# The Condition of Small Streams After Harvesting: A Summary of FREP Data from 2006-2015

FREP

**Extension Note #40**

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**Key Messages for Resource Managers:**

- The most common harvest-related activities that were observed to cause impacts to small streams were falling and yarding, low retention, and windthrow.
- Overall, S3 streams were left in better condition than S4 and S6 streams, likely because of the 20-m mandatory riparian reserves and related operational considerations that buffer S3 channels.
- S4 and S6 streams adjacent to the block were ranked better than those located within the block, which could be due to less cross-channel disturbance and retained vegetation on one side of channel.
- Across all stream classes, sites that were given more riparian retention had better outcomes, with more than 80% of reaches with a 10-m buffer ranked in the top two functioning categories: properly functioning condition (PFC) or functioning at risk (FR).

## 1.0 INTRODUCTION

This report is the second installment of a series on small streams that may be referenced to support results and strategies or harvest prescriptions intended to ensure that forest practices maintain stream function and integrity. The first extension note in this series (#38; http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/frep/extension-notes/frep-extnt38-smallstreams.pdf) explained that small streams are an important component of watersheds because they are the most common type of channel, provide valuable site-level habitat, and transfer energy and water to downstream reaches. Small streams receive the least amount of protection during harvesting operations because they do not have legislated reserves and their riparian management zones may be harvested.

This extension note series is intended to provide resource professionals and managers with valuable information on how riparian harvesting may affect the function of small streams. The objective is to promote further discussion and research on successful harvesting strategies, and to reach agreement on effective and feasible forest management standards that will sustain this important resource. The final extension note in this series will examine specific riparian best management practices that lead to the best post-harvest outcomes for small streams.

This summary of the post-harvest condition of small streams in British Columbia is based on an analysis of data collected from stream reaches over the past 10 years (2006-2015) as part of the B.C. Forest and Range Evaluation Program (FREP). FREP is a foundational element of the *Forest and Range Practices Act* (FRPA) because it provides science-based information through monitoring and assessment that supports continued improvement of practices, policies and legislation. FREP monitoring results and the identification of harvest-related effects is useful information for licensees to consider when developing forest stewardship plans and conducting harvest operations.

The Riparian Management Routine Effectiveness Evaluation (RMREE) (Tripp, et al. 2005, 2006, 2009) was the FREP protocol used to obtain the data summarized in this report. The objective of the RMREE is to determine whether forest and range practices were effective in maintaining the health

***FREP Mission:***
*Collect and communicate the best available natural resource monitoring information to inform decision making, improve resource management outcomes and provide evidence of government's commitment to environmental sustainability. http://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/integrated-resource-monitoring/forest-range-evaluation-program*

British Columbia

or "functioning condition" of streams and adjacent riparian areas. Properly functioning condition means the stream and riparian area are able to:

1. Withstand normal peak flood events without experiencing accelerated soil loss, channel movement, or bank movement;
2. Filter runoff;
3. Store and safely release water;
4. Maintain the connectivity of fish habitats in streams and riparian areas so that these habitats are not lost or isolated as a result of management activities;
5. Maintain an adequate riparian root network;
6. Maintain a large woody debris (LWD) supply; and
7. Provide adequate shade and reduce bank microclimate change.

The RMREE assigns a functioning condition ranking based on responses to 15 indicator questions that relate to the biological and physical processes of a stream and its riparian vegetation (Table 1). Each indicator question corresponds to a set of criteria that are measured, counted or estimated in the field. The resulting condition ranking is based on the number of negative responses tallied and relates to the relative "health" of a sample reach, with the highest category, properly functioning condition (PFC), representing good health and the lowest category defined as not properly functioning (NPF) (Table 2).

**Table 1.** *Indicators of stream and riparian health in riparian effectiveness evaluation.*

| Question # | Indicator |
|---|---|
| 1 | Channel bed disturbance |
| 2 | Channel bank disturbance |
| 3 | LWD characteristics |
| 4 | Channel morphology |
| 5 | Aquatic connectivity |
| 6 | Fish cover diversity |
| 7 | Moss abundance & condition |
| 8 | Fine sediments |
| 9 | Aquatic invertebrate diversity |
| 10 | Windthrow frequency |
| 11 | Riparian soil disturbance/bare ground |
| 12 | LWD supply/root network |
| 13 | Shade and microclimate |
| 14 | Disturbance increasers/noxious weeds/ invasive plants |
| 15 | Vegetation form, vigour and structure |

**Table 2.** *Condition ranking based on the number of negative responses in RMREE.*

| Number of Negative Responses (out of 15 indicator questions) | Condition Ranking |
|---|---|
| 0–2 | Properly functioning condition (PFC) |
| 3–4 | Functioning at risk (FR) |
| 5–6 | Functioning at high risk (FHR) |
| > 6 | Not properly functioning (NPF) |

## 2.0 DATA MANAGEMENT

The data used in the analyses represents stream reaches ≤ 3metres (m) in channel width and was extracted from a provincial dataset compiled from the results of FREP's Riparian Management Routine Effectiveness Evaluations (RMREE) from 2006-2015. The evaluations were completed at sites harvested from 1997-2014, representing harvest practices under both the Forest Practices Code (FPC) and the *Forest and Range Practices Act* (FRPA). There was no significant difference found in the evaluation results between the two legislative eras ($\chi^2$ 0.99; $p$ = 0.32), so the data were not separated by harvest era for further analysis. This could be because the minimum requirement for retention was unchanged with the establishment of FRPA or because the average age of FRPA blocks was less than FPC blocks (2.3 years ± 0.7 SD compared to 5.9 years ± 1.6 SD), and either impacts had not yet fully materialized in the FRPA blocks or the FPC blocks had recovered somewhat over the longer time span.

Observers working in both the Coast and Interior regions of B.C. have noticed that the responses to the RMREE indicator questions vary between these areas, which may be attributed to a number of factors, including logging methodology and natural variation in topography and/or geology. A Chi-square test using the responses to the indicator questions grouped by location (Coast, south Interior, and north Interior) confirms that the areas are different ($\chi^2$ = 34.532; $p < 0.001$). Consequently, sites have been grouped as "Coast", "south" and "north" for further analysis. All districts within the West Coast and South Coast regions and those with a coastline in the Skeena Region have been included in the Coast group; south and north Interior groups are divided at the Cariboo regional boundary, with the Cariboo-Chilcotin District representing the northernmost district in the south category.

The south (n = 632), north (n = 581) and Coast (n = 515) small stream data were further stratified to identify differences in responses to the indicator questions as a function of stream class. The small stream dataset includes all streams ≤ 3 m, which includes smaller S3 streams, as well as all streams within the S4 and S6 classifications. Both the FPC and FRPA define S3 streams as fish-bearing with a channel width of 1.5 to ≤ 5m. These streams are given a total riparian management area (RMA) of 40 m that consists of a 20-m riparian reserve zone with an additional 20-m riparian management zone to protect the reserve from harvest-related impacts. Conversely, S4 (< 1.5 m wide; fish bearing) and S6 streams (≤ 3 m wide; non-fish bearing) do not receive reserves, and their RMA consists only of management zones of 30 m and 20 m respectively, where some or all of the riparian timber may be retained to meet FRPA objectives. The negative responses for each indicator question were compared by stream class and found to be significantly different (K-Wallis test $p < 0.05$), indicating that responses varied according to stream class, which may be due to their variable retention strategies.

## 3.0 RESULTS

### 3.1. SITE CHARACTERISTICS

A summary of the sample reach characteristics for the sites used in the analysis was tabulated for each of the Coast, south and north regions (Table 3). The sample sites were separated into two groups depending on their location with respect to the cutblock. Adjacent streams were located just outside of a block boundary and were exposed to recent harvest on only one bank, while in-block streams may have been harvested on both banks. Average retention within the RMA was significantly lower, the average channel gradient was higher, and the average channel width was lower for in-block streams compared to adjacent streams in all three regions (ANOVA; $p < 0.001$).

**Table 3.** *Site characteristics for sample reaches in the three regions.*

| Region | Sample Location | N (%) of Streams | Average Channel Width | Average Channel Grade (%) | Average RMA Retention (m) |
|---|---|---|---|---|---|
| **Coast** | Adjacent | 149 (29%) | 1.8 | 16.9 | 21.3 |
| | In-Block | 366 (71%) | 1.3 | 26.5 | 5.2 |
| **Coast Total** | | 515 (100%) | 1.5 | 23.7 | 9.9 |
| | | | | | |
| **South** | Adjacent | 365 (58%) | 1.4 | 9.3 | 19.8 |
| | In-Block | 267 (42%) | 1.2 | 14.7 | 8.0 |
| **South Total** | | 632 (100%) | 1.3 | 11.6 | 14.8 |
| | | | | | |
| **North** | Adjacent | 329 (57%) | 1.5 | 4.9 | 23.0 |
| | In-Block | 252 (43%) | 1.0 | 8.3 | 8.5 |
| **North Total** | | 581 (100%) | 1.3 | 6.4 | 16.7 |

### 3.2 FUNCTIONING CONDITION

The stream class with the highest percentage of sites in the bottom two categories – functioning at high risk (FHR) and not properly functioning (NPF) – was the S6 group on the Coast, with 49% of the sites falling in these two groups (Fig. 1). This data includes stream reaches that were both adjacent to and inside the cutblocks. The S3 streams were in better condition in all three regions, as illustrated by the lowest percentage of sites in the bottom two categories compared to the other stream classes. The difference in outcomes was statistically significant between S3 streams and S6 streams in the Coast and south regions, and between S3 streams and both of the other stream classes in the north (K-Smirnov, $p < 0.05$).

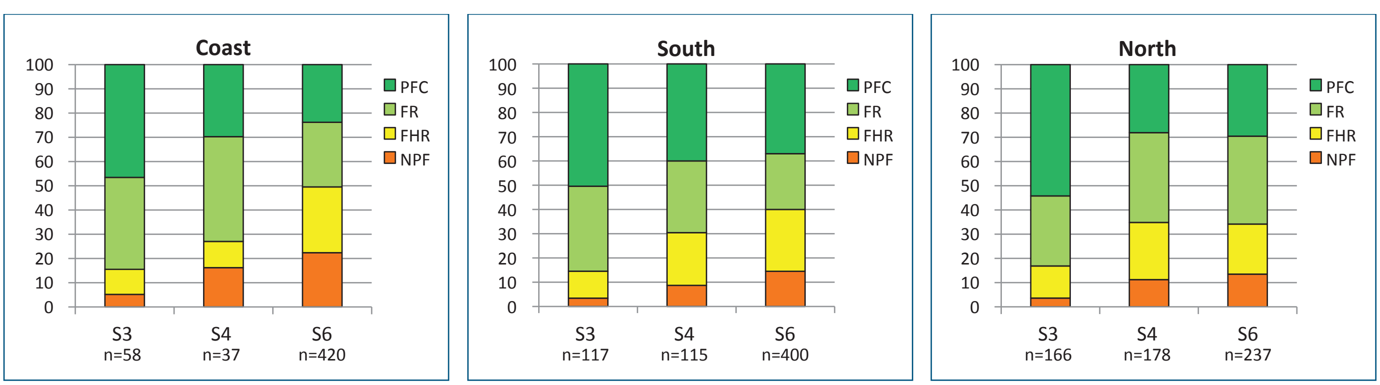



***Figure 1.*** *Proportion of sites in each condition by stream class in the three regions of B.C. PFC = properly functioning condition, FR = functioning at risk, FHR = functioning at high risk, NPF = not properly functioning.*

The lower percentage of functioning at high risk (FHR) and not properly functioning (NPF) streams in the S3 category are likely the result of the mandatory 20-m reserve or operational decisions that may have inherently considered the reserve, including aligning the block boundary to exclude the stream or anchoring wildlife retention to the channel. Other operational factors that may have led to lower impacts in S3 streams include the construction of bridge crossings as opposed to culverts, and/or less intensive logging associated with potential increased gully terrain.

To further investigate the potential influence of retention, the streams that did not have mandatory reserves (S4 and S6) were grouped together and the condition of the sample reaches inside the block (both banks subject to harvest) were compared with those adjacent to the block (only one bank subject to harvest). Although a higher percentage of in-block coastal streams fell into the bottom two categories (NPF and FHR) compared to the south and north Interior streams (Table 4), the in-block streams in all three areas displayed significantly higher percentages in these same categories compared to their respective adjacent streams, indicating that streams with some retention on at least one bank were left in better condition ($\chi^2 > 41.497$; $p < 0.001$).

**Table 4.** *Percentage of S4 and S6 streams in each condition category by proximity to the block.*

| | | PFC | FR | FHR | NPF | Total |
|---|---|---|---|---|---|---|
| **Coast** | In-Block | 17 | 28 | 28 | 27 | 100 |
| | Adjacent | 50 | 31 | 14 | 5 | 100 |
| **South** | In-Block | 28 | 25 | 29 | 18 | 100 |
| | Adjacent | 48 | 28 | 18 | 6 | 100 |
| **North** | In-Block | 23 | 34 | 27 | 16 | 100 |
| | Adjacent | 47 | 35 | 13 | 5 | 100 |

## 3.3 CAUSAL FACTORS

The FREP riparian assessment ranks the functioning condition of streams based on the responses to 15 indicator questions and is not specific to harvest-related effects. Any impacts that are observed during the assessment may be related to a number of probable causes, including logging, roads, livestock, other manmade activities, natural events, and upstream factors. Logging and natural causes were the most common reasons given for 6,460 recorded negative responses (Fig. 2), with a notable number of entries attributed to roads and upstream factors. There was a steady upward trend in the proportion of logging-related impacts from S3 to S6 streams in all regions, with an opposite decrease seen in impacts owing to natural causes, which may include, but is not limited to, the effects of wind, floods and insect infestation. Sites in the south showed more evidence of impacts from livestock than the other two regions.

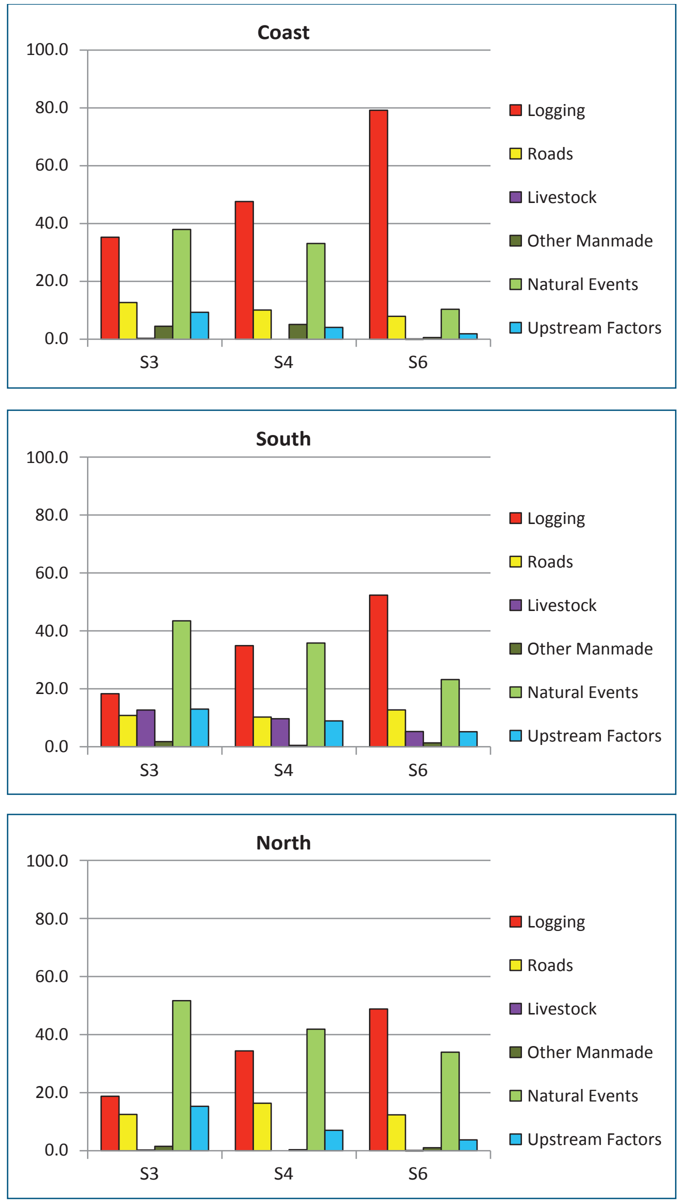



***Figure 2.*** *Proportion of identified causes of negative responses by each stream class.*

Although comparing the proportional contribution of the causal factors with respect to total number of negative responses in each stream class is helpful to identify the increasing logging-related contributions from S3 to S6 classifications, it is also useful to understand the degree to which these factors influence the results of the evaluation. The average number of negative responses for each causal factor was calculated to compare values among stream classes (Table 5). There were significant differences in the number of negative responses caused by logging within each region (ANOVA; $p < 0.05$), with the S6 reaches contributing to the highest averages owing to logging and the lowest owing to natural events. When considering all stream classes combined, the Coast had significantly higher numbers of negative responses due to logging than the other two regions (ANOVA; $p < 0.001$).

**Table 5.** *Average number of negative responses by causal factor. Results for stream classes in each region not connected by the same letter (superscript) are significantly different.*

| Region | Stream Class | Logging | Roads | Livestock | Other Manmade | Natural Events | Upstream Factors |
|---|---|---|---|---|---|---|---|
| Coast | S3 | 1.02[a] | 0.37 | 0.01 | 0.13[ab] | 1.10[a] | 0.27[a] |
| | S4 | 1.89[a] | 0.40 | 0.00 | 0.20[a] | 1.32[a] | 0.16[ab] |
| | S6 | 3.56[b] | 0.36 | 0.00 | 0.03[b] | 0.47[b] | 0.08[b] |
| **Coast average** | | **3.16** | **0.36** | **0.00** | **0.05** | **0.60** | **0.11** |
| South | S3 | 0.49[c] | 0.29 | 0.34 | 0.05 | 1.16[cd] | 0.35[c] |
| | S4 | 1.18[d] | 0.35 | 0.33 | 0.02 | 1.21[c] | 0.30[cd] |
| | S6 | 1.99[e] | 0.48 | 0.20 | 0.05 | 0.88[d] | 0.20[d] |
| **South average** | | **1.56** | **0.42** | **0.25** | **0.04** | **0.99** | **0.24** |
| North | S3 | 0.49[f] | 0.32[e] | 0.01 | 0.04 | 1.34[ef] | 0.40[e] |
| | S4 | 1.35[g] | 0.64[f] | 0.00 | 0.01 | 1.64[e] | 0.28[e] |
| | S6 | 1.87[h] | 0.47[ef] | 0.00 | 0.04 | 1.30[f] | 0.14[f] |
| **North average** | | **1.31** | **0.48** | **0.00** | **0.03** | **1.42** | **0.26** |
| All | | 1.95 | 0.42 | 0.09 | 0.04 | 1.02 | 0.21 |

## 3.4 EFFECTS OF RETENTION

The greater proportion of impacts due to logging on the Coast (Fig. 2) may be explained in part by the higher density of streams located within the block boundaries (Table 3). This high density is likely because there are a greater number of streams across the landscape compared to the Interior regions due to differences in climatic and physiographic conditions, making block placement between streams more difficult. Results show coastal in-block streams had less retention (Table 3) and were in poorer condition compared to those in the Interior regions (Table 4), and this may be associated with the logging related negative responses seen in Figure 2.

The lower level of logging-related impacts at S3 sites compared to S4 and S6 sites (Fig. 2 and Table 5) may be explained by: 1) a lower proportion of S3 streams located inside the block compared to other stream classes and/or, 2) mandatory riparian reserves and/or, 3) different stream crossing structures and/or, 4) other factors related to operational decisions around S3 streams. The difference in logging-related effects between the two stream classes without mandatory reserve zones (S4 and S6) may be explained by different stream crossing practices or higher retention levels around S4 streams because these streams are assumed to contain fish while S6 streams are not. A comparison of average treed retention around only those streams located inside cutblocks indicates that S4 stream reaches received more retention than S6 reaches in all three regions (Fig. 3).

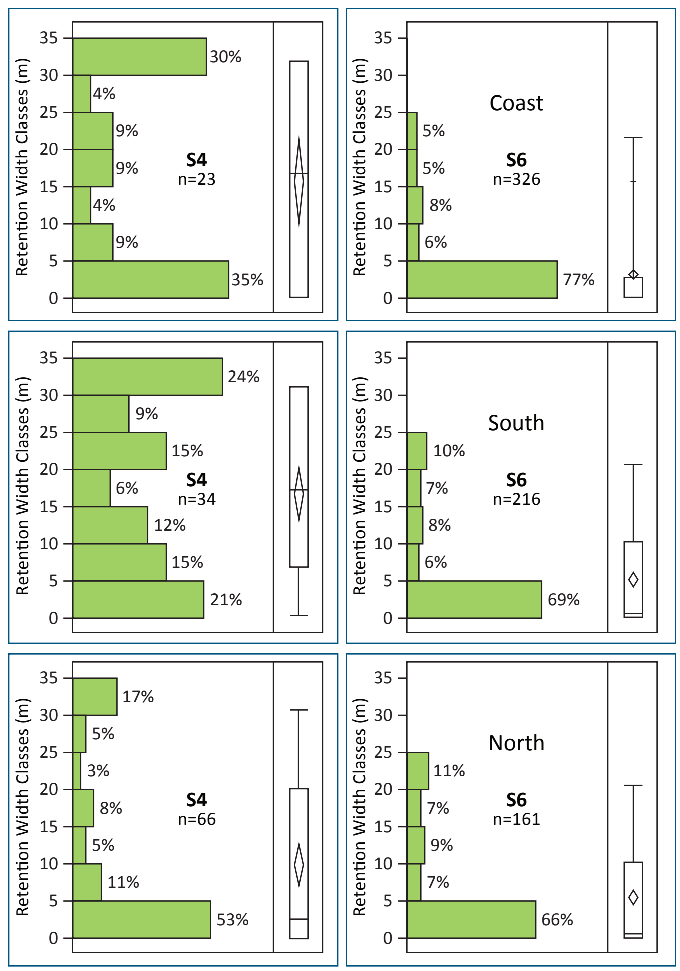



***Figure 3.*** *Frequency distribution of retention as a percentage of sample size within the riparian management area around S4 and S6 streams located inside the block. Quartiles with medians are shown on the right.*

Other studies have suggested that buffers around small streams are effective at mitigating impacts from logging (Rex et al. 2011, Richardson et al. 2010), and some retention within 10 m has been a suggested best management practice for streams without a legislated riparian reserve for more than 30 years (B.C. Ministry of Forests 1995; Toews and Brownlee 1981). All sites with 10 m or more retention were grouped together and compared with those having zero, 0.1 – 5 m, and 5.1 – 9.9 m retention.

Coastal stream reaches with 5.1 m or more retention were in overall better functioning condition than sites that had less, with more than 80% of the sites scoring in the top two categories (PFC and FR). Streams with 5.1 – 9.9 m retention in the south and north Interior did not rank quite as well as the Coast, with 64% and 69% in the top two categories respectively. This may be a reflection of more erodible soils and/or different logging methods, thereby necessitating the need for a greater root network adjacent to Interior streams. At 10 m retention and greater, 80% of both Interior sites scored in the top two categories. Reaches cut to the edge of the stream bank ranked the lowest in all three regions, with just 31 – 46% of the sites falling in the top two categories.

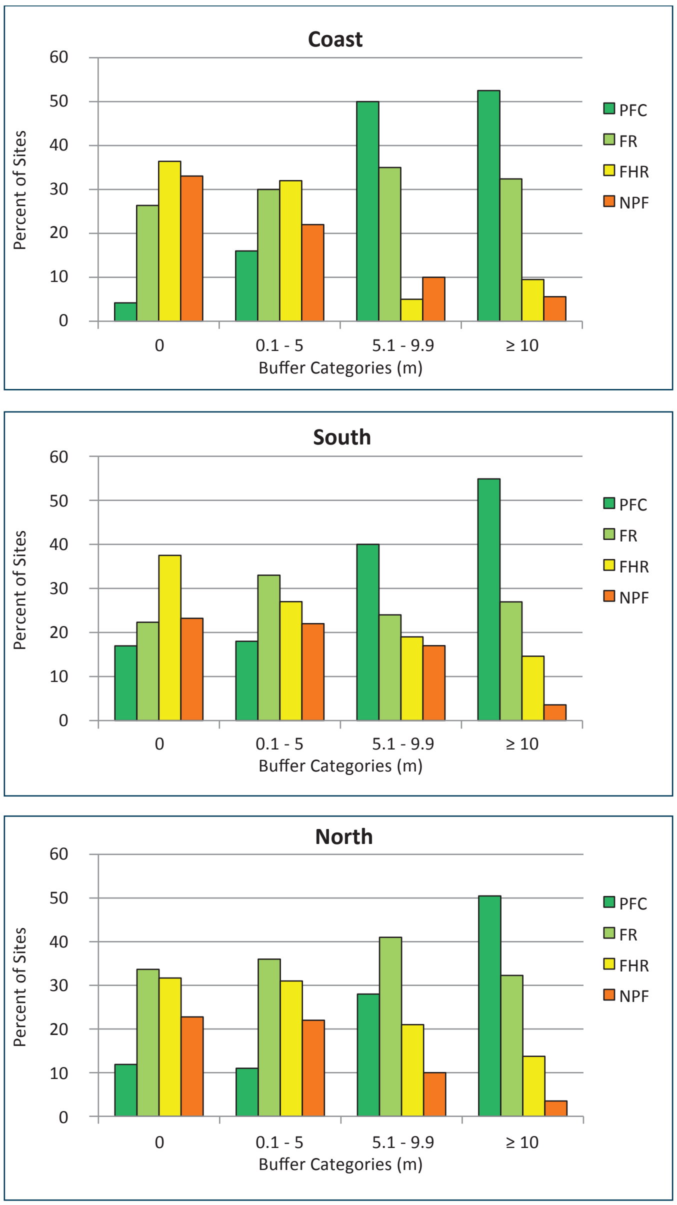
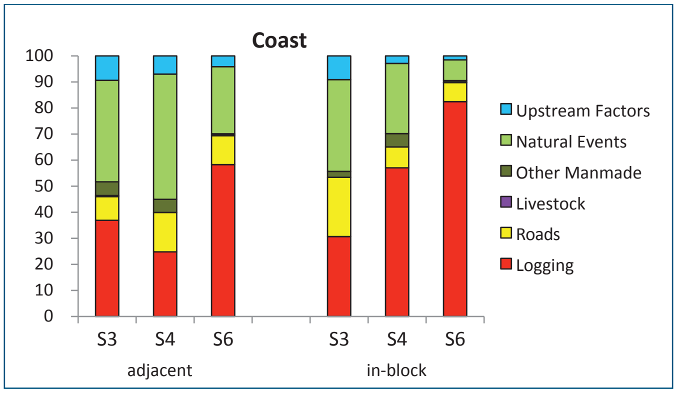
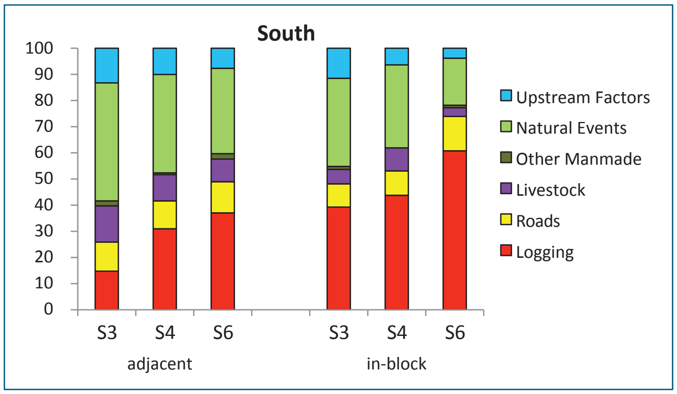



***Figure 4.*** *Proportion of streams in each condition by retention category.*

Streams are often left just outside of a block boundary, which means that only one bank is exposed to logging. Table 4 indicates that streams without legislated reserves were left in better condition when they were adjacent to the block compared to inside it. This is likely because there is little or no falling and yarding across the stream and the channel is not typically crossed by equipment. To assess the causes of negative responses further, data was grouped by the location of the stream reach (inside or adjacent to the cutblock). In-block streams had more logging-related negative responses compared to the adjacent sites (all stream classes combined, K-Smirnov; all $p < 0.001$). Although it was expected that logging effects would be less on reaches that were subject to harvesting on only one bank, negative responses owing to logging alone remained substantial (Fig. 5).

In general, the proportion of negative responses caused by logging was similar to the patterns seen previously, with higher numbers of negative responses received at sites inside the block compared to those adjacent, and a greater proportion of negative responses owing to logging activities in S4 and S6 reaches compared to S3 reaches. This pattern was apparent for all areas and stream classes, with the exception of coastal S3, which showed a relatively high proportion of adjacent sites (37%) affected by logging (Fig. 5). Although the retention given to S4 and S6 streams inside the blocks was somewhat similar among all areas (Fig. 3), the percentage of negative responses attributed to logging in-block S6 reaches was significantly higher on the Coast (Fig. 5) than the south and north (K-Smirnov; $p < 0.001$). It is uncertain whether this higher proportion of negative responses is the result of differences in topography, logging methods, history of logging, best practices, or a combination of several of these factors. For example, it may be difficult to avoid cross-stream cable yarding in steep coastal areas where small streams are numerous, and impacts may be exacerbated by the residual effects of historical logging.



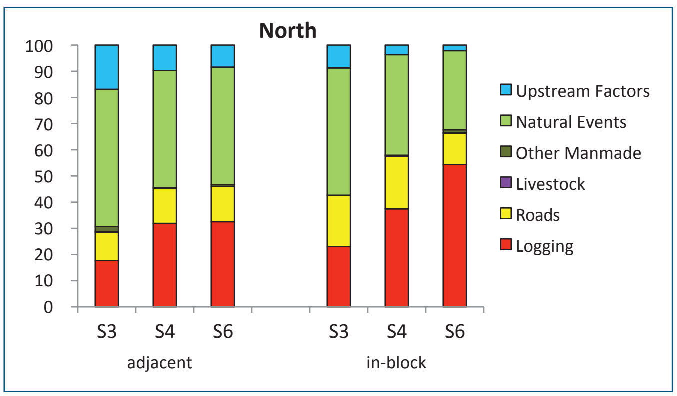




***Figure 5.*** *Percentage contribution of causal factors to total negative responses for streams inside and adjacent to harvested blocks.*

Although roads are a separate causal factor in the assessment, they often exist as part of a harvesting operation. Recently constructed, or older but active forestry roads, could explain some of the poorly functioning S3 streams. Although S3 stream reaches are given a minimum 20-m reserve under FRPA (and the equivalent of 1.5 tree heights for streams within the Great Bear Rainforest), the effects of an upstream road crossing can lead to in-stream impacts that result in negative responses to the indicator questions, even if the road is outside the sample reach or upstream of the cutblock (Nordin 2016). For example, road material that is washed downstream can disturb the bed and banks of a properly functioning stream inside a treed buffer, dislodging additional erosive material which is transported downstream until it eventually settles out and accumulates to cause changes in flow patterns or dewatering (Fig. 6).

***Figure 6.*** *FREP assessor attempting to find an original S3 stream channel under sediments approximately 100 m downstream of a road crossing.*

## 3.5 HARVEST-RELATED CAUSAL FACTORS

During each assessment, any harvest-related factors that influenced outcomes were noted, including: falling and yarding, low retention, windthrow, old logging, machine disturbance, diverted watercourses, torrenting, and slides/sloughs. The observations summarized here provide for a general understanding of the frequency of harvest-related effects. A more comprehensive review of harvest activities and their specific relation to the number of "no" answers is provided by Tschaplinski and Tripp (FREP Extension Note #39) and will be used to help guide discussion around best management practices and stream types in the final extension note in this series.

The most commonly identified harvest-related effects were falling and yarding, low retention, and windthrow (Table 6). Falling and yarding across streams was observed most frequently at S6 sites on the Coast, but was generally seen more at S6 streams in all regions when compared to S4 or S3 streams. Similarly, low retention was most frequently observed at S6 streams across all regions. The lower occurrence of low retention issues at S3 streams reflects the mandatory requirement for reserves on these streams. Windthrow was a fairly consistent observation across all stream classes and regions.

Old logging was often identified at S3 sites on the Coast (Table 6), which could partly explain the high occurrence of negative responses owing to logging in adjacent coastal S3 streams (Fig. 5). Although historical logging methods may differ from those of today, there is no differentiation when impacts affecting the health of the stream reach are identified. The residual effects from old logging are often masked by other harvest-related factors when much or all of the riparian management zone has been recently harvested. This is a common practice around S4 and S6 streams, and could explain why old logging observations were less frequent at these two stream classes.

**Table 6.** *Percentage of sites where harvest-related impacts were observed within the sample reach.*

| | Coast | | | South | | | North | | |
|---|---|---|---|---|---|---|---|---|---|
| | S3 | S4 | S6 | S3 | S4 | S6 | S3 | S4 | S6 |
| Falling & Yarding | 2 | 16 | 61 | 2 | 5 | 24 | 2 | 7 | 22 |
| Low Retention | 3 | 27 | 55 | 5 | 20 | 45 | 8 | 28 | 46 |
| Windthrow | 21 | 22 | 18 | 22 | 36 | 29 | 24 | 36 | 27 |
| Old Logging | 28 | 3 | 7 | 5 | 7 | 4 | 5 | 4 | 3 |
| Machine Disturbance | 2 | 5 | 11 | 0 | 3 | 9 | 0 | 2 | 7 |
| Watercourses Diverted | 0 | 0 | 5 | 1 | 0 | 2 | 1 | 2 | 2 |
| Torrenting | 0 | 3 | 2 | 0 | 0 | 2 | 1 | 2 | 1 |
| Slides | 2 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 0 |

## 4.0 SUMMARY

Overall, S3 streams were left in better condition than S4 and S6 streams, likely because of the 20-m mandatory riparian reserves and related operational decisions that buffer S3 channels, such as aligning the block boundary to exclude the stream, anchoring wildlife retention to the channel, or prescribing less intensive logging along gullied terrain. Retaining vegetation not only provides biological and physical value to the stream, but also mitigates effects related to harvesting. S4 and S6 streams adjacent to the block were ranked better than those within the block, which could be due to less cross-channel disturbance and retained vegetation on one side of channel. Streams with progressively wider buffers had better outcomes than those that had been logged to the bank. Across all stream classes, sites that were given more riparian retention had better outcomes, with more than 80% of reaches with a 10-m buffer ranked as properly functioning condition (PFC) or functioning at risk (FR). This indicates that retaining vegetation around streams not only provides riparian value, but also limits disturbance to the stream reach, thus leaving it in better condition despite the effects of windthrow observed in close to a quarter of the sites across the sample set.

Harvest-related impacts largely contributed to negative indicator responses. Residual impacts from old logging was noted in nearly a third of the S3 stream reaches on the Coast, which may have influenced a higher proportion of negative indicator responses recorded under the logging category for that stream class compared to the Interior sites. The influence of old logging could indicate that second-growth stands bear some legacy effects of past logging in their current state and may require additional consideration to recover completely. Impacts from windthrow were noted at S3 reaches in all regions, which may indicate that more retention is needed in the riparian management zone to protect the reserve in certain areas. Road crossings may also have contributed to impacts observed at downstream S3 reaches. Low retention, windthrow, and falling and yarding were the most common harvest-related impacts at S4 and S6 stream reaches.

The final extension note in this series will outline best management practices for small streams and will be published after collaboration with forest licensees and other stakeholders. Operational limitations and site conditions will be described, along with practical and innovative solutions to small stream management. If you or your team has developed or adopted an effective practice for maintaining the condition of small streams during harvesting, please contact Lisa Nordin (Lisa.J.Nordin@gov.bc.ca) or John Rex (John.Rex@gov.bc.ca) to provide your input.

## 5.0 REFERENCES

B.C. Ministry of Forests. 1995. Forest Practices Code. Riparian Management Area Guidebook. Published by the Government of British Columbia. Available online: https://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/rip-toc.htm.

Nordin, L.J. 2016. Riparian Management of Perennial Coastal Streams with Potential Habitat for Tailed Frog *(Ascaphus truei)*. Journal of Ecosystems and Management 16(1): 1-10.

Rex, J., D. Maloney, E. MacIsaac, H. Herunter, P. Beaudry, and L. Beaudry. 2011. Small stream riparian retention: the Prince George Small Streams Project. B.C. Min. For. Range, For. Sci. Prog., Victoria, B.C. Exten. Note 100.

Richardson, J.S., M.C. Feller, P.M. Kiffney, R.D. Moor, S. Mitchell, and S.G. Hinch. 2010. Riparian Management of Small Streams: An Experimental Trial at the Malcolm Knapp Research Forest. Streamline Watershed Management Bulletin 13 (2): 1-16.

Toews, D.A.A., and M.J. Brownlee. 1981. A Handbook for Fish Habitat Protection on Forests Lands in British Columbia. Department of Fisheries and Oceans, Vancouver, BC. 173 pp.

Tripp, D.B., P.J. Tschaplinski, S.A. Bird, and D.L. Hogan. 2009. Protocol for Evaluating the Condition of Streams and Riparian Management Areas (Riparian Management Routine Effectiveness Evaluation). Forest and Range Evaluation Program, B.C. Min. For. Range and B.C. Min. Env., Victoria, BC.