



Prepared by  
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This analysis considers the potential risk on National Forest System Lands, fish and wildlife resources, downstream private property, infrastructure and public safety with implementation of the three alternatives (including no action) considered in the Greenwater Floodplain Restoration Project environmental analysis. The action alternatives 2 and 3 were combined for this discussion, because the difference between the two alternatives does not significantly affect the risks associated with the proposed actions. The risk assessment applies to utilization of two types of Engineered Log Jams (Type 1 and 2) as proposed in the locations noted in the Greenwater River Floodplain Restoration Project Environmental Analysis.

### **Flooding**

- *No Action Alternative 1*. The Greenwater River, under current conditions, is highly flood-prone, as much of the River is still recovering from historic channel and floodplain forest/wood clearing, channel straightening, and confinement by Forest Road 70 that increased flood conveyance and reduced flood elevations (thus reducing floodplain connectivity). This historic disconnection of the river from its floodplain and increased conveyance increases downstream flood peaks (Entrix 2007). Natural wood recruitment is beginning to occur again and will gradually raise water elevations within the project reach and improve floodplain connectivity, but the process will take time and risk of flooding will continue until the riparian forest matures.
- *Proposed Action Alternative 2 & 3*. The project would intentionally restore floodplain connectivity within the project site (NFSL) through removal of the abandoned Forest Road from the floodplain and placement of engineered log jams that will deflect flows and increase flood elevations in the specified reach between river miles 5.3 and 7.8. By increasing flooding within the project site, downstream flood peaks will be dampened (reduced). The project site will also more effectively trap sediment and natural wood debris moving through the system. Energy losses induced by the project will reduce the risks associated with flood peaks and sediment and wood delivery to downstream properties. The engineered log jams have been strategically placed based within the project reach to deflect flows into existing side channels and maximize floodplain connectivity with as few structures as possible.

Pre-and post project hydraulic modeling of the reach shows an immediate reduction in peak flows immediately downstream by 80cfs as a result of the project. Project activities will increase floodplain storage by 23% (19.4 acre-ft) within the project reach (Herrera 2010). Based on model results, no perceptible changes in river discharge or flooding extends past the Forest Road 7010 bridge.

## **Erosion and Channel Migration**

- *No Action Alternative 1.* Due to historic impacts that reduced the river's sinuosity and concentrated flows into a single channel, the Greenwater has been physically simplified. This concentration of energy within a single channel also has resulted in a more dynamic channel, particularly given historic deforestation of the floodplain which reduced frictional resistance and root cohesion. The Greenwater River is currently experiencing erosion and channel migration within the project reach and downstream of the project. The abandoned Forest Road 70, within the project reach, is currently eroding due to its location in the floodplain and is loading sediment into the River. Under the no action alternative the river will continue to erode the stream banks and carve new channels until the forest matures and large trees stabilize the floodplain and disperse flows into branching channels. Under the no action alternative the river will continue to erode the stream banks and carve new channels until the forest matures and large trees stabilize the floodplain and disperse flows. This trend is observable throughout the Greenwater River, all the way to the confluence with the White River.
- *Proposed Action Alternative 2 &3.* The proposed action would encourage activation of relic side channels within the project reach on Forest Service property. There would be a short term increase in erosion and channel migration within the project reach as connection of the current river channel to the floodplain is restored, the impact of which would be localized on NFSL. In the long term, after a few high flow events, the proposed structures would provide bank stability and roughness to split flow and partition shear stress across the floodplain which would decrease erosion. The structures would trap sediment and aggrade the river bed, while creating and sustaining pools. Since the project would trap bed-load sediment, it will reduce sediment delivery downstream which together with reduced peak flows will tend to reduce channel instability downstream,

## **Structure Stability (Factor of Safety Analysis)**

- *No Action Alternative 1.* Currently an abundance of small, mobile wood is present in the Greenwater River, with very little stable structure to trap and accumulate wood moving naturally through the system.
- *Proposed Action Alternative 2 &3.* The project proposes to install stable, engineered log jams into the river. The ELJ structures would be designed and built to particular design criteria that ensure relative stability of the structures with respect to the forces of the Greenwater River. The ELJ structures would be constructed using timber piles. The piles would be logs with large rootwads installed by excavating open pits, placing the rootwad (pile tip) at the specified elevation within the pit, and orienting the pile vertically as backfill is placed around the piles and compacted. The piles would be engineered to resist the lateral and uplift loads created by hydrodynamic drag forces applied to the structures during the 100-year design flow. Flow velocities and depths

associated with the 100-year design flow would be used to evaluate the stability of the piles. Piles would also be embedded deep enough into the channel alluvium to concurrently avoid overturning when loaded while accommodating anticipated scour depths of approximately 15 feet along the face of the ELJ. Piles would be designed to achieve a minimum recommended factor of safety value of 1.4 using load and resistance factor design standards.

To minimize pile embedment depth, the ELJs would incorporate scour countermeasures to limit the vertical extent of scour around the waterward face of the ELJ. A scour apron would be constructed along the face of each ELJ using material that is more coarse (larger) than the existing channel bed material within the vicinity of each ELJ to resist mobility during the design flow event.

Buoyancy calculations would be performed to determine the minimum required ballast depth and configuration of backfill material needed to overcome the buoyant forces of the submerged woody debris used in the ELJs. Log ballast depths would be determined to obtain a minimum factor of safety of 2.0 against buoyancy assuming dry wood is used to construct the ELJ, which is representative of the immediate post construction conditions. Log ballast material for all ELJs would consist of channel alluvium excavated to construct the ELJs and material that is more coarse (larger) than the existing channel bed material within the vicinity of each ELJ to resist mobilization.

### **Downstream Private Property and Infrastructure.**

- *No Action Alternative 1.* Currently, private properties on the lower Greenwater River are experiencing erosion due to unstable stream banks and overall instability of the Greenwater River system. This trend will likely continue until some action is taken or until the Greenwater floodplain forest matures and stabilizes the system.

Two bridges exist downstream of the project action area, the FR7010 Bridge the SR 410 Bridge. The FR7010 Bridge is a full span bridge and currently has a low with respect to debris accumulation. The SR 410 Bridge is a center column bridge and currently poses a moderate to high maintenance risk due to consistent racking of wood on the center column. Given the amount of mobile wood currently in the system, the no action plan poses a relatively high risk relative to Alternatives 2 and 3, since both alternatives will decrease downstream supply of wood by trapping it within the project reach.

- *Proposed Action Alternative 2 & 3.* Hydraulic modeling of the current and proposed flow regime of the river as a result of the proposed project activities indicates a reduction in flow velocity through the project reach and a reduction in peak flows downstream of the project reach. Given the predicted reduction in peak flows on the Greenwater River and the realized benefit of wood accumulation on the ELJs, the proposed activities will reduce the risk of erosion to downstream properties in the town of Greenwater. Increased flow to relic side channels will result in some channel

expansion and wood recruitment. Any wood recruitment will be trapped within the project reach or on the large natural logjam downstream of the project reach and not impact Greenwater.

### **Public Safety and Recreational Boating**

- *No Action Alternative 1.* Under the no action alternative, recreational boating opportunities are limited and high risk due to the amount of wood currently in the river. Based upon the information presented on the American Whitewater Website (<http://www.americanwhitewater.org/content/River/detail/id/2125/#zzqjbi8oi57fnh8Ri verMainGadget18>), the project reach is rated as a difficult class IV stretch with a note that there “may be lots of logs” in the river.
- *Proposed Action Alternative 2 &3.* Recreational boating and public safety was taken into consideration in design of the proposed project. Project proponents conducted research to better understand the boating community that might be using this river. Local kayak and rafting outfitters were interviewed and confirmed no commercial use of the Greenwater River and could not confirm any independent use of the river either. The American Whitewater website lists the raft-able river flows to range between 500cfs and 800cfs. A search for postings, comments on the major rafting forums and blogspots regarding use of the Greenwater River for rafting or kayaking yielded zero results. Based upon the information collected, we conclude that the rafting use of the Greenwater River is either non-existent or limited to a small, highly experienced user group, adept at navigating wood in the river.

Nevertheless, placement of the log jams was designed to leave a portion of the channel free and clear for recreational boating so as not to preclude, safe use of the river for rafters and boaters. Initial designs of some of the proposed ELJ structures were intended to emulate natural wood accumulations of the Greenwater which are permeable channel spanning structures. The initial project design was modified to replace large permeable ELJs with the less permeable and smaller ELJs, ensuring more effective flow deflection around the structures instead of through them. The structures will still have a great deal of complex aquatic cover to preserve the ecologic goals of the project.

### **Floodplain Processes and Salmon Spawning and Rearing Habitat**

- *No Action Alternative 1.* Currently, spawning and rearing habitat for adult and juvenile salmonids is limited in the project reach. Prior to the 1950s, the watershed was characterized by a sinuous, branching floodplain flowing through a densely forested floodplain dominated by large coniferous trees (Entrix 2007). Historically, the Greenwater River was one of the principle spawning and rearing areas in the White River watershed for spring Chinook, bull trout, steelhead and coho (Laurie 2002). Based upon the old-growth forest in the Greenwater River Valley floor, evident in the 1944 aerial photographs, recruitment of large trees to the river bed was likely the

primary habitat forming factor influencing channel morphology in the basin (Entrix 2007).

A survey from 1956 shows the River to be in pristine condition, characterized by sinuous pool/riffle morphology, with high pool frequency and numerous, large, deep pools associated with natural woody debris and log jams (Laurie 2002). Pool habitat is critical for rearing salmonids, bull trout and other resident fishes to provide cool places for forage and refuge from predators.

A legacy of clearcut logging degraded the Greenwater River and between the 1950s and 1980s. During this period, the majority of the Greenwater River and its tributaries were logged to their banks; only isolated patches of mature timber were spared outside the wilderness area. Loggers used the Greenwater stream channels to skid and/or float logs downstream, disturbing natural riverine processes. Post logging, very few mature riparian trees were left in the watershed and wood recruitment was diminished to an insignificant level.

These practices effectively stripped the Greenwater River and its banks clean of any wood, left the channel without significant habitat structure and increased channel incision, stream velocities, and bed scour. The current channel is an incised plane-bed, with very few pools, little holding and rearing habitat available to salmonids and almost no functional riparian cover to provide shade, structure, input of nutrients and recruitment of woody debris. Given the current lack of large woody debris, riparian condition and large volumes of sediment available in the system, it could take centuries for the system to return to a quasi-equilibrium sustained by natural processes and channel complexity (Entrix 2007). As such, the no action approach continues to put the spawning and rearing populations of Greenwater River salmonids at risk, namely ESA Listed, White River Spring Chinook, Puget Sound Steelhead and Bull Trout.

- *Proposed Action Alternative 2 & 3.* The proposed project efforts will restore natural stream morphology, improve functional habitat and capacity to support spawning and rearing populations of salmonids and resident fish. The proposed log jam structures will accelerate and maintain system-wide natural processes while reducing sediment loading, stabilizing banks for establishment of a riparian corridor, and providing habitat for fish. The species benefiting from this project include: White River Spring Chinook, Puget Sound steelhead, pink salmon, coho salmon, bull trout and coastal and resident cutthroat trout. The Greenwater serves as one of the principal spawning areas for White River Spring Chinook. Juveniles of all salmonid species use the mainstem Greenwater River and its tributaries for rearing. Increase the stream and floodplain connectivity

The proposed project activities will not only reduce risk to habitat and the aquatic resources dependent on the habitat, but will greatly improve the habitat in the Greenwater River, thereby improving overall health and survival of aquatic resources by achieving the following goals and objectives:

1. Increase off-channel habitat to provide flood refugia and rearing areas for juvenile fish.
2. Create large, stable structures that will trap mobile debris and sediment and capture and sort suitable spawning gravels for adult salmon.
3. Decrease median substrate size of streambed material.
4. Reduce erosion and sedimentation sources within the project reach through natural bank stabilization and decreased flow velocity.
5. Increase numbers of backwater pools and primary pools for rearing juvenile salmon and staging adult salmon.
6. Restore the riparian forest for input of aquatic nutrients, input of additional woody structure, and to reduce water temperatures.

## **References**

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