Engineering Design and Installation of Large Woody Debris (LWD) for Habitat Enhancement, Stabilization, and Fish Passage

Conception technique et installation de grands débris ligneux (LWD) pour l'amélioration de l'habitat, la stabilisation et le passage des poissons

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RÉSUMÉ

La présence dans le chenal de grands débris ligneux (LWD) est essentielle aux fonctions écologiques vitales, comprenant entre autres la dissipation et la complexité des énergies hydrauliques, la stabilisation des formes de lits complexes et des remblais, l'immobilisation des sédiments et un refuge contre la prédation. L'enlèvement par le passé des arbres de la zone riveraine, combiné au nettoyage intentionnel et à la récolte du bois, a modifié les sources, les mécanismes de distribution et la redistribution des débris ligneux dans les systèmes de drainage, entraînant des changements dans l'abondance et la diversité génétique des poissons. Aujourd'hui, il y a un effort important au niveau fédéral, étatique et local pour réintroduire de grands débris ligneux dans les cours d'eau du Pacifique Nord-Ouest. Du point de vue de l'ingénierie et de la construction, cette présentation aborde les considérations, les contraintes, les méthodes et les applications pratiques liées à la conception et à l'installation de grandes structures de débris ligneux dans les cours d'eau de l'Oregon et de l’état de Washington.

ABSTRACT

The in-channel presence of Large Woody Debris (LWD) is essential to critical ecological functions, including dissipation and complexity of hydraulic energies, stabilization of complex bed forms and channel embankments, entrapment of sediments, and supply of refuge from predation. Historical removal of trees from the riparian zone, combined with intentional stream cleaning and timber harvest, has altered the sources, delivery mechanisms, and redistribution of woody debris in drainage systems, leading to changes in population abundance and genetic diversity of fish. Today, there is an extensive effort at federal, state, and local levels to reintroduce LWD into Pacific Northwestern streams. From engineering and construction perspectives, this presentation discusses the considerations, constraints, methods, and practical applications associated with the design and installation of Large Woody Debris structures in Oregon and Washington streams.

KEYWORDS

Construction, fish passage, geomorphology, stabilization, large wood

1 INTRODUCTION

A wide breadth of research and associated academic literature has documented the essential functions of Large Woody Debris (LWD) in river systems. However, in many parts of the world, public perception of the presence of LWD in rivers is negative, resulting in an obstacle for the advancement of implementing management practices that use large wood as an agent for restoration of ecological function in river systems.

In rivers and streams of the Pacific Northwest, public perception of the presence of large wood in streams is less negatively slanted, and the effort of implementing stream restoration practices has been ongoing for several decades driven by the endangered status of unique salmonid species that represent an important economic and cultural base for the region. Historical removal of trees from the riparian zone, combined with intentional stream cleaning and timber harvest, has altered the sources, delivery mechanisms, and redistribution of woody debris in drainage systems, leading to changes in population abundance and genetic diversity of fish. Today, there is an extensive effort at federal, state, and local levels to reintroduce sustainable LWD structure into Pacific Northwestern streams.

From engineering and construction perspectives, this presentation will discuss the considerations, constraints, methods, and practical applications associated with the design and installation of LWD in Oregon and Washington streams.

2 DISCUSSION

2.1 Engineering Design and Planning

In Oregon and Washington, the planning of large wood installations requires both stakeholder input and technical rigor. Input is necessary from of a diverse set of stakeholders including property owners, local non-profits, historical interests, and regional, state and federal regulatory authorities. Stakeholders help frame the design by establishing clear constraints, desires, objectives, opportunities, and mandates. For example, a project may be funded based on the need to reduce sedimentation in a stream, leading to the prioritization of the stabilization of eroded embankments. A different project site may be contain a particular species of fish that is known to be limited by its access to refuge from predation or it's inabillity to effectively migrate through the system, while a third project may be focused on the mitigation of incision and the increase of flows' access to the floodplain. Most project sites are also constrained by infrastructure factors such as property lines, utilities, and bridges. It is likely, in any case, that a combination of such objectves or constraints will be present on any given designated project site.

Taking these objectives and constraints into consideration, LWD design incorporates available technical information from geomorphological and habitat surveys, topography, hydrology, and hydraulics. These field surveys (geomorphological, habitat, and topographic) inform design by documenting evidence of biological and fluvial geomorphic activity. By identifying the structural and hydraulic signatures of desirable physical conditions in the reach, a study will distinguish successful natural functions onsite upon which the design can build. Some of the markers to be documented will include existing woody debris dynamics; floodplain and side-channel connection geometries; pool and riffle arrangements; alluvium distributions; bed and embankment composition and scour; and the presence, stability, regeneration, and succession of the site’s flora and fauna. Using available hydrological and topographic data, the design will be conducted to exploit the assessed magnitude, frequency, and timing of the biological, physical, and chemical processes already at work onsite while ensuring the dynamic stability of installations.

HEC-RAS software, developed by the United States Army Corps of Engineers, is commonly used to combine hydrological and topographic data into a spatial model to conservatively predict stream power, flow velocities, hydraulic shear stresses and the lateral and vertical extent of water present during flow events (often the 100-year return interval) and at locations of interest within a project reach. Such a model will often be developed for both existing and proposed conditions to inform the effectiveness of proposed design alternatives in meeting the demands of project objectives and constraints. Engineering predictive approaches are applied to develop a rigorous assessment of necessary structural dimensions and to confirm necessary stability. However, due to an often limited knowledge of certain factors, any design must allow for the flexibility of adapting to field conditions during installation.

2.2 Construction Implementation

With rootwads remaining attached, local evergreen species such as Douglas fir (*Pseudotsuga menziesii*), Western Red Cedar (*Thuja plicata*), and Western Hemlock (*Tsuga heterophylla)*, are used as LWD due to there resiliency over time in wet/dry conditions. Attached ootwads are placed strategically to take advantage of their complex morphology to dissipate velocities, encourage scour, provide refuge, capture debris, etc. Typically, structures are stabilized by some combination of burying logs into compacted ground, driving LWD piles into the soil, bolting logs together with steel hardware, and/or ballasting with large boulders.

Due to the inherent variability of river systems over time and of the natural materials used in installation of LWD projects, it is critical to plan for field adaptation. In these dynamic systems, site conditions do change over the course of a design period. Often, the very issues that are intented to be mitigated by a design can be exacerbated over this period, forcing the need for a design that takes into consideration such potential changes through strategic and conservative materials sourcing and planning. The materials and media (LWD, boulders, soil) are known to vary widely and, despite clear specification, are likely to not meet the exact expectation of the designer once delivered to the site. This unpredictability lends value to the ability for both designers and consctruction professionals to adapt the proposed design to conditions present at the time of installation.

Finally, construction methods must be chosen and executed to minimize impacts to the sensitive environments where these projects take place. Water diversion structures are set up to divert flows around the project reaches, reducing impacts to fish and other aquatic wildlife within the project reach. Low ground pressure equipment is used, equipped with bio-based hydraulic fluids. Access routes and methods must be carefully chosen, and implements such as steel plates, wood mats, and the creative use of actual building materials (LWD and boulders) can allow for a reduced project footprint. In some cases, where access is particularly challenging, even helicopters are used to deliver heavy materials.

3 CONCLUSION

In the Pacific Northwest, LWD has been used as an agent for the restoration of ecological and fluvial processes for decades. Design and construction of LWD structures involves the collection of both stakeholder input and technical data. Common LWD project objectives include habitat enhancment, channel stabilization, and fish passge. Once objectives and constraints are determined, LWD structures are designed based on the synthesis of field assessment and modeling analysis. Design must be developed with an ability to adapt to the potential variability of site conditions and materials character, and construction approach must be flexible and creative to allow for a field-fit while protecting the sensitive environments within which the work occurs.

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