Technical Memorandum

To: **Skagit Watershed Council**
Richard Brocksmith, Executive Director

From: **Natural Systems Design, Inc**.
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Date: July 29, 2022

Subject: Large Wood Dynamics Analysis for the Sauk River Habitat Plan

INTRODUCTION

Natural Systems Design (NSD) was contracted by the Skagit Watershed Council (SWC) to complete an analysis of large wood dynamics for the Sauk River (Sauk) between Darrington (river mile [RM] 21) and the Suiattle River (RM 13, reach SA050) in support of the Council's ongoing work for the Sauk River Habitat Restoration and Protection Plan (Plan). Assessment work completed by NSD in 2022 for the Plan indicates the Sauk's active channel corridor has widened in this reach, with a transition to a less stable channel over the available photo record (1944-2015). The reach has the second widest average floodplain width (3,280 ft) and second highest floodplain area: channel length ratio (361) of the reaches in the assessment area (RM 0 -24). This reach also has the highest ratio of off-channel area: channel length (134) in the assessment area, with numerous sloughs, side channels, and floodplain features, providing some of the highest juvenile Chinook rearing capacity in the entire lower 24 miles of the Sauk (NSD, 2022).

Review of lidar-derived canopy height data for the study reach between Darrington and the Suiattle shows few patches of intact old growth forest with tree heights over 200 ft in the Sauk's valley bottom, and much of the floodplain shows evidence of historic logging or land clearing for agriculture or grazing activities, with few or no trees in portions of the Sauk's historic floodplain. The recruitment of large floodplain trees that become large woody material (LWM) in river channels is an important element of channel forming processes and habitat development (Abbe & Montgomery, 2003; Montgomery & Abbe, 2006). Logjams and large, individual pieces of stable LWM can raise water surface elevations (WSE) or deflect flows to engage side channels, form stable hardpoints that become forested islands, encourage the development of scour pools, promote hydraulic complexity and gravel sorting, and create low velocity areas and cover for fish. Stable LWM also partitions shear stresses in the active channel corridor, which can reduce bed and bank erosion. The loss of large floodplain trees and stable LWM in the Sauk has likely contributed to the observed channel instability and widening in the study reach over the past half century.

Understanding how historic changes in LWM in the Sauk have contributed to channel widening is needed to guide SWC in planning restoration actions to improve habitat stability. This memo documents NSD's analysis of large wood dynamics in the study reach of the Sauk.

DATA AND METHODS

NSD's assessment of LWM dynamics for the study reach was based on desktop analyses utilizing the spatial data summarized in Table 1 below.

Table 1. Spatial data sources used in large wood analysis .

DATASET	SOURCE
1981 Aerial Imagery	Mosaic of georeferenced imagery provided by SRSC
1992 Aerial Imagery	Mosaic of georeferenced imagery provided by SRSC
1998 Aerial Imagery	Mosaic of georeferenced imagery provided by SRSC
2004 Aerial Imagery	Mosaic of georeferenced imagery provided by SRSC
2006 Aerial Imagery	USDA National Agriculture Imagery Program
2013 Aerial Imagery	USDA National Agriculture Imagery Program
2015 Aerial Imagery	USDA National Agriculture Imagery Program
2019 Aerial Imagery	USDA National Agriculture Imagery Program
2005 Logjam Points	Snohomish County Public Works, 2007
2013 Logjam Polygons	Beechie et al., 2017

Existing data from the NOAA's monitoring of salmon habitat in Puget Sound (Beechie et al. 2017) characterized salmonid habitat status and trends throughout large rivers draining to the Puget Sound. For that study wood jams visible within the active channel were digitized, including wood that was visible in water, on gravel bars, and in young vegetation on islands or the floodplain. Logjams in the Beechie et al. study were manually digitized from a 1-m resolution 2013 USDA NAIP aerial image, and only logjams greater than 50 m^2 in area were in included, for repeatability and based on features clearly present in the imagery.

Snohomish County Public Works (SCPW) surveyed large wood and logjams in the study reach in 2005, and recorded logjam length, width, and height (SCPW, 2007). The SCPW data were filtered for the reach from Darrington to the Suiattle River confluence and logjam areas were determined based on the product of the length and width measurements provided.

NSD followed a similar approach to Beechie et al., but based on 1981 aerial imagery that had been georeferenced and mosaiced by Skagit River System Cooperative (Ramsden and Smith, 2008).Logjams were digitized within the active channel corridor, including on gravel bars, side channels, and in young vegetation. The total channel area used for this study was the 1981 active channel corridor which covered 6,100 km^2 and 8 miles of river length (RM 13 to 21). Logjams were digitized based on a minimum area of 200 m^2 due to lower resolution imagery when compared with the 2013 dataset used by Beechie et al. The SCPW and Beechie et al. datasets were filtered to include only logjams greater than 200 m^2 to compare with the 1981 dataset digitized for this study.

Each logjam identified and digitized for 1981 was assigned a function: bank, bar top, or apex based on its context within the active channel corridor and indicators of hydraulic effect (e.g. flow splits for apex jams) in the 1981 image (Figure 1). Wood deposited on bar tops as flows recede has a lower likelihood of remaining engaged with the channel at lower flows, but a higher likelihood of forming forested bars or revegetating versus logjams formed from trees recruited from an eroding bank or deposited along an active channel margin, which have more engagement with the low flow channel. Each jam was also attributed based on whether it was engaged with the low flow channel in the image.

For each logjam digitized in 1981, subsequent photo records were reviewed to determine logjam presence or absence from 1981 – 2019. For logjams detected in subsequent photo records, the same functional attribute was assigned (bar, apex, bank), with the addition of a 'forest' category for logjams that had begun to develop forested bars or islands. Logjams in these locations were assumed to be present in subsequent years but flagged with a presence 'unknown' attribute. Logjams were again also attributed based on engagement with the low flow channel in each subsequent photo record.

Photo records were again reviewed at locations with logjams that persisted between the 1981 and 1992 photo records or became forested to determine if the channel re-occupied locations where logjams formed forested bars or islands at any point between 1992 and 2019 (Figure 2). The year of channel re-occupancy was noted to determine an estimated length of logjam presence in those locations, with year 0 assumed to be 1981.

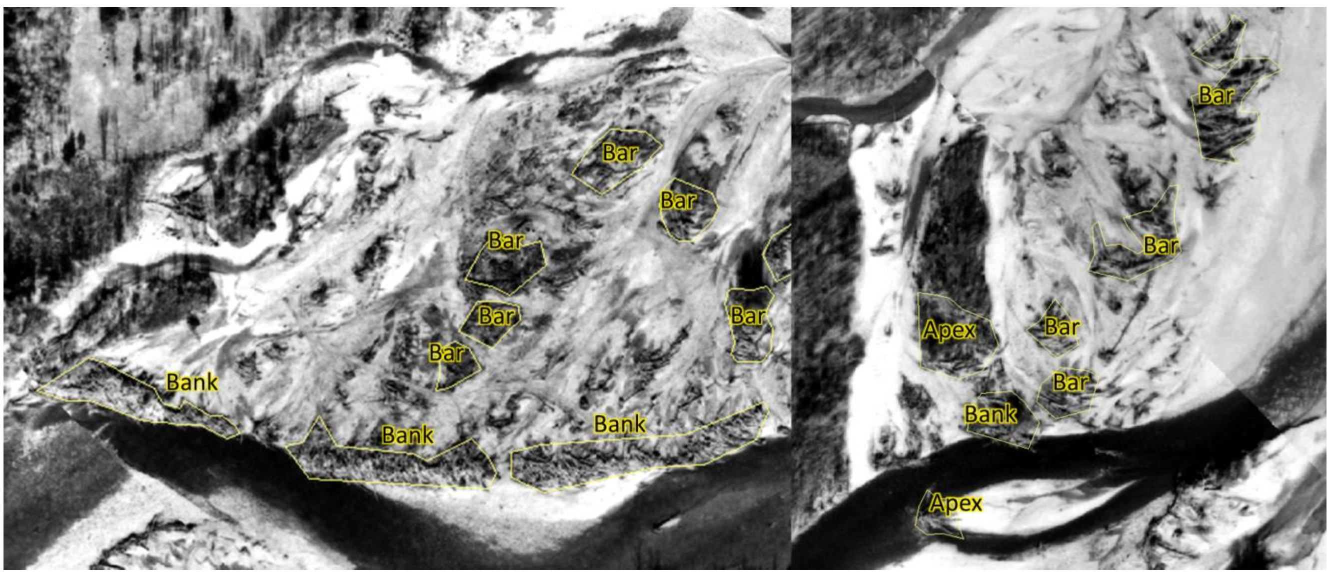

Figure 1. Example of function attributes for logjams visible in 1981 aerial imagery.

RESULTS

A total of 147 logjams greater than 200 m^2 in area were digitized from the 1981 aerial imagery. Of these, the majority (69%) were wood accumulations on bar tops, and 27% were present along channel banks (Figure 3). Only 6 apex jams that forced split flows were present in the 1981 imagery. A mapbook of log jams digitized in 1981 and persistence through 2015 is available in Appendix A.

Of the 147 jams digitized in 1981, 46% were gone by 1992 and not associated with revegetation or forested bars, indicating that wood had mobilized downstream (Figure 4). Of the 79 remaining logjams, 67 had begun to form vegetated or forested bars or islands (Figure 4). Only 7 of the remaining jams were engaged with the low flow channel in 1992, predominantly along channel banks. By 1998, only 3 of the original logjams from 1981 are still visibly present (unforested) and engaged with the channel.

The 67 logjams that became forested between 1981 and 1992 were tracked through subsequent aerial photo records to determine if the channel re-occupied those locations or if logjams created stable hardpoints that resisted channel re-occupancy. The number of forested logjams from 1981 declined throughout the photo record as the Sauk River migrated across the forested floodplain (Figure 5). 61 (91%) of those logjams that began to reforest from 1981 to 1992 remained forested in 1998, and 40 (60%) of those logjams remained forested by 2015 (Figure 5).

The total area of the 147 logjams in the 1981 aerial imagery was 15.8 hectares. The SCPW data for 2005 included 69 logjams with area greater than 200 m^2, and a total area of 4.4 hectares. 59 logjams in the 2013 Beechie et al. dataset had areas greater than 200 m^2, and these logjams had a total area of 2.40 hectares. This represents a 60 percent decline in the number of large (>200 m^2) logjams and an 85 percent decline in the area of large logjams from 1981 to 2013 (Figure 6). Logjam frequencies were 12.3, 5.8, and 4.9 logjams/km for 1981, 2005, and 2013, respectively (Figure 7). This represents a 60 percent reduction in frequency from 1981 to 2013.

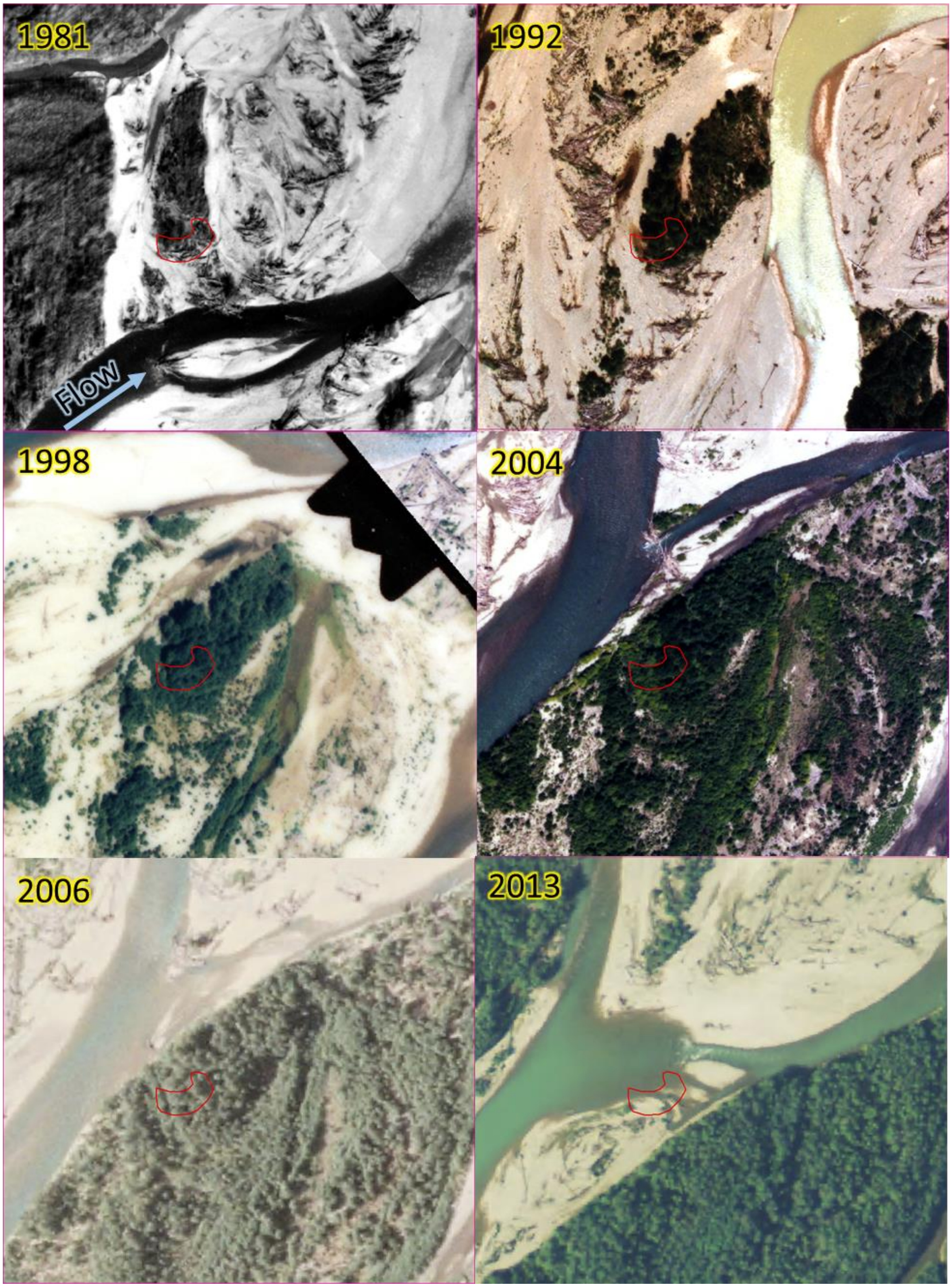

Figure 2. Example of logjam (red outline) becoming forested from 1981 - 2006 and then eroded and washed-away by channel re-occupancy in 2013.

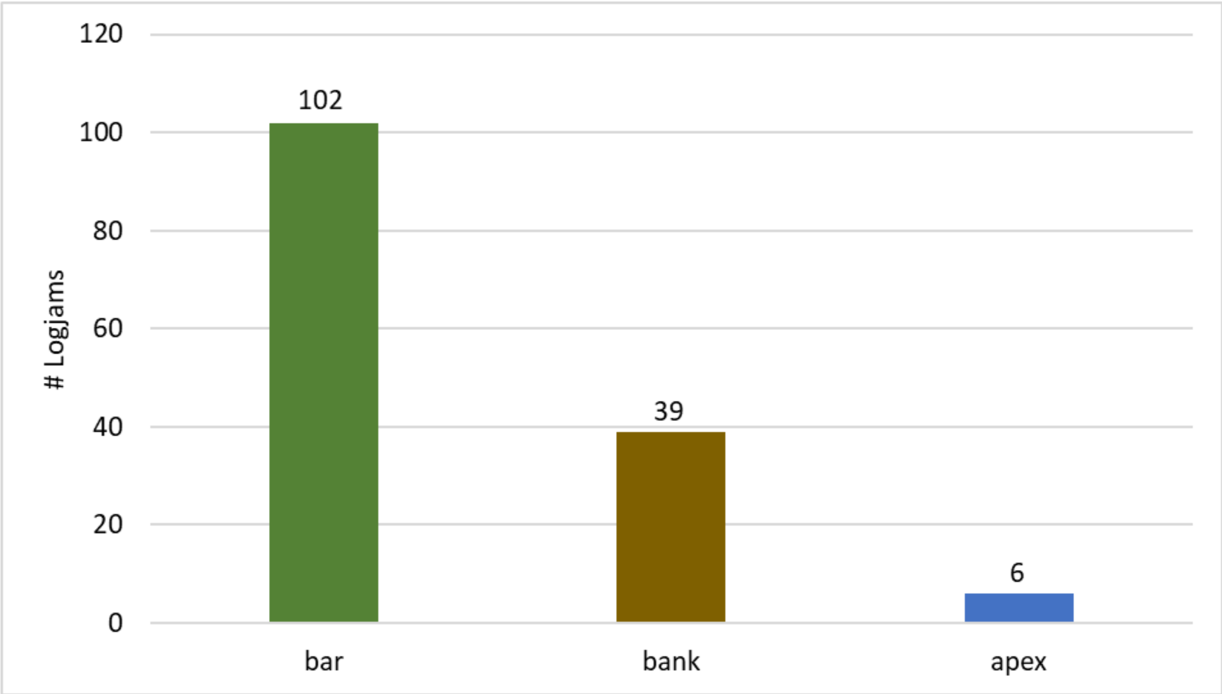

Figure 3. Functional attributes of logjams digitized from 1981 aerial imagery for the 1981 6,100 km^2 channel corridor.

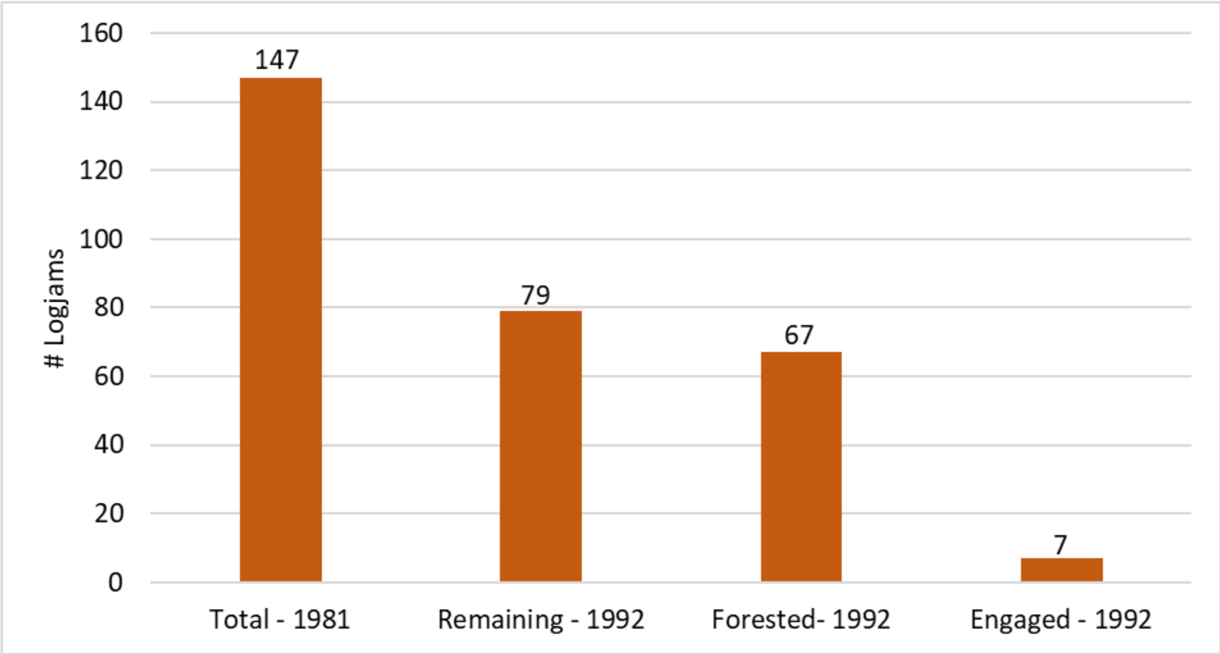

Figure 4. Logjams from 1981 to 1992.

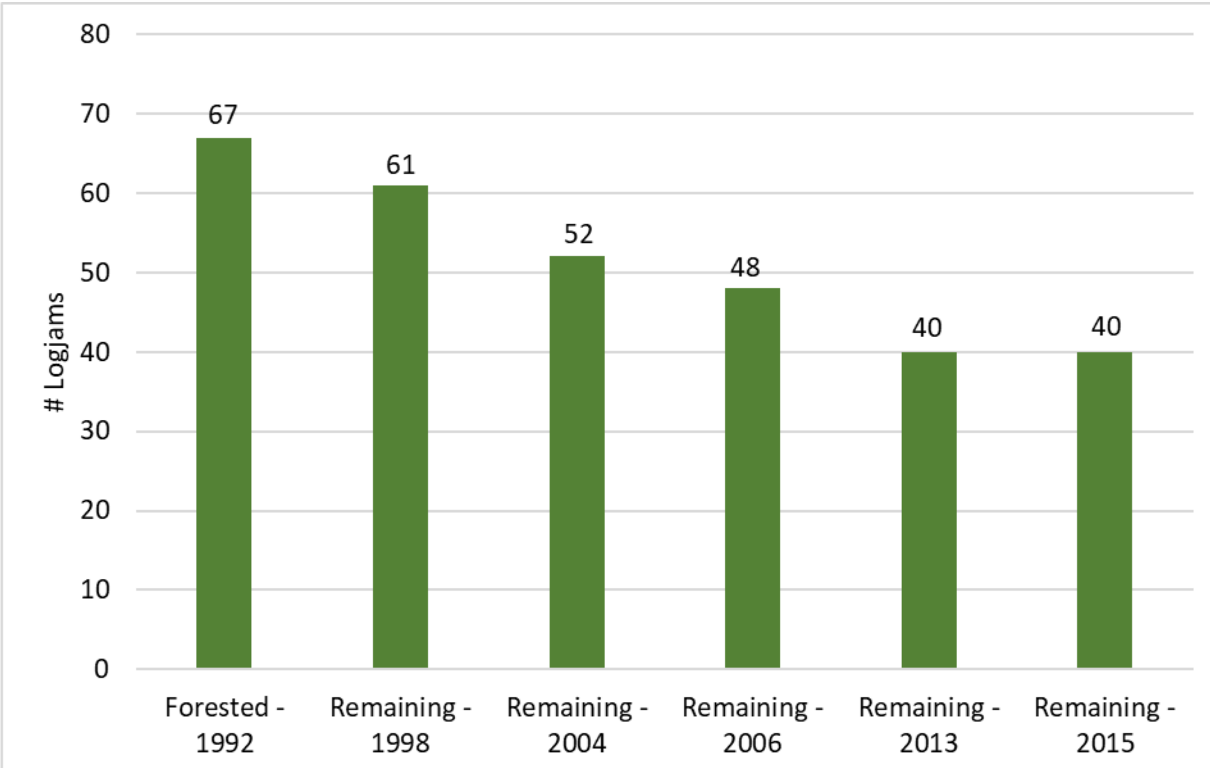

Figure 5. Channel re-occupancy of logjams that became forested from 1981 -1992.

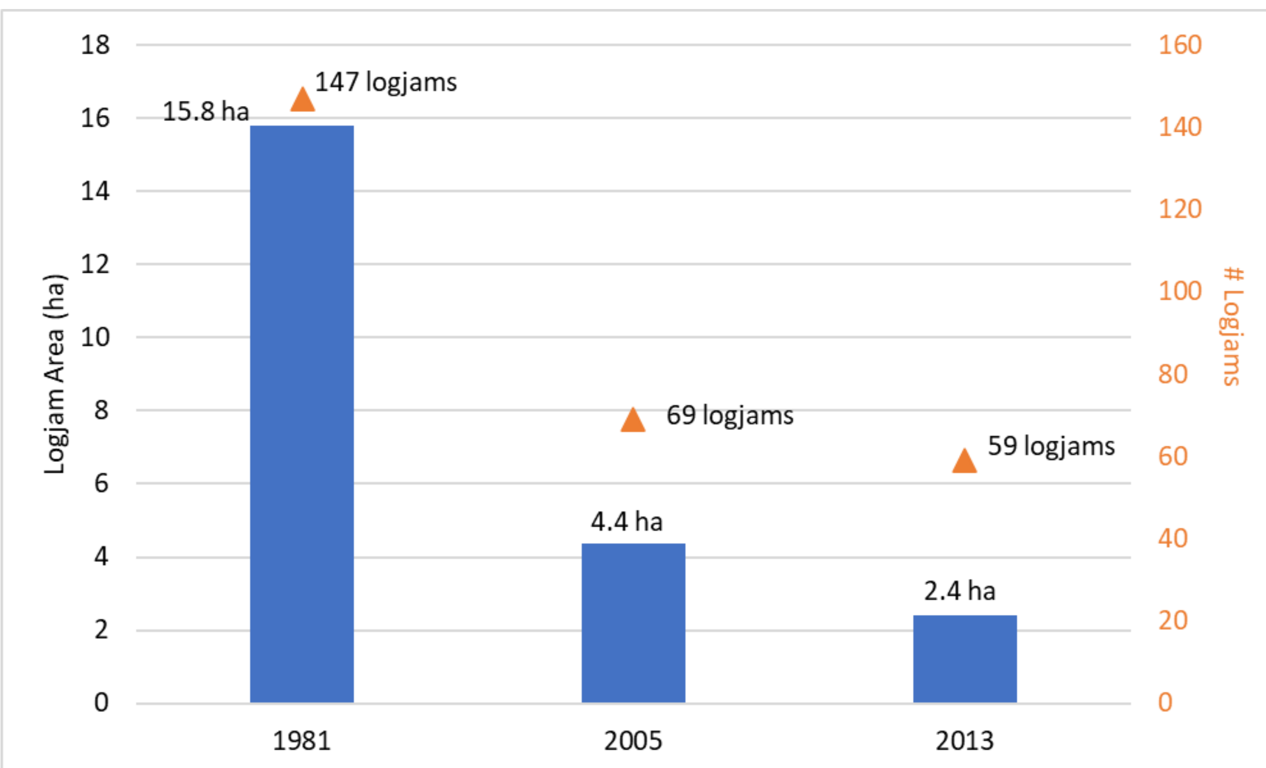

Figure 6. Logjam area and number of large logjams (>200 m^2) from 1981 to 2013. 2005 data from Snohomish County, 2013 data from Beechie et al.

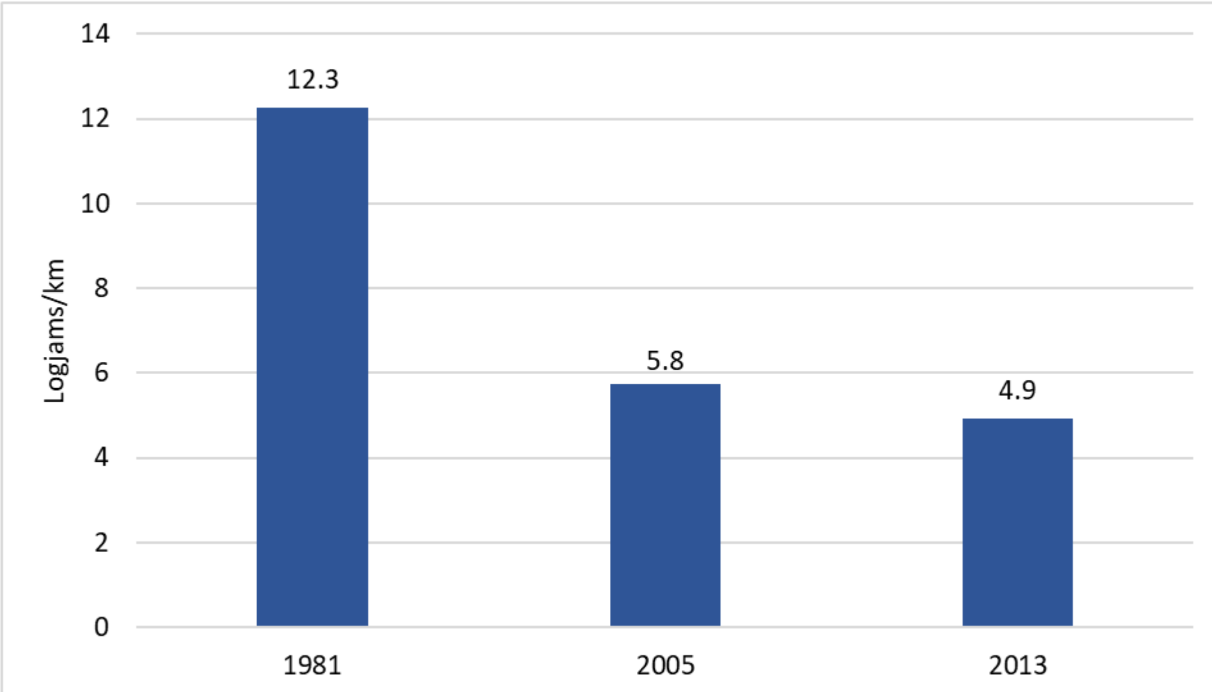

Figure 7. Logjam frequency from 1981 - 2013. Only logjams with area > 200 m^2 were included, for comparison. 2005 data from Snohomish County, 2013 data from Beechie et al.

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Discussion

Both the number of logjams and large wood area in the Sauk River from Darrington to the Suiattle River confluence have declined from 1981 to present, and this loss of large wood has occurred concurrently with channel widening in the reach. The second largest flood on record occurred in December of 1980 (40,100 cfs) and likely resulted in substantial channel migration or channel widening. It is possible that the 1981 aerial photograph used as the basis for our analysis shows excess wood compared with other photo records preceded by smaller peak flows. Channel widening through forested floodplain results in large wood recruitment to the channel, however the observed decrease in wood abundance from 1981 to 2013 suggests that wood is being lost faster than replacement in the Sauk. This is likely the result of multiple factors that include: (1) the historic removal of large floodplain trees that form stable large woody material when recruited to the channel, and (2) limited time for recovery of large trees within the Sauk River's channel migration zone.

Logging in the Sauk River valley using logging railroads is documented near Darrington as early as 1906 (DSI, 2021), and there are locations along the Sauk River where floodplain forest has been repeatedly harvested during the aerial photo record (Figure 8). Only isolated patches of old trees with heights greater than 200 ft remain in the valley bottom (Figure 9), and are indicators of forest potential in the Sauk River floodplain. Currently, floodplain forests within the channel migration zone are generally less than 100 ft in height and comprise small trees incapable of forming stable large wood pieces or wood accumulations when recruited to the channel. The historic removal of old growth forest within the valley bottom has dramatically reduced the number of large trees available for recruitment and subsequent channel-forcing processes that create and sustain instream habitat features.

In places where logjams began to revegetate to form forested bars or islands in the Sauk, few (31) locations have persisted as forest since 1992 (Figure 5). Movement of the Sauk River across the historic channel migration zone has created a positive feedback wherein channel re-occupancy of forested areas limits the regeneration of old, large floodplain trees. These old growth trees are needed to form stable hardpoints that slow channel migration by partitioning shear stress and helping to stabilize channel banks, allowing forests to mature and contribute to a channel's large wood cycle (Collins et al., 2012). Stable hard points that contain wood derived from large, old growth trees can persist for several hundred years (Abbe & Montgomery, 2003; Montgomery & Abbe, 2006), however the Sauk's valley bottom has largely been denuded of key-sized logs. Previous work in the Nooksack and Cowlitz Rivers of Washington have shown substantial increases in channel width and reductions in forested islands following logging (Collins et al., 2012; Abbe et al., 1997).

To evaluate the logjam frequency to a pre-European "natural" state we compared the numbers to estimates from the Queets River on the Olympic Peninsula (Abbe 2000). The Queets valley lies within Olympic National Park (ONP) so it offers a reference condition, but much of the valley bottom forest was cleared by homesteaders prior to formation of the ONP in 1938. Thus there are areas in the lower valley that lack the original old-growth and large trees that are critical to initiating and stabilizing natural logjams (Abbe and Montgomery 1996, 2003; Abbe 2000). Abbe (2000) documented stable and unstable logjams throughout the alluvial valleys of the Queets watershed and the numbers offer a reference condition, though may be lower than a similar sized river with intact old-growth. The comparison shows that Sauk project reach is lower than the Queets reference condition for similar drainage basin area and annual discharge (Figures 10 and 11). This is reasonable considering almost all of the Sauk valley was logged, the river was certainly cleared of wood historically and the dataset used only goes back 41 years (1981).

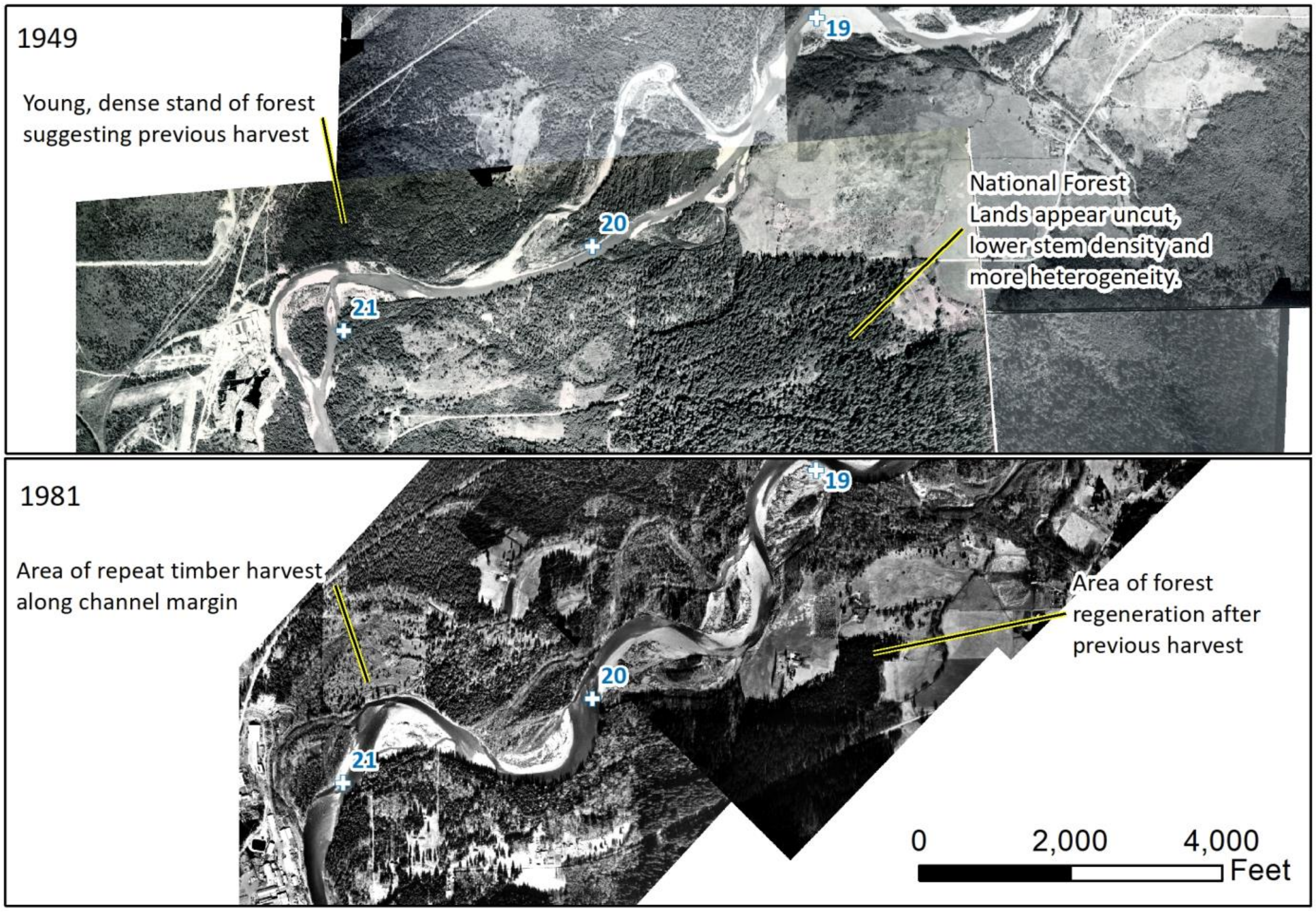

Figure 8. Aerial imagery of timber harvest along the Sauk River near Darrington. Tracts within the floodplain are visibly cleared by 1949 (upper), and additional floodplain parcels are cleared by 1981 (lower), while some stands begin to regenerate.

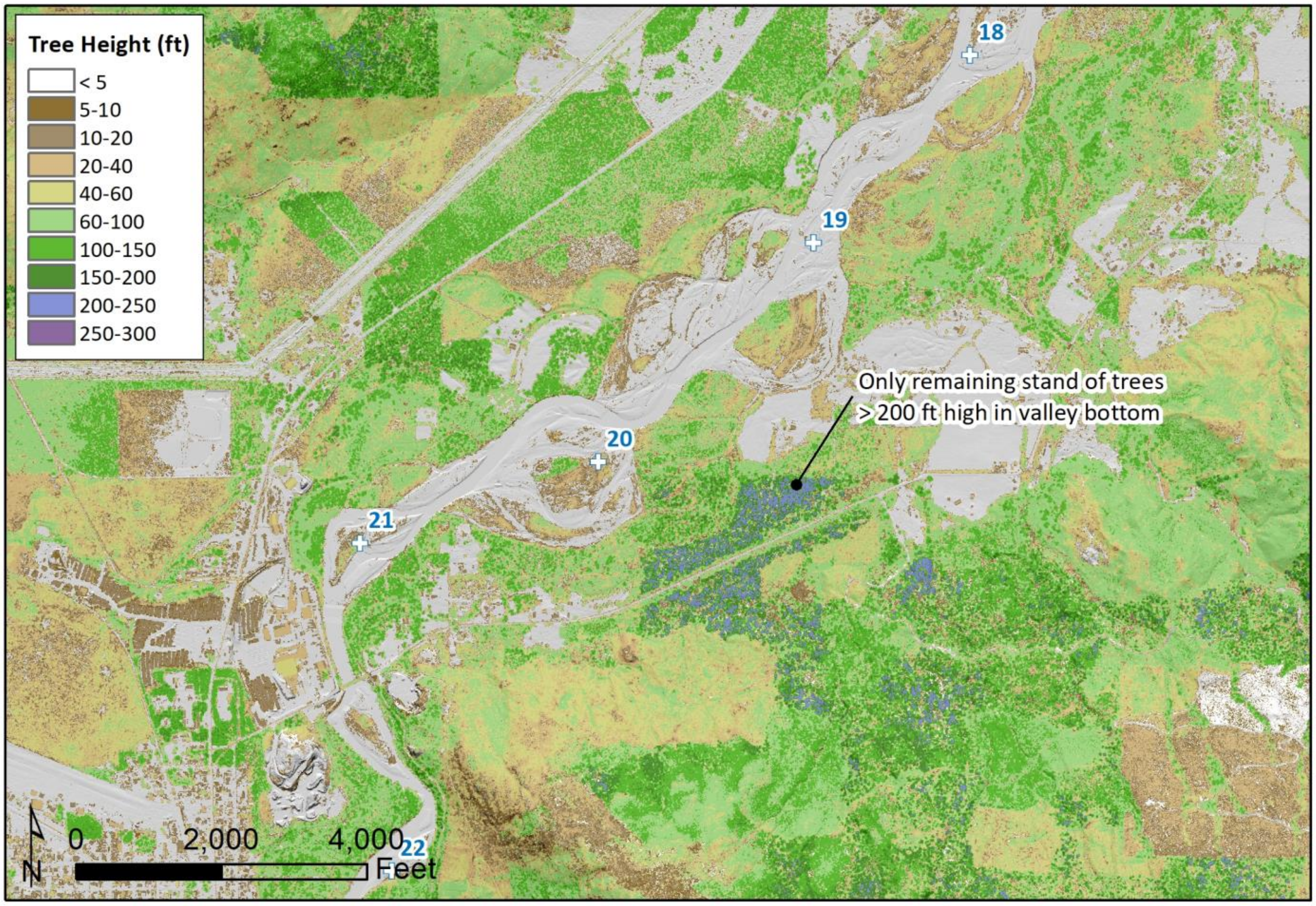

Figure 9. Canopy height derived from 2015 lidar for the Sauk River near Darrington. Remnant stand of tall trees in the valley bottom is within the National Forest.

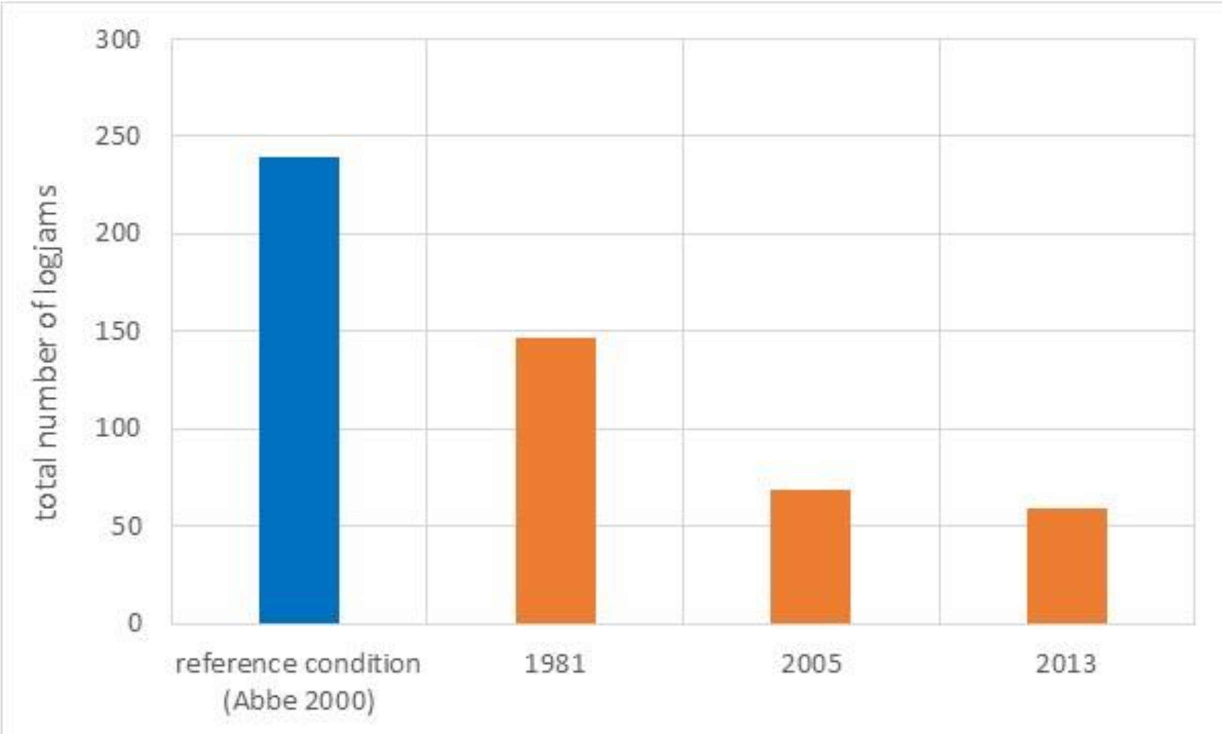

Figure 10. Total number of logjams in the Sauk study area compared to reference condition in Queets watershed with similar drainage area (stable and unstable logjams; Abbe 2000).

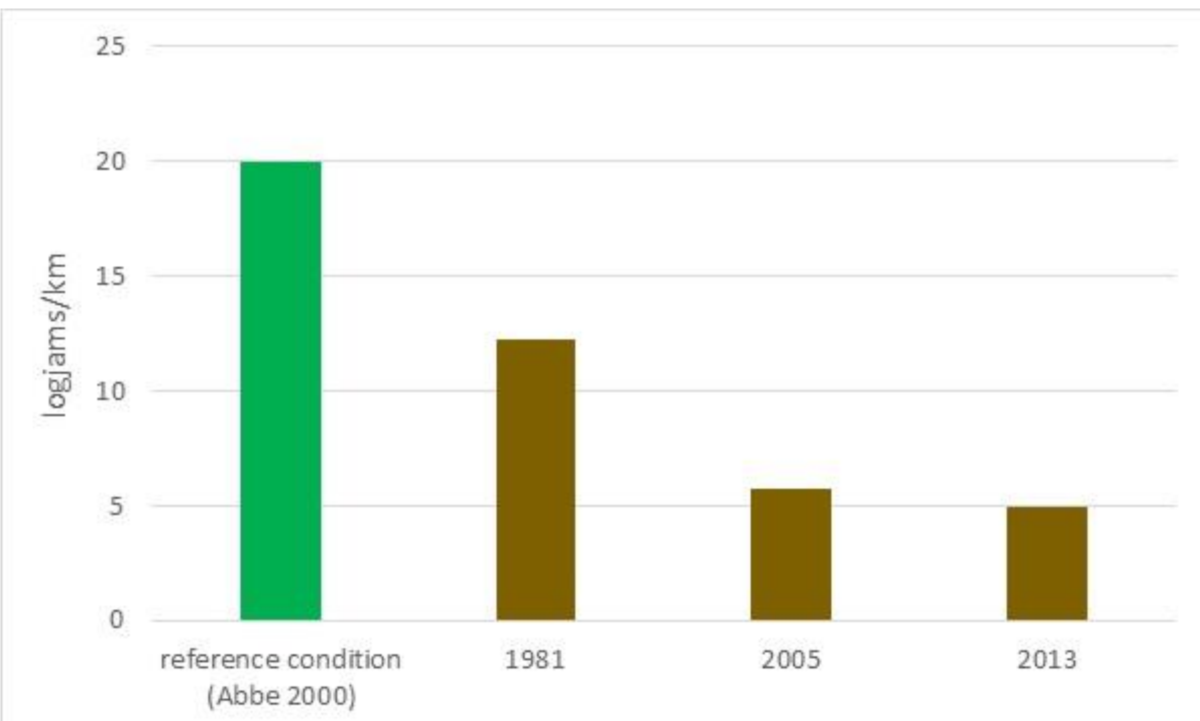

Figure 11. Logjam frequency in the Sauk study area compared to reference condition in Queets watershed with similar drainage area (stable and unstable logjams; Abbe 2000).

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