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Measuring Scour and Fill of Gravel Streambeds with Scour Chains and Sliding-Bead Monitors

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Abstract. -In the Pacific Northwest, scour and fill of streambed sediments is an often-overlooked cause of mortality of incubating salmonid eggs and developing alevins. Natural levels of scour and fill can be exacerbated by changes in watershed and channel stability caused by human disturbance. We evaluated the use of scour chains and a new device, the sliding-bead monitor, to measure scour and fill that occurs during peak flow periods. During 1987-1991, we designed and implanted 95 scour chains and 44 sliding-bead monitors in streams of western Oregon. Recovery rates of scour chains and sliding-bead monitors were 87 and 88%, respectively. Both kinds of scour devices allowed accurate, direct measurement of maximum scour depth and subsequent deposition, information that cannot be obtained from cross-sectional surveys or other conventional methods for monitoring stream habitat.

The dynamic nature of streambeds in the Pacific Northwest causes a high risk of mortality to incubating salmonid eggs and posses a challenge to scientists attempting to measure mortality factors associated with unstable streambeds. Research indicates that logging and road building can reduce stream channel stability through large inputs of sediment (Lyons and Beschta 1983; Tripp and Poulin 1986; Platts et al. 1989), but few studies have directly measured scour and fill of streambeds. We describe methods we have successfully used to quantify scour and fill of spawning and incubation habitats in highly dynamic streams of western Oregon.

Mortality during early life history stages of salmonids may be caused by infiltration of fine sediment into the spawning substrate, which reduces intragravel water flow, oxygen delivery, and waste removal; accumulations of sediment, which entomb emerging fry by forming a cap over the redd, and scour of the streambed during high stream flows, which causes premature removal and transport of developing embryos and alevins. Investigators have measured various aspects of egg-to-fry survival (Chapman 1988) but direct studies of mortality are difficult, costly, and not always successful. Therefore, physical measurements have been used to indirectly assess sediment effects on salmonid eggs and developing alevins. These methods are of three general types: (1) measurement or monitoring of spawning substrate texture; (2) measurement of suspended sediment; and (3) measurement of local streambed scour and fill related to bed-load movement. To date, most studies have focused on the quantification of fine sediment deposition. However, where scour and fill is the major cause of mortality, the measurement of fine sediment, gravel texture, or embeddedness will not give an accurate index of egg-to-fry survival and could result in an invalid assessment of habitat quality for spawning. Several authors (Gangmark and Bakkala 1960; Holtby and Healey 1986; Everest et al. 1987; Hall et al. 1987; Lisle 1989; Wesche et al. 1989) have indicated that measurement of streambed scour and fill is necessary to improve understanding of the dynamics of spawning and incubation habitat.

Scour chains are steel chains implanted in streambeds to measure scour and fill of sediments over a period of time (Figure 1). Scour chains can measure physical impacts on intragravel or hyporheic habitats of salmonid eggs and alevins during peak flow periods when most bed-load transport occurs and the streambed may be reshaped. The technique is based on the concept that bed-load movement in streams occurs as discrete scour and fill events along the stream channel (Jackson and Beschta 1982). Channel cross sections measured during floods support this concept (Leopold et al. 1964). During high flows, the streambed is scoured and the exposed portion of the scour chain lays over to the depth of scour (Figure la, b). If deep enough, this scouring can dislodge salmonid

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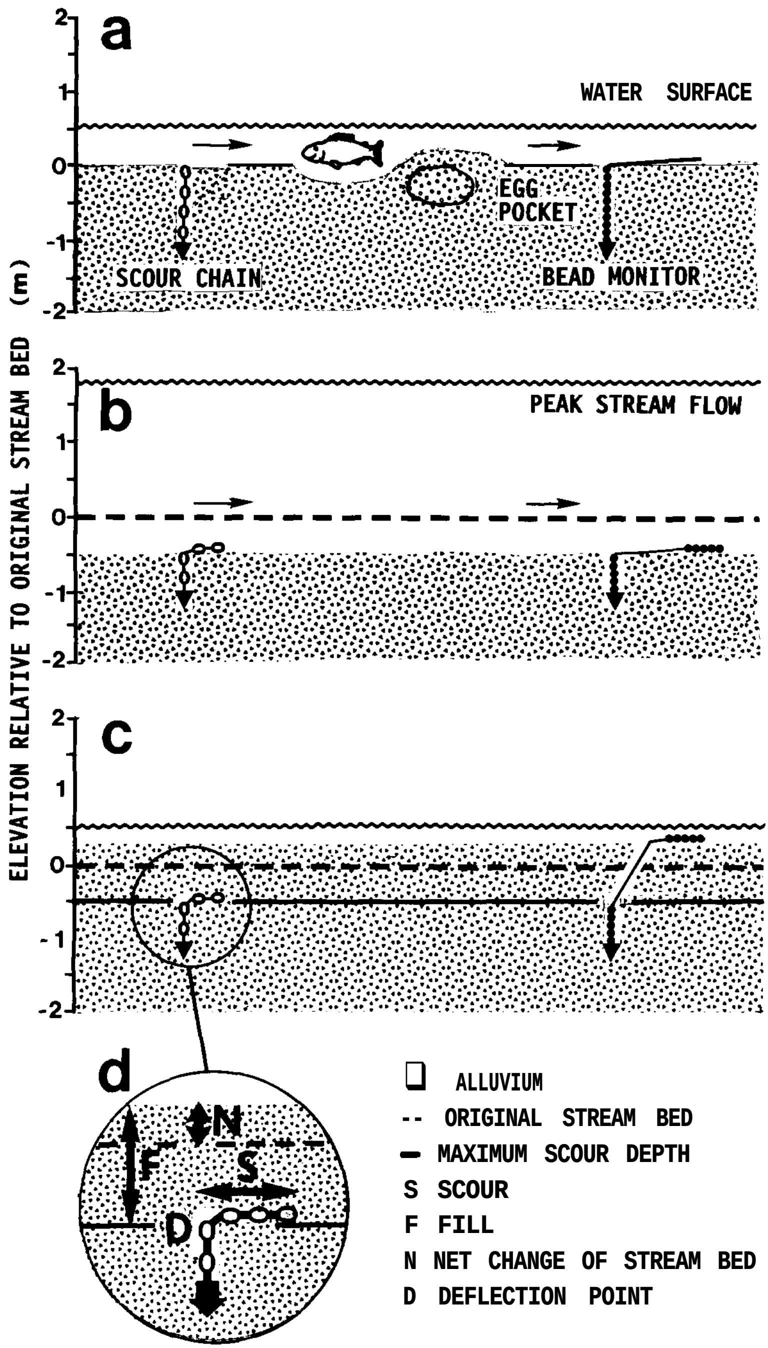

FIGURE 1.-Scour and till of a salmon redd measured with a scour chain and bead monitor. **(a)** Side view before peak flow. (Scour devices in our study were actually placed to the side of a redd, rather than in front and rear as shown). (b) Maximum streambed scour at peak flow during a large storm. All salmon eggs are washed downstream, and the streambed is scoured down 50 cm. Scour chain that is exposed lays over and exposed plastic beads slide to the end of wire cable. (c) Sediment deposition immediately after (or during) a storm buries scour chain in deflected position. Streambed in this case has aggraded from prestorm condition. Inset **(d)** illustrates measurement of scour and fill recorded by a scour chain.

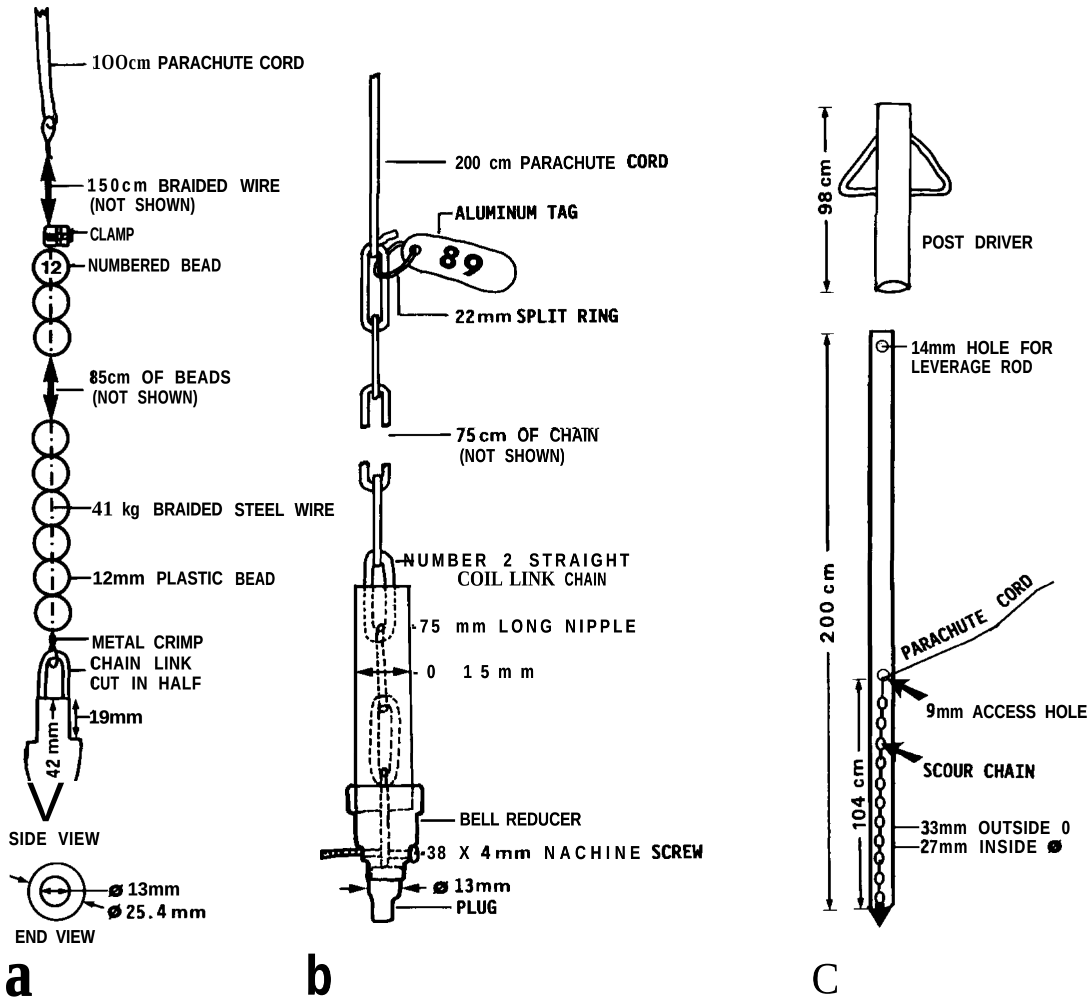

FIGURE 2.-(a) **Sliding-bead monitor with machined steel point. (b) Scour chain with point constructed from galvanized pipe fittings. (c) Galvanized steel driving pipe loaded with l-m long scour chain and point made** from galvanized pipe fittings.

eggs and developing alevins (Figure lb). As peak flows recede, deposition occurs, and the scour chain is buried (Figure 1 c). The portion of the chain now parallel to the streambed records the depth of the scour (Figure Id).

Leopold et al. (1964) used scour chains to study scour and fill in Arroyo de los Fujoles near Santa Fe, New Mexico. Since then other geomorphic and biological studies have used scour chains (Madej 1984; Tripp and Poulin 1986; Lisle 1989; Hassan 1990). Platts et al. (1983) briefly described the use of a notched driving rod and anchor ring to install scour chains. Lisle and Eads (199 1) described a two-step method to install scour chains with a probe constructed of pipes and pipe fittings.

Several other kinds of devices have been used to measure scour and fill but none have been widely adopted. A steel rod and sliding rebar device described by Duncan and Ward (1985) is prone to malfunctions because debris accumulations around the rod induce scour. The concept for the sliding-bead monitor described in this paper (Figure 2a) originated from a method that used buried ping-pong balls (Moring and Lantz 1975). Sliding-bead monitors permit measurement of scour without excavation, and the beads' small diameter results in only minor disturbance of the spawning substrate during installation. Peak flows scour the streambed and expose the plastic beads to flow turbulence and moving bed load, which slide the beads to the end of the cable (Figure 1 b, c). The length of beads excavated by peak flows records the depth of scour.

During 1987-1991 we installed 95 scour chains and 44 sliding bead monitors at 29 transects along coastal streams and rivers in southwestern and northwestern Oregon. The devices were placed along surveyed transect lines perpendicular to the stream channel. We selected sites based on their suitability for spawning (water velocity, depth, gravel size), presence of spawning salmonids, or presence of redds. Benchmarks were established on each side of the stream by driving a nail through a numbered aluminum tag and into a tree or a wooden surveyor's stake. A polyethylene-clad kevlar rope chain with 0.5-m increments was strung between the benchmarks. The horizontal distance from the true left benchmark (when facing downstream) was recorded for each scour device's location. Depending on the width of the active channel, we implanted three to seven devices 2-10 m apart along the transect line in the active channel (adjacent to individual redd sites, if redds were present). A steel pipe and post hole pounder were used to implant scour chains and sliding-bead monitors (Figure 2c). With the aid of a lead weight, a 2-m piece of 18-kg-test, braided dacron was fed down the driving pipe through an access hole. The braided dacron was then tied to the scour chain's parachute cord tail and pulled up through the pipe and out through the access hole. We placed the driving pipe, now loaded with the scour chain held vertically (Figure 2c), in the desired location and pounded it down approximately 1 m with a post driver. The smaller machined steel point shown in Figure 2a allowed the use of narrower diameter titanium driving pipe (21-mm outside diameter, 13-mm inside diameter) that was easier to drive into coarse-textured streambeds. An assistant held the parachute cord tail taut while the scour chain was driven into the streambed. Removal of the driving pipe usually required the use of a steel leverage rod to twist and pull the pipe free. Gloves and earplugs were used as safety measures.

Sliding-bead monitors were installed in a similar manner. To prevent beads from sliding up the cable wire during installation, a tiny screw clamp or a knotted rubber band was attached to the wire just above the beads (we used a number 12 copper entrance connector obtained from an electrical supply store and modified by cutting a slot through one side as a clamp). The clamp or rubber band was removed after installation.

The last task during installation was to survey the transect line with a hand level or self-leveling, tripod-mounted level and rod (we used a 5-power hand level). To ensure recovery of scour devices, the survey was sufficiently accurate to relocate the buried scour device to within 25 cm. An experienced two-person crew could install eight devices at two transects in 1 d. Materials for each kind of scour device cost about US$7.00 in 1990 and took approximately 20 min to construct.

We relocated scour chains the following summer by stringing the polyethylene-clad rope chain to its original installation distances at each benchmark. The transect was resurveyed with a hand level and rod before excavations began along the transect. Hand tools (e.g., pick, shovel, spade, and geology hammer) were used to dig down 40-60 cm, depending on water depth and substrate texture. Once the parachute cord was found, the excavation was continued upstream to where the scour chain deflected at nearly a right angle down into the streambed (Figure 1d). Excavation of the chain past the deflection point was avoided because doing so can result in overestimation of scour and fill. If the chain was installed flush with the original streambed, then the length of chain lying horizontal to the streambed was equivalent to the amount of scour. Fill was the distance from the deflection point up to the existing stream bed surface (Figure 1d). Net change in bed elevation was calculated by subtracting scour from fill.

Sliding-bead monitors were remeasured two or three times during the winter after large storms to determine if scour had occurred. The number of previously buried beads that moved to the end of the braided wire recorded the maximum depth of scour below the original streambed. In some instances, the formerly exposed bead monitor wire cable was partially or totally buried, making excavation necessary. Net change in bed elevation was determined by subtracting the initial length of exposed wire above the stream bed (immediately following installation) from the wire length exposed after the peak flow period. To prevent an overestimate of fill, excavation of some of the wire was necessary to ensure that the wire was vertically oriented above the original buried portion. Deposition, or fill, was calculated by adding the change in bed elevation (a positive or negative number) to the amount of scour (expressed as a positive number).

We established a protocol for sites where scour devices could not be found and were presumed buried beyond the depth of excavation. The site was excavated a minimum of 40 cm. If we were

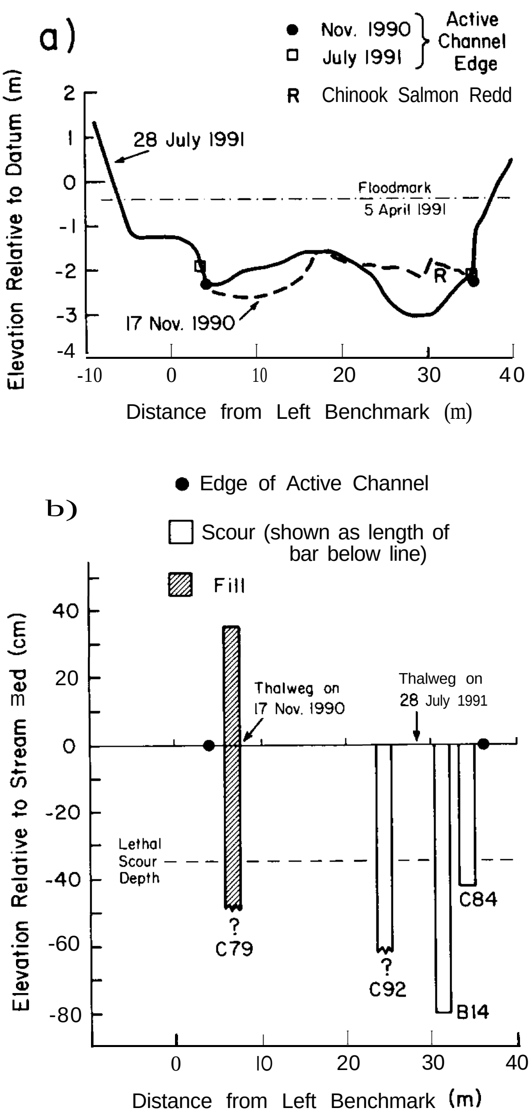

FIGURE 3.-Scour, fill, and streambed profile changes at a site in the Salmonberry River, northwestern Oregon, following a flood with peak magnitude of about 10-year recurrence interval. (a) Surveyed cross section before and after the flood season. Major streambed changes were accompanied by a thalweg shift of 20 m. (b) Scour and fill measured at scour chains (C79, C92, C89) and a bead monitor (B14). Horizontal reference line is the original streambed elevation on 17 November. Question mark indicates chain was not recovered and the minimum scour was established by maximum excavation depth. A chinook salmon redd located 32 m from the left benchmark was scoured below the probable depth of egg burial (dashed line shows probable lethal scour depth for redds).

certain the transect line was accurately positioned, the amount of fill was assumed to be at least as great as the depth of excavation (chain C79; Figure 3). An approximate estimate of scour can be calculated by subtracting the net change in streambed elevation (obtained from successive cross-sectional surveys) from fill. We discarded data for scour devices that we suspected had been tampered with or removed by humans.

Cross-sectional surveys conducted with hand levels were adequate to relocate 87% of the scour chains and 88% of the sliding-bead monitors. Scour chains were more durable than the bead monitors and easier to install, but field measurements of scour chains were practical only during the summer low flow period. Bead monitors could be used to measure the effects of separate storm events during the winter and reset between storms if scour and fill was minor. Both devices could be reset during the summer to measure bed movement during the following winter storm season. Typical results of our field studies are presented in Figure 3. Stream and floodplain cross sectional surveys provide information at a relatively coarse scale that gives a context for interpreting the more site-specific and precise measurements of microhabitats by scour devices. Cross-sectional surveys alone cannot detect maximum scour when it is masked by subsequent filling of the streambed immediately after (during) a major storm (chain C79; Figure 3).

Spawning activity by salmon and steelhead *Oncorhynchus mykiss* near scour chains can cause erroneous measurements. The scour and fill actually caused by redd digging could be mistakenly attributed to storms. We placed scour chains and sliding-bead monitors in the stream just after the peak of the spawning run, reducing the likelihood of confounding effects caused by scour and fill with those caused by spawning adults digging redds. Transects should be visited periodically to note scour and fill caused by salmon and steelhead digging redds that could perturb chains or bead monitors.

The design and placement of scour-measuring devices could be modified for other study objectives. Meter-long devices were appropriate for monitoring scour and fill at spawning sites of chinook salmon *0. tshawytscha* in main-stem rivers and major tributaries of western Oregon. Shorter devices may be appropriate in smaller tributary streams, hydrologically stable systems, or in studies of smaller fish species that dig shallower redds.

Acknowledgments

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