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Although Hamilton (1989) concluded that projects located in high-gradient streams had higher failure rates than those in gently-sloping streams, we found no evidence to support this generalization in our study streams. In fact, in southwest Washington the incidence of damage increased as slope decreased (regression analysis, $P < 0.04$, $r = -0.79$), due largely to burial of structures in low-gradient reaches. In southwest Oregon damage rate did not vary significantly with slope, nor did failure rate in either region. However, high-gradient streams were not well-represented in our sample; only three projects were located in stream reaches exceeding 2% slope. Regression of failure and damage rates against an index of stream power, defined as the product of channel slope and mean active channel depth, were similar to regressions using channel slope alone.

Neither failure nor overall damage rates appeared to be strongly related to the estimated absolute or relative magnitude of the flood peak projects experienced during 1986. There was little difference in median or range of failure rates between one group of projects that had peak flows of 2-year recurrence interval and another group that had 5-10-year peak flows. Falls Creek was the only project where no incidence of damage or failure was recorded, perhaps because this high-elevation stream (830 m) did not experience a large rain-on-snow peak flow in 1986.

The correlation between active channel width and slope (regression analysis, $P < 0.01$, $r = -0.68$) and relationships among these variables and drainage area, discharge, and bed and bank texture, make simple, univariate explanations of patterns in damage difficult. There was no obvious overall relationship between failure or damage rates and valley segment type, a broad classification that accounts for covariation of numerous geomorphic parameters (Frissell et al. 1986). In general, however, there appeared to be a trend of more extensive damage in wide, low-gradient reaches in alluvial valleys and alluvial fan areas, which are susceptible to bedload accumulation and bank erosion

when the drainage catchment has been disturbed by logging or large natural landslides. Additionally, some projects in terrace-bound valley or alluviated canyon segment types (comparatively narrow channels with restricted floodplains) in southwest Oregon had high failure rates which, based on field evidence, appeared to result from the scouring effects of high-energy, sediment-charged flood flows.

3.2 Mode of Damage

Processes that damaged structures included design- or material-related phenomena, such as failure of cables and anchoring devices, but also included a wide variety of processes producing changes in the immediate environment of structures, such as bank erosion and bedload deposition (Table 17). In some cases such channel changes appeared to be largely a direct but unanticipated hydraulic consequence of placement of the structures themselves (e.g., bank erosion at the lateral margins of log weirs; see Cherry and Beschta [1989]). However, in most instances, the channel changes that damaged structures appeared to be primarily driven by watershed-scale phenomena, such as active landslides or road failures upstream causing massive bedload deposition in the project area. Many structures exhibited evidence of multiple, sometimes interacting modes of damage.

Southwest Oregon projects suffered damage from a wide variety of processes, ranging from failure of anchoring devices and structural breakage indicative of high hydrodynamic stress, to burial and channel shifting indicative of high rates of bedload transport and deposition. In comparison, fewer failure modes were observed in southwest Washington projects, and these were mostly indicative of changes in erosion and deposition in low-gradient reaches. For example, a series of boulder placements in

Table 17. Percent of structures in each project for which there was evidence that the indicated process contributed to failure or impairment. Because many structures exhibited multiple failure modes, percentages across rows do not necessarily add to 100. Modes of damage are arranged from high-energy, scour-related processes at left to low-energy, deposition-related processes at right.

Stream	Log Breakage	Anchor Bolt Failure	Cable Failure	Logs Stranded Out of Channel	Bed scour Under-mining Structure	Bank Erosion	Anchor Tree Washout	Bar or Channel Shift	Burial by Bedload	Unknown
Bear Cr.	0	21	21	0	16	16	0	0	5	0
Silver Cr.	0	0	17	0	0	17	0	0	33	0
Snasta Costa Cr.	6	11	17	22	0	11	17	6	0	0
Foster Cr.	0	0	7	0	7	7	0	0	13	0
Euchre Cr.	0	0	0	0	0	16	0	16	0	89
Crooked Bridge Cr.	0	0	0	0	0	0	0	0	0	100
Outcrop Cr.	0	0	0	20	0	20	0	0	0	20
Boulder Cr.	0	0	0	0	20	20	0	0	0	40
Total S. W. OR	1	6	10	5	5	13	3	4	5	27

Table 17. Continued

Stream	Log Breakage	Anchor Bolt Failure	Cable Failure	Logs Stranded Out of Channel	Bed scour Under-mining Structure	Bank Erosion	Anchor Tree Washout	Bar or Channel Shift	Burial by Bedload	Unknown
Layout Cr.	0	0	0	0	4	6	0	11	11	0
Upper Trout Cr.	0	0	0	0	80	0	0	20	20	20
Lower Trout Cr.	0	0	0	0	0	0	0	0	40	0
Wind R.	0	0	0	0	0	0	0	30	80	0
Trapper Cr.	0	0	10	0	10	0	0	20	20	10
Falls Cr.	0	0	0	0	0	0	0	0	0	0
Rush Cr.	0	0	11	0	0	0	0	0	0	0
Total S.W. WA	0	0	3	0	13	7	0	10	22	3
Total All Projects	1	4	7	3	9	11	2	7	12	17

Wind River, expected to scour pools within a long riffle, instead triggered deposition of a large mid-channel gravel bar, isolating the structures from the low-flow channel.

We noted numerous sites where structures caused inadvertant physical effects that we judged to be adverse, rather than beneficial. Adverse effects for which we found evidence included 1) accelerated bank erosion at log weirs, 2) direct damage to gravel bars and riparian vegetation by heavy equipment, 3) felling of key streamside trees to provide sources of materials, causing loss of shade and bank stability, 4) flood rip-out of riparian trees used to anchor log structures, 5) aggradation of gravel bars or silt and sand deposits (see also Platts and Nelson 1985), which caused shallowing and loss of microhabitat diversity in pre-existing natural pools, and 6) concentrated flood pulses of bedload and debris triggered by collapse of structures during the flood. Eggs and fry of fish which spawned in the gravel above log weirs, as well as juvenile fishes wintering in and near the structures, may have been killed when the structures failed and washed out. Fragments of epoxy or resins used to anchor structures were very common in many pools, and there is evidence that these materials can be toxic to fishes (Fontaine 1988). Frayed cables and sheets of ripped-out geotextile or chain-link anchoring material at damaged structures created obvious aesthetic impacts. Furthermore, repairs may have exacerbated initial damage. Rip-rap, which was used extensively in attempts to suppress bank erosion associated with log weirs, may adversely affect stream habitat over the long term (Richards 1982; Sedell and Frogatt 1984; Bravard et al. 1986; Li et al. 1984; Knudsen and Dilley 1987).

Modes of damage differed by valley segment type. In canyon-type segments, scour-related damage processes, such as cable breakage and loss of anchor trees, were common. In alluvial valleys, bank erosion, channel switching, and bedload aggradation were the primary proximal causes of damage and failure. These differences are partly related to different hydraulic and sedimentological forces and constraints

between valley segment types, but are also related to differences in structure design (e.g., anchoring systems) between valley types.

3.3 Effect of Structure Type

Of the eight structure designs for which we had sufficient sample size, only two-- cabled natural woody debris, and individual boulder placements-- were not impaired or failed in more than half the cases (Fig. 28). All log weir designs had high rates of impairment or failure, and one type, the downstream-V weir, failed or was impaired in every instance. Boulder structures had lower failure rates than log weirs. Previous studies have reported low failure rates for boulder structures in streams of less than two percent gradient, but higher failure rates in steeper streams (Hamilton 1989). Although many boulders had been almost completely buried in place by bedload deposits, we classified these as impairments rather than failures, since they could someday be re-excavated by the stream.

To some extent, failure and impairment rates presented in Fig. 28 are biased by the fact that not all designs were represented in all streams. For example, the higher success rate of boulder projects is partly related to their concentration in relatively stable southwest Washington streams where damage to structures of all types was small.

Figure 28. Failure and impairment rates of structures classified by design. Structure type codes are: NLWD = cabled natural large woody debris or jam; TLOG = transverse log weir; DLOG = diagonal log weir; VLOG = downstream "V" log weir; LLOG = lateral log deflector MOG = multiple log structure; BLD = individually placed boulders; BCLUS = clustered boulders. Number at top of bar indicates number of structures in sample.

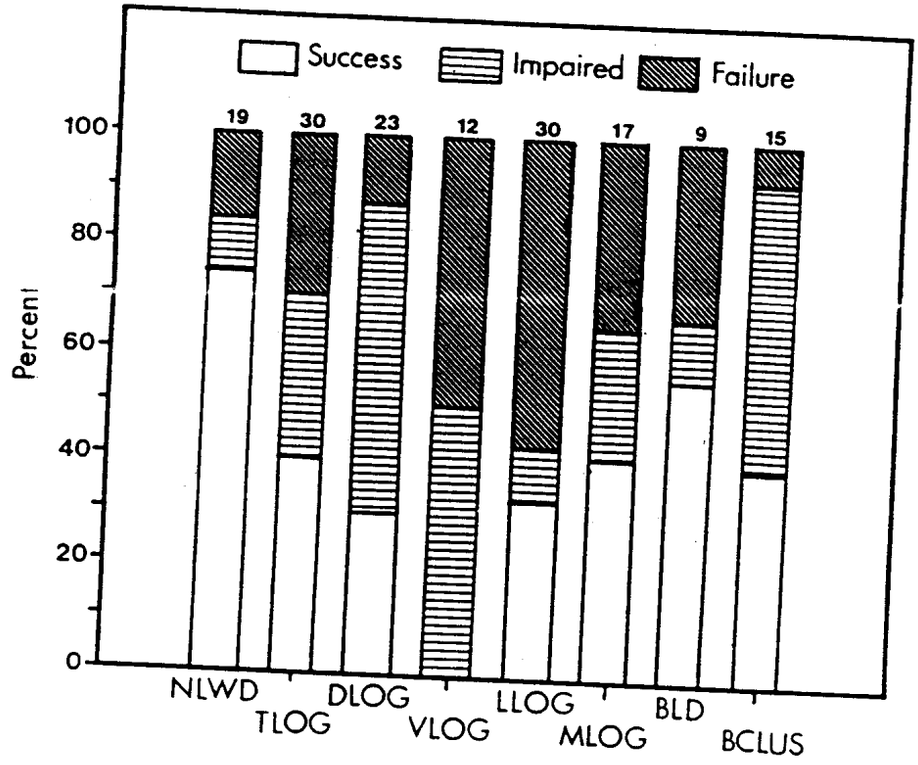

Success
Impaired
Failure
Percent
100
80
60
40
20
0
19
30
23
12
30
17
9
15
NLWD
TLOG
DLOG
VLOG
LLOG
MLOG
BLD
BCLUS

Figure 28

3.4 Inter-regional Patterns

When we compared our results with data from other regions in western Oregon (Table 18), we found that the projects we studied had higher than average rates of impairment and failure. However, the projects we evaluated were located in regions with intense winter precipitation and substantially higher peak discharge than most other regions (Figure 29, Table 19). There was a positive relationship between impairment and failure rates and peak flows. Streams in regions characterized by 10-year-recurrence-interval peak flows exceeding 1.0 $m^3 \cdot sec^{-1} \cdot km^{-2}$ had high but variable rates of damage (range 0-100%, median 46%) and failure (range 0-100%, median 14%) (Figure 30).

The regions with highest peak flows include the North Coast Range and South Coast/Klamath Mountains in Oregon, very steep and mountainous areas within intense rainfall and frequent rain-on-snow events, and the Columbia Cascades, part of the Cascade Range immediately north and south of the Columbia River that is subject to severe and frequent winter storms funneling through the Columbia Gorge from both coastal and interior areas. The South Coast/Klamath Mountains region, which had the highest incidence of damage to structures, has mean 10-year peak flows in excess of 2.0 $m^3 \cdot sec^{-1} \cdot km^{-2}$ (180 $cfs \cdot mi^{-2}$). Projects in other parts of western Oregon experience much lower peak flows and had lower rates of damage (range 0-67%, median 12%), and only limited incidence of failure (range 0-35%, median 0.5%) (Figure 30).

We had limited data for North Coast Oregon streams. We expect that when more projects are evaluated, many will suffer high failure and impairment rates because of the region's high peak flows and high frequency of long-runout debris flows (C. Frissell and R. Nawa, Oregon State University, unpublished data). However, the abundance of clays and lower proportion of fine sands and silt in soils of this region

Table 18. Rates of physical failure and damage reported for projects in western Oregon surveyed by other agencies. n = number of structures in project. Data sources indicated in parentheses as follows: a = B. Higgins and H. Forsgren, Mt. Hood National Forest, unpublished data; b = D. Hohler, Mt. Hood National Forest, unpublished data; c = House et al. (1989).

Region	Project	n	Failure Rate (%)	Damage Rate (%)
High Cascades	Lake Br. (a)	24	12.5	25
	Rock Cr. (a)	83	0	12
	Buck Cr. (a)	10	0	0
	Clear Br. (a)	15	0	20
	Robinhood Cr. (a)	12	33	67
Western Cascades	Fish Cr. (b)	252	4	31
	Pansy Cr. (a)	11	13	27
	Cooper Cr. (a)	9	0	0
	Oak Grove Cr. (a)	79	0	0
	Pinhead Cr. (a)	17	18	24
	Fall Cr. (a)	12	0	8
Central Coast Range	E.F. Lobster Cr. (1981) (c)	45	0	4
	Tobe Cr. (1982) (c)	20	0	0
	U. Lobster Cr. (1982) (c)	9	0	0
	S.Fk. Lobster Cr. (1982) (c)	65	35	35
	Little Lobster Cr. (1986) (c)	142	2	4
	J Line Cr. (1987) (c)	30	4	12
	Lobster Cr. (1987) (c)	37	7	37
	U. Lobster Cr. (1987) (c)	14	1	40
	E.F. Lobster Cr. (1987) (c)	11	0	22
North Coast Range	E. Beaver Cr. (1983) (c)	32	0	0
	U. Nestucca R. (1984) (c)	148	3	33
	L. Elk Cr. (1986) (c)	92	4	15
	Mid. Nestucca R. (1987) (c)	42	19	31
	U. Elk Cr. (1987) (c)	77	0	4
Columbia Cascades	S.Fk. Salmon R. (a)	34	3	24
	Kool Cr. (a)	6	17	17
	Clear Cr. (a)	16	56	75
	Clear Fk. Sandy R. (a)	10	100	100
	Still Cr. (a)	264	1	3
	Ramsey Cr. (a)	7	0	57

Table 19. Unit discharge ($m^3 \cdot sec^{-1} \cdot km^{-2}$) of ten-year recurrence interval peak flow (Q_{10}) of selected Oregon streams having greater than 20 years of record, drainage area exceeding 100 km^2 but less than 2500 km^2, and no significant influence of reservoir regulation. Data from Friday and Miller (1984). Some stations with records starting about 1957 or later were excluded due to bias of large floods in 1960's and 1970's. For stations with present flow regulation, data are for pre-dam period only. HC = High Cascades, WC = Western Cascades, CCR = Central Coast Range, NCR = North Coast Range, CCA = Columbia Cascades, SCK = South Coast/Klamath Mountains.

Region	Station	Elev.(m)	Unit Q_{10}
HC	Salmon R. near Government Camp	1050	0.83
	Salmon R. below Zigzag Cr.	760	0.54
	Clackamas R. at Big Bottom	620	0.48
	Squaw Cr. near Sisters	1060	0.27
	Red Blanket Cr. near Prospect	845	0.33
	Middle Fk. Rogue R. nr. Prospect	800	0.38
	Rogue R. above Bybee Cr.	1055	0.25
	High Cascades median =		0.38
WC	Clackamas R. above Three Lynx Cr.	335	0.69
	Breitenbush R. above Canyon Cr.	480	1.12
	N. Santiam R. below Boulder Cr.	485	0.74
	S. Santiam below Cascadia	230	1.32
	Calapooyia R. at Holley	160	1.03
	Mohawk R. near Springfield	135	0.63
	S. Fk. McKenzie R. above Cougar L.	520	0.66
	Salmon Cr. near Oakridge	445	0.67
	N. Fk. Mid. Fk. Willamette R. near Oakridge	315	0.65
	Hills Cr. above Hills Cr. Lake	500	0.79
	Mid. Fk. Willamette R. ab. Salt Cr.	370	0.79
	Elk Cr. near Trail	445	0.87
	Western Cascades median =		0.77
CCR	Yaquina R. near Chitwood	15	0.78
	Alsea R. near Tidewater	15	1.03
	Siuslaw R. near Mapleton	10	0.89
	N. Fk. Siuslaw R. near Minerva	10	0.84
	Central Coast Range median =		0.86
CCA	W.Fk. Hood R. near Dee	245	1.38
	Little Sandy R. near Bull Run	220	1.77
	Sandy R. near Marmot	220	1.14
	Salmon River at Welches	410	1.00
	Columbia Cascades median =		1.27
NCR	Wilson R. near Tillamook	20	1.78
	Trask R. near Tillamook	20	1.33
	Nestucca R. near Beaver	15	1.33
	Siletz R. at Siletz	30	1.56
	North Coast Range median =		1.46
SCK	S.Fk. Coquille R. at Powers	60	1.72
	E. Fk. Illinois R. near Takilma	540	2.01
	W. Fk. Illinois R. below Rock Cr.	460	2.39
	Sucker Creek near Holland	540	1.22
	Chetco R. at Brookings	15	2.64
	South Coast/Klamath Mountains median =		2.01

Figure 29. Box plots of 10-y peak flow standardized by drainage area for streams in six regions of western Oregon. Horizontal bar is median, box is interquartile range, and vertical line is data range. Number is sample size. HC = High Cascades, WC = Western Cascades, CCR = Central Coast Range, CCA = Columbia Cascades, NCR = North Coast Range, SCK = South Coast/Klamath Mountains.

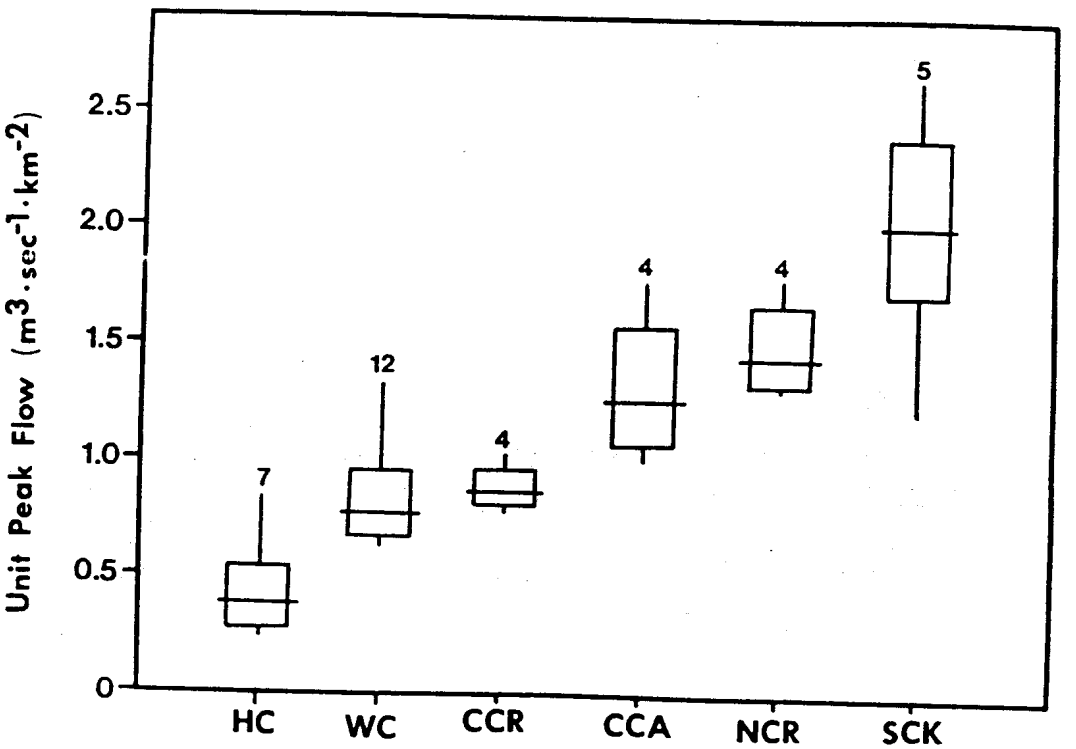
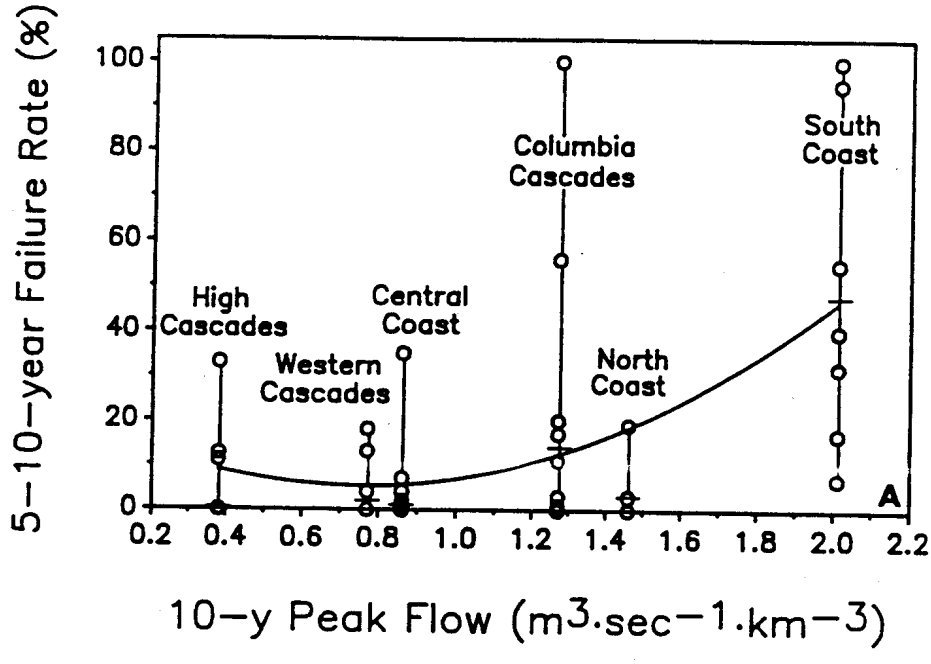

Unit Peak Flow ($m^3 \cdot sec^{-1} \cdot km^{-2}$)
2.5
2.0
1.5
1.0
0.5
0
7
12
4
4
4
5
HC
WC
CCR
CCA
NCR
SCK

Figure 29

Figure 30. Relation between rates of failure (A) and overall damage (B) of projects and regional median 10-y-recurrence-interval peak flow standardized by drainage area. Each point represents one or more projects (full data in Appendix 1). Horizontal bars indicate regional median. Curves are second-order regressions fitted to indicate trend, are not necessarily statistically significant. Southwest Washington projects from Table 2 are classified as Columbia Cascades region, except Rush Cr. and Falls Cr. in High Cascades. Southwest Oregon projects from Table 2 comprise the sample for South Coast/Klamath Mountains region.


5–10–year Failure Rate (%)
100
80
60
40
20
0
High Cascades
Western Cascades
Central Coast
Columbia Cascades
North Coast
South Coast
A
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
10–y Peak Flow (m3·sec–1·km–3)

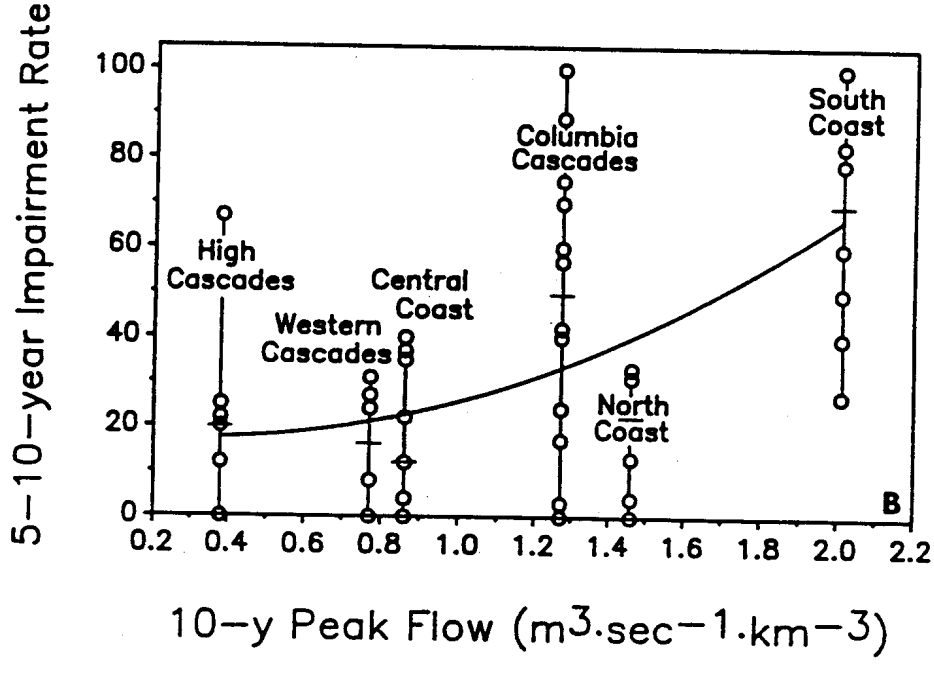

5–10–year Impairment Rate
100
80
60
40
20
0
High Cascades
Western Cascades
Central Coast
Columbia Cascades
North Coast
South Coast
B
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
10–y Peak Flow (m3·sec–1·km–3)

Figure 30

may render stream banks more resistant to erosion than those of South Coast Oregon, moderating failure rates somewhat.

Our experience indicates that sediment yield might be positively correlated and channel stability negatively correlated with regional peak flow. Undoubtedly these patterns reflect relationships among many aspects of geology, precipitation, soils, and hydrologic and geomorphic processes that are of critical importance to habitat management, from both an ecological and an engineering standpoint. The data for the South Coast/Klamath mountains region of Oregon are likely representative of conditions in much of northwest California as well.

4. Discussion

Artificial stream structures suffered widespread damage in most of the streams we surveyed in southwest Oregon and southwest Washington. Rather unpredictable damage rates and the wide range of causes of failure indicate that complex, multi-scale interactions between watershed conditions, fluvial processes, and structure design determine the physical success or failure of individual structures and projects. Because streams in these two regions experience intense flood flows, high bedload yields, and often unstable channels, artificial structures are highly vulnerable to damage.

The wide range of failure modes indicates that simple changes in structure design or materials are unlikely to overcome the problem of high damage rates. Overall, processes of failure and impairment were dominated by changes in channel morphology, apparently unanticipated by project designers. These changes were often related to dynamic conditions in the watershed or riparian zone, particularly as they

affected sediment load, streambank stability, and hydrology. Internal structure or material failure, the dominant concern of most biologists and hydrologists who build these projects, appears to be a far less important cause of damage than are watershed-driven aspects of channel dynamics.

We sampled only a subset of the projects present in southwest Oregon and Washington in 1986, but we believe our results are representative of other nearby projects. For example, we observed complete failure of structures in Deep Creek, a tributary of Pistol River in southwest Oregon caused by sediment-laden flood pulses that originated from large landslides occurring in recent clear cuts in the basin. We did not survey Deep Creek and several other projects in detail because repairs were already well underway before we were able to inspect the sites.

Few simple rules about design of artificial structures emerge from our study, but we can offer some general guidelines for stream restoration projects. Structure designs that least often failed were those that minimally modified the pre-existing channel, such as cabling intended to stabilize natural accumulations of woody debris. Elaborate log weirs and other artificial structures, which (if they stay in place) cause immediate and more obvious changes in channel morphology and hydraulics, were subject to high rates of damage. In large, low-gradient streams, configuration of the valley and large-scale roughness elements such as major channel bends exert primary control on the locations and morphology of pools and riffles (Lisle 1986), and sediment yield and peak flows strongly constrain channel stability and streambed dynamics. Smaller-scale structures such as log weirs can work effectively only within limits imposed by these larger-scale processes and patterns. These observations suggest that, at least in southwest Washington and southwest Oregon, it is unrealistic to expect the installation of new artificial structures to stabilize channels, and in fact the opposite result may be as likely.

Within the study areas, the stream habitats that are most important for fish, and most in need of restoration, are those least amenable to structural modification with existing technology. We observed the highest rates of failure and impairment in the streams draining watersheds most severely damaged by roads, logging, and landslides. Projects with highest failure rates in southwest Washington were located in an alluvial depositional areas of Trapper Creek and Layout Creek, in valley segments prone to natural instability that has been aggravated by removal of natural woody debris and logging of riparian vegetation. Deposition of bedload sediments in wide, low-gradient alluvial valley segments, and the erosion of streambanks and shifting of channels associated with this deposition were the most common causes of damage to structures in our study streams. Low-gradient alluvial valleys are also the most critical of stream habitats for spawning and rearing of chinook and coho salmon, and steelhead trout (Reimers 1971; Stein et al. 1972; Leider et al. 1986; Lichatowich 1989; and Nawa and Frissell, Oregon State University, unpublished data). Sediment accumulation in alluvial valley streams can cause numerous adverse effects: loss of pools, destabilization of woody debris, frequent channel shifting and abandonment, increased fine sediments and increased scour of spawning gravel, channel widening, and increased summer stream temperature due to loss of shade (e.g., Lisle 1982; Hagans et al. 1986; Everest et al. 1987). The dominance of sand and gravel in streambanks in alluvial valley and alluvial fan segments makes them highly susceptible to erosion, particularly when riparian vegetation, the roots, stems, and foliage of which help stabilize riparian soils, has been removed by logging, grazing, floods, or builders of artificial structures.

It may take decades or centuries for low-gradient channels in alluvial valleys to recover from downstream-propagating impacts of bedload accumulation (Lisle 1981; Madej 1984; Hagans et al. 1986). Such a recovery process proceeds only after sediment yield from the watershed declines to natural levels, which has not yet occurred

in many southwest Oregon basins. These basins continue to suffer impacts from failing roads, streamside landslides in second-growth forests, increased logging on steep, highly erodible lands under federal ownership (Frissell and Nawa 1989), and repeated short-rotation logging on private lands where there is little regulatory protection for unstable slopes and headwater stream channels (Bottom et al. 1985). Re-establishment of mature riparian forests to stabilize streambanks and floodplain surfaces is also needed for recovery of channel morphology (Lisle 1981).

4.1 Implications for Economic Analyses

Existing environmental and economic analyses assume a life span of 20 to 25 y for artificial structures in south coastal Oregon (Johnson 1984; U.S.D.A. 1989). This means that the average life span or half-life for all structures (not the maximum life span) must approach 20 y or more. More than half of the structures should survive much longer than 20 years. Our data indicate that a flood event of less than 10-y recurrence interval caused failure rates often exceeding 50 percent. Given that the probability of occurrence of a 10-y or greater flood event within the first decade after installation is about 0.65, and within the first 20 years is about 0.88, it seems likely that a majority of projects in southwest Oregon will experience failure rates exceeding 50 percent before they are 20 years old.

Larger floods might have more severe effects. The probability of at least one 20-y flood occurring within any 20-y period is 0.64, and the probability of a flood of 50-y or greater recurrence interval within 20 y is 0.33-- significant enough to be factored into half-life calculations that would be necessary to accurately estimate average life span for projects. Considering these factors, we estimate the average half-life (the time elapsed

when 50% of the structures are destroyed) of projects in southwest Oregon is less than 10 years, and that of southwest Washington is 15 years or less.

It is unlikely that most stream structure projects in Southwest Oregon and southwest Washington projects would appear cost-effective if planners used realistic estimates of project life, maintenance costs, and adverse side effects. The high rates of impairment we observed in the field indicate structural damage and wear that, if not repaired, greatly increase the risk of failure during subsequent years. The repair of flood damage that is necessary to reduce future failures of structures imposes a heavy maintenance burden, the costs of which are seldom factored into the economic analyses used to justify such projects. Unintended adverse effects, or "negative benefits," are also neglected in most benefit/cost analyses of artificial structures. Where projects have high impairment rates, there is a high likelihood of realized or potential net damage, rather than benefit to fish and water quality; such risks should be explicitly addressed in project plans and disclosed in environmental analyses.

4.2 Implications for Habitat Management

Despite the rather high incidence of physical failure and damage, and despite the lack of demonstrated biological success of surviving structures in the study areas, an inflexible, prescriptive or "cookbook" approach continues to dominate the analysis, planning, and budgeting processes within agencies responsible for fish habitat management in the region. Currently, most habitat projects in the Pacific Northwest seem to rest on the mechanistic assumption that the problem is simply lack of woody debris, and that the solution is to add standard devices such as log weirs, with each new structure creating an incremental improvement of habitat and a known poundage of

new fish. However, the widespread loss of woody debris and habitat diversity in northwest streams is symptomatic of a complex of ecological problems, driven by changes in riparian forests, channelization, and basin-scale erosion and sedimentation processes (Bisson et al. 1987; Elmore and Beschta 1987; Hicks et al. In press). Events such as sediment-laden floods and debris flows often re-shape channel morphology and fish habitat many kilometers downstream from their site of origin (Benda 1990).

Restoration programs in the regions we studied should follow a hierarchical strategy, emphasizing 1) prevention of slope erosion, channelization, and inappropriate floodplain development, especially in previously unimpacted habitat refugia, 2) rehabilitation of failing roads, active landslides, and other sediment sources, and 3) reforestation of floodplains, and unstable slopes (Lisle 1982; Overton 1984; Reichard 1984; Weaver et al. 1987). Direct structural modifications of channels are unlikely to succeed unless these larger-scale concerns are dealt with first.

Our results point to the general need to consider physical (as well as biological) phenomena in regional and watershed-scale contexts when planning stream restoration projects. In the long run, evaluation and planning of stream modification projects could greatly benefit from application of a hierarchical classification system, such as those proposed for land systems by Warren (1979) and Lotspeich and Platts (1982) and for streams by Platts (1979) and Frissell et al. (1986). Such an approach can provide a conceptual framework to order, analyze, and predict complex aspects of system behavior across different scales of space and time, by setting local, site-specific concerns in the context of large-scale dynamics of the watershed and system (Frissell et al. 1986).

If a hierarchical and contextual approach were used to plan and implement fish habitat restoration programs, many of the costly failures we observed could undoubtedly be avoided, and resources could be directed to effectively treat the primary causes of

habitat problems-- sedimentation from eroding roads and logged slopes, and logging, grazing, channelization, and urbanization in riparian areas and floodplains.

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