stream distance between two points in the channel to the straight line distance between the same two points.
[c]An index of potential stream sedimentation from silt and clay particles (G. J. Badura, H. A. Legard, and L. C. Meyer), U.S. For. Serv., Pac. Northwest Reg., Portland, Oregon, 1974, unpublished data.
[d]Length of stream channel disturbed expressed as a percentage of total channel length.
[e]See D. J. Pfankuch, U.S. For. Serv., North Reg. Missoula, Montana, 1975, unpublished data.
[f]An index of particle size distribution (Adams 1980).

The final regression equation was chosen by the backwards–stepwise method (Neter and Wasserman 1977).

Sediments from all sample cores were oven dried at 105°C for 24 h, then were passed through 11 nested sieves with openings ranging from 50.8 to 0.42 mm. Particle size distributions were plotted, and the sediment 1.0 mm in diameter and smaller was expressed as a percentage of the total sample weight. For comparison, we initially measured the fine sediment in the liquid nitrogen cores as <2.0, <1.0, and <0.84 mm in diameter, and we both included and excluded rocks larger than 50.8 mm from the analysis. Because all these definitions of size ranges give similar results (Adams 1980), we used 1 mm as the upper limit for fines. Only a small portion of a larger particle needs to be frozen for the frozen-core sampler to withdraw it from the streambed (Walkotten 1973; Hess 1977). To reduce this bias, we excluded particles >50.8 mm in our analysis, an exclusion which significantly reduced the variance in fines content within a single riffle (Adams 1980). Earlier researchers also have excluded large rocks when analyzing sediment size (McNeil and Ahnell 1964; Wendling 1978).

Results and Discussion

Because low flow does not scour and fill gravel beds, we assumed a relatively stable streambed composition between May and November 1978 on the basis of the mean daily flow at Flynn Creek (Fig. 1). We calculated 95% confidence limits for fines content at the 13 sample plots for this period; any deviation outside the limits would indicate a significant ($\alpha = 0.05$) change caused by high-flow events.

During summer 1978, we moved Plot 1 on Needle Branch (Fig. 1A) because scour and fill during the first storm season altered the gravel bed so that it no longer had a riffle configuration conducive to sampling. Both plots on Deer Creek (Fig. 1A) and Plots 1 and 3 on Flynn Creek (Fig. 1B) had significantly less fines during the high-flow season. This seasonal reduction, displayed to a lesser extent at several other plots (Figs. 1 and 2), reflects the flushing of fine sediments from gravel during high-flow events.

Although several authors have noted this effect (McNeil and Ahnell 1964; Shapley and Bishop 1965; Sheridan and McNeil 1968), none have attempted to quantify it. Only flushing by freshets and spawning activities of fish can clean fine sediment from a gravel bed. If a channel does not experience high flows, fines will tend to accumulate in the bed (Meehan and Swanston 1977). Apparently the gravel bed must be set in motion during high flows if flushing is to occur (Beschta and Jackson 1979). Whenever our time–series data indicated flushing of fines, profile measurements indicated disturbances of the gravel bed; however, fines were not flushed every time the gravel bed was disturbed. Anadromous fish do use the four study streams, but we did not observe any redds at sample plots.

Not all sample plots displayed this flushing phenomenon. Fines decreased during the winter on only 7 of the 13 plots. At Plot 1 on Flynn Creek, levels of intergravel fines differed little between the low- and high-flow seasons (Fig. 1B). Apparently, intergravel fines are flushed in localized areas of the stream during high flows. Furthermore, the net cleaning of fines from any location during a storm depends not only on the disturbance of the bed but also on the intrusion of fines back into the bed when it stabilizes.

The percentage of fines in gravel beds varies greatly with time. If percent fines, or any other measure of gravel composition, is to be used to gauge stream quality, the time of sampling is important. Generally, if a stream can be sampled only once, that should be during low flow when bed composition is relatively stable. However, if fines content in the gravel is intended to index stream quality as a fisheries resource, the bed should be sampled during the winter when the eggs of anadromous fish are in the gravel.

Fines content in streambeds also varied greatly between adjacent streams, within streams, within riffles, and with depth in a bed. For the 21 Coast Range streams, fines content averaged 19.4% (range from 10.6 to 49.3%, SD = ±8.3%). In the five undisturbed streams, fines content ranged from 10.6 to 29.4%.

Within-stream variation of fines content was evaluated by comparing means for plots within each stream (Adams 1980) using Student's t-test. About 75% of all comparisons between plots within the same stream indi-

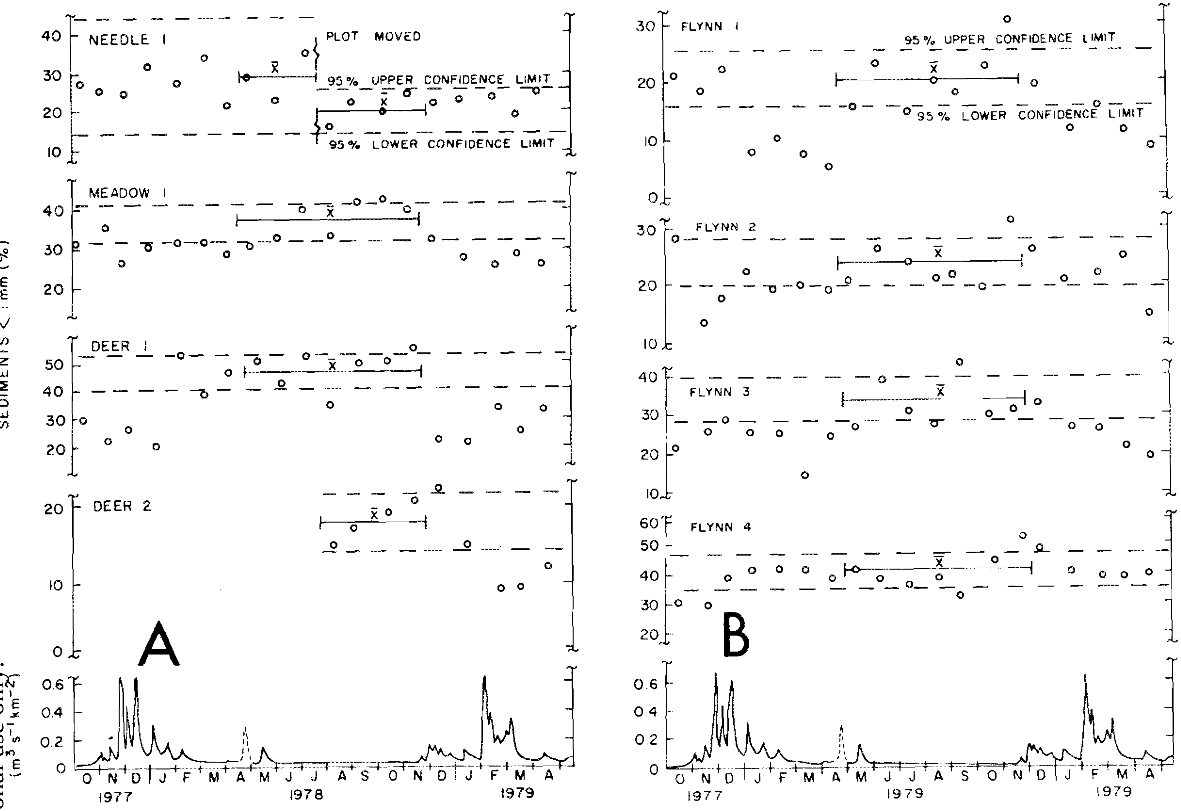

FIG. 1A. Time trends in percent fine sediment (by weight) and daily streamflow for plots in Needle, Meadow, and Deer Creeks. FIG. 1B. Time trends in percent fine sediment (by weight) and daily streamflow for four plots in Flynn Creek. Mean values ($\bar{x}$) and confidence limits are calculated for periods indicated by horizontal lines only.

cated that the levels of fines differed significantly (a = 0.05). Chance alone would, of course, produce only 5% of such cases.

Spatial variability was also significant, even within a single riffle that visually appeared to be of uniform composition. Fines content both parallel and perpendicular to the flow differed significantly ($\alpha = 0.05$, Latin square design) in 16 samples collected in a 1.2 × 1.2 m grid design from a single riffle in Flynn Creek. The differences were greatest perpendicular to the flow, with column averages ranging from 16.6 to 26.9% across the riffle.

For the 21 watersheds cored with liquid nitrogen, fines content also varied with depth in the stream bed. In 59 cores, the top 10 cm had significantly ($\alpha = 0.05$) less fines than the 10- to 25-cm and 25- to 40-cm strata. Fines content for the 0- to 10-, 10- to 25-, and 25- to 40-cm depths averaged 17.4, 22.3, and 22.2%, respectively (Adams 1980). The lower levels of fines near the bed surface may reflect an actual paucity of fines or the presence of an armor layer — an abundance of relatively large particles at the surface of the bed (Milhous and Klingeman 1971). This spatial variability in streambed composition may prohibit a simple characterization of gravel bed quality within a given area or an individual channel. The large number of samples required may also prohibit precise estimates of fines content.

From analysis of variables believed to influence gravel bed composition in the 21 Coast Range streams, three regression models were developed (Table 3). Table 4 is a correlation matrix for all the variables tested.

Model 1 was developed from the mean percent-fines data from each of the 21 Coast Range watersheds. We used topographic maps to determine area, average watershed slope, and relief ratio (the ratio of the total watershed relief to the horizontal distance between the highest point and the mouth). Roads and their construction often increase erosion and sedimentation more than any forest-harvesting activity (Anderson 1971; Swanston 1971). Therefore, we designed the "land-use factor" as a variable to account for such effects. We attempted to identify the proportion of a watershed that would have to be in roads to accelerate erosion and sedimentation the same amount as would clear-cutting the entire watershed. We set 4% in roads as equivalent to clear-cutting and cable yarding the

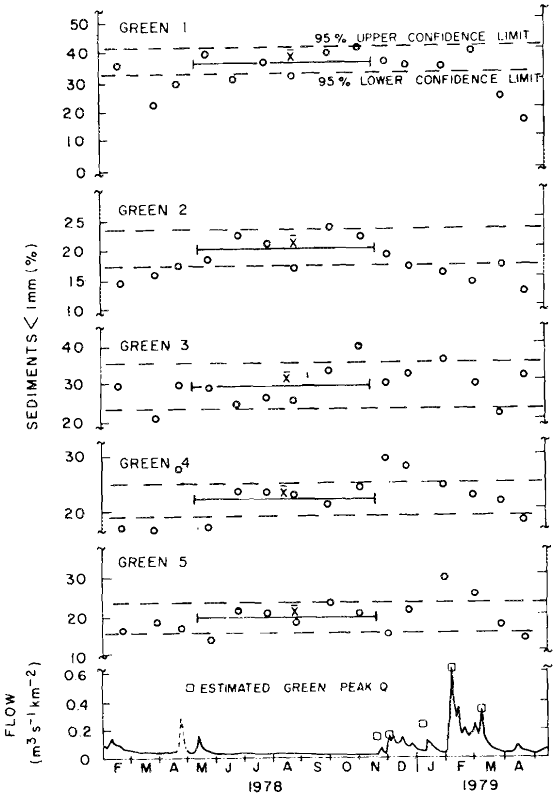

FIG. 2. Time trends in percent fine sediment (by weight) and daily streamflow for five plots in Green Creek. Mean values ($\bar{x}$) and confidence limits are calculated for periods indicated by horizontal lines only.

entire drainage. Although this percentage seems reasonable for Coast Range streams in western Oregon, it may not be applicable to other portions of the Pacific Northwest. The percentage of the drainage area in roads was obtained by multiplying the length of road within a watershed by an assumed right-of-way 15 m wide. The clear-cut equivalent (C, in %) was calculated from:

$$C = [(100)R]/4$$

where R = watershed area in roads (%).

The percentage of the watershed harvested was determined from field surveys, aerial photographs, and fire-control maps. The time between logging and the eventual recovery of the watershed was also considered. Erosion and sedimentation were assumed to return to pretreatment levels in 10 yr (Beschta 1978). Thus:

$$F = [H(10 - T)/10] + C$$

where F = land use factor (%), H = area harvested (%), and T = time since harvest (yr). For $T > 10$ yr, we assumed $H = 0$.

Model 1 (Table 2) indicates that the fines composition in a gravel bed significantly ($\alpha = 0.05$) relates differences in the watershed slope, area, relief ratio, and land-use factor. The three geomorphic variables suggest that fines composition generally increases in a downstream direction. The land-use factor suggests that road construction or logging may degrade the quality of the gravel bed, but only temporarily if sediment inputs are reduced over time and the fines are flushed by high flows as is normally the case.

The samples from the undisturbed Flynn Creek watershed offered a unique opportunity to study the relationship between bed fines and in-channel variables while holding the land-use and watershed geomorphic variables constant. The in-channel variables included bank-full stage, bank-full cross-sectional area, width-to-depth ratio, stream gradient, and stream sinuosity. Models 2 and 3, developed from the Flynn Creek samples (Table 2), are statistically significant overall. However, sinuosity in Model 3 is the only significant independent variable in either equation. The fact that neither the bank-full stage nor the sinuosity variable is significant when both are in the model suggests that they may interact. By regression:

$$\text{Bank-full stage} = 0.34\ (\text{sinuosity}) + 0.17 \qquad (r^2 = 0.46)$$

which is a significant ($\alpha = 0.10$) relationship. Bank-full stage is a measure of the water depth and influences the intrusion of fines into a clean gravel bed during high flows (Einstein 1968). Stream sinuosity could reflect differences in the depth and velocity of flow. Both depth and velocity are quantified by the Froude number which has also been found to influence the intrusion of fine sediment into gravel beds (Beschta and Jackson 1979).

Measures other than fines content have been proposed to characterize bed composition. One such method involves calculating the geometric mean diameter of streambed particles (Platts et al. 1979). This procedure is statistically sound only if the particle size–distribution is lognormally distributed. Our data indicate otherwise: in a chi-squared goodness-of-fit

TABLE 3. Regression results for fines content (PF) in percent by weight for streambed cores frozen with liquid nitrogen. * indicates significance at $\alpha = 0.05$ after application of correlation tests of linearity (t-test) and multiple linearity (F-test).

Model	No. observations	Regression equation	t	F	R^2
1	21	PF = −1.23 (Average watershed, slope, %)	*	*	0.66
		+0.03 (Watershed area, ha)	*		
		+68.89 (Watershed relief ratio, m/m)	*		
		+0.06 (Land-use factor, %)	*		
		+41.94 (Constant, %)	*		
2	7	PF = +27.02 (Sinuosity, m/m)		*	0.82
		+35.22 (Bank-full stage, m)			
		−31.04 (Constant, %)			
3	7	PF = +38.83 (Sinuosity, m/m)	*	*	0.74
		−24.94 (Constant, %)			

TABLE 4. Correlation matrix for dependent and independent variables (cf. Table 2) in 21 Oregon Coast Range streams.

Variables	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0.98	0.99	0.97	0.99	0.42	0.15	−0.13	−0.08	0.09	−0.35	0.12	0.04	−0.52	−0.05	0.11	0.19	0.18	0.18	−0.51	−0.50	0.47	−0.28	−0.26	0.34	−0.15
2		0.97	0.99	0.97	0.42	0.13	−0.21	−0.19	0.08	−0.40	0.16	−0.04	−0.55	0.02	0.17	0.18	0.20	0.20	−0.61	−0.61	0.51	−0.37	−0.28	0.37	−0.18
3			0.97	0.99	0.44	0.19	−0.10	−0.05	0.09	−0.33	0.08	0.08	−0.48	−0.04	0.10	0.18	0.18	0.18	−0.46	−0.45	0.45	−0.20	−0.24	0.37	−0.26
4				0.96	0.43	0.15	−0.20	−0.18	0.08	−0.39	0.12	−0.01	−0.52	0.03	0.17	0.17	0.20	0.22	−0.59	−0.58	0.50	−0.33	−0.27	0.40	−0.27
5					0.41	0.12	−0.13	−0.10	0.08	−0.33	0.10	0.05	−0.53	−0.02	0.13	0.19	0.20	0.18	−0.51	−0.50	0.46	−0.28	−0.25	0.34	−0.14
6						0.80	−0.07	0.34	0.55	−0.44	−0.05	−0.28	−0.23	−0.05	−0.17	−0.33	−0.24	−0.27	−0.04	0.01	0.38	0.07	0.07	0.09	−0.28
7							0.20	0.66	0.44	−0.37	−0.06	−0.37	0.06	−0.08	−0.31	−0.44	−0.43	−0.34	0.24	0.29	0.37	0.31	0.18	−0.20	−0.32
8								0.75	−0.40	0.45	−0.55	0.26	0.41	−0.15	0.17	0.16	0.21	0.25	0.35	0.27	−0.11	0.15	0.50	−0.23	−0.08
9									0.14	0.10	−0.35	0.01	0.28	−0.14	−0.21	−0.23	−0.24	−0.19	0.63	0.58	0.01	0.36	0.61	−0.28	−0.26
10										−0.52	0.24	−0.28	−0.29	0.41	−0.56	−0.63	−0.64	−0.61	0.23	0.30	0.30	0.36	−0.01	−0.13	−0.10
11											−0.12	0.47	0.49	−0.30	0.28	0.33	0.43	0.23	0.18	0.12	−0.55	−0.03	0.25	−0.17	0.13
12												−0.33	−0.48	0.19	−0.48	−0.30	−0.48	−0.50	−0.27	−0.25	0.20	−0.20	−0.32	−0.20	0.26
13													0.56	−0.26	0.26	0.40	0.44	0.15	0.26	0.23	−0.44	0.27	−0.05	0.21	−0.19
14														−0.46	0.16	0.26	0.32	0.14	0.59	0.52	−0.52	0.26	0.44	−0.13	−0.18
15															−0.16	−0.58	−0.41	−0.33	−0.09	−0.05	0.16	0.20	−0.18	−0.23	0.02
16																0.56	0.89	0.69	−0.36	−0.41	−0.23	−0.34	−0.07	0.41	0.02
17																	0.76	0.85	−0.40	−0.48	−0.17	−0.43	−0.02	0.50	0.04
18																		0.80	−0.34	−0.42	−0.22	−0.38	−0.02	0.44	0.02
19																			−0.46	−0.52	−0.04	−0.37	0.01	0.51	−0.07
20																				0.98	−0.40	0.58	0.58	−0.32	−0.25
21																					−0.40	0.70	0.43	−0.31	−0.26
22																						−0.34	−0.18	−0.12	0.11
23																							−0.11	−0.13	−0.30
24																								−0.13	−0.26
25																									−0.49

analysis (Haan 1977) of 21 liquid-nitrogen samples representing a wide range of median particle sizes, only 2 were lognormally distributed ($\alpha = 0.10$).

The amount of fine sediment in stream gravel beds evaluated in this study varies greatly in time and space. The temporal variability largely results from high flows that move the gravel bed and flush out the fines. Apparently, the net flushing of fines occurs only in a part of the channel during high flow. Rarely will flows be of sufficient magnitude to cause mobilization of the bed (and flushing of fines) over the entire length of the stream. On a watershed basis, fines content is primarily influenced by the geomorphological characteristics of the watershed and its land-use history, whereas within a given stream the amount of fine sediment in the bed is more related to stream sinuosity and bank-full stage.

The streams sampled in this study are located in a relatively homogeneous climatic and physiographic region. Yet streambed and sediment characteristics vary greatly within and between regions. Thus, criteria which designate acceptable levels of fine sediments in gravels may need to be different for each region. This variability also raises the problem of sampling design in assessing gravel quality. Even within a given stream, the large background variation in streambed composition may prohibit a simplistic characterization of bed quality. Any sampling scheme used to monitor changes in bed composition must be based on knowledge of possible seasonal trends in bed composition.

In natural streams where large variability is an inherent property of the system, our understanding of cause and effect and our capability of predicting the impacts of alternative land uses are often limited. However, the fact that regulatory agencies are implementing water quality standards based on gravel composition reflects an increasing concern for maintaining high-quality stream habitats. Numerous studies have related increased fines content with detrimental biological impacts. Our study, however, indicates that temporal variations occur naturally in western Oregon streams and that these variations may be large enough to obscure the effects of land use. The composition of streambed gravel fluctuates with the hydrology of a watershed, particularly its peak flows. Thus, more knowledge of in-stream processes that change gravel composition is needed. Furthermore, the suspected linkage between land-use activities in forested mountainous terrain and changes (either temporary or long-term) in the composition of stream gravels needs additional clarification.

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