

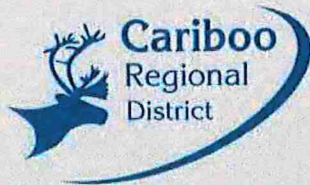


DWB Consulting Services Ltd.

Cottonwood River Protection Works Assessment



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Signature Page

DWB Consulting Services Ltd. is pleased to submit this report for your review. This report has been prepared using sound technical and professional judgement, based on our knowledge and experience, applicable regulatory framework, industry best management practices, and current understanding of project conditions, design, and project setting.

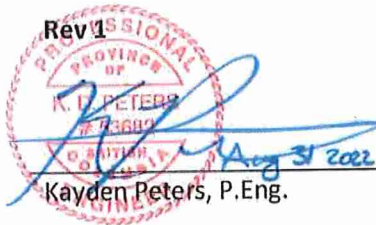
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Professional Review: Reviewed for content and professional signoff
Client Review: Reviewed by client
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Peer Review: Reviewed for content and errors by peer

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We do not represent, warrant, undertake or guarantee:

- That all project-related information has been received.
- That current and future regulations and standards of practices are consistent with those at the time of the initial project execution.
- That the use of guidance in the report will lead to any particular outcome or result.

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1.0 INTRODUCTION

1.1 OVERVIEW

DWB Consulting Services Ltd. (DWB) was retained by the Cariboo Regional District (CRD) to complete an assessment of the existing bank armouring works on the right bank of the Cottonwood River, along the Quesnel-Hixon Road. The site is located approximately 20km north of Quesnel, as shown in Figure 1, and was previously subject to significant erosion and land loss due to channel migration. This channel migration caused significant loss to private land, resulting in the loss of multiple homes situated along the river bank, circa 2009. The bank armouring works to be assessed were conducted in 2012.



Figure 1: Site Location

DWB personnel conducted a site assessment on August 2nd, 2022. During this visit standing water was observed throughout the easternmost channel, along the area of the protection works. No measurable flow was present in this channel at the time.

2.0 BACKGROUND

2.1 PREVIOUS DESIGN OVERVIEW

At the time of the 2010 design, the property banks were on the outside bend of the River, with direct impact from flows. Streamworks proposed a series of 12 rock and log spurs spaced along the bank. Spurs were to be built to the height of the design flood modelled by Streamworks, extending 6m into the active channel. For background, design and typical drawings, please refer to Streamworks' *Cottonwood River Engineering Assessment* (February 2010). It was noted that the CRD has no as-builts on file.

2.2 SITE HYDROLOGY

DWB conducted a hydrologic assessment for the site to compare to the previous design flows presented by Streamworks. Both calculations utilized the previous Cottonwood River gauging station (08KE009) approximately 900m upstream from the protection works with a catchment area of 1910km². The record from this station begins in 1955 and ends in 1998.

The Regional Frequency Analysis for the region results in an uncorrected 100-year return period flood (Q100) of 430m³/s. This is within a reasonable range of the values utilized by Streamworks.

As the gauge station record ends in 1998, DWB applied a factor of 14% based on surrounding hydrologic trends to translate flow values to the present day. Furthermore, a 20% climate change factor has also been applied to account, as is current best practice, to account for predicted future climate impacts on the river discharge over the next 80 years. The climate change factor for the region was determined through the use of the Plan2Adapt tool created by the Pacific Climate Impacts Consortium (PCIC). A comparison of the two flow values is presented in Table 1.

Table 1: Design Discharge Data Comparison

Flood Event	Streamworks 2010 Design Discharge (m ³ /s)	DWB 2022 Comparison Discharge (m ³ /s)
Q2	180	220
Q10	294	356
Q50	381	472
Q100	415	520
Q200	449	568

It is DWB's understanding that the hydrology used followed the standard practices of the day, which did not include climate change impact factors. As the Cottonwood River has both widened and shifted away from the properties, no additional modelling for hydrology or hydraulics has been completed for this assessment, nor are recommended at this time.

2.3 CHANNEL MORPHOLOGY

A brief comparison of channel morphology was completed to compare the River alignment pre-event, at the time of the erosion and protection works, as well as the current state. This comparison included historic aerial images from 1997 through 2019. River alignments are presented on the 2019 imagery in Figure 2.

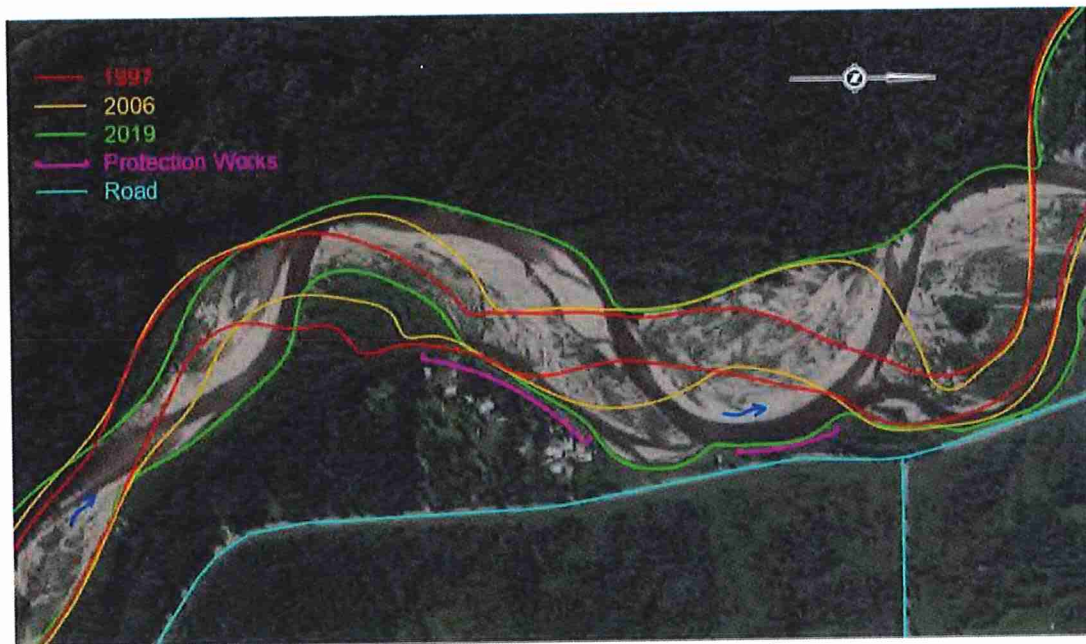


Figure 2: Cottonwood River Channel Morphology

It can be seen in this comparison that the right-hand bend in the river was directing flows toward the properties in the early 2000s (red and orange) when the major erosion events occurred. This bend has continued to push further downstream, moving approximately 100m north, past the properties (green). It was also noted that the average channel width has increased from roughly 100m in 2006 to 180m in 2019 and present. This widening allows for increased flood relief within the banks; however, it also provides easier meandering of the active channel within the gravel bar and floodplain area.

Current channel alignment does not present a direct threat to the properties as the main channel has migrated to the far side of the channel, leaving the home on the inside of the bend. This portion of the channel appears more stable than downstream reaches, due to the tall banks of the west. Vegetation has also begun re-establishing on the gravel bars in front of the properties. It was noted that bank instability further upstream may result in unknown impacts on future channel alignment.

3.0 PROTECTION WORKS ASSESSMENT

3.1 SPURS AND LARGE WOODY DEBRIS

As described in the CRD summary notes, the bank protection works prescribed in the Streamworks 2010 report were constructed in 2012. This consisted of Streamworks Option A, a collection of rock and large woody debris (LWD) spurs to deflect flows off of the riverbank in front of the remaining properties. The works identified during the DWB site visit are labelled on Figure 3, with rock spurs in Red and LWD spurs in Yellow. In total 8 structures were identified; 5 rock spurs and 3 LWD spurs. This is less than the prescribed 12 spurs from the Streamworks plan. Confirmation that only 8 structures were constructed was provided by residents during the inspection.



Figure 3: Spur Locations Overview

All rock spurs are similar in size, being roughly 2m tall, 5m wide and extending 6 to 7m from top of bank to toe of spur. This matched prescription dimensions. Spurs appear to be constructed of class 250kg riprap with larger key boulders. Riprap appears to be appropriately graded with good embedment and bank key-in. An example of the typical spur is shown in Figure 4, with additional photos in Appendix A. It should be noted that rock spur #1 was difficult to locate and identify due to heavy vegetation and conduction of the staircase. It is not believed that this has compromised the integrity of the spur.

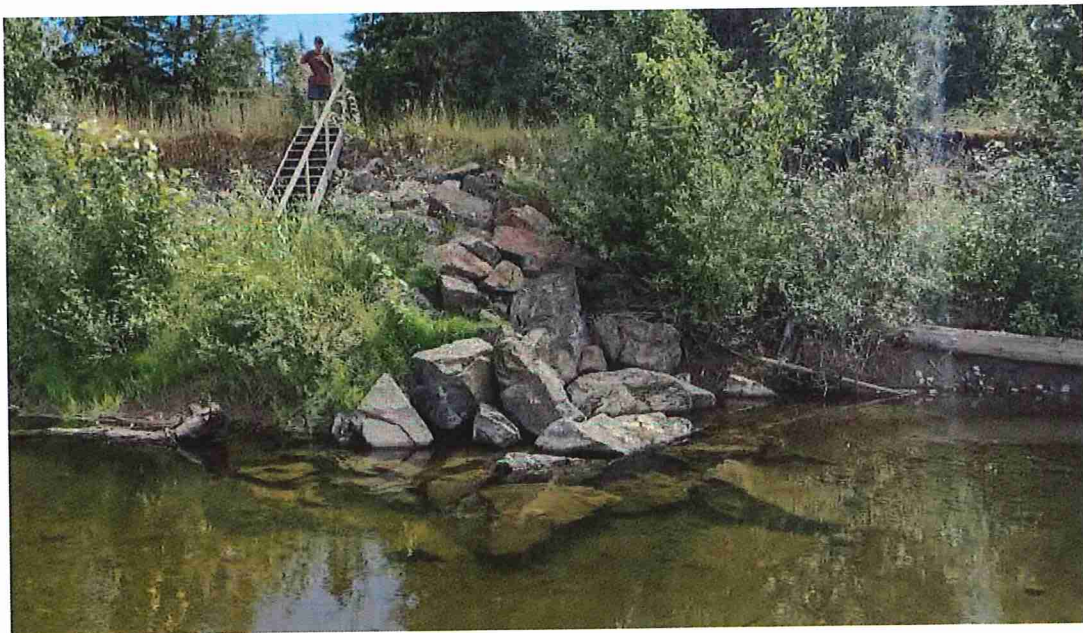


Figure 4: Rock Spur #5

Large Woody Debris spurs were also constructed (Figure 5), with additional LWD placed along the bank. This debris has been anchored to a core of riprap using bolts and chains. Visible chains are in good condition, with minimal surface rust. Chain connections to the rock anchors were not observed as they were buried in the channel bottom sedimentation. LWD spurs are similar in size to the rock spurs, with additional branch length. Both the rock and LWD spurs are vegetating well.



Figure 5: LWD Spur #3

Additionally, various log jams and natural LWD collections are present in the side channel upstream of the protection works. The upstream reaches of this side channel are now heavily vegetated, all of which is expected to have a positive impact on the protection of the right bank along this section of the river.

3.2 DOWNSTREAM RIPRAP ARMOURING

A 120m section of approximately Class 250kg riprap with larger boulders at the base, has been placed alongside Quesnel-Hixon Road where the Cottonwood River banks encroach toward the roadway. It is understood that this area, as well as the unarmoured section of bank immediately upstream, is under the jurisdiction of Ministry of Transportation and Infrastructure (MOTI). The riprap armouring was placed in 2005 and 2008 in response to erosion along the Quesnel-Hixon Road.

The rock armouring is holding up well and is currently at a stable slope between 1.5:1 and 2:1 as shown in Figure 6. Approximately 6m of grassy shoulder remains at the narrowest point between the rock armouring and the edge of road. Minor erosion with overhanging grasses and small cavities in the native soils was observed above the top of the riprap, however, vegetation suggests this is a minor or slow event.

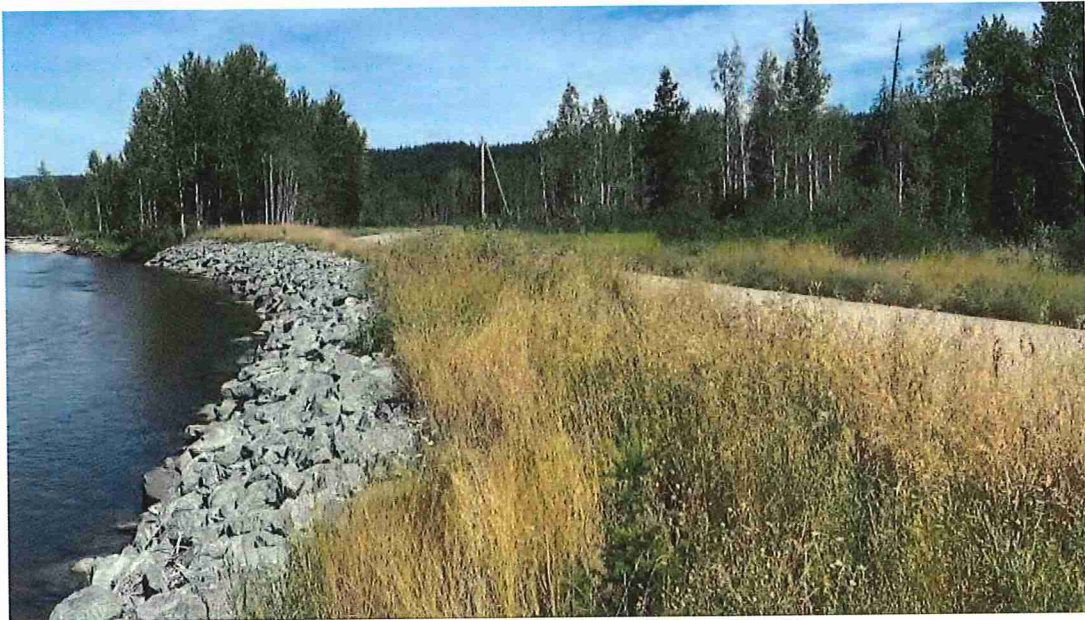


Figure 6: Riprap Armouring (Looking North)

River banks upstream from this riprap armouring have been subject to scour. A spur of large boulders is present where the east-most side channel re-enters the current main channel, with approximately 15 to 20m remaining between the bank and the road shoulder. At the time of the visit and as presented with the channel morphology above, this Cottonwood River's main channel currently impacts this unarmoured section of the bank between the spurs and downstream armouring, shown in Figure 7.

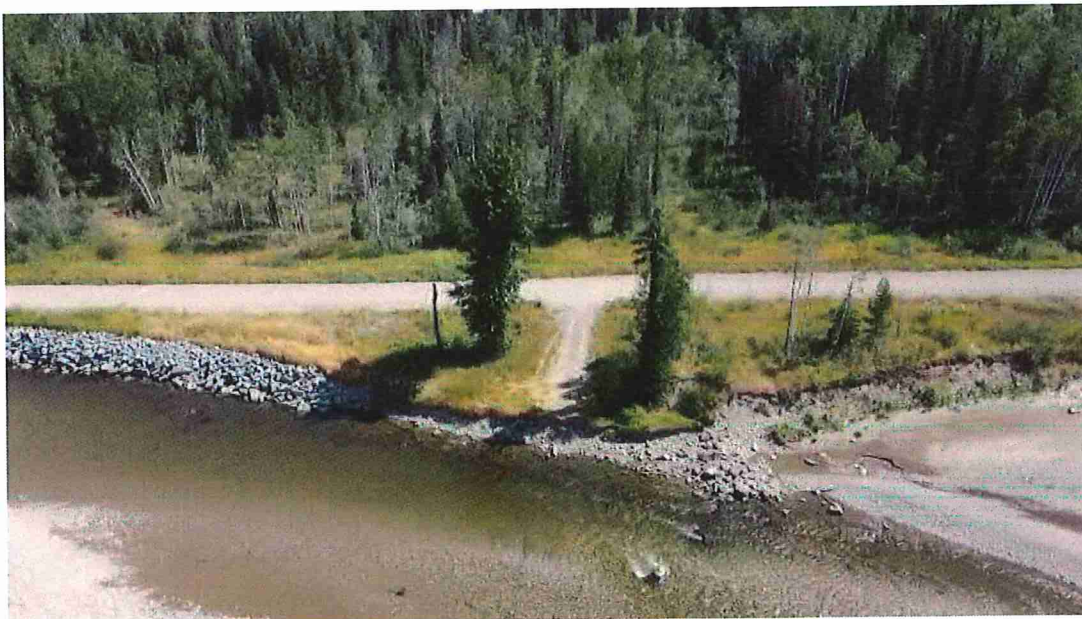


Figure 7: Unarmoured Bank (Looking East)

4.0 CONCLUSION

Based on the site inspection conducted on August 2nd, 2022, DWB believes that the bank protection along the east bank of the Cottonwood River was built to the Streamworks design and continues to function as intended. No maintenance or upgrading issues were identified for the spurs and LWD during the inspection.

At this time, the Cottonwood River has migrated such that the residential properties are at lower risk of direct erosion, although this may change again in the future due to the dynamic nature of the Cottonwood River alignment. Should a major change to the River alignment occur, site exposure and potential risks should be re-assessed.

Downstream roadside armouring also appears to be in good condition, with stable slopes, fair gradation, and no identified holes. Minor scour was identified at the top of the riprap; however, it does not appear to be migrating or undermining the armouring at this time. Armouring may be considered by MOTI for road protection if erosion continues.

If you have any questions, please feel free to contact our office.

5.0 REFERENCES

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APPENDIX A:

Record Photos

August 2, 2022



Cottonwood River – Spur Protection Site Overview



Cottonwood River – Spur Protection Site Panorama (Looking East)



Cottonwood River Spurs Overview (Looking Upstream, South)



Cottonwood River Bank Protection Spurs



Cottonwood River Floodplains (Looking Downstream, North)



Quesnel-Hixon Road Protection (Looking Downstream, North)



Cottonwood River and Side Channel Above Spurs (Looking Upstream)



Cottonwood River Side Channel Above Spurs (Looking Upstream)



Cottonwood River Spur #2



Cottonwood River Spur #4



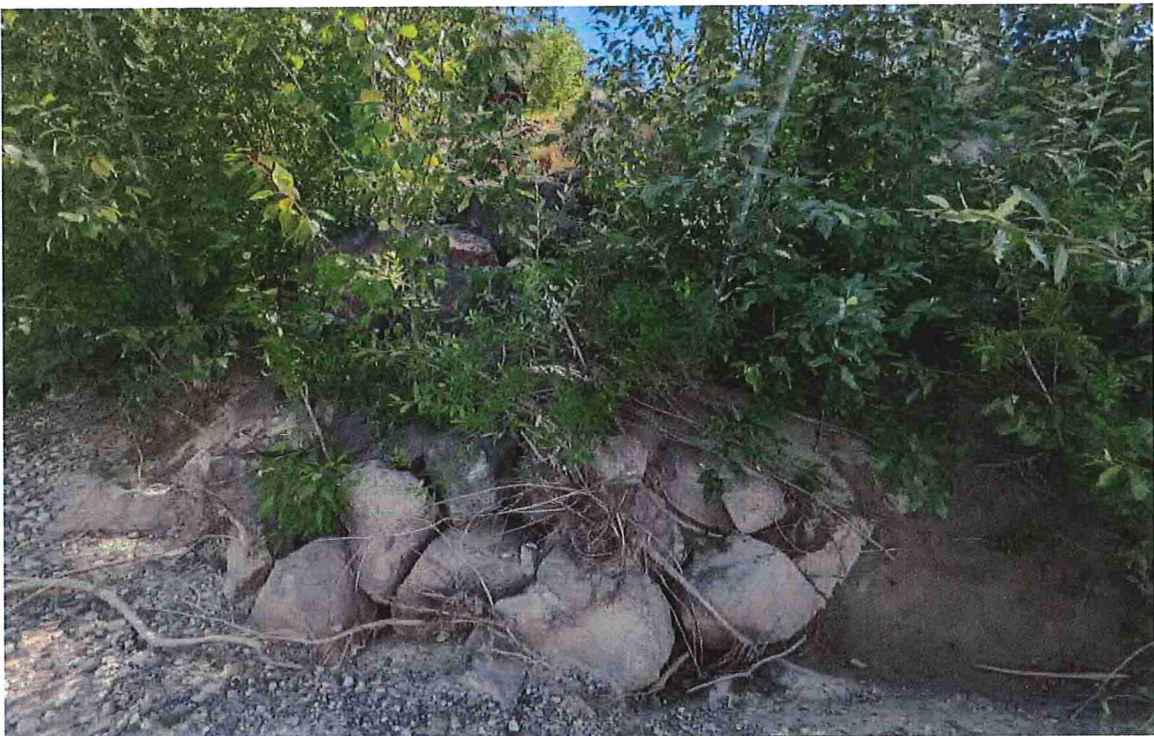
Cottonwood River Bank LWD (Between Spurs 4 & 5)



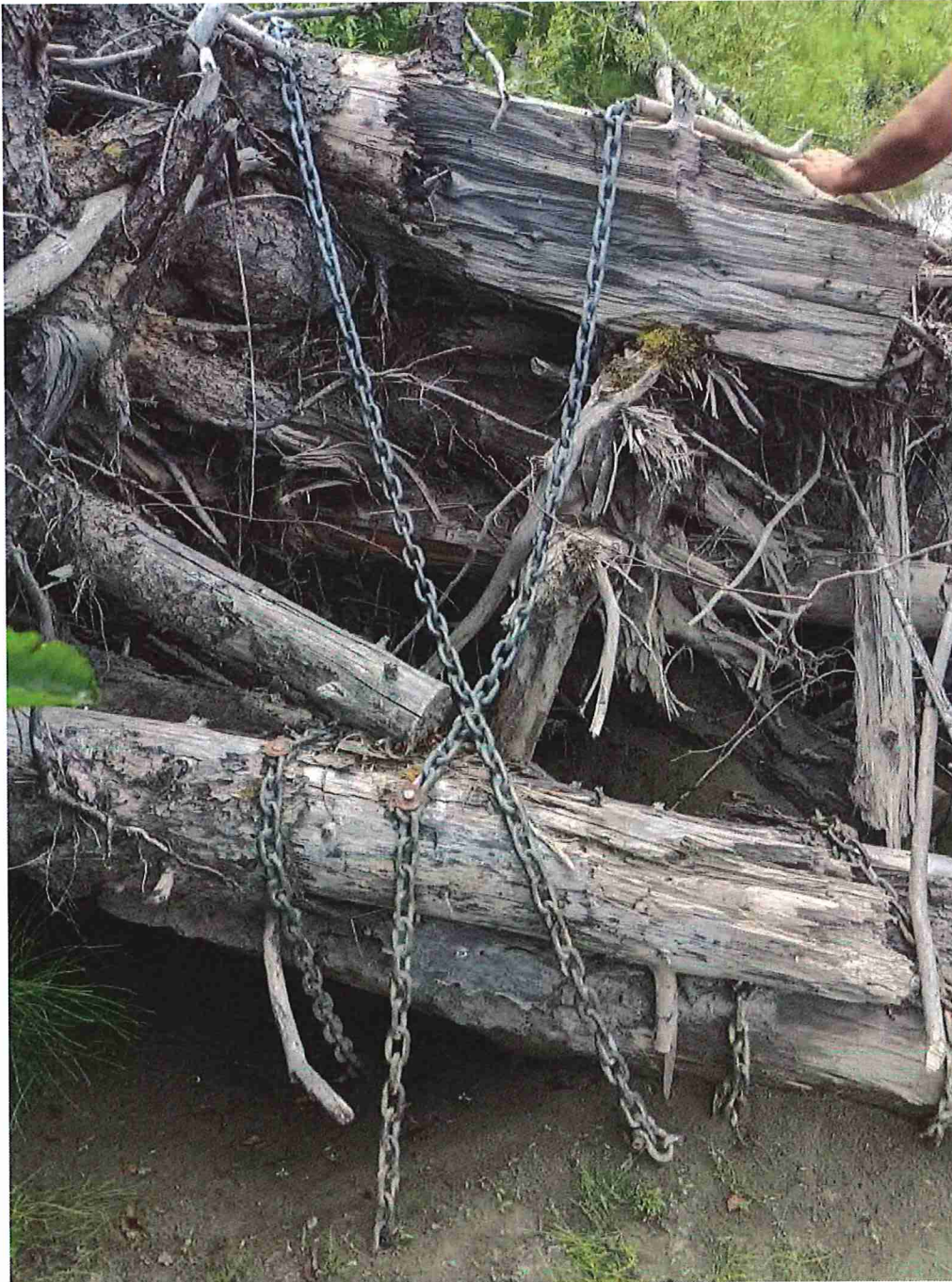
Top of Cottonwood River Spur #6 (Looking toward River)



Cottonwood River Spur #7



Cottonwood River Spur #8 (Furthest Downstream Spur)



Anchor Chains on LWD (Spur #2)



Quesnel-Hixon Road Protection - Riprap (Looking North)



Quesnel-Hixon Road Protection – Riprap Top Scour