THE EFFECTS OF RIVER FLOW AUGMENTATION ON THE CHANNEL FORM, VEGETATION, AND RIPARIAN BIRDS OF THE LITTLE BOW RIVER, ALBERTA

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ABSTRACT

Globally, river systems have been regulated, reducing flows through diversions of water for societal use. In rarer scenarios, augmentation of flows may be undertaken, generally to convey water for irrigation agriculture. The Little Bow River, a small, historically intermittent river in southern Alberta, experienced a tripling of flows in 2004. Channel restructuring, vegetation transitions favouring riparian specialist species, and increasing avian community biodiversity were anticipated. Analysis of aerial photographs from 1967 to 2010 indicated restructuring of river channels as widths increased between 2000 and 2010, and vegetation showed signs of transitioning with declines in graminoid communities. Avian community surveys indicated an increase in species richness, comparable species evenness and Shannon Wiener Index, and recovering yellow-headed blackbird populations in response to changing habitat structure. Land-use management, limited augmentation, and a short timespan delayed anticipated responses along this system, requiring continued monitoring in the future.

ACKNOWLEDGEMENTS

As my time as a graduate student and adventures along the Little Bow River (affectionately coined my “Little Bro”) come to an end, it is important to acknowledge everyone who made this endeavor possible. I would like to thank Dr. Stewart Rood for being a great supervisor. You have provided me with funding, countless edits and insights, endless support, and numerous side projects to pass the time. I could not have asked for a better mentor and cannot thank you enough for the opportunity.

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APRS	Aerial Photo Reference System
CCA	Canonical Correspondence Analysis
DA	Gross drainage area of river basin
GRA	Graminoid Vegetation Type
NMDS	Non-metric Multidimensional Scaling
OTR	Other Vegetation Type
PRW	Riparian Woodland Vegetation Type
Q	Mean daily discharge (m^3/s)
RMSE	Root Mean Square Error
TRW	True Willow Vegetation Type
TYA	Typhas Vegetation Type
WOW	Wolf Willow Vegetation Type

CHAPTER 1

AN INTRODUCTION TO THE AUGMENTATION OF RIVER FLOWS

1.1 Riparian Ecosystems and Flow Regulation

Riparian areas are highly desirable regions, rich in natural resources utilized by the domestic, agricultural, and industrial sectors, and are of growing concern due to river flow regulation that affects nearly all major river systems in the Northern Hemisphere (Leyer 2005). Historically, river systems were regulated to mitigate flooding and for storage of water for social and economic uses, meanwhile little emphasis was placed on environmental demands (Elderd 2003, McDonald *et al.* 2004). Riparian ecosystems are disproportionally used by wildlife and exhibit much greater species richness and abundance than adjacent upland areas (Iwata *et al.* 2003, Scott *et al.* 2003, Queheillalt and Morrison 2006). The vitality of riparian areas is largely dependent on river flow regimes, as they are crucial to the life histories of riparian specialist species and the physical structuring of the environment.

The channel form of river systems is sculpted and maintained through patterns of fluvial erosion and deposition (Leopold and Wolman 1960). Stream power is derived from channel slope and discharge, and determines the potential of each river system to entrain and transport sediments (Julian *et al.* 2012). The characteristic erosion/entrainment of sediment from the concave bank and deposition on the convex bank, dictates a relatively consistent meandering pattern that is conserved across unconstrained river systems (Leopold and Wolman 1960, Nicoll and Hickin 2010). These dynamic, yet predictable patterns of river form provide colonisable habitats that are crucial to the life histories of some riparian specialist vegetation species.

The colonization, recruitment, and survival of riparian vegetation along river systems are dependent upon the timing, duration, frequency, rate of change, and magnitude of both high and low flow conditions (Nilsson and Svedmark 2002, Leyer 2005). Riparian vegetation is dependent upon the frequency, duration, and magnitude of high flows for preparation of substrates for colonization, while frequency, duration, and magnitude of low flows are responsible for survival by preventing drought stress induced mortality (Hupp 1982, Dominick and O'Neill 1998, Bendix and Hupp 2000, Leyer 2005). The phreatophytic nature of riparian vegetation species dictates that water availability is the largest limiting factor for the assemblage of communities (Hupp 1982, Stromberg 1993). This intimate linkage between riparian vegetation, water availability, and fluvial disturbances highlights the importance of river flow regimes in maintaining the health of riparian ecosystems.

Healthy riparian woodlands are closely associated with rich avian communities and have been historically referred to as “the haunts of innumerable birds” by Lewis and Clark in 1805 (Queheillalt and Morrison 2006). Un-fragmented woodlands composed of native woody vegetation, such as cottonwoods (*Populus spp.*), provide the greatest diversity of bird species (Saab 1999, Pennington *et al.* 2008). Riparian birds select habitats based upon factors at both micro and macro scales including patch size/shape, habitat connectivity, resource availability, and most influentially, the vertical structure of vegetation (Saab 1999, Scott *et al.* 2003, Pennington *et al.* 2008). As previously discussed, the strong linkage between vegetation and river flows provides an indirect pathway in which river flow regime can influence avian communities. The flow regimes of river systems also drive variations in the abundance and diversity of aquatic and emergent invertebrates, indirectly influencing birds through resources availability and foraging success (Iwata *et al.* 2003, Royan *et al.* 2013). The natural variability of flow regimes is therefore crucial in maintaining the health of riparian areas and their occupation by avian and other vertebrate communities.

Agricultural conversions, livestock grazing, ground water pumping, and river flow regulation are major threats to riparian health, however, river flow regulation is the foremost threat (Stromberg 1993, Scott *et al.* 2003, Rood *et al.* 2005). River flow regulation is the modification of natural flow regimes, typically through diversions of water, resulting in reductions to natural flow variability and the dampening of floods (Fenner *et al.* 1985, Toner and Keddy 1997). The damming and diverting of river systems, that result in departures from the natural variability of flows, can have drastic impacts on aquatic and riparian communities found immediately downstream from flow infrastructure (Franz and Bazzaz 1977, Henszey *et al.* 1991, Johnson 2002). Diverting of water from river systems typically results in the narrowing of river channels and encroachment of riparian vegetation, followed by an interruption in the reproduction of vegetation due to lack of flood disturbance (Bendix and Hupp 2000, Johnson 2002, Nilsson and Svedmark 2002, Shafroth *et al.* 2002). The prominence of damming and diverting of water from river systems has led to numerous studies, while a less common form of river regulation remains to be studied extensively.

River flow augmentation is a rarely undertaken form of regulation that involves increasing flows typically in low flow periods. As river flows increase, the capacity of rivers to transport sediments increases, as well as the water table elevation, and water availability for riparian vegetation (Ponce and Lindquist 1990, Stromberg 1993).

Augmented rivers typically experience coarsening of substrates as river channels become wider and entrench in unconsolidated material (Table 1.1). Additional changes to river channel form include decreases in sinuosity index and thalweg length. Riparian vegetation typically responds to flow augmentation through transitions from facultative to obligate species; however, if extensive entrenching or erosion occurs, total vegetated area may decrease. Alterations to river systems in response to flow augmentation typically occur over multiple decades, although in rare scenarios, responses may be seen within only a few years. The geomorphic change to river channels under augmented flows is relatively well understood, while the response of riparian vegetation and birds still require further investigation.

Table 1.1 A brief summary of studies conducted along flow augmented rivers in North America.

River System	**Study**	**Flow increase (Q)**	**Time (years)**	**Response**
Las Poudre Pass Creek, Colorado	Wohl and Dust 2012	1.5x	31	Increased channel width with coarsening of substrate
Little Jackfish River, Ontario	Kellerhals *et al.* 1979	N/A	34	Increased channel width and entrenchment
Lower Kemano River, British Columbia	Kellerhals *et al.* 1979	3x	21	Increased channel width and decreasing sinuosity index (length)
Nechako River, British Columbia	Kellerhals *et al.* 1979	N/A	20	Increased channel width and entrenchment with dieback of willows
New Post Creek, Ontario	Kellerhals *et al.* 1979	N/A	10	Channel enlargement and meander cut-offs
Root River, Ontario	Kellerhals *et al.* 1979	N/A	16	Increased channel width
South Fork Middle Crow Creek, Wyoming	Henszey *et al.* 1991	2x	2	Increased abundance of flood tolerant species (sedges)
South Fork Middle Crow Creek, Wyoming	Wolff *et al.* 1989	2x	2	Increased channel length (32%) and entrenchment
Upper Arkansas River, Colorado	Dominick and O’Neill 1998	3-4x	53	Increased channel width with coarsening substrate and decreasing total vegetated area

1.2 A History of Augmented Flows along the Little Bow River, Alberta

The Little Bow River is a small, historically intermittent river, originating in High River, Alberta that flows south east towards its confluence with Mosquito Creek (Figure 1.1). With a drainage area occupying 1,963 km^2 of foothills and prairie landscapes, this river system possesses a relatively low stream power (Environment Canada 2010). The river channel is under fit within a much larger post glacial channel, and is highly interconnected both naturally and artificially with the Highwood River. The interconnected nature of these two systems has provided an opportunity for diversions of water, which have been undertaken throughout much of the Little Bow River's written history.

Flow augmentation along the Little Bow River has been persistent since commencing in 1898 with diversions of water from Baker Creek under the direction of the Government of the North West Territories (Golder and Associates 1995). Diversions of water from Baker Creek were later abandoned as a new canal system was constructed from the Highwood River in 1910. This canal was later abandoned in 1921 and the current canal system was constructed in 1923 under the direction of the Little Bow Irrigation District (LBID) (Alberta Public Works 1998; Golder and Associates 1995). Frequent flooding of these river systems resulted in major repairs and improvements to existing infrastructure in 1932, 1956, and in the late 1960's (Alberta Public Works 1998; Golder and Associates 1995). In anticipation of projected increases in irrigation agriculture within the Little Bow River basin, the most recent diversion plan, the Highwood Little Bow Diversion Project was proposed in the 1970's and implemented in

2004 following numerous environmental assessments (Alberta Public Works 1998; Golder and Associates 1995).

The Highwood Little Bow Diversion Project was proposed by Alberta Public Service and Works (1998) to secure water supplies for the towns of Vulcan, Nanton, Cayley, and three rural cooperatives. Improved water availability was expected to double the irrigated acres in this river basin from 11,500 to 20,000 acres. The infrastructure associated with this project included the construction of Twin Valley Dam, an earthen dam of 25 m height, at the confluence of the Little Bow River and Mosquito Creek creating a 61,000 dam^3 reservoir (Alberta Public Works 1998). In addition, expansion of the existing Little Bow Canal was undertaken to accommodate the increasing augmentation of flows from 2.85 m^3/s to 8.5 m^3/s. Lastly, the expansion of Women's Coulee Reservoir on Mosquito Creek, and the construction of a diversion from the Little Bow River to Clear Lake were proposed. The construction of all infrastructure associated with the Highwood Little Bow Diversion Project was completed in 2003, with the implementation of augmented flows occurring in 2004.

The recent augmentation of flows along the Little Bow River have been the subject of numerous monitoring reports prepared for Alberta Environment; however, little scientific research has been conducted to evaluate the impact of this change in flow regime (Bigelow 2006). Channel form along this river system was predicted to experience increased bank widths in order to accommodate the increased flows (Rood *et al.* 2003). Subsequent studies identified minimal changes in channel width except for localized widening, catalyzed by poor land-use management (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006). In the most recent monitoring report, increases in channel width ranging from 5 to 50 % were identified at 10 of 21 permanent transects established in 2002 (Samuelson *et al.* 2012). At the remaining 11 sites, the elevational profile of the channels remained comparable to historic conditions. System-wide increases in channel widths were however not identified in any monitoring reports.

Vegetation along the Little Bow River was predicted to respond favourably to augmented flows, showing a transition from facultative to obligate riparian species (Rood *et al.* 2003). Vegetation along the Little Bow River, however, showed minimal changes, other than a decline in cattails (*Typha latifolia* L.) following scouring (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006), and a slight die-back of facultative wolf willows (*Elaeagnus commutata* Bernh.) in select reaches (Samuelson *et al.* 2012). In response to minimal changes in vegetation, songbird and shorebird communities remained comparable between 2005 and 2007 (Herzog and McCormick 2008). In exception, rare songbird species were shown to change between years, and yellow-headed blackbirds (*Xanthocephalus xanthocephalus* (Bonaparte 1826)), an obligate wetland breeder of interest, showed dramatic declines.

In response to recent flow augmentation, the channel form, vegetation, and birds along the Little Bow River have remained resilient to change and require further monitoring. Localized changes in channel form and vegetation indicate that this system is beginning to respond to augmentation and that system-wide responses may occur in the near future. This river system provides a rare study opportunity in which the implications of flow augmentation can be further investigated.

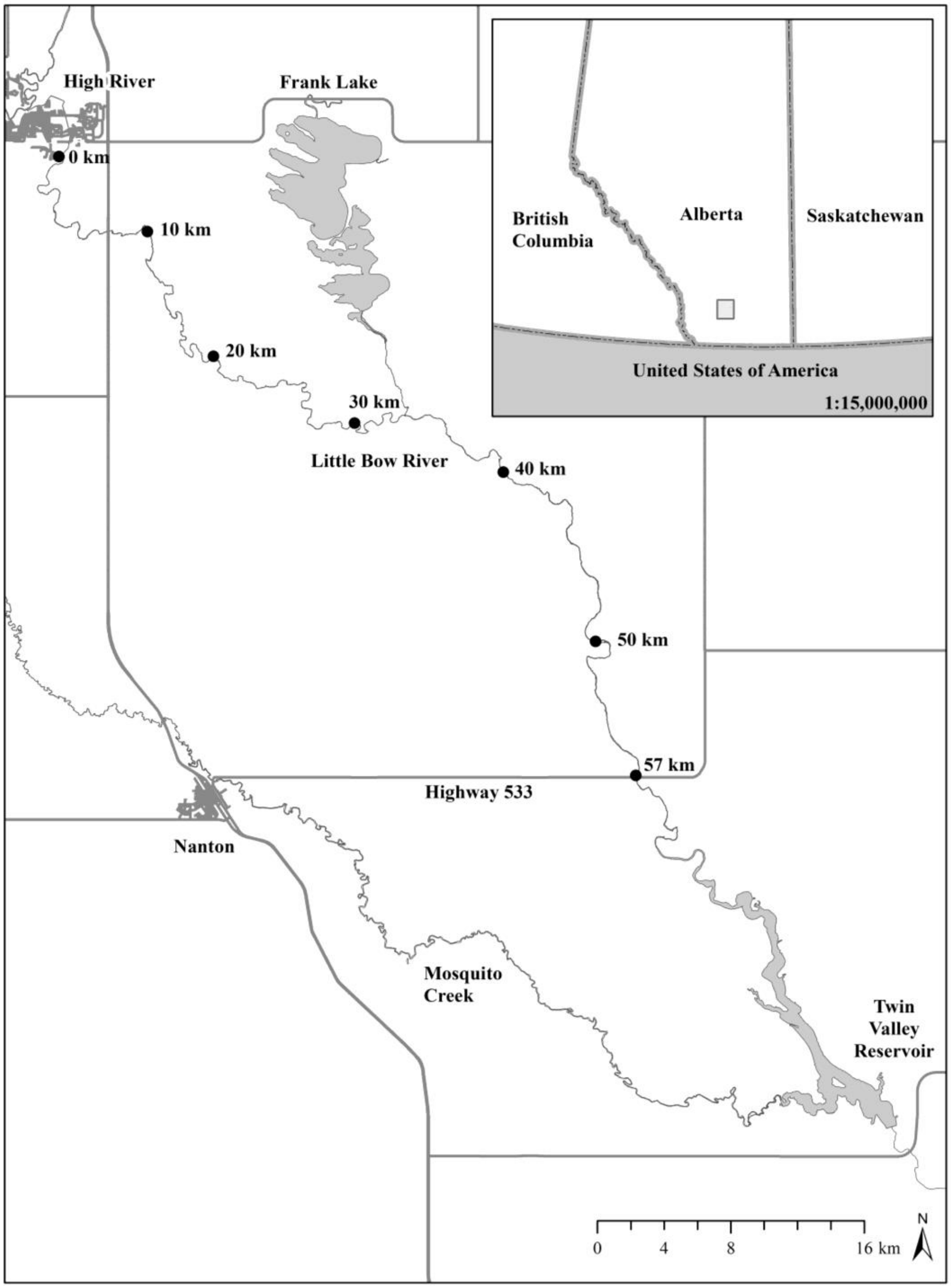

Figure 1.1 The Upper Little Bow River, Alberta with ten kilometre increments downstream from the Little Bow Canal denoted with circles. The road network and some hydrologic feature were extracted from Shapefiles provided by GeoBase.

1.3 Thesis Framework

This thesis was undertaken to further investigate and monitor the implications of the most recent augmentation of flows along the Little Bow River, Alberta. Research was conducted between summer 2012 and spring 2014, focusing on channel form, vegetation, avian communities, and yellow-headed blackbirds as a species of interest. This research is presented in four chapters as described in the following paragraphs.

Chapter One, the introductory chapter, has provided a background of flow related interactions in riparian ecosystems, and flow alterations focusing on augmentation. As well as a brief summary of augmented flows along the Little Bow River. Following this introduction, the current conditions and response of channel form, vegetation, and birds along the Little Bow River will be presented.

In Chapter Two, a historical analysis of channel form and vegetation along the Little Bow River will be presented with specific interest being placed on the conditions before and after recent flow augmentation. Geomorphic change in channel width, river sinuosity index, and meander characteristics will be identified, providing insight into the sediment transportation dynamics of this river system. Furthermore, the composition of vegetation along reaches in response to historical and present flow conditions will be presented, providing validation of possible transitions in vegetation communities.

In Chapter Three, the biodiversity and community composition of riparian songbirds and shorebirds will be presented, providing insight into possible habitat improvements along the Little Bow River in response to the recent augmentation of flows. Additionally, yellow-headed blackbird populations and colony occupation will be addressed following declines documented in previous monitoring reports.

In Chapter Four, the concluding chapter, the response of the Little Bow River to flow augmentation in terms of channel form, vegetation, and riparian birds is summarized. In addition to the conclusions provided, predictions of future conditions and directions for monitoring will be proposed.

CHAPTER 2

GEOMORPHIC AND VEGETATIVE RESPONSE OF THE LITTLE BOW RIVER, ALBERTA

2.1 Introduction

River flow regulation is prominent within modern societies, affecting nearly all major rivers in the Northern Hemisphere and two thirds of flowing freshwater globally (Jansson *et al.* 2000, Leyer 2005) . Flow regulation typically involves diversions and damming of river systems which reduce flow variability, moderate flooding, and increase late summer flows (Toner and Keddy 1997, Dominick and O'Neill 1998, Julian *et al.* 2012). The damming and diverting of river systems and their responses to regulation are well studied, while studies involving flow augmentation are rarely undertaken.

River flow augmentation, a rarely undertaken form of regulation, involves increasing flows particularly in low flow periods. Rivers undergoing flow augmentation tend to respond with channel enlargement, decreased meandering, substrate coarsening, decreases in total vegetated area, and vegetation transitions from facultative to obligate riparian species (Kellerhals *et al.* 1979, Wolff *et al.* 1989, Henszey *et al.* 1991, Dominick and O'Neill 1998, Wohl and Dust 2012). The response of each river is however unique and derived from the flow history, geology, and biogeography.

The Little Bow River, originating in High River, Alberta, has a long history of flow augmentation commencing with diversions from Baker Creek in the late 1890s (Alberta Public Works 1998). Numerous other projects followed with increasing augmentation of flow through diversions of water from the Highwood River. In 2004, the Highwood Little Bow Diversion Project was implemented, tripling flows along the Little

Bow River from 2.85 to 8.5 m^3/s (Alberta Public Works 1998). Preliminary monitoring studies prepared for Alberta Environment indicated localized changes in channel width and loss of cattails, however no system-wide responses were identified (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006, Samuelson *et al.* 2012). This study re-assesses the response of channel form and vegetation along the Little Bow River as this system approaches ten years after the implementation of the most recent augmentation project.

The Little Bow River provides a unique study opportunity as it is a prairie originating system, it possesses a low stream gradient averaging 0.15%, and flows were historically intermittent (Bigelow 2006). These factors indicate that the Little Bow River will be very susceptible to changes in channel form and vegetation following the most recent augmentation of flows (Stromberg 1993, Friedman and Lee 2002, Wohl and Dust 2012). In addition, the continued research of this river system aids Alberta Environment in their post-augmentation monitoring initiatives.

The channel form of the Little Bow River was predicted to increase in channel width, and decreases in sinuosity index and meander characteristics. Increases in channel width were predicted as enlargement in channel size is required to accommodate augmented flows and the armament of the bed limits expansion in depth. Meander dimensions were expected to decreases, as increased flows would allow meander cut-offs.

Vegetation communities along the Little Bow River were predicted to transition from facultative to obligate riparian species. Augmentation would provide sustained flows during summer months and would elevate the water table. Riparian species would be favoured by increased water availability, while upland species could become stressed.

Additionally, alterations to channel form could provide bare substrate required for colonization by riparian species such as cottonwoods (*Populus spp.*) and willows (*Salix spp.*). Increases in the extent of riparian woodlands and true willows, declines in wolf willows and graminoids, and initial declines in cattails with later recovery were predicted following the further augmentation of this system.

2.2 Research Methodology

2.2.1 Study Area

The Little Bow River is prairie originating, with no major tributaries upstream of Twin Valley Reservoir located at its confluence with Mosquito Creek (Figure 2.1). River channel widths range from less than 5 m to greater than 50 m with an average of 13.5 m. The current river planform is sinuous to meandering and is inset within a much larger post-glacial paleo-channel (Bigelow 2006). The river bed is composed of sand and coarse sediment providing armament against typical flows (Miller *et al.* 2010). Daily discharge along the Little Bow River historically averages 1.6 m^3/s, ranging from 0.0 to 54.9 m^3/s (Environment Canada 2010).

The Little Bow River has a drainage area of 1,963 km^2 (Environment Canada 2010) occupying the mixed grassland natural sub-region (Miller *et al.* 2010). Vegetation transitions from riparian woodlands (*Populus balsamifera* L. and *Acer negundo* L.) and willows (*Salix bebbiana* Sarg. and *Salix exigua* Nutt.) in the upper reaches, to graminoids, wolf willows (*Elaeagnus commutata* Bernh.), and cattails (*Typha latifolia* L.) in the lower reaches. Graminoid species however are the most prominent vegetation class along the river entire system (Bigelow 2006).

This study was undertaken along a 57.5 km stretch of the Little Bow River, between the Town of High River and Twin Valley Reservoir (Figure 2.1). The study area commenced at the inflow of the Little Bow Canal into the Little Bow River and extended to the Highway 533 Bridge, the last bridge upstream of Twin Valley Reservoir. The study area was further sub-divided into seven reaches based upon visual differentiation of river planform.

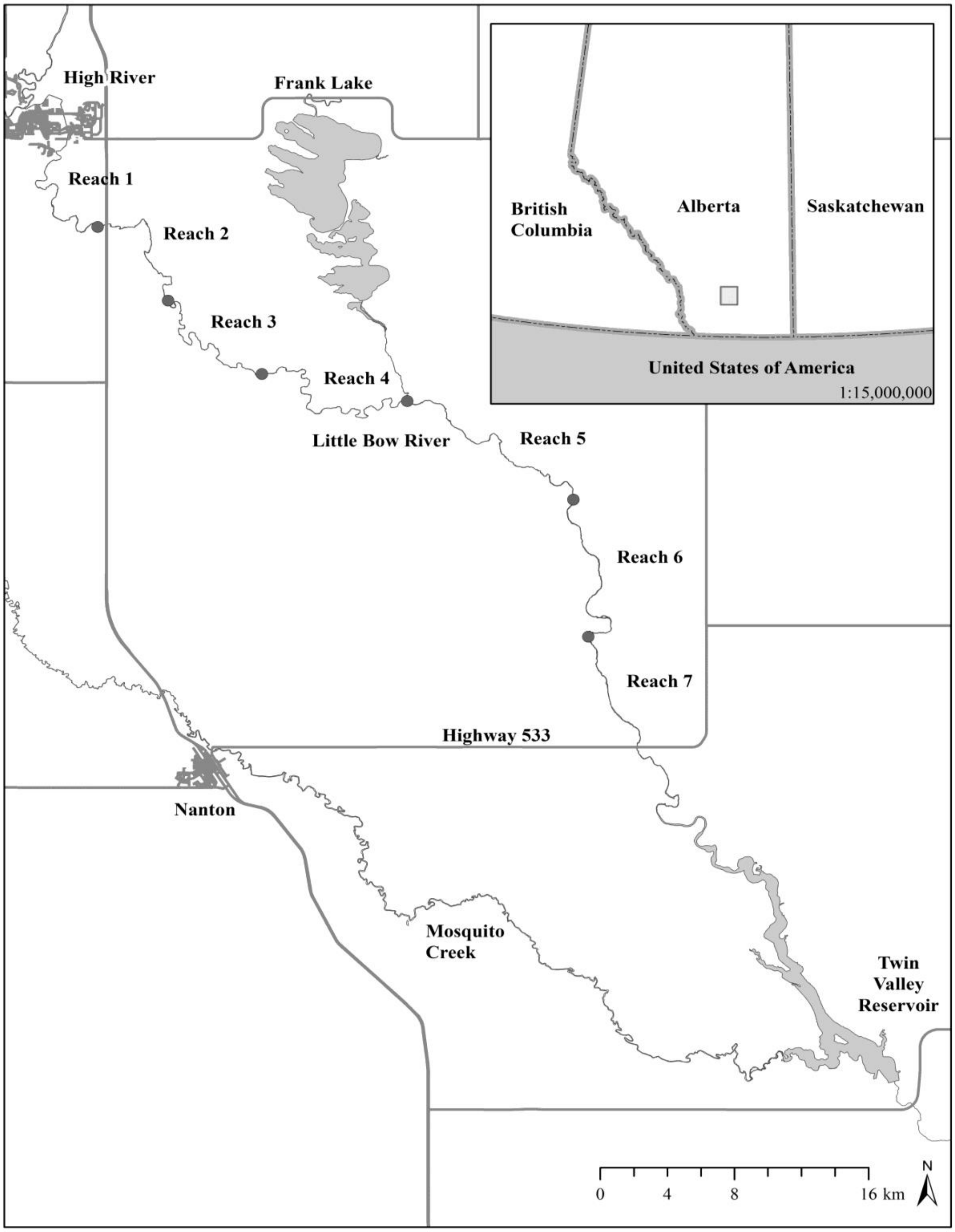

Figure 2.1 Study area and reach divisions along the Little Bow River, Alberta. Reach divisions are denoted by circles. The road network and some hydrologic feature were extracted from Shapefiles provided by GeoBase.

2.2.2 Hydrologic Analysis of the Little Bow River

Historic discharges along the Little Bow River were acquired for two gauging station near Highway 533 (05AC930) and Carmangay, Alberta (05AC003) from the HYDAT, a stream gauging data repository operated by Environment Canada (2010). Daily flow measurements were acquired for 58 years from 1955 to 2012, to determine seasonal (May to October) minimum, seasonal mean, and annual maximum discharges. Seasonal minimum and mean discharges were selected for comparison with vegetation and correspond with the growing season. Seasonal mean and annual maximum were selected for comparison with channel form, as they incorporate both flood conditions and channel forming flows. All ice flow data was excluded from this analysis.

2.2.3 Aerial Photograph Selection and Pre-Analysis Processing

The response of riparian vegetation and channel form along the Little Bow River was assessed using aerial photographs. Photos were acquired for 1967, 1981, 2000, and 2010 based on coverage of the study area, river discharge, and access from the Alberta Aerial Photo Record System (APRS) (Table 2.1). The photo datasets from 1967, 1981, and 2000 were selected to provide historical context, while photos from 2010 indicated conditions following the implementation of flow augmentation in 2004.

Aerial photographs were geo-rectified to orthophotos using a criterion of greater than 30 ground control points per image and root mean square errors (RMSE) of less than two times the largest image pixel of 1.27 m in 1981. This reduced spatial error to less than 2.5 m in all photo datasets. Geo-rectified aerial photographs were mosaicked and river features delineated in Arc Map 10 (ESRI 2010).

Table 2.1 Summary of aerial photographs selected for analysis along the Little Bow River, Alberta.

Year	Roll Number	Scale	Date Acquired	Q (m^3/s)
1967	AS986	1:31680	06/06/1967	5.07
	AS987	1:31680	06/06/1967	5.07
1981	AS2338	1:60000	12/09/1981	1.78
	AS2339	1:60000	12/09/1981	1.78
2000	*North Western Geomatics Orthorectified Base Layer*			
2010	AS5517	1:20000	21/04/2010	1.53
	AS5518	1:20000	21/04/2010	1.53

2.2.4 Assessment of Channel Form

To investigate the response of river channel to further augmentation, measurements of thalweg length and channel width were collected from the aerial photograph datasets. Thalwegs were digitized for each year based on the assumption that thalweg position would be in the center of the channel in straight reaches and would shift towards the concaved bank along meanders. Channel widths were delineated at 100 m intervals based on wetted perimeter.

Sinuosity index, a ratio of thalweg length to valley length, was calculated as a measure of river planform change in response to flow augmentation. Sinuosity index was calculated for 400 m reaches, characterizing inset meanders, rather than the much larger historic meanders that occur at 2000 m intervals (Bigelow 2006). Further analysis of river planform was conducted on 16 meanders selected from sinuosity index intervals classified as meandering (> 1.5 sinuosity index) in any year. These meanders were assessed for amplitude, wavelength, and arc radius.

Arc radius, a measure of river meander curvature, is determined by the visual or mathematical fitting of curves to river thalwegs. In ArcMap, circles were visually fitted to approximate the curvature of the meander thalweg (Figure 2.2). Wavelength and amplitude, approximates river planform to that of a sinusoidal wave. Wavelengths were measured from one point of inflection to another, while amplitudes were measured from apex to apex, both representing one full cycle of meandering.

All channel form characteristics were compared between pre and post-augmentation conditions. Throughout this thesis, pre-augmentation and post-augmentation conditions will be referred to in context to the implementation of the Highwood Little Bow Diversions Project, rather than the historic augmentation of flows since the late 1890s. Pre-augmentation conditions included the mean condition prior to recent augmentation (mean of 1967 and 1981) and 2000 conditions. Post-augmentation conditions were characterized by 2010 conditions.

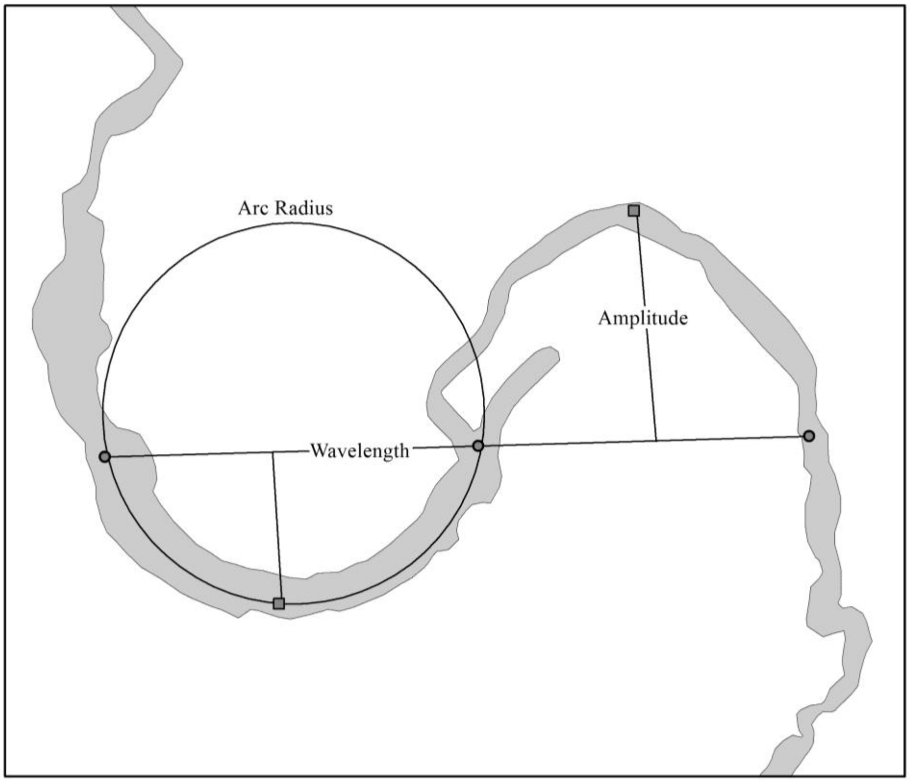

Figure 2.2 A schematic of arc radius, wavelength, and amplitude measurements of 16 meanders along the Little Bow River, Alberta. Points of inflection are denoted by circles while meander apexes are by squares.

2.2.5 Assessment of Riparian Vegetation

The response of vegetation to recent flow augmentation was assessed at 100 m intervals along the Little Bow River for each aerial photo dataset. The vegetation type of each interval was classified as riparian woodlands (*Populus balsamifera* and *Acer negundo*), true willows (*Salix bebbiana and Salix exigua*), wolf willows (*Elaeagnus commutata*), graminoids, or cattails (*Typha latifolia*). The presence of cattails within the river channel lead to immediate classification of cattails. All other vegetation types were classified based upon dominance along each bank interval. Frequencies of vegetation classes were converted into proportions per kilometre and were compared between conditions before and after the current augmentation. Proportions per kilometre were determined based upon the number of intervals of each vegetation class divided by 20 intervals per kilometre. Conditions following augmentation were defined as vegetation proportions from 2010, while conditions before augmentation included proportions from 2000 and pre-augmentation conditions (1967 and 1981).

Vegetation classification accuracy was assessed using a confusion matrix and calculation of producer accuracy, consumer accuracy, and overall accuracy. Accuracy assessment was undertaken for the 2010 aerial photograph dataset using site photographs taken in 2013. Classification accuracies for 1967, 1981, and 2000 datasets were assumed to be equivalent to 2010 due to lack of ground-truthed data and that the producer remained constant.

2.2.6 Statistical Analyses

Statistical analysis of all data was undertaken with a significance level (α) of 0.05 in SPSS Statistics version 19 (IBM 2010). Analysis of covariance (ANCOVA) was conducted on channel width, sinuosity index, and vegetation proportions using distance downstream from the Little Bow Canal as the covariate. ANCOVA model fit was defined as good ($R^2 > 0.15$), moderate ($0.10 \geq R^2 \leq 0.15$), or poor ($R^2 < 0.10$). Post hoc pairwise comparisons were undertaken, identifying periods of temporal changes. Significant differences were classified as being a trend ($p<0.10$), significant ($p<0.05$), or highly significant ($p<0.01$).

Channel width, sinuosity index, and vegetation proportions were further analyzed by reach using analysis of variance (ANOVA). ANOVA was undertaken due to limited sample sizes and lack of spatial variability, prohibiting analysis of covariance. In addition, ANOVAs were undertaken on meander wavelength, amplitude, and arc radius along the Little Bow River. As some datasets exhibited non-parametric distributions, ANOVA results were validated by Kruskal-Wallis tests.

2.3 Results

2.3.1 Hydrologic History of the Little Bow River

Hydrologic analysis of the Little Bow River indicated that maximum annual discharges have historically been declining (Figure 2.3). Following the current augmentation project, the trend of declining maximum annual discharge remained constant, resulting in post-augmentation average conditions being lower than historical conditions. Mean seasonal discharges historically exhibited an increasing trend. Increases in average mean seasonal discharge during post-augmentation years followed this historic trend. Minimum seasonal discharges have historically been increasing. Increasing minimum discharge persisted following recent flow augmentation, however at a larger magnitude than historically identified.

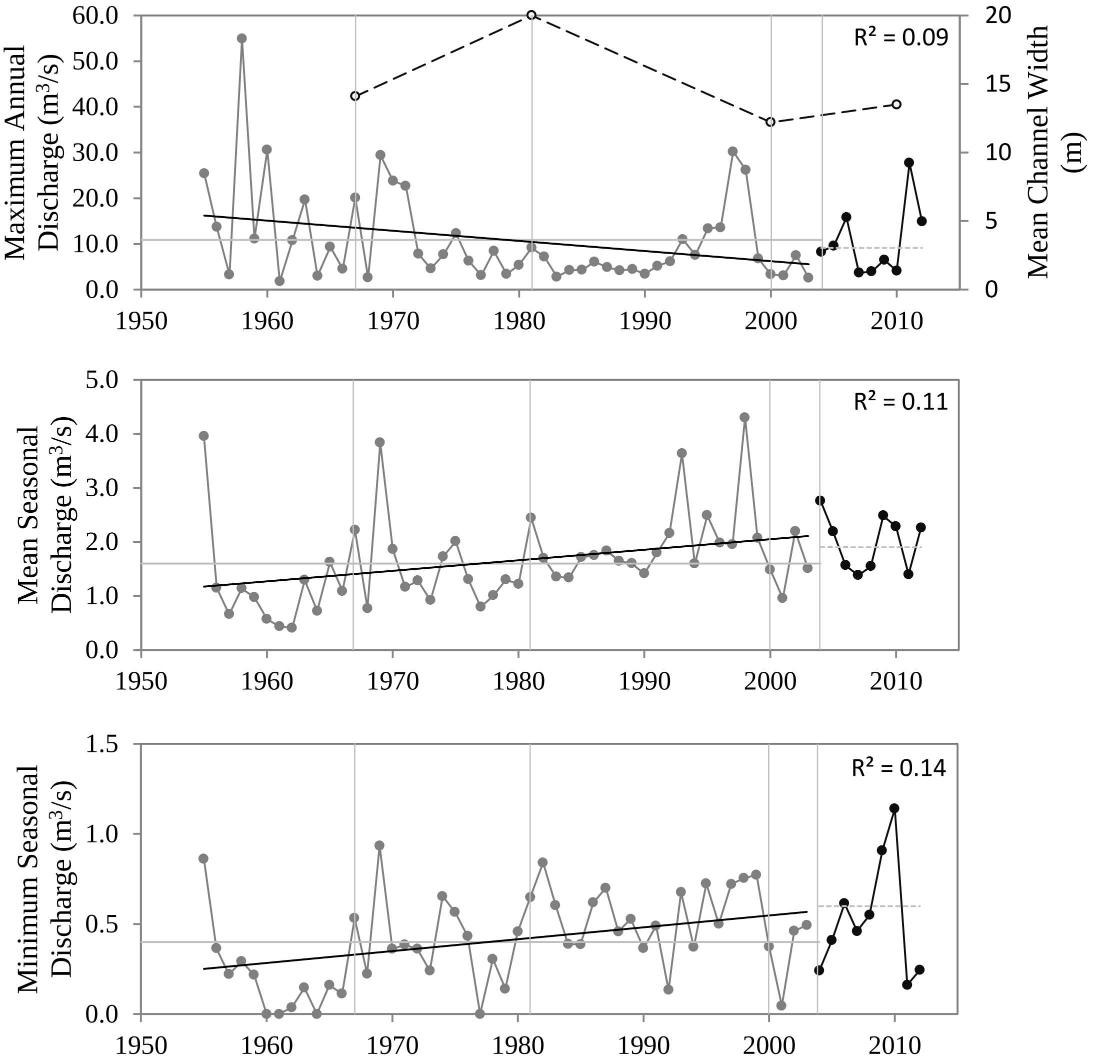

Figure 2.3 Trends of seasonal minimum (May-October), seasonal mean, and annual maximum discharges along the Little Bow River, Alberta. Pre-augmentation flows (1955-2003) are depicted in grey and were collected for a gauging station near Carmangay, Alberta (05AC003). Post-augmentation flows (2004-2012) are depicted in black and were collected for a gauging station near Highway 533 (05AC930).The large dashed line in the top plot indicates mean channel widths derived from aerial photographs. Intervals of aerial analysis are depicted with vertical grey lines, while average discharge conditions are depicted by horizontal solid or dashed grey lines.

2.3.2 Response of Channel Form

Channel width lacked a significant interaction term and exhibited a highly significant linear relationship with the distance covariate (Figure 2.4), yielding an ANCOVA model with good overall fit for the Little Bow River (R^2= 0.19). Channel width changed following flow augmentation (ANCOVA: F(2,1725)=84.59, p=0.00). Furthermore, channel width in all reaches except for reach seven, showed highly significant differences (Table 2.2).

Pairwise comparisons indicated that between historical pre-augmentation conditions and 2000, the channel width along the Little Bow River exhibited a highly significant decline from 17.0 to 12.2 m (Table 2.3; Figure 2.4). In addition, all reaches except for reach seven, exhibited highly significant decreases in channel width (Table 2.3; Figure 2.5). Channel width along reach seven remained comparable during this time period.

Channel widths between pre-augmentation and post-augmentation (2010) conditions exhibited a highly significant decrease from 17.0 to 13.5 m (Table 2.3; Figure 2.4). Highly significant decrease in channel width were identified along reaches one, three, four, five, and six (Table 2.3; Figure 2.5). During this interval, channel widths along reaches two and seven remained comparable.

Pairwise comparison between baseline (2000) and post-augmentation (2010) conditions indicated a highly significant increase in channel width from 12.2 to 13.5 m (Table 2.3; Figure 2.4). In addition, reach four exhibited a highly significant increase in channel width (Table 2.3; Figure 2.5). Trends of increasing channel width were identified along reaches three and five. All other reaches (1, 2, 6, and 7) remained comparable within this time period.

Channel widths in 1967, 1981, 2000, and 2010, visually corresponded with the maximum annual hydrographic trends of the Little Bow River at Carmangay, Alberta (Figure 2.3). Channel width along the Little Bow River exhibited a delayed response to flows. A shift in mean channel width of about 15 to 20 years, allows the alignment of low and high flow periods. Large maximum annual flows proceeding and immediately following 1967 correspond with increased channel width identified in 1981. Limited maximum flows in the 1980s correspond with decreased channel width in 2000. Furthermore, increasing maximum flows in the 1990s corresponded with increased channel widths identified in 2010.

Sinuosity index along the Little Bow River exhibited a highly significant linear relationship with the distance covariate (Figure 2.4) and lacked a significant interaction term, producing an ANCOVA model with poor goodness of fit (R^2=0.08). Sinuosity index was similar across all temporal comparisons along the Little Bow River (ANCOVA: F(2,432)=0.19, p=0.83) and all reaches (Table 2.2; Figure 2.6). Additionally, meander wavelength, amplitude, and arc radius exhibited similar values across all temporal comparisons (respective ANOVAs: F(2,48)=0.02, p=0.98; F(2,48)=0.01, p=0.99; F(2,48)=0.00, p=0.99)(Figure 2.7).

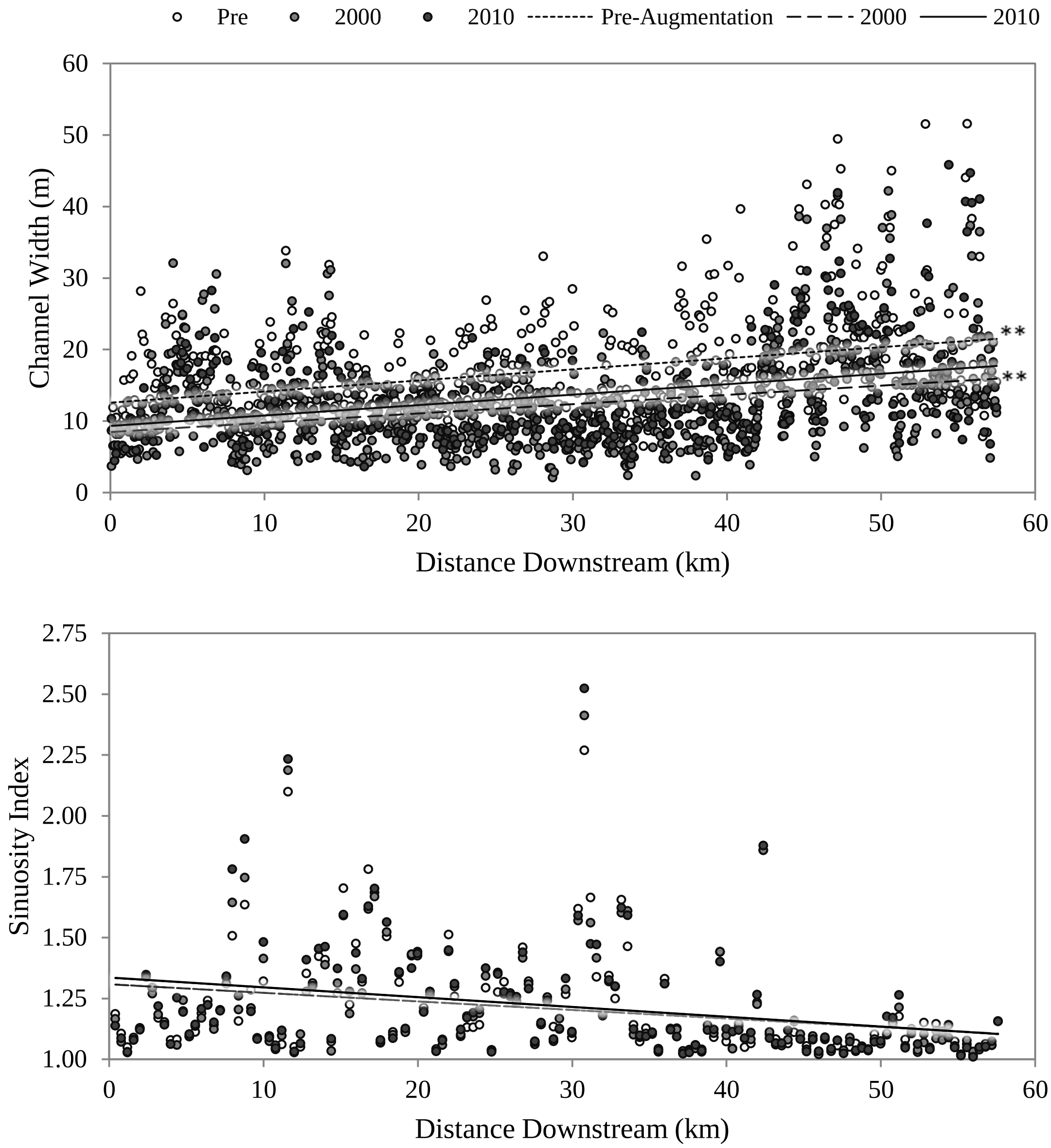

Figure 2.4 Linear relationships established for the analysis of covariance (ANCOVA) of channel width and sinuosity along the Little Bow River, Alberta. River conditions include pre-augmentation (mean of 1967 and 1981), 2000, and post-augmentation (2010). Highly significant linear relationships were established with both channel width (p=0.00, $R^2_{Pre\text{-}Aug}$=0.13, R^2_{2000}=0.09, and R^2_{2010}=0.15) and sinuosity index (p=0.00, $R^2_{Pre\text{-}Aug}$=0.08, R^2_{2000}=0.07, and R^2_{2010}=0.09). Significant differences from post-augmentation conditions are indicated with asterisks (p-value: <0.01 **).

Table 2.2 ANOVA (df=2) of channel width and sinuosity index along seven reaches of the Little Bow River, Alberta following recent flow augmentation. Significant p-values are indicated with asterisks (p-values: <0.01 **).

Reaches	**Channel Width**		**Sinuosity Index**	
	F-value	p-value	F-value	p-value
Reach 1	7.71	0.00**	0.14	0.87
Reach 2	6.33	0.00**	0.18	0.84
Reach 3	23.11	0.00**	0.07	0.94
Reach 4	76.75	0.00**	0.04	0.96
Reach 5	38.20	0.00**	0.01	0.99
Reach 6	7.17	0.00**	0.13	0.87
Reach 7	1.92	0.15	0.21	0.81

Table 2.3 ANCOVA and ANOVA pairwise comparisons of channel widths during pre-augmentation (mean of 1967 and 1981), 2000, and post-augmentation (2010) conditions along the Little Bow River, Alberta and seven reaches. Significance levels are presented with directions of change denoted beneath.

Year	**Channel Width p-values**							
	Upper Little Bow	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Pre-Augmentation to 2000	0.01 ↓	0.01 ↓	0.01 ↓	0.01 ↓	0.01 ↓	0.01 ↓	0.01 ↓	-
Pre-Augmentation to 2010	0.01 ↓	0.01 ↓	-	0.01 ↓	0.01 ↓	0.01 ↓	0.01 ↓	-
2000 to 2010	0.01 ↑	-	-	0.1 ↑	0.01 ↑	0.1 ↑	-	-

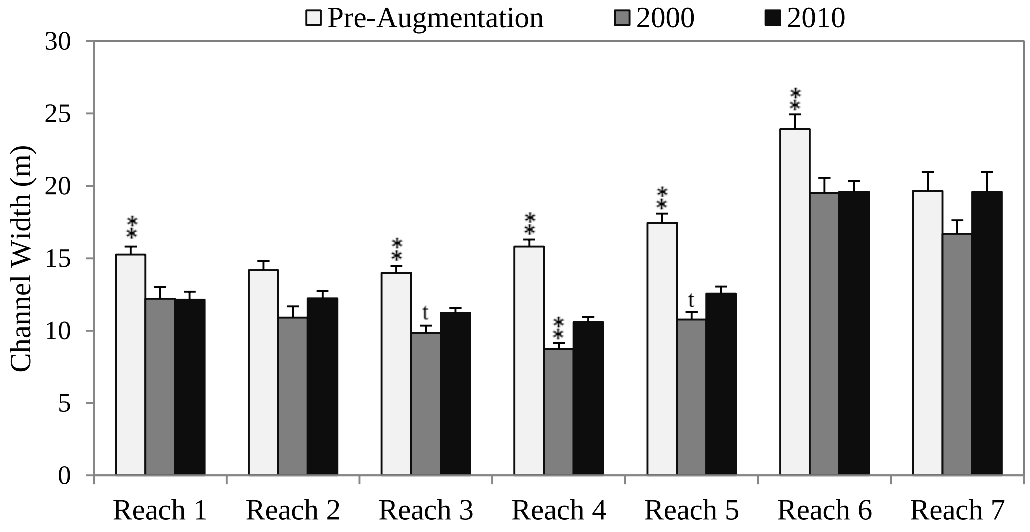

Figure 2.5 Channel widths during pre-augmentation (mean of 1967 and 1981), 2000, and post-augmentation (2010) conditions along seven reaches of the Little Bow River, Alberta. Significant differences from post augmentation (2010) conditions are indicated with asterisks (p-values: <0.1 ^{t} and <0.01 **).

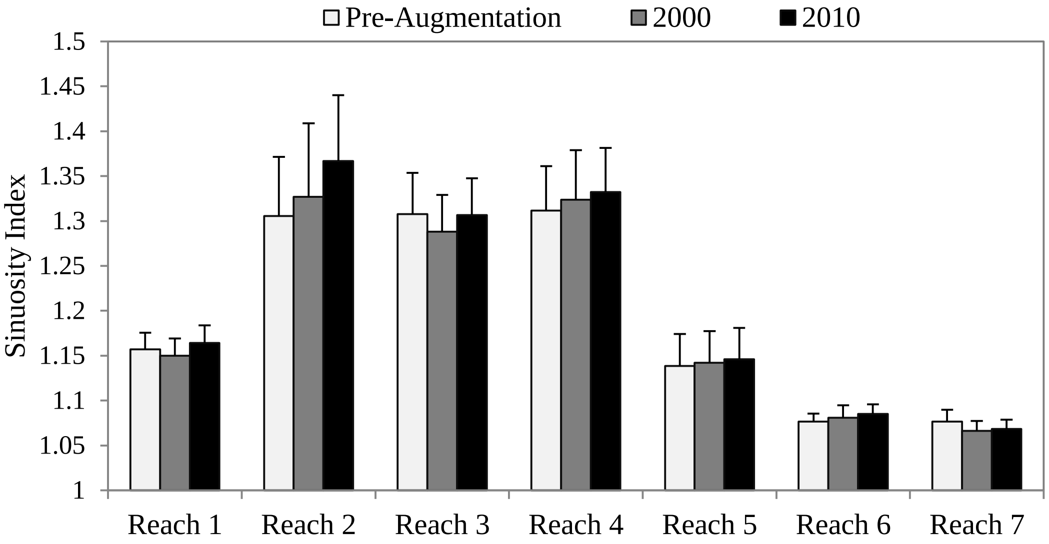

Figure 2.6 Sinuosity index during pre-augmentation (mean of 1967 and 1981), 2000, and post-augmentation (2010) conditions along seven reaches of the Little Bow River, Alberta.

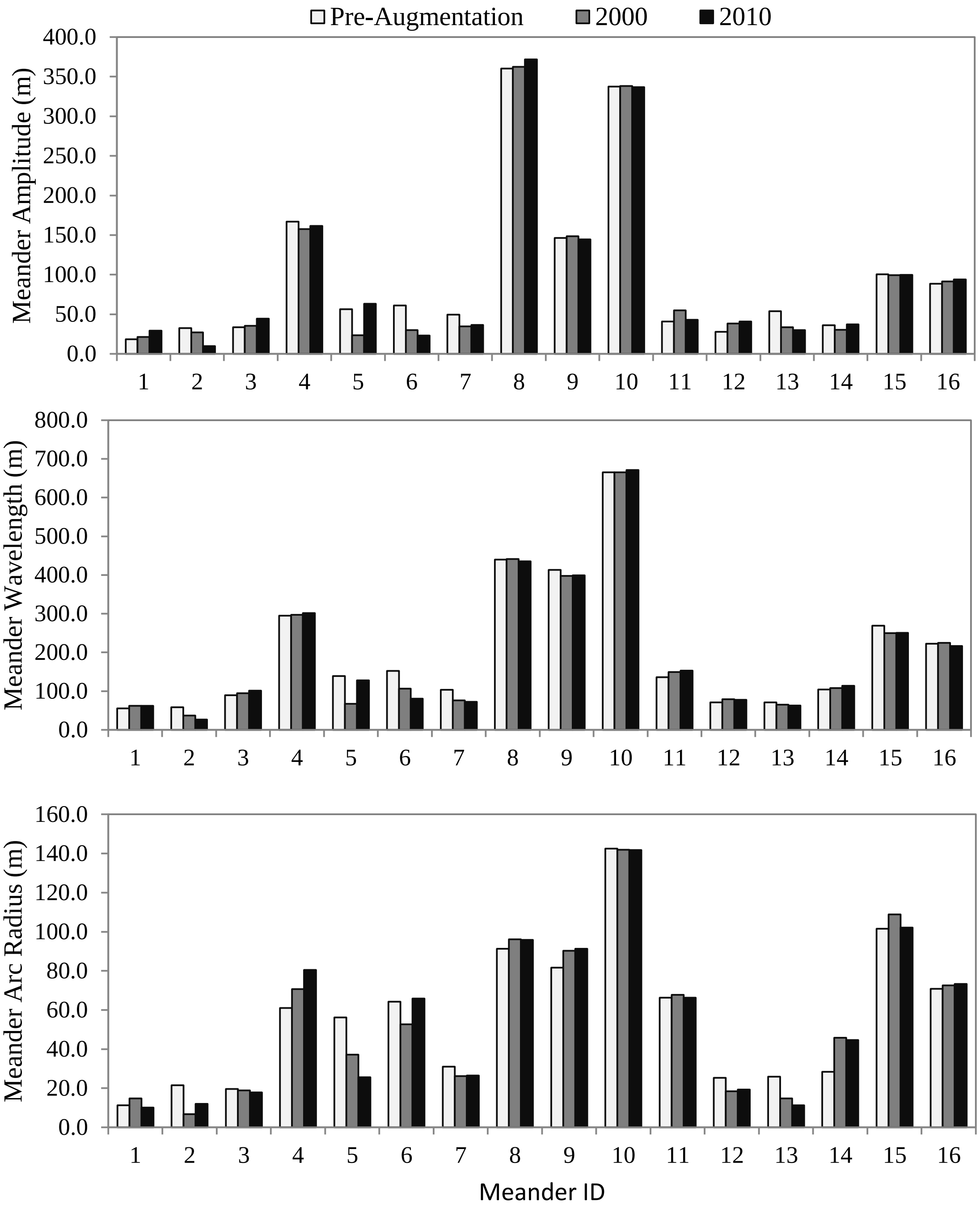

Figure 2.7 The amplitude, wavelength, and arc radius of 16 meanders during pre-augmentation (mean of 1967 and 1981), 2000, and post-augmentation (2010) conditions along the Little Bow River, Alberta. Measurements were derived from aerial photographs georectified to an RMSE of 2.5 m.

2.3.3 Response of Riparian Vegetation

Vegetation proportions along the Little Bow River lacked significant interaction terms, and exhibited highly significant linear relationships between the distance covariate and the vegetation communities of riparian woodlands, true willows, graminoids, and cattails (Figure 2.8; Table 2.4). Wolf willow communities exhibited a linear trend with the distance covariate. Goodness of fit for ANCOVA models were good for riparian woodlands, true willows, graminoids, and cattails, while fit was poor for wolf willows (Table 2.5). All vegetation classes, with the exception of graminoids, experienced no significant changes in proportions between both pre-augmentation and 2010 or 2000 and 2010 conditions (Table 2.5, Figure 2.8). Although, true willows exhibited a significant change in vegetation proportions, significant pairwise comparisons were only identified between pre-augmentation and 2000 conditions. Graminoids experienced a highly significant decline in proportions between 2000 and 2010 (p= 0.00).

The majority of reaches along the Little Bow River exhibited normal distributions of vegetation proportions allowing appropriate analysis by ANOVA. Significant alterations in vegetation proportions were indicated in true willows, wolf willows, graminoid, and typhas communities (Table 2.6). Comparisons between pre-augmentation and post-augmentation (2010) conditions indicated a significant decrease in wolf willows along reach four (p=0.02) and a trend of decreasing true willows along reach five (p=0.09) (Figure 2.9). However, wolf willow along reach four exhibited an increasing trend between 2000 and 2010 conditions (p=0.07). Following augmentation, graminoid communities along reach three exhibited a significant decrease in vegetation proportions from baseline (2000) conditions (p=0.03). All other significant alteration in vegetation proportion occurred between pre-augmentation and baseline (2000) conditions and was not of interest to this study.

The overall vegetation classification accuracy for the 2010 aerial photograph dataset was 53% (Table. 2.7). Producer and user accuracies were adequate for riparian woodlands, graminoids and cattails, however true willow and wolf willow communities exhibited poor accuracies. The overall accuracy of 53% was assumed to be representative of all years of classification (1967, 1981, 2000, and 2010).

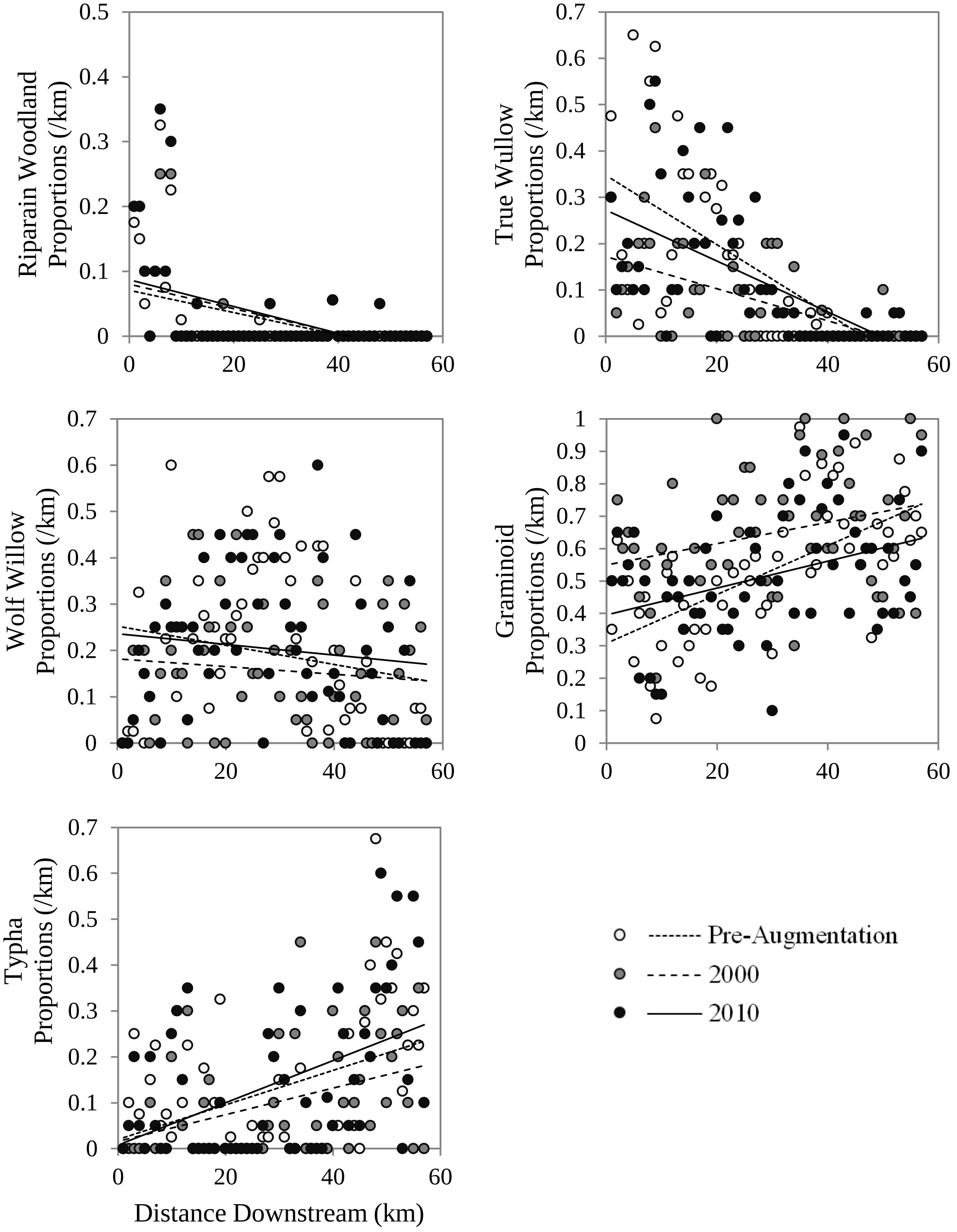

Figure 2.8 Analysis of covariance (ANCOVA) of vegetation proportions along the Little Bow River, Alberta from pre-augmentation (mean of 1967 and 1981), 2000, and post-augmentation (2010) conditions.

Table 2.4 Linear regressions used in the analysis of covariance (ANCOVA) of riparian vegetation proportions between pre-augmentation (mean of 1967 and1981), 2000, and post-augmentation (2010) conditions along the Little Bow River, Alberta. Analysis of vegetation proportions were undertaken with distance downstream from the Little Bow Canal as the covariate. Significant interactions with the distance covariate are denoted with asterisks (p-value: <0.1 ^{t} and <0.01 **).

Vegetation	**p-value**	**Linear Regression**	**R^2**
Riparian Woodlands	0.00**	Pre-Augmentation	0.22
		2000	0.26
		2010	0.23
True Willows	0.00**	Pre-Augmentation	0.42
		2000	0.29
		2010	0.38
Wolf Willows	0.07^t	Pre-Augmentation	0.04
		2000	0.01
		2010	0.02
Graminoids	0.00**	Pre-Augmentation	0.38
		2000	0.08
		2010	0.13
Typhas	0.00**	Pre-Augmentation	0.17
		2000	0.14
		2010	0.21

Table 2.5 ANCOVA (df=2) of riparian vegetation proportions between pre-augmentation (mean of 1967 and1981), 2000, and post-augmentation (2010) conditions along the Little Bow River, Alberta. Analysis of vegetation proportions were undertaken with distance downstream from the Little Bow Canal as the covariate. Significant differences in vegetation between years are denoted with asterisks (p-value: <0.05 * and <0.01 **).

Vegetation Type	**R^2**	**F-value**	**p-value**
Riparian Woodlands	0.24	0.18	0.84
True Willows	0.37	3.45	0.03*
Wolf Willows	0.04	1.30	0.28
Graminoids	0.25	9.29	0.00**
Cattails	0.19	1.40	0.25

Table 2.6 ANOVA (df=2) of riparian vegetation proportions along seven reaches of the Little Bow River, Alberta. Vegetation proportions classified from aerial photographs were compared between pre-augmentation (mean of 1967 and 1981), 2000, and post-augmentation (2010). Significant differences in proportions between years are indicated with asterisks (p-value: <0.1 ^{t} and <0.01 **).

Reach	**Vegetation Type**	**Vegetation Frequency**	
		F-value	p-value
Reach 1	Riparian Woodlands	0.11	0.90
	True Willows	0.71	0.50
	Wolf Willows	0.16	0.85
	Graminoids	2.39	0.12
	Cattails	2.87	0.08^{t}
Reach 2	Riparian Woodlands	0.04	0.96
	True Willows	1.42	0.27
	Wolf Willows	0.02	0.98
	Graminoids	1.71	0.21
	Cattails	0.16	0.86
Reach 3	Riparian Woodlands	1.00	0.38
	True Willows	5.67	0.01**
	Wolf Willows	0.86	0.44
	Graminoids	8.61	0.00**
	Cattails	1.30	0.29
Reach 4	Riparian Woodlands	0.11	0.90
	True Willows	2.20	0.13
	Wolf Willows	13.83	0.00**
	Graminoids	2.44	0.10
	Cattails	0.96	0.40
Reach 5	Riparian Woodlands	0.00	1.00
	True Willows	2.81	0.08^{t}
	Wolf Willows	0.93	0.41
	Graminoids	1.28	0.29
	Cattails	0.78	0.47
Reach 6	Riparian Woodlands	0.50	0.62
	True Willows	0.60	0.56
	Wolf Willows	1.47	0.26
	Graminoids	0.80	0.47
	Cattails	1.22	0.32
Reach 7	Riparian Woodlands	N/A	N/A
	True Willows	2.50	0.12
	Wolf Willows	2.14	0.15
	Graminoids	0.49	0.62
	Cattails	0.95	0.41

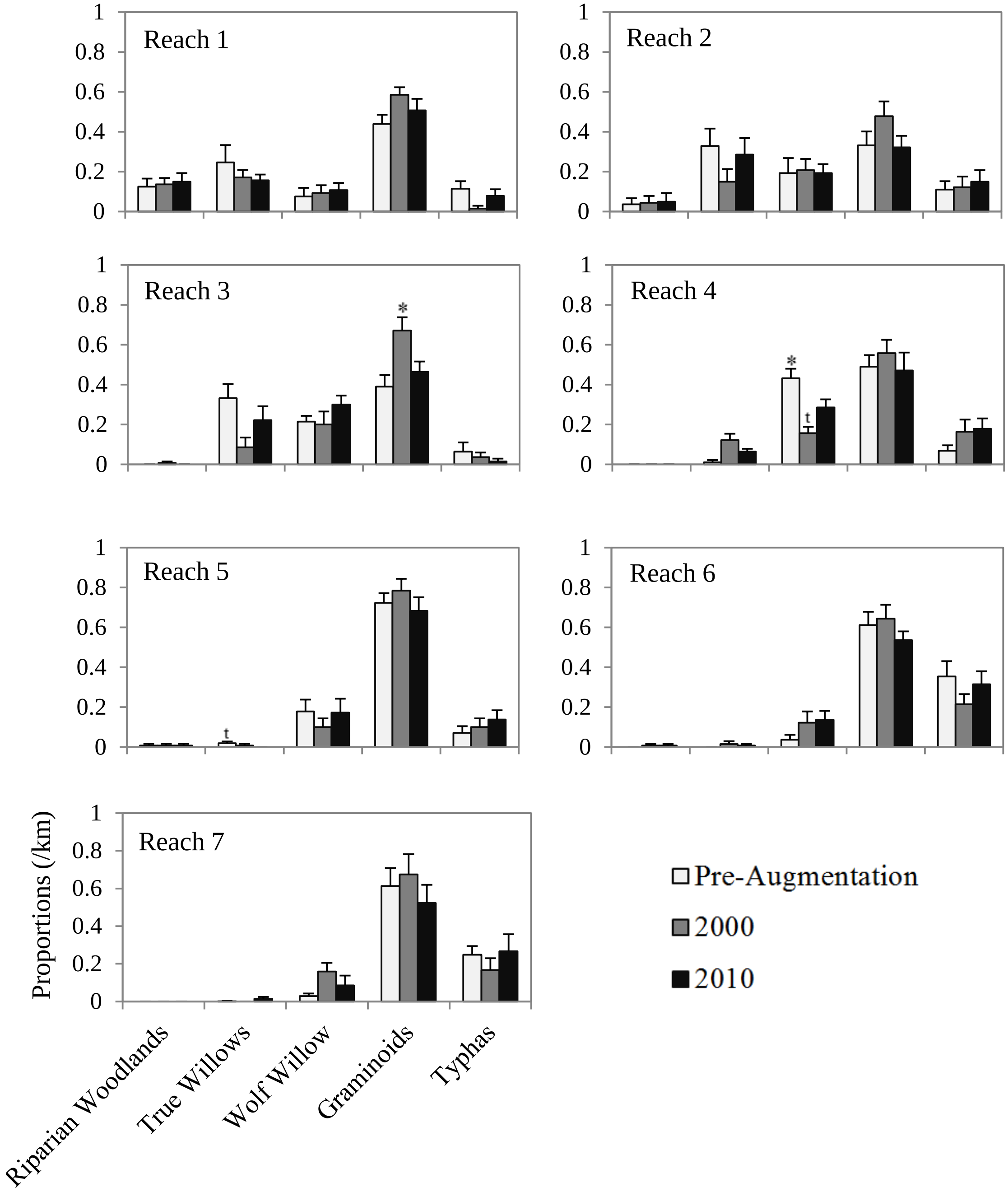

Figure 2.9 Proportions of riparian vegetation along seven reaches of the Little Bow River, Alberta during pre-augmentation (mean of 1967 and 1981), 2000, and post-augmentation (2010) conditions. Asterisks identify historic years possessing significantly different vegetation proportions than post-augmentation (2010)(p-value: <0.1 t and <0.05 *).

Table 2.7 Accuracy of riparian vegetation classifications along the Little Bow River, Alberta. Aerial photographs from 2010 were ground-truthed with transect photos acquired in 2013. Overall accuracy of classification was 52.7%.

Vegetation Class	**2010 Classification**	**2013 Images**	**Number Correct**	**Producer Accuracy (%)**	**Users Accuracy (%)**
Riparian Woodlands	7	7	7	100	100
True Willows	11	12	4	36	33
Wolf Willows	14	15	4	29	27
Graminoids	25	28	14	56	50
Cattails	15	10	10	67	100
Total	72	72	39		

2.4 Discussion

2.4.1 Response of Channel Form to Flow Augmentation

Highly significant increases in channel widths along the Little Bow River occurred between 2000 and 2010 supporting the initial prediction. This prediction was later rejected as channel widths exhibited highly significant decreases between pre-augmentation and 2010 conditions. Similar patterns were found along the majority of reaches between pre-augmentation and 2010 conditions, while all reaches except for reaches three, four, and five exhibited similar widths between 2000 and 2010. These results suggest that although channel width increased between 2000 and 2010, current widths remain less than that of some historical conditions. This system therefore currently remains within its natural range of variability. Sinuosity index and meander characteristics remained consistent across all temporal and spatial scales.

The lack of system-wide alterations in channel form along the Little Bow River supports previous monitoring reports prepared for Alberta Environment. This however contradicts the typical response of augmented rivers which exhibit increased channel width, decreased sinuosity index, and decreased meander extent. The lack of response along the Little Bow River could be the result of a large transient period, limited augmentation of flows, and implications of land-use management.

Implementation of the Highwood Little Bow Diversion Project in 2004, allowed only six years of change to be detected in the analysis of aerial photographs from 2010. Although rivers are dynamic, river channel form is maintained/changed through patterns of erosion and deposition of sediments over many years. Some rivers undergoing flow augmentation remain in transient states for greater than 20 years before undergoing rapid change (Dominick and O'Neill 1998). Additionally, the response time of rivers like the Little Bow River are generally lengthened, as prairie originating systems are rain-dominated often with lower stream powers and reduced sediment transport capabilities (Friedman and Lee 2002).

In comparison, the Milk River (Q= 19 m^3/s, DA= 57,840 km^2), a larger river in semi-arid Montana and Alberta, has undergone flow augmentation averaging 9.5 m^3/s since 1917 (Bradley and Smith 1984). Channel widths increased from 53.4 to 58.8 m over 36 years of study (1915-1951). The slow response of this river system supports that a longer transient time likely exists than the six years of study used to detect change along the Little Bow River.

In addition to a longer transient time, the implementation of augmented flows along the Little Bow River in 2004 slightly increased mean seasonal flows, while maximum annual flows remained relatively unchanged. Moderate flows along rivers are prominent in defining and maintaining river planforms, due to continual sediment transport (Wolman and Miller 1960). Although, maximum flows have much larger stream powers and larger capacities for sediment transport, their short durations reduce the geomorphic work completed during flood events. Maximum annual flows along the Little Bow River visually corresponded with mean channel widths, indicating that widths should not be much larger than historical conditions.

The limited augmentation of mean and maximum annual flows outside the natural variability of the Little Bow River could result in channel conditions approximating historical periods with similar flows. A future system-wide response in channel form should therefore not differ significantly from historical conditions, unless the Highwood Little Bow Diversion Project implemented higher flows. Subsequently, sinuosity index and meander characteristics would not decrease significantly from historical conditions due to the fact that in time comparable flows define comparable channel form.

Land-use management along the Little Bow River confounded the analysis of changes in channel form following augmentation. Large discrepancies in the health of river banks and riparian vegetation can be seen across property lines. Pugging of banks and reductions in riparian vegetation by intensive cattle grazing has increased erosion along the Little Bow River causing localized changes in channel form (Bigelow 2006). These disturbances accelerate change in affected reaches, while undisturbed reaches maintain greater bank stability and take longer to respond to flow augmentation.

Analysis of river channel form was limited by errors associated with the quality of aerial photographs and the accuracy of georectification. Historic aerial photographs were converted from contact prints to digital formats by APRS for storage purposes. This conversion of data resulted in reduced contrast, and pixilation, subsequently reducing the quality of information extracted. As aerial photographs were georectified to less than 2.5 m RMSE, any alterations in channel form less than 2.5 m may have resulted from errors associated with georectification rather than flow augmentation. Change detection in smaller rivers, like the Little Bow River, is reduced as channel width in some locations will only be slightly larger than the accepted error. Regardless of measurement accuracy, the analysis of aerial photography is still very well suited to change detection in river systems due to the historical record and that data can be collected quicker, cheaper, and easier than field studies.

The lack of system-wide change in channel form along the Little Bow River requires further monitoring. Future monitoring should follow a similar template as previous efforts, allowing the use of previous studies as baseline conditions. Aerial analysis of this system should occur every ten years, as complete aerial coverage of Alberta occurs every decade. If mean and maximum annual flows along the Little Bow River were to noticeably increase from the historical variability, analysis should be undertaken earlier. In addition, analysis should be undertaken in years following major floods with high peaks and sustained high flows, such as the flood of 2013, as these events are likely to accelerate changes along this river system (Appendix A).

2.4.2 Riparian Vegetation's Response to Flow Augmentation

Riparian woodland proportions failed to significantly increase in 2010 as predicted from both historical pre-augmentation and 2000 conditions. Lack of change in riparian woodlands supports previous monitoring reports prepared for Alberta Environment (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006). In the most recent monitoring report, riparian woodlands increased in coverage, contradicting the lack of change identified in this analysis (Samuelson *et al.* 2012).

Poplar establishment and survival along rivers is dependent on bare substrate for colonization and sustained contact with the water table for survival. Between 1972 and 1996, the Little Bow River received no floods greater than a one in five year (16 m^3/s) recurrence which would have limited the formation of bare substrate for colonization events. However, four floods of greater than one in five year magnitude occurred between 1997 and 2010 which could have provided an opportunity for colonization of new cottonwood patches. Seed sources along the Little Bow River are scare and limited to the upper reaches, hindering any expansion of new woodlands through seedling recruitment. Expansion of existing riparian woodland patches through suckering and maturing of established trees is likely responsible for the increases noted by Samuelson and colleagues (2012). This expansion is of limited spatial extent and is not largely dependent on flow events, resulting in localized changes that could be detected by vegetation transects but not through aerial analysis.

True willow proportions failed to increase significantly along the Little Bow River and the majority of reaches as initially predicted. Lack of change in proportions of true willows supports previous monitoring reports prepared for Alberta Environment

(Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006). In contrast, localized declines in true willows along reach five contradict localized expansions noted by Samuelson and colleagues (2012). These contradicting localized changes in true willows are likely in response to land-use management rather than the augmentation of flows.

The presence of obligate riparian species such as willows are dependent on discharge magnitude, timing, rate of change, duration, and frequency of low, mean, and high flows (Toner and Keddy 1997, Nilsson and Svedmark 2002, Auble *et al.* 2005). Reproduction of willows are depended on high flow events much like cottonwoods, requiring discharges greater than one in five year recurrence (Cordes *et al.* 1997).With minimal change in maximum discharge values between current and historical conditions, limited expansion of willows along the Little Bow River likely resulted from limited reproduction through colonization events. Mean and minimum flow periods are also crucial to the survival of phreatophytic riparian species as they require sustained access with the water table. Following the augmentation of mean and minimum seasonal discharges, the survival of existing and any future obligate riparian species would be benefited. Although alteration in true willow proportions are limited within this and previous studies, the possibility of future expansion still exists.

Wolf willow communities along the Little Bow River exhibited unchanged proportions following flow augmentation, supporting previous monitoring reports prepared for Alberta Environment but failing to support the predicted decline (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006, Samuelson *et al.* 2012). An increasing trend in wolf willows, localized along reach four between 2000 and 2010, contradicted all previous monitoring reports, predictions, and anecdotal evidence of a natural wolf willow dieback occurring near the border of reaches three and four (Figure 2.10). Wolf willow proportions along reach four in 2010 however remained significantly less than pre-augmentation conditions.

Facultative riparian wolf willows are drought tolerant, and were likely not benefited greatly by the increased water availability resulting from the augmentation of mean and minimum seasonal flows. The stabilization of water table fluctuations enables drought tolerant species to expand to higher valley elevations, while inundation tolerant species are supported at lower elevations (Bendix 1999, Leyer 2005). Wolf willow communities could therefore transition from river banks to valley walls and upland areas, while riparian woodlands and true willows colonize the river banks. This transition relies on facultative riparian species being outcompeted by obligate riparian species, which are currently limited in colonization by lack of high flows and seed sources. As a result, wolf willows have maintained their proportions along the majority of this river system, and likely will into the future.

Highly significant decreases in graminoid proportions along the Little Bow River and significant decreases along reach three support the initial prediction. Significant declines in graminoid proportions suggests a possible transitioning of vegetation along the Little Bow River that has not been indicated in any previous monitoring reports (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006, Samuelson *et al.* 2012). Graminoid communities are likely declining in response to the expansion of true willows, wolf willows, and cattail communities. Although these expansions may not be significant, the cumulative loss of graminoid communities is significant.

Cattail proportions remained consistent across all years of study, supporting the initial prediction of recovery from scouring (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006). Cattail communities would have been supported by increased minimum and mean seasonal flows with limited change in maximum discharge. Although proportions of cattails are comparable with historic conditions, future expansion may occur if increased mean flows produce increased suitable habitat through the inundation of low-lying areas. With increases in mean flows remaining within the present channel and limited scouring events following 2006, cattail communities were able to recover, remaining comparable with historical conditions.

Overall, the Little Bow River failed to demonstrate the typical response of transitioning vegetation communities from facultative to obligate species shown along other augmented rivers such as the South Fork of the Middle Crow River in Wyoming (Q= 0.22 m^3/s, DA= 666 km^2)(Henszey *et al.* 1991) and the Nechako River in British Columbia (Q=280 m^3/s, DA= 42,700 km^2)(Kellerhals *et al.* 1979). Additionally, the Little Bow River failed to support a less typical response of declining total area vegetated by riparian species, due to initial channel restructuring (Dominick and O'Neill 1998). The non-typical response of the Little Bow River could have resulted from lack of substantial increases in mean and maximum flows discussed earlier, a short transition period of six years, land-use management, and vegetation classification accuracy.

Vegetation along some river systems respond to flow regulation within ten years, while in others systems, vegetation communities reside in long transient periods reliant on changes to channel form before an initial equilibrium is reached and succession takes hold (Johnson 1998). The Platte River (Q= 202 m^3/s, DA= 221,107 km^2), a semi-arid river in Nebraska, experienced a 30 year transient period before declines in cottonwoods occurred following damming and augmentation of flows in 1909 (Johnson 1998). In this study, the Little Bow River is six years post-augmentation and likely remains within a transient state reliant on changes in channel form, before significant changes in vegetation will occur.

Land-use management confounds the analysis of vegetation along the Little Bow River following recent flow augmentation. Differences in land-use management can be easily identified across property lines, with intensive cattle grazing having the largest visible impact on riparian health (Figure 2.11). Cattle disproportionally use riparian areas due to the high quality forage opportunities and water availability (Gillen *et al.* 1985). This constant grazing pressure reduces the fitness of riparian vegetation through browsing stress and toppling/trampling (Fenner *et al.* 1985). The exclusion of cattle from riparian areas increases woody shrub density and canopy cover, with willow coverage being up to 8.5 times greater in excluded pastures and composed of older and larger individuals (Schulz and Leininger 1990).

Numerous beneficial management practises have been undertaken along the Lower Little Bow River, whereas fewer have been implemented along the Upper Little Bow River. During a float trip in 2013, a section of the Upper Little Bow River with cattle exclusion devices implemented showed healthy woody shrub populations dominated by true willows and wolf willows. However, further downstream in an intensively grazed pasture, banks became dominated with graminoids and leafy spurge (*Euphorbia esula* L.). Land-use management along the Little Bow River likely overshadow the response of vegetation to flow augmentation, as selection pressures for woody vegetation are counteracted by intensive land-use practises.

The accuracy of vegetation classification in this study limited change detection in vegetation proportions. Image classification accuracy was adequate for identifying change in riparian woodland, graminoid, and cattail communities. However, true willows and wolf willows had poor classification accuracies due to confusion in differentiation between these two classes during aerial photograph interpretation. In future studies, change detection in vegetation communities along the Little Bow River would greatly benefit from improved image classification accuracy. Improved classification accuracy could be acquired from higher resolution aerial photographs, as well as the inclusion of colour and colour infra-red to help differentiate true willows from wolf willows. Restriction of aerial photographs to scales less than 1:40,000 but greater than 1:10,000 would provide optimal resolution, while limiting pre-processing workloads. The historical aerial photographs of the Little Bow River will still limit the capacity of change detection as aerial photographs of improved quality are not available during these time periods.

Continued monitoring of the Little Bow River is required to document any transitions in vegetation communities. Future studies should be completed in conjunction with channel form due to complementary methodologies. Aerial classification of vegetation communities should therefore be undertaken every decade, when aerial photographs become available from APRS. Any statistically significant change from historical conditions should be ground-truthed in the following year. Additionally, future studies should address land-use management as a confounding factor.

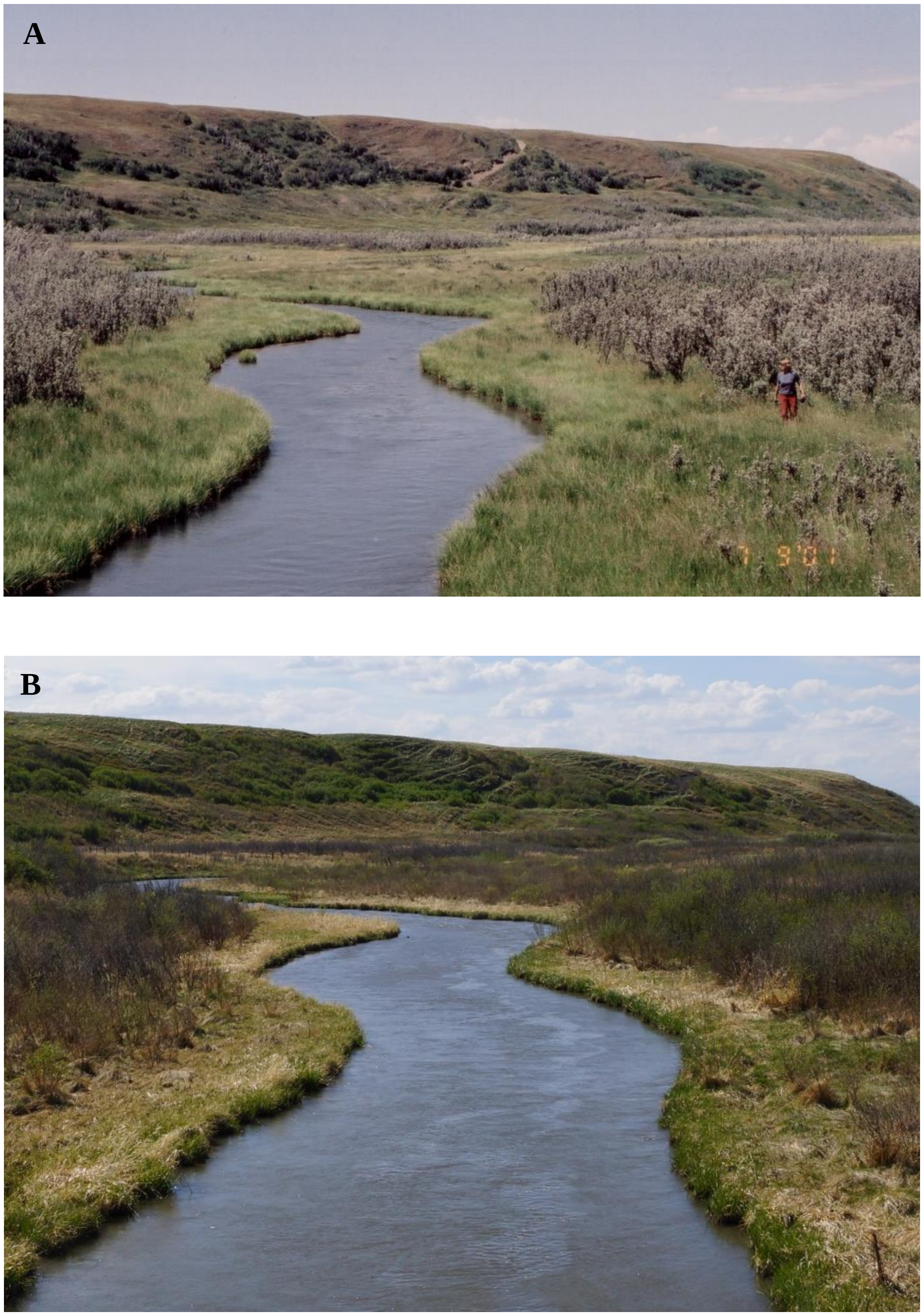

Figure 2.10 Natural die back of wolf willows upstream of 168 St. E bridge along the Little Bow River, Alberta. Photograph A) was taken on July 9 2001 (Q=1.88 m^3/s) and represents baseline pre-augmentation conditions, while B) was taken on May 21 2013 (Q=3.7 m^3/s) and represents conditions following augmentation.

Figure 2.11 Riparian vegetation health across fence lines subject to different land-use management practices along the Little Bow River. This image is a subset of a colour infrared aerial photograph taken on May 25 2001 (Q= 1.65 m^3/s) and is centered at -113.736° N 50.489° W. The fence line of interest runs from N to S along the center of the photograph; grazing of higher intensity has occurred on the eastern (downstream) side of the fence line.

CHAPTER 3

AVIAN COMMUNITY COMPOSITION ALONG THE LITTLE BOW RIVER, ALBERTA

3.1 Introduction

Despite the fact that riparian areas constitute only one percent of arid regions within western North America, they possess much greater avian abundance and diversity than adjacent upland areas (Saab 1999, Iwata *et al.* 2003, Scott *et al.* 2003). Riparian areas are rich in food resources and provide structural habitat for overwintering, breeding, and migratory bird species. Large un-fragmented deciduous woodlands with diverse age structure exhibit the greatest abundance and diversity of riparian bird species and require conservation from growing threats of agricultural infringement and river flow regulation (Saab 1999, Heltzel and Earnst 2006).

River flow regulation is extensive within North America, reducing flow variability in nearly all major river systems (Leyer 2005). Cottonwoods (*Populus spp.*) and willows (*Salix spp.*) provide the primary woody vegetation and avian habitats utilized in western riparian areas, and possess life histories reliant on natural flow regimes for seedling recruitment, growth, and survival. Additionally, natural flow regimes are crucial to the successful bank foraging and nesting of riparian birds, and the life histories of aquatic invertebrates that compose the majority of insectivorous bird species diets (Nilsson and Dynesius 1994, Iwata *et al.* 2003).

Deviations from natural flow regimes can have detrimental impacts on the health of riparian habitats, as shown along the Oldman River (Q= 70.4 m^3/s, DA=27,533 km^2) in southern Alberta, which experienced diversions of flows greater than 90% of some summer flows in the 1980's and led to substantial declines in cottonwood forests (Rood *et al.* 2005). Following the construction of the Oldman Dam in 1993, minimal flows along the river were increased 15 fold and rates of flow decline following peaks were managed to approximate a natural flow regime, which subsequently promoted the recruitment and recovery of cottonwoods (Rood *et al.* 2005).

The restorative approach used along the Oldman River of increasing low flows and managing stage declines, mirrors a rarely undertaken and studied form of river regulation in which flows are augmented typically to supply agricultural rather than environmental demands. Although studies have been conducted regarding the response of channel form and vegetation along a few augmented rivers, studies have not been conducted regarding avian responses to augmented flows. Avian communities are commonly used as indicator species for riparian health, which raises the intriguing question of how these communities might respond to shifts in flow regimes.

The Little Bow River, a small, historically intermittent river in southern Alberta, has a long history of flow augmentation dating back to the late 1890s. It provides a unique study opportunity as this system recently experienced a tripling of summer flows following the implementation of the Highwood Little Bow Diversion Project in 2004 (Alberta Public Works 1998). In a monitoring report prepared for Alberta Environment in 2008, Herzog and McCormick identified that only minimal changes to communities in incidental and rare songbird species occurred in response to initial flow alteration. Yellow-headed blackbirds (*Xanthocephalus xanthocephalus* (Bonaparte 1826)), an obligate riparian bird species, exhibited dramatic declines following flow augmentation, but limited explanation of causation was provided. Conversely, riparian shorebirds along the Little Bow River were initially low in abundance and diversity, and showed no substantial response to flow augmentation.

As the Little Bow River approaches ten years with the Highwood Little Bow Diversion Project, this study was undertaken to further investigate the response of riparian songbirds and shorebirds in terms of biodiversity and community structure. Yellow-headed blackbird population dynamics were reassessed, identifying whether the declining trend identified by Herzog and McCormick (2008) persists. Furthermore, the occupation of cattail (*Typha latifolia* L.*)* patches along the Little Bow River was assessed as an explanatory variable related to the declining yellow-headed blackbird population.

Riparian songbirds and shorebirds were predicted to increase in biodiversity following the predicted expansion of willows and poplars in response to flow augmentation. Transitions from grassland to riparian vegetation would have provided greater vertical structure and more niches for occupation by riparian specialist species. Although the only significant shift in vegetation identified in Chapter Two was a decline in graminoid communities, riparian birds are still expected to increase in biodiversity as they are more responsive to change than aerial photograph analysis.

Yellow-headed blackbirds were predicted to be recovering from initial declines, as cattail communities along the Little Bow River are likely equilibrating to the new flow regime. Initial scouring of cattail communities following the implementation of flow augmentation in 2004 was documented in Alberta Environment monitoring reports (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006) and might be responsible for declines in yellow-headed blackbirds due to reductions in suitable habitat.

3.2 Research Methodology

3.2.1 Study Area

The Little Bow River is a small, historically intermittent meandering river, under-fit within a much larger historical channel of the Highwood River. Stream power along the Little Bow River is low, with flows averaging 1.6 m^3/s and ranging from 0.0 to 54.9 m^3/s. The drainage area of the Little Bow River encompasses 1,963 km^2 dominated mainly by cattle grazing and dry-land agriculture. Irrigation agriculture is growing in popularity and was the reasoning behind the implementation of the Highwood Little Bow Diversion Project in 2004. This drainage area is occupied within the mixed grassland natural sub-region. Riparian vegetation transitions from riparian woodlands (*Populus balsamifera* L. and *Acer negundo* L.) and obligate riparian willows (*Salix bebbiana* Sarg. and *Salix exigua* Nutt.) in the upper reaches, to facultative riparian wolf willow (*Elaeagnus commutata* Bernh.), graminoids, and cattail communities in the lower reaches.

Riparian birds were surveyed along the Little Bow River between its headwaters in High River, Alberta and Highway 533 located directly upstream of Twin Valley Reservoir (Figure 3.1). Avian communities are composed of both resident and migrant bird species with breeding season for most species occurring from late-May to mid-June. The waterfowl population along this river is augmented by the adjacent Frank Lake, a restored wetland and Important Bird Area (IBA) to Ducks Unlimited Canada. Waterfowl population along the Little Bow River was therefore not a focus of this study.

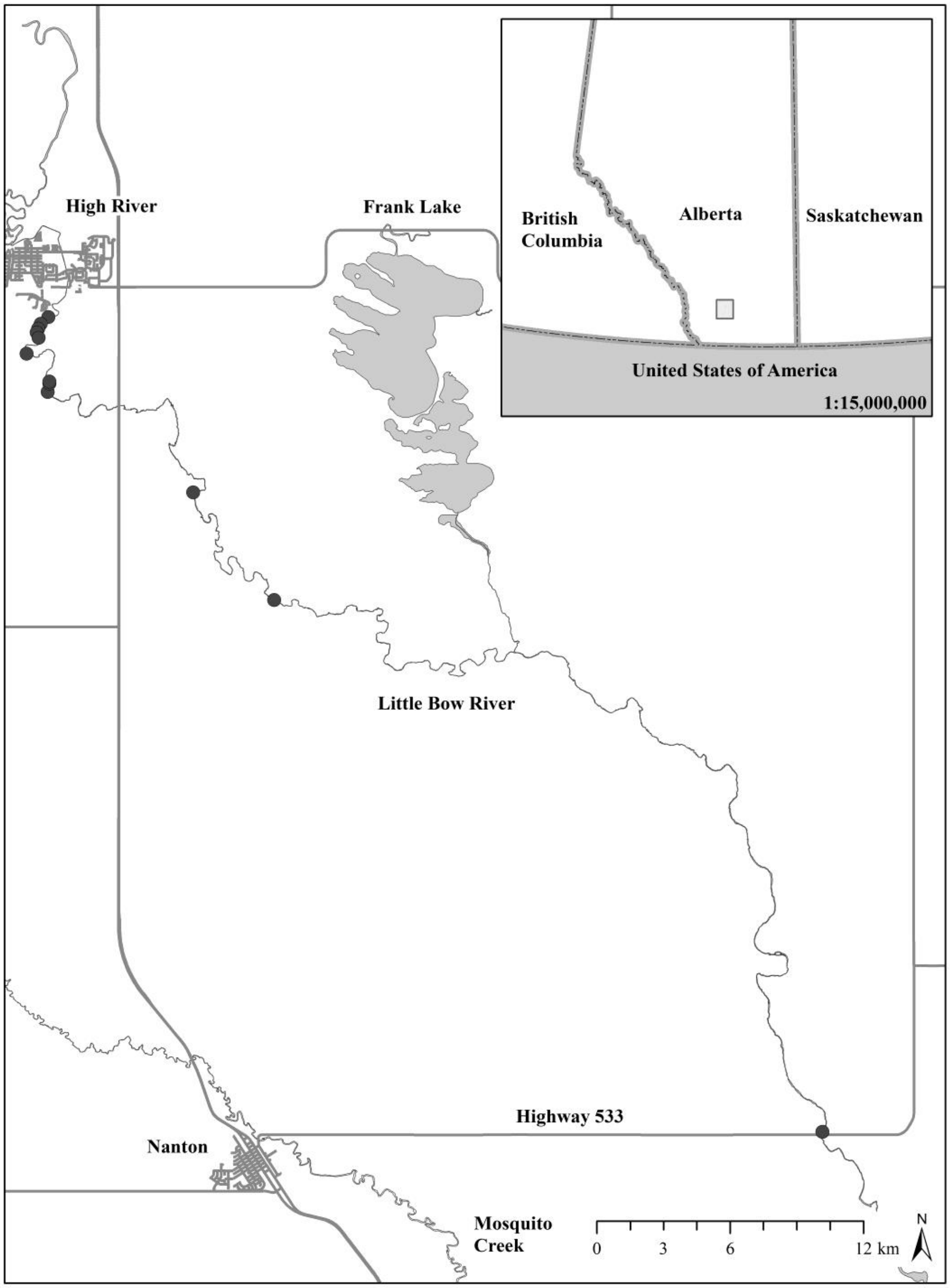

Figure 3.1 Study area and 12 riparian survey sites (denoted by circles) along the Little Bow River, Alberta. The road network and some hydrologic features were extracted from Shapefiles provided by GeoBase.

3.2.2 Riparian Songbird and Shorebird Surveys

Songbirds and shorebirds along the Little Bow River were surveyed in 2013 at 12 sites corresponding with previous surveys conducted in 2005, 2006, and 2007 by Herzog and McCormick (2008)(Figure 3.1). Surveys were conducted twice during the breeding season, in late-May and mid-June and were undertaken within three hours of sunrise and under favourable weather conditions.

Fixed radius point surveys of 50 m radius and ten minutes duration were undertaken employing both sight and sound in identifying species and quantifying abundance. Prior to each survey, a two minute resting period was undertaken, allowing birds to settle following the initial disturbance of surveyor presence. Survey protocols were comparable in radius, duration, and sampling intensity with surveys conducted by Herzog and McCormick (2008), allowing initial surveys to represent baseline conditions following the implementation of the Highwood Little Bow Diversion Project in 2004.

Site characteristics for each of the 12 sites were collected from field observations during surveys and were compiled from monitoring reports prepared for Alberta Environment (Samuelson *et al.* 2012). Site characteristics included distance downstream from the Little Bow Canal, change in channel width, cattle grazing regime (un-grazed, previously grazed, or grazed), dominant vegetation type, and relative vertical structure. The dominant vegetation types classified in order of decreasing relative vertical structure scores included riparian woodlands coded as four, true (obligate) willows as three, wolf willows as two, and cattails as one.

3.2.3 Statistical Analyses of Riparian Songbirds and Shorebirds

Riparian songbird and shorebird diversity following flow augmentation was assessed through calculation of species richness, species evenness, and Shannon Wiener Index (H') using PC-ORD version16 (McCune and Mefford 2011). Analysis of covariance (ANCOVA) of diversity measures with a covariate of distance downstream from the Little Bow Canal was undertaken in SPSS Statistics version19 (IBM 2010). A logarithmic transformation of distance downstream from the Little Bow Canal was undertaken to correct for the skewed distribution of fixed radius point survey sites. The significance of comparisons were referred to as being a trend ($p<0.10$), significant ($p<0.05$), or highly significant ($p<0.01$).

Due to the insensitivity of the Shannon Wiener Index to rare species, further analysis was conducted using Non-metric Multidimensional Scaling (NMDS), a non-parametric unconstrained ordination technique. Analysis of 12 sites along the Little Bow River by species abundance were undertaken using PC-ORD version 16 (McCune and Mefford 2011). Species abundances were relativized by the maximum number of sightings per species, equally weighting rare and common species. This analysis was paired with an explanatory matrix composed of site characteristics including distance downstream, river channel change, dominant vegetation types, relative vertical structure, and cattle grazing regimes.

NMDS analysis was conducted using the Sorenson (Bray-Curtis) city block distance measure, penalizing for unequal ordination distances and was limited to three dimensions following 500 iterations. Analysis was run a minimum of three times, ensuring consistency in the placement of sites and associations over time.

Furthermore, Canonical Correspondence Analysis (CCA), a constrained ordination technique, was undertaken on species data, visualizing associations of riparian birds based upon presence along the Little Bow River (Table 3.1). CCA was guided by the life history characteristics of each species including riparian dependency (facultative, dependent, or obligate), vegetation story occupation (under, middle, or upper), nesting substrate (ground, shrub, tree, cavity, or structure), diet (insectivorous, granivorous, omnivorous, or carnivorous), and migratory nature (resident, short distance, medium distance, or long distance).

Riparian dependency of species was determined based upon habitat usage. Facultative species were classified as not being reliant on riparian areas, dependent species as being reliant on riparian areas but utilizing upland areas in addition, and obligate species as being completely reliant on riparian areas. Riparian dependency was determined from experience, life history characteristics (Ehrlich *et al.* 1988, Cornell Lab of Ornithology 2014), and previous classifications (Bureau of Land Management 2013). Species abundances were relativized by the maximum and sora (*Porzana carolina* (Linnaeus 1758)) was removed from this analysis due to it being a large outlier and the only species occupying the floating nesting substrate. Analysis was limited to two axes and WA scores were derived from site abundance.

Table 3.1 Habitats occupied by riparian birds along the Little Bow River, Alberta determined by presence during fixed radius point surveys and displayed from left to right in order of increasing vertical structure. Habitat acronyms were defined as OTR for other, TRW for true willows, and PRW for riparian woodlands.

	Alpha Code	**Common Name**	**Scientific Name**	**Habitat Occupation**		
				OTR	TRW	PRW
Facultative	amcr	American Crow	*Corvus brachyrhynchos*		X	X
	amro	American Robin	*Turdus migratorius*	X	X	X
	bais	Baird's Sparrow	*Ammodramus bairdii*			X
	baor	Baltimore Oriole	*Icterus galbula*		X	X
	bbma	Black-billed Magpie	*Pica hudsonia*		X	X
	brbl	Brewers Blackbird	*Euphagus carolinus*	X	X	
	brth	Brown Thrasher	*Toxostoma rufum*	X		X
	bhco	Brown-headed Cowbird	*Molothrus ater*		X	
	chsp	Chipping Sparrow	*Spizella passerina*			X
	ccsp	Clay-colored Sparrow	*Spizella pallida*	X	X	X
	clsw	Cliff Swallow	*Petrochelidon pyrrhonota*	X		
	eaph	Eastern Phoebe	*Sayornis phoebe*		X	
	eust	European Starling	*Sturnus vulgaris*			X
	hosp	House Sparrow	*Passer domesticus*		X	X
	kill	Killdeer	*Charadrius vociferus*	X	X	X
	lcsp	Le Conte's Sparrow	*Ammodramus leconteii*		X	
	lefl	Least Flycatcher	*Empidonax minimus*		X	X
	modo	Mourning Dove	*Zenaida macroura*		X	X
	osfl	Olive-sided Flycatcher	*Contopus cooperi*			X
	rtha	Red-tailed Hawk	*Buteo jamaicensis*	X	X	X
	rbgu	Ring-billed Gulled	*Larus delawarensis*			X
	rnep	Ring-necked Pheasant	*Phasianus colchicus*		X	X
	savs	Savannah Sparrow	*Passerculus sandwichensis*	X	X	X
	swha	Swainson’s Hawk	*Buteo swainsoni*			X
	vesp	Vesper Sparrow	*Pooecetes gramineus*	X		
	weki	Western Kingbird	*Tyrannus verticalis*			X
	weme	Western Meadowlark	*Sturnella neglecta*			X
	wcsp	White-crowned Sparrow	*Zonotrichia albicollis*			X
	wbnu	White-breasted Nuthatch	*Sitta carolinensis*			X
Dependent	Amgo	American Goldfinch	*Carduelis tristis*	X	X	X
	Bcch	Black-capped Chickadee	*Poecile atricapillus*			X
	Eaki	Eastern Kingbird	*Tyrannus tyrannus*	X	X	X
	Howr	House Wren	*Troglodytes aedon*		X	X
	Nsts	Sharp-tailed Sparrow	*Ammodramus nelsoni*		X	
	Wewp	Western Wood Peewee	*Contopus sordidulus*			X
Obligate	BANS	Bank Swallow	*Riparia riparia*	X		
	COYE	Common Yellowthroat	*Geothlypis trichas*	X	X	X
	GRCA	Grey Catbird	*Dumetella carolinensis*		X	
	SOSP	Song Sparrow	*Melospize melodia*	X	X	X
	SORA	Sora	*Porzana carolina*	X		
	SPSA	Spotted Sandpiper	*Actitis macularius*		X	
	YEWA	Yellow Warbler	*Dendroica petechia*	X	X	X
	YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	X		

3.2.4 Yellow-headed Blackbirds as a Species of Interest

Yellow-headed blackbirds are obligate riparian breeders dependent on semi-permanent wetlands with dense emergent vegetation over deep water (Linz *et al.* 1996, Fletcher and Koford 2004). Population declines have been documented throughout much of their range in mid-western North America (Fletcher and Koford 2004). Survival rates of yellow-headed blackbirds are higher than most passerines at 75% and a mean life expectancy of 1.9 years (Bray *et al.* 1979). Foraging during the breeding season is composed of emergent insects mainly dragonflies (*Odonata*), while gleaning for seeds is dominant in non-breeding seasons. Nesting of yellow-headed blackbirds commences in late May and averages 3.7 eggs per female (Arnold 1992). Nest predation rates are low, approaching one percent (Ward 2005) and are mainly perpetrated by marsh wrens (*Cistothorus palustris* (Wilson 1810))(Neudorf *et al.* 2011). Yellow-headed blackbirds are very responsive to change in vegetation and their reliance on site selection increases with fluctuations in water levels (Beletsky and Orians 1994). This sensitivity and documented declines in population along the Little Bow River make this an important and interesting study organism.

3.2.5 Yellow-headed Blackbird Colony Surveys

Yellow-headed blackbird colonies were identified and surveyed in 2012 and 2013 during a float trip in mid-June of the entire study area. The number of male yellow-headed blackbirds occupying each colony was counted to consensus by a minimum of two observers. The number of males in 2012 and 2013 were compared to population sizes collected by Herzog and McCormick (2008) in 2005, 2006, and 2007.

In 2013, further surveying of yellow-headed blackbird colonies was undertaken, identifying cattail patch characteristics responsible for occupation of sites. Additional surveys included the number of females and red-winged blackbirds (*Agelaius phoeniceus* (Linnaeus 1766)) at each site, counted to consensus. The number of females at each colony represented the reproductive potential, while red-winged blackbirds were collected as a measure of interspecific competition.

The occupation of colonies based on habitat suitability was characterized by the length, height and density of cattail patches, water depth, and years occupied. The water depth, cattail height, and cattail density were determined categorically every 50 m along colonies. Habitat characteristics at each colony used for analysis were the mode of 50 m measurements. Water depth classification varied from 0 to 10 cm, 10 to 30 cm, and 30+ cm, while patch height included 0.0 to 0.49 m , 0.5 to 0.99 m, 1.0 to 1.49 m, and 1.50+ m. Cattail density classification included sparse, light, moderate, and dense based upon stems per quadrat (0.25 m^2). The categorization of habitat suitability measurements were determined based on ranges found within the first cattail patch surveyed. The patch length of each colony was measured using a digital range finder, accurate to within one metre. The disturbance intensity of each colony was classified as light, moderate, or heavy based on the subjective health of the riparian habitat.

Colony surveys were conducted for nine sites occupied in 2013. Additionally, surveys were conducted for three sites previously occupied in 2005, 2006, 2007, or 2012 but unoccupied in 2013, and five sites unoccupied in all years of reference.

3.2.6 Statistical Analyses of Yellow-headed Blackbird Colonies

Yellow-headed blackbirds along the Little Bow River were compared between 2005, 2006, 2007, 2012, and 2013 using an ANCOVA of the number of males per colony, and chi squared analyses (χ^2) for total number of males and colonies. ANCOVA was conducted with a covariate of distance downstream from the Little Bow Canal. Post-hoc pairwise comparisons indicated any significant temporal change in the number of males per colony following the recent augmentation of flows. Associations between colony characteristic and male yellow-headed blackbird abundance and density in 2013 were analyzed by Spearman correlation. Statistically significant associations and comparisons were described as defined previously.

3.3 Results

3.3.1 Riparian Bird Diversity

Songbird and shorebird species richness along the Little Bow River, exhibited a decreasing linear trend with the distance covariate (Figure 3.2) and lacked a significant interaction term producing an ANCOVA model with good overall fit ($R^2 = 0.30$). Species richness increased following flow augmentation in 2004 (ANCOVA: $F(3,40)= 4.86$, $p=0.01$), with significant increases from baseline conditions (2005) occurring in 2007 ($p=0.03$) and highly significant increases in 2013 ($p=0.01$)(Figure 3.3).

Species evenness of avian communities exhibited a decreasing linear trend with the distance covariate (Figure 3.2) and lacked a significant interaction term producing an ANCOVA model with good overall fit ($R^2=0.29$). Species evenness declined significantly following flow augmentation (ANCOVA: F(3,36)=3.84, p=0.02), as 2013 conditions experienced a decreasing trend from 2005 baseline conditions (p=0.05)(Figure 3.3)

Shannon Wiener Index along the Little Bow River, exhibited a significant decreasing linear relationship with the distance covariate (Figure 3.2) and lacked a significant interaction term producing an ANCOVA model with good overall fit (R^2=0.22). Songbird and shorebird diversity increased following flow augmentation, however all increases from baseline conditions (2005) were not statistically significantly (ANCOVA: F(3,36)=1.53, p=0.22)(Figure 3.3).

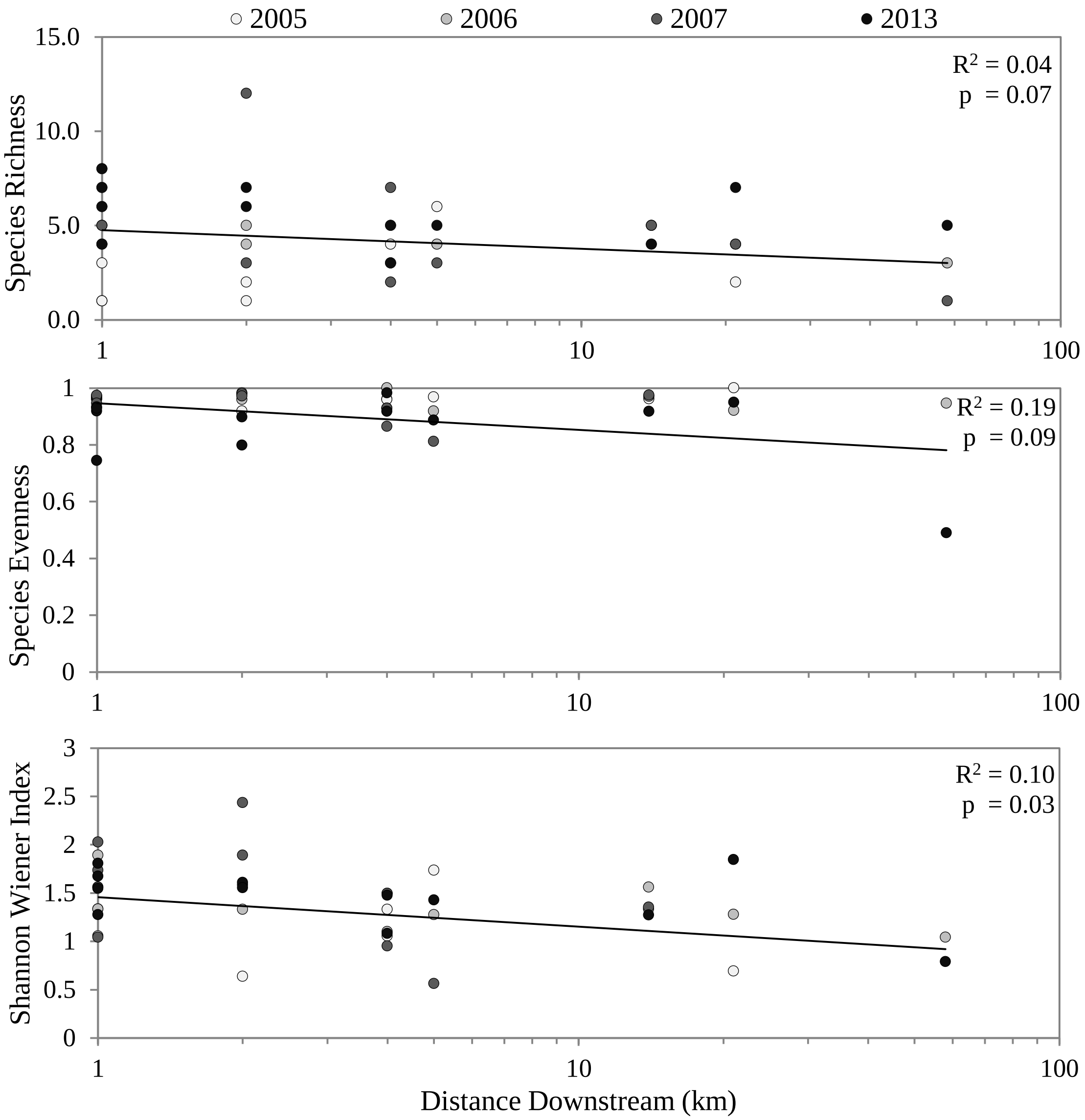

Figure 3.2 Linear relationships used in the analysis of covariance (ANCOVA) of avian diversity along the Little Bow River, Alberta following the implementation of augmented flows in 2004. Riparian bird data was compiled for 2005, 2006, 2007, and 2013. Species richness and evenness exhibited a linear trend with distance downstream for the Little Bow Canal. Shannon Wiener Index exhibited a statistically significant linear relationship with the distance downstream.

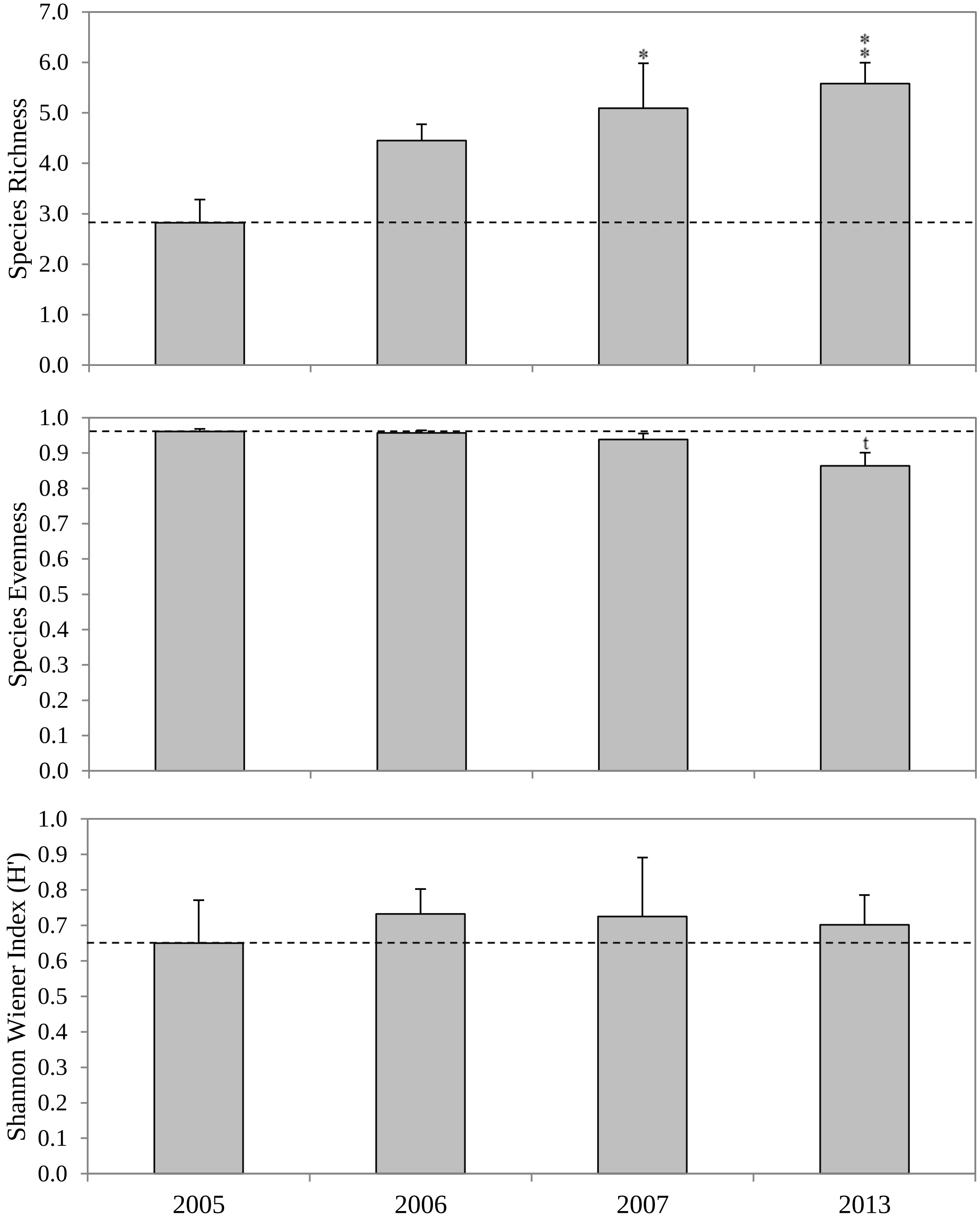

Figure 3.3 Avian diversity along the Little Bow River, Alberta following the implementation of augmented flows in 2004. Dotted lines indicate baseline (2005) conditions following flow augmentation, while asterisks indicate statistically significant differences from baseline conditions (p-values: <0.10 ^{t}, <0.05 *, and <0.01 **).

3.3.2 Non-metric Multi-dimensional Scaling of Riparian Bird Communities

NMDS of riparian bird communities along the Little Bow River provided a stable three dimensional solution with consistent placement of sites and associations in all 3 test runs. Final stress was 19.7 indicating that the solution was moderate to poor with a slight risk of misinterpretation. Goodness of fit (R^2) of axes one, two, and three were respectively 0.14, 0.22, and 0.22. Relative vertical structure of sites was the only suitable explanatory vector with a goodness of fit greater than 0.1 (R^2= 0.11, Axis 1).

Riparian woodland sites showed transitions in species space along axis one between 2005 and 2013, towards avian communities indicative of greater vertical structure of habitat (Figure 3.4). Transitions in species space also occurred along axis two during this time period; however no suitable explanatory variable in this axis indicated causation. Along axis three, no transition in riparian woodland sites was indicated.

True willow sites between 2005 and 2013 indicated no distinct transition in axis one towards avian communities indicative of increases in vertical structure of habitat (Figure 3.4). No transition in species space between 2005 and 2013 were found along axis two, while a transition of unknown causation occurred along axis three. Riparian bird communities occupying other vegetation types indicated no overall transitions in species space on any axis between 2005 and 2013.

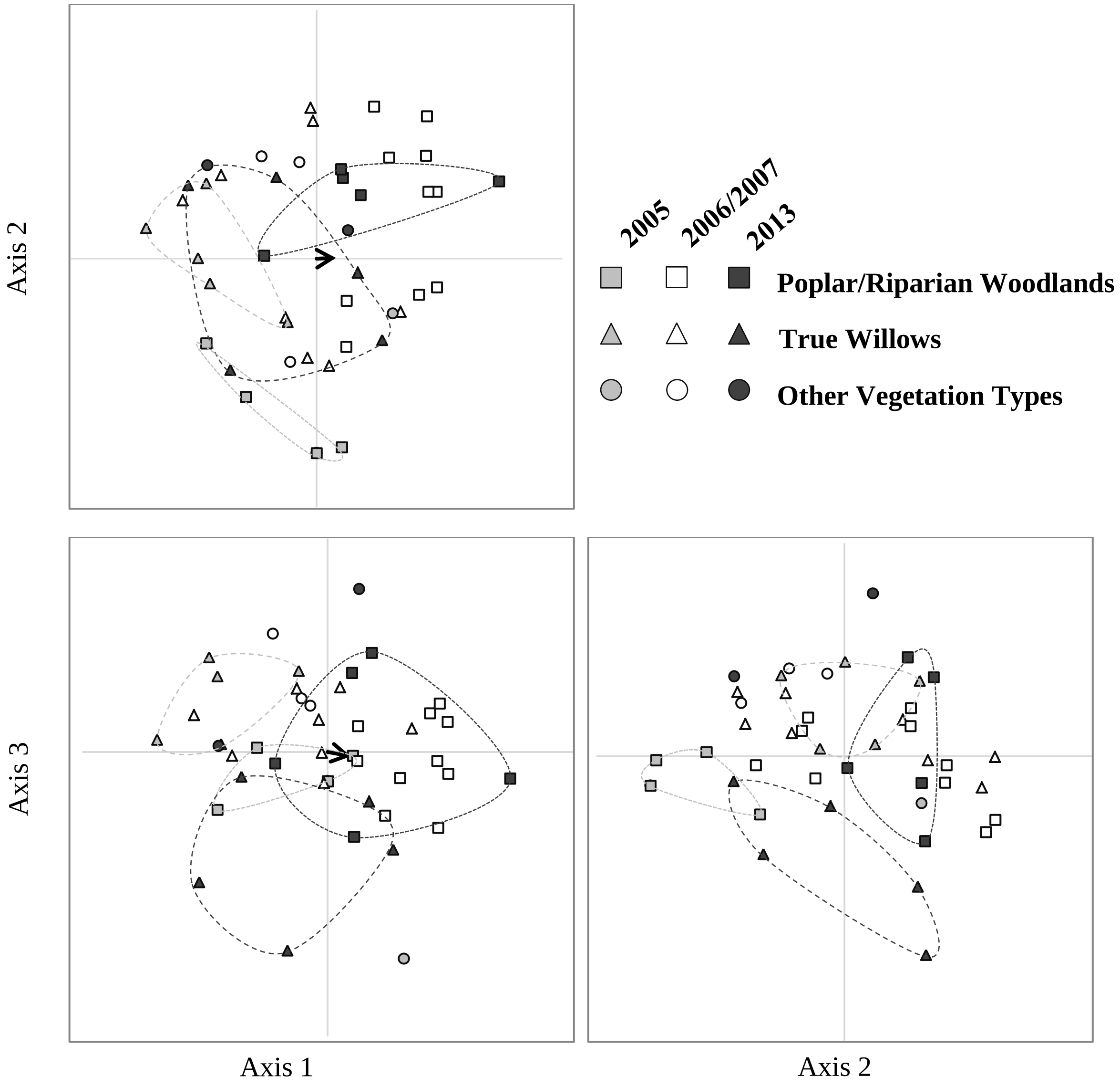

Figure 3.4 Non-metric Multidimensional Scaling (NMDS) plots of avian communities located at 12 sites along the Little Bow River in 2005, 2006, 2007, and 2013. Symbols indicate sites along the river located in species abundance space, while grey scale indicates years of measurement including baseline (grey), intermediate (white), and current conditions (black). The explanatory vector located at the origin indicates increasing vertical structure of vegetation (R^2=0.11, Axis 1).

3.3.3 Canonical Correspondence Analysis of Riparian Bird Species Associations

CCA of riparian bird associations within site space along the Little Bow River provided a stable solution and was limited to two axes explaining 9.4 % of the variation in species (4.9 % axis 1 and 4.5 % axis 2). In axis one, the explanatory variables of riparian obligate, shrub nesting, structure nesting, and resident species exceeded the goodness of fit threshold ($R^2 > 0.1$) for plotting (respective R^2: 0.17, 0.12, 0.43, and 0.11) (Figure 3.5) . In axis two, the threshold was exceeded by understory, middle story, upper story, ground nesting, and structure nesting species (respective R^2: 0.26, 0.37, 0.31, 0.52, and 0.16). In either axis, the threshold was not exceeded by riparian facultative or dependent species, tree or cavity nesting species, any diet type, and short, medium, or long distance migrants.

Obligate riparian bird species clustered within site space in the negative quadrant of axis one but were dispersed across axis two (Figure 3.5). Facultative and dependent riparian bird species were interspersed and showed no clustering within either axes.

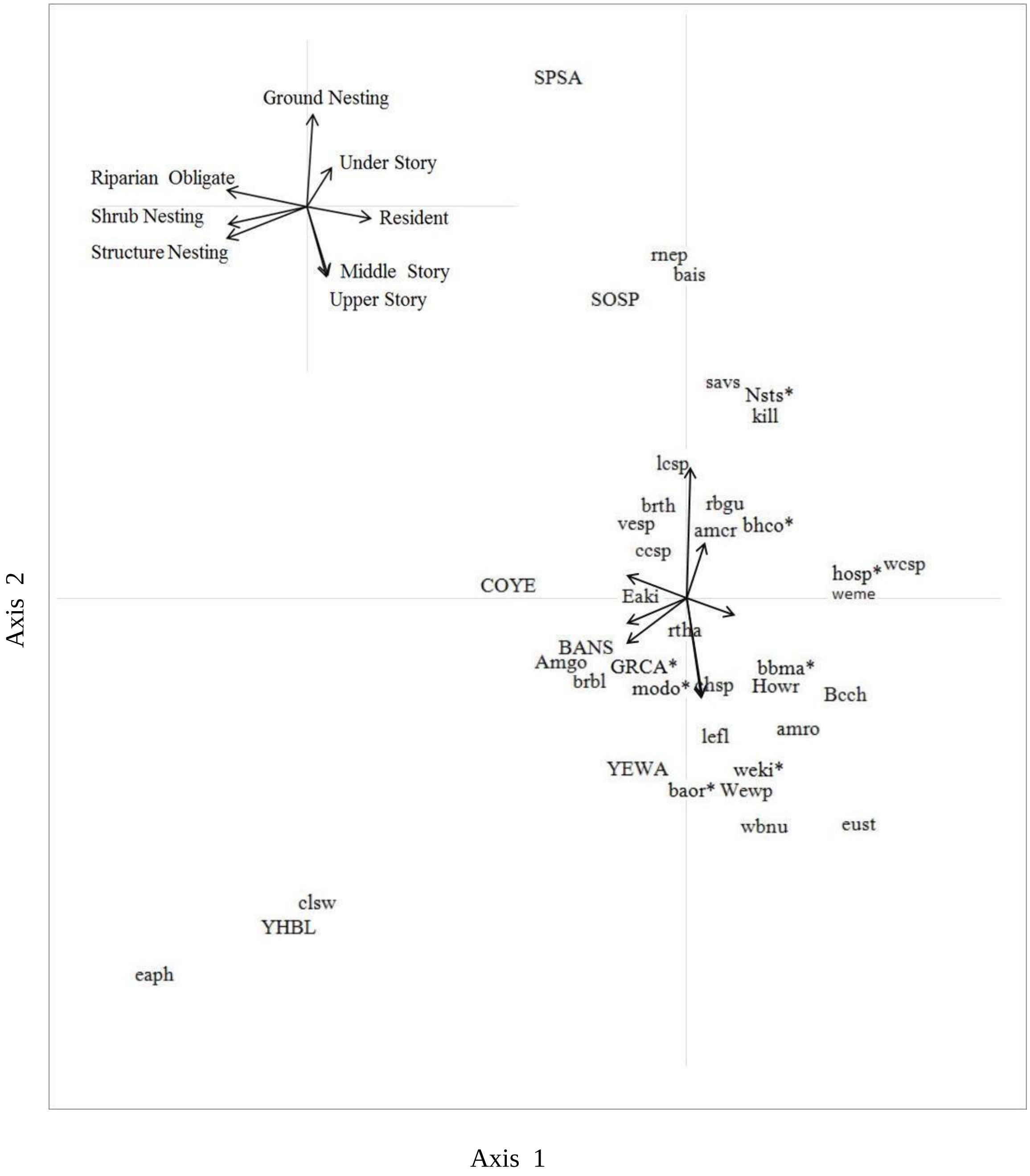

Figure 3.5 Canonical Correspondence Analysis (CCA) of riparian bird associations within site space along the Little Bow River, Alberta. Obligate riparian bird species are denoted in upper case, while dependent species are capitalized and facultative species are lower case. Species are denoted in alpha codes as described in Table 3.1 and asterisks indicate slight shifts in site space for legibility.

3.3.4 Yellow-headed Blackbird Population Dynamics

The number of male yellow-headed blackbirds per colony along the Little Bow River, lacked a significant interaction term and exhibited a highly significant increasing linear relationship with the distance covariate (Figure 3.6) producing an ANCOVA model with good overall fit (R^2=0.20). No statistically significant difference in the number of male occupants per colony were indicated across any year combination (ANCOVA: F(4,43)=0.82, p =0.52) (Figure 3.7). Total number of colonies along the Little Bow River showed a decreasing trend from baseline 2005 conditions (χ^2: χ^2(4)=8.07, p<0.10) . The total number of yellow-headed blackbird males along the Little Bow River experienced a highly significant decline from baseline 2005 conditions (χ^2: χ^2(4)=69.43 , p<0.01).

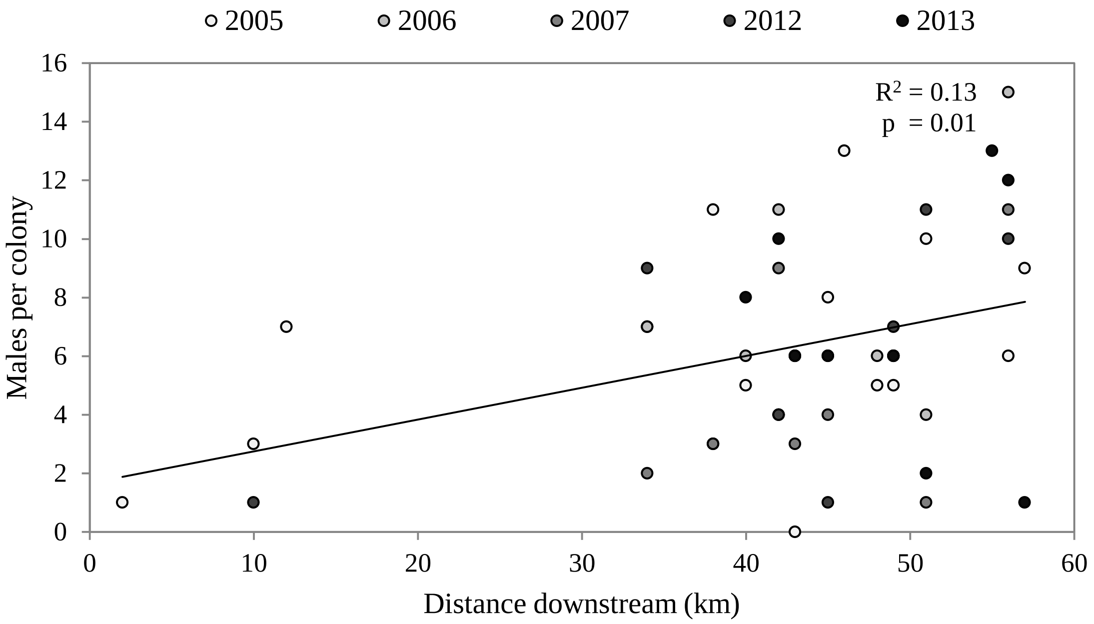

Figure 3.6 Linear relationships used in the analysis of covariance (ANCOVA) of male yellow-headed blackbirds per colony along the Little Bow River, Alberta following augmented flows in 2004. Males per colony were compiled from 2005, 2006, 2007, 2012, and 2013, and exhibited a highly significant relationship with distance downstream from the Little Bow Canal.

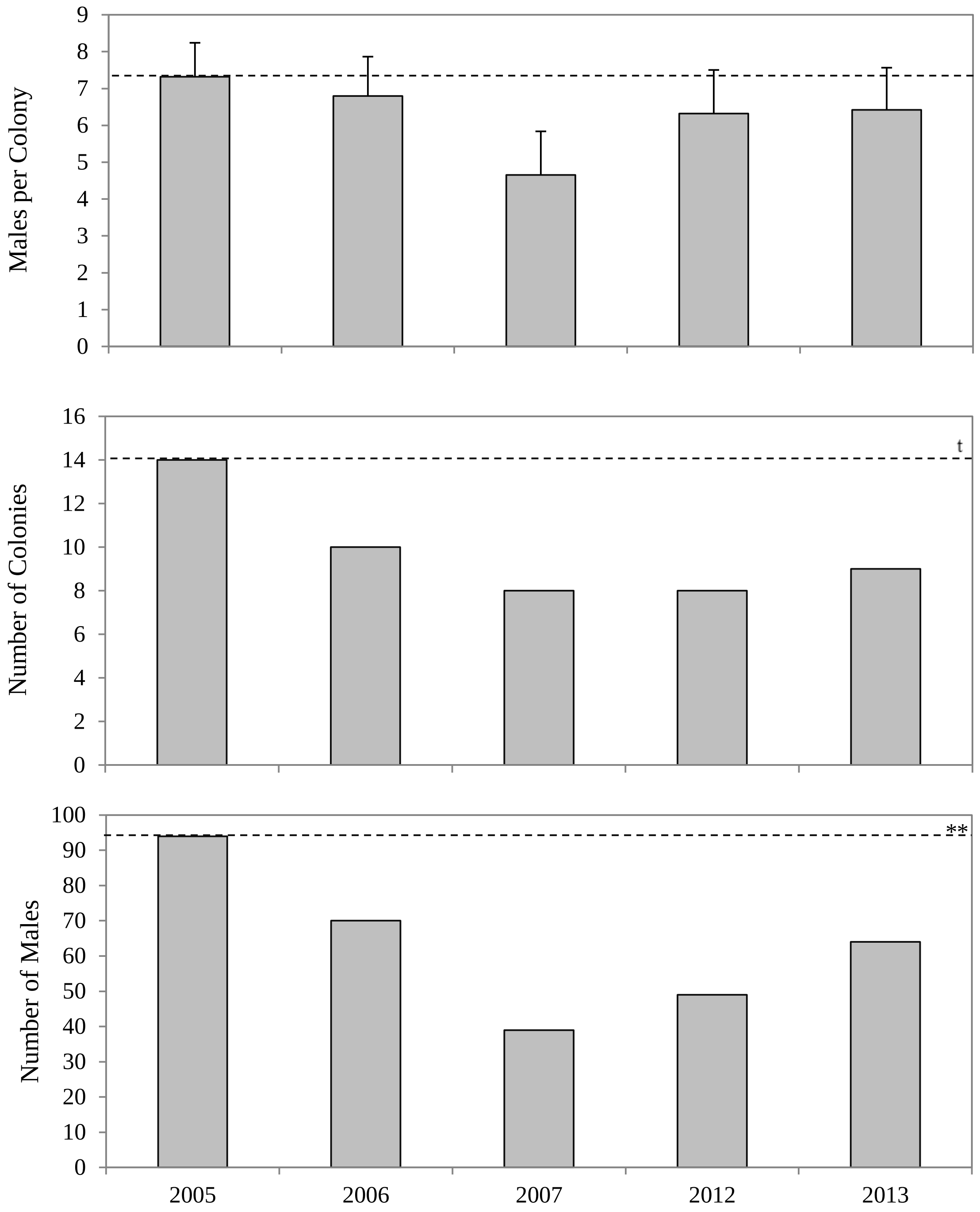

Figure 3.7 Yellow-headed blackbird colony dynamics along the Little Bow River, Alberta following flow augmentation in 2004. The dotted line indicates baseline conditions (2005), while asterisks indicate significant differences from baseline conditions overall (p-values: $<0.10^{t}$ and <0.01 **).

3.3.5 Yellow-headed Blackbird Colony Occupation

The density and number of male yellow-headed blackbirds occupying colonies along the Little Bow River exhibited a strong and highly significant positive correlation with the number of years occupied and number of females (Table 3.2). Cattail patch length correlated strongly and significantly with both the density and total number of males occupying colonies. Cattail density exhibited a positive trend of moderate strength with the number and density of male yellow-headed blackbirds. No significant correlations were identified with site disturbance intensity, the number of red-winged blackbirds, cattail height, and water depth.

Table 3.2 Spearman correlation (N=17) of the habitat suitability of nine occupied, three previously occupied, and five unoccupied yellow-headed blackbird colonies along the Little Bow River, Alberta. Significant correlations between habitat suitability factors and male occupation are indicated with asterisks (p-values: <0.10 ^{t}, <0.05 *, and <0.01 **).

Habitat Suitability Factor	**Males per colony**		**Males per km**	
	r_s	p-value	r_s	p-value
Colony Occupation (years)	0.65	0.01**	0.67	0.00**
Site Disturbance Intensity	- 0.06	0.82	0.02	0.93
Number of Females	0.99	0.00**	0.99	0.00**
Number of Red-winged Blackbirds	0.33	0.20	0.31	0.23
Colony Length (m)	0.55	0.02*	0.50	0.04*
Colony Cattail Height (m)	0.37	0.15	0.38	0.13
Colony Cattail Density	0.48	0.05^t	0.48	0.05^t
Colony Water Depth (m)	0.28	0.27	0.28	0.28

3.4 Discussion

3.4.1 Riparian Songbird and Shorebird Biodiversity

Shannon Wiener Index of avian communities remained unchanged from 2005 baseline conditions. Conversely, the species richness of avian communities along the Little Bow River increased significantly in 2007 and 2013, and species evenness exhibited a decreasing trend in 2013. The abundance of rare incidental species have therefore increasing in response to flow augmentation which has depressed species evenness and had a limited impact on the Shannon Wiener Index due to rarefaction. This supports the initial prediction that riparian songbirds and shorebirds would increase in diversity, as increases in species richness were identified after flow augmentation. Increases in rare incidental species following augmentation was consistent with Herzog and McCormick's (2008) findings, supporting the potential for continued accumulation of rare species and increases in biodiversity as this system equilibrates to the new flow regime.

Species richness and evenness of riparian bird communities is largely dependent upon habitat heterogeneity and to a lesser extent patch size and shape, and resource availability (Macarthur and Macarthur 1961, Saab 1999, Scott *et al.* 2003). Riparian areas possessing high levels of structural complexity and native woody vegetation provides the greatest habitat heterogeneity and subsequently the greatest breeding bird abundance and diversity (Scott *et al.* 2003, Pennington *et al.* 2008, Seavy *et al.* 2009). Vegetation along the Little Bow River was predicted to respond to flow augmentation with transitions from grassland species to riparian woodlands and willows, which provide greater vertical structure and more niches for occupation. Observed increases in rare species along the Little Bow River support this concept as these species are typically specialists that are reliant on narrow niches. With increases in the structural complexity of vegetation along the Little Bow River, niche availability would increase, thereby increasing the abundance of rare specialist species and the species richness of the system.

Contrary to increases in species richness and the predicted creation of specialist niches, vegetation along the Little Bow River was found to have had limited transitions in vegetation communities other than a decline in graminoid species (Chapter 2). These differences may reflect the scales to which the environment was sampled. In Chapter Two, analyses of aerial photography were undertaken and were reliant on change detection at the landscape scale. Conversely, riparian birds utilize the environment in both macro and micro scales. Site selection by riparian songbirds are mainly derived from the vertical structure (Saab 1999), which was not assessed in the aerial photograph analysis. Riparian birds are often monitored as indicator species of riparian health, due to the multiple scales of site selection, and the large variation in habitat usage and foraging between species (Vaughan *et al.* 2007). Thus niche creation in response to vegetation transitions along the Little Bow River may have occurred following flow augmentation although it was not detected with the sampling techniques used.

Non-metric Multidimensional Scaling (NMDS) of riparian bird community structure at sites along the Little Bow River indicated evidence of a slight transitioning of riparian woodland communities indicative of increasing vertical structure. This transition is likely to have resulted in niche creation supporting increases in species richness. Canonical Correspondence Analysis (CCA) of avian species associations further supported this suggestion, as species were distributed based mainly on vegetation derived characteristics (canopy occupation, and nesting substrates) rather than the dietary or migratory life histories of each species. NMDS of willow communities and other vegetation types however failed to indicate any transitions of known causation following flow augmentation. The low power of both ordination techniques (NMDS and CCA) indicate that limited reliance should be placed on the exact position of sites and bird species in their respective spaces. Transitions and associations within both ordinations however remained consistent across tests and can still provide some insight into the processes occurring along the Little Bow River.

The classification of riparian bird species based upon habitat usage (facultative, dependent, or obligate) is another concern associated with the Canonical Correspondence Analysis (CCA). As no standard classification system exists, classifications are inherently subjective, based upon experience and knowledge of the life histories of each species. While this study includes classifications based upon three independent sources, the classification of species may still be disputed. Additionally, as woodlands are limited to riparian areas and human developments within semi-arid regions, dependency on riparian areas identified in semi-arid regions might not be true in other regions. In acknowledging this caveat, the associations of riparian bird species still provide some insight into habitat usage along the Little Bow River.

Wide-spread and rapid transitions in vegetation and riparian bird communities along the Little Bow River have not occurred, as this system has only experienced ten years of augmented flows from the recent Highwood Little Bow Diversion Project. Although, Shannon Wiener Index along the Little Bow River has not substantially increased, species richness has increased. Continued accumulation of species and increases in biodiversity across all measures could occur in the future.

In comparison, the Carmel River ($Q=2.92\ m^3/s$, $DA= 500\ km^2$) in central California was degraded following groundwater depletion, and vegetation was subsequently restored in 1996 through replanting efforts (Queheillalt and Morrison 2006). Four years following restoration, riparian bird communities at restored sites were of reduced species richness in comparison to un-degraded sites. Riparian woodlands in semi-arid regions typically require 90 years to develop maximum vertical structure (Scott *et al.* 2003). Dramatic improvements along either the Little Bow River or Carmel River are therefore unlikely to be observed yet as these systems are still responding to the new environmental regimes.

Alteration to flow regimes can greatly influence resource availability and the foraging success of riparian bird communities. The access and abundance of aquatic and terrestrial invertebrates within the first five metres of river banks is crucial to the diet of insectivorous bird species (Iwata *et al.* 2003). Disruptions to this habitat through shifts in channel form, and river flows that inundate foraging areas can greatly affect the foraging success of fly-catching and gleaning bird species (Nilsson and Dynesius 1994, Iwata *et al.* 2003). Ordination of riparian birds along the Little Bow River, however showed no association of species based on foraging type, indicating that the distribution of species along the river is largely derived from vegetation.

Associations of riparian bird communities with vegetation and the predicted transitioning of vegetation in response to flow augmentation may be confounded by the impacts from cattle grazing. Decreases in bird populations in response to decreased ground and shrub cover can often result from the browsing and trampling of vegetation by cattle (Heltzel and Earnst 2006). Cattle grazing along the Little Bow River could therefore reduce or mask any improvements in riparian bird habitats following the new flow regime. Fortunately, vegetation and riparian bird communities are quick to respond to reduced grazing pressure through cattle exclusion (Heltzel and Earnst 2006). The influence of cattle grazing along the Little Bow River should be considered as a confounding factor in this and future analyses due to the prevalence of livestock along this river.

Continued monitoring of this river system is required as it equilibrates to the new flow regime following the Highwood Little Bow Diversion Project. Limited initial response in riparian bird communities is dependent upon limited changes in vegetation, which was predicted in Chapter Two to reside in a transient state dependent upon changes to channel form. Consequently, riparian birds also probably reside in a transient state dependent upon changes to vegetation. Increases in species richness could therefore be in response to localized niche creations resulting from this transient state, generally referred to as the intermediate disturbance hypothesis. If this were the case, rather than increasing habitat quality in general, continued accumulation of avian species along the Little Bow River would not occur as initially predicted. As the equilibrium condition of this system is unknown, monitoring of riparian bird species must be continued.

Monitoring of riparian bird populations should be conducted on a decade basis, with further monitoring being conducted following substantial changes to vegetation communities along this river system. Future monitoring should incorporate more sampling sites with better representation of the five common vegetation types. Increased sampling would reduce the influence of spurious variation resulting from annual variations in riparian bird communities. Ordination of site and species associations would additionally benefit from increased sampling as greater redundancy in the data would increase the explanatory power of both NMDS and CCA. Lastly, sites should be categorized based upon grazing pressure, indicating any biases likely introduced from depression of riparian bird populations as a result of cattle grazing.

3.4.2 Yellow-headed Blackbird Population Dynamics and Colony Occupation

The total number of male yellow-headed blackbirds occupying colonies along the Little Bow River have somewhat recovered from dramatic declines between 2005 and 2007 (Herzog and McCormick 2008). This supports the initial prediction that populations would initially decline and later rebound following augmentation of flows. Conversely, the number of males per colony remained unchanged and the number of colonies exhibited a declining trend from baseline conditions. The decline in total number of males along the Little Bow River likely resulted from decreases in number of colonies, rather than a decline in population at each colony. This suggests that availability of suitable sites for colonization may have declined following augmentation.

Yellow-headed blackbirds survey potential colony sites during current breeding seasons for occupation in the following breeding season, dependent on the quality of the territory and social cues (Beletsky and Orians 1994, Ward 2005). Selections of sites for colonization along the Little Bow River were strongly and significantly correlated with previous occupation of sites, number of females, and cattail patch length. Additionally, cattail patch density exhibited a positive trend correlating moderately with occupation. Observations of occupation of colonies by yellow-headed blackbirds supported the predicted decline in response to possible loss of cattails in terms of patch length, and density. However, the possible decline in yellow-headed blackbirds in response to social cues was neither hypothesized nor tested.

The reoccupation of previous colony sites is advantageous to yellow-headed blackbirds due to familiarity and knowledge of the site quality (Beletsky and Orians 1994). Subsequently, 57% of yellow-headed blackbirds occupy the same site as occupied in the previous breeding season (Beletsky and Orians 1994). These findings are supported by the highly significant correlation of current occupation and previous occupation along the Little Bow River. Reoccupation indicates that yellow-headed blackbirds are rather set in their site occupation and may possess a resilience or resistance to changing colony sites. Consequently, previous occupation is likely not to have driven yellow-headed blackbird declines, but rather acted as a moderator.

Additionally, the highly significant correlation of male and female occupation is unlikely to have caused the decline in overall population along the Little Bow River. Both sexes rely on prospecting for colony sites based upon breeding success of occupants in previous years (Ward 2005), and are highly interrelated in response to mate selection. Alterations to flow augmentation would not have directly influenced sex-specific interactions, but could have altered habitats along this river system.

Yellow-headed blackbirds are reliant on emergent vegetation as their sole habitat in riparian areas (Fletcher and Koford 2004). As a result, any alteration to the flow regime with either beneficial or negative effects on cattails should produce effects in blackbird communities. Reductions in the density of live cattail patches within wetland areas can result in declines in the occupation of sites, density, and reproductive success of blackbirds (Linz *et al.* 1996, Fletcher and Koford 2004). Yellow-headed blackbirds along the Little Bow River exhibited occupation of colonies significantly correlated with increasing cattail patch length, and a trend with increasing density of cattails within patches. Following flow augmentation in 2004, increased flows coupled with two floods of moderate intensity in 2005 and 2006 led to the localized scouring of cattails (Bigelow *et al.* 2005, Bigelow 2006, Bigelow *et al.* 2006). Localized scouring of these cattail patches, likely reduced cattail patch length and density resulting in less favorable habitat and fewer colony sites suitable for occupation by yellow-headed blackbirds. Reductions in the number of suitable colonies occupied consequently led to dramatic declines in yellow-headed blackbird populations. As cattail patches began to recover from initial scouring, cattail patch length and density likely began to rebound leading to the slight recovery in yellow-headed blackbirds seen in 2012 and 2013.

Along the Little Bow River, occupation of cattail patches by yellow-headed blackbirds was not significantly correlated with cattail height, water depth, site disturbance, or red-winged blackbird presence. Water depth and cattail height have a large impact on the accessibility of some blackbird nests to nest predators (Fletcher and Koford 2004), but yellow-headed blackbirds experience nest predation rates of only one percent (Ward 2005). Furthermore, yellow-headed blackbirds are a relatively disturbance resilient species occupying disturbed sites as regularly as undisturbed sites (Beletsky and Orians 1994). Lastly, although red-winged blackbirds provide some interspecific competition for resources, they are smaller in size than yellow-headed blackbirds allowing them to be displaced easily. Lack of occupation and subsequent declines in total yellow-headed blackbirds resulting from these factors were therefore probably slight along the Little Bow River.

One major limitation of this study was the lack of incorporating food resource availability as an explanatory factor into the analysis of the decline in yellow-headed blackbirds. In a wetland in northern Iowa, failure of yellow-headed blackbirds to settle in drought years, was suggested to be in response to either dragonfly (*Odonata*) emergence or habitat alteration (Fletcher and Koford 2004). Contradictory to this suggestion, odonate emergence occurs two weeks into yellow-headed blackbird breeding season and was not used as a cue for site occupation in studies by both Arnold (1992), and Ward (2005). Due to this time delay, analysis of food resource availability was not included in this study.

Further monitoring of yellow-headed blackbird populations in response to declines following flow augmentation is no longer as crucial as previously thought as total populations size appears to be recovering. However in 2013, the new flood of record for the Little Bow River was experienced partially through the fledging of yellow-headed blackbird chicks (Appendix A). Cattail patches along this system are predicted to have been scoured, greatly reducing the suitable habitat for colonization in 2014. In response, yellow-headed blackbird populations are predicted to decline and warrant further monitoring.

Although the cues for site selection of suitable habitat for yellow-headed blackbirds along the Little Bow River were determined in this study, further research is required to identify the specific requirements of each selection cue utilized. Once these requirements are determined, guidelines can be implemented allowing accurate and successful assessment, restoration, and conservation of habitat for yellow-headed blackbirds.

CHAPTER 4

CONCLUSIONS OF MONITORING ALONG THE LITTLE BOW RIVER, ALBERTA

4.1 Channel Form, Vegetation, and Riparian Bird Response to Flow Augmentation

Monitoring of the Little Bow River was undertaken following a tripling of flows in 2004 under the direction of the Highwood Little Bow Diversion Project. The Little Bow River was predicted to increase in channel width, decrease in sinuosity index, and transition in vegetation from facultative to obligate riparian species, as observed along other flow augmented rivers within North America (Kellerhals *et al.* 1979, Wolff *et al.* 1989, Dominick and O'Neill 1998, Wohl and Dust 2012). In addition, riparian birds were predicted to increase in diversity in response to habitat improvements resulting from flow augmentation. Monitoring of this system was undertaken between summer 2012 and spring 2014, and the key findings of this initiative are summarized in the following paragraphs.

The channel form of the Little Bow River failed to support the predicted increases in channel width, and decreases in sinuosity index and meander characteristics (Chapter 2). Channel widths along the Little Bow River increased from baseline conditions (2000), but remained within the historical variability of the system (pre-augmentation)(Table 2.3). Additionally, sinuosity index and meander characteristics exhibited comparable conditions before and after flow augmentation (Figure 2.6 and 2.7). The recent augmentation of flows along the Little Bow River has not significantly altered channel form at this point in time. However, if flow augmentation persists, alterations may occur in the future.

The transitioning of vegetation from facultative to obligate species as predicted in Chapter Two, failed to occur along the Little Bow River. Riparian woodlands, true willows, wolf willows, and cattail species exhibited no significant difference in proportions across the entire study area following augmentation (Figure 2.8; Table 2.5). Graminoid proportions declined significantly from pre-augmentation conditions (2000) but remained comparable to historical conditions (pre-augmentation). Vegetation proportions along reaches remained relatively consistent with the response of the entire study area with the exception of a localized decrease in true willows along reach five and an increase in wolf willow along reach four (Figure 2.9). Wolf willow communities along reach four in 2010 however remained significantly less than historical conditions. Vegetation along the Little Bow River exhibited some indications of transitioning with decreases in graminoid proportions, however all other vegetation classes remained unchanged failing to support a transition. Vegetation along the Little Bow River therefore likely resides within a transient state reliant on change in channel form before significant alterations in vegetation proportions occur.

In Chapter Three, avian communities fail to fully support the predicted increase in biodiversity, following the augmentation of flows in 2004. Riparian songbirds and shorebirds increased in species richness following augmentation; Avian communities however failed to increase in species evenness or Shannon Wiener Index, suggesting that rare incidental species are increasing in abundance (Figure 3.3). Furthermore, avian community composition indicated that assemblages of species are largely dictated by vegetation, and that increases in rare species are likely resulting from increases in vertical structure, particularly within riparian woodlands (Figure 3.4).

Yellow-headed blackbird populations along the Little Bow River have begun recovering from declines documented by Herzog and McCormick (2008) as discussed in Chapter Three. Although yellow-headed blackbird population size has declined and begun to recover, the number of males per colony remained comparable between years (Figure 3.7). The number of colonies occupied along the Little Bow River showed a decreasing trend likely resulting in the total population decline. Selection of sites for occupation by yellow-headed blackbirds were derived from previous occupations, number of females, cattail patch length, and cattail patch density (Table 3.2). Occupation of sites suggests that initial declines in population could have been in response to decreases in habitat suitability (cattail patch length and density) following scouring in 2005 and 2006, and that recovery occurred in response to the regrowth of cattail patches.

In conclusion, the channel form, vegetation, and avian communities of the Little Bow River have been slow to respond to flow augmentation and in most cases exhibited comparable conditions to pre-augmentation. The lack of change along this river system is suggested to be in response to limited augmentation of flows, land-use management, and a current transient period. Limited augmentation of flow has greatly limited the fluvial work undertaken, which is required in order to increase channel width, and that enables the promotion of riparian woodland and true willow expansion through colonization events. Additionally, land-use management, particularly cattle grazing, can greatly reduce the structure of riparian vegetation (Fenner *et al.* 1985, Schulz and Leininger 1990), subsequently reducing the diversity of avian communities (Heltzel and Earnst 2006), and masking the responses of riparian vegetation and birds to flow augmentation. Foremost, river systems typically respond to alteration in flows through transient periods between equilibrium states (Johnson 1998), often requiring decades for equilibration. The Little Bow River will require greater than 10 years before it exhibits its future equilibrium conditions, and therefore requires further monitoring.

4.2 Predicted Future Conditions

The response of the Little Bow River is largely dependent on the implementation of augmented flows mandated by the Highwood Little Bow Diversion Project, and adequate temporal scales for equilibration. River flows have largely not been augmented outside of the historic variability of this system, consequently leading to minimal changes in sediment transport influencing channel form, water availability and disturbances influencing vegetation, and habitat quality influencing avian communities. The predicted future conditions of this river system must therefore include scenarios in which the current flow regime persists or flows are augmented at the proposed 8.5 m^3/s.

The channel form of the Little Bow River has been slow in responding to flow augmentation, showing only localized increases in channel width; however, recent flooding in 2013 is suggested to have accelerated changes resulting in either maintenance of the flood expanded channel or floodplain encroachment dependent on future flows (Appendix A). If flows are augmented to the proposed level, increased channel widths following flooding will be maintained by the augmented flow regime. Sinuosity index and meander characteristics would also decline slightly over decades before significant alterations in river planform are detected. If flows are not augmented, encroachment of the floodplain into the flood widened channel should occur resulting in river channels consistent with historical dimensions, as un-augmented flows would not be adequate in maintaining the oversized channel. Sinuosity index and meander characteristics would remain consistent with baseline conditions, as sediment transport would be unaltered. In general, if the Little Bow River is to exhibit the typical response of augmented rivers, flows must be increased outside the historical variability or else increased channel width and decreased sinuosity will not occur in the future.

Vegetation along the Little Bow River suggests that a transition from facultative to obligate riparian species may occur in the near future. The declining graminoid proportions suggest that this transition might be currently in progress. The flood of 2013 has provided significant disturbance in channel form and an opportunity for the establishment of new obligate riparian communities (Appendix A). The future community structure of riparian vegetation along the Little Bow River remains reliant on future flows.

If flows along the Little Bow River remain consistent with the current regime, slight expansion of obligate species along the banks of the upper reaches and expansion of wolf willows and cattails along the lower reaches is predicted. Riparian woodland and true willow communities should experience expansion of existing patches in response to increased water availability. Expansion would however be undertaken through suckering as successful colonization events would be rare due to minimal seed sources. Wolf willow communities should benefit from the current water availability, expanding into graminoid dominated communities. Cattail communities would expand as drought stress along the Little Bow River is reduced by current river stage stabilization during low flow periods. As changes from the current flow regime are not outside the historical variability of this system, vegetation response to augmentation will likely be slow and the new equilibrium state will not exhibit large deviations from historical conditions.

If flows along the Little Bow were augmented to 8.5 m^3/s, obligate riparian vegetation should expand along the banks, while facultative species would relocate higher within the elevational profile as initially predicted (Rood *et al.* 2003). With the stabilization of stream flow and increased groundwater elevation, phreatophytic riparian woodland and true willow communities would be directly benefited leading to expansion. Expansion of these communities would mainly occur through suckering; however with alterations in channel form, bare substrate for colonization could be present allowing progressive expansion of new patches downstream. Wolf willow communities would initially expand in response to increased water availability, however as inundation stress persists and obligate riparian species progress downstream, relocation to higher elevations would occur. Cattail communities would likely be displaced to the lower reaches, as well as occupying inundated low-lying land. Graminoid vegetation would subsequently decline as other vegetation species of later successional states would dominate the banks.

Avian communities along the Little Bow River are dependent on the response of riparian vegetation, in particular the development of vertical structure. In response to both current and proposed flow regimes, vertical structure and subsequent niche creation is predicted to increase. If the current flow regime persists, riparian bird community biodiversity would increase as riparian woodland and true willow patches expand and increase in vertical structure. Conversely, if flows were augmented as proposed in the Highwood Little Bow Diversion Project, increases in riparian bird diversity should be greater, as the expansion of obligate riparian vegetation would be greater, thereby providing greater habitat. The responses of riparian birds are dependent on vegetation and will therefore respond to augmentation in the same time-scale, with noticeable changes expected within the following decades.

The recovery of yellow-headed blackbirds from documented declines has likely stopped, as the flood of 2013 will have adversely affected population size (Appendix A). The yellow-headed blackbird population will have declined as cattails were scoured and nests containing fledglings were inundated during flooding. Populations are however predicted to recover and expand within the near future (5-10 years), as cattails regrow and expand in response to increased minimum flows.

Predicted future conditions along the Little Bow River were derived from flow interactions with channel form, vegetation, and riparian birds. These predictions do not account for differing land-use management, in particular livestock grazing. Browsing and grazing by livestock alters the composition and structure of riparian vegetation, and contributes to increased erosion through pugging and defoliation of banks (Fenner *et al.* 1985, Schulz and Leininger 1990). These predicted responses of channel form, vegetation, and avian communities must therefore not be taken as the only probable outcome, but rather as a potential response of this river system.

4.3 A Potential Monitoring Schematic

With minimum observed change in channel form, vegetation and avian communities, further research is required to determine how this system will respond to flow augmentation. The effects of flow augmentation are predicted to be beneficial, as channels widen, obligate riparian vegetation communities increase in abundance, and avian communities increase in diversity. Validation of these predictions has yet to occur along this river system. The Little Bow River is suggested to currently reside within a transient state; however, following the flood of 2013, conditions are likely to have been accelerated towards a mutual equilibrium (Appendix A). Monitoring of this river system is still required over a long time period including multiple decades before equilibrium conditions are likely reached.

In comparable river systems, change in response to flow alteration took greater than 20 years to equilibrate (Dominick and O'Neill 1998). The Little Bow River likely remains in a transient state due to minimal changes in channel form, vegetation, and birds. In order to identify significant changes and to minimize the costs of sampling, the time-span of future surveying along the Little Bow River is proposed for intensive sampling occurring every decade and less intensive sampling within inter-decade periods.

Proposed monitoring consists of two sampling protocols with intensive sampling being undertaken every ten years, while less intensive sampling is undertaken at the midpoint (Figure 4.1). Intensive sampling is suggested to be undertaken in 2020 and 2030, and comprises bridge photo comparisons, channel form and vegetation surveys, and fixed point bird surveys. Less intensive sampling should be undertaken in 2015 and 2025, and consists of bridge photo comparisons. However, if discharges at the Highway 533 gauging station (05AC930) have recorded flows greater than 8.5 m^3/s for more than 30 days in any of the five prior years, resurveying of permanent transects and fixed point bird surveys should be undertaken. If flows do not satisfy this criterion, additional surveying is not required in that year. The incorporation of a flow discharge criteria allows identification of time periods with higher potential for change as a result of augmented flows and long duration flooding, as experienced in 2013. This reduces sampling intensity and maximizes surveying resources.

Methodologies of future monitoring efforts should remain consistent with previous studies, allowing data to be comparable over time. Bridge photo points have been collected since the implementation of the Highwood Little Bow Diversion Project and collection should be continued at the same photo points as dictated by Bigelow (2006). Channel form and vegetation surveys consist of two components, the resurveying of permanent transects discussed in Bigelow (2006) and aerial photograph analysis of the most current photo datasets as described in Chapter Two. Lastly, fixed point bird surveys should be conducted at the same locations and using the same methodologies as discussed in Chapter Three. With a rich background data-set acquired for the Little Bow River, continued collection of data will document the response of the Little Bow River to flow augmentation.

Following monitoring until 2030, this protocol should be revised based upon river conditions. The current protocol was constructed to monitor the response of the Little Bow River to flow augmentation; however additional study objectives may easily be added in the future. The incorporation of additional factors into this protocol, in particular land-use management, specifically livestock grazing could greatly improve the understanding of the Little Bow River. With this rare study opportunity, continued monitoring is crucial in expanding our knowledge of this and other flow augmented river systems.

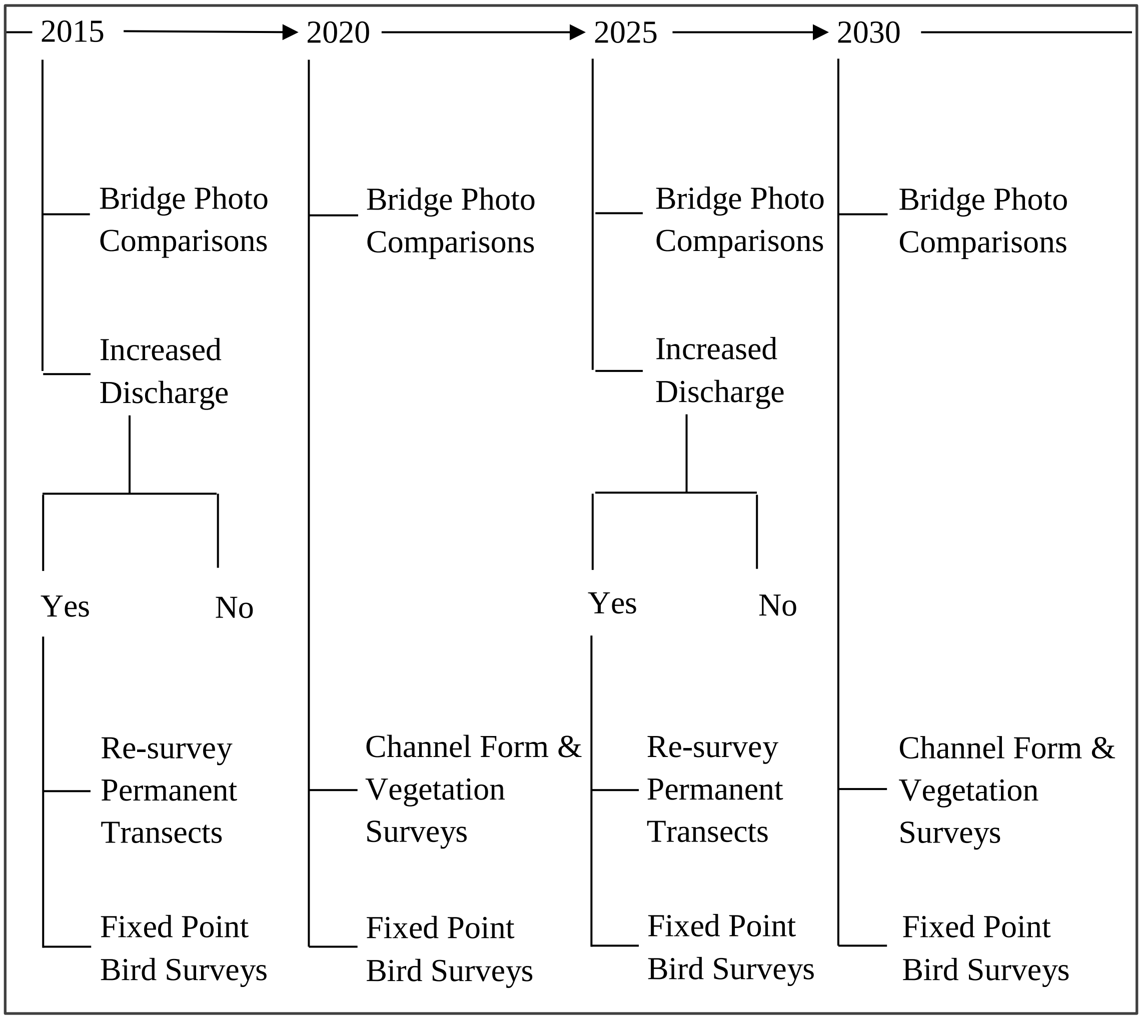

Figure 4.1 A proposed monitoring protocol for the Little Bow River, Alberta following the implementation of augmented flows in 2004. Increased discharge is defined as flows ≥8.5 m^3/s at the Highway 533 gauging station (05AC930) for more than 30 days duration in any of the five preceding years.

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APPENDIX A

Flooding as a Catalyst of Change

In 2013, the Little Bow River experienced a flood of record following greater than 75 mm of precipitation in High River, Alberta and overland flows from the Highwood River which received substantially greater precipitation. Preliminary flow data shows an instantaneous discharge of 151 m^3/s and maximum daily discharge of 99 m^3/s were recorded at a gauging station near Highway 533 (05AC930)(Alberta Environment 2014). Maximum daily discharge was nearly one and a half times the previous record of 67 m^3/s, recorded in 1920 at a gauging station near Carmangay, Alberta (05AC003)(Alberta Environment 2014). Recurrence analysis was inhibited by complexities associated with the placement of the Carmangay gauging station, as discharges are recorded below the confluence of Mosquito Creek and the Little Bow River. A crude recurrence estimate of 1 in 200 was calculated using a generalized extreme value (GEV) function in EasyFit 5.5 Professional (Mathwave Technologies Inc. 2010). However, as flows and recurrence intervals remain to be disputed, this flood is more appropriately referred to as the new flood of record with large implications to the infrastructure and ecosystems along the Little Bow River.

Flooding along the Little Bow River, quickly overwhelmed flow infrastructure designed to accommodate augmented flows of 8.5 m^3/s. Destruction of infrastructure between High River and Twin Valley Reservoir included five of nine bridges (5th St. SE, HWY 2A, 168th St. E, 232nd St. E, and RR. 270), and numerous culverts and fords. In addition, inundation of a large portion of eastern High River by the Highwood River resulted in pumping of flood waters into the Little Bow Canal prolonging flooding. Flows along the Little Bow River remained greater than 15 m^3/s for greater than 30 days, resulting in visible alterations in channel form and vegetation.

The large magnitude and duration of flooding resulted in increased channel width, visible from bridge photos taken before, during, and after the flood (Figure A1.1). Bed substrates coarsened from sands, silts, and gravels to gravels and cobbles. Cattail communities were scoured likely having adverse effects on yellow-headed blackbirds populations. No visible changes in graminoid, wolf willow, true willow, or riparian woodland communities were identified; however graminoid and wolf willow communities are likely to have been stressed by inundation resulting in some mortality. Alterations in channel form and vegetation were similar to the typical responses of flow augmentation, accelerating the Little Bow River towards a mutual equilibrium of increased channel width, coarsened substrate, and increased obligate riparian species abundance.

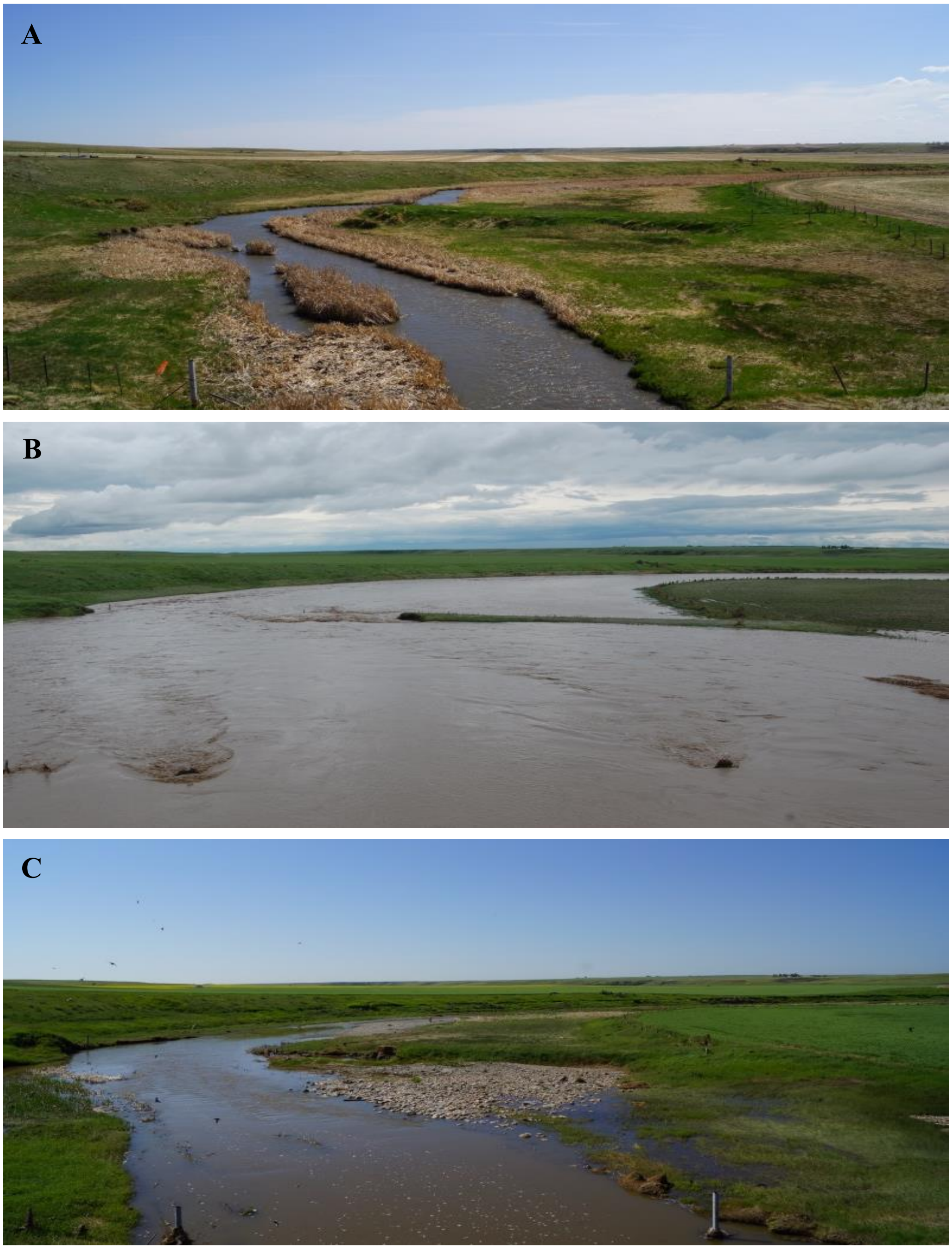

Figure A1.1 Riparian conditions downstream of the Highway 534 Bridge along the Little Bow River, Alberta following the flood of 2013. Photos A, B, and C respectively represent before (3.3 m^3/s), during (115 m^3/s), and after (15 m^3/s) the flood event. Discharge values for each photograph were coordinated with the Highway 533 gauging station (05AC930).

APPENDIX B

Data Repository

B1 Channel Width

Table B1.1 Channel widths along the Little Bow River, Alberta as derived from georectified aerial photographs collected in 1967, 1981, 2000, and 2010. Aerial photographs were georectified to an RMSE of 2.5 m. Channel width for 1967/1981 was calculated as the average value of 1967 and 1981 conditions.

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
0.1	1	297845	5605561	5.6	11.7	8.6	3.7	10.3
0.2	1	297903	5605486	10.1	13.6	11.9	6.5	8.9
0.3	1	297988	5605434	6.6	13.7	10.1	6.6	4.4
0.4	1	297987	5605343	7.0	14.0	10.5	8.1	5.4
0.5	1	297902	5605291	5.0	11.9	8.5	9.0	6.6
0.6	1	297805	5605267	4.5	12.1	8.3	8.1	9.4
0.7	1	297714	5605290	4.0	13.7	8.8	5.4	8.4
0.8	1	297625	5605245	4.2	18.8	11.5	6.5	6.6
0.9	1	297551	5605179	17.5	13.8	15.7	5.8	9.4
1.0	1	297482	5605110	11.1	10.3	10.7	9.0	6.1
1.1	1	297434	5605026	5.4	13.3	9.4	9.1	12.6
1.2	1	297393	5604934	15.1	10.5	12.8	5.8	8.5
1.3	1	297356	5604842	19.4	12.4	15.9	5.5	10.4
1.4	1	297370	5604751	25.2	12.9	19.1	5.9	10.2
1.5	1	297414	5604661	20.0	13.0	16.5	5.6	9.0
1.6	1	297445	5604567	19.4	6.4	12.9	7.7	10.0
1.7	1	297380	5604495	11.8	12.7	12.3	7.9	5.9
1.8	1	297281	5604471	3.9	7.4	5.7	4.6	10.0
1.9	1	297183	5604488	5.0	12.5	8.8	6.0	7.9
2.0	1	297086	5604495	29.5	26.8	28.1	10.4	11.2
2.1	1	297016	5604457	15.8	28.4	22.1	10.2	12.3
2.2	1	296999	5604367	17.7	24.5	21.1	9.5	14.6
2.3	1	297035	5604278	8.0	12.7	10.3	8.6	7.2
2.4	1	297100	5604216	7.8	11.5	9.7	5.1	9.8
2.5	1	297187	5604201	8.3	30.5	19.4	9.2	9.1
2.6	1	297270	5604151	5.5	20.6	13.0	8.0	7.7
2.7	1	297369	5604147	13.8	22.1	17.9	19.2	8.0
2.8	1	297419	5604221	8.2	16.2	12.2	5.6	7.1
2.9	1	297492	5604272	10.5	18.6	14.5	10.3	11.8
3.0	1	297582	5604307	8.9	21.5	15.2	8.7	5.2
3.1	1	297661	5604354	13.4	20.3	16.8	7.2	9.5
3.2	1	297759	5604319	8.7	17.2	12.9	8.9	9.6
3.3	1	297823	5604241	12.4	14.6	13.5	11.8	10.6
3.4	1	297845	5604145	10.5	19.2	14.8	11.3	14.5
3.5	1	297818	5604056	7.5	23.8	15.7	17.0	13.7
3.6	1	297786	5603962	13.4	35.6	24.5	23.5	12.2
3.7	1	297762	5603866	14.6	14.0	14.3	15.8	9.9

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
3.8	1	297701	5603792	16.5	16.8	16.7	19.4	10.1
3.9	1	297625	5603731	13.6	14.6	14.1	8.5	7.7
4.0	1	297586	5603641	21.2	27.2	24.2	19.5	12.8
4.1	1	297575	5603541	26.5	26.2	26.4	32.0	12.4
4.2	1	297638	5603465	10.1	14.9	12.5	8.1	14.3
4.3	1	297656	5603364	18.7	25.3	22.0	17.9	20.0
4.4	1	297641	5603265	17.5	17.2	17.3	16.9	17.7
4.5	1	297600	5603183	8.3	25.3	16.8	5.7	11.8
4.6	1	297623	5603091	14.0	24.2	19.1	21.0	18.1
4.7	1	297686	5603025	22.2	27.2	24.7	24.9	19.6
4.8	1	297773	5602968	18.9	27.2	23.1	19.1	16.8
4.9	1	297854	5602924	13.8	23.4	18.6	22.9	20.8
5.0	1	297943	5602874	13.2	17.2	15.2	20.3	17.3
5.1	1	298030	5602853	14.4	21.2	17.8	10.1	13.8
5.2	1	298131	5602883	14.9	14.0	14.4	10.1	15.8
5.3	1	298209	5602893	7.0	15.6	11.3	10.9	14.8
5.4	1	298249	5602982	24.1	14.0	19.1	7.9	11.0
5.5	1	298346	5603024	11.3	15.4	13.3	11.1	14.3
5.6	1	298443	5603044	9.7	22.2	16.0	13.9	12.7
5.7	1	298509	5602976	10.7	18.4	14.6	12.6	18.2
5.8	1	298548	5602878	10.7	17.7	14.2	10.5	21.9
5.9	1	298515	5602783	10.8	27.1	18.9	16.7	13.0
6.0	1	298480	5602689	10.1	10.0	10.0	26.9	16.6
6.1	1	298456	5602593	17.9	11.7	14.8	27.7	6.3
6.2	1	298477	5602496	11.2	27.0	19.1	22.5	9.8
6.3	1	298526	5602426	6.5	16.1	11.3	15.6	12.9
6.4	1	298622	5602392	7.1	13.6	10.4	9.6	13.5
6.5	1	298715	5602400	10.1	22.4	16.3	12.0	16.9
6.6	1	298790	5602449	11.1	26.7	18.9	10.2	28.2
6.7	1	298841	5602530	8.3	31.3	19.8	6.9	17.9
6.8	1	298914	5602598	13.0	26.8	19.9	25.6	21.6
6.9	1	298994	5602658	16.4	23.2	19.8	30.5	18.4
7.0	1	299077	5602706	8.8	16.7	12.8	11.4	10.6
7.1	1	299170	5602705	8.0	14.2	11.1	9.8	13.6
7.2	1	299255	5602652	7.7	17.7	12.7	7.9	13.3
7.3	1	299281	5602560	11.8	15.7	13.7	7.6	7.6
7.4	2	299381	5602573	21.4	23.0	22.2	11.3	12.9
7.5	2	299468	5602615	13.8	24.5	19.1	13.2	10.8
7.6	2	299560	5602651	5.9	19.2	12.6	13.7	18.4
7.7	2	299652	5602669	7.2	11.1	9.1	8.0	8.1
7.8	2	299750	5602662	5.1	15.4	10.2	15.9	8.3
7.9	2	299775	5602609	7.3	15.3	11.3	6.8	4.3
8.0	2	299802	5602561	7.2	10.5	8.8	4.9	9.7
8.1	2	299893	5602542	7.8	10.6	9.2	5.2	8.8
8.2	2	299968	5602565	8.3	21.3	14.8	4.1	6.2
8.3	2	300066	5602568	4.8	15.8	10.3	6.6	10.5
8.4	2	300136	5602507	7.6	9.3	8.4	5.3	10.1
8.5	2	300133	5602448	5.3	12.5	8.9	3.9	11.3

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
8.6	2	300229	5602474	6.4	8.3	7.3	5.7	7.3
8.7	2	300287	5602499	5.3	9.2	7.2	4.6	6.4
8.8	2	300385	5602503	7.4	11.6	9.5	4.6	9.1
8.9	2	300475	5602513	5.7	11.3	8.5	3.1	10.4
9.0	2	300575	5602511	7.3	16.9	12.1	6.3	6.6
9.1	2	300667	5602495	21.0	9.1	15.1	10.4	10.1
9.2	2	300721	5602553	8.9	10.1	9.5	8.9	17.6
9.3	2	300803	5602606	9.0	27.2	18.1	15.3	9.8
9.4	2	300883	5602662	6.7	15.2	10.9	9.1	8.4
9.5	2	300933	5602743	7.3	22.7	15.0	4.3	10.8
9.6	2	300998	5602814	8.0	16.8	12.4	7.2	8.4
9.7	2	301068	5602771	15.3	26.3	20.8	10.5	17.4
9.8	2	301125	5602687	11.9	15.6	13.8	12.2	19.5
9.9	2	301115	5602641	7.1	9.9	8.5	9.7	17.3
10.0	2	301173	5602571	6.9	19.5	13.2	6.2	16.4
10.1	2	301210	5602485	6.6	13.8	10.2	8.4	8.6
10.2	2	301239	5602393	15.8	13.1	14.5	5.5	8.0
10.3	2	301254	5602300	8.6	12.2	10.4	6.8	12.9
10.4	2	301282	5602219	29.9	17.8	23.8	6.2	12.0
10.5	2	301285	5602125	29.8	13.7	21.8	9.4	14.5
10.6	2	301281	5602023	9.1	14.3	11.7	6.0	11.1
10.7	2	301300	5601930	7.1	11.7	9.4	19.1	12.7
10.8	2	301305	5601833	10.1	24.8	17.4	10.2	11.5
10.9	2	301289	5601737	4.6	22.9	13.8	12.7	11.0
11.0	2	301258	5601645	4.6	13.8	9.2	7.4	9.3
11.1	2	301214	5601550	9.0	12.7	10.9	7.9	15.1
11.2	2	301192	5601464	11.4	15.0	13.2	13.3	19.7
11.3	2	301102	5601478	6.0	15.7	10.9	14.1	10.4
11.4	2	301019	5601515	28.3	39.3	33.8	32.0	12.0
11.5	2	301023	5601417	17.8	23.0	20.4	20.8	18.6
11.6	2	301057	5601324	12.1	13.0	12.5	10.8	14.5
11.7	2	301106	5601239	17.0	26.6	21.8	19.2	16.9
11.8	2	301160	5601156	30.3	20.5	25.4	26.7	13.7
11.9	2	301222	5601075	22.7	7.9	15.3	13.7	22.9
12.0	2	301279	5601006	17.0	9.0	13.0	5.2	15.2
12.1	2	301315	5600912	26.7	13.2	19.9	5.3	13.6
12.2	2	301366	5600834	19.5	11.2	15.4	4.3	7.3
12.3	2	301427	5600779	6.7	13.1	9.9	11.7	13.4
12.4	2	301495	5600706	7.2	15.8	11.5	8.6	12.1
12.5	2	301505	5600606	19.7	6.4	13.0	23.3	9.5
12.6	2	301591	5600622	8.8	12.9	10.9	12.8	15.2
12.7	2	301666	5600567	6.5	10.6	8.6	8.1	8.7
12.8	2	301715	5600498	4.6	14.9	9.8	7.8	17.0
12.9	2	301812	5600497	13.2	12.3	12.7	7.8	25.2
13.0	2	301888	5600483	11.1	13.0	12.1	4.8	11.2
13.1	2	302001	5600462	10.3	11.8	11.0	7.3	9.8
13.2	2	302005	5600355	10.7	10.1	10.4	8.8	11.6
13.3	2	302006	5600257	14.1	7.5	10.8	14.2	10.2

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
13.4	2	301996	5600159	13.8	16.1	14.9	12.9	5.1
13.5	2	301895	5600149	28.9	12.0	20.4	16.4	13.8
13.6	2	301787	5600140	18.4	13.4	15.9	14.0	19.4
13.7	2	301705	5600160	21.9	23.0	22.5	18.5	9.9
13.8	2	301670	5600068	21.3	22.9	22.1	17.6	16.4
13.9	2	301678	5599974	26.6	14.4	20.5	12.1	11.8
14.0	2	301697	5599882	31.7	15.9	23.8	22.4	11.9
14.1	2	301715	5599786	26.7	16.0	21.3	30.6	13.5
14.2	3	301737	5599688	47.4	16.2	31.8	27.5	19.8
14.3	3	301776	5599595	34.1	12.9	23.5	31.1	13.6
14.4	3	301847	5599526	37.5	11.6	24.5	17.8	21.9
14.5	3	301891	5599436	7.5	11.3	9.4	11.6	9.4
14.6	3	301870	5599368	11.6	12.5	12.0	7.0	7.6
14.7	3	301917	5599313	11.0	8.3	9.6	4.9	5.7
14.8	3	301987	5599244	6.6	10.6	8.6	13.3	16.9
14.9	3	302076	5599239	9.8	11.9	10.9	11.0	20.5
15.0	3	302114	5599297	10.0	10.5	10.3	6.7	16.1
15.1	3	302099	5599380	8.7	12.4	10.5	7.1	7.8
15.2	3	302110	5599471	15.9	8.7	12.3	4.7	9.7
15.3	3	302208	5599453	15.9	14.2	15.1	6.5	10.7
15.4	3	302292	5599392	9.0	18.7	13.9	10.3	8.3
15.5	3	302311	5599290	11.2	19.3	15.3	17.7	9.1
15.6	3	302317	5599190	11.8	12.3	12.0	15.1	4.3
15.7	3	302327	5599097	13.4	9.5	11.5	16.5	10.6
15.8	3	302284	5599014	27.3	11.5	19.4	10.5	11.4
15.9	3	302324	5598971	8.9	13.9	11.4	9.1	13.6
16.0	3	302336	5598895	5.9	29.0	17.4	7.2	9.3
16.1	3	302354	5598798	9.5	9.0	9.2	4.3	12.3
16.2	3	302327	5598714	11.6	14.7	13.2	12.7	15.1
16.3	3	302243	5598687	16.0	13.6	14.8	7.6	9.4
16.4	3	302268	5598584	10.4	16.8	13.6	4.9	15.8
16.5	3	302337	5598515	10.5	33.5	22.0	8.9	3.6
16.6	3	302433	5598498	15.3	18.9	17.1	8.7	16.3
16.7	3	302437	5598415	4.1	7.9	6.0	5.9	15.7
16.8	3	302382	5598369	6.4	17.6	12.0	4.2	15.2
16.9	3	302289	5598357	15.0	8.9	11.9	8.7	8.8
17.0	3	302205	5598362	11.3	13.4	12.3	7.2	8.9
17.1	3	302208	5598266	9.6	14.7	12.2	4.9	10.4
17.2	3	302226	5598167	7.7	11.4	9.6	9.9	14.8
17.3	3	302307	5598103	7.8	18.4	13.1	5.2	11.3
17.4	3	302364	5598014	6.2	16.5	11.4	11.3	9.4
17.5	3	302371	5597920	5.9	19.5	12.7	9.0	12.5
17.6	3	302431	5597855	6.9	13.5	10.2	10.1	12.6
17.7	3	302510	5597794	12.6	13.5	13.1	12.9	12.7
17.8	3	302580	5597719	12.0	13.5	12.7	14.8	12.4
17.9	3	302665	5597750	14.6	14.3	14.5	4.7	12.9
18.0	3	302691	5597849	12.3	16.7	14.5	15.0	8.2
18.1	3	302642	5597937	15.1	20.0	17.5	8.9	10.7

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
18.2	3	302580	5598015	11.8	9.4	10.6	13.8	11.2
18.3	3	302579	5598108	8.5	12.9	10.7	9.6	10.5
18.4	3	302607	5598192	12.1	15.0	13.5	8.3	13.8
18.5	3	302699	5598233	8.1	17.4	12.8	9.8	12.0
18.6	3	302784	5598197	15.1	13.7	14.4	7.3	11.9
18.7	3	302834	5598125	21.7	20.0	20.8	9.1	8.5
18.8	3	302869	5598045	26.4	18.1	22.3	14.5	12.0
18.9	3	302916	5597952	23.8	12.8	18.3	6.0	8.2
19.0	3	302972	5597892	4.6	15.4	10.0	9.7	7.2
19.1	3	303007	5597809	7.2	15.5	11.4	5.0	12.2
19.2	3	303022	5597712	7.3	7.4	7.4	7.9	8.0
19.3	3	303031	5597617	6.6	12.4	9.5	7.8	11.4
19.4	3	303066	5597536	4.7	12.3	8.5	9.0	13.1
19.5	3	303154	5597502	6.5	18.3	12.4	11.0	10.7
19.6	3	303241	5597534	7.2	15.3	11.3	8.9	10.9
19.7	3	303294	5597611	7.4	23.4	15.4	10.0	14.4
19.8	3	303303	5597704	5.9	26.5	16.2	5.9	11.1
19.9	3	303377	5597758	4.7	25.7	15.2	10.5	11.8
20.0	3	303469	5597714	8.7	17.0	12.8	16.0	12.8
20.1	3	303526	5597636	9.5	19.1	14.3	6.7	7.7
20.2	3	303583	5597557	8.6	19.1	13.8	3.9	12.3
20.3	3	303667	5597541	7.7	19.7	13.7	7.6	11.4
20.4	3	303692	5597445	8.1	22.8	15.5	11.9	13.3
20.5	3	303719	5597347	9.5	23.5	16.5	10.8	10.6
20.6	3	303676	5597258	12.8	16.7	14.7	14.9	15.0
20.7	3	303608	5597193	9.4	16.9	13.2	12.9	13.7
20.8	3	303630	5597120	24.7	17.8	21.3	13.6	9.1
20.9	3	303705	5597055	18.0	13.7	15.9	12.1	13.8
21.0	3	303784	5596994	22.0	11.7	16.9	19.4	10.9
21.1	3	303849	5596917	14.2	13.1	13.6	16.2	13.1
21.2	3	303934	5596878	14.3	14.1	14.2	6.7	8.8
21.3	3	304025	5596844	14.2	15.9	15.1	10.9	7.8
21.4	3	304105	5596782	10.7	18.8	14.7	18.0	12.3
21.5	3	304195	5596771	12.2	13.0	12.6	8.9	8.5
21.6	3	304290	5596749	11.3	23.8	17.6	6.1	6.0
21.7	3	304359	5596782	5.5	19.3	12.4	4.3	7.0
21.8	3	304353	5596879	5.5	16.9	11.2	5.2	8.7
21.9	3	304433	5596933	5.4	14.8	10.1	7.8	8.6
22.0	3	304526	5596902	7.4	10.8	9.1	8.2	12.0
22.1	3	304557	5596822	6.9	3.2	5.0	3.6	6.6
22.2	3	304593	5596745	4.2	13.5	8.8	8.1	13.7
22.3	3	304678	5596702	6.7	32.4	19.5	8.0	7.4
22.4	3	304759	5596689	5.4	21.9	13.6	6.2	6.7
22.5	3	304847	5596672	9.5	16.8	13.1	4.7	6.8
22.6	3	304935	5596626	20.5	10.0	15.3	11.8	11.0
22.7	3	305006	5596555	19.9	24.8	22.4	12.6	12.3
22.8	3	305052	5596470	9.3	15.1	12.2	7.6	10.7
22.9	3	305119	5596421	23.5	17.8	20.7	8.8	12.2

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
23.0	3	305213	5596443	13.7	18.3	16.0	9.3	14.3
23.1	3	305309	5596455	22.9	20.0	21.4	4.4	11.6
23.2	4	305392	5596491	11.3	14.6	12.9	6.0	9.1
23.3	4	305470	5596484	20.8	25.2	23.0	6.9	11.2
23.4	4	305568	5596468	14.4	19.1	16.8	8.4	15.5
23.5	4	305667	5596472	6.1	14.1	10.1	7.6	21.6
23.6	4	305751	5596471	3.3	21.1	12.2	10.6	11.6
23.7	4	305839	5596506	6.3	19.1	12.7	9.1	14.9
23.8	4	305861	5596586	11.1	15.9	13.5	5.4	9.4
23.9	4	305924	5596648	8.1	26.8	17.5	7.3	8.3
24.0	4	306013	5596696	10.1	13.2	11.7	6.6	6.8
24.1	4	306109	5596705	7.0	25.1	16.0	14.5	17.6
24.2	4	306199	5596676	5.3	19.7	12.5	6.2	7.1
24.3	4	306218	5596585	12.2	33.4	22.8	7.7	12.6
24.4	4	306277	5596531	17.4	36.3	26.9	17.2	8.8
24.5	4	306377	5596535	18.5	20.8	19.6	16.0	19.2
24.6	4	306474	5596549	11.7	24.2	18.0	13.6	11.9
24.7	4	306570	5596525	12.8	35.7	24.3	12.7	12.7
24.8	4	306668	5596508	16.4	30.0	23.2	15.9	11.2
24.9	4	306755	5596559	6.2	22.0	14.1	4.1	7.3
25.0	4	306819	5596598	5.9	22.0	13.9	3.2	19.6
25.1	4	306900	5596568	8.3	15.8	12.0	7.9	9.0
25.2	4	306976	5596515	8.5	19.0	13.8	8.8	14.3
25.3	4	306946	5596418	6.9	26.4	16.6	8.0	15.9
25.4	4	306842	5596389	9.2	13.2	11.2	8.5	8.8
25.5	4	306800	5596333	10.8	18.8	14.8	11.7	10.4
25.6	4	306811	5596243	6.2	31.4	18.8	18.1	11.2
25.7	4	306905	5596220	11.9	27.0	19.5	12.5	15.5
25.8	4	307002	5596235	9.3	22.8	16.1	8.2	15.2
25.9	4	307078	5596180	8.5	18.0	13.2	7.6	10.2
26.0	4	307099	5596090	5.2	11.9	8.6	6.4	9.2
26.1	4	307073	5595994	5.7	29.9	17.8	3.0	9.5
26.2	4	307019	5595911	6.6	16.8	11.7	3.9	8.6
26.3	4	306928	5595873	7.8	23.8	15.8	5.8	9.4
26.4	4	306838	5595885	7.0	21.6	14.3	3.8	6.4
26.5	4	306764	5595839	9.5	26.1	17.8	6.6	12.8
26.6	4	306762	5595741	13.9	23.5	18.7	13.8	11.4
26.7	4	306782	5595653	14.1	30.3	22.2	9.8	18.6
26.8	4	306861	5595614	19.9	13.5	16.7	15.7	13.4
26.9	4	306956	5595600	8.3	42.6	25.5	12.3	12.7
27.0	4	307047	5595567	6.6	17.0	11.8	8.6	17.7
27.1	4	307137	5595526	11.2	20.3	15.8	6.1	9.5
27.2	4	307128	5595426	24.1	16.4	20.2	14.4	11.0
27.3	4	307105	5595330	24.2	21.6	22.9	16.7	11.9
27.4	4	307053	5595238	8.2	13.3	10.7	9.5	11.8
27.5	4	306983	5595184	10.0	16.1	13.0	7.2	10.4
27.6	4	306946	5595093	11.2	14.3	12.8	8.0	8.9
27.7	4	306974	5595008	8.4	19.4	13.9	7.8	10.1

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
27.8	4	307057	5594983	10.3	15.0	12.6	6.3	13.5
27.9	4	307133	5594921	14.2	13.4	13.8	5.2	8.8
28.0	4	307207	5594859	27.2	20.2	23.7	18.2	12.8
28.1	4	307286	5594805	35.7	30.3	33.0	14.0	20.1
28.2	4	307383	5594805	29.3	21.0	25.1	10.9	19.5
28.3	4	307471	5594843	36.3	16.4	26.4	6.4	12.5
28.4	4	307524	5594928	11.1	25.3	18.2	14.0	11.1
28.5	4	307602	5594987	13.5	39.8	26.7	3.4	10.1
28.6	4	307698	5595005	15.7	20.4	18.0	3.4	12.3
28.7	4	307796	5595000	11.0	10.7	10.8	2.1	7.1
28.8	4	307892	5595001	15.2	21.2	18.2	2.8	6.1
28.9	4	307988	5595007	17.6	24.3	21.0	14.1	8.6
29.0	4	308085	5595025	7.9	16.2	12.0	8.8	11.4
29.1	4	308172	5595046	6.8	17.9	12.4	7.3	7.9
29.2	4	308245	5595000	5.4	24.2	14.8	7.4	8.9
29.3	4	308271	5594912	8.9	29.9	19.4	9.0	9.2
29.4	4	308275	5594813	12.4	31.5	22.0	7.4	9.7
29.5	4	308362	5594766	12.0	12.1	12.1	8.9	6.7
29.6	4	308443	5594760	4.4	19.3	11.8	5.9	9.0
29.7	4	308525	5594808	9.3	9.0	9.2	6.6	6.1
29.8	4	308595	5594875	5.7	10.3	8.0	6.0	6.9
29.9	4	308655	5594952	11.5	16.8	14.2	4.6	14.1
30.0	4	308755	5594950	22.7	34.1	28.4	19.9	18.4
30.1	4	308843	5594906	19.5	27.0	23.3	10.6	16.5
30.2	4	308935	5594879	5.3	11.9	8.6	6.6	11.0
30.3	4	308972	5594828	4.2	23.6	13.9	8.2	8.5
30.4	4	308930	5594750	6.9	15.7	11.3	6.1	7.0
30.5	4	308876	5594694	9.5	10.2	9.9	7.1	9.0
30.6	4	308865	5594701	8.3	14.5	11.4	8.8	9.6
30.7	4	308873	5594604	5.5	15.0	10.3	4.3	4.1
30.8	4	308972	5594588	3.7	19.7	11.7	5.8	6.7
30.9	4	309067	5594562	5.8	17.9	11.8	6.2	12.1
31.0	4	309163	5594575	7.3	16.3	11.8	5.2	11.0
31.1	4	309243	5594625	7.5	18.2	12.8	7.2	13.9
31.2	4	309227	5594646	6.0	21.3	13.7	7.7	6.7
31.3	4	309164	5594709	4.2	22.3	13.2	7.8	9.8
31.4	4	309129	5594784	4.1	19.2	11.7	7.3	7.6
31.5	4	309121	5594882	4.9	20.4	12.6	12.4	9.8
31.6	4	309197	5594948	5.7	14.2	9.9	7.6	8.0
31.7	4	309286	5594993	6.6	15.3	10.9	10.7	12.3
31.8	4	309377	5595038	7.1	15.4	11.3	10.7	10.3
31.9	4	309474	5594999	8.9	20.3	14.6	18.9	10.2
32.0	4	309552	5594941	7.7	20.7	14.2	22.3	8.7
32.1	4	309614	5594867	8.9	16.6	12.8	15.8	9.4
32.2	4	309691	5594872	8.4	27.1	17.8	6.8	12.5
32.3	4	309773	5594925	15.3	36.0	25.6	6.9	8.4
32.4	4	309837	5595001	15.2	25.9	20.5	5.6	7.2
32.5	4	309839	5595096	7.1	35.4	21.3	15.2	12.9

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
32.6	4	309811	5595185	8.6	41.6	25.1	5.8	6.6
32.7	4	309875	5595253	13.2	13.3	13.2	5.5	7.8
32.8	4	309971	5595290	8.3	17.6	12.9	10.8	10.5
32.9	4	310068	5595296	8.5	9.7	9.1	13.1	9.5
33.0	4	310167	5595319	10.9	15.1	13.0	9.2	11.2
33.1	4	310204	5595225	8.7	19.9	14.3	6.7	8.7
33.2	4	310173	5595127	23.2	17.9	20.5	12.2	9.1
33.3	4	310128	5595044	10.3	12.2	11.2	5.6	7.5
33.4	4	310161	5594959	10.9	11.1	11.0	3.9	5.2
33.5	4	310249	5594937	4.7	24.1	14.4	3.6	8.1
33.6	4	310339	5594950	18.8	21.9	20.3	2.4	5.9
33.7	4	310399	5595003	9.1	8.7	8.9	3.9	8.0
33.8	4	310449	5595084	6.4	13.1	9.8	3.9	4.8
33.9	4	310511	5595151	23.1	16.7	19.9	6.2	5.2
34.0	4	310596	5595207	16.4	25.4	20.9	4.9	7.5
34.1	4	310691	5595179	7.7	18.3	13.0	8.8	8.9
34.2	4	310788	5595173	7.6	14.6	11.1	10.0	8.8
34.3	5	310884	5595147	7.2	15.9	11.5	9.3	12.2
34.4	5	310957	5595080	6.7	16.3	11.5	15.7	11.4
34.5	5	311038	5595039	7.7	18.4	13.1	19.9	22.4
34.6	5	311135	5595027	3.6	9.4	6.5	19.1	15.5
34.7	5	311227	5595054	7.9	14.3	11.1	19.2	13.9
34.8	5	311311	5595100	6.5	12.7	9.6	17.6	17.1
34.9	5	311396	5595139	7.5	9.8	8.7	11.5	9.1
35.0	5	311491	5595181	10.3	11.4	10.8	9.2	12.1
35.1	5	311589	5595174	10.4	12.4	11.4	9.7	10.1
35.2	5	311686	5595149	9.1	15.2	12.1	6.3	9.5
35.3	5	311765	5595087	8.0	14.2	11.1	8.5	10.5
35.4	5	311855	5595053	6.9	25.7	16.3	12.1	14.3
35.5	5	311951	5595030	10.7	13.7	12.2	8.5	12.3
35.6	5	312052	5595018	7.6	15.4	11.5	11.4	10.5
35.7	5	312138	5594958	7.8	19.6	13.7	7.9	11.7
35.8	5	312192	5594866	5.9	16.9	11.4	6.8	10.8
35.9	5	312251	5594808	9.2	17.4	13.3	4.7	9.7
36.0	5	312212	5594738	9.3	9.8	9.5	5.5	5.5
36.1	5	312263	5594653	5.1	13.6	9.4	6.4	8.2
36.2	5	312262	5594554	7.5	18.9	13.2	4.7	8.1
36.3	5	312256	5594466	6.7	27.3	17.0	6.1	8.4
36.4	5	312295	5594392	7.2	22.0	14.6	14.1	13.7
36.5	5	312362	5594348	12.8	28.7	20.7	6.6	11.3
36.6	5	312411	5594254	7.0	17.5	12.3	10.9	11.2
36.7	5	312444	5594170	11.2	11.4	11.3	18.3	10.9
36.8	5	312517	5594106	12.5	18.7	15.6	15.8	11.8
36.9	5	312593	5594046	13.3	38.5	25.9	11.2	9.4
37.0	5	312683	5594002	14.3	41.4	27.8	5.6	15.5
37.1	5	312771	5593956	14.7	48.6	31.6	13.2	15.0
37.2	5	312854	5593896	17.8	35.1	26.5	11.6	16.4
37.3	5	312905	5593808	13.7	35.8	24.7	8.3	14.9

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Channel Width (m)**				
		E	N	1967	1981	1967/1981	2000	2010
37.4	5	312951	5593717	13.5	16.6	15.0	7.9	16.8
37.5	5	312989	5593635	11.0	19.2	15.1	5.9	11.7
37.6	5	313061	5593573	25.6	21.1	23.3	9.5	13.9
37.7	5	313142	5593512	16.9	21.3	19.1	5.9	12.4
37.8	5	313222	5593470	21.0	15.7	18.3	13.6	18.5
37.9	5	313301	5593405	13.3	14.7	14.0	9.4	12.9
38.0	5	313386	5593362	13.0	11.0	12.0	2.3	7.6
38.1	5	313476	5593384	21.0	18.2	19.6	5.9	6.5
38.2	5	313565	5593429	26.5	23.0	24.8	5.6	7.1
38.3	5	313656	5593461	17.6	31.4	24.5	7.2	9.9
38.4	5	313754	5593474	16.3	24.2	20.2	10.0	11.5
38.5	5	313833	5593518	19.7	26.4	23.0	6.6	12.4
38.6	5	313873	5593595	21.1	31.3	26.2	7.0	15.3
38.7	5	313893	5593697	30.8	40.0	35.4	7.3	17.6
38.8	5	313976	5593753	9.1	26.9	18.0	5.1	4.6
38.9	5	314070	5593743	23.7	37.1	30.4	7.2	11.0
39.0	5	314143	5593674	22.1	28.5	25.3	11.7	12.0
39.1	5	314195	5593591	21.3	33.4	27.3	6.3	9.2
39.2	5	314246	5593511	26.0	35.1	30.5	9.5	15.9
39.3	5	314314	5593437	13.7	23.3	18.5	13.4	14.9
39.4	5	314248	5593376	10.1	18.0	14.0	10.7	10.6
39.5	5	314225	5593322	9.2	33.0	21.1	8.6	12.8
39.6	5	314242	5593217	9.3	15.1	12.2	7.4	10.9
39.7	5	314256	5593121	7.5	15.0	11.3	7.5	12.9
39.8	5	314279	5593026	14.8	19.0	16.9	7.5	17.8
39.9	5	314300	5592943	15.6	14.5	15.1	7.0	10.6
40.0	5	314380	5592888	16.1	19.8	17.9	6.3	11.2
40.1	5	314445	5592817	28.5	34.9	31.7	5.3	5.0
40.2	5	314499	5592732	18.6	20.1	19.4	11.9	5.7
40.3	5	314557	5592655	13.1	19.1	16.1	8.8	6.3
40.4	5	314648	5592618	8.6	15.1	11.8	10.3	9.2
40.5	5	314733	5592555	9.5	11.7	10.6	10.5	16.8
40.6	5	314769	5592478	9.7	33.2	21.5	11.6	6.1
40.7	5	314846	5592443	6.8	26.4	16.6	9.7	10.7
40.8	5	314936	5592409	22.3	37.7	30.0	9.5	14.3
40.9	5	315030	5592380	20.5	58.8	39.6	7.7	7.8
41.0	5	315124	5592375	6.9	20.2	13.5	9.3	8.1
41.1	5	315214	5592386	4.7	27.2	15.9	8.7	9.6
41.2	5	315315	5592382	14.4	19.6	17.0	5.6	7.1
41.3	5	315403	5592379	19.9	13.7	16.8	5.7	9.6
41.4	5	315494	5592334	18.3	16.5	17.4	7.2	6.0
41.5	5	315572	5592276	29.0	19.2	24.1	3.8	8.9
41.6	5	315662	5592239	16.2	18.6	17.4	21.2	23.1
41.7	5	315681	5592219	7.3	19.4	13.3	6.3	11.5
41.8	5	315783	5592133	7.3	18.2	12.7	6.7	8.7
41.9	5	315843	5592062	6.5	13.2	9.8	8.5	7.5
42.0	5	315904	5591992	10.2	12.1	11.1	10.4	9.1
42.1	5	315985	5592043	8.4	21.4	14.9	12.0	12.5

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
42.2	5	316054	5592053	14.0	18.1	16.0	16.5	14.4
42.3	5	316103	5591959	10.4	17.6	14.0	17.5	18.0
42.4	5	316096	5591867	16.4	26.8	21.6	16.4	19.0
42.5	5	316106	5591770	13.6	17.1	15.3	17.5	22.8
42.6	5	316161	5591697	12.2	18.9	15.6	20.2	18.3
42.7	5	316241	5591639	15.5	24.3	19.9	22.6	25.3
42.8	5	316330	5591603	15.5	17.1	16.3	19.2	18.9
42.9	5	316429	5591612	15.1	12.6	13.8	18.0	21.7
43.0	5	316521	5591644	21.2	32.7	26.9	19.3	17.1
43.1	5	316589	5591715	22.0	27.3	24.6	20.6	29.0
43.2	5	316676	5591764	28.6	15.4	22.0	16.3	19.3
43.3	5	316766	5591724	20.9	20.6	20.8	23.0	16.3
43.4	5	316821	5591641	18.8	16.7	17.8	24.1	21.3
43.5	5	316886	5591566	12.6	26.5	19.5	16.5	14.9
43.6	5	316941	5591487	7.9	16.6	12.2	7.8	9.6
43.7	5	316961	5591391	8.0	12.7	10.3	7.9	9.6
43.8	5	316943	5591301	8.5	13.1	10.8	9.5	11.0
43.9	5	316963	5591204	10.4	15.8	13.1	14.2	12.4
44.0	5	316957	5591114	7.0	18.6	12.8	9.9	10.6
44.1	5	316966	5591014	10.9	21.9	16.4	10.7	10.1
44.2	6	316934	5590926	6.1	21.9	14.0	17.0	13.7
44.3	6	316933	5590822	21.3	47.6	34.5	22.4	19.8
44.4	6	316855	5590756	23.9	27.0	25.4	24.1	24.1
44.5	6	316790	5590683	24.3	24.3	24.3	28.1	24.9
44.6	6	316731	5590612	15.5	33.7	24.6	20.8	23.8
44.7	6	316711	5590521	34.5	44.7	39.6	38.6	20.4
44.8	6	316737	5590421	28.8	33.3	31.1	27.3	27.2
44.9	6	316742	5590325	18.9	31.6	25.3	26.1	24.9
45.0	6	316769	5590231	16.7	18.8	17.7	16.7	20.9
45.1	6	316832	5590160	30.5	23.8	27.2	28.4	25.6
45.2	6	316895	5590092	46.4	39.7	43.1	38.2	31.0
45.3	6	316971	5590046	9.4	13.6	11.5	14.9	13.8
45.4	6	317061	5590001	16.4	28.8	22.6	19.6	17.3
45.5	6	317139	5589942	9.4	16.5	13.0	14.6	12.7
45.6	6	317188	5589858	6.7	13.5	10.1	8.4	15.0
45.7	6	317200	5589758	22.6	14.2	18.4	5.0	10.5
45.8	6	317204	5589659	24.8	12.9	18.9	6.6	10.0
45.9	6	317213	5589559	19.1	12.8	16.0	12.7	12.1
46.0	6	317207	5589462	9.0	18.0	13.5	8.5	11.3
46.1	6	317251	5589372	27.2	13.4	20.3	8.5	16.0
46.2	6	317231	5589278	7.7	16.9	12.3	14.5	11.6
46.3	6	317256	5589183	17.9	22.7	20.3	16.6	9.9
46.4	6	317309	5589099	34.0	46.5	40.2	34.5	30.2
46.5	6	317356	5589013	35.2	36.1	35.6	36.9	30.0
46.6	6	317411	5588931	20.2	28.1	24.2	24.5	28.3
46.7	6	317474	5588853	11.4	20.2	15.8	19.3	18.5
46.8	6	317552	5588802	19.0	41.4	30.2	21.3	26.1
46.9	6	317648	5588781	15.0	30.9	23.0	20.3	19.8

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
47.0	6	317731	5588725	10.9	64.0	37.4	18.9	15.4
47.1	6	317799	5588653	23.9	57.0	40.4	21.0	25.3
47.2	6	317857	5588562	44.4	54.4	49.4	41.5	41.9
47.3	6	317866	5588467	27.6	52.9	40.2	28.0	32.3
47.4	6	317865	5588363	38.5	52.0	45.2	38.2	30.6
47.5	6	317844	5588263	20.4	20.9	20.6	18.6	19.6
47.6	6	317840	5588166	12.7	13.3	13.0	9.2	26.0
47.7	6	317845	5588072	20.3	19.2	19.7	17.5	16.9
47.8	6	317857	5587973	25.6	20.5	23.0	15.8	20.8
47.9	6	317906	5587900	30.0	20.2	25.1	24.1	26.1
48.0	6	317915	5587801	22.6	11.4	17.0	25.7	24.5
48.1	6	317931	5587702	30.1	20.1	25.1	19.3	19.0
48.2	6	317929	5587601	33.4	15.4	24.4	17.7	23.0
48.3	6	317914	5587501	22.3	21.2	21.8	22.9	24.7
48.4	6	317865	5587411	28.7	35.0	31.9	11.5	17.7
48.5	6	317787	5587350	43.8	24.4	34.1	22.4	19.9
48.6	6	317731	5587270	29.2	16.6	22.9	22.6	23.2
48.7	6	317665	5587194	15.4	28.0	21.7	17.6	18.2
48.8	6	317588	5587160	13.6	41.4	27.5	17.0	23.4
48.9	6	317510	5587088	11.3	31.9	21.6	6.2	10.7
49.0	6	317436	5587026	7.9	23.7	15.8	9.1	10.3
49.1	6	317401	5586932	21.2	24.3	22.7	16.8	12.6
49.2	6	317354	5586846	16.8	20.1	18.4	22.4	22.5
49.3	6	317320	5586753	11.3	14.9	13.1	10.6	16.0
49.4	6	317300	5586661	17.9	15.7	16.8	14.7	13.0
49.5	6	317315	5586562	14.9	25.5	20.2	18.4	18.8
49.6	6	317358	5586476	15.5	39.7	27.6	19.5	19.1
49.7	6	317424	5586408	13.0	34.0	23.5	18.1	22.1
49.8	6	317502	5586345	17.2	21.4	19.3	12.9	13.8
49.9	6	317590	5586309	20.4	28.9	24.7	17.3	16.6
50.0	6	317692	5586310	29.5	32.7	31.1	24.2	16.5
50.1	6	317782	5586272	43.5	19.9	31.7	37.0	20.1
50.2	6	317868	5586309	23.7	19.1	21.4	25.2	25.8
50.3	6	317970	5586340	20.3	17.1	18.7	24.4	21.1
50.4	6	318066	5586301	22.9	26.7	24.8	29.2	22.7
50.5	6	318157	5586259	29.4	47.8	38.6	42.1	22.5
50.6	6	318222	5586175	29.8	44.2	37.0	35.5	32.7
50.7	6	318231	5586074	45.1	44.9	45.0	38.8	28.1
50.8	6	318214	5585977	24.1	24.7	24.4	10.7	12.3
50.9	6	318213	5585875	15.0	10.7	12.8	6.4	10.6
51.0	6	318228	5585795	13.6	17.4	15.5	5.9	15.0
51.1	6	318175	5585709	32.4	13.2	22.8	5.0	7.9
51.2	6	318083	5585672	31.6	13.3	22.5	8.9	6.9
51.3	6	317986	5585633	9.4	17.2	13.3	9.3	10.9
51.4	6	317900	5585647	11.2	18.8	15.0	15.5	15.0
51.5	6	317797	5585649	16.0	20.2	18.1	12.6	22.8
51.6	6	317706	5585641	13.6	23.4	18.5	19.7	15.4
51.7	6	317599	5585638	12.5	20.4	16.4	15.0	18.0

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Channel Width (m)				
		E	N	1967	1981	1967/1981	2000	2010
51.8	6	317511	5585688	14.2	17.7	16.0	23.1	18.1
51.9	6	317410	5585712	10.1	22.4	16.2	20.7	23.3
52.0	6	317345	5585711	12.6	17.4	15.0	7.2	11.0
52.1	6	317328	5585617	18.5	19.1	18.8	7.2	15.3
52.2	6	317338	5585518	23.6	32.0	27.8	8.3	20.9
52.3	7	317356	5585421	15.5	19.5	17.5	9.0	13.3
52.4	7	317397	5585329	28.9	21.6	25.2	18.5	18.1
52.5	7	317468	5585255	11.0	15.4	13.2	21.4	14.2
52.6	7	317513	5585179	12.6	24.1	18.3	25.4	18.0
52.7	7	317554	5585097	7.0	21.5	14.3	14.5	15.0
52.8	7	317620	5585029	11.6	12.0	11.8	14.2	15.3
52.9	7	317663	5584937	50.0	53.0	51.5	20.8	30.7
53.0	7	317669	5584838	27.6	34.5	31.1	11.2	37.6
53.1	7	317661	5584738	25.4	27.9	26.7	13.4	30.2
53.2	7	317634	5584643	11.8	29.1	20.4	20.6	25.9
53.3	7	317655	5584546	10.3	20.1	15.2	13.4	15.0
53.4	7	317631	5584448	16.4	16.5	16.4	11.2	13.0
53.5	7	317613	5584369	15.9	13.8	14.9	16.2	16.8
53.6	7	317640	5584276	9.1	15.9	12.5	8.2	11.0
53.7	7	317677	5584186	13.1	19.3	16.2	14.0	18.8
53.8	7	317740	5584111	11.7	15.2	13.5	13.1	16.0
53.9	7	317793	5584031	17.6	16.1	16.8	14.9	19.2
54.0	7	317824	5583946	9.9	23.0	16.5	13.0	17.4
54.1	7	317907	5583898	16.6	21.9	19.3	16.8	15.8
54.2	7	317964	5583815	9.8	18.9	14.3	14.9	16.3
54.3	7	317988	5583719	17.0	14.9	15.9	15.7	16.8
54.4	7	317991	5583619	25.3	24.7	25.0	27.8	45.8
54.5	7	318018	5583526	12.9	14.7	13.8	10.9	21.1
54.6	7	318016	5583428	18.8	17.0	17.9	20.2	18.3
54.7	7	318014	5583329	19.3	20.4	19.9	28.6	10.5
54.8	7	318019	5583231	11.6	18.9	15.2	11.1	9.1
54.9	7	318031	5583132	13.8	21.4	17.6	12.7	10.4
55.0	7	318050	5583037	11.4	16.9	14.2	14.2	10.4
55.1	7	318074	5582939	10.0	16.6	13.3	17.2	13.7
55.2	7	318103	5582845	13.2	18.2	15.7	12.3	17.8
55.3	7	318117	5582756	14.9	14.0	14.5	20.6	7.4
55.4	7	318154	5582661	17.1	33.0	25.0	13.2	27.3
55.5	7	318207	5582577	43.3	44.7	44.0	13.2	40.7
55.6	7	318254	5582492	43.9	59.2	51.5	12.6	36.4
55.7	7	318311	5582411	15.0	27.2	21.1	11.3	10.0
55.8	7	318386	5582349	33.7	40.7	37.2	37.3	44.7
55.9	7	318459	5582274	38.2	38.4	38.3	33.0	40.5
56.0	7	318508	5582188	17.9	17.8	17.9	15.9	22.9
56.1	7	318575	5582114	7.4	16.7	12.0	13.5	13.3
56.2	7	318661	5582073	14.4	16.4	15.4	14.5	21.6
56.3	7	318756	5582044	21.1	24.5	22.8	26.5	24.2
56.4	7	318832	5581990	38.4	27.6	33.0	36.5	41.0
56.5	7	318913	5581925	11.3	15.9	13.6	18.7	21.7

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Channel Width (m)**				
		E	N	1967	1981	1967/1981	2000	2010
56.6	7	318973	5581851	6.5	9.1	7.8	17.9	12.3
56.7	7	319058	5581809	10.7	10.8	10.7	13.3	8.4
56.8	7	319125	5581727	17.5	10.1	13.8	16.1	12.3
56.9	7	319156	5581626	13.0	12.3	12.6	8.4	14.3
57.0	7	319168	5581528	20.8	13.0	16.9	20.0	21.8
57.1	7	319184	5581445	35.2	5.1	20.2	4.8	6.8
57.2	7	319183	5581341	9.3	22.2	15.8	17.0	15.1
57.3	7	319144	5581249	13.8	17.6	15.7	20.9	18.2
57.4	7	319068	5581192	9.2	14.7	11.9	12.8	14.7
57.5	7	319062	5581109	15.2	15.7	15.5	11.1	11.8

B2 Sinuosity

Table B2.1 Sinuosity index along the Little Bow River, Alberta as derived from georectified aerial photographs collected in 1967, 1981, 2000, and 2010. Aerial photographs were georectified to an RMSE of 2.5 m. Sinuosity index for 1967/1981 was calculated as the average value of 1967 and 1981 conditions.

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Sinuosity Index				
		E	N	1967	1981	1967/1981	2000	2010
0.4	1	297829	5605630	1.19	1.18	1.18	1.16	1.14
0.8	1	297986	5605340	1.11	1.10	1.10	1.07	1.09
1.2	1	297623	5605250	1.07	1.02	1.05	1.03	1.03
1.6	1	297390	5604940	1.10	1.07	1.09	1.08	1.08
2.0	1	297442	5604570	1.12	1.13	1.13	1.12	1.12
2.4	1	297087	5604500	1.36	1.33	1.35	1.34	1.34
2.8	1	297093	5604200	1.29	1.29	1.29	1.27	1.29
3.2	1	297421	5604220	1.19	1.15	1.17	1.18	1.22
3.6	1	297757	5604320	1.18	1.13	1.15	1.14	1.14
4.0	1	297781	5603960	1.08	1.07	1.08	1.06	1.06
4.4	1	297578	5603640	1.09	1.07	1.08	1.06	1.25
4.8	1	297633	5603270	1.20	1.19	1.20	1.24	1.19
5.2	1	297764	5602960	1.10	1.08	1.09	1.09	1.10
5.6	1	298128	5602880	1.11	1.11	1.11	1.14	1.14
6.0	1	298444	5603040	1.19	1.19	1.19	1.17	1.21
6.4	1	298472	5602690	1.26	1.22	1.24	1.22	1.22
6.8	1	298620	5602390	1.14	1.14	1.14	1.12	1.15
7.2	1	298924	5602590	1.20	1.20	1.20	1.20	1.20
7.6	2	299252	5602650	1.35	1.32	1.33	1.31	1.34
8.0	2	299563	5602650	1.49	1.52	1.51	1.64	1.78
8.4	2	299799	5602560	1.16	1.15	1.16	1.20	1.26
8.8	2	300143	5602510	1.61	1.66	1.63	1.74	1.90
9.2	2	300388	5602500	1.20	1.37	1.28	1.21	1.19
9.6	2	300720	5602550	1.08	1.08	1.08	1.09	1.08
10.0	2	300999	5602810	1.35	1.29	1.32	1.41	1.48
10.4	2	301161	5602570	1.02	1.16	1.09	1.07	1.09
10.8	2	301277	5602220	1.03	1.05	1.04	1.06	1.04
11.2	2	301299	5601830	1.08	1.04	1.06	1.10	1.12
11.6	2	301187	5601470	2.10	2.10	2.10	2.19	2.23
12.0	2	301052	5601320	1.04	1.06	1.05	1.03	1.03
12.4	2	301272	5601000	1.04	1.06	1.05	1.10	1.06
12.8	2	301492	5600700	1.33	1.37	1.35	1.28	1.41
13.2	2	301712	5600490	1.32	1.30	1.31	1.30	1.30
13.6	2	302000	5600360	1.45	1.40	1.42	1.45	1.45
14.0	2	301791	5600150	1.34	1.47	1.41	1.39	1.46
14.4	3	301692	5599880	1.02	1.12	1.07	1.03	1.08
14.8	3	301836	5599520	1.24	1.30	1.27	1.31	1.37
15.2	3	301983	5599240	1.66	1.74	1.70	1.59	1.59
15.6	3	302110	5599470	1.21	1.23	1.22	1.19	1.28
16.0	3	302314	5599190	1.30	1.65	1.47	1.37	1.44
16.4	3	302330	5598900	1.33	1.30	1.32	1.27	1.33

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Sinuosity Index				
		E	N	1967	1981	1967/1981	2000	2010
16.8	3	302257	5598580	1.80	1.76	1.78	1.62	1.63
17.2	3	302382	5598380	1.69	1.68	1.68	1.67	1.70
17.6	3	302219	5598170	1.06	1.07	1.07	1.07	1.08
18.0	3	302427	5597850	1.43	1.58	1.50	1.52	1.56
18.4	3	302697	5597850	1.10	1.13	1.11	1.10	1.09
18.8	3	302610	5598190	1.34	1.29	1.32	1.35	1.36
19.2	3	302866	5598040	1.10	1.13	1.12	1.11	1.13
19.6	3	303019	5597710	1.45	1.40	1.42	1.43	1.37
20.0	3	303245	5597530	1.41	1.44	1.42	1.44	1.43
20.4	3	303466	5597710	1.17	1.25	1.21	1.20	1.19
20.8	3	303686	5597440	1.32	1.23	1.28	1.26	1.28
21.2	3	303628	5597120	1.05	1.03	1.04	1.03	1.03
21.6	3	303933	5596870	1.07	1.09	1.08	1.06	1.08
22.0	3	304289	5596750	1.62	1.40	1.51	1.44	1.45
22.4	3	304524	5596900	1.32	1.19	1.26	1.30	1.31
22.8	3	304758	5596690	1.09	1.09	1.09	1.10	1.12
23.2	4	305048	5596470	1.13	1.13	1.13	1.18	1.17
23.6	4	305398	5596490	1.15	1.11	1.13	1.17	1.19
24.0	4	305752	5596470	1.22	1.06	1.14	1.19	1.20
24.4	4	306014	5596690	1.33	1.25	1.29	1.34	1.37
24.8	4	306276	5596530	1.03	1.04	1.04	1.04	1.03
25.2	4	306668	5596500	1.31	1.24	1.27	1.36	1.35
25.6	4	306972	5596520	1.30	1.34	1.32	1.27	1.28
26.0	4	306805	5596240	1.26	1.25	1.26	1.27	1.26
26.4	4	307094	5596090	1.26	1.19	1.23	1.24	1.26
26.8	4	306838	5595890	1.39	1.52	1.46	1.42	1.44
27.2	4	306859	5595610	1.29	1.35	1.32	1.31	1.29
27.6	4	307123	5595430	1.05	1.07	1.06	1.07	1.07
28.0	4	306942	5595090	1.14	1.14	1.14	1.14	1.15
28.4	4	307202	5594850	1.22	1.25	1.24	1.25	1.24
28.8	4	307528	5594930	1.08	1.19	1.13	1.07	1.08
29.2	4	307894	5595000	1.15	1.09	1.12	1.17	1.13
29.6	4	308241	5595000	1.30	1.23	1.27	1.29	1.33
30.0	4	308445	5594760	1.09	1.09	1.09	1.11	1.11
30.4	4	308754	5594940	1.64	1.60	1.62	1.57	1.59
30.8	4	308921	5594750	2.40	2.14	2.27	2.41	2.52
31.2	4	308971	5594590	1.74	1.59	1.66	1.56	1.47
31.6	4	309227	5594650	1.42	1.25	1.34	1.42	1.47
32.0	4	309200	5594950	1.21	1.15	1.18	1.18	1.18
32.4	4	309548	5594940	1.30	1.38	1.34	1.32	1.32
32.8	4	309839	5595000	1.25	1.24	1.25	1.30	1.30
33.2	4	309970	5595290	1.59	1.72	1.65	1.60	1.62
33.6	4	310169	5595130	1.54	1.38	1.46	1.61	1.59
34.0	4	310338	5594950	1.12	1.16	1.14	1.10	1.12
34.4	5	310597	5595200	1.09	1.05	1.07	1.09	1.10
34.8	5	310953	5595080	1.13	1.12	1.13	1.10	1.09
35.2	5	311315	5595090	1.11	1.09	1.10	1.11	1.11
35.6	5	311683	5595140	1.03	1.03	1.03	1.04	1.04

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Sinuosity Index**				
		E	N	1967	1981	1967/1981	2000	2010
36.0	5	312050	5595010	1.29	1.37	1.33	1.31	1.31
36.4	5	312210	5594740	1.17	1.08	1.12	1.13	1.12
36.8	5	312289	5594390	1.14	1.12	1.13	1.12	1.09
37.2	5	312513	5594100	1.02	1.05	1.03	1.02	1.02
37.6	5	312846	5593890	1.04	1.03	1.04	1.03	1.03
38.0	5	313059	5593560	1.06	1.06	1.06	1.04	1.06
38.4	5	313386	5593360	1.02	1.03	1.03	1.04	1.03
38.8	5	313755	5593470	1.12	1.12	1.12	1.14	1.12
39.2	5	313977	5593750	1.07	1.10	1.09	1.11	1.12
39.6	5	314243	5593510	1.48	1.40	1.44	1.44	1.40
40.0	5	314236	5593220	1.08	1.07	1.07	1.10	1.12
40.4	5	314378	5592890	1.04	1.05	1.04	1.04	1.11
40.8	5	314647	5592620	1.15	1.12	1.13	1.15	1.12
41.2	5	314936	5592400	1.06	1.03	1.05	1.08	1.08
41.6	5	315313	5592380	1.04	1.09	1.06	1.08	1.11
42.0	5	315658	5592230	1.25	1.22	1.23	1.22	1.26
42.4	5	315904	5591990	1.91	1.81	1.86	1.86	1.88
42.8	5	316083	5591870	1.09	1.11	1.10	1.11	1.08
43.2	5	316330	5591590	1.05	1.11	1.08	1.06	1.07
43.6	5	316677	5591760	1.04	1.07	1.06	1.05	1.06
44.0	5	316936	5591480	1.07	1.05	1.06	1.08	1.12
44.4	6	316950	5591110	1.15	1.07	1.11	1.15	1.16
44.8	6	316844	5590770	1.08	1.09	1.08	1.10	1.08
45.2	6	316722	5590420	1.06	1.05	1.05	1.04	1.03
45.6	6	316872	5590060	1.08	1.08	1.08	1.09	1.08
46.0	6	317178	5589850	1.03	1.02	1.03	1.02	1.03
46.4	6	317201	5589460	1.09	1.07	1.08	1.09	1.09
46.8	6	317294	5589090	1.05	1.03	1.04	1.03	1.04
47.2	6	317548	5588790	1.07	1.04	1.05	1.08	1.08
47.6	6	317841	5588560	1.03	1.03	1.03	1.04	1.02
48.0	6	317820	5588170	1.09	1.01	1.05	1.09	1.07
48.4	6	317900	5587800	1.04	1.09	1.06	1.03	1.04
48.8	6	317859	5587420	1.04	1.06	1.05	1.05	1.04
49.2	6	317568	5587170	1.04	1.03	1.03	1.04	1.04
49.6	6	317346	5586850	1.10	1.10	1.10	1.08	1.07
50.0	6	317348	5586470	1.06	1.07	1.07	1.06	1.07
50.4	6	317689	5586310	1.12	1.08	1.10	1.10	1.17
50.8	6	318057	5586290	1.17	1.11	1.14	1.15	1.17
51.2	6	318207	5585980	1.15	1.20	1.17	1.21	1.26
51.6	6	318082	5585680	1.09	1.07	1.08	1.05	1.05
52.0	6	317704	5585650	1.14	1.10	1.12	1.11	1.10
52.4	7	317338	5585710	1.03	1.02	1.03	1.04	1.06
52.8	7	317390	5585330	1.16	1.14	1.15	1.07	1.10
53.2	7	317614	5585020	1.02	1.06	1.04	1.05	1.04
53.6	7	317624	5584640	1.18	1.11	1.14	1.08	1.12
54.0	7	317638	5584270	1.13	1.04	1.09	1.08	1.11
54.4	7	317818	5583940	1.15	1.13	1.14	1.14	1.09
54.8	7	317978	5583620	1.09	1.06	1.07	1.05	1.05

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Sinuosity Index**				
		E	N	1967	1981	1967/1981	2000	2010
55.2	7	318015	5583230	1.01	1.02	1.02	1.02	1.01
55.6	7	318097	5582840	1.08	1.05	1.06	1.08	1.05
56.0	7	318241	5582480	1.02	1.01	1.02	1.03	1.01
56.4	7	318500	5582180	1.04	1.04	1.04	1.04	1.05
56.8	7	318825	5581970	1.06	1.07	1.06	1.05	1.05
57.2	7	319120	5581720	1.03	1.08	1.06	1.06	1.07
57.6	7	319175	5581340	1.11	1.20	1.16	1.15	1.15

B3 Meander Characteristics

Table B3.1 Meander amplitudes of 16 selected meanders along the Little Bow River, Alberta as derived from georectified aerial photographs collected in 1967, 1981, 2000, and 2010. Aerial photographs were georectified to an RMSE of 2.5 m. Amplitude for 1967/1981 was calculated as the average value of 1967 and 1981 conditions.

Distance (km)	**ID**	**NAD 1983 UTM Zone 12 N**		**Amplitude (m)**				
		E	N	1967	1981	1967/1981	2000	2010
8.0	0	299563	5602650	19.8	17.2	18.5	21.5	29.2
8.8	1	300143	5602510	20.6	44.9	32.8	27.2	9.7
11.6	2	301187	5601470	32.1	35.0	33.6	35.4	44.5
15.2	3	301983	5599240	158.2	175.4	166.8	157.5	161.6
16.0	4	302314	5599190	55.0	58.1	56.6	23.5	63.2
16.8	5	302257	5598580	70.8	51.5	61.1	30.0	23.3
17.2	6	302382	5598380	35.4	63.4	49.4	34.9	36.4
18.0	7	302427	5597850	350.3	370.6	360.4	362.6	371.9
22.0	8	304289	5596750	140.2	152.9	146.6	148.6	144.5
26.8	9	306838	5595890	329.3	345.6	337.4	338.3	336.7
30.4	10	308754	5594940	32.4	49.7	41.0	55.1	42.9
30.8	11	308921	5594750	22.0	33.7	27.9	38.2	40.9
31.2	12	308971	5594590	29.7	78.3	54.0	33.8	29.9
33.2	13	309970	5595290	36.0	36.5	36.2	30.5	37.3
33.6	14	310169	5595130	96.8	104.1	100.4	99.5	99.7
42.4	15	315904	5591990	90.5	86.4	88.4	91.3	93.8

Table B3.2 Meander wavelengths of 16 selected meanders along the Little Bow River, Alberta as derived from georectified aerial photographs collected in 1967, 1981, 2000, and 2010. Aerial photographs were georectified to an RMSE of 2.5 m. Wavelength for 1967/1981 was calculated as the average value of 1967 and 1981 conditions.

Distance (km)	**ID**	**NAD 1983 UTM Zone 12 N**		**Wavelength (m)**				
		E	N	1967	1981	1967/1981	2000	2010
8.0	0	299563	5602650	51.0	60.3	55.6	62.2	62.3
8.8	1	300143	5602510	31.2	85.7	58.4	37.3	26.7
11.6	2	301187	5601470	87.9	90.5	89.2	94.3	101.6
15.2	3	301983	5599240	288.7	300.7	294.7	297.0	301.5
16.0	4	302314	5599190	165.8	112.1	138.9	67.3	127.6
16.8	5	302257	5598580	157.2	147.2	152.2	106.1	80.4
17.2	6	302382	5598380	81.7	125.5	103.6	75.8	72.5
18.0	7	302427	5597850	437.9	442.3	440.1	440.9	435.1
22.0	8	304289	5596750	403.4	423.3	413.3	397.3	399.4
26.8	9	306838	5595890	664.2	666.4	665.3	665.0	671.0
30.4	10	308754	5594940	111.1	161.6	136.4	149.4	153.4
30.8	11	308921	5594750	56.9	84.3	70.6	79.4	77.7
31.2	12	308971	5594590	60.7	81.4	71.0	64.8	62.6
33.2	13	309970	5595290	105.3	103.6	104.4	107.6	113.5
33.6	14	310169	5595130	258.5	280.2	269.3	250.2	250.8
42.4	15	315904	5591990	222.3	222.7	222.5	224.9	216.8

Table B3.3 Meander arc radius of 16 selected meanders along the Little Bow River, Alberta as derived from georectified aerial photographs collected in 1967, 1981, 2000, and 2010. Aerial photographs were georectified to an RMSE of 2.5 m. Arc radius for 1967/1981 was calculated as the average value of 1967 and 1981 conditions.

Distance (km)	**ID**	**NAD 1983 UTM Zone 12 N**		**Radius (m)**				
		E	N	1967	1981	1967/1981	2000	2010
8.0	0	299563	5602650	8.4	14.2	11.3	14.8	10.0
8.8	1	300143	5602510	16.1	26.8	21.5	6.7	11.9
11.6	2	301187	5601470	19.2	20.1	19.6	18.8	17.9
15.2	3	301983	5599240	61.2	60.8	61.0	70.7	80.4
16.0	4	302314	5599190	77.4	35.0	56.2	37.1	25.6
16.8	5	302257	5598580	67.5	61.0	64.3	52.7	65.9
17.2	6	302382	5598380	27.7	34.3	31.0	26.2	26.5
18.0	7	302427	5597850	91.8	90.7	91.3	96.2	95.9
22.0	8	304289	5596750	87.4	76.0	81.7	90.3	91.3
26.8	9	306838	5595890	148.1	136.9	142.5	141.9	141.7
30.4	10	308754	5594940	67.6	64.8	66.2	67.8	66.3
30.8	11	308921	5594750	16.0	34.5	25.3	18.5	19.3
31.2	12	308971	5594590	15.4	36.3	25.8	14.8	11.2
33.2	13	309970	5595290	35.9	20.8	28.4	45.8	44.7
33.6	14	310169	5595130	110.5	92.6	101.6	108.8	102.1
42.4	15	315904	5591990	68.3	73.2	70.7	72.6	73.3

B4 Vegetation Classification

Table B4.1 Vegetation along the Little Bow River, Alberta as classified from georectified aerial photographs collected in 1967, 1981, 2000, and 2010.Vegetation classes included riparian woodlands (PRW), true willows (TRW), wolf willow (WOW), graminoids (GRA), and cattails (TYA).

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Vegetation Classification**							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
0.1	1	297849	5605563	TRW	TRW	TRW	TRW	TRW	TRW	TRW	TRW
0.2	1	297904	5605489	TRW	TRW	TRW	GRA	TRW	GRA	TRW	GRA
0.3	1	297990	5605438	GRA	TRW	TRW	TRW	GRA	TRW	TRW	GRA
0.4	1	297987	5605343	TRW	TRW	GRA	TRW	TRW	GRA	TRW	GRA
0.5	1	297904	5605281	TRW	GRA	GRA	TRW	TRW	GRA	TRW	GRA
0.6	1	297805	5605265	GRA	GRA	TRW	TRW	GRA	GRA	GRA	GRA
0.7	1	297717	5605285	TRW	GRA	PRW	TRW	PRW	GRA	PRW	GRA
0.8	1	297629	5605239	PRW	GRA	PRW	GRA	PRW	GRA	PRW	GRA
0.9	1	297550	5605180	PRW	GRA	PRW	GRA	PRW	GRA	PRW	GRA
1	1	297481	5605110	PRW	GRA	PRW	GRA	PRW	GRA	PRW	GRA
1.1	1	297426	5605029	PRW	GRA	PRW	GRA	PRW	GRA	PRW	GRA
1.2	1	297391	5604935	PRW	GRA	PRW	GRA	PRW	GRA	PRW	GRA
1.3	1	297360	5604840	PRW	GRA	PRW	GRA	PRW	GRA	PRW	GRA
1.4	1	297371	5604751	TRW	GRA	TRW	GRA	PRW	GRA	PRW	GRA
1.5	1	297417	5604662	TYA	GRA	TRW	GRA	GRA	GRA	TRW	GRA
1.6	1	297438	5604567	TYA	GRA	TRW	GRA	TRW	GRA	TRW	GRA
1.7	1	297381	5604494	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
1.8	1	297281	5604472	GRA	GRA	GRA	WOW	GRA	GRA	GRA	GRA
1.9	1	297183	5604486	GRA	GRA	GRA	TYA	GRA	GRA	GRA	GRA
2	1	297089	5604506	GRA	GRA	TYA	GRA	GRA	GRA	TYA	GRA
2.1	1	297026	5604450	TYA	GRA	TYA	GRA	TRW	GRA	TYA	GRA
2.2	1	297007	5604368	GRA	GRA	TRW	GRA	TRW	GRA	TRW	GRA
2.3	1	297031	5604276	GRA	PRW	TRW	PRW	PRW	PRW	PRW	PRW
2.4	1	297097	5604210	GRA	TRW	GRA	TRW	GRA	GRA	TRW	GRA
2.5	1	297189	5604204	GRA	TRW	TRW	TRW	GRA	GRA	GRA	TRW
2.6	1	297271	5604157	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
2.7	1	297366	5604158	GRA	GRA	WOW	GRA	GRA	GRA	GRA	GRA
2.8	1	297416	5604226	TYA	GRA	TYA	TYA	WOW	WOW	GRA	TYA
2.9	1	297492	5604272	TYA	TYA	TYA	TYA	WOW	GRA	WOW	TYA
3	1	297579	5604314	GRA	GRA	TYA	GRA	GRA	WOW	TYA	GRA
3.1	1	297659	5604347	GRA	WOW	GRA	TYA	TRW	TRW	TRW	TYA
3.2	1	297756	5604315	GRA	WOW	GRA	TYA	TRW	GRA	TRW	GRA
3.3	1	297821	5604241	WOW	WOW	GRA	TYA	GRA	GRA	GRA	GRA
3.4	1	297850	5604145	TRW	WOW	GRA	WOW	GRA	WOW	WOW	GRA
3.5	1	297849	5604056	WOW	WOW	GRA	WOW	WOW	WOW	WOW	GRA
3.6	1	297815	5603953	WOW	GRA	GRA	WOW	WOW	GRA	WOW	GRA
3.7	1	297773	5603862	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
3.8	1	297703	5603785	GRA	GRA	WOW	GRA	GRA	GRA	GRA	GRA
3.9	1	297632	5603723	TRW	GRA	WOW	GRA	GRA	GRA	TRW	WOW
4	1	297597	5603638	TRW	GRA	TRW	GRA	GRA	GRA	TRW	GRA

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Vegetation Classification							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
4.1	1	297591	5603543	TRW	TRW	TRW	GRA	WOW	GRA	TRW	GRA
4.2	1	297634	5603463	TRW	TRW	TRW	TRW	WOW	TRW	GRA	GRA
4.3	1	297659	5603363	TRW	TRW	GRA	TRW	GRA	GRA	GRA	GRA
4.4	1	297649	5603266	GRA	TRW	TRW	GRA	WOW	GRA	GRA	GRA
4.5	1	297619	5603179	TRW	TRW	TRW	TRW	TRW	GRA	GRA	GRA
4.6	1	297627	5603093	TRW	TRW	TRW	GRA	WOW	GRA	GRA	WOW
4.7	1	297690	5603030	GRA	TRW	TRW	GRA	GRA	GRA	WOW	WOW
4.8	1	297775	5602970	GRA	TRW	TRW	GRA	GRA	GRA	GRA	GRA
4.9	1	297854	5602924	GRA	PRW	TRW	PRW	GRA	PRW	TRW	PRW
5	1	297942	5602873	TRW	PRW	TRW	PRW	GRA	PRW	GRA	PRW
5.1	1	298030	5602852	GRA	PRW	TRW	PRW	TRW	PRW	TRW	PRW
5.2	1	298126	5602878	PRW	GRA	GRA	PRW	GRA	TRW	PRW	GRA
5.3	1	298211	5602889	PRW	GRA	PRW	PRW	PRW	GRA	PRW	PRW
5.4	1	298255	5602974	PRW	GRA	PRW	TYA	PRW	TYA	PRW	TYA
5.5	1	298347	5603018	PRW	GRA	PRW	TYA	PRW	TYA	PRW	TYA
5.6	1	298442	5603046	PRW	GRA	PRW	TYA	PRW	GRA	PRW	TYA
5.7	1	298506	5602974	WOW	GRA	WOW	GRA	GRA	GRA	GRA	GRA
5.8	1	298549	5602878	WOW	GRA	WOW	GRA	GRA	GRA	WOW	WOW
5.9	1	298537	5602774	GRA	GRA	GRA	TYA	GRA	TRW	GRA	TRW
6	1	298486	5602686	GRA	GRA	TYA	TYA	GRA	TRW	TYA	TRW
6.1	1	298466	5602594	GRA	PRW	TYA	PRW	TRW	PRW	TYA	PRW
6.2	1	298494	5602502	TYA	TYA	TYA	PRW	TRW	PRW	WOW	PRW
6.3	1	298525	5602419	TYA	GRA	GRA	TYA	GRA	WOW	GRA	GRA
6.4	1	298623	5602395	TYA	GRA	GRA	TYA	GRA	TRW	GRA	TRW
6.5	1	298716	5602392	GRA	GRA	WOW	TYA	GRA	TRW	GRA	GRA
6.6	1	298795	5602448	GRA	GRA	WOW	GRA	GRA	TRW	WOW	GRA
6.7	1	298837	5602534	GRA	TRW	TRW	GRA	GRA	TRW	WOW	GRA
6.8	1	298909	5602603	GRA	TRW	TRW	GRA	GRA	GRA	WOW	GRA
6.9	1	298985	5602670	GRA	GRA	GRA	TRW	GRA	GRA	WOW	GRA
7	1	299073	5602717	TRW	TRW	GRA	TRW	GRA	GRA	TRW	GRA
7.1	1	299171	5602708	GRA	TRW	TRW	TRW	GRA	GRA	TRW	TRW
7.2	1	299255	5602652	GRA	TYA	GRA	TRW	GRA	GRA	TRW	TRW
7.3	1	299282	5602564	TRW	TRW	TRW	TRW	GRA	TRW	TRW	TRW
7.4	2	299380	5602576	TRW	TRW	TRW	GRA	GRA	TRW	GRA	TRW
7.5	2	299466	5602626	GRA	TRW	TRW	TYA	GRA	WOW	GRA	TRW
7.6	2	299554	5602659	GRA	GRA	TRW	TRW	GRA	WOW	TRW	GRA
7.7	2	299652	5602670	PRW	PRW	PRW	PRW	PRW	PRW	PRW	PRW
7.8	2	299750	5602666	TRW	PRW	TRW	PRW	TRW	PRW	PRW	PRW
7.9	2	299773	5602621	TRW	PRW	TRW	PRW	PRW	PRW	PRW	PRW
8	2	299796	5602557	TRW	PRW	TRW	TRW	WOW	TRW	GRA	TRW
8.1	2	299893	5602540	TRW	TRW	TRW	TRW	WOW	TRW	TRW	TRW
8.2	2	299965	5602553	TRW	TRW	TRW	TRW	WOW	TRW	TRW	TRW
8.3	2	300067	5602573	TRW	WOW	TRW	TRW	GRA	TRW	GRA	TRW
8.4	2	300136	5602507	WOW	WOW	TRW	TRW	TRW	TRW	TRW	TRW
8.5	2	300130	5602443	WOW	TRW	TRW	WOW	TRW	TRW	TRW	TRW
8.6	2	300230	5602473	WOW	WOW	TRW	TRW	TRW	WOW	TRW	WOW

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Vegetation Classification							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
8.7	2	300294	5602520	GRA	WOW	TRW	TRW	WOW	WOW	WOW	WOW
8.8	2	300385	5602504	GRA	TRW	TRW	TRW	GRA	TRW	TRW	WOW
8.9	2	300475	5602521	TYA	TRW	GRA	TRW	GRA	WOW	GRA	WOW
9	2	300574	5602518	TYA	TYA	WOW	TRW	WOW	GRA	WOW	GRA
9.1	2	300671	5602479	TYA	PRW	TRW	TRW	GRA	TYA	GRA	TYA
9.2	2	300721	5602553	WOW	GRA	GRA	WOW	WOW	GRA	TRW	TRW
9.3	2	300799	5602610	WOW	GRA	WOW	GRA	WOW	GRA	TRW	TRW
9.4	2	300879	5602665	WOW	WOW	WOW	WOW	GRA	GRA	WOW	TRW
9.5	2	300919	5602746	WOW	GRA	WOW	WOW	GRA	WOW	WOW	TRW
9.6	2	300995	5602819	WOW	GRA	WOW	WOW	GRA	GRA	GRA	TRW
9.7	2	301067	5602770	WOW	GRA	WOW	WOW	GRA	TYA	WOW	TYA
9.8	2	301113	5602683	WOW	GRA	WOW	WOW	GRA	TYA	WOW	TYA
9.9	2	301096	5602660	GRA	GRA	WOW	WOW	GRA	WOW	WOW	TYA
10	2	301124	5602574	WOW	GRA	WOW	GRA	TYA	GRA	GRA	TYA
10.1	2	301215	5602492	WOW	GRA	GRA	GRA	TYA	GRA	TYA	GRA
10.2	2	301249	5602404	WOW	TYA	WOW	GRA	TYA	GRA	TYA	GRA
10.3	2	301278	5602299	TYA	TYA	GRA	WOW	GRA	TYA	TYA	TYA
10.4	2	301285	5602218	TYA	TYA	GRA	TYA	TYA	TYA	GRA	TYA
10.5	2	301280	5602124	GRA	TYA	GRA	TYA	GRA	TYA	GRA	GRA
10.6	2	301281	5602023	TYA	TYA	GRA	GRA	GRA	GRA	GRA	TYA
10.7	2	301307	5601932	TYA	TYA	GRA	GRA	GRA	GRA	GRA	WOW
10.8	2	301319	5601835	GRA	TRW	GRA	GRA	GRA	WOW	GRA	WOW
10.9	2	301300	5601726	GRA	TRW	GRA	GRA	GRA	WOW	WOW	WOW
11	2	301266	5601643	GRA	TRW	GRA	GRA	GRA	WOW	GRA	WOW
11.1	2	301213	5601552	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
11.2	2	301188	5601468	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
11.3	2	301102	5601478	TRW	WOW	GRA	GRA	GRA	GRA	GRA	TYA
11.4	2	301019	5601515	TRW	TRW	TYA	GRA	GRA	GRA	TYA	GRA
11.5	2	301023	5601417	TRW	TRW	TYA	GRA	WOW	GRA	TRW	GRA
11.6	2	301061	5601326	WOW	GRA	TYA	GRA	WOW	GRA	TRW	WOW
11.7	2	301113	5601243	WOW	GRA	TYA	GRA	GRA	GRA	WOW	WOW
11.8	2	301163	5601159	GRA	GRA	GRA	GRA	GRA	WOW	WOW	WOW
11.9	2	301211	5601070	GRA	WOW	TRW	GRA	GRA	GRA	GRA	GRA
12	2	301283	5601007	WOW	WOW	GRA	TRW	GRA	TYA	GRA	TYA
12.1	2	301331	5600917	TRW	WOW	GRA	GRA	TYA	TYA	GRA	TYA
12.2	2	301374	5600836	TRW	TYA	GRA	WOW	TYA	TYA	GRA	TYA
12.3	2	301422	5600774	TRW	TYA	TRW	GRA	GRA	GRA	GRA	GRA
12.4	2	301498	5600707	TRW	TYA	TRW	GRA	GRA	GRA	PRW	TYA
12.5	2	301505	5600606	TYA	TYA	TRW	GRA	PRW	TYA	TYA	TYA
12.6	2	301591	5600622	TRW	TYA	TRW	TRW	GRA	GRA	GRA	TYA
12.7	2	301659	5600563	TRW	TRW	TYA	TRW	TRW	GRA	GRA	TRW
12.8	2	301711	5600487	TYA	TRW	TRW	GRA	GRA	TRW	TYA	GRA
12.9	2	301809	5600478	TYA	TRW	TRW	GRA	GRA	TRW	WOW	GRA
13	2	301888	5600482	GRA	TRW	GRA	TRW	TYA	TRW	GRA	TRW
13.1	2	301998	5600457	WOW	TRW	WOW	TRW	WOW	GRA	WOW	GRA
13.2	2	302005	5600355	WOW	GRA	WOW	GRA	WOW	GRA	WOW	GRA

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Vegetation Classification							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
13.3	2	302004	5600256	WOW	GRA	WOW	GRA	WOW	GRA	WOW	TRW
13.4	2	301994	5600164	TRW	GRA	WOW	GRA	GRA	WOW	WOW	GRA
13.5	2	301896	5600143	TRW	GRA	GRA	GRA	GRA	WOW	TRW	GRA
13.6	2	301794	5600156	TRW	GRA	GRA	GRA	GRA	WOW	TRW	GRA
13.7	2	301708	5600157	TRW	TRW	TRW	GRA	TRW	WOW	TRW	TRW
13.8	2	301669	5600068	TRW	TRW	TRW	GRA	TRW	GRA	TRW	TRW
13.9	2	301683	5599978	TRW	GRA	TRW	WOW	TRW	WOW	GRA	TRW
14	2	301700	5599882	GRA	GRA	TRW	WOW	TRW	WOW	GRA	WOW
14.1	2	301705	5599782	TRW	WOW	TRW	TRW	GRA	WOW	TRW	TRW
14.2	3	301741	5599689	TRW	WOW	TRW	GRA	TRW	WOW	GRA	WOW
14.3	3	301760	5599588	GRA	WOW	TRW	WOW	GRA	WOW	GRA	TRW
14.4	3	301842	5599522	GRA	TRW	GRA	WOW	GRA	WOW	GRA	TRW
14.5	3	301893	5599437	GRA	TRW	GRA	TRW	WOW	GRA	WOW	GRA
14.6	3	301870	5599368	TRW	GRA	TRW	GRA	WOW	GRA	GRA	TRW
14.7	3	301914	5599310	TRW	WOW	WOW	WOW	WOW	GRA	GRA	TRW
14.8	3	301986	5599242	TRW	WOW	TRW	WOW	GRA	GRA	GRA	GRA
14.9	3	302079	5599228	GRA	WOW	WOW	GRA	GRA	WOW	GRA	WOW
15	3	302127	5599299	GRA	WOW	WOW	GRA	GRA	WOW	GRA	WOW
15.1	3	302080	5599374	GRA	TYA	WOW	TYA	GRA	WOW	WOW	GRA
15.2	3	302110	5599469	GRA	TYA	WOW	TYA	TYA	WOW	WOW	GRA
15.3	3	302212	5599459	TYA	GRA	TYA	TYA	TYA	WOW	GRA	TRW
15.4	3	302280	5599387	WOW	GRA	WOW	GRA	WOW	GRA	WOW	TRW
15.5	3	302310	5599290	WOW	GRA	WOW	GRA	GRA	GRA	WOW	TRW
15.6	3	302323	5599192	WOW	GRA	WOW	WOW	GRA	GRA	WOW	TRW
15.7	3	302341	5599085	TRW	GRA	GRA	TRW	GRA	GRA	WOW	GRA
15.8	3	302257	5599050	TRW	TRW	TRW	GRA	TRW	GRA	GRA	GRA
15.9	3	302317	5598956	GRA	WOW	GRA	WOW	GRA	GRA	GRA	WOW
16	3	302377	5598896	TRW	TRW	GRA	TRW	TRW	GRA	WOW	GRA
16.1	3	302389	5598798	WOW	TRW	GRA	TRW	TRW	WOW	WOW	GRA
16.2	3	302351	5598691	WOW	TRW	TRW	TRW	TRW	GRA	WOW	GRA
16.3	3	302261	5598682	TRW	TRW	TRW	TRW	GRA	TYA	GRA	TRW
16.4	3	302285	5598594	TRW	TRW	TRW	TRW	GRA	TYA	TRW	TRW
16.5	3	302344	5598525	TRW	TRW	GRA	TRW	WOW	TYA	TRW	GRA
16.6	3	302434	5598499	GRA	GRA	GRA	TRW	GRA	WOW	WOW	GRA
16.7	3	302451	5598401	TRW	TRW	WOW	TRW	GRA	GRA	GRA	TRW
16.8	3	302382	5598349	TRW	GRA	GRA	TRW	GRA	WOW	GRA	TRW
16.9	3	302285	5598352	TRW	TRW	TRW	TRW	GRA	WOW	GRA	TRW
17	3	302220	5598359	TRW	TRW	TRW	GRA	GRA	GRA	TRW	TRW
17.1	3	302216	5598269	TRW	TRW	GRA	TRW	TRW	TRW	GRA	TRW
17.2	3	302238	5598171	TRW	GRA	GRA	TRW	GRA	TRW	GRA	TRW
17.3	3	302298	5598097	TRW	TRW	GRA	TRW	GRA	TRW	GRA	TRW
17.4	3	302356	5598012	GRA	GRA	GRA	TRW	TRW	TRW	GRA	GRA
17.5	3	302366	5597917	WOW	GRA	TYA	TRW	GRA	TRW	GRA	GRA
17.6	3	302427	5597849	WOW	WOW	GRA	TRW	GRA	GRA	GRA	WOW
17.7	3	302505	5597786	GRA	WOW	GRA	WOW	GRA	GRA	GRA	WOW
17.8	3	302580	5597719	GRA	WOW	TYA	WOW	GRA	GRA	GRA	WOW

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Vegetation Classification**							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
17.9	3	302659	5597752	GRA	WOW	TYA	TRW	GRA	PRW	GRA	TRW
18	3	302679	5597844	GRA	WOW	TYA	WOW	GRA	GRA	GRA	WOW
18.1	3	302634	5597931	GRA	GRA	TYA	GRA	GRA	WOW	WOW	GRA
18.2	3	302575	5598012	GRA	TYA	TYA	TYA	GRA	WOW	WOW	GRA
18.3	3	302562	5598109	TYA	TYA	TYA	TYA	TYA	WOW	TYA	GRA
18.4	3	302598	5598205	TYA	TYA	TYA	TYA	GRA	GRA	GRA	GRA
18.5	3	302698	5598232	GRA	TYA	TRW	TRW	GRA	TYA	TYA	GRA
18.6	3	302784	5598198	GRA	TRW	TRW	TRW	GRA	GRA	WOW	GRA
18.7	3	302828	5598123	WOW	TRW	TRW	TRW	GRA	WOW	WOW	GRA
18.8	3	302865	5598041	WOW	TRW	TRW	GRA	GRA	WOW	WOW	WOW
18.9	3	302915	5597951	WOW	TRW	WOW	TRW	GRA	WOW	GRA	WOW
19	3	302974	5597898	WOW	TRW	WOW	TRW	GRA	WOW	WOW	WOW
19.1	3	303007	5597809	TRW	GRA	TRW	TRW	GRA	GRA	GRA	GRA
19.2	3	303011	5597711	GRA	GRA	TRW	TRW	GRA	GRA	GRA	GRA
19.3	3	303022	5597613	GRA	GRA	TRW	GRA	GRA	GRA	GRA	WOW
19.4	3	303067	5597538	GRA	GRA	TRW	WOW	GRA	GRA	GRA	WOW
19.5	3	303154	5597503	GRA	GRA	TRW	WOW	GRA	GRA	GRA	WOW
19.6	3	303236	5597542	GRA	GRA	TRW	GRA	GRA	GRA	GRA	GRA
19.7	3	303279	5597605	GRA	GRA	TRW	GRA	GRA	GRA	GRA	WOW
19.8	3	303290	5597707	GRA	GRA	TRW	WOW	GRA	GRA	GRA	WOW
19.9	3	303377	5597768	WOW	GRA	WOW	WOW	GRA	GRA	GRA	GRA
20	3	303468	5597712	WOW	GRA	WOW	WOW	GRA	GRA	GRA	WOW
20.1	3	303532	5597639	WOW	GRA	WOW	WOW	GRA	GRA	WOW	WOW
20.2	3	303584	5597557	WOW	GRA	WOW	GRA	GRA	GRA	WOW	GRA
20.3	3	303669	5597544	WOW	GRA	WOW	TYA	GRA	GRA	WOW	GRA
20.4	3	303695	5597447	GRA	GRA	GRA	TRW	GRA	GRA	WOW	GRA
20.5	3	303720	5597347	GRA	GRA	GRA	TRW	GRA	GRA	WOW	GRA
20.6	3	303678	5597254	GRA	GRA	TRW	TRW	GRA	GRA	GRA	GRA
20.7	3	303608	5597193	GRA	GRA	TRW	TRW	WOW	GRA	TRW	GRA
20.8	3	303630	5597120	TRW	GRA	TRW	WOW	WOW	WOW	TRW	WOW
20.9	3	303708	5597061	TRW	GRA	TRW	WOW	WOW	GRA	TRW	WOW
21	3	303781	5596990	TRW	GRA	TRW	TRW	WOW	GRA	TRW	TRW
21.1	3	303847	5596915	GRA	GRA	TRW	WOW	WOW	GRA	TRW	TRW
21.2	3	303936	5596888	GRA	GRA	TRW	GRA	WOW	GRA	TRW	WOW
21.3	3	304030	5596851	GRA	GRA	TRW	TRW	WOW	WOW	TRW	TRW
21.4	3	304110	5596784	GRA	WOW	TRW	GRA	WOW	GRA	TRW	GRA
21.5	3	304191	5596786	WOW	WOW	TRW	TRW	WOW	WOW	TRW	TRW
21.6	3	304294	5596767	WOW	WOW	GRA	GRA	WOW	WOW	GRA	TRW
21.7	3	304335	5596785	GRA	GRA	GRA	WOW	GRA	GRA	GRA	GRA
21.8	3	304345	5596879	GRA	GRA	GRA	WOW	GRA	GRA	GRA	WOW
21.9	3	304434	5596949	GRA	GRA	GRA	WOW	GRA	GRA	GRA	WOW
22	3	304529	5596910	WOW	GRA	GRA	WOW	GRA	GRA	GRA	WOW
22.1	3	304538	5596826	WOW	GRA	WOW	WOW	TRW	GRA	GRA	GRA
22.2	3	304596	5596753	GRA	WOW	WOW	WOW	GRA	GRA	WOW	WOW
22.3	3	304678	5596702	GRA	WOW	WOW	GRA	GRA	WOW	GRA	WOW
22.4	3	304761	5596699	GRA	GRA	WOW	GRA	GRA	GRA	GRA	GRA

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Vegetation Classification**							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
22.5	3	304864	5596703	GRA	GRA	GRA	GRA	GRA	GRA	WOW	TRW
22.6	3	304938	5596630	GRA	GRA	WOW	GRA	GRA	GRA	WOW	TRW
22.7	3	305012	5596562	GRA	GRA	GRA	GRA	GRA	GRA	WOW	GRA
22.8	3	305050	5596469	GRA	TRW	GRA	TRW	GRA	GRA	GRA	GRA
22.9	3	305119	5596421	TRW	TRW	TRW	TRW	GRA	TRW	TRW	TRW
23	3	305213	5596444	GRA	WOW	TRW	WOW	WOW	TRW	WOW	WOW
23.1	3	305309	5596465	GRA	WOW	GRA	WOW	GRA	WOW	WOW	GRA
23.2	4	305379	5596498	GRA	WOW	TRW	WOW	GRA	WOW	GRA	WOW
23.3	4	305471	5596496	GRA	WOW	TRW	WOW	GRA	TRW	GRA	WOW
23.4	4	305570	5596476	GRA	WOW	GRA	WOW	GRA	GRA	GRA	WOW
23.5	4	305668	5596479	WOW	WOW	TRW	WOW	GRA	GRA	TRW	TRW
23.6	4	305748	5596480	WOW	WOW	TRW	WOW	WOW	GRA	WOW	TRW
23.7	4	305831	5596520	GRA	WOW	TRW	TRW	GRA	TRW	WOW	WOW
23.8	4	305884	5596582	GRA	WOW	WOW	TRW	GRA	GRA	GRA	TRW
23.9	4	305910	5596654	GRA	GRA	WOW	TRW	GRA	WOW	WOW	GRA
24	4	306008	5596712	GRA	GRA	WOW	WOW	GRA	WOW	WOW	TRW
24.1	4	306113	5596717	PRW	GRA	GRA	WOW	GRA	GRA	TRW	GRA
24.2	4	306201	5596679	GRA	GRA	GRA	GRA	GRA	GRA	WOW	GRA
24.3	4	306220	5596585	GRA	GRA	WOW	WOW	GRA	GRA	GRA	WOW
24.4	4	306278	5596559	WOW	WOW	WOW	WOW	GRA	WOW	WOW	WOW
24.5	4	306379	5596559	WOW	WOW	WOW	WOW	GRA	WOW	WOW	WOW
24.6	4	306471	5596566	WOW	GRA	GRA	WOW	GRA	WOW	WOW	GRA
24.7	4	306574	5596534	WOW	TYA	WOW	GRA	GRA	GRA	WOW	WOW
24.8	4	306665	5596546	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
24.9	4	306747	5596576	GRA	GRA	GRA	TYA	GRA	GRA	GRA	TRW
25	4	306814	5596616	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
25.1	4	306902	5596588	WOW	GRA	WOW	WOW	GRA	GRA	WOW	GRA
25.2	4	306961	5596519	WOW	GRA	WOW	WOW	GRA	GRA	WOW	GRA
25.3	4	306930	5596428	GRA	WOW	GRA	WOW	GRA	GRA	WOW	GRA
25.4	4	306844	5596400	GRA	WOW	TRW	TRW	WOW	GRA	GRA	GRA
25.5	4	306784	5596336	GRA	TRW	GRA	TRW	GRA	GRA	GRA	TRW
25.6	4	306822	5596257	GRA	WOW	GRA	WOW	GRA	WOW	WOW	GRA
25.7	4	306903	5596237	GRA	WOW	WOW	GRA	GRA	GRA	WOW	GRA
25.8	4	307002	5596237	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
25.9	4	307079	5596182	GRA	WOW	GRA	WOW	GRA	GRA	WOW	GRA
26	4	307066	5596097	GRA	WOW	GRA	GRA	WOW	GRA	GRA	GRA
26.1	4	307063	5596001	GRA	GRA	GRA	GRA	WOW	GRA	GRA	GRA
26.2	4	307004	5595926	WOW	WOW	GRA	GRA	PRW	GRA	PRW	GRA
26.3	4	306928	5595884	WOW	WOW	WOW	GRA	GRA	GRA	TRW	TRW
26.4	4	306839	5595893	WOW	GRA	WOW	GRA	GRA	GRA	GRA	TRW
26.5	4	306753	5595842	WOW	GRA	WOW	WOW	WOW	GRA	GRA	TRW
26.6	4	306746	5595746	GRA	GRA	GRA	GRA	GRA	GRA	GRA	TRW
26.7	4	306777	5595650	GRA	GRA	GRA	GRA	GRA	WOW	GRA	TRW
26.8	4	306857	5595601	GRA	GRA	GRA	GRA	GRA	WOW	GRA	GRA
26.9	4	306957	5595614	WOW	WOW	WOW	GRA	GRA	WOW	GRA	GRA
27	4	307046	5595593	WOW	WOW	WOW	TYA	GRA	WOW	TYA	GRA

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Vegetation Classification							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
27.1	4	307134	5595526	WOW	GRA	WOW	TYA	GRA	TYA	TYA	TYA
27.2	4	307113	5595428	WOW	WOW	WOW	WOW	GRA	GRA	WOW	GRA
27.3	4	307095	5595332	WOW	GRA	WOW	WOW	GRA	TRW	WOW	WOW
27.4	4	307041	5595263	WOW	GRA	WOW	GRA	GRA	GRA	TRW	TRW
27.5	4	306961	5595194	WOW	WOW	WOW	GRA	WOW	GRA	GRA	GRA
27.6	4	306923	5595098	GRA	GRA	WOW	GRA	WOW	GRA	TYA	GRA
27.7	4	306979	5595013	GRA	WOW	WOW	WOW	WOW	GRA	TYA	GRA
27.8	4	307062	5594994	GRA	WOW	WOW	WOW	GRA	GRA	GRA	TYA
27.9	4	307134	5594922	WOW	GRA	GRA	WOW	GRA	GRA	GRA	GRA
28	4	307201	5594854	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
28.1	4	307292	5594828	GRA	WOW	GRA	WOW	TYA	TRW	TYA	WOW
28.2	4	307380	5594824	GRA	WOW	GRA	WOW	GRA	TRW	GRA	WOW
28.3	4	307457	5594855	GRA	WOW	WOW	WOW	TYA	GRA	GRA	WOW
28.4	4	307493	5594947	GRA	GRA	WOW	WOW	GRA	GRA	GRA	TYA
28.5	4	307579	5595023	GRA	GRA	GRA	WOW	GRA	GRA	GRA	GRA
28.6	4	307698	5595003	WOW	GRA	GRA	GRA	GRA	GRA	WOW	WOW
28.7	4	307796	5595001	WOW	TYA	GRA	WOW	GRA	WOW	WOW	GRA
28.8	4	307889	5595006	TYA	TYA	GRA	WOW	GRA	WOW	TYA	TYA
28.9	4	307989	5595011	TYA	WOW	GRA	WOW	WOW	TRW	WOW	TRW
29	4	308093	5595013	WOW	WOW	GRA	WOW	WOW	TRW	WOW	TRW
29.1	4	308173	5595041	WOW	WOW	GRA	WOW	GRA	TRW	GRA	TRW
29.2	4	308270	5595017	GRA	GRA	GRA	WOW	GRA	TRW	WOW	TRW
29.3	4	308300	5594896	WOW	WOW	WOW	WOW	GRA	WOW	WOW	WOW
29.4	4	308301	5594832	WOW	WOW	TYA	WOW	GRA	WOW	TYA	WOW
29.5	4	308364	5594783	TYA	WOW	TYA	WOW	GRA	TRW	TYA	WOW
29.6	4	308434	5594766	TYA	WOW	TYA	WOW	GRA	TRW	TYA	WOW
29.7	4	308528	5594805	GRA	WOW	WOW	WOW	TYA	GRA	TYA	WOW
29.8	4	308611	5594862	TYA	GRA	WOW	GRA	TYA	GRA	TYA	WOW
29.9	4	308663	5594939	WOW	GRA	WOW	GRA	TYA	TYA	TYA	TYA
30	4	308758	5594963	WOW	WOW	GRA	GRA	TYA	GRA	GRA	WOW
30.1	4	308852	5594923	WOW	WOW	GRA	GRA	TYA	GRA	GRA	GRA
30.2	4	308942	5594890	GRA	GRA	GRA	GRA	GRA	WOW	GRA	GRA
30.3	4	309011	5594830	GRA	GRA	WOW	WOW	WOW	WOW	WOW	WOW
30.4	4	308930	5594750	GRA	WOW	GRA	WOW	GRA	WOW	WOW	GRA
30.5	4	308876	5594691	GRA	TYA	GRA	WOW	GRA	GRA	WOW	TYA
30.6	4	308864	5594700	GRA	WOW	GRA	WOW	GRA	GRA	TYA	TYA
30.7	4	308876	5594618	GRA	WOW	GRA	WOW	WOW	TRW	GRA	TRW
30.8	4	308973	5594596	GRA	WOW	GRA	WOW	GRA	TRW	GRA	WOW
30.9	4	309068	5594571	GRA	WOW	GRA	WOW	GRA	TRW	GRA	WOW
31	4	309168	5594566	GRA	GRA	GRA	WOW	WOW	TRW	GRA	GRA
31.1	4	309257	5594607	GRA	WOW	GRA	WOW	WOW	TRW	GRA	TRW
31.2	4	309228	5594670	GRA	WOW	GRA	GRA	GRA	WOW	GRA	GRA
31.3	4	309176	5594708	WOW	WOW	GRA	GRA	GRA	WOW	GRA	GRA
31.4	4	309150	5594782	WOW	WOW	GRA	GRA	GRA	WOW	GRA	WOW
31.5	4	309148	5594875	GRA	WOW	GRA	GRA	GRA	GRA	GRA	GRA
31.6	4	309211	5594937	GRA	GRA	GRA	GRA	GRA	GRA	WOW	WOW

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Vegetation Classification							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
31.7	4	309289	5594987	GRA	WOW	GRA	GRA	GRA	GRA	GRA	WOW
31.8	4	309378	5595024	GRA	WOW	GRA	GRA	GRA	GRA	GRA	GRA
31.9	4	309483	5595005	WOW	WOW	GRA	GRA	GRA	GRA	GRA	GRA
32	4	309555	5594944	GRA	WOW	GRA	WOW	GRA	GRA	WOW	GRA
32.1	4	309616	5594869	GRA	TRW	GRA	WOW	GRA	TYA	GRA	GRA
32.2	4	309701	5594857	TRW	TRW	GRA	GRA	TYA	WOW	GRA	WOW
32.3	4	309779	5594919	GRA	WOW	GRA	GRA	TYA	GRA	GRA	WOW
32.4	4	309841	5594998	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
32.5	4	309834	5595096	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
32.6	4	309814	5595185	WOW	GRA	GRA	GRA	GRA	TYA	GRA	GRA
32.7	4	309883	5595241	GRA	GRA	GRA	GRA	GRA	TYA	GRA	WOW
32.8	4	309970	5595280	GRA	GRA	WOW	WOW	GRA	GRA	GRA	GRA
32.9	4	310071	5595282	GRA	GRA	WOW	WOW	GRA	GRA	GRA	GRA
33	4	310165	5595315	GRA	GRA	WOW	WOW	GRA	GRA	WOW	GRA
33.1	4	310211	5595227	GRA	GRA	WOW	WOW	TYA	GRA	GRA	GRA
33.2	4	310183	5595123	GRA	GRA	WOW	WOW	GRA	TYA	GRA	GRA
33.3	4	310143	5595043	GRA	GRA	WOW	WOW	TYA	TYA	GRA	GRA
33.4	4	310160	5594958	TYA	TYA	WOW	WOW	TRW	WOW	WOW	TRW
33.5	4	310244	5594923	TYA	TYA	WOW	WOW	GRA	TRW	GRA	WOW
33.6	4	310325	5594922	TYA	TYA	WOW	GRA	GRA	TRW	GRA	WOW
33.7	4	310436	5594969	TYA	GRA	WOW	GRA	TYA	WOW	TYA	WOW
33.8	4	310445	5595087	GRA	GRA	WOW	GRA	GRA	GRA	TYA	WOW
33.9	4	310504	5595159	GRA	GRA	WOW	WOW	TYA	TYA	TYA	TYA
34	4	310592	5595228	GRA	GRA	WOW	WOW	TYA	TYA	TYA	TYA
34.1	4	310691	5595179	GRA	GRA	GRA	GRA	WOW	GRA	TYA	TYA
34.2	4	310787	5595169	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
34.3	5	310883	5595142	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
34.4	5	310961	5595084	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
34.5	5	311036	5595023	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
34.6	5	311135	5595010	GRA	GRA	GRA	GRA	GRA	GRA	GRA	WOW
34.7	5	311231	5595043	GRA	GRA	GRA	GRA	GRA	GRA	GRA	WOW
34.8	5	311319	5595088	GRA	GRA	GRA	GRA	GRA	GRA	GRA	WOW
34.9	5	311409	5595124	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
35	5	311491	5595170	WOW	GRA	GRA	GRA	GRA	GRA	GRA	GRA
35.1	5	311590	5595164	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
35.2	5	311688	5595151	GRA	GRA	GRA	GRA	GRA	GRA	WOW	GRA
35.3	5	311768	5595092	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
35.4	5	311854	5595051	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
35.5	5	311950	5595020	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
35.6	5	312047	5595005	GRA	WOW	GRA	GRA	GRA	GRA	GRA	GRA
35.7	5	312133	5594954	GRA	WOW	GRA	GRA	GRA	GRA	GRA	GRA
35.8	5	312195	5594866	WOW	WOW	GRA	GRA	GRA	GRA	GRA	GRA
35.9	5	312246	5594806	WOW	GRA	GRA	GRA	GRA	GRA	GRA	GRA
36	5	312214	5594739	WOW	GRA	WOW	GRA	GRA	GRA	WOW	GRA
36.1	5	312263	5594653	WOW	GRA	WOW	GRA	WOW	WOW	WOW	WOW
36.2	5	312270	5594556	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Vegetation Classification**							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
36.3	5	312255	5594466	GRA	GRA	WOW	GRA	GRA	GRA	GRA	GRA
36.4	5	312294	5594391	WOW	GRA	WOW	GRA	GRA	GRA	WOW	GRA
36.5	5	312361	5594343	GRA	TRW	WOW	GRA	WOW	TYA	WOW	WOW
36.6	5	312416	5594256	WOW	WOW	GRA	WOW	GRA	GRA	WOW	GRA
36.7	5	312444	5594170	WOW	GRA	WOW	TRW	WOW	GRA	WOW	WOW
36.8	5	312517	5594106	WOW	GRA	WOW	GRA	WOW	GRA	WOW	GRA
36.9	5	312600	5594065	WOW	GRA	WOW	GRA	WOW	GRA	WOW	WOW
37	5	312690	5594015	WOW	GRA	WOW	GRA	WOW	GRA	WOW	GRA
37.1	5	312779	5593978	WOW	GRA	GRA	GRA	WOW	GRA	GRA	WOW
37.2	5	312857	5593898	WOW	WOW	GRA	GRA	GRA	WOW	GRA	WOW
37.3	5	312917	5593814	WOW	WOW	GRA	GRA	GRA	WOW	GRA	WOW
37.4	5	312955	5593717	WOW	WOW	WOW	GRA	GRA	GRA	GRA	GRA
37.5	5	312989	5593635	WOW	GRA	WOW	GRA	WOW	GRA	WOW	WOW
37.6	5	313062	5593576	WOW	WOW	WOW	GRA	WOW	GRA	GRA	WOW
37.7	5	313147	5593516	GRA	WOW	WOW	WOW	WOW	GRA	GRA	GRA
37.8	5	313220	5593464	GRA	GRA	GRA	WOW	GRA	GRA	GRA	GRA
37.9	5	313304	5593410	GRA	GRA	GRA	GRA	GRA	GRA	GRA	WOW
38	5	313386	5593361	GRA	TRW	GRA	GRA	GRA	GRA	GRA	WOW
38.1	5	313482	5593373	GRA	TRW	GRA	GRA	GRA	GRA	TYA	GRA
38.2	5	313568	5593417	GRA	TRW	GRA	GRA	GRA	GRA	GRA	GRA
38.3	5	313654	5593469	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
38.5	5	313837	5593515	GRA	WOW	GRA	GRA	GRA	GRA	GRA	GRA
38.6	5	313873	5593595	GRA	GRA	GRA	GRA	GRA	TRW	GRA	GRA
38.7	5	313894	5593697	GRA	GRA	GRA	GRA	GRA	GRA	TYA	GRA
38.8	5	313971	5593764	PRW	GRA	PRW	GRA	PRW	GRA	PRW	GRA
38.9	5	314072	5593746	GRA	GRA	GRA	GRA	GRA	GRA	GRA	WOW
39	5	314151	5593683	GRA	GRA	GRA	GRA	GRA	GRA	WOW	GRA
39.1	5	314199	5593595	GRA	GRA	GRA	GRA	TYA	GRA	GRA	GRA
39.2	5	314256	5593526	GRA	GRA	GRA	GRA	TYA	GRA	GRA	GRA
39.3	5	314326	5593445	GRA	GRA	GRA	GRA	TYA	GRA	GRA	GRA
39.4	5	314246	5593371	GRA	GRA	GRA	WOW	GRA	WOW	GRA	WOW
39.5	5	314261	5593311	TRW	GRA	WOW	GRA	WOW	GRA	GRA	WOW
39.6	5	314254	5593217	TRW	GRA	GRA	WOW	GRA	GRA	GRA	GRA
39.7	5	314269	5593122	GRA	WOW	GRA	WOW	GRA	GRA	GRA	GRA
39.8	5	314295	5593026	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
39.9	5	314305	5592946	WOW	WOW	TYA	GRA	TYA	GRA	GRA	WOW
40	5	314377	5592886	WOW	GRA	TYA	GRA	TYA	TYA	TYA	GRA
40.1	5	314444	5592816	GRA	GRA	TYA	TYA	TYA	TYA	TYA	TYA
40.2	5	314509	5592744	GRA	WOW	GRA	GRA	TYA	GRA	TYA	GRA
40.3	5	314564	5592665	GRA	GRA	GRA	WOW	TYA	GRA	TYA	GRA
40.4	5	314648	5592618	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
40.5	5	314735	5592555	GRA	GRA	GRA	GRA	GRA	WOW	GRA	GRA
40.6	5	314771	5592480	GRA	GRA	GRA	WOW	GRA	GRA	GRA	TYA
40.7	5	314845	5592439	WOW	GRA	GRA	WOW	GRA	WOW	GRA	WOW
40.8	5	314936	5592407	GRA	GRA	GRA	GRA	GRA	WOW	GRA	WOW
40.9	5	315036	5592401	GRA	GRA	GRA	GRA	GRA	WOW	TYA	GRA

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Vegetation Classification							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
41	5	315124	5592373	GRA	GRA	GRA	GRA	GRA	GRA	GRA	TYA
41.1	5	315214	5592386	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
41.2	5	315314	5592380	TYA	GRA	TYA	WOW	GRA	GRA	GRA	GRA
41.3	5	315403	5592378	TYA	GRA	TYA	WOW	GRA	GRA	TYA	TYA
41.4	5	315494	5592334	GRA	GRA	GRA	GRA	TYA	GRA	GRA	GRA
41.5	5	315572	5592274	GRA	GRA	GRA	GRA	TYA	GRA	TYA	TYA
41.6	5	315658	5592227	GRA	GRA	GRA	GRA	GRA	GRA	TYA	GRA
41.7	5	315692	5592212	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
41.8	5	315781	5592133	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
41.9	5	315838	5592058	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
42	5	315905	5592005	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
42.1	5	315968	5592057	GRA	GRA	GRA	TYA	GRA	GRA	GRA	GRA
42.2	5	316057	5592056	GRA	GRA	GRA	TYA	GRA	GRA	GRA	GRA
42.3	5	316092	5591960	GRA	GRA	GRA	TYA	GRA	GRA	GRA	GRA
42.4	5	316098	5591868	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
42.5	5	316099	5591768	GRA	GRA	TYA	GRA	GRA	GRA	GRA	GRA
42.6	5	316163	5591699	GRA	GRA	TYA	GRA	GRA	GRA	GRA	GRA
42.7	5	316243	5591641	GRA	WOW	TYA	GRA	GRA	GRA	GRA	GRA
42.8	5	316331	5591607	GRA	GRA	TYA	GRA	GRA	GRA	GRA	GRA
42.9	5	316429	5591618	GRA	GRA	TYA	TYA	GRA	GRA	GRA	GRA
43	5	316507	5591664	GRA	WOW	TYA	WOW	GRA	GRA	TYA	GRA
43.1	5	316585	5591719	GRA	WOW	TYA	WOW	TYA	GRA	TYA	GRA
43.2	5	316676	5591772	GRA	WOW	TYA	WOW	TYA	GRA	TYA	GRA
43.3	5	316769	5591726	GRA	WOW	WOW	WOW	GRA	GRA	TYA	GRA
43.4	5	316833	5591651	GRA	WOW	GRA	WOW	GRA	GRA	GRA	GRA
43.5	5	316895	5591569	GRA	GRA	GRA	WOW	GRA	GRA	GRA	GRA
43.6	5	316948	5591491	WOW	WOW	GRA	WOW	GRA	GRA	WOW	GRA
43.7	5	316957	5591393	GRA	GRA	GRA	WOW	GRA	GRA	WOW	WOW
43.8	5	316946	5591302	GRA	GRA	GRA	GRA	WOW	GRA	WOW	WOW
43.9	5	316956	5591209	GRA	GRA	GRA	GRA	GRA	WOW	WOW	WOW
44	5	316961	5591114	GRA	GRA	GRA	GRA	GRA	GRA	WOW	WOW
44.1	5	316966	5591014	GRA	GRA	GRA	GRA	GRA	WOW	WOW	WOW
44.2	6	316992	5590938	GRA	GRA	GRA	GRA	GRA	GRA	WOW	WOW
44.3	6	316929	5590825	GRA	GRA	GRA	GRA	TYA	GRA	GRA	GRA
44.4	6	316850	5590763	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
44.5	6	316780	5590694	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
44.6	6	316730	5590612	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
44.7	6	316728	5590525	GRA	GRA	GRA	GRA	GRA	GRA	TYA	GRA
44.8	6	316729	5590422	GRA	GRA	GRA	GRA	GRA	TYA	GRA	GRA
44.9	6	316746	5590326	GRA	GRA	WOW	GRA	WOW	TYA	WOW	GRA
45	6	316770	5590231	GRA	GRA	WOW	WOW	WOW	GRA	WOW	GRA
45.1	6	316837	5590164	GRA	GRA	GRA	WOW	GRA	GRA	GRA	GRA
45.2	6	316888	5590084	GRA	GRA	WOW	GRA	GRA	TYA	GRA	GRA
45.3	6	316972	5590048	GRA	GRA	GRA	WOW	GRA	GRA	GRA	WOW
45.4	6	317066	5590008	GRA	GRA	GRA	WOW	GRA	GRA	GRA	WOW
45.5	6	317142	5589946	GRA	TYA	GRA	WOW	GRA	GRA	GRA	WOW

Distance (km)	Reach	NAD 1983 UTM Zone 12 N		Vegetation Classification							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
45.6	6	317185	5589857	TYA	TYA	GRA	WOW	GRA	GRA	GRA	WOW
45.7	6	317202	5589758	GRA	TYA	TYA	TYA	TYA	TYA	TYA	TYA
45.8	6	317206	5589659	GRA	TYA	GRA	TYA	TYA	TYA	TYA	TYA
45.9	6	317211	5589559	GRA	GRA	TYA	GRA	TYA	GRA	TYA	GRA
46	6	317208	5589462	TYA	TYA	WOW	GRA	GRA	GRA	GRA	GRA
46.1	6	317252	5589372	TYA	TYA	TYA	TYA	TYA	GRA	TYA	GRA
46.2	6	317231	5589279	TYA	TYA	TYA	GRA	GRA	GRA	GRA	GRA
46.3	6	317262	5589185	TYA	GRA	TYA	GRA	GRA	GRA	TRW	TYA
46.4	6	317320	5589106	GRA	GRA	GRA	GRA	GRA	GRA	GRA	WOW
46.5	6	317356	5589013	GRA	GRA	GRA	GRA	GRA	GRA	GRA	WOW
46.6	6	317415	5588935	GRA	GRA	TYA	GRA	GRA	GRA	GRA	WOW
46.7	6	317480	5588858	GRA	GRA	TYA	GRA	GRA	GRA	GRA	GRA
46.8	6	317564	5588826	GRA	TYA	TYA	GRA	GRA	GRA	TYA	GRA
46.9	6	317652	5588790	GRA	TYA	GRA	GRA	GRA	GRA	GRA	TYA
47	6	317741	5588743	TYA	GRA	GRA	TYA	GRA	GRA	GRA	GRA
47.1	6	317809	5588662	TYA	TYA	GRA	TYA	TYA	TYA	TYA	TYA
47.2	6	317856	5588562	TYA	TYA	TYA	TYA	TYA	TYA	TYA	TYA
47.3	6	317864	5588467	TYA	TYA	TYA	TYA	TYA	TYA	TYA	TYA
47.4	6	317865	5588363	TYA	TYA	GRA	GRA	TYA	TYA	GRA	TYA
47.5	6	317832	5588266	TYA	TYA	GRA	GRA	TYA	GRA	GRA	GRA
47.6	6	317820	5588166	TYA	TYA	GRA	GRA	GRA	GRA	GRA	GRA
47.7	6	317823	5588069	TYA	TYA	TYA	TYA	GRA	GRA	GRA	GRA
47.8	6	317825	5587979	GRA	GRA	GRA	GRA	GRA	PRW	GRA	PRW
47.9	6	317916	5587901	GRA	TYA	TYA	TYA	GRA	GRA	GRA	GRA
48	6	317915	5587801	TYA	TYA	GRA	TYA	GRA	GRA	GRA	GRA
48.1	6	317938	5587702	TYA	GRA	GRA	TYA	TYA	WOW	TYA	GRA
48.2	6	317904	5587603	TYA	GRA	GRA	GRA	TYA	GRA	TYA	GRA
48.3	6	317887	5587510	TYA	GRA	GRA	TYA	TYA	GRA	TYA	GRA
48.4	6	317853	5587424	TYA	GRA	GRA	GRA	WOW	TYA	TYA	TYA
48.5	6	317758	5587378	GRA	GRA	GRA	GRA	GRA	TYA	TYA	WOW
48.6	6	317729	5587271	GRA	GRA	TYA	TYA	GRA	WOW	GRA	GRA
48.7	6	317618	5587234	GRA	GRA	GRA	TYA	GRA	GRA	TYA	GRA
48.8	6	317579	5587165	GRA	GRA	GRA	TYA	WOW	GRA	GRA	TYA
48.9	6	317504	5587096	GRA	GRA	GRA	TYA	GRA	WOW	TYA	TYA
49	6	317443	5587022	GRA	GRA	TYA	TYA	GRA	WOW	TYA	TYA
49.1	6	317408	5586927	GRA	GRA	TYA	TYA	GRA	WOW	GRA	WOW
49.2	6	317359	5586843	GRA	GRA	TYA	TYA	GRA	WOW	GRA	WOW
49.3	6	317308	5586761	GRA	TYA	GRA	GRA	GRA	TRW	GRA	WOW
49.4	6	317291	5586660	TYA	TYA	GRA	TYA	GRA	TRW	TYA	WOW
49.5	6	317310	5586562	TYA	GRA	TYA	TYA	GRA	WOW	TYA	TYA
49.6	6	317357	5586475	TYA	GRA	TYA	TYA	GRA	WOW	TYA	GRA
49.7	6	317417	5586393	TYA	TYA	GRA	GRA	GRA	WOW	TYA	GRA
49.8	6	317499	5586327	TYA	TYA	GRA	GRA	TYA	GRA	TYA	TYA
49.9	6	317590	5586297	GRA	GRA	GRA	GRA	TYA	WOW	GRA	WOW
50	6	317683	5586298	GRA	GRA	GRA	GRA	GRA	WOW	GRA	GRA
50.1	6	317782	5586270	GRA	GRA	GRA	GRA	GRA	WOW	TYA	GRA

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Vegetation Classification**							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
50.2	6	317886	5586290	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
50.3	6	317969	5586315	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
50.4	6	318056	5586288	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
50.5	6	318147	5586243	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
50.6	6	318224	5586176	TYA	GRA	TYA	TYA	GRA	TYA	GRA	TYA
50.7	6	318250	5586074	TYA	TYA	TYA	GRA	GRA	TYA	TYA	TYA
50.8	6	318239	5585971	TYA	GRA	TYA	GRA	GRA	GRA	TYA	TYA
50.9	6	318217	5585877	TYA	TYA	TYA	TYA	TYA	GRA	GRA	TYA
51	6	318232	5585795	TYA	GRA	GRA	TYA	TYA	GRA	TYA	GRA
51.1	6	318181	5585698	GRA	GRA	TYA	TYA	TYA	TYA	TYA	TYA
51.2	6	318089	5585654	GRA	GRA	GRA	GRA	TYA	TYA	TYA	TYA
51.3	6	317984	5585618	GRA	TYA	GRA	GRA	GRA	WOW	TYA	TYA
51.4	6	317901	5585633	TYA	TYA	GRA	GRA	GRA	WOW	TYA	GRA
51.5	6	317796	5585636	TYA	TYA	GRA	TYA	GRA	WOW	TYA	GRA
51.6	6	317711	5585622	TYA	TYA	GRA	GRA	GRA	GRA	TYA	GRA
51.7	6	317596	5585624	GRA	TYA	GRA	GRA	GRA	GRA	GRA	GRA
51.8	6	317516	5585665	GRA	TYA	TYA	TYA	GRA	GRA	GRA	TYA
51.9	6	317405	5585706	GRA	GRA	TYA	GRA	GRA	GRA	GRA	GRA
52	6	317359	5585705	TYA	GRA	TYA	GRA	TYA	GRA	TYA	TRW
52.1	6	317336	5585617	TYA	GRA	TYA	GRA	TYA	WOW	GRA	TRW
52.2	6	317348	5585519	GRA	GRA	TYA	GRA	TYA	WOW	GRA	WOW
52.3	7	317360	5585422	GRA	GRA	GRA	GRA	GRA	WOW	GRA	WOW
52.4	7	317398	5585330	GRA	GRA	GRA	GRA	TYA	WOW	GRA	GRA
52.5	7	317470	5585256	GRA	GRA	GRA	GRA	GRA	WOW	GRA	GRA
52.6	7	317514	5585181	GRA	GRA	TYA	GRA	TYA	WOW	GRA	GRA
52.7	7	317555	5585098	GRA	GRA	TYA	GRA	GRA	GRA	GRA	WOW
52.8	7	317612	5585018	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
52.9	7	317662	5584937	GRA	GRA	GRA	GRA	GRA	TYA	GRA	WOW
53	7	317674	5584838	GRA	GRA	GRA	GRA	GRA	TYA	GRA	GRA
53.1	7	317673	5584737	GRA	GRA	GRA	TYA	GRA	TYA	GRA	GRA
53.2	7	317660	5584652	TYA	TYA	GRA	TYA	GRA	TYA	GRA	GRA
53.3	7	317666	5584545	TYA	GRA	GRA	TYA	GRA	GRA	TYA	GRA
53.4	7	317645	5584435	TYA	GRA	GRA	GRA	GRA	WOW	TYA	WOW
53.5	7	317615	5584370	GRA	GRA	GRA	GRA	GRA	WOW	GRA	WOW
53.6	7	317637	5584274	GRA	GRA	GRA	GRA	GRA	WOW	WOW	WOW
53.7	7	317677	5584185	GRA	GRA	GRA	GRA	GRA	WOW	GRA	WOW
53.8	7	317733	5584105	GRA	GRA	GRA	GRA	GRA	GRA	GRA	WOW
53.9	7	317784	5584023	GRA	GRA	GRA	TYA	GRA	GRA	GRA	WOW
54	7	317818	5583936	GRA	GRA	GRA	TYA	GRA	GRA	GRA	TYA
54.1	7	317903	5583894	TYA	TYA	GRA	GRA	GRA	GRA	GRA	TYA
54.2	7	317965	5583816	TYA	GRA	GRA	GRA	GRA	GRA	TYA	TYA
54.3	7	317994	5583720	TYA	GRA	GRA	TYA	GRA	GRA	GRA	TYA
54.4	7	318011	5583614	GRA	GRA	GRA	TYA	GRA	GRA	TYA	TYA
54.5	7	318023	5583527	TYA	TYA	GRA	TYA	GRA	GRA	GRA	TYA
54.6	7	318020	5583428	GRA	GRA	GRA	GRA	GRA	GRA	TYA	TYA
54.7	7	318027	5583330	GRA	TYA	GRA	GRA	GRA	GRA	TYA	TYA

Distance (km)	**Reach**	**NAD 1983 UTM Zone 12 N**		**Vegetation Classification**							
				1967		1981		2000		2010	
		E	N	Right	Left	Right	Left	Right	Left	Right	Left
54.8	7	318027	5583233	TYA	GRA	WOW	GRA	GRA	GRA	GRA	GRA
54.9	7	318043	5583133	GRA	GRA	WOW	GRA	GRA	GRA	GRA	GRA
55	7	318059	5583037	GRA	GRA	WOW	TYA	GRA	GRA	GRA	GRA
55.1	7	318080	5582940	GRA	GRA	WOW	TYA	GRA	GRA	GRA	GRA
55.2	7	318103	5582844	GRA	TYA	GRA	TYA	GRA	GRA	GRA	GRA
55.3	7	318115	5582754	GRA	GRA	GRA	TYA	GRA	WOW	GRA	TYA
55.4	7	318151	5582660	GRA	GRA	WOW	GRA	TYA	WOW	GRA	TYA
55.5	7	318203	5582575	GRA	GRA	GRA	WOW	GRA	TYA	TYA	TYA
55.6	7	318267	5582502	GRA	GRA	GRA	GRA	TYA	WOW	GRA	TYA
55.7	7	318314	5582413	GRA	GRA	TYA	GRA	TYA	WOW	GRA	TYA
55.8	7	318382	5582344	GRA	GRA	TYA	TYA	TYA	WOW	TYA	GRA
55.9	7	318457	5582273	GRA	GRA	TYA	TYA	TYA	TYA	TYA	TYA
56	7	318506	5582186	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
56.1	7	318577	5582124	GRA	GRA	GRA	GRA	GRA	WOW	GRA	GRA
56.2	7	318661	5582072	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA
56.3	7	318759	5582048	GRA	GRA	TYA	GRA	GRA	GRA	GRA	GRA
56.4	7	318832	5581989	GRA	GRA	TYA	TYA	GRA	GRA	GRA	GRA
56.5	7	318904	5581920	GRA	GRA	TYA	GRA	GRA	GRA	GRA	GRA
56.6	7	318974	5581853	GRA	TYA	GRA	GRA	GRA	GRA	GRA	GRA
56.7	7	319056	5581803	TYA	TYA	GRA	GRA	GRA	GRA	GRA	GRA
56.8	7	319116	5581723	TYA	TYA	GRA	GRA	GRA	GRA	GRA	GRA
56.9	7	319145	5581628	TYA	TYA	GRA	TYA	GRA	GRA	GRA	TYA
57	7	319151	5581531	TYA	GRA	GRA	TYA	GRA	GRA	GRA	TYA
57.1	7	319180	5581444	GRA	GRA	GRA	GRA	GRA	TYA	GRA	TYA
57.2	7	319175	5581342	GRA	TYA	GRA	TYA	TYA	GRA	TYA	TYA
57.3	7	319136	5581251	GRA	GRA	GRA	GRA	GRA	GRA	GRA	TYA
57.4	7	319062	5581200	TYA	TYA	GRA	GRA	GRA	GRA	GRA	GRA
57.5	7	319053	5581109	GRA	GRA	GRA	GRA	GRA	GRA	GRA	GRA

B5 Fixed Radius Point Survey

Table B5.1 Fixed radius point surveys along the Little Bow River, Alberta conducted in summer 2013 following flow augmentation. Species are denoted in alpha codes with multiple sightings indicated in brackets.

Site ID	Sub Site	NAD 1983 UTM Zone 12N	Survey #	Species Codes Observed
LB01	1	297698 E 5605281 N	1	MALL(3), CAGO(21), CCSP(6), BBMA, SAVS, BRBL(2), HOWR, LEFL, RBNH
			2	MALL(2), CCSP(6), BBMA, SAVS, AMCR, EUST
	2	297596 E 5605221 N	1	RWBL(4), MALL, CCSP(3), BBMA(2), MODO
			2	MALL(4), CCSP(2), BBMA, BHCO, EUST,TRES
LB02	1	297480 E 5605091 N	1	RWBL(5), MALL(5), CCSP(2), HOWR, BAIS
			2	RWBL, MALL(2), CCSP(2), AMCR, HOWR, BAIS
	2	297402 E 5604958 N	1	RWBL(4), MALL(2), CCSP(3), BBMA, EUST(2), CHSP(2)
			2	MALL(6), CCSP, BBMA, KILL, EAKI, RTHA, CHSP
LB03	1	297355 E 5604843 N	1	RWBL(3), MALL(1), CCSP(2), BBMA, RBGU, COYE, RTHA(2), EUST(2), WEKI
			2	RWBL(5), MALL(3), BBMA(2), AMCR, RTHA(2), EUST, OSFL
	2	297403 E 5604692 N	1	RWBL(2), MALL(4), CCSP(2), SAVS, EAKI(2), COYE, OSFL
			2	RWBL(3), MALL(2), CCSP(2), AMRO, WBNU
LB04	1	297042 E 5604249 N	1	RWBL(2), HOSP(5), BBMA, HOWR, SWHA, WCSP(2)
			2	RWBL(2), MALL, HOSP(5), BBMA, AMRO, EUST, HOWR(3)
	2	297112 E 5604226 N	1	RWBL(5), MALL(2), CAGO(7), SMLO
			2	RWBB(4), CCSP, HOSP(3), BBMA, AMRO, BARS, RTHA(2), TRES(3), SMLO
LB05	1	296980 E 5604333 N	1	RWBL(8), CLSW(5), CCSP(2), BBMA, TRES, HOFI
			2	RWBL(6), MALL(2), CLSW, AMRO(2), NODO
	2	297001 E 5604305 N	1	RWBL(2), MALL(2), HOSP(2), BBMA, AMRO(3), YEWA
			2	CLSW, CCSP, HOSP(2), AMRO, MODO(3), TRES(2), HOFI(2)
LB06	1	303978 E 5596879 N	1	RWBL, MALL(3), BRBL(3), COYE, REDH(2), GRCA

Site ID	Sub Site	NAD 1983 UTM Zone 12N	Survey #	Species Codes Observed
			2	RWBL(6), MALL(3), CLSW(2), BRBL(2), EAKI(2), REDH(2), YEWA
	2	303862 E 5596936 N	1	RWBL(7), CCSP, AMWI, VESP(2)
			2	RWBL(7), CLSW(2), CCSP(2), EAKI, COYE, BANS
LB07	1	304271 E 5596774 N	1	RWBL(4), CCSP(2), HOSP(10), GADW(2), RNEP, GRCA
			2	RWBL(4), CLSW(3), CCSP, HOSP(5), BHCO(4), AMRO, AMCR(3), EUST, RNEP, YEWA
	2	304051 E 5596832 N	1	RWBL(3), MALL(2), CCSP(2), AMRO(2), GADW(2)
			2	RWBL(2), CCSP(2), AMRO(2), EAKI(2), LASP(3), AMGO
LB08	1	301798 E 5600179 N	1	RWBL (5), MALL(9), CCSP, ROPI(5), RBGU
			2	RWBL(5), MALL(3), BHCO, RBGU, EAKI(3)
	2	301658 E 5600099 N	1	RWBL(3), MALL(19), CAGO(2), HOSP, BHCO(2), AMCR
			2	RWBL(4), MALL(5), HOSP(2), BHCO(4), EAKI(2), AMCR, CITE
LB09	1	301985 E 5600330 N	1	RWBL(10), CAGO, CCSP(2), RBGU(3), RTHA, CANV(3)
			2	RWBL(4), MALL(3), BBMA(2), RTHA, GRCA, AMGO
	2	301986 E 5600185 N	1	RWBL(7), MALL(2), CAGO(12), YHBB(2), ROPI(6)
			2	RWBL(5), CCSP(2), BBMA(3), BHCO(3), NSHO(2), RTHA, GRAP
LB10	1	297602 E 5603135 N	1	RWBL(8), MALL(2), CAGO(2), BBMA, BHCO(2), KILL(2), SAVS, AMCR
			2	RWBL(2), MALL(7), CAGO(29), KILL(2)
	2	297652 E 5603375 N	1	RWBL(4), MALL(2), CAGO, SAVS, BWTE(2), BRBL, LEFL
			2	RWBL(3), SAVS(2), COYE, LCSP
LB11	1	297657 E 5603428 N	1	RWBL(5), AMCR(2), GADW(2), GWTE(2)
			2	RWBL(4), MALL(3), GADW
	2	297591 E 5603572 N	1	RWBL(4), MALL(4), CAGO, BBMA, LASP
			2	RWBL(5), MALL(2), LASP
LB12	1	311108 E 5595001 N	1	RWBL(4), YHBB, RBGU, KILL, SAVS, WILL
			2	RWBL(4), MALL(2), CAGO, KILL(6), SAVS, WILL, NOPI
	2	311274 E 5595043 N	1	RWBL(2), CAGO(2), NSHO(2), WILL, CITE(4)

Site ID	Sub Site	NAD 1983 UTM Zone 12N	Survey #	Species Codes Observed
			2	RWBL(3), MALL(3), CLSW, KILL(3), WILL(2), NOPI
LB13	1	310882 E 5595117 N	1	RWBL(3), BBMA, RBGU(2), KILL, BWTE(2), WILL
			2	RWBL(5), RBGU(12), KILL, AMRO, NSHO(2)
	2	310975 E 5595036 N	1	RWBL(3), CCSP, BBMA, COTE
			2	RWBL(5), CCSP, ROPI(6), BWTE(2), COYE, REDH
LB14	1	314713 E 5592588 N	1	RWBL(5), MALL(2), YHBB, CCSP, HOSP(2), SAVS, NSHO(2)
			2	RWBL(6), MALL(3), CCSP, HOSP, BARS(13), NSHO, HOWR, LESC
	2	314595 E 5592642 N	1	RWBL(5), MALL(4), YHBB, BARS, GADW(2)
			2	RWBL(5), MALL(2), CCSP, BWTE, WISN
LB15	1	314513 E 5592740 N	1	RWBL(6), YHBB(4), CCSP(2), BWTE(2), GWTE, WEME
			2	RWBL(7), YHBB(6), BWTE(2), COYE, NSHO(2), LESC(2)
	2	314418 E 5592870 N	1	RWBL(3), CAGO, YHBB(23)
			2	RWBL(5), MALL, YHBB(12), CCSP(2), BRBL, COYE(2)
LB16	1	318049 E 5585676 N	1	RWBL(7), MALL(2), YHBB(3), CCSP, KILL
			2	RWBL(9), MALL(3), CLSW(5), YHBB(3), BHCO, KILL(2), AMRO
	2	317922 E 5585672 N	1	RWBL(4), MALL, ROPI(9), BARS, MODO, NOPI(2)
			2	RWBL(2), MALL(6), YHBB(1), ROPI(6), BBMA, AMRO(2), EAKI(3), MODO, AMWI(2)
LB17	1	318226 E 5585846 N	1	RWBL(9), MALL(4), YHBB(2), HOSP(2), BWTE(2)
			2	RWBL(8), MALL(2), CLSW(15)
	2	318144 E 5585745 N	1	RWBL(5), YHBB(9)
			2	RWBL(8), CLSW(3), YHBB, KILL, BWTE, MODO
LB18	1	319060 E 5581120 N	1	RWBL(4), CLSW(9), CCSP(2), BRBL, EUST
			2	RWBL(4), CLSW(10), YHBB, BWTE
	2	319160 E 5581274 N	1	RWBL(6), MALL(4), CLSW(3), CAGO(2), BHCO, WIPH(2)
			2	RWBL(8), CLSW(1), BHCO(2), WIPH
LB19	1	319193 E 5581420 N	1	RWBL(9), CLSW(2), YHBB(3), BHCO, COYE(3), BAIS
			2	RWBL(8), MALL(2), BBMA, BHCO(4), AMRO

Site ID	Sub Site	NAD 1983 UTM Zone 12N	Survey #	Species Codes Observed
	2	319175 E 5581646 N	1	RWBL(5), MALL, YHBB, RBGU(3), KILL, BWTE
			2	RWBL(5), CLSW, BWTE, BRBL(6), LESC(2), NOPI, BAIS
LB24	1	305374 E 5596490 N	1	RWBL(4), MALL(2), CCSP(4), BBMA, SAVS(3), RNEP
			2	RWBL(4), REDH(2), RNEP
	2	305178 E 5596445 N	1	RWBL(6), MALL(4), SAVS(2), SWHA, WEME
			2	RWBL(2), SAVS(2), COYE, REDH(3), LESC(2)
LB25	1	305636 E 5596475 N	1	RWBL(8), MALL(3), CCSP, RNEP
			2	RWBL(8), CLSW(6), COYE, REDH(2), MODO
	2	305775 E 5596477 N	1	RWBL(4), MALL(7), CLSW(40), ROPI(1), AMRO(2),OSFL
			2	RWBL(4), MALL(2), CCSP(2), ROPI(2), COYE, GADW, MODO, OSFL