ENGINEERED LOG JAM

Description

Engineered log jams are collections of large woody debris that create or redirect flow and provide stability to a downstream bar or island. Engineered-log-jam constructions are patterned after stable, natural log jams and can be either unanchored or anchored in place using man-made materials. Naturally occurring log jams in alluvial channels are usually formed by one or several key members, consisting of large trees with rootwads attached, that stabilize and anchor other debris that is "racked" against the key members.[1] Log jams extend above bankfull water surface and, when connected to a streambank, are hydraulically similar to groins. *Figure 6-1, Engineered log jams* shows examples of engineered log jams.

Naturally occurring log jams may start as a single, large tree, as a large number of trees drifting together or as an undercut, timbered bank giving way and the trees coming with it. Over the years, people have removed many of these naturally formed structures for navigation, firewood and flood-control purposes. However, log jams provide habitat for a wide variety of fish species during most of their life stages. Engineered log jams are also fundamental to the dynamics of a healthy, forested, river ecosystems.[2] Engineered log jams as a bank-protection treatment are still considered experimental, but they are becoming increasingly popular as bank protection because they integrate fish-habitat restoration with bank protection.

Application

Prior to extensive logging activities in the past century, log jams were common throughout many of our streams. These accumulations of woody material helped create stable stream channels and habitat for fish and wildlife. Only in recent years have engineers and scientists begun studying the role of log jams in stabilizing streambanks. Mimicking how these accumulations form and function is the basis for the concept and design of engineered log jams.

Engineered log jams are used to realign a channel or redirect flow away from a streambank to protect it from erosional forces. They are also used to increase channel roughness to reduce flow velocities and shear stress along eroding banks. Large-woody-debris jams create a hydraulic shadow, a low-velocity zone for some distance downstream that allows sediment to settle out and stabilize. By locating a log jam along an eroding bank, the bank downstream of the jam becomes a deposition zone rather than an erosion zone. The deposition zone tends to become vegetated and continues to grow in volume over time.

Prior to designing and constructing an engineered log jam as a bank-protection technique, it is important to understand the existing physical characteristics and geomorphic processes present at a potential project site and along the reach (see Chapter 2, *Site Assessment* and Chapter 3, *Reach Assessment* for guidance).

Engineered log jams are best applied on long, uniform bends in alluvial channels. They are also appropriate when the mechanism of failure is toe erosion since they provide roughness and redirect erosive flows away from an eroding bank. When applied along a bend, they are apt to grow significantly as they recruit wood, so changes to the opposite bank should be expected. Engineered log jams are also useful in degrading channels for capturing and storing sediment and large woody material.[3] They can slow the rate of erosion in an equilibrium channel that is migrating laterally or where there is potential for a chute-cutoff, though they still allow for gradual meander migration. Large-woody-debris jams occur naturally at the inlet of many side channels. Jams can be assembled at the inlet of pre-existing or constructed side channels to regulate the amount of flood flow entering the side channel. This protects the banks in the side channel, prevents the side channel from capturing the main channel and protects existing spawning and rearing habitat in the side channel.

Engineered log jams may be appropriate when the mechanism of failure is scour. They should be placed upstream from the scour hole to redirect flow away from the obstacle that is creating the scour or to dissipate some of the energy that is causing the scour. They should not be placed directly in a scour hole. In tight-radius bends or other constricted reaches, they may not be very effective, and their application can further exacerbate existing erosion problems or move them upstream. Care in sizing and spacing engineered log jams is crucial to avoid creating a constriction.

In aggrading channels, engineered log jams may be appropriate, depending upon the severity of aggradation. They can be effective strategically if placed in a mildly aggrading channel where they can collect and store sediment. Their presence in such circumstances will better define the low-flow channel. Engineered log jams also recruit floating, large woody debris, which reduces the likelihood of the jam becoming buried and ineffective over time. When a channel has been disturbed and is carrying a high bedload, jams can be constructed in upstream reaches to stabilize sediment movement. Over the long term, engineered log jams reduce aggradation and erosion in the downstream reach. These jams can be placed either at the bank or in midchannel.

Engineered log jams provide excellent fish habitat by developing deep scour pools and associated tailout spawning areas, as well as complex cover. The structural complexity and hydraulic diversity associated with log jams provide ideal habitat for a variety of life stages and species of fish. For these reasons, engineered log jams receive high marks as a habitat-restoration and mitigation tool.

To learn more about the applicability of engineered log jams based on the mechanism of failure and causes of streambank erosion, review the selection matrices found in Chapter 5, *Identify and Select Solutions*.

Emergency

Engineered log jams are not appropriate for emergency situations. They cannot be constructed quickly, nor can they be assembled during high-flow events.

Effects

Depending upon their size relative to the channel, the constriction caused by an engineered log jam may result in scour at the opposite bank or point bar. Engineered log jams generally produce scour adjacent to themselves. The scour at the margin of the jam, and the associated downstream deposition, moves the location of the thalweg away from an eroding bank. One observed effect is the tendency for a side channel to form on the back side of the jam, against the bank.[1] This is a result of the jam causing an obstruction to flows above the bankfull elevation. Jams tend to split the flow, and the flow directed along the bank may create a side channel. If side-channel development is anticipated and undesirable, extend the jam into the bank and floodplain, and anchor it to a stable location.

Engineered log jams offer a distinct advantage over most rock structures such as barbs and groins. As scour holes develop adjacent to the log jam, the interlocking nature of log jams allow them to deform and settle; effectively retaining the structural integrity of the structure.[2]

Design

Conceptual design drawings of engineered log jams are shown in *Figure 6-2, Engineered Log Jams* and *Figure 6-3, Engineered Log Jams*.

Stability

The design of an engineered log jam requires a thorough analysis of channel hydraulics, which should be conducted by a qualified engineer. Engineered log jams can be designed with or without the use of anchoring hardware. Properly designed and located log jams can be very stable with life expectancies equal to or exceeding the design life of traditional bank protection techniques (e.g., groins, drop structures, revetments).[2]

Stabilizing key members (large logs with rootwads attached) can be accomplished at most flows by the ballasting effect of large logs and/or boulders.[2] Determining the necessary ballast mass requires a detailed stability analysis of fluid drag, buoyancy, lift and friction-resisting forces, and weight of the ballast logs and/or boulders.[2] A structure is stable when the sum of the resisting forces exceeds the sum of the driving forces (e.g., drag, lift, and buoyancy). Hydraulic conditions often result in sediment deposition on the downstream side of a log jam. This deposition buries much of the wood and will increase the effective weight and, hence, the stability of the log jam. The process of deposition can occur naturally or be accelerated by placing excavated sediments during initial construction to bury the key members.[2]

Designing an unanchored, engineered log jam requires excavating the streambed to provide a trench for the key member(s). The depth of excavation depends on channel hydraulics, substrate characteristics, channel dimensions and the size of wood. Once a key member is placed in a trench, the trench is covered with excavated sediment to provide additional ballast and frictional resistance to drag forces. Large woody material (whole trees with rootwads attached) are stacked (stacked members) on the key members for ballast. Next, whole trees, logs and/or rootwads are racked (racked members) on the upstream side of the key-piece rootwad(s) The number of pieces racked against the rootwad(s) depends upon the need for immediate protection, channel dimensions and hydraulics, and the likelihood of recruiting additional debris.

Unanchored, engineered log jams must be dense, with racked and stacked pieces carefully interlocked. The more dense the rack, the less flow will pass through it, thereby increasing the stability of the log jam. Scour under part of a loosely assembled structure may destabilize it and allow portions to be washed away. Dense structures, on the other hand, act as a unit. They settle uniformly and hold ballast well.

Engineered log jams can be anchored with pilings (see *Figure 6-2, Engineered Log Jams*). In small-grained substrates, a row of log pilings can be driven vertically into the streambed using the excavator bucket. In larger substrate, pile-driving equipment may be required, as well as steel tips on the logs. The logs need to be long enough to extend below estimated scour depths. A second row of pilings should be driven into the streambed at least 20 feet downstream, and brace logs should be anchored between them. Large woody debris is then racked against the upstream side of the brace logs and the first row of pilings, just as they are for unanchored engineered log jams. The braces are needed because there is a limit to the size and, consequently, the strength of logs that can be driven with an excavator. The braces distribute the shearing force of the racked logs between the two rows of pilings. The upstream row of piles is in the area where scour will form around the log jam. The downstream row is positioned in the deposition zone, safe from the undermining effects of scour.

In cases where the substrate will not allow logs to be driven, steel pilings can be used. If they can be driven deep enough, a single row may be sufficient. The buildup of debris will eventually hide the pilings from view.

Other methods of anchoring include attaching cable to the key logs and using an adhesive (e.g., epoxy) to glue the cable to boulders for ballast. If possible, the boulders should be buried in the bed to act as deadman anchors. Another approach is to partially bury logs into the bank so that they still extend into the channel, perpendicular to the direction of flow. Logs are then racked against the upstream side of the partially buried log. Some sites may require brace logs and/or a rock toe as additional reinforcement. To learn more about how to anchor large woody debris, refer to Appendix I, *Anchoring and Large-Woody-Debris Placement*.

Dimensions and Orientation

The shape of engineered log jams depends upon channel hydraulics, desired results and cost. In naturally formed jams, the most stable configuration is one where key members are oriented parallel to the high flow, with their rootwads upstream. Racked wood is generally positioned perpendicular to the flow direction. In many cases, debris collects upstream against the bank and forms a concave shape (from plan view) that is more streamlined. Using different methods of anchoring the jam may allow different shapes and alignments to form, and collection of additional wood on the engineered log jam during floods will potentially change the shape and dimensions of the jam.

The correct spacing and dimensions of jams are closely related. When positioning a series of engineered log jams along an eroding channel bend, they should begin below the cross-over riffle at the head of the bend. Spacing should be similar to that recommended for groins, but bear in mind that engineered log jams may become longer than groins as woody material is captured and collected over time. Groins are discussed as a separate technique in this chapter. The effective length (L_e) of an engineered log jam is the distance the structure extends into the channel, measured perpendicular to the bank. It does not include that portion that is keyed into the bank. Effective length must be considered when establishing spacing requirements. The furthest upstream jam in a series should be expected to grow the most as it will intercept additional floating woody material before it reaches subsequent jams. This phenomenon allows increased spacing between the first and second structures. Downstream structures may accumulate debris, but it will probably collect at a slower rate than the first jam in the series. Expect the accumulation to occur in both the upstream direction and laterally. This growth must be anticipated and may present a problem if channel constriction is an issue.

The size of materials used in the engineered log jam will depend upon the method of anchoring. The required size of pieces will be based on the calculations of drag, friction, lift and buoyancy. It's also important to take into consideration the anticipated rate of wood decomposition, wood density and the length of project life. Racked pieces do not usually function as structural members of engineered log jams, so they can be any size, particularly if accumulation of additional debris on the rack is anticipated. Determining the correct size for structural members should be accomplished by a qualified engineer.

Biological Considerations

Mitigation Requirements for the Technique

Engineered log jams provide valuable fish and wildlife habitat. Because they are so valuable to fish and wildlife, only construction impacts need to be mitigated. Immediately following placement of engineered log jams, there may be temporary, short-term impacts on spawning. Existing spawning areas may shift or scour; while others may accrete with fines while new spawning areas are forming. It may take the channel a period of time to adjust to the jams. However, the long-term habitat benefits of engineered log jams far out-weigh these short-term impacts.

Construction-related impacts do, however, require mitigation. Care should be used in gaining equipment access to the site to minimize construction impacts.

Mitigation Benefits Provided by the Technique

The structural and hydraulic diversity that engineered log jams provide creates habitat for a multitude of fish species at nearly every stage of life. Engineered log jams create excellent cover, holding and rearing habitats. At the tailout from the scour hole created by an engineered log jam, spawning habitat may be created. The detritus they accumulate, particularly smaller twigs and leaves that decay rapidly, also serves as a food to some aquatic insects that fish consume.

Risk

Engineered log jams pose inherent risks to infrastructure and human stream users. These risks include:

- safety hazards caused by the log jams or the cables that anchor them (this risk can be somewhat reduced by placing warning signs upstream from the log jams to alert boaters),
- blockage of culverts or bridge openings by large woody debris that has been dislodged from a log jam upstream,
- unanticipated erosion across the channel or to the adjacent streambank,
- increased channel roughness and constriction, and/or
- increased flood stage.

Careful, well-calculated design and positioning of engineered log jams can minimize all of these risks.

Reliability/Uncertainty in Technique

The use of engineering log jams as a streambank-protection technique is relatively new, with little available research information to document their performance. Monitoring and performance reporting is encouraged to aid in further development of this technique by future practitioners. Appendix J, *Monitoring* provides more information on how to observe and record project performance over time.

Construction Considerations

Equipment and Materials Required

Large woody debris should be of a size (length and width) and species that can remain intact and stable for many years. Avoid using hardwood species such as alder or cottonwood, which decay rapidly. Coniferous species such as cedar, fir and pine are better choices. If sufficiently large key members are not available or can not be transported in one piece to the site, several trees could be cabled or pinned together to form a composite key member. Large and long logs imported from off-site locations may need to be cut into pieces for transport and then reassembled on site by splicing, gluing and tacking pieces back together. This technique has been tested and refined on the Stillaguamish River in Washington State for limited use.

Use of on-site wood resources can greatly simplify construction and reduce costs. Appropriating single logs from dry gravel bars is an option with minimal short-term impacts. Consider the density or loading of large wood in the reach before deciding to use on-site wood. If the channel is deficient of large wood, it may be necessary to import wood for the structure(s). One of the factors that will help determine whether off-site wood can and should be imported to the site is whether or not equipment can move wood of the required size and length from a distant site to the work site.

Wood buoyancy can be a problem during construction since much of the log needs to be installed below the water surface. To address this problem, the site may need to be dewatered to allow for placement and anchoring of large pieces. The use of previously saturated wood can simplify construction by reducing buoyancy problems during installation. See Appendix M, *Construction Considerations* for information about dewatering.

Turbidity may be a significant problem during installation due to the amount of digging in the channel bed required during installation. This can be avoided by dewatering the installation site, or by creating a coffer system that isolates the immediate site from flowing water.

Protection of the existing riparian zone is a high priority, particularly in drier climates where replacement of the canopy can take decades. The use of walking excavators, winches and hand labor may be required at some sites.

Timing Considerations

Construction should be conducted during a period where impacts to critical salmonid life cycles, such as spawning or migration, are avoided and when dewatering for construction is possible. Low-flow conditions are ideal for the placement of engineered log jams and may be essential for dewatering efforts. Dewatering eases installation and prevents siltation of the stream during construction. In-stream work windows vary among fish species and streams. Contact the Washington Department of Fish and Wildlife's Area Habitat Biologist for information on work windows (see Appendix B, *Washington Department of Fish and Wildlife Contact Information*). Further discussion of construction timing and dewatering can be found in Appendix M, *Construction Considerations.*

Cost

Costs for installing engineered log jams are site-specific and are affected primarily by availability of wood materials, dewatering capabilities and equipment access. Engineered log jams constructed in Washington State have ranged in cost between $1,800 to $80,000 to install.

Large woody debris can vary considerably in cost from virtually free (as locally salvaged wood), to quite costly (large-diameter, full-length cedar trees that may have to be sawn for transport and later re-assembled). Large woody debris can cost between a few hundred dollars to a thousand dollars per piece. Equipment costs can also be substantial, especially when specialized equipment is required, such as helicopters for wood delivery, spider hoes for access and considerable manual labor for installation. Appendix L, *Cost of Techniques,* provides additional information and a case study on estimating project costs.

Operation and Maintenance

Maintenance of engineered log jams includes replacement, realignment or removal of pieces following storm events equal to or greater than what they were designed to withstand. If anchored, the anchoring hardware may also need to be readjusted or replaced. Any biotechnical bank protection between the log jams will also need maintenance.

Monitoring

Monitoring engineered jams should determine if the structures are performing in accordance with design flow criteria and whether they are providing the habitat and bank protection desired. Because large-woody-debris projects generally involve impacts to the channel and banks, they will require comprehensive monitoring of both channel and bank features, with particular attention to habitat monitoring. For a comprehensive review of habitat-monitoring protocols, refer to *Inventory and Monitoring of Salmon Habitat in the Pacific Northwest –Directory and Synthesis of Protocols and Management/Research and Volunteers in Washington, Oregon, Idaho, Montana, and British Columbia.*[4] Habitat-monitoring protocols will likely require a monitoring schedule that is more comprehensive than that required for the integrity of the structure.

Monitoring to evaluate structural integrity should be conducted annually and following any flow events that meet or exceed design flow events. This can be accomplished by surveying precise locations of key members relative to a stationary point on shore by determining whether the jam has lost key members and by conducting a visual inspection of anchoring systems.

Details on how to develop a monitoring plan can be found in Appendix 10, *Monitoring*.

Examples

References

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