FREP

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FOREST AND RANGE EVALUATION PROGRAM

December 2013

Provincial Water Quality Effectiveness Evaluation Results (2008-2012)

Prepared by:
Brian Carson and Dave Maloney

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Sustainability of Forest and Range Resources Through Science and Stewardship

MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS
FOREST AND RANGE EVALUATION PROGRAM

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This report will be updated periodically—if you have any edits, corrections, or other feedback, please email Peter Bradford **Peter.Bradford@gov.bc.ca**

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British Columbia

Management of forest and range resources is a complex process that often involves the balancing of ecological, social, and economic considerations. This evaluation report represents one facet of this process. Based on monitoring data and analysis, the Timber resource value team offers the following recommendations to those who develop and implement forest and range management policy, plans, and practices.

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EXECUTIVE SUMMARY

British Columbia's Water Quality Effectiveness Evaluation (WQEE) protocol evaluates the propensity of forestry-disturbed sites to generate and transport fine sediment to natural water bodies, which include fish streams and (or) drinking water sources. The outcome provides a means to rank sampled sites into "Very Low," "Low," "Moderate," "High," and "Very High" fine sediment generation classes. These classes were originally formulated on the basis of discussions with sedimentologists, hydrologists, fisheries biologists, district staff, licensees, and water purveyors, and reflect their consensus on the severity of impact a particular site may have on a watershed's water quality. The protocol also provides a simple and repeatable means of flagging potential fecal contamination from rangelands where domestic water intakes occur downstream.

Between 2008 and 2012, the Forest and Range Evaluation Program used the WQEE protocol to sample fine sediment generation potential at 4033 randomly selected sites in 24 forest districts. Of these sites, 34% were classified as "Very Low," 37% as "Low," 24% as "Moderate," 4% as "High," and 1% as "Very High." When an evaluation was conducted on 398 sites located upstream of a drinking water intake, the results were similar—28% of sites were classified as "Very Low," 39% as "Low," 29% as "Moderate," 4% as "High," and 0% as "Very High."

A list of specific recommendations are provided in the protocol that evaluators select from and highlight to reduce water quality impacts at sites with a "Moderate," "High," or "Very High" fine sediment generation rating. Problems with road management, and associated solutions, are focussed on five operational areas: (1) road location; (2) design of roads and cutblocks; (3) construction of roads and harvesting; (4) road maintenance; and (5) road deactivation. The importance of addressing fine sediment reduction is apparent through all stages of a road's life, especially when roads are located in proximity to a stream. The use of appropriate techniques in design, construction, and maintenance of road networks can mitigate many situations that may have negative water quality impacts. Generally, risk of fine sediment generation ends only when a road is properly deactivated.

Some recognized situations that lead to water quality impacts, such as locating a road too close to a stream, may be impossible to address without relocating road. This fact emphasizes the need for careful consideration to road locations around streams. Other sediment related issues are easy to address. For example, improved management of grader berms can be a timely, simple, and cost-effective solution.

Of a total of 194 range evaluations completed in four forest districts between 2008 and 2012, more than 68% indicated that water quality may have been negatively affected by fecal contamination. The main indicators identified as leading to fecal contamination risk were a lack of livestock control structures, evidence of livestock drinking directly in a stream, and the presence of livestock feces immediately adjacent to stream banks.

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Districts* included in this report

Region (region office)	District (district office)	District Abbreviation
Coast (Nanaimo)	Campbell River (Campbell River)	DCR
	Haida Gwaii (Queen Charlotte City)	DQC
	North Island–Central Coast (Port McNeill)	DNI
	South Island (Port Alberni)	DSI
	Chilliwack (Chilliwack)	DCK
	Metro Vancouver–Squamish (Squamish)	DSQ
	Sunshine Coast (Powell River)	DSC
Cariboo (Williams Lake)	100 Mile House (100 Mile House)	DMH
	Cariboo-Chilcotin (Williams Lake)	DCC
	Quesnel (Quesnel)	DQU
Kootenay/Boundary (Cranbrook)	Selkirk (Nelson)	DKL
	Rocky Mountain (Cranbrook)	DRM
Thompson/Okanagan (Kamloops)	Okanagan Shuswap (Vernon)	DOS
	Thompson Rivers (Kamloops)	DKA
	Cascades (Merritt)	DCS
Skeena (Smithers)	Kalum (Terrace)	DKM
	Nadina (Burns Lake)	DND
	Skeena Stikine (Smithers)	DSS
Omineca (Prince George)	Fort St. James (Fort St. James)	DJA
	Mackenzie (Mackenzie)	DMK
	Prince George (Prince George)	DPG
	Vanderhoof (Vanderhoof)	DVA
Northeast (Fort St. John)	Peace (Dawson Creek)	DPC
	Fort Nelson (Fort Nelson)	DFN

* Data from the following five districts have been amalgamated with adjacent districts: Arrow Boundary (DAB), Chilcotin (DCH), Columbia (DCO), Headwaters (DHW), and North Coast (DNC).

1.0 INTRODUCTION

This report, which is intended for natural resource managers, water purveyors, and government monitoring staff:

- describes the protocol developed by British Columbia's Forest and Range Evaluation Program (FREP) to quantify the effect of forestry and range-related disturbances on water quality (Carson et al. 2009);
- summarizes the results of water quality monitoring conducted by FREP over the last five field seasons (2008–2012); and
- highlights opportunities to reduce the water quality impacts of forest and range use in British Columbia.

2.0 WATER QUALITY EFFECTIVENESS EVALUATION PROTOCOL

2.1 *Background*

The Water Quality Effectiveness Evaluation (WQEE) protocol (Carson et al. 2009) was designed to assess government policy that supports a "results-based" management style. The methodology requires an on-site evaluation of water quality impacts but does not (directly) assess specific prescriptions that may affect water quality. This provides road managers with greater flexibility and, theoretically at least, can be more cost effective than regulating potentially unnecessary prescriptions. For example, a culvert can be of any diameter or at any road spacing as long as it handles storm flows and does not generate excess fine sediment.

Research indicates that the most likely impact to water quality from forestry operations is from the input of sediment into streams, lakes, and wetlands (Hetherington 1987). The three main sources of sediment input are surface erosion, landslides, and streambank erosion (Hetherington 1987). In forest operations, sediment inputs from surface erosion usually occur from resource roads and skid trails (Hetherington 1987; Elliot 1999; MacDonald and Stednick 2003). Specific road sources are the road-running surface, cutslope, inside ditch, fillslope, and other areas subjected to concentrated road drainage (MacDonald and Stednick 2003). The highest erosion rates usually occur during road construction when the greatest volumes of fines are available for entrainment. After construction is completed, erosion rates generally decrease over time as disturbed sites develop an armoured surface or become revegetated. Nevertheless, hauling during wet periods generates a constant source of sediment from the road surface for the life of the road. Road grading, a maintenance activity that removes the road's armoured surface and exposes the underlying fines, also contributes to a high erosion rate (MacDonald and Stednick 2003).

The sediment particle sizes most detrimental to fish and water quality are 2 mm or smaller in diameter (Reid and Dunne 1984; Waters 1995; Lowe and Bolger 2000; Nerbonne and Vondracek 2001; Singleton 2001). These particles remain in suspension with minimal water movement, thereby increasing turbidity and limiting feeding opportunities for fish. The particles also abrade fish gills and affect fish reproduction rates by smothering spawning habitat and by filling the interstitial spaces between gravel particles where eggs are laid for incubation (Cederholm et al. 1980).

Range activities may result in stream and riparian impacts, including alterations to watershed hydrology, changes in stream morphology, compaction and erosion of soil, damages to riparian vegetation, and degraded water quality. The most common pollutants resulting from range activities involve the introduction of pathogens, siltation, habitat alterations, organic enrichment, and nutrients (Agouridis et al. 2005).

Drinking water purveyors are concerned about any land use that increases turbidity and pathogen levels within their water source area. Turbid waters are not only unsightly but can seriously reduce the effectiveness of water disinfection treatment.

FREP's Water Quality Effectiveness Evaluation methodology assesses the potential for introduction of fine-textured sediment during forestry operations by defining the disturbed areas that result in surface erosion and mass wasting and determining their connectivity to water bodies. Evaluators then classify the site's sediment generation potential.

2.2 *Estimating Rates of Surface Erosion*

A considerable body of research has focussed on sediment generated on forested lands, including forest roads. This research has led to estimates of the magnitude of sediment generation expected over a year. Undisturbed forest surfaces do not generate any surface erosion and can be ignored in any estimation of sediment generation. In the absence of any conservation practices, newly exposed, fine-textured surface soils that are common on slopes during road construction can erode a 1 cm depth over 1 year Megahan et al. 1983; Reid and Dunne 1984; Coe 2006). While erosion rates have exceeded 22 kg/m^2 per year (or 15 mm/yr), more typical values are in the range of 0.2–2.0 kg/m^2 per year (or 0.13–1.3 mm/yr) (MacDonald and Stednick 2003). These values are consistent with the range of erosion rates found by other researchers in environments similar to those in British Columbia.

Because of frequent and repeated disturbance by heavy vehicular traffic and by maintenance grading, erosion from road surfaces must be evaluated differently. A heavily used gravel road generates at least an order of magnitude more sediment than a lightly used road (Reid and Dunne 1984; Elliot et al. 2009). A frequently used mainline may generate as much as 10 tonnes per 100 m of running road surface, whereas a lightly used gravel road may generate less than 0.5 tonnes per 100 m (Coe 2006). Depending on the nature of their surfacing material, slope gradient, amount of traffic and moisture conditions, gravel road surfaces are subject to erosion rates ranging from nil to over 1 cm per year.

The developers of the WQEE protocol reviewed the Revised Universal Soil Loss Equation (U.S. Department of Agriculture 2003) as a preliminary basis for assessing the magnitude of erosion; however, its limitations in assessing effects on distinctly non-agricultural surfaces were recognized, along with the complications associated with water channelling via ditches, road ruts, and culvert outfalls. Washington State has developed a road surface erosion model (Elliot 1999; Dubé et al. 2004) that was also reviewed. Useful aspects of this model were incorporated into the protocol and the predictive outcomes of both models are similar.

2.3 *Estimating Sediment Inputs from Mass Failures*

The input of sediment into streams, lakes, and wetlands by a landslide is evaluated when it is apparent that the failure was a result of forestry operations. The volume of fine sediment reaching the stream is based on the volume of material moved, minus the amount still on-site, multiplied by the fraction of fine textured soil in the landslide material. This simple estimate of mass failure is used along with an assessment of predicted surface erosion to derive the water quality impacts generated at evaluated sites. The protocol does not account for the effect that large volumes of coarse sediment may have on channel stability and riparian function.

2.4 *Estimating Connectivity*

An estimate of connectivity between sediment source and stream is also required. The degree of connectivity may be as obvious as a road ditch flowing directly into a stream. In this case, the connectivity is 100% and the portion of sediment reaching the stream from the road is designated as “1.” In other instances, the partial filtering or infiltration effects of a forest floor or retaining pond must be considered when storm water is delivered to the forest floor by concentrated flow. To estimate the level of connectivity, the protocol considers the size of area drained (to estimate the volume of discharge) and the length of the non-channellized drainage issuing from the component. The degree of connectivity is presented as a table for field use.

2.5 *Classifying Site Sediment Generation Potential*

With an estimate of disturbed surface area, amount of erosion anticipated, and the connectivity, as well as the mass wasting contribution, a simple calculation provides a reasonable approximation of the amount of fine sediment entering a stream as a result of a forestry disturbance at the site evaluated. In this context, reasonable means that the value generated by the assessment falls within the range of the actual value determined in the field by an order of magnitude. If, for example, we estimate the fine sediment volume as 2 m^3, then this means the actual amount is closer to 2 m^3 than either 0.2 m^3 or 20 m^3. Although the layman may be astonished by this lack of precision, sediment generation and transport are exceedingly complex processes. A higher level of accuracy could only be attained through a much more complicated and costly evaluation methodology. Unfortunately, this higher level of accuracy will not provide commensurate value when directed toward management decisions. ***Current WQEE results adequately reflect the level of information required to recommend management options that address water quality impacts***. By reconsidering the individual surface components that are responsible for generating fine sediment, the evaluator can then quantitatively analyze how the impact might be mitigated through improved management activities.

Table 1 shows the breakdown of a site's "fine sediment generation potential" (or its "water quality impact rating") into five classes.[1] This classification indicates the degree of intensity appropriate for screening water quality impacts at a landscape level. These general classes, which reflect the experts' consensus on the severity of water quality impact a particular site may have on a watershed, were used to rate provincial WQEE outcomes.

Sites rated as "Very Low" generate insignificant amounts of sediment and are flagged as dark green in Table 1. Sites rated as "Low," flagged as light green, generate some sediment that is still within background levels of stream turbidity. "Very Low" or "Low" ratings are not related to potential impacts on water quality and would rarely be of concern to water purveyors downstream.

Sites with moderate levels of sediment generation resulted in more discussion between experts and a lower degree of certainty when assigning threshold values. The levels of increased sedimentation generated at "Moderate" sites, flagged as yellow in Table 1, would be measurable and of interest to watershed managers as indicating a need for caution. Of particular importance to such an evaluation is the concurrent need to address specific stream values downstream from the site, whether these values are related to fish or drinking water. If a drinking water intake or a critical salmon spawning bed was located 50 m downstream from the site, impact thresholds might be lower and the site may require further consideration; however, such an assessment of downstream consequences is currently beyond the scope of the WQEE protocol.

Sites with a "High" or "Very High" rating, flagged as orange and red in Table 1, are considered to generate unacceptable levels of fine sediment. Such sites would have a significant impact on water quality in a watershed.

This "traffic-light" classification scheme provides both the Ministry of Forests, Lands and Natural Resource Operations and the licensee with a means to discuss and prioritize water quality issues on specific sites requiring further consideration. Users are reminded that the procedure, being a routine or extensive evaluation conducted by non-specialists, cannot replace rigorous investigations by an experienced hydrologist or sedimentologist, but the procedure provides an indication of where such experts could be directed.

1 Any classification system involving thresholds to rate impacts carries problems associated with ranges, means, medians, and averages and their relevance to rigid impact thresholds. For example, a site with a WQEE value of 4.8 m^3 falls into a moderate class; however, a value of 4.8 m^3 is much closer to a 5 (which falls into a high class) than to a 0.9 (which falls into a low impact class). As a result, WQEE uses mode values that mirror the order of magnitude nature of estimates because this is considered to be the most sensible way to view the class ranges.

Table 1. Fine sediment volume thresholds developed for assigning water quality impact ratings

Fine sediment volume (m^3)	Mode value	WQEE Score	Site description	Typical site	Level of management
< 0.2	0.1	Very Low	Site does not generate significant amounts of sediment. Reflects best management practices.	Most deactivated roads, recent, well-engineered crossings.	↑ Good
0.2–1	0.5	Low	Site generating some sediment but would still be within the range that would be considered normal for background levels of stream turbidity. Reflects good management practices.	Light to moderate use well-managed, industrial roads.	
1–5	1	Moderate	Site generating measureable levels of fine sedimentation and, under certain situations, of interest to watershed managers.	Moderate to heavily used industrial roads under a range of conditions.	
5–20	10	High	Site generating unacceptable levels of fine sediment and has a significant impact on water quality in a watershed. Remedial action required to reduce water quality impacts.	Heavily used mainlines built more than 20 years previously in sensitive location.	
> 20	100	Very High	Site generating very high levels of fine sediment with major consequences for water quality within a watershed. Remedial action critical for protection of water resources.	Slope failure caused by road or harvesting. Poor location and (or) water management.	↓ Poor

2.6 *Verificiation of Protocol*

The methodology used in the WQEE protocol has been supported and verified by a diverse range of activities.

- Work carried out by Beaudry (2006) in the development and verification of the Stream Crossing Quality Index (SCQI) identified a similar foundation for its conception. The SCQI has subsequently adopted several features of the WQEE protocol, with the two methodologies providing similar outcomes.
- Carson and Younie (2003) conducted field research on forest road locations to determine the level of sediment generated. Differences in sediment loading measured upstream and downstream of the experimental sites were compared with measured sediment loading of road ditches and road surface rills draining towards the stream. Order of magnitude values for water quality impacts were assigned to these sites. Values used by the WQEE protocol adequately reflected how sediment loadings would affect a stream flowing at 1 m^3/sec.
- Carson (unpublished data, 2003) measured numerous internal basins where all sediment generated by a road segment could be measured. The amount of sediment found within these internal basins supported the estimates calculated using the WQEE protocol. During the training exercise for the protocol, trainees were encouraged to occasionally investigate sites unconnected to streams that drain into an isolated basin where generated sediment from a road segment could be measured. This provides a means of local verification and is also useful to highlight potential anomalies not considered by the protocol.

- During frequent field trips, a diverse panel of hydrologists, sedimentologists, engineers, foresters, and water purveyors concluded that the WQEE protocol provided a reasonably quantitative assessment of water quality impact, that the thresholds for classes were supportable, and that the evaluation provided clear opportunities to improve watershed management.
- An independent University of British Columbia review, led by Dr. Hans Schreier, an international water quality expert, and Dr. Les Lavkulich, a soil expert, concluded in 2006 that "the protocol is a most positive step and contribution to a rapid, useful, practical and credible field assessment of disturbance effects of fine sediment on receiving water systems" (Schreier and Lavkulich 2006).
- Baird et al. (2012) investigated the use of the WQEE protocol for determining the impact of the Honna Mainline in the Haida Gwaii on water quality within the Honna Community Watershed. Measurements of turbidity at culvert outlets were compared with that predicted by the WQEE protocol from the upslope mini-catchment. The study concluded that the WQEE methodology was an appropriate tool for estimating sediment generation from the selected sites.

2.7 *Estimating Impacts of Free-ranging Livestock on Water Quality (Fecal Contamination)*

As part of the overall water quality evaluation, a separate rating of the potential impact of free-ranging livestock on water quality was also included. This was largely designed by a provincial range specialist (D. Fraser, Range Stewardship Officer, Ministry of Forests, Lands and Natural Resource Operations, pers. comm.). This rating focuses on fecal contamination and its potential effects on raw water quality entering drinking water intakes. While on a site, the evaluator first takes note of the presence or absence of free-ranging livestock. The presence of livestock is restricted to a few districts in British Columbia. Since 2009, the number of sites requiring the livestock evaluation was further reduced as it is only conducted when a known drinking water intake exists downstream. For this evaluation, 15 simple indicators were considered, including vegetation, condition of ground and stream channel, presence of livestock feces, and range management techniques. When a threshold of indicative observations is made, the site is considered likely to have negatively impacted water quality. This information is then forwarded to the local range specialist for review and action – if required.

Because the protocol developers could find no agreement on how far downstream fecal material could be transported and still harbour disease, no clear criteria had been developed. A 1999 British Columbia Auditor General report determined that fecal coliform would most likely fall out of suspension within 1 km on a flowing stream, although spores of several human pathogens carried by livestock could live for long periods within organic material and become re-entrained during storm events or by disturbance (e.g., when cattle entered the stream) (Office of the Auditor General of British Columbia 1999). Given the size of most community watersheds, and the existing management guidelines now in place for water purveyors, 10 km seems to be a reasonably conservative value.

2.8 *Selection of Water Quality Evaluation Sites*

Randomly selected cutblocks are used as a starting point in the identification of WQEE sites. Because of the focus on water quality impacts, disturbed forestry sites (predominately associated with roads) in proximity to natural water bodies (usually stream crossings) are selected for evaluation. Thus, the basic evaluation unit is the "site," of which there could be from 1 to 15 sites associated with any given sample area. This differs from other FREP protocols in which the basic sampling unit is within or immediately adjacent to a cutblock opening and any results are tied to the cutblock. The WQEE protocol recognizes that the licensee who harvested the cutblock may or may not be responsible for a considerable portion of the sampled road network. The evaluation is meant to assess the impact of overall industry operations across the forest district rather than the operations of a single licensee. In some districts, the forest industry may not even be the predominant user as mining exploration and recreation uses can often be much more prevalent. This is an important complication in the management of industrial roads, where forestry operators were previously the sole users.

After sites are identified and located, if livestock presence is noted and a drinking water intake occurs downstream, then a range evaluation is also conducted. Stream crossings invariably reflected the most heavily utilized range sites in the area and as such, made the evaluation highly sensitive to any livestock disturbance.

2.9 *Data Reliability*

In 2008, WQEE protocol developers randomly revisited completed sites to check assessments completed by the district staff. They found that 85% of the revisited sites fell within the same impact class as assigned by the district. For 2009–2012, completed site assessment forms were randomly chosen from each district and field reviewed by protocol developers for consistency and reliability. In general, the outcome of these data verifications indicated that field staff were conducting evaluations in a proficient manner and that the results provided an accurate reflection of actual water quality impact. The great majority of district staff understood how the WQEE protocol works, were capable of conducting accurate field assessments, and produced evaluations that reflected the site's impact on water quality. Many of the common errors committed in the field, such as choosing incorrect values or making mistakes with calculations, were caught during data input into FREP's Information Management System. These concerns were raised with 10% of samples, although not all of these led to misclassification. Consideration is now being given to preventing such errors through the use of a digital format to collect and automatically input the data.

3.0 FIELD RESULTS

To obtain this provincial summary, water quality field data originally entered into FREP's Information Management System (IMS) repository over the previous 5 years was downloaded, sorted, and statistically analyzed on the basis of selected parameters. The results presented in this section represent data generated at 4033 sample sites in 24 forest districts from 2008 to 2012. To meet individual requirements, resource managers are encouraged to download and analyze these data directly from the FREP IMS.[2]

3.1 *Provincial Summary of WQEE Results*

Table 2 presents a provincial summary of WQEE results at all 4033 sample sites over the previous five field seasons.

Of the 4033 sites evaluated between 2008 and 2012, 34% were classified as having a "Very Low" water quality impact and 37% were classified as "Low" impact (Figure 1). Water quality at these sites was considered not adversely impacted in any measurable way. Twenty-four percent of evaluated sites were classified as having a "Moderate" water quality impact. ***Depending on the sensitivity of the stream and presence of, and distance from, downstream water intakes, these levels of impact may or may not be of concern to water resource managers.*** To reflect the differences at the higher and lower end of the range and to accommodate differing downstream consequences, a more detailed breakdown within the moderate class may be considered. In either case, the protocol requires the evaluator to consider options for improved management of these sites.

Four percent of sites were classified as having a "High" water quality impact and 1% as "Very High." Serious water quality impacts had been (or are) occurring at these sites. A more detailed professional assessment of these sites should be considered to determine whether management could be improved. Small changes in portions of different classes noted between years were not considered significant and do not represent changes in water quality impact or management.

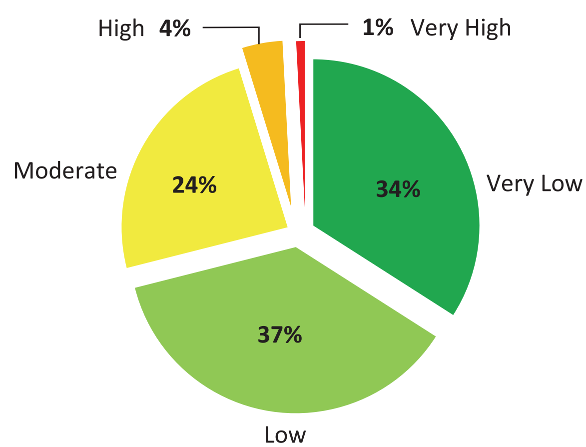

Figure 1. ***Proportional distribution of water quality impact ratings for 4033 sites evaluated in British Columbia between 2008 and 2012.***

Table 2. ***Provincial WQEE results for 2008–2012***

Sites with assigned WQEE impact rating (no. and % of provincial total)										
Very Low		Low		Moderate		High		Very High		Total
No.	%	No.	%	No.	%	No.	%	No.	%	
1373	34	1493	37	975	24	159	4	33	1	4033

2 See http://apps18.for.gov.bc.ca/frep/. Access available to government users or those with a BCeID.

3.2 Provincial Water Quality Data Associated with Drinking Water Intakes

Figure 2 shows the relative proportion of assigned impact ratings for those sites with drinking water intakes located downstream. This included 398 sites extracted from the total provincial database. These results show little significant difference in the performance of licensees working in watersheds known to have intakes downstream, a surprising result considering community watersheds are usually managed in recognition that water quality is a major concern for the water purveyors and licensee(s). Many of these sites were subject to lower standards associated with older (20–30 years) road location, design, and construction techniques, which may account for the apparent lack of difference from watersheds without drinking water intakes.

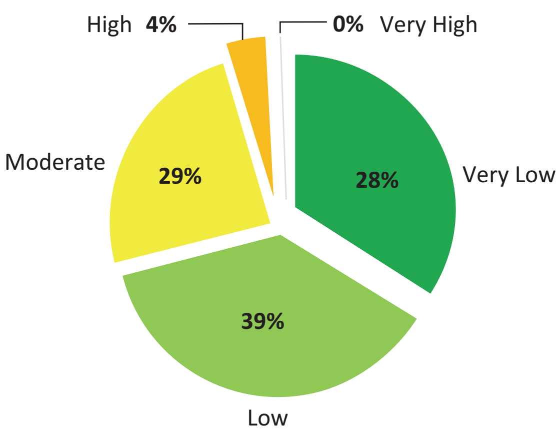

***Figure 2.* Proportional distribution of water quality impact ratings for 398 sites upstream from drinking water intakes.**

3.3 Provincial Water Quality Data Associated with Mass Wasting versus Surface Erosion

One hundred and thirty-one sites (3%) evaluated between 2008 and 2012 recorded a mass wasting component in excess of 0.5 m^3 (Table 3). Although not common, mass wasting strongly affects water quality when it occurs. Province-wide, sites with mass wasting accounted for 79% of the "Very High" water quality Impact ratings and 28% of the "High" ratings. These sites were usually associated with road- and cutblock-initiated slope failures.

3.4 Provincial Water Quality Data Associated with Different Stream Sizes

Table 4 summarizes data comparing stream size and water quality impact rating at the 4033 sampled sites evaluated between 2008 and 2012. Seventeen percent of site evaluations were conducted on streams less than 0.5 m wide (Figure 3). This stream width was most often associated with inter-drainage culverts that were connected to a natural drainage. Such streams were usually ephemeral and neither supported year-round fish presence nor drinking water intakes. Peak flows seldom exceeded 0.01 m^3/sec. When inter-drainage culverts have been in place for many years, capturing a significant volume of water through interception of slope drainage, a stream may form downslope. Prolonged discharge will eventually cut down into the soil and (or) the channel will become armoured, either from the coarse sediment load derived from the road or from selective removal of fines in the developing channel. On the Coast, many such streams increase the natural drainage density (and potentially peak flow) of a watershed. A total of 169 sites (or 24.8% of < 0.5 m streams) fell into the moderate or higher impact classes. (Figure 4)

***Table 3.* A comparison of relative importance of surface erosion versus mass wasting for generating fine sediment (2008–2012 data)**

	Sites with assigned WQEE impact rating (no. and % of provincial total)									
	Very Low		Low		Moderate		High		Very High	
Dominant erosion process	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Surface erosion (3902 sites)	1373	34	1493	37	975	24	159	4	33	1
Mass wasting > 0.5 m^3 (131 sites)	0	0	8	0.5	52	5	45	28	26	79
All sites (4033 sites)	1373	100	1493	100	975	100	159	100	33	100

Table 4. A comparison of stream size versus water quality impact rating for 4033 sites (2008–2012 data)

Stream size	Sites with assigned WQEE impact rating (no. and % of provincial total)										Total no. streams	% of total
	Very Low		Low		Moderate		High		Very High			
	#	%	#	%	#	%	#	%	#	%		
< 0.5 m	263	38.6	250	36.7	141	20.7	25	3.7	3	0.4	682	17
0.5–1.5 m	740	34.5	814	38	505	23.6	65	3.0	18	0.8	2142	54
1.5–5 m	280	29.9	332	35.5	266	28.4	49	5.2	8	0.9	935	22
5–20 m	84	34	88	35.6	55	22.3	17	6.9	3	1.2	247	6
> 20 m	6	22.2	9	33.3	8	29.6	3	11.1	1	3.7	27	1
All sizes	1373	34	1493	37	975	24	159	4	33	1	4033	100

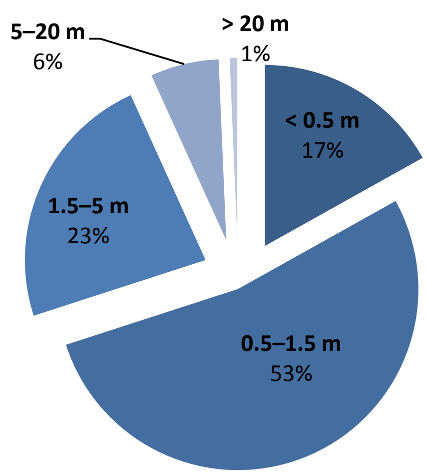

Figure 3. Proportional distribution of stream sizes in the provincial sample of 4033 sites.

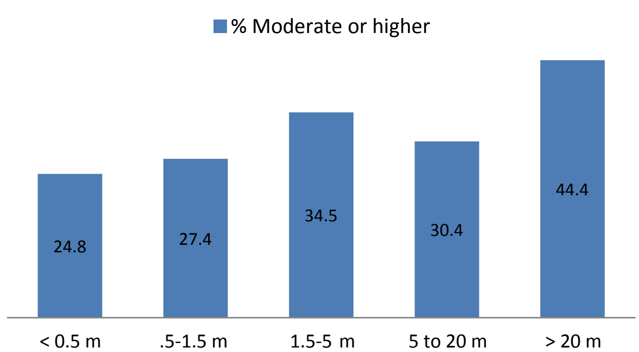

Figure 4. Percentage of sites on streams of a given width with a moderate or higher water quality impact rating.

Fifty-four percent of all sites were located on streams with a wetted width of 0.5–1.5 m. This stream size corresponds to an "S6" (< 3 m wide) non-fish-bearing stream, or an "S4" (< 1.5 m wide) fish-bearing stream. Such streams are rarely large enough to be named, except if they occur close to population centres. The expected peak flows of these, usually culverted, streams seldom exceed 0.1 m^3/sec. Although many of the assessed streams may not have been fish-bearing, they often flowed into fish-bearing waters and their cumulative effect on watershed health is assumed. A total of 588 sites (or 27.4% of all 0.5–1.5 m streams) fell into the moderate or higher impact classes.

Some 22% of sites were located on streams 1.5–5 m wide. Streams of such size are usually named. Peak discharges would seldom exceed 1 m^3/sec. Crossings were culverted or bridged and, generally, fish presence is assumed. A total of 323 sites (or 34.5% of 1.5–5 m streams) fell into the moderate or higher impact classes.

Streams 5–20 m wide represented 6% of the total provincial sample. These streams and their corresponding watersheds usually bear the same name. Such streams are invariably bridged and fish presence is assumed. Peak discharges would average around 5 m^3/sec. A total of 75 sites (or 30.4% of 5–20 m streams) fell into the moderate or higher impact classes.

Finally, streams over 20 m wide represented only 1% of the sample. Peak flow discharges would usually exceed 10 m^3/sec. These, always bridged and named, streams drain major areas. A total of 12 sites (or 44.4% of > 20 m streams) fell into the moderate or higher impact classes.

An increasing trend was noted in the percentage of "Moderate," "High," or "Very High" water quality impact sites as stream size increased. In part, this is explained by the disparate sample sizes of different stream classes. In the provincial sample, 682 sites were located on streams less than 0.5 m wide and only 27 sites were located on streams greater than 20 m wide. The large streams cannot be directly compared because of the small sample numbers; however, the larger bridges on mainlines had usually been in place for a long time, and were constructed to lower standards than those prevalent today. Virtually all new bridges built on logging roads in British Columbia now conform to a high standard, using a range of best management practices to minimize fine sediment generation.

3.5 *Provincial Water Quality Data Associated with Type of Sites Evaluated*

Table 5 provides a breakdown of the type of sites that have been evaluated over the 5-year sampling period. Almost 86% of these were at stream crossings and 11.8% were at inter-drainage culverts. Both road- and harvesting-related failures were uncommon; however, when these failures did occur, they constituted a large proportion of the "High" water quality impact sites. Twenty-four riparian windthrow sites were evaluated, of which 23 sites were assigned to a "Very Low" or "Low" water quality impact class. Whereas riparian windthrow can have very serious consequences for fish habitat and riparian function, the fine sediment contribution from windthrown trees was rarely rated as a major problem for the sites evaluated.

Table 5. A comparison of site type versus water quality impact rating for 4033 sites (2008–2012)

Site type	Sites with assigned WQEE impact rating (no. and % of provincial total)										Total no. sites	% of total
	Very Low		Low		Moderate		High		Very High			
	#	%	#	%	#	%	#	%	#	%		
Stream crossings	1152	33.3	1296	37.4	848	24.5	146	4.2	22	0.6	3464	85.9
Inter-drainage culverts	173	36.3	176	36.9	114	23.9	11	2.3	3	0.6	477	11.8
Road-generated failures	0	0	2	28.6	2	28.6	0	0	3	42.8	7	0.2
Harvesting-related failures	26	42.6	18	29.5	10	16.4	2	3.3	5	8.2	61	1.5
Riparian blowdown	22	91.7	1	4.2	1	4.2	0	0	0	0	24	0.6
All sites	1373	34	1493	37	975	24	159	4	33	1	4033	100

3.6 *Provincial Range Results*

Table 6 summarizes the number of sites evaluated for water quality potentially impacted by range use. The drop in numbers evaluated after 2008–2009 reflects a change in sampling criteria, whereby only sites with a known water intake downstream (as well as a recognized livestock presence) were evaluated. During the 5-year period, 194 sites were evaluated, of which 133 sites indicated that water quality had potentially been compromised; that is, more than 68% of sites where cattle occurred in combination with a drinking water intake were rated as negatively impacted.

Table 6. Summary of range assessments (2008–2012)

District	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	5-year total for water quality impacts	Total sites sampled
Arrow Boundary	19	2	0	0	0	21	26
Cariboo-Chilcotin	13	0	0	1	0	14	22
Cascades	0	0	2	5	0	7	12
Thompson Rivers	8	2	7	2	9	28	30
100 Mile House	11	1	0	0	0	12	15
Okanagan Shuswap	21	5	0	3	1	30	55
Rocky Mountain	18	0	0	0	0	18	27
Vanderhoof	2	0	0	0	0	2	6
Sunshine Coast	1	0	0	0	0	1	1
Provincial							
Total sites	**93**	**10**	**9**	**11**	**10**	**133**	**194**

At these same sites, accelerated erosion initiated by cattle presence was almost never as important as sediment issued from the adjacent road itself. A summary of 951 range observations identifying the potential cause of water quality impacts is provided below:

- Absence of best management practices for range areas (e.g., lack of livestock control structures keeping livestock from stream) (172 incidents)
- Livestock drinking directly from stream (154 incidents)
- Livestock feces noted within 3 m of water's edge (143 incidents)
- Evidence of livestock standing in streambed (140 incidents)
- Streambank erosion (106 incidents)
- Recent pugging and unvegetated hummocks common (93 incidents)
- Bare soil and compaction apparent (80 incidents)
- Riparian vegetation absent or highly modified (63 incidents)

3.7 *Regional and District Summaries of Water Quality Effectiveness Evaluation Results*

Table 7 provides regional and district summaries of WQEE results for all sites evaluated between 2008 and 2012. The average number of sites evaluated by participating districts was 168 over the 5-year period, or about 34 sites per district per field season. Regions, and even between districts, proportions of different water quality impact classes assigned to sites are reasonably uniform. Data users are cautioned that this information should not be used to compare one district to another, or one year to the next within districts. The number of samples for any one district is small and the diversity of landscapes and nature of forestry operations is too large. The data is robust when evaluating how well licensees are performing to minimize water quality impacts. The results also provide very clear direction to the areas of management that are satisfactory and those areas where improvements could be forthcoming.

Table 7. Water quality impact ratings of all provincial forest regions and districts (2008–2012)

Region	No. sites evaluated in region	District	No. sites evaluated in district	Very Low	Low	Moderate	High	Very High
Cariboo	344	100 Mile House, DMH	119	56	41	18	2	2
		Cariboo-Chilcotin, DCC	181	65	80	31	5	0
		Quesnel, DQU	44	16	20	6	1	1
Kootenay/ Boundary	445	Selkirk, DKL	95	40	29	25	1	0
		Rocky Mountain, DRM	350	122	127	82	14	5
Northeast	79	Fort Nelson, DFN	11	2	8	0	1	0
		Peace, DPC	68	28	22	12	3	3
Omineca	390	Fort St. James, DJA	133	39	46	38	8	2
		Mackenzie, DMK	82	16	23	29	11	3
		Prince George, DPG	48	7	5	20	15	1
		Vanderhoof, DVA	127	41	46	30	10	0
Thompson/ Okanagan	784	Cascades, DCS	102	12	29	50	11	0
		Thompson Rivers, DKA	452	141	157	128	24	2
		Okanagan Shushap, DOS	230	46	107	68	8	1
Skeena	465	Kalum, DKM	134	49	64	21	0	0
		Nadina, DND	220	42	76	83	18	1
		Skeena-Stikine, DSS	111	83	24	3	1	0
South Coast	578	Chilliwack, DCK	212	33	83	85	11	0
		Metro Vancouver–Squamish, DSQ	136	34	47	51	2	2
		Sunshine Coast, DSC	230	81	105	42	2	0
West Coast	948	Campbell River, DCR	412	124	173	107	6	2
		Haida Gwaii, DQC	173	92	67	11	2	1
		North Island–Central Coast, DNI	229	111	78	31	3	6
		South Island, DSI	134	93	36	4	0	1
Province total	**4033**		**4033**	**1381**	**1493**	**975**	**159**	**33**

3.8 *Management Options for Sites showing "Moderate" to "Very High" Water Quality Impacts*

Management observations, which summarize shortcomings in resource road management and harvesting throughout British Columbia, were recorded by evaluators for all sites (1157) with "Moderate," "High," or "Very High" water quality impact ratings (Table 8). Some sites received two or more observations, for a total of 1924 specific management observations.

Table 8. Specific recommendations made to reduce water quality impacts (1924 management observations)

Activity	Recommendations made to reduce observed water quality impact	No. times recommendations made for sites with > 1 m^3 fine sediment generation
Location of roads	1. Re-locate road away from stream	31
	2. Avoid steep, unstable slopes	34
	3. Locate bridge to cross stream where opportunity exists to control drainage	193
Total		**258**
Design of roads and cutblocks	4. Avoid deeply dug ditches in proximity to stream	66
	5. Use strategically placed culverts	290
	6. Design bridge deck higher than road grade	37
	7. Design narrow road	22
	8. Ensure trees remaining within riparian leave strip are windfirm	3
Total		**418**
Construction of roads or harvesting of cutblocks	9. Minimize soil disturbance	25
	10. Armour, seed, or spread out debris to protect disturbed ground	298
	11. Avoid wet areas or use brush mats to avoid incision	4
	12. Use good-quality subgrade and capping materials	86
	13. Place rock armouring over areas of concentrated flow	54
	14. Construct sediment basins capable of handling sediment load expected	50
Total		**517**
Road maintenance	15. Bring in good-quality road fill and surfacing material	148
	16. Remove grader berm	190
	17. Limit traffic during wet weather	41
	18. Reduce or prevent traffic	5
	19. Fall away and yard away when logging near streams	1
	20. Improve range management to minimize water quality impact	17
Total		**402**

Activity	Recommendations made to reduce observed water quality impact	No. times recommendations made for sites with > 1 m^3 fine sediment generation
Deactivation	21. Install strategically placed cross-ditches and waterbars	308
	22. Pull back and end-haul unstable fill to safe location	7
	23. Pull culverts and armour crossings	14
Total		**329**
Total observations from all activities on higher impact sites		***1924***

Figure 5 shows that sediment production issues associated with impacted sites ("Moderate" rating or higher) were divided fairly equally between the five areas of management concern, from initial road location planning to road deactivation.

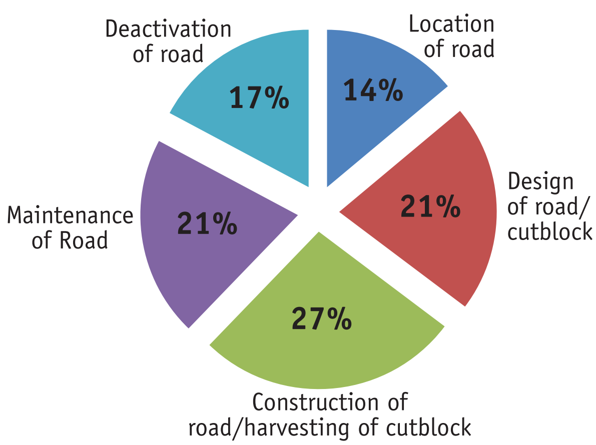

***Figure 5.* Areas of management concern associated with water quality impact sites ("Moderate" or higher).**

3.9 *Application of Water Quality Effectiveness Evaluations to Districts, Watersheds, and Licensees*

To meet specific management requirements, the evaluation data presented for this provincial analysis can also be reported by individual regions or districts. Figures 6–8 provide examples of data summaries for the North Island–Central Coast Forest District.

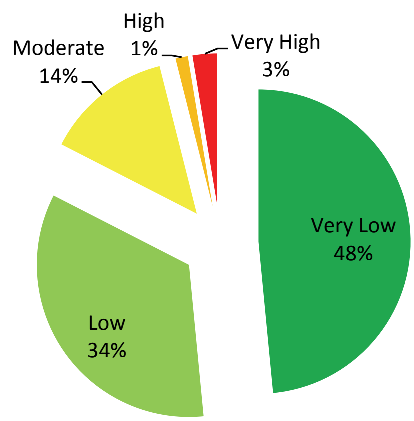

***Figure 6.* Proportional distribution of North Island–Central Coast Forest District water quality impact ratings.**

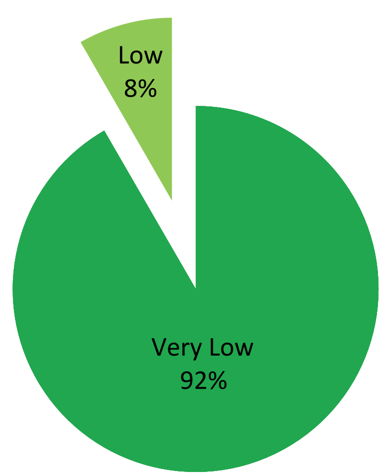

***Figure 7.* North Island–Central Coast Forest District water quality impact ratings for sites upstream from drinking water intakes.**

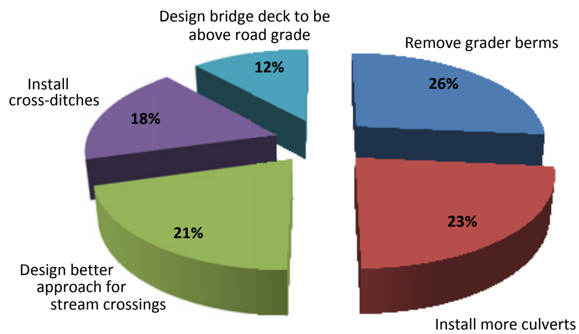

Figure 8. ***Recommendations made for 40 sites in North Island–Central Coast Forest District with "Moderate" or higher water quality impact ratings.***

Note that the fewer sites evaluated, the more difficult it is to ensure a representative sample. One or two sampling seasons are not sufficient to verify the relative degree with which individual licensees or forest districts are meeting water quality objectives. At the district level, the data can guide assessments of overall strategies for forestry development by targeting weaknesses in management that results in water quality impacts. More importantly, the evaluation pinpoints individual sites where improved management would directly result in a reduced water quality impact. If the sampling captured a representative number of sites, then a manager will have a good snapshot of the industrial water quality impacts within the district.

For some districts, sample sites were concentrated within the opening itself, with a reduced number of sites on active branch roads and mainlines. Such a sampling bias would tend to skew results away from the cross-landscape assessment that the WQEE methodology was intended to provide. Maintaining an unbiased sampling procedure that captures the full spectrum of operations and landscapes within a district is an ongoing concern. For example, some discussions have focussed on using selected watersheds as the basic unit for sampling. ***Nevertheless, to ascertain a gradual improvement with the small number of samples taken, the evaluator would be required to re-evaluate previously assessed sites to document any changes that may have occurred.***

The WQEE methodology, used here to evaluate forest-related water quality impacts, has also been used by other resource managers. For example, community watershed managers have used the WQEE protocol to help set priorities for cost-effective road maintenance budgets. Licensees have trained their road management staff (including foremen, surveyors, engineers, and excavator and grader operators) to use the protocol for fine-tuning their day-to-day operations. The best locations for placing cross-ditches or waterbars can be determined using the WQEE protocol, and this knowledge can then help reduce sediment delivery to a stream without increasing costs. Training is all that is required. The Forest Practices Board has also used the protocol to evaluate compliance with regulations under the *Forest and Range Practices Act*.

4.0 CONCLUSIONS

4.1 *Forestry*

Resource roads are a major source of fine sediment generation that can potentially affect water quality throughout British Columbia. More than 71% of sites evaluated using the WQEE protocol between 2008 and 2012 show a "Very Low" or "Low" impact on water quality. Twenty-four percent of sites rated as "Moderate" had a small but measurable impact on water quality. Immediate action was not necessarily required at these sites, although practices could be improved, and possibly should be improved, if consequences warrant it. Five percent of sites rated with "High" and "Very High" water quality impacts would require changes to management to address the root causes of such impacts. For all sites rated as "Moderate," "High," and "Very High," evaluators were required to choose from 23 potential management responses that could reduce the level of water quality impact. Of these responses, the following six specific management opportunities addressed the problems associated with more than 75% of the sites with water quality impacts.

1. Locating bridges to cross stream where opportunity exists to control drainage.
2. Using strategically placed culverts.
3. Armouring, seeding, and spreading out debris to protect disturbed ground.
4. Bringing in good-quality road fill and surfacing materials.
5. Removing grader berms.
6. Installing strategically placed cross-ditches and waterbars.

4.2 *Range*

The potential for free-ranging livestock to negatively affect water quality was noted on 68% of the sites evaluated in the province. The high number of range-sampled sites showing a potential water quality impact indicates that livestock management to minimize fecal contamination in a community watershed is a difficult undertaking.

In all field observations of range sites, livestock control structures were absent, permitting free access of grazing livestock to water. Contrary to common expectations, signs of heavy grazing within a riparian area were not a prerequisite for water quality impacts. Only 63 (or 47%) of the 133 sites identified as having potentially impacted water quality had heavily grazed riparian vegetation. Lightly or non-grazed sites that were important watering sites invariably experienced serious fecal contamination. This was a common occurrence under higher-elevation conifer forest canopy where forage is scarce. Therefore, the results of assessments evaluating overall range health may not correlate well with those that evaluate the water quality impacts of range animals.

5.0 RECOMMENDATIONS

5.1 *Roads*

Improvements associated with all stages of a road network's life, from initial location through to deactivation, provide opportunities to reduce fine textured sediment loading of nearby streams. Observed problems with road management, and associated recommendations, are covered below for five operational areas: (1) road location; (2) design of roads and cutblocks; (3) construction of roads and harvesting cutblocks; (4) road maintenance; and (5) road deactivation.

5.1.1 Road location

Concerns about road location were noted in 258 instances, with the majority of these (193, or 74.8%) related to control of road and slope drainage, roads paralleling streams, sensitive stream crossing sites, and road alignments located on steep and unstable slopes. Most of these sites were associated with road alignments built more than 20 years ago when standards for water quality and road construction were not as stringent as today's. Road managers who inherit such roads have limited options for reducing fine sediment impacts. Sometimes changing the road's location is the only option but for practical reasons cannot be implemented. ***The frequency with which a precarious road location is recognized as a problem affecting water quality emphasizes the ongoing need for vigilance in the layout of future roads and cutblocks near water bodies and (or) along unstable slopes.*** Such sites can continue to produce substantial fine sediment loads until the road is deactivated.

5.1.2 Design of roads and cutblocks

Concerns with road and cutblock design were noted at 418 sites. The most frequent recommendation associated with road design was the need to increase the number of culverts or improve their placement, which was mentioned 290 times by evaluators. On older roads, inside road ditches often transported all road surface, ditch, and cutbank sediment directly into a stream. The WQEE protocol provides a simple technique to determine exactly where the inside road ditch should be diverted. A ditchblock and cross drain culvert can minimize the flow of ditch-transported sediment directly into a stream and also maximize the forest-floor buffering effect to absorb and filter water from the road. Avoiding deep ditches along roads adjacent to streams was mentioned by evaluators 66 times, again mostly on older roads where road subgrade was built up directly from excavated ditches. The deeper the ditch, the fewer the options for safely removing road surface drainage and allowing its reabsorption into the forest floor before reaching a stream. ***Ensuring that road designers carefully consider how a road will affect sediment generation will substantially improve water quality.*** Although windthrow was commonly associated with riparian leave strips, the volume of sediment generated from windthrown trees remained in the "Very Low" and "Low" water quality impact class for 23 of the 24 sites where such observations were made.

5.1.3 Construction of roads and harvesting of cutblocks

Concerns with road construction and cutblock harvesting were mentioned by evaluators 517 times. The most frequent recommendation identified was the need to armour and (or) reseed bare ground as soon as possible after construction (298 sites). Depending on the amount of coarse rock in a native soil, most disturbed soils eventually "self-armour" as fines are selectively removed by erosion. Road construction in stone-free

silty soils is problematic because these soils depend only on revegetation for natural protection. On cutbanks, such soils were found to resist revegetation because of pervasive needle ice formation and its destruction of surface vegetation root systems. Sensitive soils require special consideration when roads are being built, and other means of sediment management should be considered in road design (e.g., interception of any generated storm flow and diversion before reaching a stream). Unfortunately, sensitive soil pockets are difficult to anticipate before road construction.
Using better road subgrade and capping material was mentioned by evaluators 86 times; however, fulfilling such recommendations will depend on the presence of nearby gravel pits and quarries containing good-quality materials. Because of the long haul distances in some districts, many licensees must sometimes address sediment problems by resorting to other means. ***Although the road-construction phase potentially generates the highest levels of fine sediment, reducing the area of disturbance, protecting disturbed surface areas, and addressing connectivity of runoff during construction can dramatically lessen the water quality impact while new roads are "hardening up."***

5.1.4 Road maintenance

Improving road management as a means to reduce water quality impacts was mentioned by evaluators 402 times; 190 of these mentions were associated with grading operations (managing road crowns and grader berms).
In many instances, simply breaking a berm to allow water to leave a road before it reaches the stream could dramatically reduce water quality impacts. Road berms are occasionally used effectively to divert road water away from streams and safely onto forest floors where both sediment and water can be absorbed. The second most cited improvement recommended in this category was the application of good-quality road fill and surfacing materials. Where road subgrade permits crowning, maintenance of the crowned profile will permit at least the outside half of road drainage to flow safely onto the forest floor. ***Problems associated with road management are mostly addressed in day-to-day decisions made by road maintenance crews within their annual budget. As such, road maintenance issues are one of the best targets for immediately reducing sediment impacts in a watershed.***

5.1.5 Road deactivation

Improving road deactivations was mentioned by evaluators 329 times. The most frequently cited improvement involved the strategic placement and design of cross-ditches, waterbars, and spoil areas (308 observations). Sometimes, ongoing water quality impacts from deactivated roads are beyond the licensee's control. For example, heavy recreation use was the primary reason for the breakdown of once-functioning cross-ditches and waterbars, and occasionally the rutting of roads. Non-status roads were also recognized as a problem because no agency has the responsibility or authority to carry out improvements to reduce sediment impacts. ***The WQEE methodology provides a simple, direct means to choose specific locations for ditchblocks, cross-ditches, and waterbars, and should be one of the tools employed in the design of road deactivation plans.***

In summary, all aspects of road management (and to a lesser degree, cutblock management), from the initial location through to eventual deactivation, play a crucial role in helping to minimize water quality impacts.
The provincial WQEE results reported here underline the overarching importance of artificial drainage management and of ensuring disturbed sites are either quickly revegetated or armoured. In all five activities of concern related to roads, training workers about the potential water quality impacts associated with their activities is vital. Such training will allow workers to prioritize their responses, making their mitigation efforts more cost-effective during all phases of a road's life.

5.2 *Range*

Based on WQEE data collected to date, more attention is required to mitigate the **potential** impact of free-grazing livestock on water quality in British Columbia.
This problem was especially important in the Cariboo, Thompson/Okanagan, and Kootenay/Boundary regions where free-grazing livestock coexist with relatively high human populations and an abundance of community watersheds.

The transport and persistence of disease agents related to fecal contamination is a complicated process. Nevertheless, flagging fecal contamination that occurs less than 10 km upstream of a drinking water intake was provisionally adopted as a water quality threshold to make WQEEs comply with community watershed standards.

5.3 *Importance of Mass Wasting versus Surface Erosion in Evaluating Water Quality Impacts*

The provincial WQEE results confirm the importance of mass wasting as a major impact on water quality. Although mass wasting was observed on only 3% of the evaluated sites, these sites included 79% of the "Very High" and 28% of the "High" water quality impact ratings assigned in the province. In general, mass failures are well documented by Compliance and Enforcement Branch officers, whereas many sites that exhibit only surface erosion (even though extensive) are often overlooked. Therefore, opportunities exist for both licensees and enforcement officers to improve their recognition of surface erosion. Because gravel road surfaces always generate fine sediment, managing this sediment needs to be addressed.

5.4 *Analysis of Water Quality Impacts on Streams of Different Sizes*

When applying the WQEE methodology, evaluators do not account for stream size when assigning an impact rating class. The degree of impact is based on a cumulative watershed approach, whereby an amount of fine sediment entering a stream is additive (for the watershed) regardless of stream size; that is, small streams flow into big streams and fine sediment is rapidly transported downstream. However, an amount of sediment that may have no effect on a larger stream could potentially be a serious water quality concern on a small stream with a drinking water intake immediately below the evaluated site. Such concerns are not addressed by the WQEE protocol. Nevertheless, results arising from the existing WQEE protocol can be used as a base upon which more detailed information is collected and analyzed.

5.5 *Intensive Water Quality Evaluations*

The WQEE protocol is currently designed for use in Routine/Extensive evaluations. To better understand the consequences of a site's sediment production and how this might be mitigated, more detailed, intensive evaluations may be required where site impacts are rated as "Moderate," "High," or "Very High," or where special downstream values are recognized. If more information is required about a site, revisiting some assumptions made at the Routine/Extensive level may be required to refine the analysis. The development of a more detailed intensive evaluation of actual water quality impacts is needed to incorporate information on stream discharge and the nature and duration of sediment-generating events. Such an evaluation will permit the reporting of water quality impacts as sediment concentrations (milligrams per litre) rather than sediment volumes (cubic metres).

5.6 *Other Issues*

Many of the situations influencing water quality noted by FREP district evaluators reflected land use issues that are outside the direct responsibility or authority of forest managers. For instance, a major resource road issue concerns situations where the primary users of the road are not the road permit holder. Mining and oil exploration companies were dominant users of certain resource roads, but the roads were still under forest licensee permitting and forestry personnel lacked the authority to address compliance concerns. Recreationists were found to use some resource roads heavily, sometimes substantially increasing the water quality impact of sensitive sites. In particular, constructing informal stream crossings, building trails, and removing barricades from deactivated roads were commonly reported in recreation areas, all activities which lead to greater sedimentation and water quality impact. Although newly opened forest roads may be constructed and maintained to have very low sediment generation, if free-grazing livestock are present, the improved access of cattle to new grazing areas may exacerbate fecal contamination by livestock. Community forest committees throughout the province struggle with fine-tuning and then administering access management plans to address such issues. High priority should be given to revisiting policies that deal with resource road management in British Columbia.

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For more information about the Water Quality Effectiveness Evaluation Protocol, go to: http://www.for.gov.bc.ca/ftp/hfp/external/!publish/frep/indicators/Indicators-WaterQuality-Protocol-2009.pdf

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