Non-Permanent Stream Crossing Assessments in the Notikewin River Watershed

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EXECUTIVE SUMMARY

In Alberta there are numerous detrimental effects on aquatic ecosystems from access infrastructure. These impacts can pose risks to the distribution, abundance and subsequent viability of fish stocks. Aquatic habitat degradation through sedimentation, physical habitat alteration and fragmentation, are impacts directly attributable to some industrial activities. The effects of non-permanent stream crossings on aquatic habitat quality in the Notikewin River watershed were examined during summer of 2003. Stream crossings were identified through spatial analysis of hydrological and linear disturbance attribute data collected in 1998. Stratified random sampling was used to select sites for assessment. Stream crossings were qualitatively and quantitatively assessed for habitat degradation and potential sediment contributions.

From GIS queries there were 10,062 linear disturbances (cutlines, pipelines, winter roads, etc) that crossed streams in the Notikewin River watershed. Stream length was proportionate to the number of crossings per order. First order streams represent 50.2% of the total stream lengths within the watershed and are crossed by 63.5 % of the linear disturbances.

In this relatively low gradient watershed 93% of rights-of-way (ROW) slopes had gradients less than 20%. Soils were found to be highly erodible at 50% of sites. Approximately 60% of sites assessed had greater than 90% vegetative cover on ROW's. Grasses were the dominant vegetative cover recorded and appeared to provide suitable root mass to prevent erosion or sediment delivery into the stream. Sediment delivery potential ranking corresponds to this determination with 81% of sites having low to no sediment delivery potential. It is believed that the condition of non-permanent stream crossings in this watershed is largely a result of the low frequency of off-high-way vehicle (OHV) use. There were 51% of sites with little to no visible use. It is believed that in a watershed with more frequent OHV use, sediment delivery potential and impacts would be greater due to the disturbance to vegetative cover and sedimentation from mechanical disturbance and surface runoff. As a result of low use, low gradient and high vegetative cover there appears to be a low risk of impact on a site-specific basis. In-stream effects of sedimentation should be quantified and these results applied to the watershed level to gain a better understanding of cumulative effects. Continued improvement in integrated resource management with regard to access infrastructure is critical to minimizing terrestrial and aquatic habitat fragmentation and degradation.

1.0 INTRODUCTION

1.1 Study Rationale

Cumulative effects of stream crossings on watersheds threaten aquatic ecosystems with the expansion of industry and extraction of the natural resources (Scrimgeour et al. 2003). An understanding and quantification of impacts of this expansion are required to optimize conservation and regulatory efforts. The risk of impacts from habitat alteration or destruction increases as industrial use and access to areas increase (Reeves et al. 1993 and Eaglin and Hubert 1993).

Non-permanent stream crossings are mainly used to access resources during winter months without the added cost of a permanent crossing structure. These crossings when properly installed allow for machinery to access areas for industrial use with minimal aquatic impact. However, there are detrimental effects from improperly constructed non-permanent stream crossings. One main detrimental effect to fish and fish habitat is the input of sedimentation through erosion of the right-of-way (ROW) into the stream. This effect increases the suspended solids in the water, which in turn settle into the interstitial spaces of critical habitat making them inaccessible by fish (Newcombe and MacDonald 1991). Increased sediment load irritates fish and puts them under high stress (Newcombe and MacDonald 1991). Sedimentation can lead to an increase in stream water temperature. This warming effect adds further stress to all fish populations (Waters 1995).

1.2 Study Objectives

This project was designed to address issues of potential fish habitat degradation caused by non-permanent stream crossings. This is an evaluation of both impact of non-permanent stream crossing and the methodologies of assessing non-permanent stream crossing. We had two primary objectives:

- To determine the density of non-permanent stream crossings in the Notikewin River watershed.

- To determine the potential of non-permanent crossings to cause degradation of aquatic habitats due to erosion.

2.0 STUDY AREA

2.1 Site Description

Notikewin River watershed is located in Northwestern Alberta, Canada approximately 100 km Northwest of Peace River (Figure 1). The watershed drains an area of ~9,799 km^2 with 10,006 linear disturbance / stream intersections. Elevations ranged from 207 – 1090 meters above sea level, from 1996 Digital Elevation Model. Most of this watershed is characterized by a low gradient elevation change with only a small area of significant elevation changes in the western portion of the watershed.

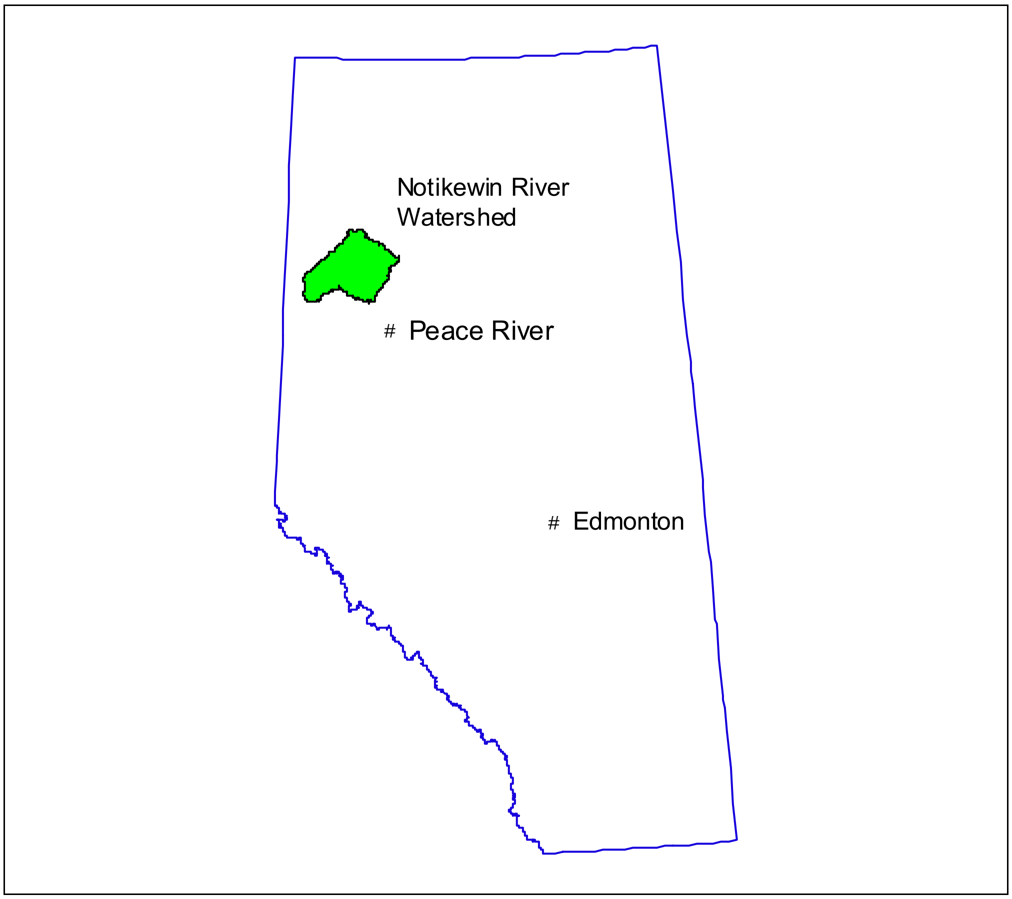

Figure 1. Location of Notikewin River Watershed in Northwestern Alberta, Canada.

2.2 Ecoregion and Description

Notikewin River watershed is within mainly the Lower Boreal-Cordilleran ecoregion with a proportion of the watershed (near Manning) in the Low Boreal Mixed Wood ecoregion.

Lower Boreal-Cordilleran
Gray luvisol soil allows for growth of aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*) and lodgepole pine (*Pinus contorta*) with succession leading to white (*Picea glauca*) and black spruce (*Picea mariana*) as well as balsam fir (*Abies balsamea*). Annual precipitation is approximately 464mm, with 295 mm in the summer months and 60 mm in the winter months. Mean summer temperature is 12.8^{o}C with a range of 6.9 to 18.3 ^{o}C. Mean winter temperature is -7.8 ^{o}C with a range of –14.3 to -2.1^{o}C (Strong and Leggat 1992).

Low Boreal Mixed Wood
Gray luvisol soils allows for mainly the growth of aspen with succession to white spruce in this area. Annual precipitation is approximately 380 mm, with 235 mm in the summer months and 61 mm in the winter months. Mean summer temperature is 13.8^{o}C with a range of 7.0 to 20.4 ^{o}C. Mean winter temperature is –7.8 ^{o}C with a range of –14.3 to -2.1^{o}C (Strong and Leggat 1992.).

2.3 Fish Communities

Fish communities in the Notikewin River drainage are comprised of seventeen species dominated by Arctic grayling (*Thymallus arcticus*), longnose sucker (*Catostomus catostomus*), lake chub (*Couesius plumbeus*), brook stickleback (*Culaea inconstant*), trout-perch (*Percopsis omiscomaycus*) and northern pike (*Esox lucius*) (Scrimgeour et al. 2003).

2.4 Activity in Watershed

Main industrial activities in this watershed are forestry, oil and gas extraction. As a result of these activities there is ongoing development of cutlines, seismic lines, pipelines and roads. All terrain vehicle use and recreational activity appeared minimal.

3.0 MATERIALS AND METHODS

3.1 ArcView Watershed Analysis (Site Selection and Proportions)

Densities and relative proportions of stream crossings in the Notikewin Drainage were determined using 1998 spatial data and ArcView 3.02 with the 'geo-processing' and 'line intersections to points' extensions. Stream crossings were categorized by stream order and 'type of crossing'. Proportion of linear length (km) per Strahler stream order (Strahler 1957) and 'types of crossings' relative to order were determined for the watershed.

Sites were selected using a stratified random sampling design, reflecting the above stated proportions. For example, if 43% of linear length of the watershed is from first order streams then 43% of the sites assessed are on first order streams. If 50% of these crossings are cutline crossings, then 50% of total sites randomly picked are from this category. Types of linear crossings were recorded as: cutlines (including seismic lines), pipelines, winter roads and non-permanent crossings, and permanent crossings. However, it is believed that the number of winter roads represented in our data was not a true representation of the number and density of winter roads in the watershed. This is likely the case because of the perceived high turn over rate from seismic or cutlines to winter roads.

To determine density for each type of crossing relative to stream order the number of crossings per order was divided by the total length of that order in (km). These values were tabulated (Table 8, Table 9) and a line graph (Figure 2) was constructed to illustrate the trends.

3.2 Field Watershed Analysis (Field Methods)

Stream crossing assessments were conducted from July 2- July 4, 2003. Assessments were designed to evaluate habitat degradation and sediment delivery potential. A sample assessment form is presented in Appendix 1. Two crews with 2 people per crew assessed sites via helicopter transport. Teams worked in a 'leap-frog' system. Crossings were ranked according to the following list of tables. These tables were created from adaptations of Fontana et al. (2002), Beaudry (2003) and external research. The following are qualitative and quantitative variables described or measured during field assessments.

Evaluation Zone was the area included in the assessment and was dependant on the bank full width of the channel (BFW). Size of the evaluation zone assessed relative to bank full width is outlined in Table 1.

Table 1. Evaluation Zone Guidelines determining depth of assessment area in the ROW based upon Bank Full Width (BFW).

Type of Waterbody	Evaluation Zone
<1m BFW	10m
1-3m BFW	20m
3-5m BFW	30m
>5m BFW	50m

Frequency of Use was determined from visual evaluation of the ROW and ranked according to Table 2.

Table 2. Frequency of Use of the ROW and stream crossing.

Score	Description
1.0	High Use (i.e. evidence of ruts, frequent use, bare soil tracks, evidence of regularly used vehicle trail)
0.6	Moderate Use (i.e. little evidence of ruts predominantly vegetated vehicle path)
0.2	Low Use (i.e. evidence of minimal vehicular disturbance vegetated pathway, minimal shallow ruts)
0.0	None (i.e. No evidence of vehicular disturbance)

Surface Erosion Level was a rank determined by visible erosion at the stream crossing. Criteria are outlined in Table 3.

Table 3. Surface Erosion Level present at stream crossing**.**

Score	Description
1.0	Massive Erosion (>than approx. 0.2m^3)(e.g. rill/gully of 20X15 cm and greater than 7m long)
0.9	Very Extensive Erosion (approx. 0.15-0.20m^3)(e.g. rill/gully of 20X15 cm and 7m long)
0.8	Extensive Erosion (approx. 0.10-0.15m^3)(e.g. rill/gully of 20X15 cm and 5 m long)
0.7	High Erosion (approx.0.05–0.10 m^3)(e.g. rill of 15x15 cm and 4m long)
0.6	Moderate to High Erosion (0.02-0.05 m^3)(e.g. one rill of 15x15 cm and 2m long)
0.5	Moderate Erosion (0.005-0.02 m^3)(e.g. one rill of 10x10 cm and 2m long)
0.4	Slight to Moderate Erosion (e.g. up to 5 shallow rills <2cm deep and less than 2m long)
0.3	Slight Erosion (e.g. 2-5 shallow rills <2cm deep and less than 2m long)
0.2	Minor Erosion (e.g. 1-2 rills <1.5cm deep and less than 2m long)
0.1	Negligible Erosion (almost not visible)
0.0	Absolutely No Erosion Evident

The **Channel Profile** was ranked according to criteria outlined in Table 4. This measure was aimed at ranking the bank profile and stability adjacent to the stream.

Table 4. Channel Profile of stream banks with potential for sediment contribution to the stream

Score	Description
1.0	Extremely Steep Bank (i.e. U-shape >90^o)
0.8	Very Steep Bank (i.e. V-shaped 80-90^o)
0.6	Moderately steep (i.e. Notched 60-80^o)
0.4	Steep Bank (i.e. Planar 20-60^o)
0.2	Not Steep (i.e. <20^o)
0.0	Flat (i.e. <0^o)

ROW Slope was a measurement taken with a clinometer and categorized into ranks based upon the percent inclination. The categorization is outlined in Table 5.

Table 5. ROW Slope rank based upon measure degrees

Score	Description
1.0	Extremely steep (i.e. >40%)
0.8	Very steep (i.e.30-39%)
0.6	Moderately steep (i.e. 20-29%)
0.4	Steep (i.e. 10-19%)
0.2	Not steep (i.e. <9%)
0.0	Flat (i.e. <0%)

Soil Erodibility rank is outlined in Table 6. It was a record of soil texture present at the sites.

Table 6. Soil Erodibility rank based upon texture of substrate at site.

Score	Description
1.0	Extremely erodible (i.e. mainly fines)
0.8	Highly Erodible (i.e. mixed fines & other substrate)
0.6	Erodible (i.e. Sand)
0.4	Somewhat Erodible (i.e. Clay or clay mixture)
0.2	Low Erodibility (i.e. Stones, gravel, soil, mixture)
0.0	Not erodible (i.e. armoured slope, rockface)

Sediment Delivery Potential rank is outlined in Table 7. It was used as an estimate of potential future risk of sediment input into the channel.

Table 7. Sediment Delivery Potential to the stream from the ROW.

Score	Description
1.0	Direct delivery is evident, direct and un-interrupted and negligible deposition
0.9	Sediment is very weakly filtered (e.g. less than 10% grass cover) and most of the material reaches the stream
0.8	Sediment is weakly filtered (e.g. less than 20% grass cover) and much of the material reaches the stream
0.7	Sediment filtered through scattered grass and logs (20-30% cover0 and substantial amount reaches the stream
0.5	About half of the eroded material reaches stream
0.2	Most of the material is deposited or diverted away from the strean (about 80%)
0.0	No sediment delivery possible

Percent of vegetative cover in the evaluation zone was determined through visual estimation. **Dominant erosion type** present at a site was recorded along with its dimensions. **Slope length** (distance until positive gradient break away from stream) and width of the ROW was recorded. Other general comments were recorded for the site. All measurements were taken for left and right sides (facing upstream) of the stream crossing.

Photographic record was taken of upstream of crossing, downstream of crossing and one picture looking up each of the 'rights of way'.

4.0 RESULTS AND INTERPRETATIONS

4.1 ArcView Watershed Analysis and Site Proportions

Using hydrographic data from 1998 we estimated 9440.16 km of stream in the Notikewin River watershed (Table 8). There were 10,062 stream crossings identified from GIS information (Table 8). There was more linear length (50.2%) and stream crossings (63.5%) associated with first order streams within this watershed than any other crossing (Table 8, Table 9, Figure 2). According to our GIS data 'Cutlines' outnumbered all other linear disturbances.

Table 8. Stream length and number of crossings for each type of crossing, relative to stream order in the Notikewin drainage, Alberta.

Stream Order	Stream Length (km)	Cutline Crossings	Pipeline Crossings	Winter Roads and Non-permanent Crossings	Permanent Crossings	Total Crossing
1	4743.56	5766	300	101	223	6390
2	1958.13	1938	139	32	107	2216
3	939.77	747	36	12	47	842
4	717.05	386	17	3	9	415
5	657.97	163	18	2	10	193
6	392.64	2	2	1	1	6
7	31.04	0	0	0	0	0
Total	9440.16	9002	512	151	397	10062

Specific cumulative effects within these orders should be identified due to the large spatial scale of the disturbances (Table 9). Potential siltation first order streams could reduce fish habitat as well as lowering water quality throughout the watershed.

Table 9. Proportions of stream length and number of crossings relative to stream order in the Notikewin drainage, Alberta.

Order	Stream length (% of total km)	Cutline Crossing (%) of total	Pipeline Crossing (%) of total	Non-permanent road Crossing (%) of total	Permanent Road Crossing (%) of total	Total Linear disturbance (%)
1	50.25	64.05	58.59	66.89	56.17	63.51
2	20.74	21.53	27.15	21.19	26.95	22.02
3	9.95	8.30	7.03	7.95	11.84	8.37
4	7.60	4.29	3.32	1.99	2.27	4.12
5	6.97	1.81	3.52	1.32	2.52	1.92
6	4.16	0.02	0.39	0.66	0.25	0.06
7	0.33	0.00	0.00	0.00	0.00	0.00

Using hydrographic data from 1998 we tabulated the density of crossings per stream order (Table 10). Overall, 1.07 stream crossings per km of stream were identified. This watershed is considered low to moderately developed when compared to Swan and Simonette River watersheds (Tchir et al. 2002). Through comparisons of these effects upon various watersheds with different parameters more information and relationships can be identified. The identification of site-specific impacts and the cumulative effects of densities of stream crossings through future studies could allow for development of a watershed risk assessment.

Table 10. Stream length and density of crossings for each type of crossing, relative to stream order in the Notikewin Drainage, Alberta.

Stream Order	Linear Distance (km)	Density of Cutline Crossing Cross/km	Density of Pipeline Crossings Cross/km	**Density of non-permanent crossing cross/km	Density of Permanent crossings cross/km	Total Density of Crossings/km
1	4743.56	1.22	0.06	0.02	0.05	1.35
2	1958.13	0.99	0.07	0.02	0.05	1.13
3	939.77	0.79	0.04	0.01	0.05	0.90
4	717.05	0.54	0.02	0.00	0.01	0.58
5	657.97	0.25	0.03	0.00	0.02	0.29
6	392.64	0.01	0.01	0.00	0.00	0.02
7	31.04	0.00	0.00	0.00	0.00	0.00
Total	9440.16	0.95	0.05	0.02	0.04	1.07

**Density of non-permanent crossings are believed to be much higher than what are presented in this table. Many of the cutlines and pipelines have been converted to seasonal roads, which were not captured in the GIS data layers used in this analysis.

As a result of a high frequency of linear disturbances occurring on first order streams (headwaters), first order watersheds are important in the quality of water, sediment input levels and are a critical part of the aquatic ecosystem of the watershed (Figure 2).

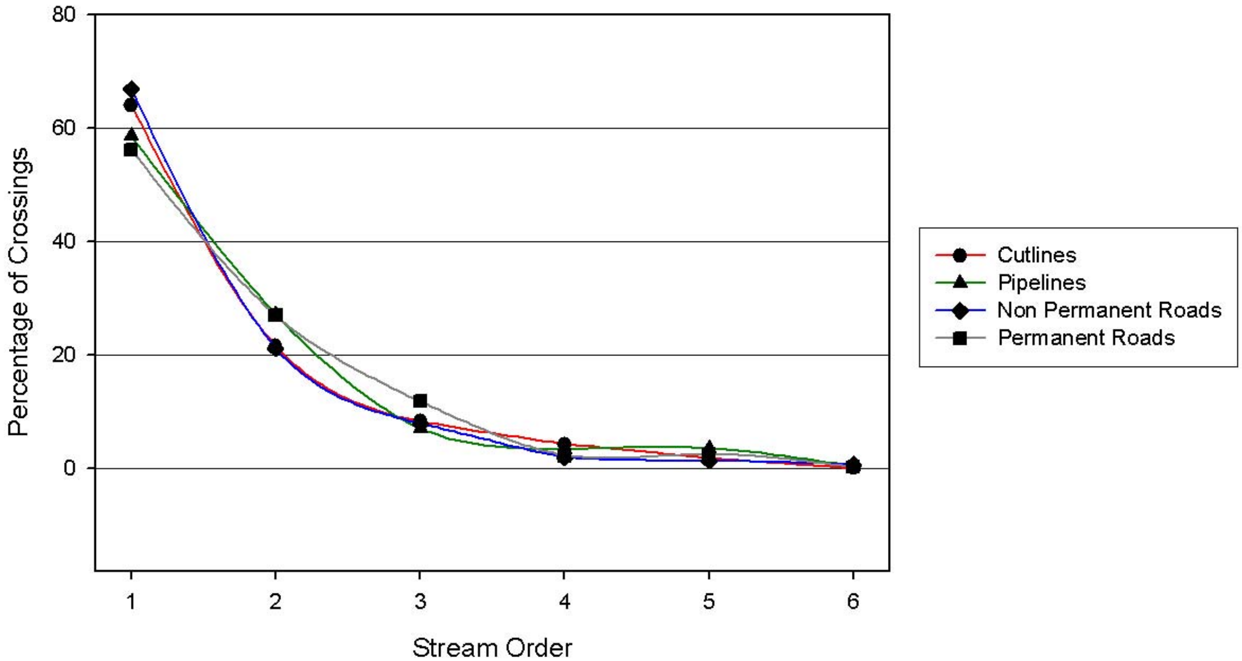

Figure 2. Relative percent of stream crossings by stream order in the Notikewin Drainage for cutlines, pipelines, non-permanent roads and permanent roads. Information based upon 1998 GIS data, Alberta.

We speculate that potential sedimentation resulting in degradation of first order streams, larger portions of watersheds may be altered with regard to aquatic habitat and flow regime.

Arctic grayling and other fish in this watershed, require access to heterogeneous habitat types and pristine water conditions to ensure strong population dynamics. Cumulative effects of stream crossings and potential sedimentation, habitat degradation may threaten local sport fish population.

4.2 Field Work Results and Interpretations

We visited 77 crossing sites of which 50 were ground surveys and because of limitations to landing 27 sites were partially assessed by air. Of the sites evaluated 51% had no to low frequency of off-highway-vehicle (OHV) use (Figure 3). Low frequency OHV use and other recreational activities are believed to be a major reason for low erosion potential. In an OHV study performed by ACA in Southwestern Alberta, it was shown that there was a significant impact on terrestrial and aquatic habitat quality as a result of excessive OHV use (Fontana et al. 2002). This supports our conclusions that in a low gradient watershed with minimal OHV use and high vegetative cover Erosion potential and subsequent sedimentation can be reduced.

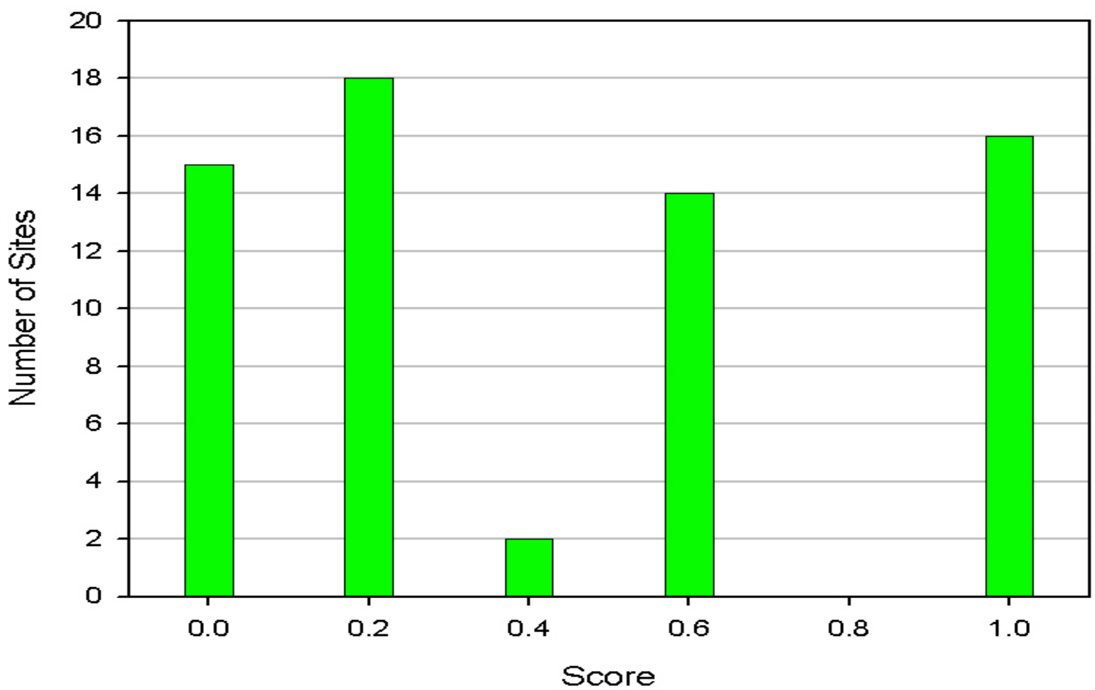

Figure 3. Frequency of vehicular use of right-of-ways crossings streams during unfrozen conditions in the Notikewin watershed, Alberta (2003).

From our observations fine soils made up of silt and clay are predominant throughout Notikewin River watershed. These soils are highly susceptible to erosion. Fifty percent of the sites we assessed were scored as highly erodible (0.8) to extremely erodible (1.0) (Figure 4). Highly erodible soils are likely to enter and remain in suspension in the water column and impact areas far reaching from the point source.

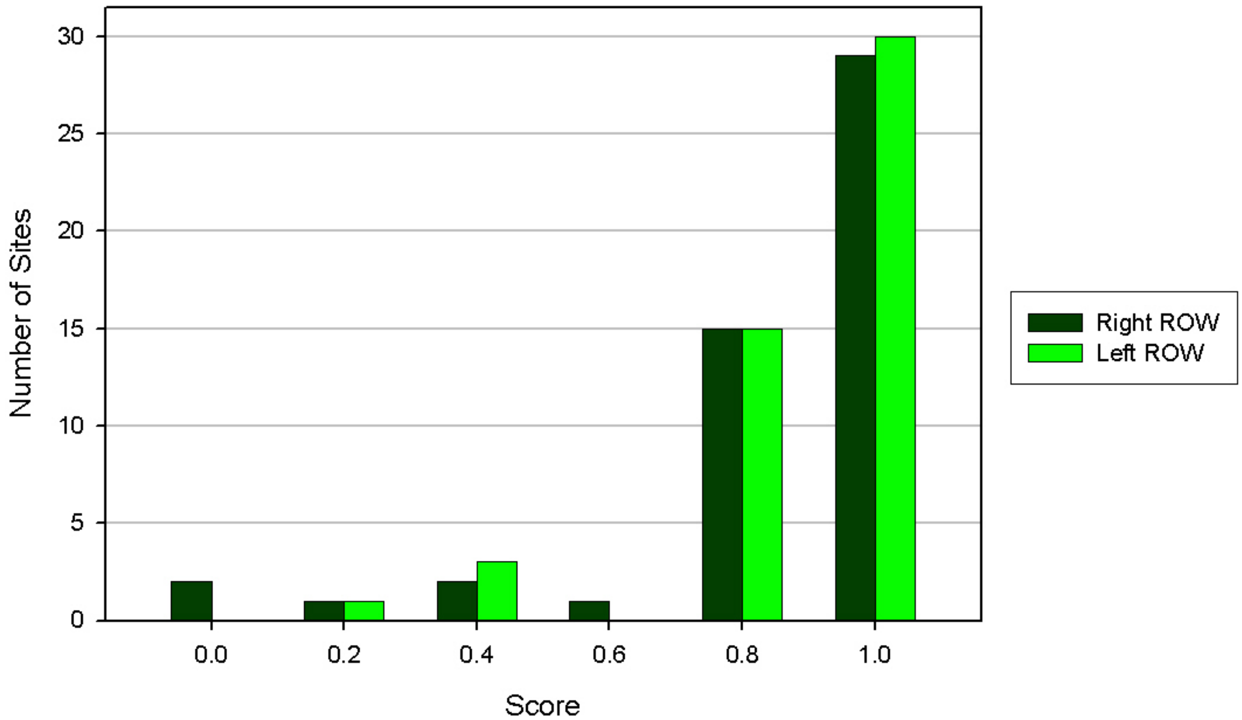

Figure 4. Erodiblity of soils located on right-of-ways at assessed stream crossings in the Notikewin watershed, Alberta (2003).

Notikewin River watershed is a low gradient watershed. Of the sites assessed, 93% scored 0.4 (less than 20% slope) or less (Figure 5). Slope is a dominant factor in erosion and sediment delivery to a stream channel. Slope and large elevation changes of the watershed could provide a macro-filter for watersheds at risk.

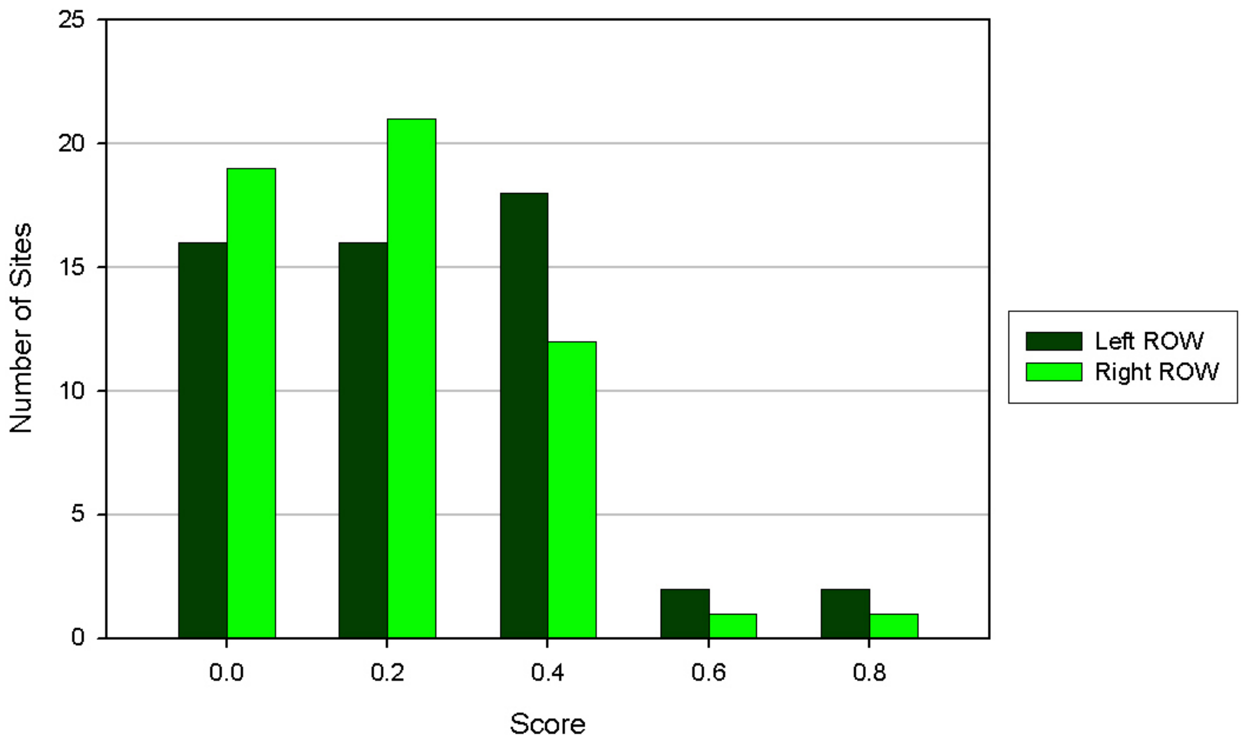

Figure 5. Slope of right-of-ways located at assessed stream crossings in the Notikewin watershed, Alberta (2003).

The majority of sites scored very low on sediment delivery potential. Of the sites assessed 81% were scored as having no sediment delivery potential to most of the sediment being deposited or diverted away from the stream (Figure 6). The reduction of potential sediment delivery partially mitigates the potential impact from stream crossings within this low gradient watershed. Within a high gradient watershed effects may differ.

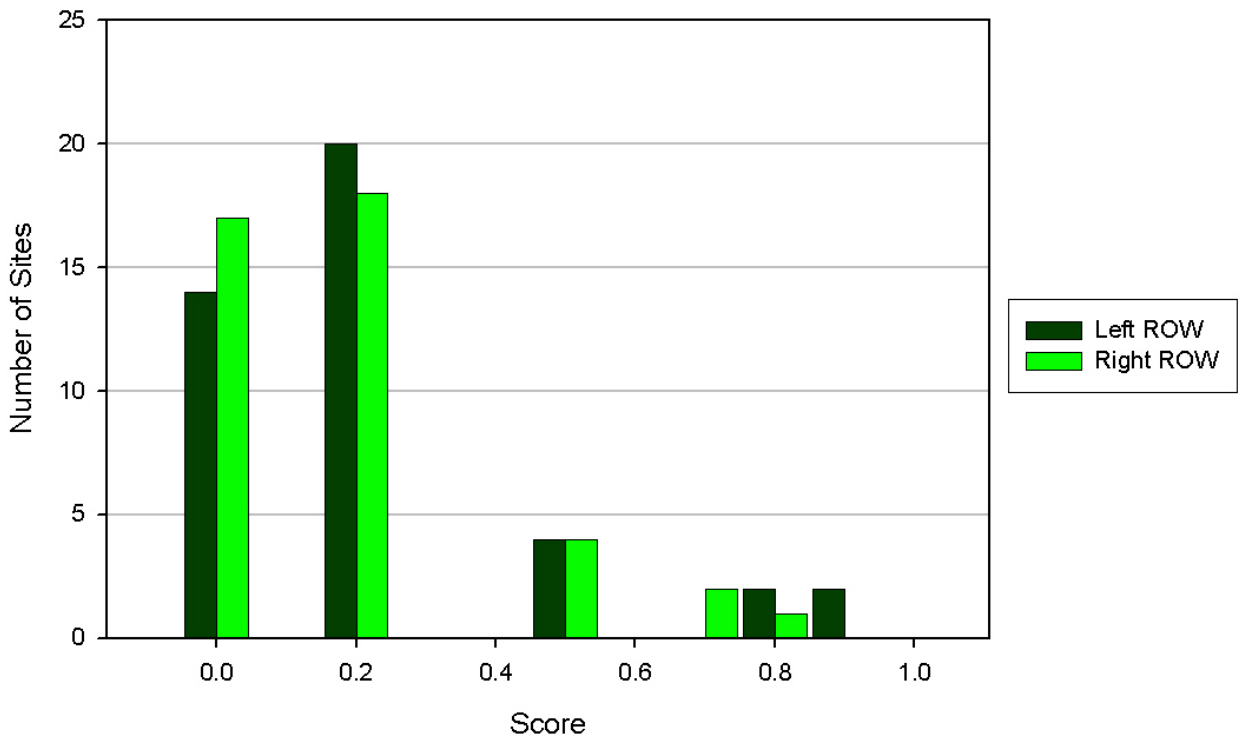

Figure 6. Sediment delivery potential of the right-of-ways at stream crossings in the Notikewin watershed, Alberta (2003).

Sites assessed had good vegetative cover on right-of-ways (ROWs) (Figure 7). Vegetative cover allowed for soil stability and soil retention. Low frequency of use and the apparent lack of OHV use in the watershed allowed for vegetative growth on ROWs and stream banks. However, the majority of the vegetative cover is in poorly rooted grasses (Figure 8). Deep-rooted vegetation (trees and shrubs) were in low abundance on ROWs assessed. A risk of impact exists if the frequency of OHV use or activity increases in this watershed.

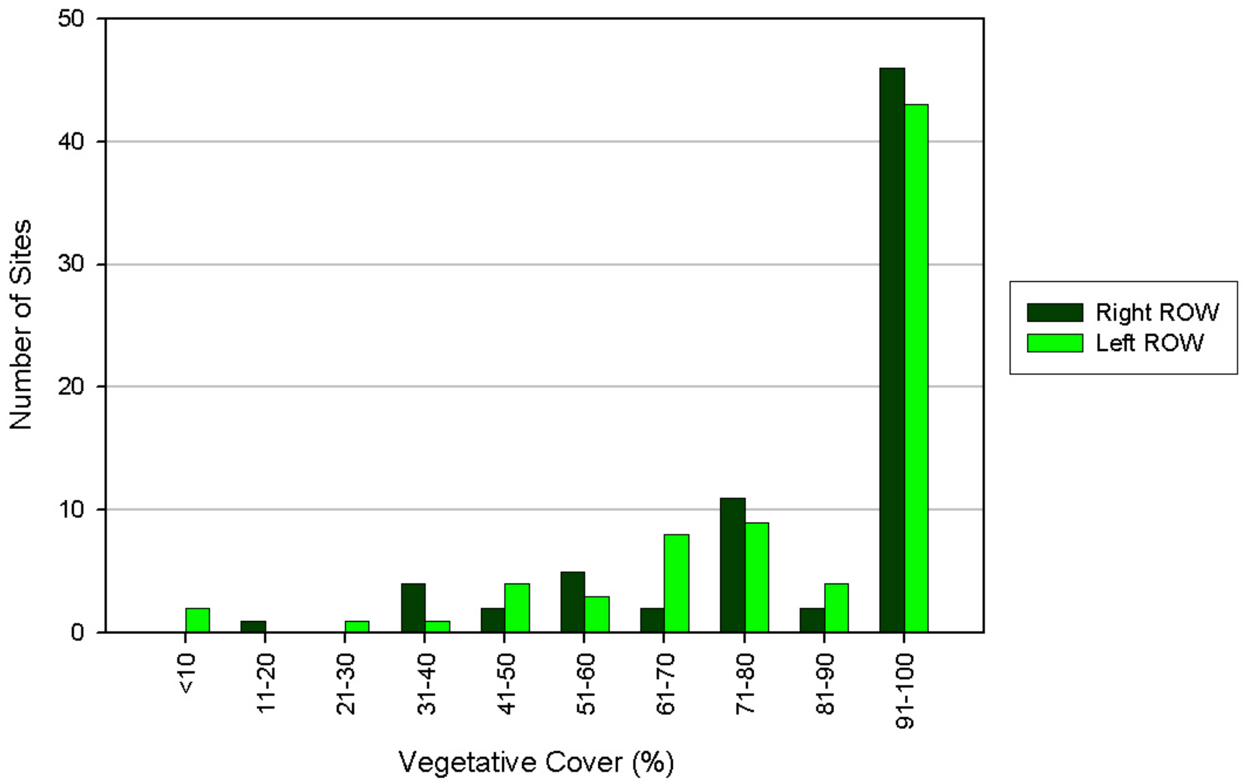

Figure 7. Vegetative cover on the rights of way at the stream crossings assessed in the Notikewin Watershed, Alberta.

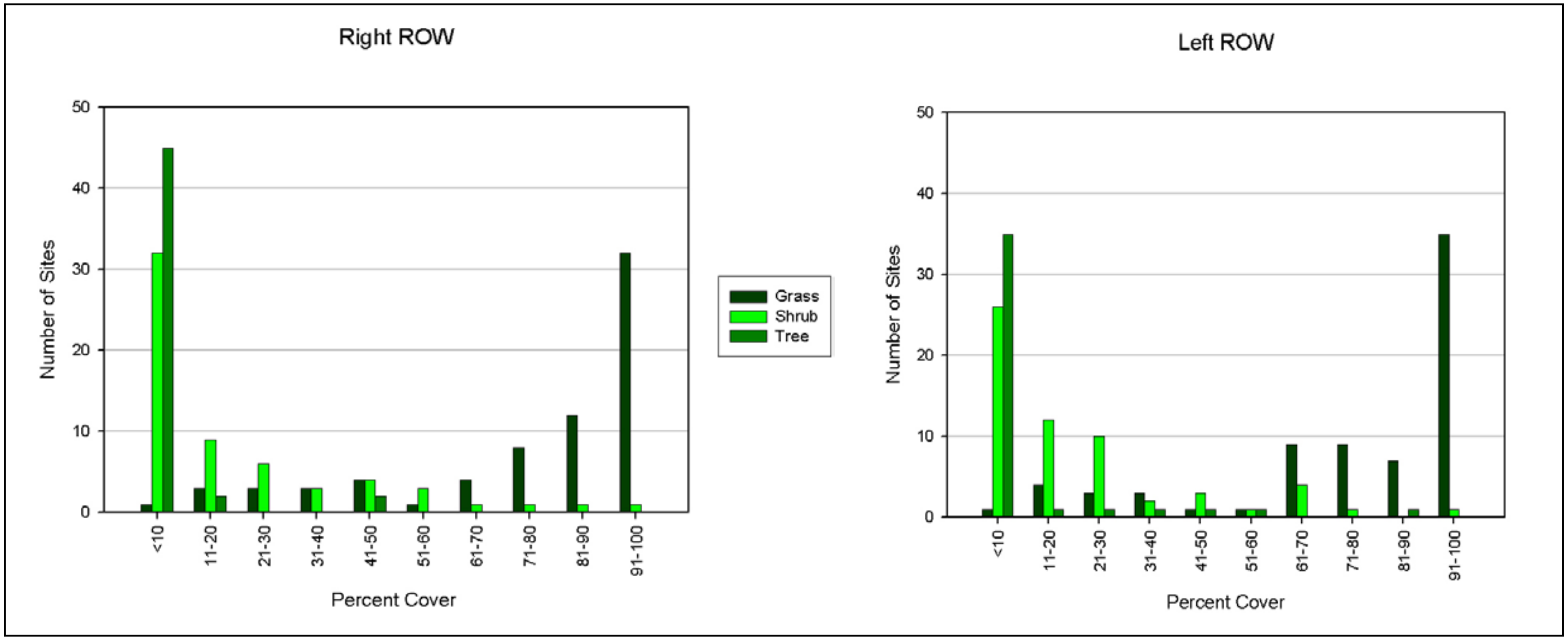

Figure 8. Percentage of vegetative cover type found on rights of way at stream crossings in the Notikewin Watershed, Alberta.

The Notikewin watershed is a relatively low gradient drainage with indications of low OHV use (Figure 3). Most sites were comprised of highly erodible soils (Figure 4) and relatively low slopes channeling into the stream (Figure 5). Vegetative cover was found to be high at assessed sites (Figure 7), however the majority of this vegetation was classified as grasses, with little to no existing shrubs and trees (Figure 8). Combination of low slopes and high vegetation cover reduces the impact of these crossings and also correspond to the overall low sediment delivery potential ranking (Figure 6).

5.0 CONCLUSIONS AND RECOMMENDATIONS

Expansion of industrial activities in Alberta's boreal forest and the continued development of road networks and linear disturbances have raised questions about the sustainability of stream fish communities. The extent that road networks impact stream fish communities in boreal ecosystems are not well understood. Through the continuation of ACA studies in collaboration with other parties, impacts on the natural ecosystems of Alberta from industry may be better managed. Specifically, future studies should be performed to increase our ability to detect and evaluate impacts of non-permanent stream crossings.

Focus should be placed upon proportionately stratified random sampling to allow for future watershed level assessments. Affordable methods to better quantify site-specific instream impacts from sedimentation are required to quantify cumulative effects.

Effects of access related disturbances at the watershed scale are largely unknown in Northern Alberta. Reducing the footprint of access development in watersheds is critical to maintaining fish habitat and ultimately fisheries value. Quantification of current impacts of non-permanent crossings on fish habitat is essential to focus remediation efforts. Non-permanent stream crossings can limit fish passage and degrade fish habitat. The identification of crossings that act as fish passage barriers and conveyors of deleterious substances (silt) is a critical component in working to conserve lotic fish species. Further, determining crossing types in use that have the least effect on fish habitat will provide the basis for improving access management practices in Alberta.

Integrated landscape management would benefit an ecological system in the reduction of linear disturbances and crossings as well reduce the cost by sharing financial requirements of access construction and maintenance. Determining impacts on fish populations and habitat due to temporary stream crossings is critical to improving access management and reducing the footprint in watersheds throughout Alberta.

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American Fisheries Society Monograph 7.

7.0 APPENDICES

7.1 Appendix 1. Non Permanent Stream Crossing Field Form

Site ID	
UTM Easting	
UTM Northing	
Upstream Photo	
Downstream Photo	
ROW Left Photo	
ROW Right Photo	
Type of Use	
Access	
Evaluation Zone	
Slope Length Left	
ROW Width Left	
Area Disturbed Left	
Slope Degree Left	
Slope Rank Left	
Soil Erodibility Left	
Vegetative Cover Left	
Grass Cover Left	
Shrub Cover Left	
Tree Cover Right	
Erosion Type 1 Left	
Frequency of 1 Left	
Length of 1 Left	
Erosion Type 2 Left	
Frequency of 2 Left	
Length of 2 Left	
Slope Length Right	
ROW Width Right	
Area Disturbed Right	
Slope Degree Right	
Slope Rank Right	
Soil Erodibility Right	

Vegetative Cover Right	
Grass Cover Right	
Shrub Cover Right	
Tree Cover Right	
Erosion Type 1 Right	
Frequency of 1 Right	
Extent of 1 Right	
Erosion Type 2 Right	
Frequency of 2 Right	
Extent of 2 Right	
Frequency of Use	
Channel Profile	
Culvert Present	
Stream Order	
Culvert diameter 1	
Culvert diameter 2	
Culvert diameter 3	
Outfall Drop Height c1	
Bankfull Width 50m up	
Bankfull Width 50m dow	
Bankfull Width at Cross	
Sediment Delivery pot L	
Sediment Delivery pot R	
Discernable Channel	

Evidence of ROW Left material in stream

Evidence of ROW Right material in

Temp Erod Control L	
Temp Erod Control R	
Erod Control Effect L	
Erod Control Effect R	

Comments	