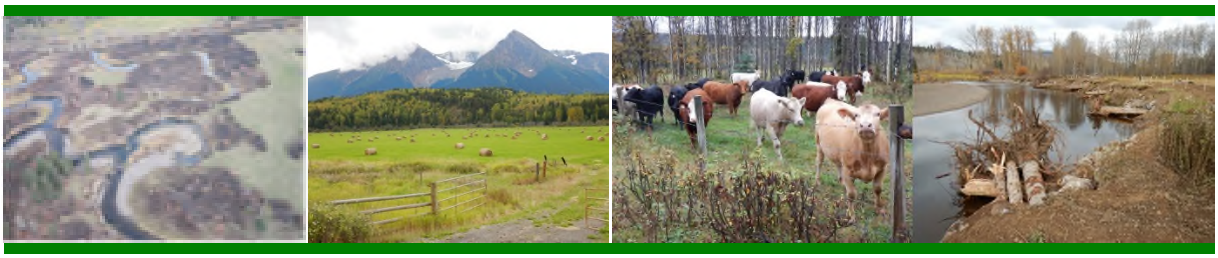
AS-BUILT REPORT OF AQUATIC RESTORATION AND ON-FARM CATTLE MANAGEMENT IMPROVEMENTS WITHIN THE WET'SUWET'EN FIRST NATION TERRITORY, 2016



Prepared for:

Fish Habitat Restoration Initiative
Fisheries and Oceans Canada
Ecosystem Management Branch
985 McGill Place
Kamloops, BC V2C 6X6

November 2016

LGL LIMITED
environmental research associates

EA3731

AS-BUILT REPORT OF AQUATIC RESTORATION AND ON-FARM CATTLE MANAGEMENT IMPROVEMENTS WITHIN THE WET'SUWET'EN FIRST NATION TERRITORY, 2016

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ACKNOWLEDGMENTS

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1 INTRODUCTION

Aquatic and riparian habitat restoration within the upper Bulkley and upper Fraser (Francois Lake) river watersheds is considered a pre-requisite to the long-term survival and recovery of Chinook, Coho and Sockeye salmon, as well as Steelhead, Rainbow and Bull trout. Stream and riparian habitats within Wet'suwet'en First Nation (WFN) traditional territory (Figure 1) have been impacted by past forestry activities and linear corridor developments, and will be impacted in the future from liquefied natural gas (LNG) pipeline development.

Through Fisheries and Oceans Canada's (DFO's) Fish Habitat and Restoration Initiative (FHRI), Yinka Dene Economic Development Limited Partnership Inc. (YLP), in collaboration with LGL Limited environmental research associates (LGL), proposed to develop aquatic restoration designs and implement restoration works between 2015 and 2019 at high-priority sites within WFN territory. The objective of these restoration projects was to recover high-valued stream habitats to proper functioning condition. Habitat restoration within the WFN traditional territory is required to re-establish salmon and trout abundances to levels which were prevalent in the mid-20th century.

In 2015/2016, YLP and LGL developed aquatic habitat restoration designs and on-farm cattle management improvement plans for 16 high-priority sites within WFN territory (Figure 2). Site-specific construction drawings, implementation schedules, material specifications and quantities, and estimated construction costs were reported by Gaboury and Smith (2016).

The as-built report that follows describes physical works undertaken at four of these sites in 2016 (Table 1). Included in this report are the constructed materials summary, ballast calculations, and photographic documentation of pre- and post-construction activities.

Table 1. Location of four aquatic rehabilitation sites completed in 2016.

Site Name	Watershed Code	UTM Zone	Easting	Northing
Lower Maxan Cr	460-924300	9U	686033	6029472
Bulkley R - Groot Farm	460	9U	668061	6044360
Bulkley R - McKilligan Rd - Upper	460	9U	659824	6036606
Bulkley R - McKilligan Rd - Lower	460	9U	658880	6035831

2 REHABILITATION OBJECTIVES

Rehabilitation objectives for each of the four sites were the same. Survival during early freshwater life stages is critical for the maintenance of Steelhead, Chinook and Coho salmon populations. Lack of stable complex habitat in the upper Bulkley River is likely a limiting factor in the recovery of these species. Consequently, the rehabilitation measures were constructed to provide primarily high-quality salmonid summer rearing, overwintering and spawning habitat for the targeted anadromous salmonids in the Bulkley River drainage. These works will also reduce sediment sources (downstream benefits) and improve land management practices by riparian area landowners.

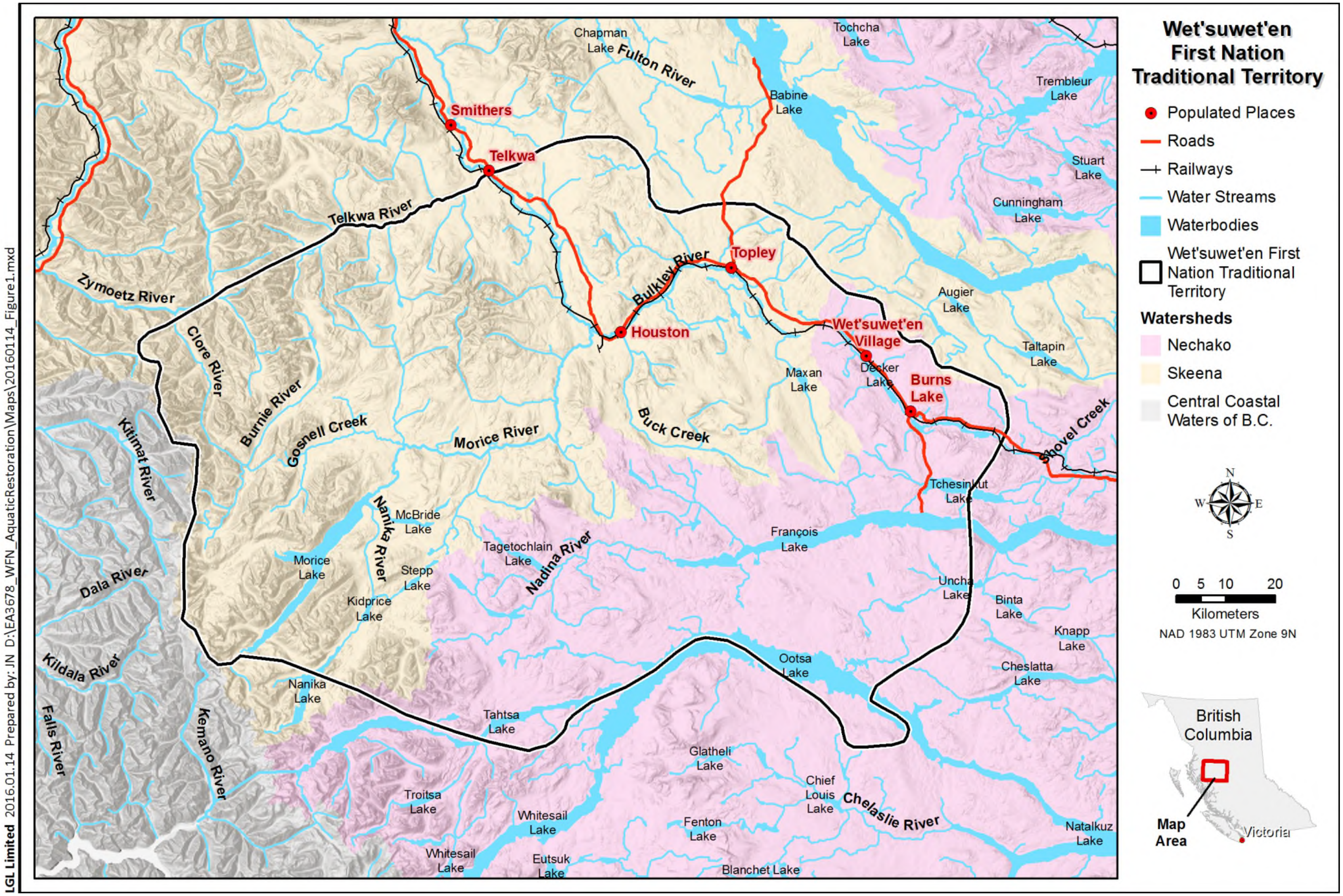


Figure 1. Map of the Wet'suwet'en First Nation (WFN) traditional territory which includes portions of the upper Bulkley and upper Fraser river watersheds.

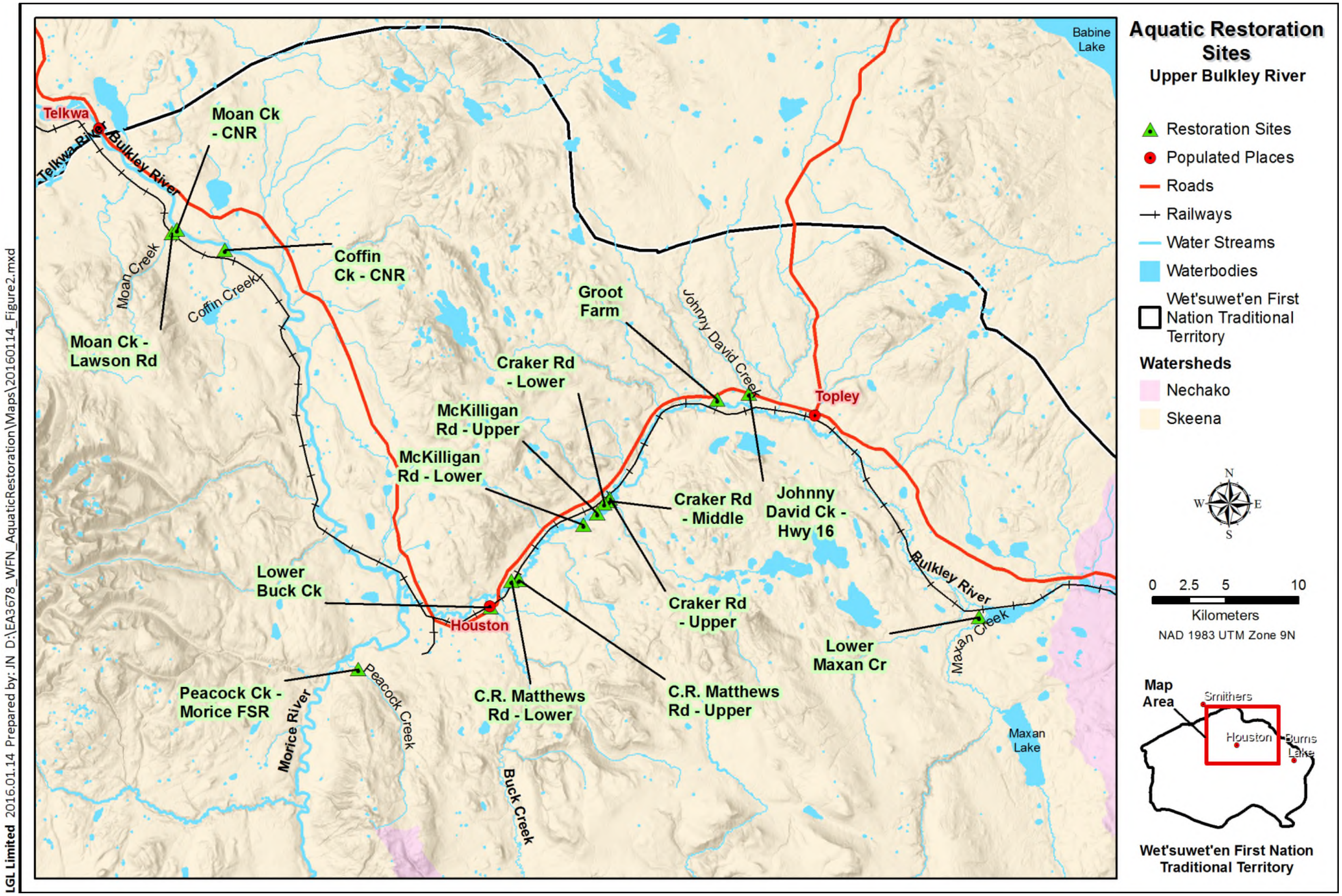


Figure 2. Map of the Bulkley and Morice rivers showing the location of 15 potential restoration sites within the Wet'suwet'en First Nation traditional territory that were identified in 2015/2016. Of these, instream works were completed at four sites in 2016 (Lower Maxan Cr, Groot Farm, McKilligan Rd – Upper, McKilligan Rd – Lower).

For the constructed rehabilitation works, the biological objectives were to:

- provide significant improvements in the useable area and function of spawning, rearing, and overwintering habitats for native salmon, steelhead, trout and char; and
- increase fry-to-smolt survival and smolt production per spawning pair.

The structural objectives at each of the four rehabilitation sites were to:

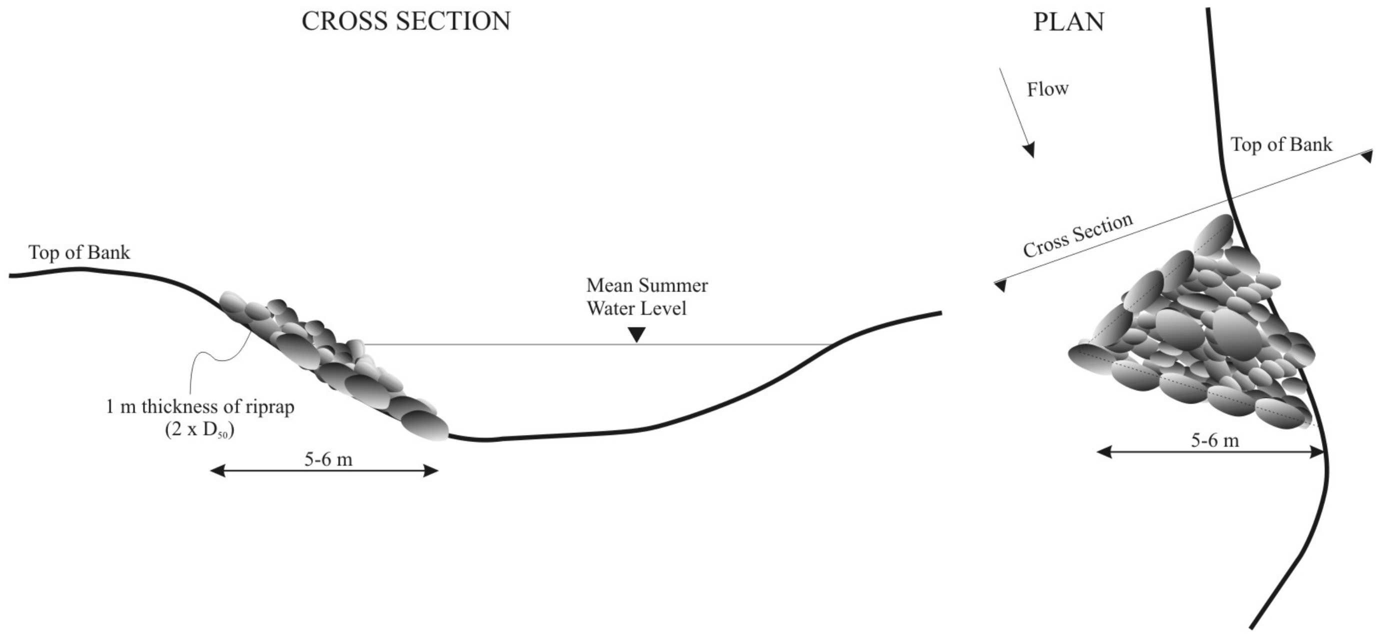
- stabilize chronic sediment sources (i.e., streambank erosion);
- improve holding and rearing habitat for salmonids by increasing pool frequency and the amount of functional large woody debris (LWD) cover in pools; and
- re-establish a more stable channel with appropriate bankfull widths.

3 GENERAL REHABILITATION DESIGN

The objectives of the 2016 aquatic rehabilitation project were to stabilize the stream bank, reduce the rate of meander migration, and provide stabilized complex instream holding, spawning, and rearing fish habitat. Constructed works included LWD structures consisting of five logs each (3 with rootwads, 2 without rootwads) and rock groins (Figure 3 and Figure 4). Structures were spaced approximately 10–20 m apart. The short spacing between the structures ensured that the river's energy was deflected away from the eroding stream bank. Fencing along the riparian corridor of the rehabilitation sites was also installed to restrict livestock access and protect planted vegetation. Native riparian vegetation will be planted in the spring of 2017 along the entire length of the reconstructed banks to provide shading, bank stability, and food and nutrients to downstream fish habitats.

Constructed works at each site generally followed structural designs and specifications as per Gaboury and Smith (2016). Although the total number of each structure type constructed was the same as in the design, the locations for the constructed LWD structures and rock groins were adjusted in the field as a consequence of the water depths of the existing habitat along the restoration section and the anticipated functional benefit of each structure type at each designated instream site. LWD structures were placed in existing deep pools where instream cover would be most beneficial to rearing, overwintering and holding habitats. Rock groins were placed in shallower riffle habitats where boulder cover would be most beneficial to rearing salmonids, such as Steelhead parr.

Structures were constructed from shore so no equipment entered the wetted perimeter of the stream. Trenching and placement of rootwads and boulders was done with excavators (site-specific models listed below). All logs with rootwads attached used in the LWD structures were from locally obtained spruce trees. LWD structures were ballasted by cabling logs to oversized boulders using epoxy (Red Head Epcon Ceramic 6+). The epoxy-cabling attachment technique is described by Melville (1997). Boulders were drilled using 15.9 mm (5/8 in.) diameter bits to accommodate 12.7 mm (1/2 in.) diameter galvanized cable. An environmental monitor was on site during all periods of instream construction. Particular care was taken to minimize disturbance to the riparian area. Containment equipment was kept on site in the event of a fuel or oil spill. The sites were fenced following construction.



Construction Notes:

1) Construct low height triangular riprap groin with 3:1 or shallower slope face.
2) Class 250 kg riprap: 0.3 to 0.8 m diameter with a D_{50} of 0.6 m.
3) Riprap gradation for Class 250 kg riprap: 85% larger than 25 kg (0.3 m); 50% larger than 250 kg (0.6 m); and 15% larger than 750 kg (0.8 m) (Northwest Hydraulic Consultants Ltd. 2000)
4) Minimum thickness of riprap equal to 1.2 m, or 2 times the median diameter (D_{50}) of the riprap.
5) Riprap at the streambank should extend vertically to a minimum elevation equal to bankfull discharge.

Typical Riprap Groin Structure
Plan & Cross Section

LGL Limited

Scale : Not to Scale

Figure 3. Typical plan and cross-section views of a riprap groin structure.

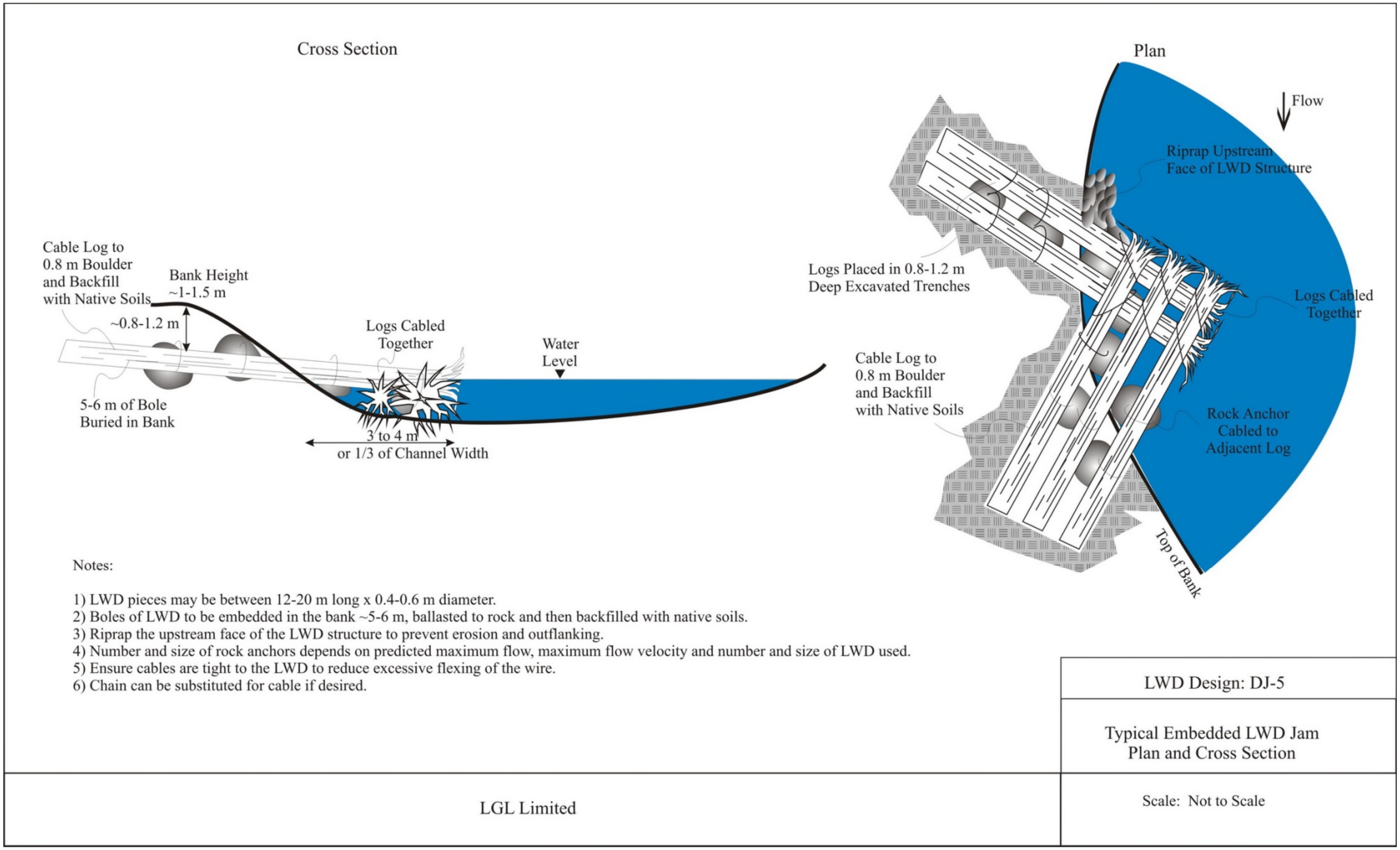


Figure 4. Typical plan and cross-section views of a large woody debris (LWD) structure, DJ-5.

Ballast requirements for the LWD structures were determined during the design phase following guidelines provided in D'Aoust and Millar (1999). It is important to note that the ballast estimate calculation assumed a multiple-LWD structure with all logs being cut logs. The calculation also assumed that the structures were anchored to live trees on the streambank with a factor of safety for buoyancy of 1.5, and a design velocity of 2.5 m/s (D'Aoust and Millar 1999). All of the LWD at the 2016 sites was buried in trenches in the streambank as no large riparian trees existed proximal to the structures. Also, three of the five trees in each LWD structure had rootwads attached. The boulder ballast provided to anchor the structures was in all cases more than the minimum required as specified through the calculations. Boulder ballast that was attached to the LWD in the trenches was subsequently buried. The ballast provided, which appears to be in excess of that required, therefore accounts for rootwad drag, buoyancy, and potential differences between anchoring LWD to live trees versus being ballasted and buried in the bank.

4 CONSTRUCTED WORKS

4.1 Lower Maxan Creek

The Lower Maxan Creek project site was located approximately 1 km upstream from the mouth of Maxan Creek approximately 35 km northwest of Burns Lake, BC (Table 1; Figure 2). Constructed works involved seven LWD structures installed along a 95-m reach (Figure 5) and 1.5 km of barbed-wire fence installed along the left bank of the creek. Acquisition and transporting of construction materials to the site was initiated on 9 August 2016 (Photo 1 to Photo 3). Construction of the instream structures began on 11 August and was completed by 16 August 2016 (Photo 4 to Photo 10). Two types of excavators were used at this site (Volvo EC330CL and Komatsu PC200LC). Ballast requirements for the LWD structures as determined during the design phase are shown in Table 2. The quantity of materials used in construction was compared to the design requirements for ballast in Table 3. The fence was constructed from 16–19 August and 14–16 September 2016.

4.2 Bulkley River at Groot Farm

The Groot Farm project site was located on the upper Bulkley River approximately 22 km northeast of Houston, BC (Table 1; Figure 2). Constructed works involved six LWD structures installed along a 75-m reach (Figure 6) and 130 m of barbed-wire fence installed along the right bank of the river. Acquisition and transporting of construction materials to the site was initiated on 5 September 2016, and construction of the instream structures occurred from 7–13 September 2016 (Photo 11 to Photo 16). A Caterpillar 322B excavator was used at this site. Ballast requirements for the LWD structures as determined during the design phase are shown in Table 4. The quantity of materials used in construction was compared to the design requirements for ballast in Table 5.

Figure 5. As-built plan view of rehabilitation works at the lower Maxan Creek site.

Table 2. Structure locations and quantities of materials at the Lower Maxan Creek rehabilitation site as estimated during the design phase.

Site (m)	Structure Type	Right or Left Bank	LWD Required (no. of logs)	LWD Size (m)	LWD Ballast		Comments
					Boulders Required	Dia. (m)	
0	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
20	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
40	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
55	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
75	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
95	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
105	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
	Total		35		63		

Note:

1. Groin riprap - gradation for Class 250 kg riprap: 85% larger than 25 kg (0.3 m); 50% larger than 250 kg (0.6 m); and 15% larger than 750 kg (0.8 m) (Northwest Hydraulic Consultants Ltd. 2000).

Table 3. Quantities of materials used in LWD structure construction at the Lower Maxan Creek rehabilitation site.

Structure Number	Type of Structure	Large Woody Debris: Diameter (m)	Large Woody Debris: Log Type - Rootwad (RW), No Rootwad (NRW)	Large Woody Debris: Buried Length (m)	Large Woody Debris: Potentially Submerged Length (m)	Estimated Total Mass of Ballast Required (kg)[a]	Boulder Ballast Provided: Number of Boulders	Boulder Ballast Provided: Mean Diameter (m)	Boulder Ballast Provided: Total Mass of Ballast Provided (kg)
0+000	DJ-5	0.35	RW	6	6				
		0.55	NRW	6	6				
		0.35	RW	6	6				
		0.55	NRW	6	6				
		0.35	RW	6	6	6,550	8	1.03	17,920
0+035	DJ-5	0.60	RW	6	6				
		0.65	NRW	6	6				
		0.30	RW	6	6				
		0.50	NRW	4.5	6				
		0.40	RW	6	6	6,550	10	0.84	8,660
0+055	DJ-5	0.45	RW	6	6				
		0.65	NRW	5	6				
		0.40	RW	6	6				
		0.50	RW	6	6				
		0.65	NRW	6	6	6,550	9	1.00	15,700
0+075	DJ-5	0.45	RW	6	6				
		0.45	NRW	6	6				
		0.35	RW	6	6				
		0.70	RW	4	6				
		0.65	NRW	6	6	6,550	10	0.89	10,180
0+095	DJ-5	0.50	RW	6	6				
		0.65	NRW	6	6				
		0.45	RW	6	6				
		0.55	NRW	6	6				
		0.45	RW	6	6	6,550	8	1.25	23,750
0+115	DJ-5	0.40	RW	6	6				
		0.70	NRW	6	6				
		0.45	RW	6	6				
		0.40	NRW	6	6				
		0.60	RW	6	6	6,550	9	0.93	11,090
0+135	DJ-5	0.40	RW	5	6				
		0.60	NRW	6	6				
		0.40	RW	6	6				
		0.40	RW	6	6				
		0.60	NRW	6	6	6,550	10	0.82	8,060

[a] Ballast estimate calculation assumes a multiple-LWD structure (assumes all logs are cut logs only) that is anchored to live trees on the streambank, factor of safety for buoyancy of 1.5, and design velocity of 2.5 m/s (D'Aoust and Miller 1999). See Table 15 in Gaboury and Smith (2016) for more detail.

Figure 6. As-built plan view of rehabilitation works at the Groot Farm site on the upper Bulkley River.

Table 4. Structure locations and quantities of materials at the Groot Farm rehabilitation site on the upper Bulkley River as estimated during the design phase.

Site (m)	Structure Type	Right or Left Bank	LWD Required (no. of logs)	LWD Size (m)	LWD Ballast		Comments
					Boulders Required	Dia. (m)	
0	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
20	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
40	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
60	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
80	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
98	DJ-5	Right	5	0.5 x 10-12	9	0.8	Logs with rootwads
	Total		30		54		

Note:

1. Groin rip rap - gradation for Class 250 kg rip rap: 85% larger than 25 kg (0.3 m); 50% larger than 250 kg (0.6 m); and 15% larger than 750 kg (0.8 m) (Northwest Hydraulic Consultants Ltd. 2000).

Table 5. Quantities of materials used during LWD structure construction at the Groot Farm rehabilitation site on the upper Bulkley River.

		Large Woody Debris				Estimated Total Mass of Ballast Required (kg)[a]	Boulder Ballast Provided		
Structure Number	Type of Structure	Diameter (m)	Log Type - Rootwad (RW), No Rootwad (NRW)	Buried Length (m)	Potentially Submerged Length (m)		Number of Boulders	Mean Diameter (m)	Total Mass of Ballast Provided (kg)
0+000	DJ-5	0.45	RW	6	6				
		0.45	RW	6	6				
		0.60	NRW	6	6				
		0.45	RW	6	6				
		0.70	NRW	6	6	6,550	10	0.88	10,880
0+015	DJ-5	0.55	RW	6	6				
		0.50	RW	6	6				
		0.65	NRW	6	6				
		0.50	RW	6	6				
		0.70	NRW	6	6	6,550	10	0.80	6,940
0+030	DJ-5	0.40	RW	6	6				
		0.70	NRW	6	6				
		0.45	RW	6	6				
		0.70	NRW	6	6				
		0.40	RW	6	6	6,550	10	0.85	8,630
0+045	DJ-5	0.45	RW	6	6				
		0.65	NRW	6	6				
		0.65	RW	6	6				
		0.50	RW	6	6				
		0.65	NRW	6	6	6,550	10	0.77	6,580
0+060	DJ-5	0.50	RW	6	6				
		0.65	NRW	5	6				
		0.40	RW	6	6				
		0.40	RW	6	6				
		0.70	NRW	5	6	6,550	10	0.93	13,510
0+075	DJ-5	0.40	RW	6	6				
		0.65	NRW	4	6				
		0.45	RW	6	6				
		0.45	RW	6	6				
		0.65	NRW	5	6	6,550	10	1.00	16,990

[a] Ballast estimate calculation assumes a multiple-LWD structure (assumes all logs are cut logs only) that is anchored to live trees on the streambank, factor of safety for buoyancy of 1.5, and design velocity of 2.5 m/s (D'Aoust and Miller 1999). See Table 24 in Gaboury and Smith (2016) for more detail.

4.3 Bulkley River at McKilligan Road (Upper)

The McKilligan Road (Upper) project site was located on the upper Bulkley River approximately 8.8 km northeast of Houston, BC (Table 1; Figure 2). Constructed works involved twelve LWD structures and four rock groins installed along a 290-m reach (Figure 7) and 341 m of barbed-wire fence installed along the left bank of the river. Acquisition and transporting of construction materials to the site was initiated on 26 September 2016, and construction of the instream structures occurred from 28 September to 4 October 2016 (Photo 17 to Photo 24). Two types of excavator were used at this site (Caterpillar 34 and Caterpillar 330FB). Ballast requirements for the LWD structures as determined during the design phase are shown in Table 6. The quantity of materials used in construction was compared to the design requirements for ballast in Table 7. The fence was constructed from 4–5 October 2016.

4.4 Bulkley River at McKilligan Road (Lower)

The McKilligan Road (Upper) project site was located on the upper Bulkley River approximately 8.8 km northeast of Houston, BC (Table 1; Figure 2). Constructed works involved seven LWD structures and two rock groins installed along a 160-m reach (Figure 8) and 198 m of barbed-wire fence installed along the left bank of the river. Acquisition and transporting of construction materials to the site was initiated on 19 September 2016, and construction of the instream structures occurred from 20–24 September 2016 (Photo 25 to Photo 32). Two types of excavator were used at this site (Caterpillar 34 and Caterpillar 330FB). Ballast requirements for the LWD structures as determined during the design phase are shown in Table 8. The quantity of materials used in construction was compared to the design requirements for ballast in Table 9. The fence was constructed from 3–4 October 2016.

5 CONSTRUCTION MONITORING

An environmental monitor (Jason Smith, LGL) was on site daily throughout the project. The environmental monitor ensured that the proposed works had minimal or no impact on the fish habitat of Maxan Creek or the upper Bulkley River, as per the environmental protocol outlined in Appendices A and B in Gaboury and Smith (2016). All land-based equipment or machinery operated from the upland and thus did not enter either watercourse. Visual observations at all sites showed no significant increases in turbidity as result of construction activities. No fuel or oil spills occurred during construction, and all construction equipment was fueled at least 30 m from the river.

Figure 7. As-built plan view of rehabilitation works at the McKilligan Road (Upper) site on the upper Bulkley River.

Table 6. Structure locations and quantities of materials at the McKilligan Road (Upper) rehabilitation site on the upper Bulkley River as estimated during the design phase.

Site (m)	Structure Type	Right or Left Bank	LWD Required (no. of logs)	LWD Size (m)	LWD Ballast		Groin Riprap		Comments
					Boulders Required	Dia. (m)	Dia. (m)	Volume (m^3)	
0	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
20	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
40	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
60	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
80	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
97	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
120	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
140	Groin	Left					0.3-0.8	43	See Note 1
160	Groin	Left					0.3-0.8	43	See Note 1
180	Groin	Left					0.3-0.8	43	See Note 1
200	DJ-6	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
220	DJ-6	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
240	DJ-6	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
260	DJ-6	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
274	DJ-6	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
290	Groin	Left					0.3-0.8	43	See Note 1
	Total		60		108			172	

Note:

1. Groin riprap - gradation for Class 250 kg riprap: 85% larger than 25 kg (0.3 m); 50% larger than 250 kg (0.6 m); and 15% larger than 750 kg (0.8 m) (Northwest Hydraulic Consultants Ltd. 2000).

Table 7. Quantities of materials used during construction at the McKilligan Road (Upper) rehabilitation site on the upper Bulkley River.

		Large Woody Debris				Estimated	Boulder Ballast Provided		
Structure Number	Type of Structure	Diameter (m)	Log Type - Rootwad (RW), No Rootwad (NRW)	Buried Length (m)	Potentially Submerged Length (m)	Total Mass of Ballast Required (kg) [a]	Number of Boulders	Mean Diameter (m)	Total Mass of Ballast Provided (kg)
0+000	DJ-5	0.50	RW	6	6				
		0.50	NRW	8	6				
		0.50	RW	6	6				
		0.50	RW	6	6				
		0.60	NRW	7	6	6,550	10	0.86	9,240
0+019	DJ-5	0.40	RW	6	6				
		0.50	NRW	4	6				
		0.60	RW	6	6				
		0.60	RW	6	6				
		0.60	NRW	6	6	6,550	9	1.03	21,470
0+038	DJ-5	0.45	RW	6	6				
		0.55	NRW	6	6				
		0.45	RW	6	6				
		0.45	RW	6	6				
		0.55	NRW	7	6	6,550	10	0.84	8,150
0+058	DJ-5	0.45	RW	6	6				
		0.45	NRW	6	6				
		0.35	RW	6	6				
		0.50	RW	6	6				
		0.70	NRW	6	6	6,550	9	0.96	17,530
0+077	DJ-5	0.45	RW	6	6				
		0.50	NRW	6	6				
		0.35	RW	6	6				
		0.40	RW	6	6				
		0.50	NRW	6	6	6,550	10	0.80	7,110
0+096	DJ-5	0.45	RW	6	6				
		0.65	NRW	5	6				
		0.65	RW	6	6				
		0.50	RW	6	6				
		0.50	NRW	4	6	6,550	9	1.06	29,490
0+112	DJ-5	0.45	RW	6	6				
		0.60	NRW	6	6				
		0.40	RW	6	6				
		0.45	RW	6	6				
		0.60	NRW	6	6	6,550	10	0.84	8,640
0+192	DJ-5	0.35	RW	6	6				
		0.40	NRW	6	6				
		0.60	RW	6	6				
		0.55	NRW	6	6				
		0.55	RW	6	6	6,550	10	1.05	16,980

Table 7. Continued.

		Large Woody Debris				Estimated	Boulder Ballast Provided		
Structure Number	Type of Structure	Diameter (m)	Log Type - Rootwad (RW), No Rootwad (NRW)	Buried Length (m)	Potentially Submerged Length (m)	Total Mass of Ballast Required (kg) [a]	Number of Boulders	Mean Diameter (m)	Total Mass of Ballast Provided (kg)
0+212	DJ-5	0.40	RW	6	6				
		0.50	NRW	5	6				
		0.50	RW	6	6				
		0.45	RW	4	6				
		0.50	NRW	6	6	6,550	10	0.85	8,690
0+231	DJ-5	0.45	RW	6	6				
		0.60	NRW	4	6				
		0.45	RW	6	6				
		0.55	NRW	4	6				
		0.55	RW	6	6	9,180	9	0.97	17,690
0+250	DJ-5	0.45	RW	6	6				
		0.65	NRW	6	6				
		0.50	RW	6	6				
		0.40	NRW	6	6				
		0.55	RW	6	6	6,550	10	0.84	8,420
0+268	DJ-5	0.45	RW	6	6				
		0.65	NRW	6	6				
		0.50	RW	6	6				
		0.40	RW	6	6				
		0.50	NRW	6	6	6,550	10	0.87	9,360

[a] Ballast estimate calculation assumes a multiple-LWD structure (assumes all logs are cut logs only) that is anchored to live trees on the streambank, factor of safety for buoyancy of 1.5, and design velocity of 2.5 m/s (D'Aoust and Miller 1999). See Table 12 in Gaboury and Smith (2016) for more detail.

Figure 8. As-built plan view of rehabilitation works at the McKilligan Road (Lower) site on the upper Bulkley River.

Table 8. Structure locations and quantities of materials at the McKilligan Road (Lower) rehabilitation site on the upper Bulkley River as estimated during the design phase.

Site (m)	Structure Type	Right or Left Bank	LWD Required (no. of logs)	LWD Size (m)	LWD Ballast		Groin Riprap		Comments
					Boulders Required	Dia. (m)	Dia. (m)	Volume (m^3)	
0	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
20	Groin	Left					0.3-0.8	43	See Note 1
40	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
60	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
80	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
100	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
120	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
140	DJ-5	Left	5	0.5 x 10-12	9	0.8			Logs with rootwads
160	Groin	Left					0.3-0.8	43	See Note 1
	Total		35		63			86	

Note:

1. Groin riprap - gradation for Class 250 kg riprap: 85% larger than 25 kg (0.3 m); 50% larger than 250 kg (0.6 m); and 15% larger than 750 kg (0.8 m) (Northwest Hydraulic Consultants Ltd. 2000).

Table 9. Quantities of materials used during construction at the McKilligan Road (Lower) rehabilitation site on the upper Bulkley River.

		Large Woody Debris				Estimated Total Mass of Ballast Required (kg)[a]	Boulder Ballast Provided		
Structure Number	Type of Structure	Diameter (m)	Log Type - Rootwad (RW), No Rootwad (NRW)	Buried Length (m)	Potentially Submerged Length (m)		Number of Boulders	Mean Diameter (m)	Total Mass of Ballast Provided (kg)
0+000	DJ-5	0.35	RW	6	6				
		0.55	NRW	6	6				
		0.35	RW	6	6				
		0.55	NRW	6	6				
		0.35	RW	6	6	6,550	8	1.03	17,920
0+035	DJ-5	0.60	RW	6	6				
		0.65	NRW	6	6				
		0.30	RW	6	6				
		0.50	NRW	4.5	6				
		0.40	RW	6	6	6,550	10	0.84	8,660
0+055	DJ-5	0.45	RW	6	6				
		0.65	NRW	5	6				
		0.40	RW	6	6				
		0.50	RW	6	6				
		0.65	NRW	6	6	6,550	9	1.00	15,700
0+075	DJ-5	0.45	RW	6	6				
		0.45	NRW	6	6				
		0.35	RW	6	6				
		0.70	RW	4	6				
		0.65	NRW	6	6	6,550	10	0.89	10,180
0+095	DJ-5	0.50	RW	6	6				
		0.65	NRW	6	6				
		0.45	RW	6	6				
		0.55	NRW	6	6				
		0.45	RW	6	6	6,550	8	1.25	23,750
0+115	DJ-5	0.40	RW	6	6				
		0.70	NRW	6	6				
		0.45	RW	6	6				
		0.40	NRW	6	6				
		0.60	RW	6	6	6,550	9	0.93	11,090
0+135	DJ-5	0.40	RW	5	6				
		0.60	NRW	6	6				
		0.40	RW	6	6				
		0.40	RW	6	6				
		0.60	NRW	6	6	6,550	10	0.82	8,060

[a] Ballast estimate calculation assumes a multiple-LWD structure (assumes all logs are cut logs only) that is anchored to live trees on the streambank, factor of safety for buoyancy of 1.5, and design velocity of 2.5 m/s (D'Aoust and Miller 1999). See Table 15 in Gaboury and Smith (2016) for more detail.

6 REFERENCES

D'Aoust, S.G., and R.G. Millar. 1999. Large woody debris fish habitat structure performance and ballasting requirements. BC Ministry of Environment, Lands and Parks, and BC Ministry of Forests, Watershed Restoration Program, Management Report No. 8, 119 pp.

Gaboury, M.N., and J.J. Smith. 2016. Development of aquatic restoration designs and on-farm cattle management improvements within the Wet'suwet'en First Nation territory. Prepared for the Fish Habitat Restoration Initiative, Fisheries and Oceans Canada, Kamloops, BC, by the Yinka Dene Economic Development Limited Partnership Inc., Burns Lake, BC, and LGL Limited, Sidney, BC.

Melville, C. 1997. Securing instream structures: epoxy attachment method. Streamline, BC Stream Restoration Technical Bulletin. Vol.2, No.1.

Northwest Hydraulic Consultants Ltd. 2000. Riprap design and construction guide. Prepared for Public Safety Section, Water Management Branch, BC Ministry of Environment, Lands and Parks, Victoria, BC.

PHOTO PLATES

Photo 1. Lower Maxan Creek – Self-loading logging truck delivering logs from West Fraser in Houston (9 August 2016).

Photo 2. Lower Maxan Creek – High-lift dump truck delivering ballast rocks for LWD structures (9 August 2016).

Photo 3. Lower Maxan Creek – John Deere skidder transporting a log with rootwad attached to the site from a nearby area (12 August 2016).

Photo 4. Lower Maxan Creek – Three upstream-facing logs and ballast rocks in a trench at 0+055 m during construction (13 August 2016).

Photo 5. Lower Maxan Creek – Two downstream-facing logs and ballast rocks in a trench at 0+055 m during construction (13 August 2016).

Photo 6. Lower Maxan Creek – Looking upstream at the LWD structure at 0+085 m after construction (14 August 2016).

Photo 7. Lower Maxan Creek – Looking upstream from 0+000 m before construction (14 October 2015).

Photo 8. Lower Maxan Creek – Looking upstream from 0+000 m after construction (19 August 2016).

Photo 9. Lower Maxan Creek – Looking downstream from ~0+095 m before construction (14 October 2015).

Photo 10. Lower Maxan Creek – Looking upstream from 0+080 m after construction (19 August 2016).

Photo 11. Bulkley River at Groot Farm – An excavator placing a log with rootwad attached in a trench at 0+030 m (8 September 2016).

Photo 12. Bulkley River at Groot Farm – Securing ballast rocks to logs using epoxy and 12.7 mm diameter cable at 0+015 m (7 August 2016).

Photo 13. Bulkley River at Groot Farm – Looking upstream at a LWD structure at 0+045 m after construction (9 September 2016).

Photo 14. Bulkley River at Groot Farm – Looking upstream from just below 0+000 m after construction (25 September 2016).

Photo 15. Bulkley River at Groot Farm – Looking downstream from ~0+085 m before construction (7 September 2016).

Photo 16. Bulkley River at Groot Farm – Looking downstream from ~0+085 m after construction (25 September 2016).

Photo 17. Bulkley River at McKilligan Rd (Upper) – Looking downstream from 0+287 m before construction (9 September 2016).

Photo 18. Bulkley River at McKilligan Rd (Upper) – Looking downstream from 0+295 m after construction (5 October 2016).

Photo 19. Bulkley River at McKilligan Rd (Upper) – Looking upstream from 0+192 m after construction (5 October 2016).

Photo 20. Bulkley River at McKilligan Rd (Upper) – Looking downstream from 0+192 m after construction (5 October 2016).

Photo 21. Bulkley River at McKilligan Rd (Upper) – Looking upstream from 0+140 m before construction (8 October 2015).

Photo 22. Bulkley River at McKilligan Rd (Upper) – Looking upstream from 0+134 m after construction (5 October 2016).

Photo 23. Bulkley River at McKilligan Rd (Upper) – Looking upstream from 0+000 m before construction (8 October 2015).

Photo 24. Bulkley River at McKilligan Rd (Upper) – Looking upstream from 0+000 m after construction (5 October 2016).

Photo 25. Bulkley River at McKilligan Rd (Lower) – Looking downstream at an excavator constructing a rock groin at 0+287 m (24 September 2016).

Photo 26. Bulkley River at McKilligan Rd (Lower) – Looking downstream at the rock groin at 0+018 m after construction (23 September 2016).

Photo 27. Bulkley River at McKilligan Rd (Lower) – Looking downstream from 0+160 m before construction (8 October 2015).

Photo 28. Bulkley River at McKilligan Rd (Lower) – Looking downstream from 0+165 m after construction (2 October 2016).

Photo 29. Bulkley River at McKilligan Rd (Lower) – Looking downstream from 0+080 m before construction (8 October 2015).

Photo 30. Bulkley River at McKilligan Rd (Lower) – Looking downstream from 0+100 m after construction (2 October 2016).

Photo 31. Bulkley River at McKilligan Rd (Lower) – Looking upstream from 0+000 m before construction (8 October 2015).

Photo 32. Bulkley River at McKilligan Rd (Lower) – Looking upstream from just below 0+000 m after construction (2 October 2016).