EXHIBIT F1

IN-STREAM HABITAT FEATURES

LARGE WOODY MATERIAL

Description: Large woody material (LWM) is placed in streams to act like spurs or hardpoints to create diversity and habitat. LWM has been used for river training and stabilization for many years throughout this country. During the 1990s use of large woody material increased in efforts to emulate the form and function of naturally–occurring wood debris. In the Rocky Mountain region of the U.S., the use of root wads is not uncommon as a type of LWM. In the Pacific Northwest engineered log jams is typical of LWM.

The purpose of using LWM in Grand County rivers and streams would be: 1) to provide additional habitat and increase diversity in habitat, and 2) to slightly narrow the low flow portion of the channel. LWM will create deeper pools, increase aquatic cover for shade and protection, provide velocity shelter, facilitate pool development and undercut banks, and diversifies local flow conditions.

Types of LWM: LWM can be continuous or discrete features, depending on the need. Types of LWM include rootwad revetments such as spurs or cross vanes, rootwad revetments used as toe protection or underwater berm, and engineered log jams.

Applicability: Large woody material applications are well suited for use in wide, low flow and moderately stable channels. The channels would typically be experiencing a deficit of woody material that might otherwise be present without unnatural influences such as flow regulation and deforestation. LWM is not suitable for degrading or incising channels.

Pros and cons

1. Pros of LWM:
    a. typically inexpensive to construct,
    b. provides habitat for fish and benthic macroinvertebrates, and
    c. recreates a naturally occurring type of habitat that has been lost with anthropogenic impacts.

2. Cons of LWM:
    a. LWM will decay within a few years unless it is continuously submerged,
    b. can be easily flanked in sandy soils, and
    c. not recommended in reaches where failure would endanger human life or critical infrastructure.

LWM on channel island and outer bank

LWM placed as tow protection during channel reconstruction

Example woody material on the Fraser River acting as a spur or hard point and providing fish habitat.

BOULDER CLUSTERS

Description: Boulders of varying size can be placed in the channel to provide habitat diversity. Primarily, boulders serve to disrupt the flow line of the water, thus reducing velocities and creating turbulence which helps to introduce oxygen in the water. Boulders can be placed individually, in clusters, depending upon the desired effect.

Boulders placed individually and in clusters in the stream will generally form a scour hole on the downstream side of the rock. This creates pockets of slower moving water than is found in the rest of the channel. This eddy area provides excellent resting opportunity for the aquatic population.

Applicability: Individual and clusters of boulders can be placed in channels that have a decreased amount of flow diversity in the channel. These are best suited for streams and rivers that have a bed of cobble to gravel sized material and are not suitable in highly erodible, alluvial sand channels.

Pros and Cons:

1. Pros of individual and boulder clusters:
    a. The design is simplistic and does not involve extensive engineer efforts
    b. Construction is typically a fairly simple process, the installation typically consists of placement in the channel without overexcavation and placement of filter material
    c. Construction is relatively inexpensive
2. Cons of individual and boulder clusters:
    a. The feature does not provide channel stability or extensive changes to habitat

Instream boulders with visible pockets of slower moving water

BOULDER STRUCTURES

Description: Boulder structures consist of several boulders typically constructed with filter material and generally provide a structural component. Examples of boulder structures include j-hook weirs, drop structures, grade control structures, and stone toe embankment. Most of the boulder structures are design to provide stability to a portion of the channel while also provide the secondary benefits such as decreased velocities, increased aeration and shade.

The different structures are used for different needs. The j-hook, shown in the picture below, is used to deflect flow from the channel bank while directing it into a pool at the center of the “J”. This protects the bank from erosive forces while provide slower water in the pool. When spaced properly, this structure can also aid in fish passage.

Boulder drop structures and grade control structures perform similarly in that the main goal is to hold the channel bottom in place, i.e. to reduce bed degradation either due to head cutting, scour or general degradation.

Applicability: Boulder structures can be used to stabilize channel banks and provide habitat diversity. These are best suited for streams and rivers that have a bed of cobble to gravel sized material and are not suitable in highly erodible, alluvial sand channels. Boulder structures could also be used to improve headgate diversions.

Pros and Cons:

1. Pros of the boulder structures:
    a. provide stability and prevent erosion / down cutting
    b. provide a disturbance to flow patterns, introducing aeration and locally decreasing velocities
2. Cons of boulders structures:
    a. placement typically requires access to and in the river which will disturb the creek bed.

J-weirs in series along right bank during channel reconstruction

Boulder cross vane for bank protection and grade control.