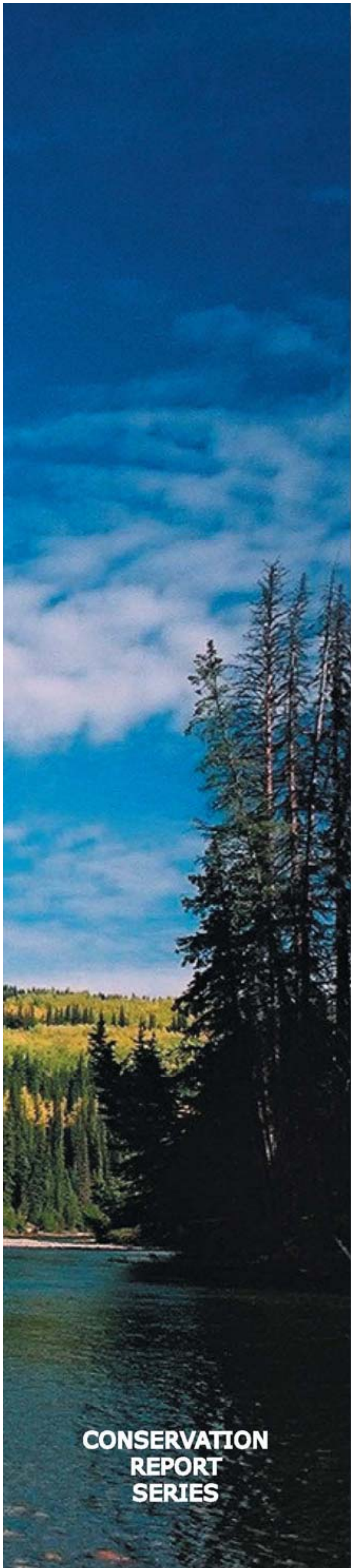

Swan River Arctic Grayling and Watercourse Crossing Assessment

Alberta Conservation Association

Conserving Alberta's Wild Side

The Alberta Conservation Association is a Delegated Administrative Organization under Alberta's Wildlife Act.

Swan River Arctic Grayling and Watercourse Crossing Assessment

Brad Hurkett and Logan Redman
Alberta Conservation Association
101 – 9 Chippewa Road
Sherwood Park, Alberta, Canada
T8A 6J7

Alberta Conservation Association
Conserving Alberta's Wild Side

Report Editors
PETER AKU
Alberta Conservation Association
101 – 9 Chippewa Rd.
Sherwood Park, AB T8A 6J7

KELLEY KISSNER
50 Tuscany Meadow Cres. NW
Calgary, AB T3L 2T9

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Alberta Conservation Association
101 – 9 Chippewa Rd.
Sherwood Park, AB T8A 6J7
Toll Free: 1-877-969-9091
Tel: (780) 410-1998
Fax: (780) 464-0990
Email: info@ab-conservation.com
Website: www.ab-conservation.com

EXECUTIVE SUMMARY

The Swan River Arctic grayling population has decreased drastically because of habitat fragmentation and degradation from extensive road networks and high densities of stream crossings associated with industrial development in the watershed. In 2002, Alberta Conservation Association conducted a stream-crossing inventory that identified 195 culvert crossings, of which approximately 70% were fish barriers. In 2015, we reassessed the status of Arctic grayling and stream crossings in the watershed to generate data to support the development of the provincial Arctic grayling Fish Sustainability Index (FSI) and regulatory plans to remediate the effects of industrial activities on Arctic grayling in the watershed. We collected data on the distribution, relative abundance and population structure of Arctic grayling (≥150 mm fork length; FL) and on the level of fragmentation in the watershed associated with stream crossings.

Stream crossings were assessed using the Alberta government's Watercourse Crossing Inspection Protocol, focusing on three main fish passage and habitat components, including erosion and sedimentation, culvert placement and condition, and outlet gap height and outfall pool depth. We sampled fish by angling, which aligns with the Arctic grayling FSI sampling protocol. The information collected from crossing assessments permitted us to identify fish barriers and consequently determine the degree of fragmented habitat in the Swan River watershed.

From June 28 to July 31, 2015, we assessed 218 stream crossings in the Swan River watershed, of which 195 crossings were previously assessed in 2002. A total of 66 (30%) crossings were dry, likely due to the historically low stream flows that occurred in 2015; 10 additional sites were ephemeral and non-fluvial. Of the remaining 142 fluvial sites, 131 crossings were impassable to fish; only 11 (8%) stream crossings permitted fish passage. Approximately 737 km of stream (25% of the total stream length in the Swan River watershed) have been fragmented due to damage or poorly installed crossing structures, predominantly in low-order streams.

We completed fish sampling (angling) at 62 sites and sampled a total of 31 km of stream between July and August 2016. We did not observe grayling at 17 sites, 5 of which were located upstream of fish barriers. Most grayling were captured in order-4 streams; most sites where grayling were not observed were in order-3 streams. We captured a total of 431 Arctic grayling, ranging in length between 67 and 315 mm FL, only 6 of which were adult fish (≥283 mm FL). Catch rates for immature grayling (150 – 282 mm FL) ranged between 0 and 13.5 fish/h and averaged (± SE) 1.48 ± 0.31 fish/h (n = 274); catch rates for adult grayling ranged between 0 and 1 fish and averaged 0.03 ± 0.02 fish/h (n = 6). Catches of immature grayling were highest in order-4 and -5 streams and lowest in order-3 and -6 streams; the few adults were only captured in order-5 and -6 streams.

Key words: abundance, angling, Arctic grayling, distribution, fish barrier, habitat fragmentation, stream-crossing inventories, Swan River watershed.

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1.0 INTRODUCTION

Alberta`s Arctic grayling (*Thymallus arcticus*) populations have declined drastically in abundance and distribution as a result of habitat fragmentation and degradation, and overfishing (Alberta Sustainable Resource Development [ASRD] 2005). Roads and other linear developments associated with industrial development have greatly impacted grayling populations because improper watercourse crossings impede fish passage and degrade fish habitat; road access also leads to overfishing. Linear developments adjacent to streams contribute to increased sediment loads, which degrade fish habitat and reduce fish health by covering clean spawning bed gravels and reducing water quality (i.e., reduced clarity and light penetration, increased water temperatures) (Derksen 1980; Warren and Pardew 1998; Tchir et al. 2003). The greatest declines have occurred in the species' southern range, where up to half of the grayling populations have decreased by up to 90% in abundance (ASRD 2005). As a result, Arctic grayling is designated as *Sensitive* in Alberta (see the *General Status of Alberta Wild Species*; Alberta Environment and Parks 2010).

Stream connectivity is vital for Arctic grayling, a highly migratory species, as it uses different streams to fulfill its specific life history requirements. Fragmented habitat threatens grayling populations by altering population structure and disrupting gene flow, which can ultimately lead to extirpation (Winston et al. 1991; Morita and Yokota 2002; Park 2006). Extensive road networks and high densities of stream crossings associated with industrial development have reduced grayling populations in the Swan River watershed. Previous surveys showed that 74% of culverts in the Swan River watershed acted as barriers to fish passage and prevented fish from accessing 20% of the headwaters (Tchir et al. 2003).

In 2015, we reassessed the status of grayling and stream crossings in the Swan River watershed to generate data that support the development of the provincial Arctic grayling Fish Sustainability Index (FSI) and regulatory actions to remediate the effects of industrial activities on Arctic grayling stocks and their habitats. We collected data on the distribution, relative abundance and population structure of Arctic grayling (≥150 mm fork length; FL) and on the level of fragmentation in the watershed due to stream crossings. The specific objectives of our study were to

- evaluate the condition of stream crossings assessed throughout the Swan River watershed;
- determine the extent of habitat fragmentation due to stream crossings in the watershed; and
- determine the distribution, relative abundance and population structure of Arctic grayling (≥150 mm FL) in the watershed.

We conducted stream crossing surveys across the entire watershed, but Arctic grayling population assessments were conducted within the HUC 8 (Hydrological Code Unit) portion only, in alignment with FSI protocols (Government of Alberta 2014a).

2.0 STUDY AREA

The Swan River watershed is located in the Swan Hills between the communities of Swan Hills and Kinuso, Alberta. The river originates from the Swan Hills (1,300 m elevation) and drains through the watershed southward into Lesser Slave Lake (580 m elevation) (Figure 1). The watershed area and total stream length are 3,117 km^2 and 2,967 km, respectively. Major tributaries entering the Swan River include the Inverness and Moosehorn rivers and Chalmers, Boulder, Jerry, Island and Adams creeks.

The Swan Hills occupy the Foothills Natural Region, Upper and Lower Foothills subregions, which are dominated by lodgepole pine, white and black spruce, and balsam and aspen poplar forests (Natural Regions Committee 2006). Eleven fish species inhabit the Swan River watershed, including Arctic grayling, northern pike (*Esox lucius*), walleye (*Sander vitreus*), longnose sucker (*Catostomus catostomus*), and several cyprinid species (Scrimgeour et al. 2003). Stream fishing in the watershed is popular among local anglers.

Roads and other linear networks associated with oil and gas development and forestry have drastically altered the landscape. Road density in the Swan River watershed is estimated to be between 1.10 and 1.21 km/km^2 (Tchir et al. 2003; Management and Solution in Environmental Science 2011). Our study area encompasses the entire watershed and surrounding sub-sheds previously surveyed in 2002.

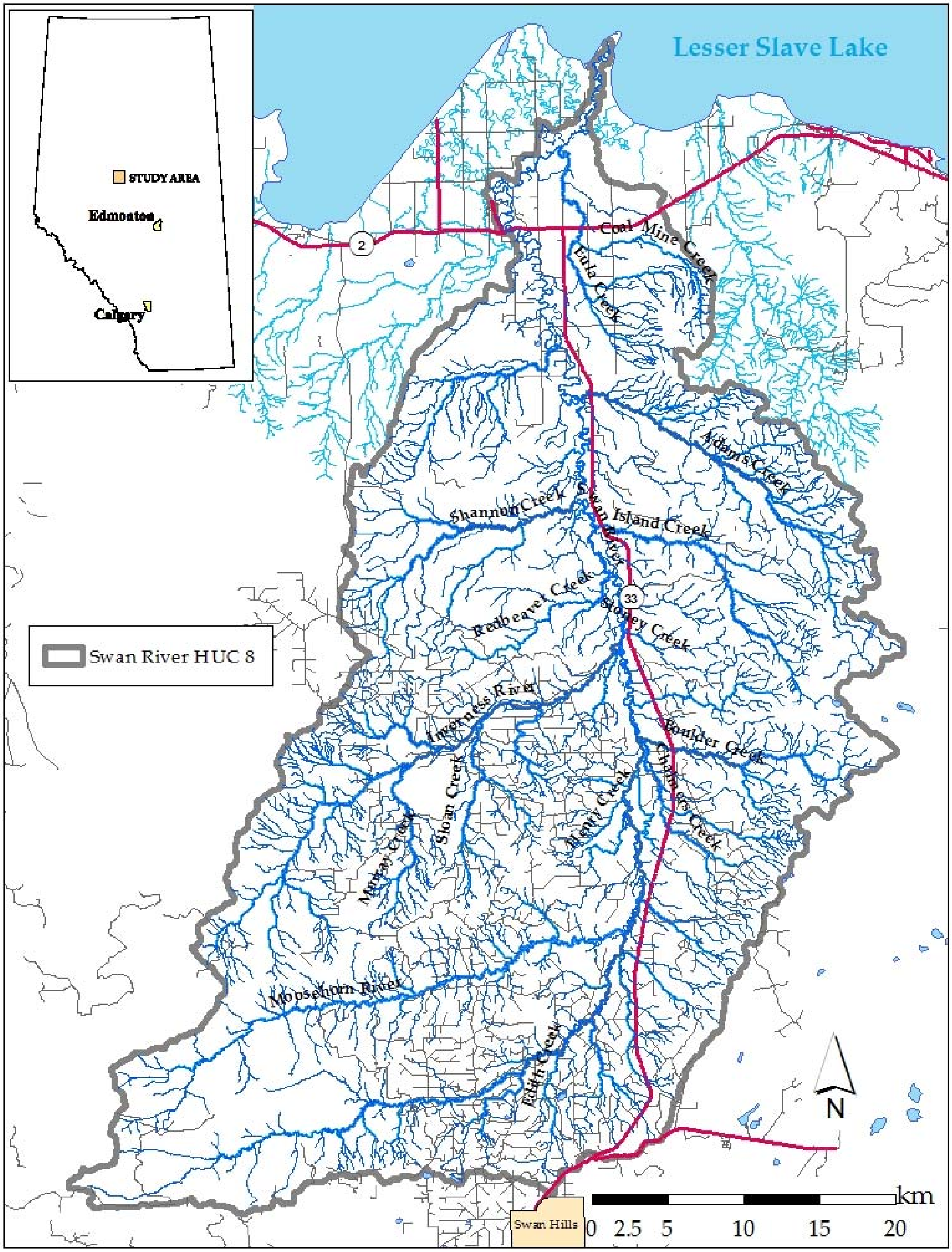

Figure 1. Swan River Arctic grayling and watershed connectivity assessment study area, 2015.

3.0 MATERIALS AND METHODS

3.1 Stream crossing assessment

From June 28 to July 31, 2015, we assessed stream crossings throughout the Swan River watershed using the Alberta government's Watercourse Crossing Inspection Protocol (WCIP) (Government of Alberta 2014b). The WCIP is different from the rapid assessment protocol used for the 2002 survey (Tchir et al. 2003). The WCIP is more efficient and requires less time to complete, but the two protocols are similar and produce comparable fish passage results (Government of Alberta 2014b). New crossings were identified using geographic information systems or were discovered during field assessments. Crossings were selected using ArcMap 10.1© by identifying intersection points between a Government of Alberta Resource Management Information Branch hydro line data layer and current linear feature layers (e.g., roads, cutlines and pipelines). We assessed a total of 218 crossings (Figure 2), of which 195 were previously assessed in 2002 (Tchir et al. 2003) and 23 were newly discovered crossings.

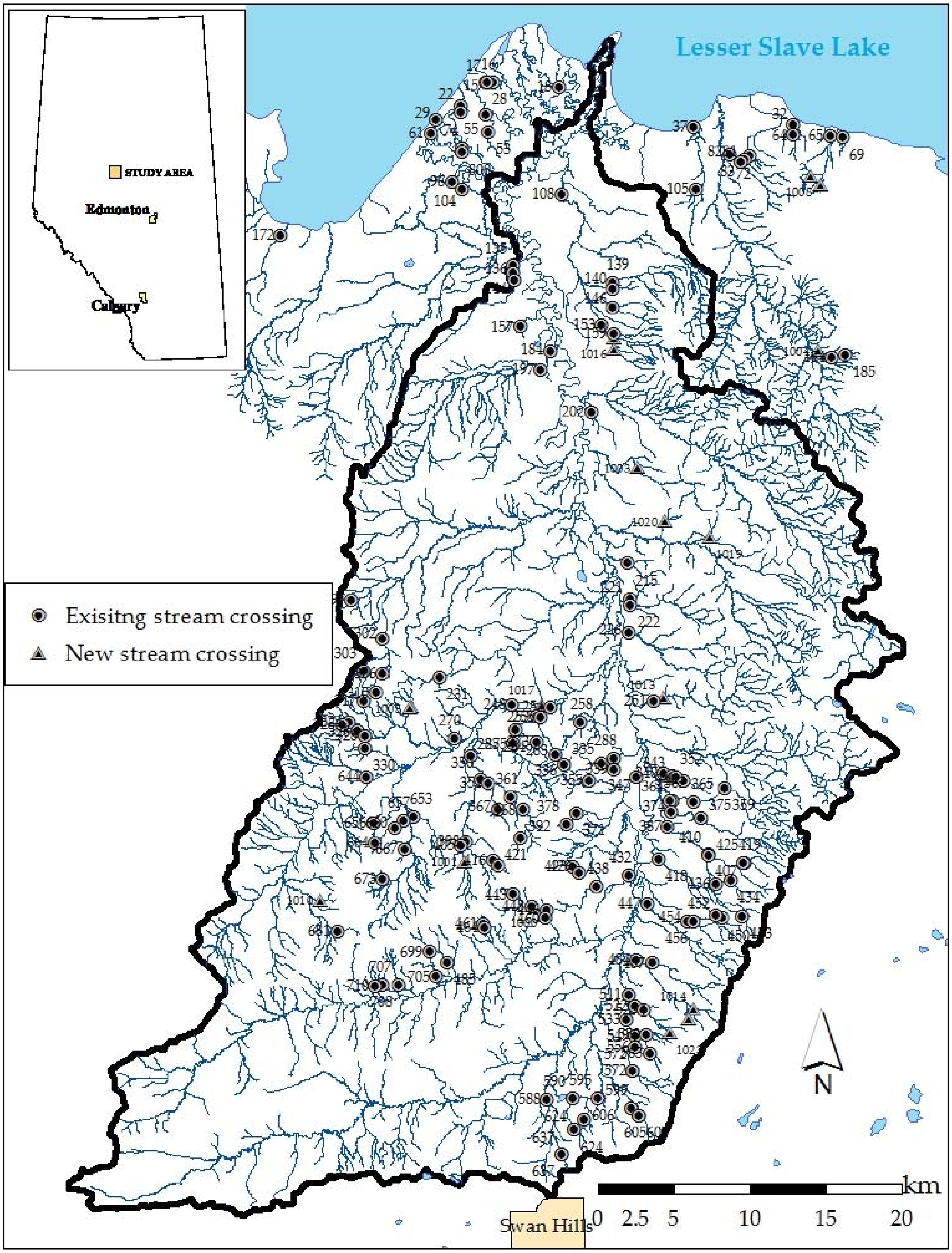

Figure 2. Watercourse crossings assessed in the Swan River watershed and surrounding sub-sheds in 2015.

Crossing inspections were completed by one 2-person crew. We conducted initial inspections to classify streams as fluvial, non-fluvial or ephemeral; fluvial streams were sub-classified as large-permanent, small-permanent or intermittent (see Appendix 1 for stream classification criteria). Data collected included site reference geographic coordinates (UTM), waterbody name, crossing ID, stream channel bankfull width (m) downstream of the crossing, and crossing type (i.e., whether the crossing was a bridge, culvert, ford, fill-log or reclaimed; see Appendix 2 for crossing-variable categories). We completed full crossing inspections on fluvial streams only.

We focused our full crossing inspections on three fish habitat and connectivity parameters: erosion and sedimentation, culvert placement and condition, and outlet gap height and outfall pool depth. Our evaluation of erosion and sedimentation included identifying potential erosion source(s) and estimating the extent and area (m^2) of all eroded areas. Our evaluation of culvert placement and condition included identifying whether culverts were blocked (>10% blocked), sloped, bent, embedded or damaged; had backwater flow and substrate inside; and were appropriately sized in relation to stream size. Outlet gap height and outfall pool depth were measured using a measuring staff. Outlet gap height was measured as the distance between the water surface and the culvert bottom, and outfall pool depth was measured in the deepest depth of the pool; both were measured to the nearest 0.1 m. Both outlet gap height and outfall pool depth helped us determine if pool scouring was present at each site. Photographs of each crossing, both inlet and outlet, were taken as a visual aid in the stream-crossing inventory.

Using McCleary et al.'s (2004) fish barrier criteria, we categorized culverts based on fish passage potential as *no barrier*, *potential barrier* and *full barrier* (Appendix 3). We designated full barrier and potential barrier crossings as fish barriers and quantified the level of fragmented fish habitat by measuring the stream length of all streams per stream order upstream of barriers using ArcGIS 10.1©. Categorizing fish passage potential for dry culvert crossings was difficult because we could not fairly assess if the crossing would permit fish passage. To account for this uncertainty, we calculated fragmented habitat for identified fish-barrier crossings alone, and both fish-barrier crossings and dry crossings; future crossing assessments would be required to validate fish passage potential at dry crossing sites.

3.2 Arctic grayling sampling

In alignment with the Arctic grayling FSI protocol, we used angling as the standard capture method for the species (Government of Alberta 2014a). Sampling sites were randomly selected without replacement using the General Random Tessellation Stratified (GRTS) design on streams that were third order (Strahler 1957) or higher; lower-order streams were excluded because they are typically smaller, less suitable to angling and have a lower likelihood of fish presence (Fitzsimmons and Blackburn 2009). Using ArcGIS 10.1©, we divided streams into 2,000 m segments and assigned a site location to each segment end, producing a total of 390 potential sites available for selection. Based on our angling experience, we inferred 2,000 m would be the maximum length that could be thoroughly sampled in any size of stream in 90 min. Fish sampling was limited to 32 sampling days, which consisted of two 2-person crews working two 8-day shifts. Based on the total number of sampling days, we estimated that the minimum number of sites that could be sampled in one day would be 1 site and the maximum number would be 5 sites, which equates to sampling between 32 and 192 sites. To ensure we sampled a minimum of 60 sites and allow for an adequate number of oversampled sites, we generated a list of 192 spatially balanced sites (maximum number of sites) using the GRTS selection with the R software program. Non-response sites included dry sites, streams with intermittent flow, sites that neighboured a completed site, or sites that exceeded a distance greater than 1,000 m from the nearest road or trail access.

We sampled 62 sites between July 15 and September 9, 2015; 7 non-response sites were visited but not angled because of low flows (Figure 3). Sites were angled using fly fishing gear and spin cast equipment; we used dry flies and nymphs (size 12 – 20) for fly fishing equipment and spinner hardware (size 1 – 2) for spin casting equipment. We sampled sites in an upstream direction, alternating site reaches between anglers while ensuring our efforts were evenly distributed across all habitat types. Fish sampling was limited to 90 min at each site when fish were observed and 45 min when fish were not observed. Most sites where fish were not observed were typically smaller, non-fluvial streams or streams with intermittent channelling and were angled for 45 min; the few sites in mainstem channels where we expected to catch fish but did not observe fish were angled for a full 90 min. We measured FL for all fish (all species) and clipped fins on all Arctic grayling; fin clips served as both marks for identifying previously captured fish and specimens for DNA analysis.

We collected UTM coordinates with a handheld Global Positioning System (Garmin® GPSmap 62s) at all fish capture sites and at the beginning and end of each site. We estimated relative abundance using fish catch rates (fish/h) for fish >150 mm FL. Fitzsimmons and Blackburn (2009) excluded fish <150 mm FL from their results because capture efficiencies of fish this size were typically below 20%; the FSI scoring criterion for immature grayling also excludes fish <150 mm FL (Government of Alberta 2014a). Stream habitat data, including wetted and rooted channel widths (m), maximum depth (m), and stream type composition (run, riffle, pool), and site photographs were collected at the beginning, middle and end of each site.

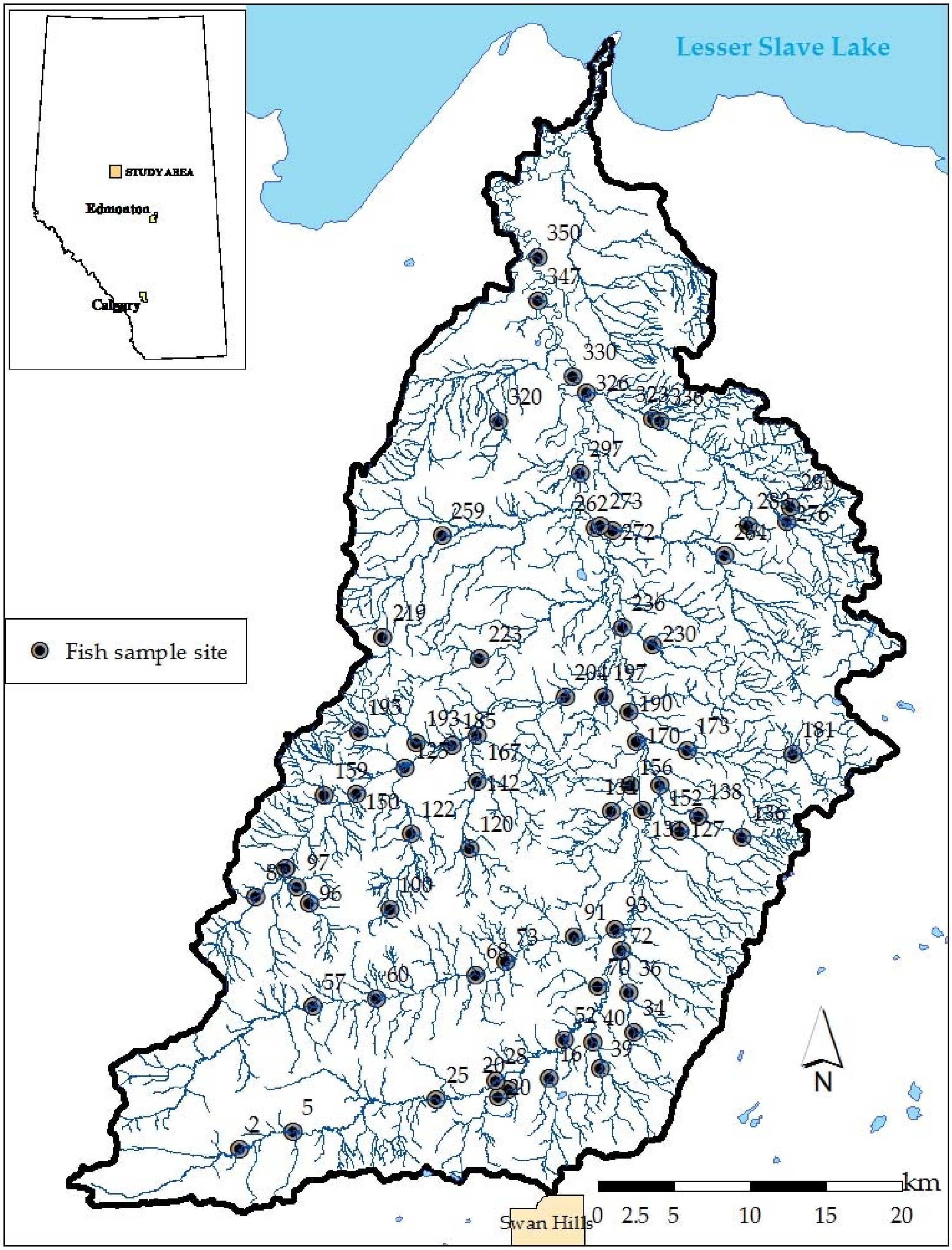

Figure 3. Fish sample sites completed in the Swan River watershed, 2015.

4.0 RESULTS

4.1 Stream crossing assessments

Overall, culverts were the most common stream crossing structure assessed in 2015, and only 4% of the crossings were reclaimed (Table 1). Of the 218 stream crossings we assessed, 66 (30%) were dry, likely due to the historically low stream flows that occurred in 2015 (Appendix 4). Of the remaining 152 crossing sites that had water, 143 were in fluvial streams, all of which but one were culvert crossings, and the remaining 10 sites were in ephemeral and non-fluvial streams.

Table 1. Stream crossing watercourse classification and structure type assessed in the Swan River watershed, 2015 (n = 218).

Stream type	Structure type				
	Culvert(s)	Bridge	Reclaimed	Ford	Log-fill
Fluvial - small	136	1	6	2	1
Fluvial - large	21	–	1	–	–
Fluvial - intermittent	18	–	–	–	–
Non-fluvial	22	–	1	–	–
Ephemeral	9	–	–	–	–

Of the 142 culverts examined at fluvial sites, only 8% (n = 11) were designated as not perched/blocked, thereby permitting fish passage (Table 2). The remaining 92% (n = 131) were classified as fish barriers; this value is much higher than in 2002 (74%; Tchir et al. 2003). Potential barrier crossings (≤0.59 m outlet gap) comprised 59% of total fish barriers identified in the Swan River watershed, followed by full barriers (>0.6 m outlet gap) (33%) and non-perched/blocked barriers (8%).

Fish barriers were most prevalent in small permanent flowing streams (Table 2). Overall, 114 sites had bent or sloped culverts, and 126 sites were affected by pool scouring (Appendix 5). In total, instream erosion occurred at 168 sites, and the extent of unimpeded erodible material entering into streams for most of these sites was rated as either high unsatisfactory (n = 81) or low unsatisfactory (n = 76); 164 of these sites were culverts (Appendix 6). Overall, bank slumping was the most common erosion source, followed by fill slope and road surface (Figure 4). Eight crossings had been reclaimed back to natural flow conditions, four of which were at sites previously assessed in 2002. In general, there has been little to no change in the overall condition of crossings assessed in 2002 (See Appendix 7 for the baseline crossing comparison).

Table 2. Fish barrier severity for culvert crossings in fluvial streams with water throughout the Swan River watershed (n = 131).

Barrier type	Stream type			Total
	Intermittent	Large - permanent	Small - permanent	
Full perched/blocked/shallow	0	0	2	2
Full perched barrier	2	2	20	24
Full barrier/shallow	0	2	2	4
Full barrier/blocked	1	1	11	13
Potential perched/shallow/blocked	0	2	19	21
Potential perched barrier	2	1	8	11
Potential barrier/shallow	4	3	26	33
Potential barrier/blocked	1	1	10	12
Not perched/blocked	1	6	4	11

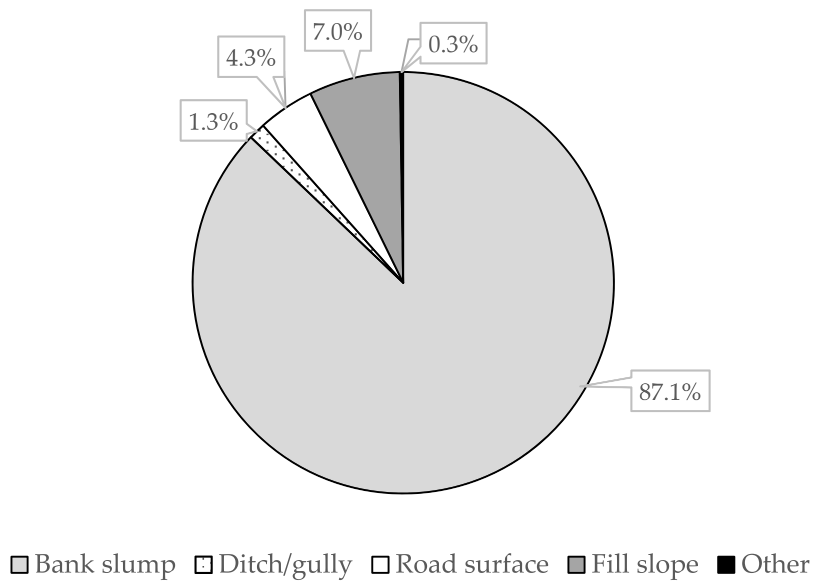

Figure 4. Common erosion sources at watercourse crossings in the Swan River watershed, 2015 (n = 168).

Based on the fish barriers identified in 2015, we calculated that approximately 25% or 737 km of stream in the Swan River watershed were fragmented due to damaged or poorly installed crossing structures; 873 km (29%) of stream were fragmented when dry crossings are included (Figure 5). Habitat fragmentation was most severe in lower-order streams (Table 3). In 2002, Tchir et al. (2003) estimated that 20% of the streams in the watershed were fragmented, also most common in headwater streams.

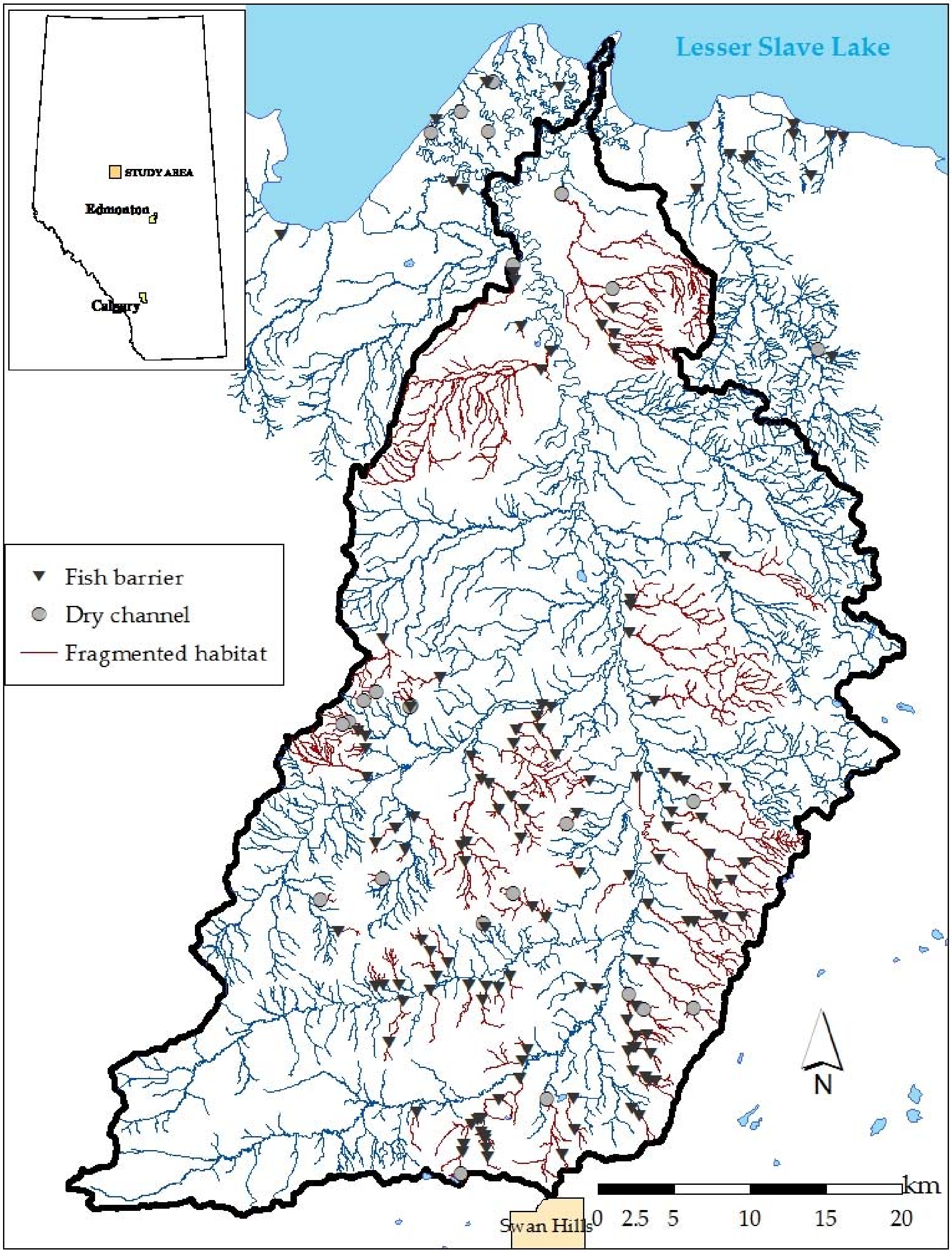

Figure 5. Habitat fragmentation severity in the Swan River watershed, 2015.

Table 3. Proportion of fragmented habitat, by stream order, as a result of stream crossings impassable to fish in the Swan River watershed, 2015.

Stream order	Available stream (km)	Fish barrier (minimum values)		
		Connected habitat (km)	Fragmented habitat (km)	Fragmentation (%)
1	1,559.5	1,114.4	445.1	29
2	626.3	443.7	182.7	29
3	366.7	291.6	75.1	21
4	227.3	193.5	33.8	15
5	101.0	101.0	0	0
6	86.2	86.2	0	0

4.2 Arctic grayling distribution

We captured a total of 431 Arctic grayling, ranging in FL between 67 and 315 mm; only six of these fish were adults (≥283 mm FL) (Table 4 and Figure 6). Seven of the fish we captured escaped before they were measured. Collectively, we sampled over 31 km of stream in the watershed, with the greatest proportion of sites sampled in order-3 and -4 streams, 32% (n = 20) and 42% (n = 26), respectively. Averages site lengths where grayling were captured (n = 46) varied between stream orders, ranging from 267 to 1,820 m (Appendix 8). Arctic grayling were not observed at 17 sites; no fish (any species) were observed at 14 of these sites. Most grayling were captured in order-4 streams; most sites where grayling were not observed were order-3 streams.

Table 4. Size of Arctic grayling (ARGR), by stream order, that were captured in the Swan River drainage, 2015 (n = 424).

Stream order	Total number of ARGR	Number of sampling sites		Fork length (mm)	
		ARGR observed	ARGR not observed	Mean (± SD)	Range
3	63	9	11	126 ± 7.1	67 – 250
4	255	24	2	160 ± 3.3	60 – 297
5	70	7	2	188 ± 5.3	83 – 282
6	36	5	2	229 ± 2.6	100 – 315

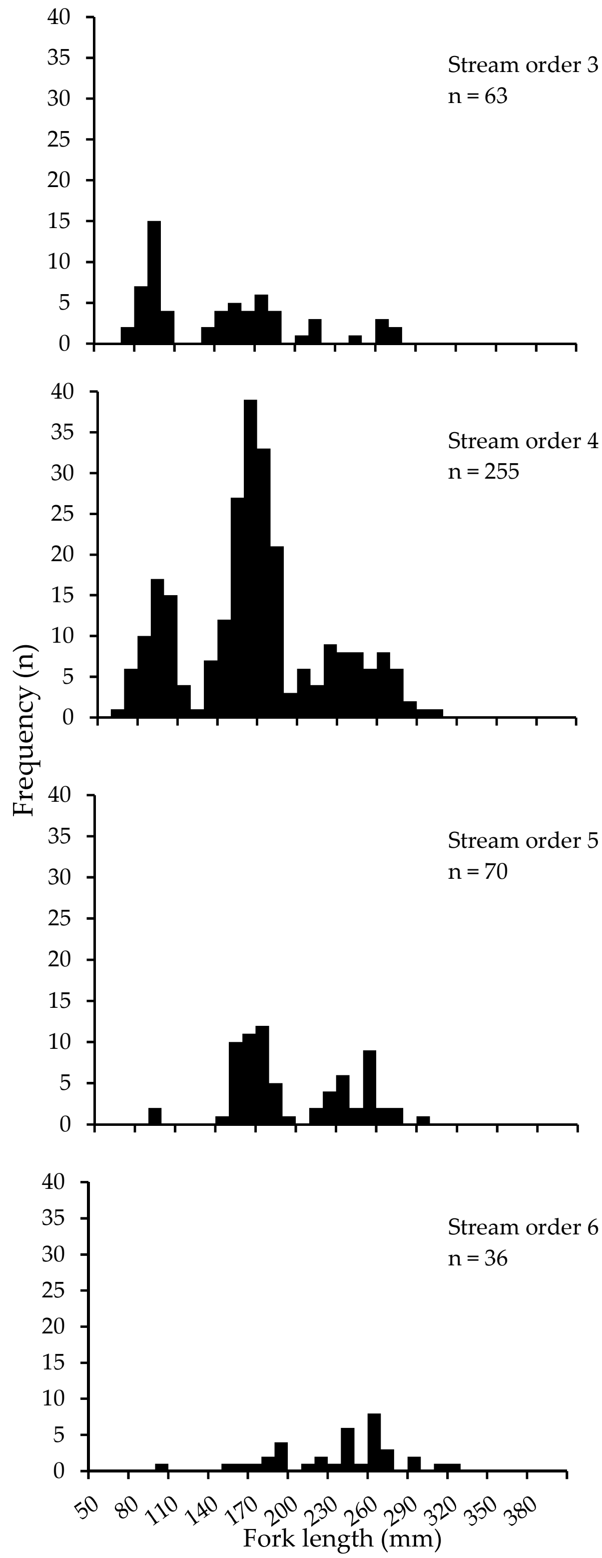

Figure 6. Length frequency distributions of Arctic grayling (ARGR), by stream order, that were captured by angling in the Swan River watershed, 2015.

4.3 Relative abundance of Arctic grayling

Our combined sampling effort totalled 162.8 h; mean (± SE) sampling effort per site was 2.63 ± 0.11 h and ranged between 0.84 and 4 h. Mean catch rate (± SE) of immature grayling (150 – 282 mm FL) was 1.48 ± 0.31 fish/h and ranged between 0 and 13.5 fish/h (n = 274) (Figure 7). Catches of immature grayling were highest in order-4 and -5 streams and lowest in order-3 and -6 streams. Catch rates for all fish (>150 mm FL) ranged between 0 and 13.5 fish/h, with a mean of 1.51 ± 0.32 fish/h. Adult grayling catch rates ranged from 0 to 1 fish/h and averaged 0.03 ± 0.02 fish/h (n = 6); adults were only captured in order-5 and -6 streams. The highest catch rates for all sizes of fish (60 – 315 mm FL) were in order-4 and -5 streams. Of the 17 sites where Arctic grayling were not observed, 5 sites were upstream of fish barriers (Figure 8).

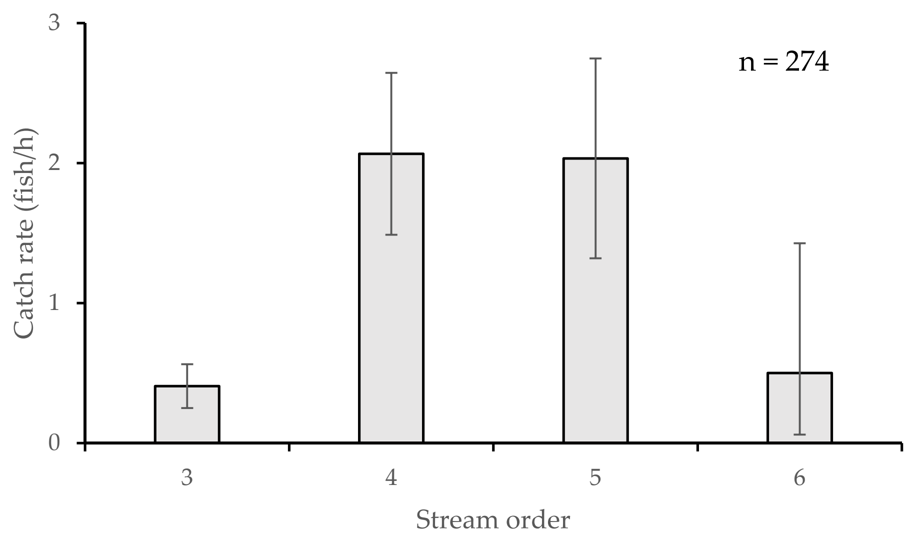

Figure 7. Relative abundance (mean [± standard error] catch rate) of immature Arctic grayling (150 – 282 mm FL) captured by angling in streams in the Swan River drainage, 2015.

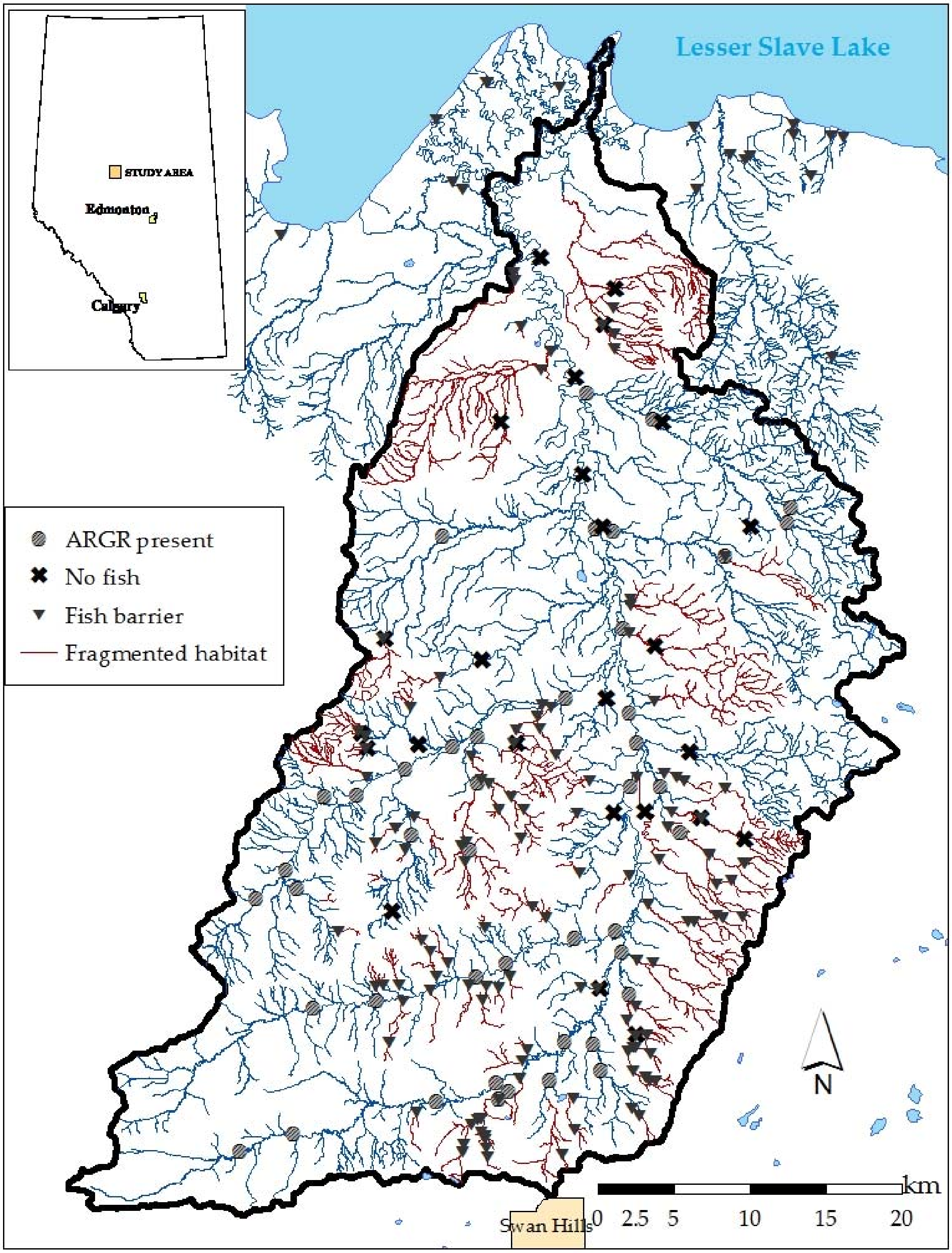

Figure 8. Arctic grayling (ARGR) presence in the Swan River watershed, 2015.

4.4 Project summary

Results from 2015 suggest that little to no improvements have occurred at problem stream crossings previously assessed in 2002. The high density of crossings have fragmented at least one-quarter of streams in the Swan River HUC 8 watershed, and most of these crossings acted as fish barriers, subject to erosion and pool scouring.

Our fish data also support this trend, as we did not observe grayling in more than one-quarter of our sites, which include sites on the Swan River downstream of the convergence of the Inverness River, streams with fish barriers and non-fluvial streams. Overall, Arctic grayling catches varied among sites throughout the watershed. Grayling catches were higher in remote, upper major tributaries and lower in streams adjacent to roads and other linear developments. Juvenile grayling catches were relatively high and widespread in the watershed, and adult grayling catches were low and limited to the Swan River and the lower reaches of the Inverness and Moosehorn rivers.

Re-establishing stream connectivity in the watershed is critical for recovering the Swan River Arctic grayling population. Grayling recovery efforts need to focus on restoring stream connectivity and remediating the degraded fish habitat by replacing all problematic stream crossing structures. Failure to replace these crossings will likely further the decline of the Alberta grayling population.

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6.0 APPENDICES

Appendix 1. The Alberta government's Watercourse Crossing Inspection Protocol (Government of Alberta 2014b) stream classification used in the Swan River watershed, 2015.

Stream classification	Stream width (m)	Fish occurrence probability	Description
Fluvial - large permanent	>5	High	Large continuous, uniform flowing channel with defined banks
Fluvial - small permanent	0.7 – 5	High	Small continuous, uniform flowing channel with defined banks
Fluvial - intermittent	<0.6	High	Intermittent channelling with some bank development
Non-fluvial	Variable	Low	Highly variable channel, with organic bed material and minimal stream flow
Ephemeral	Small	None	Stream channel is no longer than 50 m and filled with vegetation

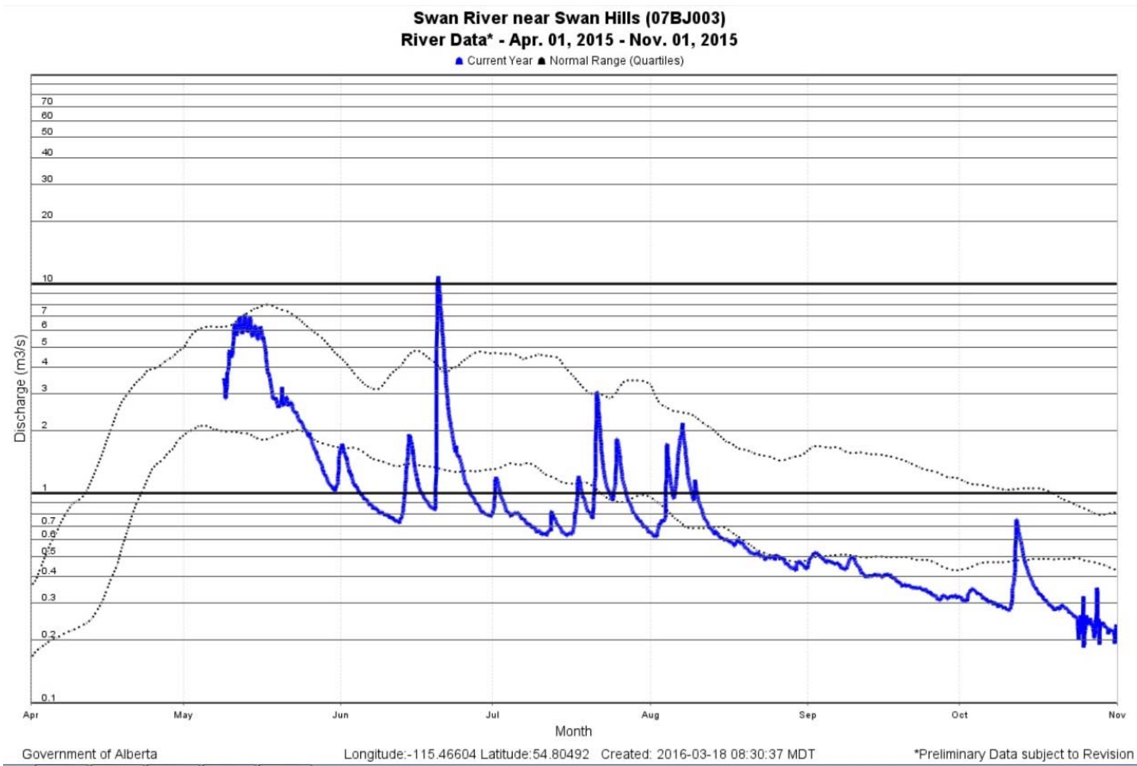
Appendix 2. The Alberta government's Watercourse Crossing Inspection Protocol (Government of Alberta 2014b) stream-crossing categories used in the Swan River watershed, 2015.

Crossing types	Potential erosion sources	Substrate type	Extent of substrate in culvert (%)	Culvert backwater extent (%)	Fish passage
Culvert - single	Ditch/gully	Sand	0	0	No concerns
Culvert - multiple	Bank slump	Gravel	<25	25	Some concerns
Culvert - open bottom	Fill slope	Cobble	50	50	Serious concerns
Bridge - permanent	Road surface	Boulder	75	75	–
Bridge - temporary	Bridge deck	Other	100	100	–
Log fill	other	–	–	–	–
Ford	–	–	–	–	–
Reclaimed	–	–	–	–	–

Appendix 3. Fish barrier parameters used to distinguish fish passage potential at stream crossings in the Swan River watershed, 2015.

Full barrier	Potential barrier	No barrier
Outlet gap height >0.6 m	Outlet gap height ≤0.59 m	Outlet not hanging
>10% of culvert diameter obstructed by debris	Outfall pool depth >1.25 × outlet gap height	Culvert even and level
	Culvert is sloped (increased water velocity)	Culvert not blocked by debris

Appendix 4. Stream flow hydrograph in the Swan River generated by an Alberta Environment and Parks stream gauging station, 2015 (Alberta Environment and Parks 2016).



Appendix 5. Total stream crossings with bent or vertical culverts, or pool scouring in the Swan River watershed, 2015.

Stream type	Number of sloped/ vertically bent culverts	Number of culverts prone to pool scouring
Fluvial - intermittent	10	13
Fluvial - large	12	13
Fluvial - small	79	92
Ephemeral	3	2
Non-fluvial	10	6
Total	114	126

Appendix 6. Extent of erosion assessed at stream crossings in the Swan River watershed, 2015 (n = 168).

Stream type	Number of crossings	Erosion extent			Crossing type			
		High unsatisfactory	Low unsatisfactory	Non-specified	Culverts	Reclaimed	Log fill	Bridge
Intermittent - permanent	13	3	3	7	13	0	0	0
Large - permanent	15	6	9	0	15	0	0	0
Small - permanent	122	69	50	3	118	2	1	1
Ephemeral	4	0	3	1	4	0	0	0
Non-fluvial	14	3	11	0	14	0	0	0
Total	168	81	76	11	164	2	1	1

Appendix 7. Baseline inventory of stream crossings assessed in the Swan River watershed in 2002 and 2005.

Because of its large size (400+ pages), this appendix is provided as a separate document.

Appendix 8. Fish sampling distances at sites where Arctic grayling (ARGR) were captured in the Swan River watershed, 2015.

Stream order	ARGR total	Mean (± SE) sample distance (m)	Sample distance range (m)
3	10	396 ± 43.5	271 – 708
4	24	589 ± 72.6	267 – 1,820
5	7	610 ± 68.3	429 – 946
6	5	741 ± 20.7	669 – 774

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Alberta Government

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