MULTI-DISCIPLINED APPROACH ON THE UPPER QUINAULT RIVER GEOMORPHIC STUDY, 18 KM REACH UPSTREAM OF LAKE QUINAULT

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Abstract: A team of scientists with backgrounds in fluvial engineering, geology, geomorphology, woody debris, and biology worked together to evaluate whether human disturbances along 18 km of the Upper Quinault River had adversely impacted river processes and sockeye salmon habitat. At the start of the study, many believed the Upper Quinault River was pristine because the north side of the river is managed by Olympic National Park (ONP) and there are no major dams or levees along the river. Our study found that near valley-wide logging and removal of large woody debris from the river channel area in the early 1900s (by 1939) did alter river processes. This occurred prior to the establishment of ONP. Since 1939, the mature vegetated islands and large woody debris have not yet been restored to the system in enough quantity to recreate the reference conditions in the late 1800s. The lack of mature terrace forest has resulted in rapid rates of terrace bank erosion and limited large woody debris in the channel of large enough size to slow channel migration, form large pools, and serve to generate floodplain surfaces that can form into vegetated islands. LiDAR data and comparison of historical information to the present river setting were two key data sets that allowed the study findings to be determined. Working with a multi-disciplined team facilitated an integrated study that allowed a geomorphic analysis to be successfully applied to biological management issues. A reach-based restoration strategy has been proposed to protect remaining sockeye habitat and begin to recover lost habitat in the system. This strategy was designed to work with river processes and existing land use to make projects more feasible and sustainable.

INTRODUCTION

Biologists have documented a decline in the number of sockeye salmon in the Upper Quinault River on the Olympic Peninsula in northwest Washington State (Figures 1 and 2) (QIN, 2002). In an effort to better understand what opportunities exist to restore sockeye salmon habitat, the Bureau of Reclamation was asked to undertake a geomorphic evaluation of the river (Bountry et al., 2005). The primary goal of restoring fish habitat in the Upper Quinault River is to increase the quantity and quality of sockeye spawning habitat; i.e., increase the capacity of the habitats to hold more spawning sockeye and produce greater numbers of emergent juveniles for recruitment into Lake Quinault. Funding for the study was provided by Reclamation and a Salmon Recovery Fund Grant that was part of a cooperative agreement with the Quinault Indian Nation, Reclamation, and the Salmon Recovery Fund Board.

Figure 1 Location of the Upper Quinault River.

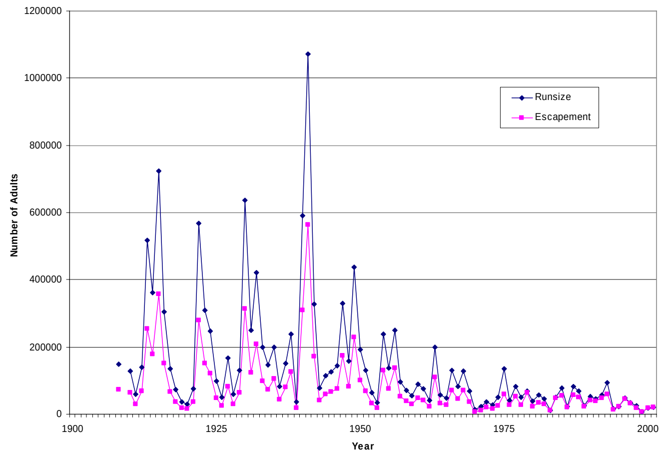

Figure 2 Annual sockeye data for last hundred years from Quinault Department of Fisheries.

STUDY QUESTIONS

Questions addressed in the geomorphic study about the Upper Quinault River are:

1. What were the natural river processes on the Upper Quinault River before settlement in the valley in the late 1800s and early 1900s?
2. Is the existing system different from that which existed prior to human settlement?
3. If differences exist, has the magnitude and frequency of change steadily increased with time, or has it varied in a more complex fashion?
4. What natural or human activities have taken place in the watershed and valley, and to what extent has each of these altered the system?
5. What might the river and its adjacent floodplain look like during the next 50 to 100 years?
6. If river conditions today differ from pre-settlement conditions and if today's land-use practices remain the same in the valley for some time into the future, what is the potential that the river will recover on its own? How long might recovery take?
7. On the basis of information gathered in this study, what restoration strategies for improving fish habitat are feasible, and which locations in the Upper Quinault would they most greatly increase habitat?

METHODS

A multi-disciplinary team with backgrounds in geology, geomorphology, fluvial engineering, and biology worked together on the project to address the stud y questions. Data collection and analysis techniques utilized by the team are summarized as follows:

- Bathymetric survey data combined with light distance and ranging (LiDAR) data to develop digital elevation map and to delineate channels in vegetated areas
- 1D hydraulic model to estimate the hydraulic properties of the river channel
- Timeline of the geologic history using radiocarbon dating and LiDAR data to evaluate potential age of surfaces binding river and erodibility, and identify any controls that naturally limit river migration or downcutting
- Woody debris analysis (Herrera Environmental Consultants) to assess the size and density of wood accumulation necessary to form stable hard points that would help limit channel migration.
- Time-lapse photography during a winter flood season to qualitatively characterize transport and deposition patterns of woody debris and their relation to growth or removal of gravel bars.

- Mapping of dominant vegetation species and general age class to see if terrace forests were of sufficient age and native species type needed to help resist bank erosion at presumed natural levels present prior to disturbance
- Sediment transport analyses included using a sediment budget, stream power (energy) computations, observations of sediment sizes present in the river bed, channel planform and active channel width between 1939 and 2002, and a longitudinal profile comparison between 1929 and the present (2002) measured channel slope.
- Mapping of channel position, width, and sediment bars in decadal spaced historical aerial photography between 1939 and 2002 and historical maps dating back to 1897 to look for trends over time.
- Flood peak analysis to look at possibility of trends over period of record of USGS gaging data
- Stability analysis of side and terrace channels utilized by sockeye to look for any response to human disturbances in basin

RIVER PROCESS FINDINGS

At the start of the study, some researchers felt human disturbances could have altered habitat conditions but others felt the Upper Quinault was in pristine condition because the north side of the river was mainly managed by the National Park Service. Based on journal accounts and historical geologic mapping, it is proposed that the Quinault River functioned as a natural, undisturbed river system through most of the 1800s. The river has changed markedly since the late 1800s. We propose the river was in a state of transition to a new “altered” condition in the early 1900s in response to the removal of large woody debris and increased sediment load from vegetated islands and terraces that were eroded. River process changes during the early part of the twentieth century in response to human-caused disturbance along the study reach were based on historical journal accounts, anecdotal accounts, reports, and maps up to 1939:

1. Homesteading and logging activities cleared forested islands and large woody debris in the active floodplain, which in turn led to rapid erosion of the islands and an increased sediment supply.
2. Once the sediment stored in the islands was available to the river, deep pools and channel areas quickly filled in to accommodate the increased sediment supply.
3. Even with pool storage utilized, the river could still not accommodate the increased sediment supply and the active channel widened and aggraded, causing the river to evolve to a more braided planform.
4. The largest flood of record occurred between 1900 and 1939, which would have resulted in substantial reworking of the channel area.
5. The braided channel was overly wide and unstable, so the low-flow channels rapidly migrated across the new braid plain. Large, wide gravel bars were frequently reworked by floods.
6. As the channel widened and shifted across the floodplain more rapidly, it put more pressure on adjacent terrace banks that historically bound the channel migration zone. Concurrent removal of mature vegetation on these terrace banks made them more vulnerable to erosion and less stable, leading to significant loss of property and infrastructure.
7. As the sediment supply from the eroding islands began to reduce, the width of the active channel would have tended to narrow within the wider floodplain, but this tendency was at least partially offset by the increase in terrace bank erosion.
8. On the 1929 map, the channel appears to be relatively confined and has only one or two flow paths. This configuration is as would be expected given the accounts of late-1800s expeditions. On the other hand, the 1929 map illustrates few of the vegetated islands that are described in expedition accounts of 40 to 50 years earlier. There do appear to be several side channels, although these are not detailed in the mapping to a great extent.
9. By 1939 (first aerial photograph available), the active channel was wide, braided, and flanked by very little mature riparian vegetation or side channels within the active area of the floodplain.
10. Because there was very little mature vegetation in the floodplain, it is assumed the channel migrated across the floodplain at a rapid rate, hence the reason for very few vegetated side channels in 1939.

A quote from a 1936 fisheries survey describes the changes thought to have occurred in the early part of the Twentieth Century:

> The early settlers and inhabitants of this region describe the Upper Quinault River as a large stream that flowed between two rather narrow heavily wooded banks. This condition, however, does not prevail at the present time for the logging off of the watersheds of the river has caused excessive washing to the extent that there is no definite river bed but a wide river valley through which the stream frequently changes its course with the winter and spring freshets. At the present time the devastated area caused by shifting of the channels varies in width from one-quarter to one-half mile and is noticeable the entire distance of twelve miles to the main forks. (Davidson and Barnaby, 1936)

Since 1939, our analysis indicates the river has remained relatively consistent in this altered channel state and has not recovered back to a natural state. The mature vegetated islands and large woody debris have not yet been restored to the system in enough quantity to recreate the reference conditions (Figure 3). The lack of mature terrace forest has resulted in rapid expansion of the historic channel migration zone (HCMZ). The HCMZ is defined as the area containing the active channel and floodplain most frequently reworked over at least about the last 100 years. Additionally, the channel continues to rework the area within the HCMZ with limited large woody debris of large enough size to slow channel migration, form large pools, and serve to generate floodplain surfaces that can form into vegetated islands (Figure 4). Large flood peaks have not changed in magnitude, but the 2-year flood has increased in magnitude in recent decades. Sediment loads to the river are believed to be accelerated to the rapid erosion rates of the terrace surfaces binding the HCMZ. However, increased HCMZ area has also increased the storage area for sediment. Although localized areas experience fluctuations in the channel bed elevation as the river erodes and fills the floodplain as a result of lateral shifting and migration, no long-term aggradation of more than a few feet is predicted to have occurred over the last century. In contrast to the changes in floodplain forest and channel response, no significant, measurable changes have occurred in mass wasting in the upper watershed above the confluence of the two forks of the Quinault River, or in geologic processes (such as uplift or the influence of Lake Quinault) during the twentieth century. A summary of the changes are presented in Table 1.

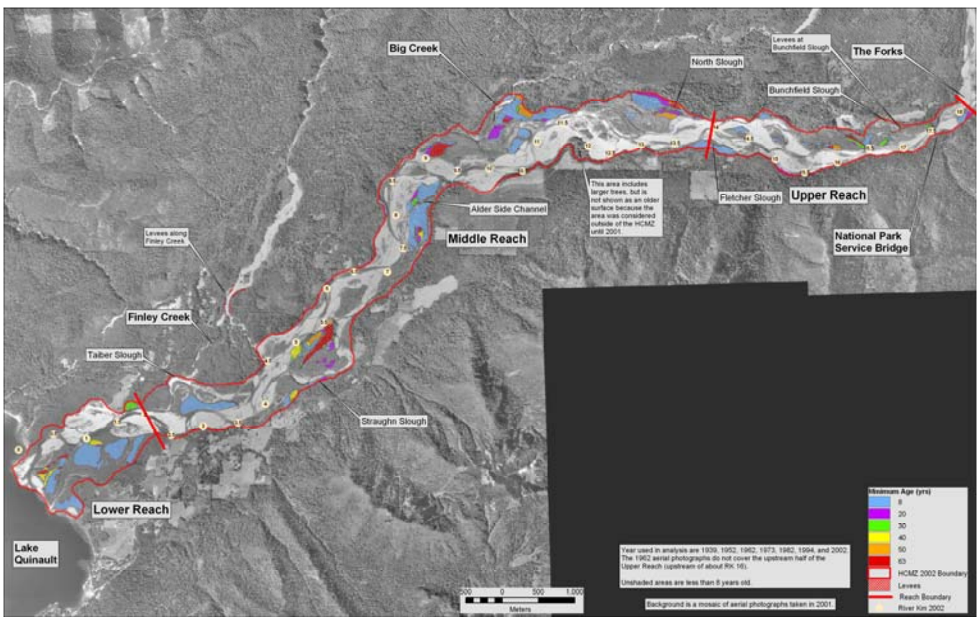

Figure 3 Minimum age of areas containing trees within the 2002 HCMZ. Note the area at RK 12 does have mature trees of significant age but did not get captured in the raster age analysis because it was considered terrace until the main channel recently punched through one of the terrace channels.

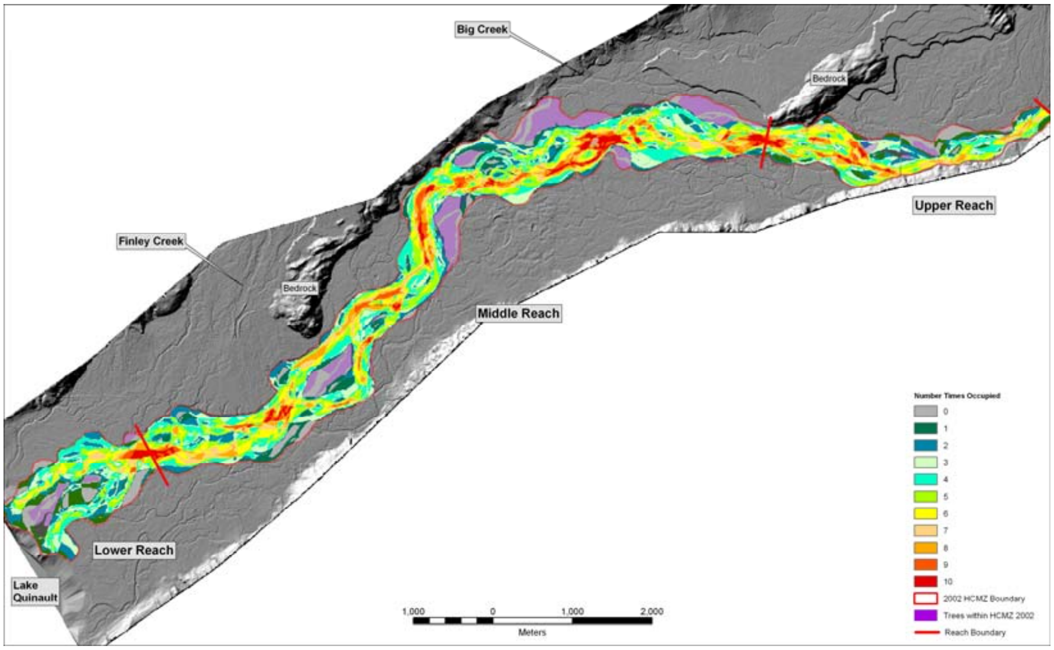

Figure 4 The number of times the active, unvegetated channel of the Quinault River has been located at a particular location as observed on aerial photography spaced about a decade apart. Red and orange areas within the HCMZ are areas where the unvegetated channel has been the most. Gray areas within the HCMZ area are where the unvegetated channel has not been in at least 64 years.

SOCKEYE RESPONSE TO CHANGES IN RIVER PROCESSES

Monitoring data show the Quinault sockeye produced cyclic, but substantial runs in the first fifty years of the twentieth century, but beginning in the 1950s experienced a decline that has not yet recovered. It is not known why the overall sockeye population numbers continued to be high into the 1950s when the most significant response of the main river to disturbance is thought to have peaked in the 1920s to 1930s and remained relatively consistent since that time. It is possible that remaining tributary channels and protected terrace channels provided sufficient premium habitat to sustain the sockeye population at high levels until cumulative effects of river disturbance degraded the overall habitat productivity.

In addition to cumulative effects of river channel instability and migration, the decline of sockeye population size after 1950 could have been influenced by increasing frequencies of channel reworking flood events. The more frequent and slightly larger flood flows occurring on a disturbed, unstable floodplain could have eliminated any remaining premium habitats for sockeye, and would have further degraded the over all habitat productivity in the system.

Increased channel migration, channel bank and terrace erosion, and the consequent reduction of the number of spawning salmon in the Upper River would also cause a decline in water quality and trophic productivity within the rearing environment of Lake Quinault. This is a critical phase for over all productivity of the system, and poor conditions in the Lake would act as a bottleneck that would limit production. Deteriorating conditions in Lake Quinault likely occurred simultaneously with changes occurring in the Upper River to affect and limit the capacity of the system to produce sockeye salmon.

The river can no longer sustain the same quantity of quality sockeye habitat for decades to centuries as it did in the reference conditions. Tributary channels that are less susceptible to river processes presently provide the most stable habitat in the present system. Terrace channels that were historically stable for several decades to centuries are now at a higher risk to erosion by the river. The presently wide, shallow river with a general lack of large, stable woody debris does not provide adequate holding pools that can remain wetted during low flow periods. These pools are essential for sockeye survival to help them survive between hatching and migration down to Lake Quinault. The few areas that are available are at high risk for being washed out by the river during subsequent high flows.

Table 1. Summary of comparison of the characteristics of the reference conditions and present conditions on the Quinault River.

	Characteristics of Quinault River	
Property	**Reference Conditions**[1]	**Present Conditions**
Main Channel	One or two dominant low-flow channels; in places, the channel is confined by vegetated surfaces	Multiple low-flow channels; unvegetated bars common adjacent to the channel
Unvegetated Channel	Relatively confined by mature, dense vegetation on either side	Relatively wide and not bound by mature vegetation in most areas
Vegetated Surfaces	Range in age from pioneer bars to mature terraces	Range in age, but limited mainly to pioneer bars and developing floodplain; only a few transitional terraces; mature terraces are virtually absent
Woody Debris	Numerous large logs available to be recruited as key members, which in some cases initiate the formation of large jams	Few large logs available, so the river system lacks large jams because potential key members are absent
Side Channels Within HCMZ	Variable location within the river system; stability ranges from only a few years to tens of years; mature vegetation along boundaries limits the rate at which the main channel erodes into the side channel; large woody debris at entrances can help limit the rate at which the main channel shifts into the side channel	The wider HCMZ allows for more side channels to persist but generally with less stability than reference conditions due to more rapid shifting of main channel and less large woody debris; a few side channels appear to have lower risk than reference conditions due to wider HCMZ with more places for main channel to occupy
Terrace Side Channels	Stable for several centuries; very slow erosion and reworking rates of these areas	Large portion of the network of terrace channels has been lost and not replaced because of expansion the HCMZ; remaining terrace channels are at risk for erosion due to cleared banks; many terrace channels modified at entrances and at road crossings
Habitat Quality and Quantity	Diverse network of interconnected side and terrace channels that provided a wide range of habitat sustained from only a few years to centuries	Remaining habitat areas generally have less complexity and higher risk of being lost over a faster timeframe than in reference setting

[1]Reference conditions have been inferred from historical accounts and photographs and from the present characteristics of the Queets River

LAND MANAGEMENT CONSIDERATIONS

Landowners whose property and infrastructure directly abut the active channel have also suffered from a change in river processes because they run a greater risk of bank erosion and loss of land than previously. Surfaces on the south shore near Lake Quinault may contain old lake bed deposits (clay) that have more ability to resist erosion than upstream, more erodible, alluvial terrace surfaces (Figure 5). Over the last century river-front landowners have responded to loss of property and endangered infrastructure by re-arranging or removing large woody debris and log jams in the river and placing cabled logs and rock riprap along the river bank to try to limit erosion. This approach has worked in places, but can also cause unanticipated effects to other land across or downstream from the site protected.

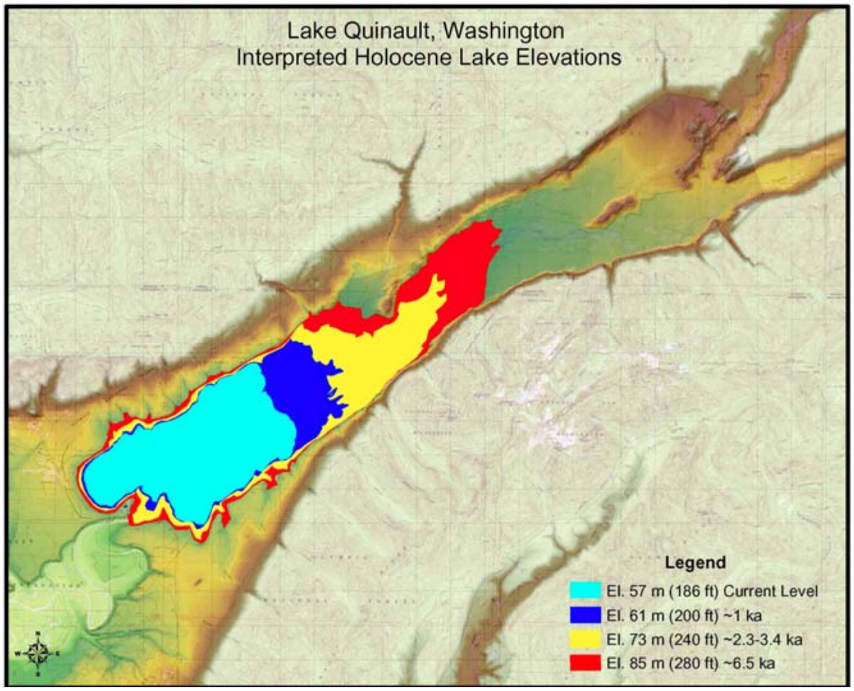

Figure 5 Interpretation of Quinault Lake's rate of regression based on radiocarbon ages and the elevation of where the sample was obtained.

RESTORATION STRATEGY

We propose both short-term and long-term restoration strategies to improve the ability of the river to sustain habitat features vital to sockeye salmon and to protect adjacent property. Short-term strategies would protect the most vulnerable terrace banks and sockeye side channel and terrace habitat areas. Long-term strategies would restore the mature forest on both terrace banks and patches within the active floodplain to provide an adequate recruitment source of large woody debris. This would re-establish the ability of the river to build stable hard points and terrace surfaces that have been lost over the last century. A reach-based restoration approach is recommended that will lead towards a more self-sustaining system, but also consider upstream and downstream implications of any actions. The long-term restoration strategy includes:

1. Restore floodplain conifer reproduction to slow rates of bank erosion and channel migration to match the interpretation of reference conditions from the late 1800s.
2. Restore stable wood jam-generated forested islands.
3. Restore mature (late-successional stage) floodplain forests.
4. Restore the sources of large woody debris (mature floodplain forests).
5. Restore stable wood jam and floodplain forest to create a deeper, narrower channel with more morphological complexity than the wide, shallow channel that exists today.
6. Modify existing infrastructure (roads, bridges, levees) that cut off historical channel paths and floodplains to allow natural flow paths to occur.

Within the vicinity of each side channel and terrace channel complex, specific short-term restoration actions include:

1. Engineered log jams at channel entrances to slow rate of being overtaken by the main channel (some rate of reworking is necessary over several decades)
2. Protection (engineered log jams and/or rock) of young vegetated bars within the active floodplain that have a chance at developing into mature forest (stable hard points)
3. Replanting (long-term) and protection (short-term) of cleared terrace surfaces most at risk to erosion, mainly on the south side of the active floodplain
4. Further evaluation of any infrastructure that could be modified to enhance sockeye habitat areas and manage flooding issues

REFERENCES

Bountry, J. A., Piety, L. A., Randle, T., Lyon, Jr., E.W., Abbe, T., Barton, C., Ward, G., Fetherston, K., Armstrong, B., Gilbertson, L. (2005). Geomorphic Investigation of Quinault River, 18 km Reach of Quinault River Upstream of Quinault Lake, unpublished, developed by Bureau of Reclamation, Herrera Environmental Consultants, and Quinault Indian Nation Fisheries Department.