P. Beaudry and Associates Ltd.
Integrated Watershed Management

Results of the Stream Crossing Quality Index (SCQI) Survey for the Nichyeskwa Watershed, Skeena Stikine Forest District

Prepared for:
The Trustees of the
Babine Watershed Monitoring Trust
c/o BV Research Centre
Box 4274
Smithers, BC
V0J 2N0

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Prince George, BC
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1.0 INTRODUCTION

The following quote was extracted from the Babine Watershed monitoring plan (Babine Watershed Monitoring Trust 2005). It provides an accurate and concise introduction to this report.

"Effectiveness monitoring assesses whether following planned management strategies achieves desired objectives. The Babine Watershed Monitoring Trust (BWMT) is responsible for guiding effectiveness monitoring in the Babine River Watershed. The Trust allocates funds to monitoring projects based on a process for determining priorities and costs prescribed in the Trust Agreement and described in the Babine Watershed Monitoring Framework (BWMF) (Price and Daust, 2005).

The 2005 Annual Monitoring Plan describes the first year of monitoring activities guided by the Babine Watershed Monitoring Trust. It lists high-priority monitoring topics, and identifies those topics chosen for direct funding or for seeking additional funding. The plan provides a rationale for each funding decision".

Four projects were approved for funding by the BWMT in 2005. One of these four projects was the "Stream Crossing Quality Index (SCQI)" survey, identified as project #2005-2 in the plan. This report present the results of the SCQI survey conducted in the Nichyeskwa watershed during the week of July 10, 2005.

This report was commissioned by the Babine Watershed Monitoring Trust. However, the methods and conclusions are the professional work of the author. The Trustees do not take a position on any conclusions that are contained in the report.

2.0 DEVELOPMENT OF THE STREAM CROSSING QUALITY INDEX

2.1 Background

One of the six main *criteria* of sustainable forest management established by the Canadian Council of Forest Ministers (CCFM; 1997) is the <u>Conservation of Soil and Water Resources.</u> One of the goals of this criterion is the <u>maintenance of water quality</u>. It is largely recognized that one of the biggest single impacts that logging activities have on water quality is accelerated sediment delivery to streams in the vicinity of road crossings. If good road building and maintenance practices can minimize (or eliminate) accelerated erosion and sediment delivery to streams, than negative impacts to water quality will be minimized. Based on this assumption, several forest licencees operating in British Columbia and Alberta have decided that a good SFM indicator to address the goal of "protection of water quality" should be based on a survey that evaluates how well accelerated erosion and sediment delivery is being controlled in the vicinity of stream crossings. Although potentially negative impacts to water quality can occur from other forestry related activities, such as poor riparian management practices, poor range management practices and logging of steep slopes, these practices and potential impacts are addressed using other SFM indicators.

Important characteristics of a good SFM indicator include “easily understandable”, “valid” and “cost effective”. The SCQI was designed to have these characteristics. The scientific literature clearly indicates road building and maintenance, particularly at stream crossings, is the dominant point source for forestry-generated sediment in landscapes where landslides are not a dominant process (Beaudry 2001, Beschta 1978, Bilby et al. 1989, Cafferata and Spittler 1998). Consequently, the SCQI is a valid indicator because it assesses the level of erosion and sediment delivery at stream crossings. The SCQI is cost effective because it is a simple survey that takes about 15 to 20 minutes to complete at each crossing and provides good qualitative information about that hazard level of accelerated erosion and sediment delivery associated with roads. It is “easy to understand” that if you control erosion and sediment delivery to streams, you will be reducing potential impacts to water quality. Although the SCQI certainly does not address all issues related to forestry and water quality, it addresses the issue that, in most cases, is considered to be the most important and does so in a very cost effective manner.

2.2. Development and Refinement of the SCQI

In 2000, Canadian Forest Products Ltd, Prince George Division was exploring the use of various SFM indicators for water quality. They were considering the concept of the stream crossing density used in the BC Watershed Assessment Procedure (WAP) as an indicator of protection of water quality (i.e., # of stream crossings counted on a map divided by the watershed area). It was suggested that, although the stream crossing density is very inexpensive to measure, it is not very meaningful. Thus, it was decided that it would be better if the crossings were actually visited in the field and scored on a scale of 0 to 1 relative to the crossing’s potential for accelerated erosion and sediment delivery to the stream. This would be done rather than making the assumption that all crossings produce the same amount of sediment to the stream environment (as assumed by the crossing density measurement). Thus was born the concept of the SCQI, a simple and quick field based assessment of the potential for accelerated erosion and sediment delivery at stream crossings. The main objective of the assessment was to generate a sediment delivery hazard level (i.e., none, low, moderate, high, or very high), and not to develop a detailed quantitative sediment delivery model.

The origins of the SCQI methodology were based on the concepts of the sediment source survey (SSS) presented in version 2.01 of the WAP (Government of BC 1999a). In the WAP, the road related SSS is used as an assessment of the level of hazard that forestry roads have of delivering sediment to the aquatic ecosystem and thus potentially reducing water quality. In both methods (i.e., the SCQI and the SSS), there are broad descriptive categories of erosion indicators and delivery potential. One of the major refinements in the SCQI methodology is the systematic description of sediment sources and delivery potential for each of eight major sediment producing “elements” that flow directly into the stream network (i.e., the two road running surfaces, the two road fills and the four ditches).

Implementation and validation of the SCQI procedure in subsequent years, since its origin, has enabled us to refine the SCQI tool. One major finding was that, for operational purposes, it is necessary to prioritize crossings so that erosion and sediment control techniques can be improved to better protect water quality in adjacent streams. The initial SCQI procedure had a maximum SCQI score of 1, which meant that all crossings with high sediment hazard ratings were indiscernible from one another, no matter how big the real hazard. For example, if five crossings are rated as high, they were all assigned values of 1, so ranking them on a scale of most to least problematic was not possible. In 2004 the SCQI survey procedure was altered so that it would no longer be limited to a scale of 0 to 1, meaning there is no preset maximum. Another change was that the SCQI tool incorporates eight major sediment producing elements rather than just six. This allows us to more clearly account for potential delivery from the two road fill slopes, if necessitated by the crossing. Other refinements have been made over time and they are outlined within further sections of this report.

The SCQI is certainly not an assessment tool to evaluate the specific impacts of road crossings on the aquatic environment, but rather a tool to score the hazard level that forest roads have on increasing erosion and sediment delivery to the stream network. As an SFM indicator, the basic assumption that underlies the SCQI is that if erosion and sediment delivery in the vicinity of stream crossings is minimized, through proper road building and maintenance practices, then the potential impact to water quality from increased sediment delivery is also minimized. It is important to emphasize that the SCQI focuses exclusively on the sediment source and the potential of that sediment to reach a stream environment. It does not in any way attempt to measure, evaluate or score the impact of increased sediment delivery to the aquatic environment. Consequently, the procedure does not collect any data about the stream environment itself relative to determining the “sensitivity” of the stream to increases in sediment delivery. The procedure does collect some very basic information about the size and gradient of the stream in the vicinity of the crossing; however, this information is not used to judge the sensitivity of the stream or in the determination of the hazard assessment. The stream information is used solely to provide some descriptive information about the assessment site.

3.0 SCQI METHODOLOGY AND SAMPLING

3.1 Sampling Intensity

The execution of an SCQI survey begins with the mapping of current access within the watershed and planning an effective way of completing a 100 % sampling of stream crossings within that watershed (or area of interest). In many situations, 100 % sampling is not possible and thus a sub-sampling strategy must be developed. The intensity of sampling is usually determined by a combination of field access and project budget. For this particular project, the sampling intensity was mostly defined by budget, which allowed for sampling of somewhere between 50 and 70 crossings. During the planning phase of this project we identified approximately 150 stream crossings in the Nichyeskwa watershed based on the stream network provided on the TRIM II maps. Since it was not possible to sample all stream crossings with the allocated budget, a sampling strategy was designed so that as much of the variability across the entire watershed could be sampled. The selection of stream crossings to be sampled in 2005, in the Nichyeskwa watershed, was based on the following criteria:

1. Complete surveys on approximately 50 to 70 stream crossings
2. Complete surveys throughout the watershed, not just in the lower end.
3. Concentrate the surveys on those streams that wider than 0.5 m in bankfull width
4. Concentrate the surveys where road access is reasonable (4X4 truck and ATV).
5. Avoid roads that are totally de-activated and grassed-over. There are two basic justifications for this particular criterion: 1) surveys of crossings on these types of roads are very time consuming because of poor access and thus less crossings get done in a given time and 2) access to these sites with ATVs often create the exact erosion problems that the good erosion control is actually trying to prevent (i.e. ATV caused erosion).

3.2 Survey Methodology

Stream crossings are accessed using 4X4 trucks, ATVs or by walking. Once the surveyor has arrived at the stream crossing, the procedure begins by evaluating the size and characteristics of all sediment sources that can potentially contribute sediment to the aquatic environment. Each stream crossing is divided into eight distinct and independent “elements”. These include four road ditches that run into the stream, two road fill slopes and two road running surfaces, each of these potential sediment sources being assessed independently. The sediment source hazard score for each individual element is a product of the *erosion potential* and the *delivery potential* of that source. The *erosion potential* is calculated as a function of several factors which include:

1. the size of the sediment source,
2. the soil texture of the source,
3. the slope gradient of the source,
4. the percentage of non-erodible cover,
5. the level of road use (for road surface), and
6. the shape of the ditch (for ditch elements).

The cornerstone of the SCQI procedure is the measurement of the size of the sediment source (m^2). The other variables act as modifiers to increase or decrease the hazard associated with the size of the sediment source (Appendix 1). Each of the modifiers is scaled from 0 to 1, where zero (0) represents a condition that would eliminate the hazard (e.g., coarse gravel, no slope or an abandoned fully revegetated road) and one (1) represents a condition that would maximize the hazard (e.g., silt, slope greater than 15% or active mainline). The size of the sediment source (m^2) is multiplied by the value of each modifier to generate an *erosion potential* score for the particular element being assessed. The erosion potential is then multiplied by the *delivery potential* (scaled from 0 to 1) to obtain the element score. The *delivery potential* is determined using a two stage process that first characterizes the sediment control structure with a numerical value by working through a dichotomous key. The dichotomous key categorizes (1) the type of sediment control structures (retention or filtration), (2) the size of the sediment control structure relative to the size of the sediment source, and (3) the efficacy of the sediment control structure to impede delivery of suspended sediment to the stream. The second stage modifies the numeric value from the first stage by considering the spatial location of the sediment control structure in relation to the stream (see Appendix 1 for a detailed explanation of the delivery potential methodology). The total score for the crossing is simply the sum of the eight scores for each of the individual elements. The final SCQI crossing score generates five hazard classes as defined in Table 1. These hazard classes are adapted from guidelines published in the Department of Fisheries and Oceans (2000) and the Government of British Columbia (2001) regarding turbidity and suspended sediment levels.

Table 1 Correspondence between SCQI score, water quality concern rating (WQCR), expected increase in turbidity and risk to fish habitat.

SCQI crossing score	**Water Quality Concern Rating (WQCR)**	**Expected increase in turbidity caused by the crossing for a stream of approximately 1 m in width (NTU)**	**Risk to fish habitat (DFO 2000)**
0	None	None	None
0< score <0.4	Low	1 to 8	Very low
0.4 ≤ score ≤ 0.7	Moderate	8-70	Low to moderate
0.8 ≤ score ≤ 1.6	High	70-130	High
Greater than 1.7	Very High	> 130	Unacceptable

The values for each of the modifiers are based on the concepts and values developed for the Revised Universal Soil Loss Equation (RUSLE) presented by Wall et al. (2002). The universal soil loss equation was initially developed by Wischmeier and Smith (1965). The objective of the RUSLE was to provide a quantitative tool to assess the potential for soil erosion at a given site.

The SCQI procedure is a useful management tool because it identifies the specific location and magnitude of erosion problems. If scores are high, the crossing can be improved through remedial actions and current practices can be altered to avoid high scores in the future. If scores are low, then it shows that good erosion and sediment control practices are being implemented and by extension water quality is being protected. The procedure has been presented to numerous field practitioners in a series of field workshops and received a favourable response because it clearly identifies the specific location of the problem and the practice that generates the problem (if problems actually do exist).

It is important to note that the SCQI method was designed to be quick (about 20 to 25 minutes per crossing) so that a maximum number of crossings can be assessed, thus providing a better landscape level perspective. The SCQI has evolved over the last four years from its initial structure based mostly on subjective assessments. The procedure is now more objective, repeatable and transparent, using values based on the RUSLE.

It must be noted that the whole SCQI approach is largely a conceptual model, based on the general concepts of the RUSLE, and was not developed based on an experimentally acquired set of empirical relationships. It provides a score in a consistent way that can be compared with other crossings in a given watershed and evaluated for how "good" or "bad" the crossings are. The SCQI does not provide a quantitative evaluation (e.g., kg/ha/yr) of exactly how much sediment is entering the stream or what the impact of that sediment has on the stream environment. The SCQI approach tells you where there are erosion and sediment control problems, how frequent in the landscape those types of problems appear and provides a basis of information to judge the magnitude of the problem and how to fix it so that impacts to water quality will be minimized. It is important to emphasize that the SCQI focuses exclusively on the evaluation of the sediment source and the potential of that sediment to reach a stream (i.e., the “hazard”). It does not in any way attempt to measure, evaluate or score the sensitivity of the stream or the impact of increased sediment delivery to the aquatic environment (i.e., it does not evaluate “consequence”).

3.3 SCQI Sampling in 2005 in the Nichyeskwa Watershed

Sampling was conducted throughout the roaded portion of the Nichyeskwa watershed. Sampling focused on streams larger than 0.5 m in bankfull width and on roads that had relatively good access. Figure 1 shows all of the sampling sites completed during the week of July 11, 2005.

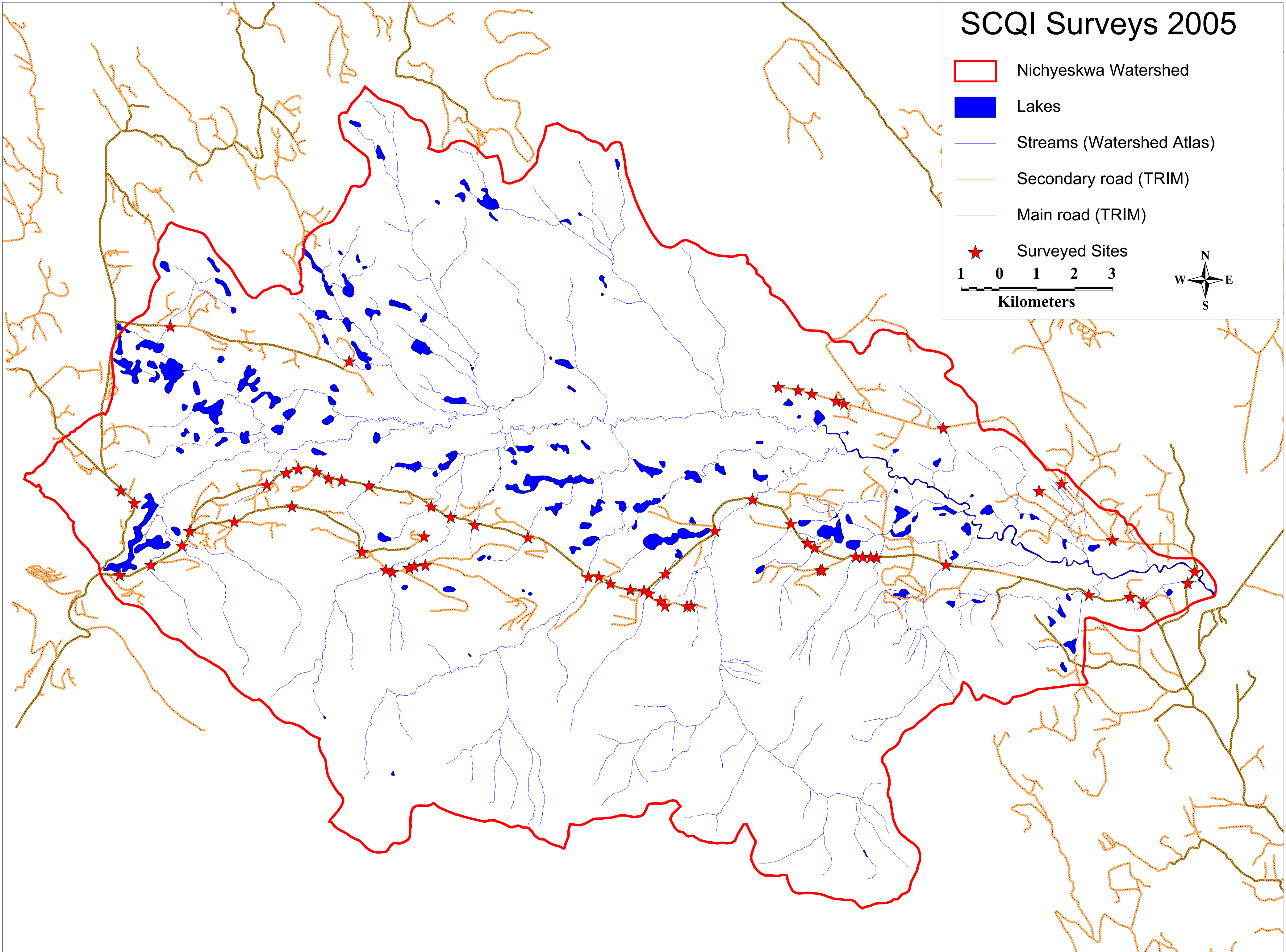


Figure 1. Location of all stream crossings surveyed in the Nichyeskwa watershed in 2005.

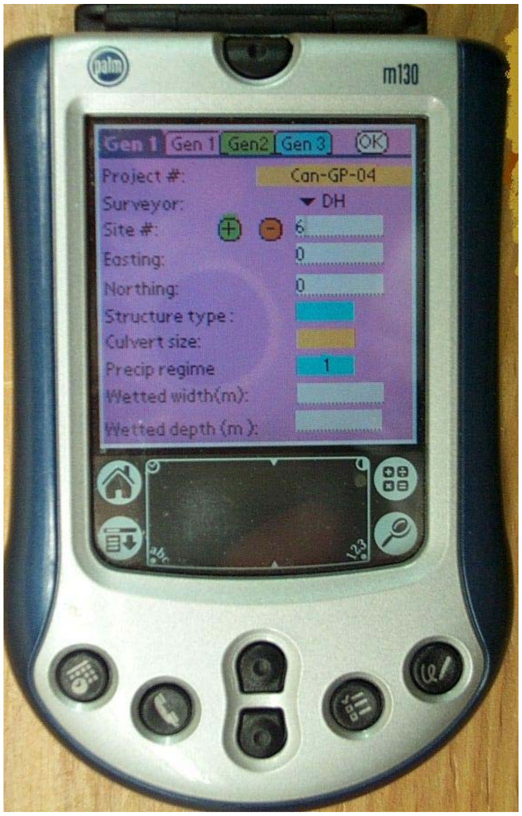
The field survey focused on evaluating the potential for erosion and sediment delivery at each stream crossing. The majority of the surveying was done using ATVs and occasionally a pick-up truck to maximize efficiency. Situations where walking was the only access choice were kept to a minimum, mainly because of the expense associated with walking any significant distance. In most instances, roads were travelled to the end where a survey point of commencement (POC) was marked. On roads where the surveyor could only access part of the road, a survey POC was marked at a turnaround spot. All survey POC's were marked using a Geographic Positioning System (GPS).

Crossings were only assessed if they were considered streams or if they had the potential to impact a stream. For running water to be considered a stream there had to be significant scour and a defined channel. When water that was not considered part of a stream was flowing through a crossing and it had the potential to reach a stream it was included in the SCQI survey. This often occurred on roads with tight switchbacks leading to a stream crossing or when roads ran parallel to streams. In situations such as this, the road cut can expose ground water and, even when drainage control is practiced through the use of cross drains, the flows in the ditchline are high enough and the road is close enough that this water connects directly to the stream. The ability of the ditch water to reach the stream is primarily a function of the proximity to the stream, the vegetation complex between the road and the stream and the steepness of the slope. The decision to include the "crossing" in the survey was made based on the above and the experience of the surveyor. Each crossing assessed was marked using a GPS. All survey points have been transferred to a GIS Arcview Shape file, which includes the complete survey database. The Shape file along with all of the photographs taken during the survey are provided on a CD in Appendix 3.

3.4 SCQI Data Collection

All 2005 SCQI data were collected in the field using an electronic Palm Pilot™ Personal Digital Assistant (PDA) with a HanDbase™ 3.0 database solution that has been custom developed to capture and process SCQI survey data (Figure 2). The location of each survey point is collected in the field with a Garmin™ etrex GPS receiver. Data are downloaded from the PDA database and exported to a Microsoft Excel Spreadsheet where it is merged digitally with the GPS coordinates. Once all of the field data have been exported and merged in a spreadsheet format, the spreadsheet is imported into the Mapinfo Professional™ mapping/GIS solution for spatial analysis.

Survey results are presented in Section 3.0 of this report. The pictures taken at crossings during the SCQI survey are located on CD in Appendix 3. Reference for all data and pictures collected in the field are provided digitally as an ESRI™ SHAPE file.



Project #: Can-GP-04
Surveyor: DH
Site #: 6
Easting: 0
Northing: 0
Structure type:
Culvert size:
Precip regime 1
Wetted width(m):
Wetted depth (m):

Figure 2. Personal Digital Assistant (PDA) loaded with SCQI database on HanDbase™ software.

4.0 RESULTS

4.1 Nichyeskwa watershed

A total of 60 stream crossings were surveyed in the Nichyeskwa watershed in 2005, of which only 16.7% received a WQCR of High or Very High (Table 2). Of the crossings that were classed as high or very high WQCR, 70% were located over small streams (0.5 to 1.5 m in width) and 30% were located on moderate sized streams (class 3). Table 3 shows that most of the crossings surveyed (63%) were located over small streams (class 4) and only 8% of crossings surveyed were located over large streams (class 1 and 2). Overall, water quality concerns (i.e. increases in stream turbidity) were quite low in the Nichyeskwa watershed with 83% of the crossings surveyed generating a score of 0.7 or less.

Table 2 Water Quality Concern Ratings in the Nichyeskwa Watershed – 2005 survey results.

# of Crossings Surveyed	Water Quality Concern Rating (WQCR)									
	None		Low		Medium		High		Very High	
	#	%	#	%	#	#	%	#	%	#
60	11	18.3	29	48.3	10	16.7	8	13.3	2	3.3

Table 3 Water Quality Concern Ratings by stream width class in the Nichyeskwa Watershed – 2005 survey results.

Stream Width Class*	Total number per class	Water Quality Concern Rating (WQCR)									
		None		Low		Medium		High		Very High	
		#	%	#	%	#	%	#	%	#	%
1	1	1	1.67	0	0	0	0	0	0	0	0
2	4	1	1.7	3	5	0	0	0	0	0	0
3	17	2	3.3	9	15	3	5	3	5	0	0
4	38	7	11.7	17	28.3	7	11.7	5	8.3	2	3.3
5	**Class 5 streams were not surveyed in 2005**										

* 1=Greater than 20m 2=5-20 m 3=1.5-5 m 4=0.5-1.5m 5=Less than 0.5

4.2 Interpretation of the Results

The SCQI procedure has been validated over the past several years by measuring induced turbidity levels (i.e. the turbidity caused by the stream crossing) at over 50 stream crossings in BC and western Alberta. The validation procedure measures continuous turbidity levels above and below selected stream crossings using electronic turbidity sensors and data-loggers (Beaudry 2004). The turbidity data, collected for the central BC sites, shows a very good relationship between the SCQI score and the average measured induced turbidity (Figure 3). This indicates that the SCQI tool does a reasonably good job at predicting increases in turbidity caused by the stream crossing and thus can be used as an SFM indicator for the protection of water quality.

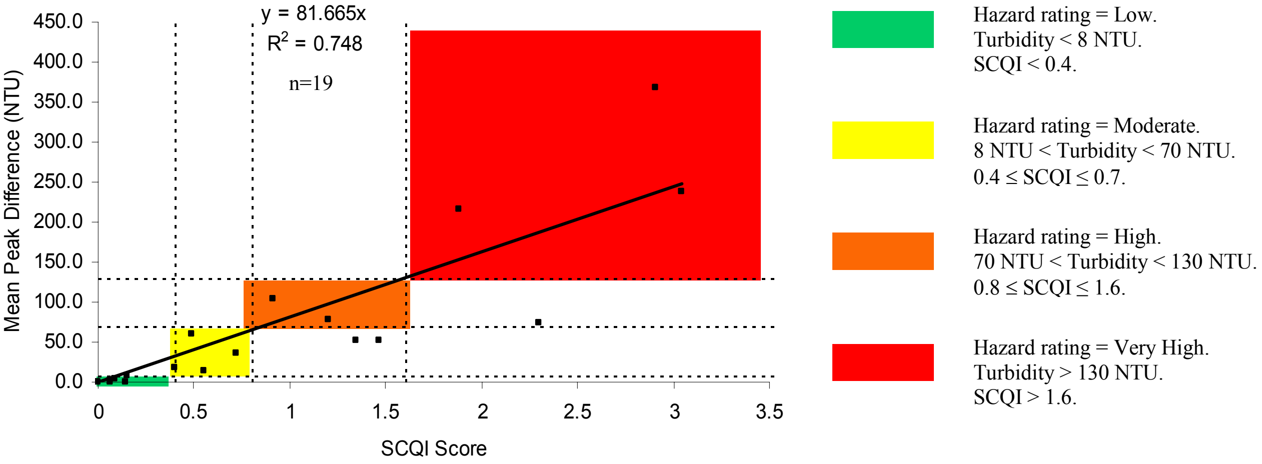


Figure 3. Relationship between SCQI score and induced turbidity (mean peak difference NTU).

As an example of the validation results, the expected turbidity response from a stream crossing scored in the range of 0.8 to 1.2 (i.e. high WQCR) would typically look like the graph presented in Figure 4 (P. Beaudry and Associates Ltd 2004). Note that the peak of induced turbidity lasts only about 30 minutes (each bar represents rainfall intensity over a 15 min period). These results are very typical of crossings classed in the high category for central BC. Thus, the SCQI survey for the Nichyeskwa watershed, shows the vast majority of stream crossings sampled (83%) would have induced turbidities less than those represented by Figure 4. According to Newcombe (2003) this means that the vast majority of crossings in this watershed will not induce turbidity levels that are generally considered to be harmful to fish habitat. A full E-size map showing the location and WQCR of each stream crossings surveyed in the Nichyeskwa watershed in 2005 is provided in Appendix 2.

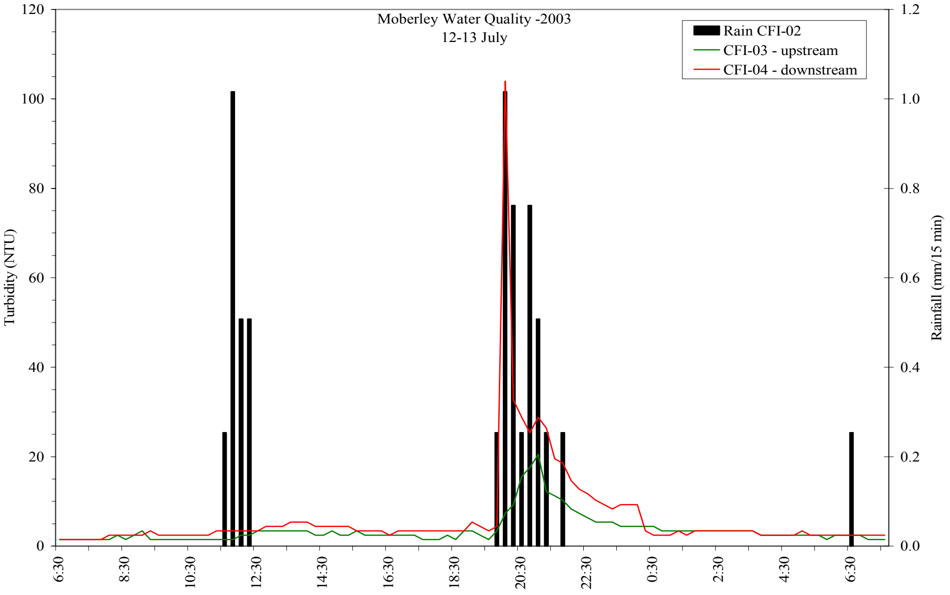


Figure 4. Example of measurement of induced (red) turbidity, where the downstream turbidity peak is about 80 NTU greater than the upstream peak (green).

5.0 SELECTED PHOTOS FROM FIELD ASSESSMENTS

5.1 Selected Photographs of crossings with a High or Very High WQCR

Approximately 16.7 % of the crossings surveyed in the 2004 field season were rated at high or very high in terms of water quality concern. A stream crossing with a high or very high WQCR will likely result in accelerated delivery of fine sediment to the streams, which will in turn cause an increase in turbidity above the acceptable provincial standards (although the increase will likely be of short duration). This section provides a series of pictorial examples to illustrate these problems.

All photos for crossings surveyed in the Nichyeskwa watershed in 2005 have been included on the digital photo CD ROM enclosed in Appendix 3.

Figure 5. Crossing RC-15, cut-slope sediment source

Figure 6. Crossing RC-16, slope/ditch sediment source

Figure 7. Crossing RC-42, Stream diverted down ditch

Figure 8. Crossing RC-21, small road failure directly into stream

5.2 Selected Photographs of crossings with a Moderate WQCR

Approximately 16.7 % of the stream crossings surveyed in the Nichyeskwa watershed in 2005 were given a rating of moderate for water quality concerns. This means that during large rainfall events, the crossing will likely cause an increase in stream turbidity that is slightly higher than provincial water quality guidelines, and typically only for a very short duration. According to Newcombe (2003), this type of turbidity event does not cause a significant impairment to fish habitat This section provides examples of several crossings of a moderate water quality concern.

 11. 7. 2005	 12. 7. 2005
Figure 9. Crossing RC-02, some sediment is making it from the road surface to the stream	Figure 10. Crossing RC-17, Some sediment is still be eroded from the ditchline and transported to the stream.
 12. 7. 2005	 13. 7. 2005
Figure 11.Crossing RC-19,sediment is being delivered from the road surface	Figure 12. Crossing RC-40, sediment delivered from road and ditches surface

5.3 Selected Photographs of crossings with a Low WQCR

Crossings with a low water quality concern rating made up the largest component of those surveyed in the 2005 season at approximately 48.3 %. These are crossings with very minor to slight problems concerning sediment delivery to the stream. This section provides examples of typical crossings with a low WQCR.

Figure 13. Crossing RE4, some minor sediment is delivered from road

Figure 14. Crossing RE6, some minor sediment is delivered down the ditch

Figure 15. Crossing RE14, Some minor sediment is delivered to the stream from the road surface and onto the bridge deck and then into stream.

Figure 16. Crossing RC14, Some minor sediment is delivered from the road and down the ditch.

5.4 Selected Photographs of a None WQCR

A component of the stream crossings surveyed in the Nichyeskwa watershed during the 2005 season (18.3 %) received a WQCR of None. This indicates that there were no visible signs of sediment delivery to the stream caused by crossings.


13. 7. 2005

Figure 17. Crossing RC26, Nitchyeskwa River – no sediment delivery


11. 7. 2005

Figure 18. Crossing RC05, elevated bridge – no sediment delivery


13. 7. 2005

Figure 19. Crossing RC11, no sediment delivery issues identified


11. 7. 2005

Figure 20.Crossing RC12, no sediment delivery issues identified

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Babine Watershed Monitoring Trust 2005 Annual Monitoring Plan Approved: May 2005

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APPENDIX 1. SCQI SCORING RATIONALE

The Stream Crossing Quality Index (SCQI) is a field based exercise that systematically assesses the hazard of road originated sediment sources at stream crossings as a potential impact to water quality. A variety of sediment source characteristics, which may have potential to deliver sediment to the stream, are examined in the field. The purpose of this document is to provide explanations and examples of the components used to assess the sediment source hazard and delivery potential at stream crossings.

Assessment Procedure and Description

The primary sources of road related sediment at stream crossings are the road surface, the ditchlines, and the cut and fill slopes. For the purposes of the SCQI assessment, each crossing is divided into eight "elements": (1) right back ditchline, (2) right front ditchline, (3) left front ditchline, (4) left back ditchline, (5) front fill slope, (6) back fill slope, (7) right road surface, and (8) left road surface (Figure A1-1). Each component is assessed and scored for its erosion potential and also the potential for the eroded material to be delivered to the stream network.

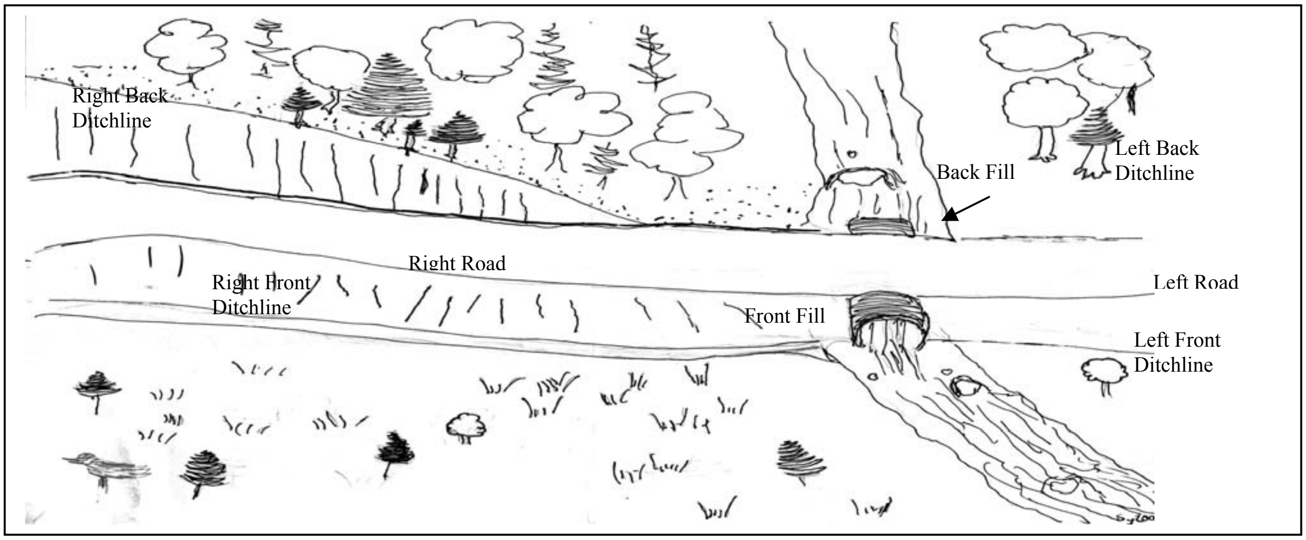

Figure A1-1. Diagram of the components assessed during an SCQI survey.

The SCQI score for each element of each individual crossing is a product of the *erosion potential* and the *delivery potential* of the sediment source. The erosion potential is a function of several factors that include the following:

1) the gross size of the sediment source,
2) the % effective area of the sediment source,
3) the % erosion control cover of the effective area,
4) the shape of the ditch and the size of its side slopes,
5) the soil texture of the source,
6) the slope of the source, and
7) the level of road use.

Each of these factors are measured, or assessed, and assigned a value. The erosion potential is computed as the product of these seven values. This number is then multiplied by the delivery potential to generate a sediment source hazard score, termed the "individual crossing score". The following text provides a description of each of these factors, how they are measured or assessed and how they are rated.

We define the "sediment source" as the "contributing watershed area" of each sediment source feature. This is simply the area that is topographically able to direct suspended sediment towards the stream. Once the sediment source area is determined, it receives a score based on Table A1-1. For example, if a sediment source feature is determined to have an area of 12 m^2, it receives a score of "0.5".

Table A1-1 Sediment source area scores.

Size (m^2)	Score	Size (m^2)	Score	Size (m^2)	Score
0	0	**100-150**	3	**700-750**	15
0-1	0.1	**150-200**	4	**750-800**	16
1-2	0.2	**200-250**	5	**800-850**	17
2-4	0.3	**250-300**	6	**850-900**	18
4-8	0.4	**300-350**	7	**900-950**	19
8-14	0.5	**350-400**	8	**950-1000**	20
14-20	0.6	**400-450**	9	**1000-1050**	21
20-26	0.7	**450-500**	10	**1050-1100**	22
26-32	0.8	**500-550**	11	**1100-1150**	23
32-40	0.9	**550-600**	12	**1150-1200**	24
40-50	1	**600-650**	13	**1200-1250**	25
50-100	2	**650-700**	14	**Etc.**	

The % effective sediment source area modifier adjusts the sediment source area defined in Table A1-1 to account for erosion control features that have effectively made portions of the contributing watershed area non-erodible (see Table A1-2). Examples of erosion control that would reduce the % effective sediment source area include forest floor with developed LFH layer, 100% grass cover with developed humus layer or area that is essentially bedrock.

Table A1-2 Effective sediment source area scores.

% Effective Area	Score	% Effective Area	Score
less than 5	0.05	**50-55**	0.55
5-10	0.1	**55-60**	0.6
10-15	0.15	**60-65**	0.65
15-20	0.2	**65-70**	0.7
20-25	0.25	**70-75**	0.75
25-30	0.3	**75-80**	0.8
30-35	0.35	**80-85**	0.85
35-40	0.4	**85-90**	0.9
40-45	0.45	**90-95**	0.95
45-50	0.5	**95-100**	1

The % erosion control cover accounts for processes that have occurred within the effective sediment producing area that reduce the erosion potential. The following list includes the type of characteristics that develop within a sediment source that reduce its erodibility (i.e., potential of sediment from a given source to become suspended and transported):

a) Extent and type of vegetative cover (e.g., grass, shrubs, herbaceous vegetation)

b) Extent and type of erosion control materials (e.g., straw mulch, debris, etc.), or

c) Stoniness of surface (i.e., how armoured is the sediment source or how much of the fines have been washed away by rain and other erosion processes over time).

Based on these characteristics, the surveyor makes a visual estimate of the extent to which the effective sediment source area should be further reduced to account for erosion control that has occurred (see Table A1-3). For example, the effective sediment source area of a road surface with low activity that has 50% cover of pea gravel and stones emerging after the fine sediment has washed off the top receives a score of 0.53.

Table A1-3 Percent (%) erosion control cover scores.

% Cover	**Score**	**% Cover**	**Score**	**% Cover**	**Score**
0	1	**35-40**	0.63	**75-80**	0.23
2-5	0.98	**40-45**	0.57	**80-85**	0.17
5-10	0.93	**45-50**	0.53	**85-90**	0.13
10-15	0.87	**50-55**	0.47	**90-95**	0.08
15-20	0.83	**55-60**	0.43	**95-98**	0.05
20-25	0.77	**60-65**	0.37	**> 98**	0
25-30	0.73	**65-70**	0.33		
30-35	0.68	**70-75**	0.28		

The “Soil Texture Class” modifier is based on the various soil texture classes and their degree of compaction. Each textural class is assigned a value (Table A1-4) that is incorporated into the final SCQI calculation. For example, pure silt that has a Low compactness level receives a score of 0.86. Highly compacted clay is less erodible than pure silt and receives a score of 0.41. The soil textural class score modifies the element score to account for the difference in erosion characteristics that result with different soil textural classes (e.g., with the exception of clay and its cohesiveness, smaller particle sizes are more easily eroded than larger particles). These soil texture classes relate to how easily the material can be eroded from its source and is used to estimate erosion potential. The water quality monitoring work of 2004 identified that a different set of soil texture modifier scores need to be developed for use in the estimation of delivery potential (i.e., how easy the material can be transported). This is important because the erosion characteristics of a certain soil are not necessarily the same as the transport characteristics. For example a sand is easily eroded but because of its size and weight is not easily transported. On the other hand a clay particle is relatively difficult to erode because of it cohesiveness, yet is very easily transported in water once it is eroded. One of the major changes to the SCQI procedure in 2004 was the introduction of this concept in the estimation of the delivery potential.

Table A1-4 Soil texture class modifier scores to estimate erosion potential.

Soil Textural Class	**Soil Compactness Level**			
	L	**M**	**H**	**V-H**
Very Fine Sand	0.9	1.0	0.8	0.65
Silt	0.86	0.97	0.77	0.66
Silt-Loam	0.8	0.88	0.7	0.55
Silty-Clay Loam	0.7	0.74	0.6	0.5
Clay	0.46	0.51	0.41	0.31
Sandy Loam	0.27	0.3	0.24	0.19
Medium Sand	0.14	0.16	0.13	0.09
Coarse Sand	0.013	0.014	0.011	0.008
Stones and Gravel	0.006			

The "Road Use Level" modifier refers to activity/maintenance level of the road and crossing. Table A1-5 presents the road use level categories and the score that each receives. Frequent grading disturbs the fine, more erodible material, so roads with high activity are assigned a higher score. It is our observation that high ATV traffic can cause substantial disturbance to the surface of the road pullbacks/stream banks and can tear up vegetation/erosion control structures that are already in place. For this reason, deactivated roads with evidence of frequent ATV use are assigned a higher score than ones with occasional use. Abandoned roads are assigned the lowest score because they have had time to stabilize, and vegetation cover is usually abundant.

Table A1-5 Road use level modifier scores.

Road Use Level	**Score**
Active mainline	1.0
Active branch line	0.99
Moderate activity (occasional grading)	0.95
Low activity (no grading, crossing structure still present)	0.90
De-activated (crossing structures removed)	
-used extensively by 4 wheelers	0.92
-minor use by 4 wheelers	0.85
-no 4 wheeler use evident	0.80

Gradient of the sediment source towards the stream is measured to account for the erodible force of flowing water. As the gradient increases, water flows faster and has increased potential to erode the surface it is flowing over. Furthermore, high, fast flows are not only able to suspend more material than low, slow flows, but they are also able to suspend and transport a larger range of particle sizes (i.e., coarser material). Thus, the assigned modifier score increases with the steepness of the slope (Table A1-6).

Ditchlines are unique in that they are comprised of two side slopes as well as the main water flow surface. The shape of the ditch and steepness of the side slopes are an important "erosion potential" characteristic of any ditch sediment source. The conceptual image of a ditch is that of a small scale valley. Each of the side slopes can be of differing gradients, just as the gradient of the main surface perpendicular to the stream gradient is site-specific. Precipitation falling in the local area can flow over all of the three surfaces, and thus the erosion potential of each must be incorporated into the overall SCQI score. The main surface is accounted for by the average gradient modifier list in Table A1-6. The two side slopes are addressed by incorporating a ditch shape variable. Each ditch starts out with a score indicated by the ditch shape (see Table A1-7), which also acts as a modifier to the total sediment source size. There are two main types of ditch shape, being ‘V’ or ‘U’. The difference between the two is that the ‘V’ shape indicates a greater potential for down-cutting than the ‘U’ shape, which corresponds to a higher rate of erosion. All the possible permutations of steepness for the two side slopes from very steep down to flat modify the ditch shape score further. For example, a ditch that is V-shaped and both side slopes are very steep will get a score of 1.55, while a U-shaped, flat sloped ditch will get a score of 0.85. Since the ditch shape score acts as a modifier of the sediment source size, a very steep V-shaped ditch will result in a much higher score than will a flat U-shaped ditch, for the same sized sediment source.

Table A1-6 Slope modifier scores.

Gradient	Score	Gradient	Score
away from stream	0	**7%**	0.65
0.1 to 1%	0.1	**8%**	0.72
1%	0.15	**9%**	0.81
2%	0.22	**10%**	0.85
3%	0.26	**11%**	0.9
4%	0.35	**12%**	0.96
5%	0.46	**greater than 12%**	1
6%	0.55		

Table A1-7 Ditch shape modifiers.

	Score	
Gradient of Ditch Slopes (Two Slope Combination)	**V-Shaped**	**U-Shaped**
Very Steep and Very Steep	1.55	1.4
Steep and Very Steep	1.45	1.3
Gentle and Very Steep	1.35	1.2
Flat and Very Steep	1.1	1.1
Steep and Steep	1.35	1.2
Gentle and Steep	1.25	1.1
Flat and Steep	1.15	1.0
Gentle and Gentle	1.15	1.0
Flat and Gentle	0.9	0.9
Flat and Flat	0.85	0.85

The values for each of the modifiers used in determining the “erosion potential” are based on the concepts and values developed for the Revised Universal Soil Loss Equation (RUSLE) presented in Wall et al. (2002). The universal soil loss equation was initially developed by Wischmeier and Smith (1965). The objective of the RUSLE is to provide a quantitative tool to assess the potential for soil erosion at a given site. RUSLE is based on measurements of rainfall intensity, soil texture, gradient of slope, length of slope and erosion control practices. The values for the different variables in the equation are continuously being refined by a large collective of soil scientists in both the United States and Canada.

The "delivery potential" is intended to be an estimate of the amount of eroded material that will reach the aquatic environment thus causing an increase in stream turbidity. It is expressed as a percentage of the erosion potential, and thus receives a score of between 0 and 1, the value of 1 meaning that it is expected that 100% of the eroded material will reach the stream. Initially, the delivery potential was estimated based on a few key visual indicators and through a relatively subjective process a delivery score was assigned. It eventually became evident that a more objective process needed to be developed, similar to the process used to estimate the erosion potential. The estimation of the delivery potential needed to be based on the description of several physical factors that control this process. It was decided that the key processes that control sediment delivery along a ditchline or road surface and that can be relatively easily described and scored are as follows: 1) the size of the sediment control feature or structure relative to the total size of the sediment source, 2) the type of sediment control practice that is implemented, 3) the dominant soil texture of the erodible material, and 4) the location of the sediment control practice relative to the water course.

The development of a more objective procedure for estimating delivery potential is fraught with several challenges. These include: 1) the lack of a formal published process, like the Universal Soil Loss Equation (USLE), that can serve as a template for choosing and scoring meaningful variables (note the USLE is used to estimate erosion potential only and does not have a true delivery component), 2) the stated objective of the SCQI process is to be a "simple and quick" procedure and thus the estimation of delivery potential should be relatively quick and simple and should avoid complex measurements that may add only a small marginal accuracy to the procedure, 3) the PDA database that we currently use for field data collection (i.e., HanDbase^{TM} 3.0) has a maximum of 100 fields which effectively limits how much data can be collected at any one site (this technological constraint is, in all likelihood, only temporary). The current process to estimate delivery potential is described below along with the scoring system. This process will likely continue to evolve if a demand for increased accuracy is expressed.

The first step in the estimation of the delivery potential is to determine the size of the sediment control feature relative to the size of the sediment source (brief reminder for the reader: a sediment control practice is intended to reduce the transport of sediment that has already been eroded, while an erosion control practice is intended to reduce the erosion itself). Sizes are categorized into three classes; small, medium and large. A large sediment control feature is defined as one that covers 50% or more of the sediment source, a medium is defined as covering 10 to 50% of the sediment source and a small only covers 10% or less of the size of the sediment source.

The next step involves the categorization of the type of sediment control practice that is being utilized. At this time we are using only two categories, which include 1) a retention type practices such as a sediment pond or a dyke, or 2) a filter type practice such as grass, organic material and, in certain circumstances, a structure like a sediment fence. The assumption here is that a retention type practice is generally more effective than a filter type and consequently the delivery potential will be less for a retention type. Unfortunately, in the real world the categorization is usually not “cut and dry” and in many cases it is some combination of filter and retention. Thus, choosing the appropriate category remains somewhat subjective and is based on what the assessor determines to be the dominant type.

The third step involves an evaluation of the “effectiveness” of the sediment control practice. The choice of a particular practice may have been appropriate; however the implementation of the practice may have been poorly done or ineffective. This variable is meant to score the effectiveness of a particular sediment control feature for a particular soil type. For example, a moderately thick cover of grass and organic matter may be quite effective for a sandy loam, however it would be mostly ineffective for the fine silty soils found in the Peace region of north eastern BC and west central Alberta.

Table A1-8 provides a list of the choices that are available to the assessor in the field when determining sediment control size, type and effectiveness. The table also provides the corresponding scores for each of the selections. These selections appear as a “pop-up” choice on the field PDA and the corresponding score is automatically entered into the SCQI equation as part of the determination of the total “sediment delivery” score for a particular element.

Types of erosion control such as application of grass seed and hay (mulch) will not only reduce the effective sediment source size (depending on its comparative size), but also act as a filter that slows water movement and facilitates deposition of sediment on route, potentially resulting in a reduction in delivery that is scored on a site specific basis. Sediment basins and check dams are other sediment control structures that can also reduce delivery potential by interrupting the flow, reducing the effective gradient of the ditchline and creating a depositional area for the coarser sediments to fall out of suspension (i.e., retention). The effectiveness of the filter and/or retention structures also influences the amount of sediment delivered to a stream. For example, if a retention pond has a high percentage of spill (e.g., 30-50 %), than it is less effective at trapping sediment than a pond that allows for less spill (e.g., < 5 %). As well, the effectiveness of a filter buffer is dependent on the type of filter (e.g., grasses versus shrubs) and its thickness. If a grass filter is sparse, it will be less effective than a thickly established grass buffer.

Table A1-8 Sediment control measure size, type, and effectiveness.

Sediment Control Size[1] and Type[2]	**Sediment Control Effectiveness**	**Score**
100 % filter coverage	Thick and effective	1.0
100 % detention or diversion	No transport to stream possible	1.0
Large retention	< 5 % spill	0.9
Medium retention	< 5 % spill	0.8
Large retention	5-30 % spill	0.8
Large filter coverage	Thick and effective	0.8
Large retention	30-50 % spill	0.7
Medium filter coverage	Thick and effective	0.7
Small retention	< 5 % spill	0.7
Medium retention	5-30 % spill	0.7
Medium retention	30-50 % spill	0.6
Small filter coverage	Thick and effective	0.55
Small retention	5-30 % spill	0.5
Large filter coverage	Moderate effectiveness	0.5
Medium filter coverage	Moderate effectiveness	0.25
Large filter coverage	Weak effectiveness	0.25
Small retention	30-50 % spill	0.2
Medium filter coverage	Weak effectiveness	0.15
Small filter coverage	Moderate effectiveness	0.15
Small filter coverage	Weak effectiveness	0.05
None	No deposition, direct delivery	0

[1] *Large* = > 50%, *medium* = 10-50%, and *small* = < 10% of the effective sediment source size. [2] *Retention* refers to settling pond, dyke, sediment fence, dam-type obstacle (e.g., log), or similar structure, while a *filter* is grasses, shrubs, rocks, or other debris that slows water flow. Note that a retention structure with >50% spill is a filter. Scores assume that the sediment control measure has the most effective location.

The location of sediment control structures, relative to the location of the stream, is also considered as a very important variable when determining the sediment delivery potential. A sediment control structure applied adjacent to the stream will regulate sediment transport from a greater area than those located further from the stream. For example, a dyke placed in a ditch next to the stream will receive waters from more of the ditch area than a dyke installed 10 m up the ditchline. Table A1-9 provides the list of options that are used to characterize this variable and the corresponding scores. The final "potential delivery" score for any single element is computed as follows: 1-(score from Table A1-8 multiplied by the score from Table A1-9). In essence, the delivery potential score for each individual element attempts to answer the question: "How much of this actively eroding sediment source is actually reaching (or is likely going to reach) the stream?"

It is important to note that the relatively simple SCQI procedure, described above, cannot quantify sediment deliver precisely (e.g., kg/year) and its intent is not to do so. However, we believe that this system can be used to "score" the relative hazard level of different sediment sources within an operating area to determine: 1) the magnitude of the road related sediment source problem out on the landscape and 2) priorities for erosion and sediment control activities to minimize impacts to water quality.

Table A1-9 Sediment control measure location relative to stream.

Sediment Delivery Potential Description	**Score**
Sediment control is located essentially everywhere along the sediment source	1.0
> 2 proximal to stream	1.0
1 adjacent,+ 1 10-40% up	0.95
1 only-adjacent to stream	0.9
1 adjacent + 1 > 40% up	0.9
1 >20%, + 1>50%	0.8
> 2 > 30% up from stream (none proximal)	0.8
1 only-10-40% up from stream	0.7
1 only->40% up from stream	0.6
no retention or filtering	0

The SCQI equation for each individual element of a crossing is as follows:

Element Score = SS *DS* %E * EC* SL * TC * RU * D

Where:
SS = Sediment Source Area score
DS = Ditch shape modifier (used only for the ditches)
%E = Effectiveness Sediment Source Area Modifier
EC= Percent Erosion Control Modifier
SL = Slope Modifier
TC = Textural Class Modifier
RU = Road Use Level Modifier
D = Delivery = (1-(Sediment Control Size/Type/Effectiveness * Sediment Control Location)

The total score for the crossing is simply the addition of the eight scores for each of the individual elements.

Crossing Score = ∑ of the eight element scores

To assist in the interpretation and understanding of the sediment source hazard scores, five water quality concern rating (WQCR) classes have been created. These five classes are “none”, “low”, “moderate”, “high”, and “very high”. For example, a “high” WQCR means that the sediment source hazard is large enough that there is a “high” level of concern for negative impacts to water quality caused by increased sediment delivery to the stream. The relationship between the individual crossing scores and the WQCR classes is provided in Table A1-10 below.

Table A1-10 Relationships between the individual crossing scores and the WQCR.

Score	**WQCR**
<0.1	None
0.1 ≤ score < 0.3	Low
0.4 < score < 0.7	Moderate
0.8 < score < 1.6	High
> 1.7	Very High

Although the main focus of the SCQI survey is to assess the erosion and sediment delivery potential at stream crossings, additional data/information that is useful for analyses and access management purposes is also collected by the SCQI surveyor at the crossing. Additional data/information collected during the SCQI survey that is not factored into the final score includes the following:

1. Unique crossing identifier
2. Northing
3. Easting
4. Crossing structure type
5. Culvert diameter (if applicable)
6. Wetted Stream Width
7. Wetted Stream Depth
8. Stream gradient class
9. Stream width class
10. Functional condition of structure
11. Percentage (%) of structure plugged
12. Culvert outfall drop (in centimetres)
13. Substrate in culvert (y/n)
14. Channel Constriction (y/n)
15. Photo numbers
16. Erosion and sediment control site prescriptions for each element (when appropriate)

The following Tables A1-11 through A1-14 define the codes used in the SCQI field survey to record and identify some of the additional information that is collected.

Table A1-11 Functional condition of crossing structure.

Functional condition of structure	Code
Structure working as designed	1
Ends of the culvert are partly crushed or plugged	2
Ends of culvert are mostly crushed	3
Bridge structure showing signs of failing components	4
No structure	5

Table A1-12 Crossing structure type.

Crossing structure types	Code
Clear span bridge	1
Bridge encroaches Wb	2
Arch Culvert	3
Wooden culvert	4
Corregated metal pipe	5
Designed ford	6
No structure	8

Table A1-13 Stream gradient class.

Stream Gradient Class	**Code**
less than 1 %	1
1 to 5 %	2
6 to 10 %	3
11 to 15 %	4
16 to 20 %	5
>20 %	6

Table A1-14 Proportion of crossing structure that is plugged.

% of Structure Plugged (inlet)	**Code**
0-25	1
25-50	2
50-75	3
75-100	4

APPENDIX 2. MAP OF SCQI CROSSINGS SURVEYED IN THE NITCHYESKWA WATERSHED FOR 2005

APPENDIX 3. PHOTOGRAPHS AND SHAPE FILES ON COMPACT DISC OF STREAM CROSSINGS SURVEYED IN 2005