

Strategic 5 Year Plan for Operational Brushing Research in the Kootenays

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Executive summary

BC Timber Sales and industry in the Kootenays recently requested support from the BC provincial government for acquiring additional research evidence to address operational stocking standards, stand performance expectations, and brushing requirements as found in current free-growing obligations and forest stewardship plans. To address this request, seven operational foresters from the Kootenays, the provincial government research ecologist for the Kootenays, and a University of British Columbia forest ecologist with strong ties to brushing and free-growing were surveyed. This document compiles and synthesizes their concerns and priorities for operational brushing research. The document then provides a five year plan for future operational brushing research for the Kootenays, based in part on measurement and reporting of existing PROBE (Protocol for Operational Brushing Evaluations) installation. There are 96 PROBE installations across the southern interior (21 in the Kootenay-Boundary and 75 in the Thompson-Okanagan Region).

The main concern of the operational foresters was that in order to satisfy the legal free-growing obligations they must brush some stands that they feel are healthy and do not require treatment (i.e., conduct what they call “administrative brushing”). Their reasons for opposition to this type of brushing includes high cost (up to \$1500/ha), increased losses to *Armillaria*, negative impacts on soils, wildlife and biodiversity, and safety concerns. They did not have issues with brushing very dense broadleaf or tall shrub vegetation, or dense low vegetation such as thimbleberry-fireweed that they feel is impeding conifer survival. Six of the seven operational foresters reported that the free-growing requirements have resulted in an increase in area of broadleaves they brush, and four of the seven reported an increase in brushing of shrubs or herbs. The free-growing requirements have resulted in some increases in broadcast brushing instead of partial removal treatments, but broadcast brushing is often used anyways because it is easier for the field crews to implement and reportedly costs about the same as selective brushing. All brushing in the Kootenays is done manually and there are over-riding reasons why this treatment is chosen (i.e. it is not related to free-growing requirements). Overall, 39% of brushing was reported to be applied in broadleaf complexes (61% in shrub/herb plant communities) and 78% is applied in the Interior Cedar-Hemlock biogeoclimatic zone.

One of the highest priorities for the operational foresters was compiling and summarizing into one document the PROBE data articles and other brushing research reports that are relevant to the Kootenays. This is recommended for year one to provide immediate information, then updating it with new results in year five.

Overall, the highest priority species for brushing research were identified as Douglas-fir, western larch, and western redcedar, followed by hybrid spruce and western white pine. The ecosystems of most interest are circum-mesic sites in the ICHmw2 (old classification system; now ICHmw2, mw4, and mw5) and ICHdw1 variants. The competing species of most concern are paper birch, trembling aspen, mixtures of Douglas maple/ willow/Sitka alder, and ceanothus. The respondents are primarily interested in manual cutting. Most said that the most competitive and extensive low shrub or herb complexes are those dominated by fireweed and/or thimbleberry, especially on mesic-subhygric ICHmw2 sites.

The gap analysis indicates that there is only one PROBE installation in the high priority ICHdw1 variant. However, because some of the ICHmw2 variant in the Thompson-Okanagan has recently been reclassified as ICHdw4, it is recommended that the PROBE sites which fall into this situation be identified as soon as possible (i.e., in year one in the plan), and the locations checked with the regional ecologists to determine which, if any, are similar to the ICHdw1.

There are a considerable number of existing *Mixed Broadleaf-Shrub*-Douglas-fir-manual cutting PROBE installations (as well as other trials) and this vegetation complex-conifer species-treatment cell was a high research priority for Kootenay foresters. Four of these PROBE sites include partial birch retention. For all operational foresters surveyed, the highest priority for future PROBE field work was the remeasurement at Champion Creek (established in 2001), where three levels of birch retention were tested with Douglas-fir, as well as western larch and lodgepole pine. The remeasurement of the Champion Creek installation is recommended for 2020 (year four of the plan). Remeasurement of three partial retention Douglas-fir/birch sites at Burton Creek, Honeymoon Road and Pisima are not as high a priority for the Kootenay foresters because the sites are located at Adams Lake which is not in the Kootenays. However, because the treatments are unique, sites are reasonably similar to the Kootenays and only five year data has been collected, it is recommended to proceed with the 19-year remeasurement in the first year of the plan (2017) (Burton Creek) and year three of the plan (2019) (Honeymoon Road and Pisima). This schedule would result in remeasurement of all four sites at the same number of years post-treatment (19 years). The existing data from these four sites has not been analyzed and reported. For broadcast manual cutting, girdling, and cut-stump glyphosate treatment of the *Mixed Broadleaf-Shrub* complex, only short term (5 year) PROBE data has been reported even though ten year data has been collected. It is recommended that all of the *Mixed Broadleaf-Shrub*-Douglas-fir data be included in journal articles and extension notes, the latter of which will be directed towards operational foresters. It is recommended to produce a separate journal article and extension note for partial and broadcast birch removal.

Determining long-term effects of brushing on stand productivity is a research priority for many of the foresters surveyed, but overall this is not as immediate a priority for them as are the standard PROBE remeasurements. Permanent Measurement Plots (PMPs) have been established on 20 PROBE sites and can provide stand productivity data on the effects of brushing birch or aspen growing with Douglas-fir or lodgepole pine. Because the Douglas-fir/birch-manual cutting PMPs are replicated they should be considered the first priority out of these, but field remeasurements are recommended to be left until ample funding is available.

An important research priority of the Kootenay foresters was to relate conifer performance to the three free-growing brush criteria (number of brush-free quadrants, broadleaf density, and conifer/brush height ratio). There is no existing PROBE (or probably other) data on how the number of brush filled quadrants affects conifers. PROBE data has been collected that can be used to relate Douglas-fir, lodgepole pine, western larch, hybrid spruce and western red cedar performance to conifer/brush height ratios and density of neighbouring broadleaves. Only the latter has been analyzed, and only for Douglas-fir and lodgepole pine. For those two species, there is now more data than was in

the original analysis. Several other experiments also have data from the ICHmw subzone relating broadleaf density and conifer/brush height ratios to Douglas-fir, western larch and western redcedar performance, and these are valuable data sources. It is recommended that analysis be conducted in year five of new and existing PROBE and other data to contribute to validating the appropriateness of the broadleaf density and conifer/brush height ratio requirements.

Additional work that is recommended if funding is available is establishment of operational manual brushing trials (PROBE methodology) at three Douglas maple (willow/alder) sites in the Kootenays. However, results from these trials would not be available for several years. Considering that climate is predicted to change across southern interior BC, another undertaking that is relevant and could be accomplished immediately is a meta-analysis of cross-climate responses using the large PROBE and other vegetation management databases.

Total five year funding to conduct all of the recommended work is estimated at \$124,500. Four of the surveyed operations people were willing to contribute funding and most felt that funding should come from a combination of government and industry. No one had committed a dollar amount at the time this document was written. One mentioned they could potentially make an in-kind contribution. Work conducted in the Thompson-Okanagan Region should be funded at least partially by the local licensees.

The field work would best be carried out by the persons who installed and remeasured the experiments to provide consistency and increase the likelihood of locating the sites and measurement plots (GPS coordinates are not available for all sites). It is recommended that reporting be carried out by Jean Heineman, Jean Roach and Suzanne Simard as they are familiar with the sites, field measurement techniques and data, and have done all of the previous reporting.

1 Introduction

BC Timber Sales (BCTS) and industry in the Kootenays recently requested support from the BC provincial government for acquiring additional research evidence to address operational stocking standards, stand performance expectations, and brushing requirements as found in current free-growing obligations and forest stewardship plans. To address this request, in January 2017 Skyline Forestry Consultants Ltd was contracted by George Harper, Resource Practices Branch, BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) in Victoria to:

1. Survey key government, industry and BCTS staff to compile and synthesize their concerns and priorities for operational brushing research
2. Prepare a strategic five year plan with the goal of providing a rationale and guidance document for future PROBE (Protocol for Operational Brushing Evaluations) re-measurement and reporting priorities. See Section 4 for background about PROBE.

A total of seven operational foresters in the following organizations were surveyed in March 2017:

1. BCTS, Castlegar
2. BCTS, Cranbrook
3. BCTS, Nelson
4. ATCO Wood Products, Fruitvale
5. Kalesnikoff Lumber Co. Ltd, Thrums (Nelson)
6. Interfor, Castlegar
7. Interfor, Grand Forks

Two additional people were interviewed to obtain their perspectives about brushing as related to administrative requirements, and their thoughts on operational brushing research needs in the Kootenays:

1. Deb MacKillop, Research Ecologist, Kootenay Boundary Region, FLNRO, Nelson
2. Suzanne Simard, Professor of Forest Ecology, Department of Forest and Conservation Sciences, University of British Columbia, Vancouver (developer and overseer of the PROBE program)

2 Problem analysis based on survey results

2.1 The problem

The information described in this section reflects the views of the persons who were surveyed and not necessarily the author of this document. The problem that the operational Kootenay foresters clearly conveyed is that they must brush some conifer stands that they say show little or no sign of suppression, in order to meet free-growing obligations and remove the legal liability on those sites. They refer to this as “administrative brushing”. Deb MacKillop suggested that existing data may not necessarily support the licensees concerns but that we need a more thorough look at the situation to see whether brushing is warranted. While the legislated requirements are considered by several of the

operational foresters to be overly conservative, they did not have issues with brushing in certain situations. These include: very dense broadleaf complexes (mainly birch and aspen), dense tall shrub complexes (e.g., maple and willow), or dense low vegetation such as thimbleberry-fireweed that they report is impeding conifer survival.

A concern raised by several operational foresters is that free-growing assessments are focused on the competition and not the conifers. Respondents felt that we should be concentrating assessments on the health, vigor, form, and growth (leader, diameter) of the conifers and not, for example, on the number of brush-filled quadrants. These concerns reflect results that have emerged from the PROBE program, where the authors have recommended that the assessments should focus on whether crop trees are “well-growing” rather than “free-growing”.

More specifically, respondents questioned whether the required conifer/brush ratios, number of brush free quadrants and allowable number of broadleaves are appropriate. They commented that these requirements could be differentiated more than they currently are, such as by conifer tree species and growth characteristics. One respondent indicated that perhaps shade tolerant trees should be able to have 2 quadrants overtopped rather than one, depending on the vigor of the tree. This suggestion illustrates the recognized need to gauge the success of the stand in relation to the performance of the crop trees.

The operational foresters felt that free-growing requirements and stand expectations are in most instances applied in too short a time frame to determine if the goal of achieving long term stand health is being met. Deb MacKillop noted, however, that in some cases licensees are brushing very young stands (e.g., age 5) in order to fulfill their free-growing requirements as early as possible. At this young age many pests that may affect free-growing status have not yet manifested themselves. A research need that was identified by the operational foresters is to conduct post-free-growing monitoring to look at stands 10-15 years after declaration. It was suggested that free-growing survey methodology could be used to compare silviculture and inventory labels, stand productivity, species suitability, forest health, and brush issues of stands at the free-growing declaration date versus at 10-15 years after declaration, to determine if current requirements and expectations are adequate and appropriate. The respondents acknowledged that there has been some work done on this (e.g., Woods and Bergerud 2008; Heineman et al. 2010; Mather et al. 2010) but that a more intensive sample would better illustrate trends. It was also suggested that study of mid and long-term costs and benefits (volume losses and gains) of brushing treatments, for example, by modeling stand dynamics in treated and untreated stands post-free growing, could help refine treatment need, timing, intensity and effectiveness.

2.2 Reasons for opposition to brushing

High cost, compromised safety and negative ecosystem effects were provided as reasons operational foresters would like to avoid “administrative brushing”.

Six out of the seven respondents identified cost as very important or the main reason why they are opposed to brushing where they feel the conifers are in satisfactory condition. The survey indicated

that the current average cost of brushing broadleaf complexes in the Kootenays varies from \$650-1500/ha (average \$900/ha). Treating shrub/herb plant communities costs \$500-900/ha (average \$740/ha). The survey indicated that brushing is done extensively in some areas of the Kootenays. The amount of area currently brushed by individual licensees and BCTS in the Kootenays varied from 40 to 800 ha per year, with the 40 ha area for operations based out of Cranbrook and 800 ha for operations out of Fruitvale. Considering all survey respondents together (n=7), 39% of the area currently brushed is broadleaf-dominated (699 ha) and 61% herb/shrub dominated (1066 ha). Using the average costs for each organization, together the seven respondents spent \$632,380 per year treating broadleaf complexes and \$699,250 per year treating shrub-herb plant communities for an annual total of \$1.33 million/year.

Six of the seven respondents said they were concerned about negative effects of brushing on ecosystems, including increased root disease, changes in nutrient cycling, and loss of biodiversity and wildlife habitat. There was an overall consensus that brushing may actually reduce the long term volume of the stand (e.g. on sites where *Armillaria* or other pests are present). One respondent cited Teresa Newsome's research in the Cariboo showing snow breakage to conifers may increase where broadleaf trees are no longer present for protection. One respondent elaborated that administrative brushing diminishes a critical phase of site establishment after harvest; many tree species rely on the pioneer herb/shrub layer to rebuild the ecology of a disturbed site by keeping the nutrients at the site and releasing them for the benefit of the forest. Broadleaf foliage was acknowledged as providing needed nutrients for conifers, and aiding in retaining moisture and a balanced soil pH. Pioneer herb and shrub species were recognized as providing forage for various species of ungulates and at times even acting as a barrier to ungulate browse of seedlings. Vegetation, including broadleaves, was identified as providing critical habitat for small mammals, reptiles, amphibians and birds. One respondent had no concern about nutrient cycling or root disease in treated stands because cut broadleaf trees and woody brush species re-sprout and continue to provide the same functions soon after treatment. He also had no concern about biodiversity or wildlife habitat because there are generally pockets of brush that exist outside the treatment area that are available for these values.

Two of the seven respondents cited safety as a concern, especially on steep slopes, because brushing exposes workers to risk of injury.

2.3 Effect of administrative requirements on area brushed

For sites dominated by broadleaf trees, one operational forester said brushing requirements had no effect on the area they brushed and six reported an increase. For herbs and shrubs, one forester reported a slight decrease in brushing as a result of the standards, two no effect, and four a moderate or substantial increase.

Appendix A-1 provides a breakdown by vegetation complex of the amount of brushing done primarily to meet administrative requirements. All respondents (the four in the table, plus one who provided general comments) reported that brushing to meet administrative requirements comprised a moderate to high proportion of treatment applied to broadleaf complexes. The perceived

competitiveness of the *Mixed Broadleaf-Shrub* and *Aspen* complexes varied across the Kootenays and across sites, but one respondent applied moderate amounts of brushing in the *Mixed Broadleaf-Shrub* complex even though they rated it as posing a minimal to non-existent competitive risk on most sites. Three respondents conducted “administrative” brushing in broadleaf stands only, even though brushing of herb-shrub communities was moderately common to common. Two of the five respondents conducted “administrative” brushing not only in broadleaf complexes but also in the *Mixed Shrub*, *Dry Shrub*, *Willow*, *Wet Alder* and/or Douglas maple sites, and one person sometimes brushed the *Subalpine Herb* and *Fern* complexes primarily to meet the free-growing requirements. Most respondents said that brushing of low shrubs/herbs, such as fireweed – thimbleberry, is routinely done for establishment survival, but not specifically to meet free-growing brush criteria.

2.4 Effect of administrative requirements on brushing techniques

The operational foresters were asked if they do any selective brushing (e.g. treatments applied in a radius around crop trees) and if the free-growing requirements affected their choice of selective versus broadcast treatment. Four out of seven people reported that they never or rarely do selective brushing of broadleaves; for two of them this was due to the free growing requirements and for two there were other over-riding reasons (e.g. similar costs for broadcast and selective brushing, coupled with the simplicity of applying broadcast treatments for the brushing crews). Two of the three respondents that sometimes apply selective brushing to broadleaves revert to broadcast treatment on certain sites due to the free-growing requirements, and all noted that spot treatments are essentially the same as broadcast treatments where conifer stocking is high. For shrub and herb communities, three of the seven people surveyed reported that they never or rarely do selective brushing, and for one of them broadcast brushing is preferentially used in order to achieve the free-growing requirements. Of the four respondents that commonly or often selectively brush herbs and shrubs, two of them indicated that on some sites they must broadcast brush because this is the only way to meet the standards.

The free-growing requirements are not an important driver of brushing method (e.g. manual cutting, girdling, grazing, herbicide application, etc.) for the Kootenay operational foresters surveyed. They only use manual brushing methods to treat broadleaf trees, shrubs and herbs. Herbicides are not used in forestry in the Kootenays for reasons that include the hassle of obtaining permits and the need to protect community water sources.

3 Research priorities of Kootenay foresters

This section summarizes the comments of the surveyed operational foresters and does not necessarily reflect the opinions of the author of this document,

An priority for the operational foresters was to obtain operational brushing research data that is local to the Kootenays.

The operational foresters provided information on the BEC units, vegetation species/complexes and crop tree species for which they feel more research is needed to validate free-growing requirements, and they listed specific research priorities. Appendix A-2 summarizes this information for

broadleaf and tall shrub complexes and indicates whether and how existing PROBE data could address those questions. According to the survey respondents, low shrubs/herbs are typically brushed for conifer survival and not to meet free-growing brush requirements so are not included in this table.

The specific questions asked by the respondents were:

1. What is the most effective timing of brushing treatments in terms of cost and enhancement of tree form and vigour?
2. In the ICHdw1, how do Fdi, Lw, Cw, and Pw trees growing with untreated aspen (birch) compare to ones that are growing where brushing has not been done?
3. What are acceptable birch (maple) levels for survival and long-term productivity of Fdi, Pw, Cw, Hw, Sx on mesic ICHdw1 and ICHmw2 sites?
4. Are the requirements for total no. of acceptable birch and aspen, conifer/brush ratio, and number of brush free quadrants appropriate for all tree species in the ICHdw and ICHmw2?
5. Does spruce perform well or better with overtopping broadleaf trees present compared to without broadleaves in the ICH and MS zones?
6. Should we be increasing brushing of competing broadleaves in larch-leading stands in the ICH and MS?
7. On mesic-submesic ceanothus (willow, alder) sites in the ICHdw1 and ICHmw2, will Fdi, Lw and Pl reach free-growing in time without treatment?
8. Maple/beaked hazelnut/ocean spray/thimbleberry complexes in the ICHdw1 with Fdi, Lw and Py are common targets of administrative brushing. Is this brushing needed?
9. What is the efficacy of establishment brushing of fireweed for Fdi, Sx, Cw, and Lw in the ICHmw2 01 and of Cw and Sx in the ICHmw2 05.
10. On rich, mesic-subhygric ICH sites with fireweed, lady fern, bracken and thimbleberry, how can we best manage for increased survival of Sx and Cw, including the best timing of treatments?

Regarding high priority BEC units, the ICHmw2 (old classification system) and ICHdw1 were overwhelmingly chosen as research priorities by the operational foresters with one person also choosing the ESSF zone (all subzones) (Castlegar) and another person the MS zone (Grand Forks). These choices reflect the fact that the total area currently brushed by the survey participants was 78% in the Interior Cedar-Hemlock (ICH), 18% in the Engelmann Spruce-Subalpine Fir (ESSF), 3% in the Montane Spruce (MS) and <1% in the Interior Douglas-fir (IDF) biogeoclimatic zone. While most individual respondents

conduct brushing mainly in the ICH zone, one reported that brushing is concentrated in the ESSF (Nelson) and one in the MS (Cranbrook).

Regarding high priority vegetation complexes, in both the ICHdw1 and ICHmw2 (old classification) variants, the most common competing broadleaf trees and shrubs of concern to the operational foresters were: paper birch, trembling aspen, Douglas maple, willow, Sitka alder, and ceanothus. Deb MacKillop agreed that these are important competing species in the Kootenays. Overall, broadleaf complexes and tall shrubs (Douglas maple, willow and Sitka alder) were rated as higher priority for research related to free-growing brush requirements than low herb-shrub plant communities. Overall, the most competitive low shrub-herb vegetation community was fireweed-thimbleberry, especially on mesic-subhygric ICHmw2 sites. These species were reported to be causing extensive survival problems in parts of the Kootenays, but they are brushed out of need for survival, not to meet free-growing brush requirements.

The tree species with the most widespread interest as priorities for research related to free-growing were identified as Douglas-fir, western larch and western redcedar. The second most common species of interest were hybrid spruce and western white pine. In contrast, lodgepole pine, ponderosa pine, western hemlock, grand fir, and subalpine fir were targeted as research priorities across fewer vegetation complexes and by fewer respondents.

The operational foresters were asked to prioritize various field PROBE measurements for gaining additional research evidence to address concerns over free-growing requirements and stand expectations. Re-measurement at Champion Creek, where Douglas-fir, western larch and lodgepole pine were treated with three levels of birch retention, was rated high priority by all respondents Appendix A-3). At the other extreme, there was no interest in re-measurements of lodgepole pine-Sitka alder PMPs. All the other work averaged out to be about medium in priority, but with wide variety among respondents. Interest in re-measurement of the three partial birch retention–Douglas-fir sites at Burton Creek, Honeymoon Road and Pisima varied, with interest dampened by the fact that the sites are not in the Kootenays.

The operational foresters were asked to prioritize measurement of Permanent Measurement Plots (PMPs). Appendix A-4 provides their priority ratings for each vegetation complex-conifer species-treatment combinations. Manual cutting of the *Mixed Broadleaf-Shrub* and *Aspen-ICH zone* complex with Douglas-fir, and manual cutting of the *Aspen-ICH zone* complex with lodgepole pine were rated the highest priority for re-measurement, although there was less interest in pine than Douglas-fir. There was intermediate interest in manual cutting treatment in lodgepole pine stands in the *Mixed Broadleaf-Shrub*, *Aspen-(IDF zone)*, and *Dry Alder* complexes. There was little interest in any PMPs where girdling or herbicide application was the treatment.

There was variable interest in 10+ year re-measurement of replicated herb/low shrub sites. Interest was highest in the manual cutting treatments (Appendix A-5). Only one person had an interest in herbicide treatments, and there was no interest in grazing for brush control. As mentioned above, the

operational foresters indicated that brushing in these short plant communities is mostly for survival and they consider the treatment necessary.

Appendix A-6 provides a summary of how the operational foresters prioritized analysis and reporting work. The suggestions for this work were provided by the author of the survey. Although they were asked, the operational foresters did not offer their own suggestions for analysis and reporting. Respondents want summaries of local data and in an easily readable concise form. Reporting on any new field data collection was a priority for several respondents. Every respondent gave a high priority rating to compiling and summarizing into one document the PROBE data articles and other brushing research reports that are relevant to the Kootenays. Four out of five respondents gave high to medium priority for analyzing and reporting on 10-year results for three broadcast birch removal treatments (manual cutting, girdling and cut stump-glyphosate) in Douglas-fir stands, each replicated 3-4 times. The most interest was in the manual cutting treatment.. Overall, there was less interest in reporting on existing 10-year data for manual cutting of birch in lodgepole pine stands than Douglas-fir stands, and no interest in manually cutting of Sitka alder in lodgepole pine stands.

4 PROBE project background

4.1 Original PROBE study

From 1991-2007, the PROBE project gathered information to test the effects of operational brushing treatments on young conifers and vegetation. The project includes 96 sites and encompasses 13 vegetation complexes that occur across a range of ecosystems. Twenty-one sites are in the Kootenay-Boundary Region and 75 in the Thompson-Okanagan.

The original PROBE study utilized a randomized complete block design to test specific operational brushing treatments, where blocks were replicate study sites. The project was designed to include a minimum of three replicate sites in each combination of BEC zone/vegetation complex/conifer species/brushing treatment (known as cells in the PROBE matrix; Appendix A-70, although funding has been insufficient to fill all cells. Sites were selected by choosing clearcut blocks that were scheduled for operational brushing and that fit into a cell of interest in the matrix.

A summary of location, vegetation complex, BEC unit, brushing treatment and measurement history for individual PROBE sites is in Appendix A-8. Heineman and Roach (2012) provide PROBE accomplishments (e.g. extension products) to 2012 and status of each site including accessibility and anticipated re-measurement difficulty.

At each study site, a treatment and an untreated control were randomly assigned to two adjacent plots that each measured 90x90 m (0.8 ha) in size. The two plots were required to have similar site characteristics, vegetation species and abundance, and conifer species, size, stocking and health. Thirty-six points were systematically located in a 10 m grid within each plot, with the closest “undamaged” conifer of the chosen species and age selected as the measurement tree and sub-plot centre (72 sub-plots per site). If damage was considered to be due to competition, the tree was eligible as a measurement tree. Measurements were made immediately before brushing (year 0), and 1, 3, 5,

and 10 years afterward. Data was collected on standardized forms and the measurement methods are summarized in Appendix A-9. For a complete description of PROBE methods and the forms, see Simard (1993).

4.2 Permanent measurement plots

Beginning in 2002, permanent measurement plots (PMPs) were installed on a subset of sites that had yielded 10 years of PROBE data. The PMPs were intended to provide long-term information about the effects of vegetation management treatments on growth and yield and stand development, with particular focus on broadleaf and tall shrub complexes. By 2006, PMPs were installed on 20 sites in the *Mixed Broadleaf-Shrub*, *Aspen*, and *Dry Alder* complexes. Three of the *Aspen* complex PMPs were re-measured in year 5 (2008), but since then funding has been unavailable.

The PMPs are circular plots with an area of 0.1 ha ($r=17.84$ m), or 0.04 ha ($r=11.28$ m) where stand density exceeded 7500 stems ha^{-1} . PMPs were established at the centre of each of the treatment and control plots. Information collected for each PMP is described in Appendix A-10 and includes: tree measurements, site index, non-crop vegetation species data, regeneration data, and site and soil descriptions.

4.3 Management and funding sources

Suzanne Simard initiated the PROBE project in 1991 when she was Research Silviculturist for the Kamloops Forest Region of the BC Ministry of Forests and Range (the current Thompson-Okanagan Region in the Ministry of Forests, Lands and Natural Resources Operations). When Suzanne joined the Faculty of Forestry at UBC in 2002, Jean Roach (Skyline Forestry Consultants Ltd., with the project since 1991) and Jean Heineman (J. Heineman Forestry Consulting, with the project since 1995) took over its management, with continuing input from Suzanne. The PROBE project continued to receive funding until 2010 (19 years). Over the years, the project received generous funding support from both government and industry. Supporting agencies include: B.C. Ministry of Forests and Range, Forest Resource Development Agreement (FRDA II), Forest Renewal British Columbia (FRBC), Forestry Innovative Investment (FII), the Kamloops and Lillooet TSA committees, Ainsworth Lillooet, Atco Lumber, International Forest Products, Kalesnikoff Lumber Company, LP Engineered Wood Products, Meadow Creek Cedar, Riverside Forest Products, Slocan Forest Products Vavenby, Tembec, Tolko Industries Limited, and Weyerhaeuser.

4.4 Value of PROBE project

The PROBE project continues to be a valuable source of operational research data for the following reasons:

1. There are numerous sites (96) spanning 13 vegetation complexes in the Thompson-Okanagan and Kootenay - Boundary Regions, where a consistent methodology has been applied

2. Sites with the same biogeoclimatic (BEC) zone, vegetation complex, conifer species, and brushing treatment are replicated over the landscape
3. Treatments were applied by operational brushing crews on sites that were part of industry's brushing program, rather than on sites selected and treated specifically for research, which have tended to be biased toward representing some of the most extreme vegetation competition conditions
4. Operationally relevant treatments were studied
5. Plots are large (90x90 m).
6. Control (no brushing) and treated plots were established at each site
7. Pre-treatment data was collected
8. Measurements were collected at regular intervals: pre-treatment, and 1, 3, 5 and 10 years post-treatment
9. Plots were well marked, including rebar stakes and metal tags marking each crop tree and fence posts at plot corners, and have been maintained over time (until 2008)
10. Long-term data is available or can be collected – treatments were applied between 1991 and 2007 (10-26 years ago)
11. Permanent measurement plots, in which growth and yield in treated and control plots can be monitored, were established on 20 sites
12. Results have been published in numerous peer-reviewed scientific articles and government publications, reflecting globally-recognized scientific credibility for the program
13. Results are available in various extension media, including an on-line expert system, on-line talks, and summarized in a range of popular science articles

5 Gap analysis

(1) Champion Creek is the only PROBE site in the ICHdw1, which was rated a high priority BEC unit for brushing research data.

Existing data: Some PROBE sites are in the geographic area where the ICHmw2 has been reclassified as ICHdw4 (e.g., in the Okanagan). Some of these sites may be similar to the ICHdw1.

Data gaps and research priority: Because the maps and elevations of the sites are not in electronic format, and GPS coordinates were not recorded in the field for many sites, it was beyond the scope of this contract to determine which sites are now classified as ICHdw4. Determining the coordinates of the sites using maps on file in project binders should be given high priority, enabling the BEC variants under the new classification system to be determined. Deb MacKillop then should be consulted regarding which, if any, of these sites are similar to the ICHdw1.

(2) Limited PROBE data exists for spruce, western redcedar and western larch growing with broadleaf/tall shrub complexes.

Existing data: There are three spruce/birch and one western redcedar/birch PROBE site in the ICHmw subzone in the Thompson/Okanagan Region and one western larch/birch site in the Kootenays. There are other sources of data for these species but they are not based on operational treatments (e.g., Simard 1996; Simard and Hannam 2000; Simard and Sachs 2004).

Data gaps and research priority: The relationship between the free-growing brush criteria and the performance of spruce, western redcedar and western larch has not been determined for the ICHdw1 variant. Newsome and Heineman (2016) recommend that future investigations of free-growing status versus conifer performance be focused on crop tree-brush-site combinations where brushing is least likely to be required biologically (i.e., likely the more shade-tolerant species western redcedar and spruce should be given priority over western larch).

(3) There are no PROBE installations on sites dominated by Douglas maple/willow

Existing data: No PROBE data exists and it is unknown if other trials in the southern interior have looked at Douglas maple competition. Margaret Schmidt and her graduate students at Simon Fraser University have published numerous peer-reviewed scientific papers on the effects of vine and bigleaf maple on conifers and soils in CWH ecosystems

Data gaps and research priority: Maple is a common and sometimes strong competitor in parts of the Kootenays. The survey indicated that it is often treated in order to meet free-growing brush criteria and Deb MacKillop suggested it can be the major species of a currently undefined vegetation complex. Research related to this species should a priority for future operational brushing research in the Kootenays, however, new trials would need to be established meaning several years would be required before results are obtained.

(4) There are no PROBE installations on Kootenay ceanothus sites.

Existing data: One PROBE site was installed on a ceanothus site. It is in the Thompson-Okanagan Region. Deb MacKillop suggested that this site is probably not representative of the Kootenays.

Data gaps and research priority: As the operational foresters and Deb MacKillop indicated, ceanothus can be problematic for conifers in the Kootenays. Ceanothus is a nitrogen fixing and drought tolerant species, and is also favoured wildlife browse, so it also provides a range of important ecosystem services that will likely become more crucial as climate change imposes stress on these sites. Because ceanothus only reaches chest height, it should be a lower priority than tall shrubs or broadleaves for brushing research focusing on meeting free-growing brush criteria.

(5) The relationship between conifer performance and density of neighbouring broadleaves, conifer/brush height ratios and number of brush-free quadrants has been only partially summarized.

Existing data: Simard et al. (2001) used PROBE data to calculate brushing thresholds (percent cover and density of broadleaves) at which Douglas-fir and lodgepole pine stem diameter was reduced and vegetation competition became a major limiting factor to growth. Additional PROBE data has been collected but not analyzed and it could be added in to strengthen the analysis. Non-operational brushing research investigating birch neighbourhood effects on Douglas-fir, western larch and western redcedar includes Simard and Hannam (2000), Simard and Sachs (2004) and Baleshta et al. (2016). Conifer/brush height ratio data exists in the PROBE data set (as well as experiments established by Simard) for Douglas-fir, lodgepole pine, spruce, western redcedar and western larch.

Data gaps and research priority: PROBE did not collect data on the number of brush free-quadrants and such data is probably not available from other Kootenay brushing research.

(6) Long-term effects of brushing on stand productivity has not been reported.

Existing data: PMP data from PROBE sites has been collected for 20 sites and can provide long-term productivity data. The PROBE sites where PMP plots were established are typically 25-35 years old (in 2017).

Data gaps and research priority: The PMP data has not been analyzed. Because there is a particular interest in manual cutting of birch in Douglas-fir stands by the operational Kootenay foresters, and there are three sets of PMPs for the *Mixed Broadleaf-Shrub-Douglas-fir*-manual cutting PROBE cell (three control and three treated plots), the current data (2001-2003) should be analyzed and, if funding allows, re-measurements conducted.

(7) Only short-term PROBE data for broadcast or partial treatment of birch in Douglas-fir stands has been reported.

Existing data: Ten year data has been collected for ten *Mixed Broadleaf-Shrub-Douglas-fir* PROBE installations where broadcast treatments were done. There are four replicate sites for the manual cutting treatment (Enterprise Creek, Johnson Lake, Minnova Road and Mabel Lake), three replicate sites for girdling (Gordon Bay, Vavenby and Russell Creek), and three replicate sites for cut stump-glyphosate treatment (John Creek, Upper John Creek and Larch Hills). For birch partial retention in Douglas-fir stands, ten year data has been collected for the Champion Creek PROBE site and five year data collected for Burton Creek, Honeymoon Road and Pisima.

Data gaps and research priority: The ten PROBE data for broadcast treatment is not yet analyzed or reported, nor is any of the partial birch retention data. This should be a priority because of the effort already invested in collecting the data, and the interest in the Kootenays of Douglas-fir/birch interactions.

(8) PROBE brushing research results unique to Kootenay ecosystems and treatments is not available in one place.

Existing data: A Kootenay-focused summary of brushing research has not been done to date.

Data gaps and research priority: In publications to date, the Kootenay PROBE data is mixed in with data from the Thompson/Okanagan, which is not always relevant to the Kootenays, either ecologically or in terms of treatment. This includes data in Land Management Handbook 48 (Simard et al. 2001) and journal articles (Simard et al. 2004; Heineman et al. 2005; 2007; 2009). In particular, almost all of the broadleaf complex data is from the Thompson-Okanagan Region. Most of the Kootenay PROBE sites were established in low shrub-herb plant communities. As well, manual cutting (of various types) is the only treatment currently applied in the Kootenays, but half of the 96 PROBE sites were treated by other methods (girdling, herbicide application, grazing, or mulch mats). Most operational Kootenay foresters are primarily interested in research related to manual cutting. All of the surveyed operational Kootenay foresters rated as a very high priority the development of a clear, easy to read summary of PROBE and other brushing research from Kootenay or very similar sites.

A five year plan is presented here (Table 1) that addresses a number of the research priorities identified by the foresters that were surveyed. It is recommended that in the first year a compilation and synthesis of all existing Kootenay PROBE data and other Kootenay brushing research be carried out. This would give operational people some immediate results. It should be updated in year five after additional data is collected and analyzed. Overall, the priority should be to analyze existing data and remeasure existing research sites before setting up new experiments.

There are so many crop tree species of interest in the Kootenays that short-term priority species need to be chosen. Overall, Douglas-fir, western larch, spruce and western redcedar were of most interest to the operational Kootenay foresters. Manual cutting is really the only brushing method of interest to the Kootenay foresters so research should be focused on that treatment. Broadleaf trees (primarily birch and aspen) and tall shrubs (maple/willow (alder)) were identified as the highest priorities for research into the appropriateness of free-growing requirements. Broadleaf installations were selected as the main research focus in the plan since the existing tall shrub PROBE installations are mostly in Sitka alder, which in pure stands is of low interest to most of the operational Kootenay foresters. Establishing Douglas maple/willow (alder) operational brushing trials in the Kootenays would be valuable but was given a secondary funding priority because results will not be available for several years. PMP remeasurement is important because it will provide long-term growth and yield data, but it was also given secondary funding priority because all of the PMP sites are in the Thompson/Okanagan Region.

Table 1. Five year research plan.

Year	Field work	Field work cost	Analysis and reporting	Office work cost	Total cost
1 (2017)	Burton Creek 19-year remeasurement (<i>Mixed Broadleaf-Shrub</i> -variable birch retention-Fdi-ICHmw3). Access to the site was good in 2003.	\$8,500	1. Compilation of old and new Kootenay PROBE data and other Kootenay brushing research (\$22,000) 2. Determine GPS coordinates for all PROBE sites using plot location maps; adjust BEC classifications as needed (\$3,000)	\$25,000	\$33,500
2 (2018)			Data analysis and preparation of an extension note and journal article for previously collected 10 year PROBE <i>Mixed Broadleaf-Shrub</i> -Fdi data (4 broadcast manual cutting sites, 3 broadcast girdling sites, and 3 broadcast cut stump-glyphosate sites) (\$10,000)	\$20,000	\$20,000
3 (2019)	1. Honeymoon Road and Pisima 19-year re-measurements (<i>Mixed Broadleaf-Shrub</i> -variable birch retention-Fdi-ICHmw3). Access to Pisima is good; Honeymoon Road may require 0.5-1 km walk in.	\$17,000			\$17,000
4 (2020)	Champion Creek 19-year remeasurement (<i>Mixed Broadleaf-Shrub</i> -variable birch retention-Fdi/Lw/Pl-ICHdw1). Access to the site is good.	\$13,000	Data analysis and preparation of an extension note and journal article incorporating PROBE <i>Mixed Broadleaf-Shrub</i> –Fd-partial birch retention data from Burton Creek, Honeymoon Road, Pisima and Champion Creek sites	\$20,000	\$33,000
5 (2021)			1. Analysis of PROBE data for broadleaves and various conifer species to contribute to validating free-growing requirements; extension note (relating conifer performance to conifer/brush height ratio and density of neighbouring broadleaves) (\$15,000) 2. 3. Update of compilation report prepared in year 1 (\$6000)	\$21,000	\$21,000
5 yr Total		\$38,500		\$86,000	124,500

If additional funding is available, other priorities are:

1. Re-measurement of the three birch-Fdi-manual cutting PMPs (established 2002-2003), to provide 25-40 year growth and yield data for brushed versus untreated stands.

The three sites are all located in the Thompson-Okanagan Region so industry and government from that region should contribute funding. Field cost: \$24,000, Data entry and analysis: \$4,000. Results could be included in the Douglas-fir-birch journal article proposed for 2018 if measurements are done in time. Access to the sites is good.

2. Collect, analyze and report on data on performance of Douglas-fir, western larch, western redcedar and spruce with varying number of brush-free quadrants.

This work could be done at existing ICHmw and ICHdw PROBE sites and verified at a sample of about ten Kootenay sites in each subzone. Field cost: \$15,000. Data entry, analysis and extension note: \$7,500.

3. Establishment of operational manual brushing trials (PROBE methodology) at three Douglas maple/willow(alder) sites in the Kootenays.

More than one conifer species could be measured at each site. Field cost: approx. \$25,000 depending on how many conifer species per site are measured. Funding would need to be available for subsequent measurements (year 1, 5 and 10 at a minimum).

4. Analysis of cross-climate responses

The large databases that exist from the vegetation management research trials, including PROBE and older mixed broadleaf experiments, that cover climate gradients can be collated and analyzed at low cost with meta-analyses to help identify, verify and predict best brushing practices in current and future climates. Meta-analytical approaches include standard meta-analysis, maximum likelihood regression modeling, Kaplan-Meier logistical regression modeling, and/or structural equation modeling.

7 Funding options

The operational Kootenay foresters had various ideas about how operational brushing research should be funded, but all felt that the government should pay for at least part of it. Deb MacKillop suggested that licensees should definitely contribute funding, which the government could potentially match. A multi-agency collaboration (licensees/BCTS/Ministry) was suggested by several respondents. One suggested that research could be paid for through government funds diverted from the carbon initiative, and another suggested taking money from stumpage revenue and setting it aside specifically for silviculture research. The need for stable, long-term funding was a key theme in the responses, with enough set aside to ensure that all the work including reporting for each study is dedicated for that study before it begins.

Four respondents (Interfor - Castegar/Nakusp and Grand Forks, Kalesnikoff and BCTS Cranbrook) said their organization could potentially provide funding, especially if it involved co-funding with other organizations. One (Kalesnikoff) mentioned they could potentially contribute in-kind funding. The organizations that were hesitant were BCTS, Nelson, who said that it was not part of their mandate, and ATCO, whose representative said their ability to provide funding would depend entirely on what

happens with the softwood lumber agreement and other trade issues that are currently not resolved. BCTS Castlegar did not provide any feedback about funding. One respondent mentioned that they need cooperation with management, who would need to know the amount of funding, the time period and what the products will be. No one provided a dollar amount they would commit.

Deb MacKillop mentioned that if sites are in the Thompson/Okanagan, the local licensees should contribute funding.

George Harper applied in March 2017 to the Forest Enhancement Society of B.C. (FESBC) for \$96,000 in funding to support four years of PROBE research. Another FESBC proposal could be submitted in the fall of 2017 to include the additional work recommended in this document.

8 Responsibilities

Collection of new field data should be done by contractors, possibly combined with in-kind support of licensees, if they have the resources. The ideal situation is for contractors with previous experience with PROBE data collection to participate in the PROBE work, particularly for sites that they installed and measured over time. This would provide continuity in measurement, and importantly a high likelihood of relocating the plots (GPS coordinates are not available for many sites). However, if direct awards are not possible and/or the original contractors are not available, the work would have to be advertised (e.g., BC Bid), with both experience and price considered when awarding the work.

The original contractors who installed the PROBE plots and collected field data over the years are:

1. Skyline Forestry Consultants Ltd
2. Jean Heineman Forestry Consulting
3. JMJ Holdings
4. Newhouse Woodland Consultants
5. Silver Ring Forestry
6. Silva Smart Forestry Services

JMJ set up and remeasured all of the Kootenay sites including the most recent remeasurement at Champion Creek. The other five contractors installed and remeasured the old Kamloops Region sites. The Kamloops area sites with variable birch retention were set up and measured by Jean Roach (Skyline Forestry) (Burton Creek and Honeymoon Road) and Jean Heineman (Pisima).

It is recommended that analysis and reporting of existing or newly collected PROBE data be done by contract to ensure that it is completed in a timely manner. Don Sachs did all of the PROBE analysis (1991-2007) and would be the ideal person to carry on this work if he is available, since he is familiar with the datasets. Reporting would best be done by Jean Roach and Jean Heineman, with input from Suzanne Simard, since these three people are familiar with the sites, field measurement techniques and data, and have done all of the previous reporting, including Land Management Report 48 (Simard et al. 2001) and several journal articles.

All of the work should be overseen by George Harper, Suzanne Simard and Deb MacKillop.

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Appendix A-1. A summary for major vegetation species of the competitiveness, commonness of brushing, and proportion of brushing conducted primarily to meet administrative requirements, as provided by operational Kootenay foresters.

Competitiveness codes are: 1=competitive to moderately competitive on many sites; 2=moderately competitive at worst; 3=minimally to not competitive on most sites.

	Respondent 1			Respondent 2			Respondent 3			Respondent 4		
Vegetation complex	Compet- Itiveness	Amt of brushing	% of brushing done for admin	Compet- Itiveness	Amt of brushing	% of brushing done for admin	Compet- Itiveness	Amt of brushing	% of brushing done for admin	Compet- Itiveness	Amt of brushing	% of brushing done for admin
Mixed broadleaf-shrub	1	Common	20%	1	Moderate	40%	3	Moderate	Moderate	2	Common	Common
Aspen dominated	1	Common	0	1	Common	40%	2	Moderate -common	Common	2	Rare- never	Moderate
Cottonwood-shrub	1	Rare- never	0	2	Rare- never	0	3	Rare- never	Rare to never			
Willow	2	Moderate	0	2	Rare- never	50%	2	Common	Rare to never	3	Moderate	Moderate
Wet alder	2	Rare- never	0	2	Rare- never	10%	3	Moderate		2	Common	Moderate
Dry alder	3	Rare- never	0	2	Rare- never					3	Rare- never	Rare to never
Ericaceous shrub	3	Rare- never	0	3	Rare- never	5%	1	Moderate		1	Common	Rare to never
Dry shrub	2	Rare- never	0	2	Moderate	10%	1	Common	Rare to never	2	Moderate	Moderate
Mixed shrub	2	Moderate	0	2		30%	1	Common		1	Common	Common
Fireweed	3	Rare- never	0	3	Rare- never	0	1	Common		1	Common	Rare to never
Subalpine herb				3	Rare- never	0	3	Rare- never		1	Common	Moderate
Fern	2	Rare- never	0	3	Rare- never	0	1	Common		1	Common	Moderate
Pinegrass				3	Rare- never	0	1	Rare- Never		2	Moderate	Rare to never

Appendix A-2. A summary of BEC units, vegetation species, and crop tree species that are priorities of operational Kootenay foresters for research into the appropriateness of free-growing requirements; specific research priorities of the operational foresters for these units; and availability of PROBE data to address these priorities.

BEC unit	Vegetation species	Crop tree species	Priority	Specific research priorities	PROBE data availability
ICHdw1, ICHmw2, ESSF all subzones MS	Birch, aspen	ICH – Fdi, Lw, Pw, Sx, Cw and other MS - Sx ESSF –Se, Bl, Pl	ICH and MS – high ESSF – medium	Compare performance of conifers growing with untreated vs treated birch/aspen; compare conifer performance of overtopped vs not overtopped conifers; investigate if brushing should be increased in Lw-leading stands	Simard et al. (2001) provide aspen and birch density thresholds for Fdi diameter growth. PROBE data is available to compare conifer performance by broadleaf density, conifer/brush height ratios, and free-growing status. No data available relating to no. of brush-free quadrants. Data exists for Fdi, Lw, Pl, Sx and Cw with birch and Pl with aspen. Sites are in various ICH subzones, mostly mw for Fdi, Sx & Cw; one dw1 Fdi/Lw/Pl site. No Pw data; no ESSF or MS data. Most sites have 5-10 yrs of data.*
ICHdw1, ICHmw2 (mesic)	Birch, maple	Fdi, Pw, Sx, Cw, Hw	High	Acceptable birch/maple levels for survival and long-term conifer productivity	PMP data (stand age 25 yrs+) can be used to compare Fdi productivity in treated birch vs control plots. Re-measuring PMPs would enable assessment of G & Y over time. Data (5-10 yrs) is available to determine Fdi survival thresholds (birch density & cover). Limited data for Sx and Cw, none for Pw or Hw; only one ICHdw1 site; most sites mesic ICHmw. Data focuses on birch; maple may occur on some PROBE sites but needs verification.**
ICHdw1 and ICHmw2	Maple/willow	Fdi, Lw, Cw, Py, Sx	High – ICHdw1 Medium - ICHmw2		One willow PROBE site and it is in the IDF. Maple may occur on some PROBE sites but this needs to be verified
ICHdw1 and ICHmw2 (mesic-submesic)	Ceanothus, (willow, alder)	Fdi, Lw, Pl	High – ICHdw1 Medium - ICHmw2	Ability of conifers to reach free-growing in time without treatment and best time to treat in terms of cost and effectiveness	5 yr data available for one ICHmw2 ceanothus-Pl site but probably not representative of Kootenay ceanothus sites. Ceanothus may occur as a secondary species on some other Kootenay PROBE sites but needs verification. No cost data available.
ICHdw1	Maple/beaked hazelnut/ocean spray/ thimble-berry	Fdi, Lw, Py	Medium		No PROBE data for this vegetation species-crop tree-variant

*No. of ICH sites are: 18 birch-Fd (4 with partial retention), 3 birch-Pl (one with partial retention), 3 birch-Sx, 1 birch-Lw (one with partial retention), 1 birch-Cw, 5 aspen-Fd and 3 aspen-Pl

**No. of ICH sites are: 18 birch-Fd (4 with partial retention), 3 birch-Sx, 1 birch-Cw. There are 9 birch-Fdi PMPs.

Appendix A-3. PROBE field measurements: priorities of the operational Kootenay foresters.

The highest priority item is shaded gray.

Description	Location	BEC unit	No. of sites	Field measurement cost	Priority (% of respondents)
(1) 19 yr PROBE remeasurement - Fd/Lw/PI with variable birch retention (0, 600 & 2500 sph) (Champion Creek)	Champion Creek	ICHdw	1	\$14,000 *	High 100%
(2) 19 yr PROBE remeasurement - Fd with variable birch retention (600 & 2500 SPH) (Burton Creek, Honeymoon Road, Pisima)	North Thompson	ICHmw3	3	\$8500 per site*	High 20% Medium 60% Low 20%
(3) PMP remeasurement at PROBE sites - Fd or PI - birch or aspen various brushing treatments	Mostly Thompson/ Okanagan	ICH, IDF, MS	21	\$8,700 per site **	High 33% Medium 33% Low 33%
(4) PMP remeasurement at PROBE sites - PI - Sitka alder - manual cutting & glyphosate spray	Thompson/ Okanagan	IDF, MS	3	\$8,700 per site **	Low 100%
(5) 10+ yr remeasurement - replicated herb/low shrub complexes - various brushing treatments	Kootenays & Thompson/ Okanagan	ICH, ESSF	25	\$3,000 per site *	High 33% Medium 33% Low 33%
(6) Additional data collection at PROBE sites (e.g. conifer performance as related to brush-free quadrants)	Kootenays & Thompson/ Okanagan	high priority variants	To be decided	Depends upon what is measured	Medium 75% Low 25%
(7) Verification data collection (similar to Newsome & Heineman 2016)***	Kootenays	high priority variants	~ 10 per variant	\$7500 per variant	Medium 67% High 33%

* Excluding detailed understory plant assessment, which may be of interest, but would cost extra

** Average cost; varies with stand density

***To supplement data from their Cariboo research trials, Newsome and Heineman (2016) visited approximately 10 juvenile conifer-aspen mixed juvenile stands per BEC variant of interest, spread across the variant's geographic range. Stands were chosen that were identified by operational staff as requiring rushing but were not yet treated. They measured temporary plots centred on crop trees that were undamaged (unless by competition) at 50-m intervals along transects. At each plot they recorded, for the crop tree (PI usually): vigour (4 subjective classes); height; height 1 year ago; height 2 years ago; and ground-level diameter. Broadleaf trees (aspen in their case) were measured in a 1.78 m radius plot around the crop tree. They recorded modal height of aspen within the plot, and for the 3 tallest aspen in the plot: height, ground-level diameter, and height increments for the past 2 years. For some of the variants, density of broadleaves that were ≥ 1.0 , ≥ 1.25 , ≥ 1.5 , ≥ 2.0 and ≥ 3.0 times as tall as the crop tree was recorded. This or a similar methodology could be applied in the Kootenays to collect data to verify and compare with that from existing PROBE installations.

Appendix A-4. PROBE PMP measurements: priorities of the Kootenay operational foresters.

PMPs were established 2002-2006 and the 3 Aspen-lodgepole pine-manual cutting sites were re-measured in 2008. The shaded rows were rated the highest priority.

Vegetation complex	Crop tree species	Treatment	BEC zone	No. of sites	Priority (% of respondents)
Mixed Broadleaf-shrub	Douglas-fir	Manual cutting	IDF,ICH	3	High 100%
Mixed Broadleaf-shrub	Douglas-fir	Girdling	IDF,ICH	3	Medium 25% Low 75%
Mixed Broadleaf-shrub	Douglas-fir	Cut stump-glyphosate	ICH	3	Medium 25% Low 75%
Mixed Broadleaf-shrub	Lodgepole pine	Manual cutting	ICH	2	High 20% Medium 80%
Mixed Broadleaf-shrub	Lodgepole pine	Glyphosate spray	ICH	1	Medium 25% Low 75%
Aspen	Douglas-fir	Manual cutting	ICH	1	High 80% Low 20%
Aspen	Douglas-fir	Girdling	ICH	2	Medium 25% Low 75%
Aspen	Douglas-fir	Basal triclopyr	ICH	1	High 25% Low 75%
Aspen	Lodgepole pine	Manual cutting	IDF,MS	3	Medium 50% Low 50%
Aspen	Lodgepole pine	Manual cutting	ICH	1	High 60% Medium 40%
Aspen	Lodgepole pine	Manual - partial retention	IDF,ICH	2	High 25% Medium 75%
Dry alder	Lodgepole pine	Manual cutting	MS	2	Medium 50% Low 50%
Dry alder	Lodgepole pine	Glyphosate spray	MS	1	Low 100%

Appendix A-5. PROBE shrub-herb complex measurements: priorities of operational Kootenay foresters. Five-year PROBE data has been collected and 10+ year data could be collected. All sites are in the ICH or ESSF.

Vegetation complex	Crop tree species	Treatment	No. of sites	Priority (% of respondents)
Fireweed	Lodgepole pine	Manual cutting	3	Medium 40% Low 60%
Fireweed	Spruce	Manual cutting	5	Medium 40% Low 60%
Fireweed	Spruce	Glyphosate spray	4	High 20% Low 80%
Fireweed	Spruce	Grazing	4	Low 100%
Fern	Spruce	Glyphosate spray	3	High 20% Low 80%
Mixed Shrub	Spruce	Manual cutting	3	High 20% Medium 40% Low 40%
Mixed Shrub	Spruce	Grazing	3	Low 100%

Appendix A-6. Analysis and reporting: priorities of the Kootenay operational foresters. The shaded rows were rated the highest priority.

Description	Site locations	BEC unit	No. of sites	Priority (% of respondents)
Analysis/reporting of data from current field work	Kootenays & Thompson/Okanagan	ICH, ESSF, IDF, MS		High 80% Medium 20%
Analysis/reporting of 10-yr results for 3 broadcast birch treatments (manual cutting, girdling, cut stump glyphosate) in Fd stands (PROBE sites)	North Thompson & Shuswap	ICH	10	High 40% Medium 40% Low 20%
Analysis/reporting of 10-yr results for broadcast manual cutting of birch in PI stands (PROBE sites)	North Thompson & Kootenays	ICH	3	Medium 50% Low 50%
Analysis/reporting of 10-yr results for broadcast manual cutting of alder in PI stands (PROBE sites)	Kamloops, South Okanagan, Lillooet	MS	3	Low 100%
Compile/summarize all PROBE data articles and other brushing research relevant to the Kootenays	Kootenay & relevant Thompson/Okanagan sites		96 PROBE sites (20 in Kootenays)	High 100%

Appendix A-7. Matrix that was used to guide selection of PROBE sites. All cells that are shaded have at least one PROBE installation. The number in the cell indicates the number of sites, and in parenthesis is the minimum number of measurement years for those sites as of 2016. Yellow shading indicates treatment cells for which no data has been published. Green shading indicates that some data has been published, but not the most recent. Blue shading indicates treatment cells for which the most recent data has been published (see footnotes j through n). Red text means at least one site in the treatment cell has 10 or more years of data. In unshaded areas, "U" indicates treatments that are uncommonly applied to a particular vegetation complex, "x" indicates treatments that are not appropriate in the complex, and "0" indicates the cells were of interest for PROBE but suitable sites and/or funding was unavailable.

Complex	BEC zone	Tree species	Manual cutting ^a	Partial manual ^b	Girdling ^c	Glyphosate spray ^d	Cut stump glyphosate ^e	Cut and spray glyphosate ^f	Basal triclopyr ^g	Grazing ^h	Mulch mats ⁱ
Herb and low-elevation shrub complexes											
<i>Fireweed</i>	ICH, ESSF	PI	3 (5 year) ^j	X	X	2 (5 year)	X	X	X	0	0
		Sx	5 (5 year) ^k	X	X	4 (5 year) ^k	X	X	X	4 (5 year) ^k	2 (3 year)
		Fd	2 (3 year)	X	X	1 (4 year)	X	X	X	0	0
	MS	Sx	1 (5 year)	X	X	0	X	X	X	0	0
<i>Fern</i>	ICH, ESSF	Sx	1 (5 year)	X	X	3 (5 year) ^k	X	X	X	0	0
<i>Subalpine herb</i>	ESSF	Se	0	X	X	0	X	X	X	1 (5 year)	0
<i>Pinegrass</i>	IDF, MS	PI	1 (1 year)	X	X	1 (3 year)	X	X	X	0	0
		Fd	0	X	X	0	X	X	X	0	0
<i>Mixed shrub</i>	ICH, ESSF	Sx	3 (5 year) ^k	X	X	0	X	X	X	3 (5 year) ^k	X
		Fd	1 (5 year)	X	X	1 (5 year)	X	X	X	0	X
		PI	0	X	X	0	X	X	X	0	X
		Cw	1 (4 year)	X	X	1 (5 year)	X	X	X	0	X
<i>Dry shrub</i>	IDF, ICH	PI	1 (5 year)	X	X	0	X	X	X	0	X
		Fd	0	X	X	0	X	X	X	0	X

Complex	BEC zone	Tree species	Manual cutting ^a	Partial manual ^b	Girdling ^c	Glyphosate spray ^d	Cut stump glyphosate ^e	Cut and spray glyphosate ^f	Basal triclopyr ^g	Grazing ^h	Mulch mats ⁱ
High elevation shrub complexes											
Ericaceous shrub	ESSF	PI		X	X		X	X	X	0	X
		Se	6 (10 year) ^l	X	X	2 (5 year)	X	X	X	0	X
Tall shrub complexes											
Dry alder	IDF, MS	PI	4 (10 year)	X	X	1 (11 year)	U	U	U	X	X
		Sx	1 (13 year)	X	X	0	U	U	U	X	X
Dry alder	ESSF	PI	1 (5 year)	X	X	0	U	U	U	X	X
		Se	1 (9 year)	X	X	0	U	U	U	X	X
Wet alder	ICH, ESSF	Sx	3 (5 year) ^m	X	X	0	0	0	U	X	X
		PI	0	X	X	0	0	0	U	X	X
Willow	IDF, ICH, MS, ESSF	Fd	0	X	X	1 (14 year)	0	0	U	0	X
Broadleaf complexes											
Aspen	IDF, MS	PI	3 (10 year) ⁿ	1 (9 year)	0	0	0	0	2 (11 year)	X	X
		Fd	0	0	0	0	0	0	0	X	X
	ICH	PI	1 (10 year)	1 (10 year)	0	0	0	1 (17 year)	0	X	X
		Fd	2 (5 year)	0	2 (3 year)	0	0	0	1 (5 year)	X	X
Mixed broadleaf-shrub	IDF, ICH	Fd	4 (10 year)	4 (5 year)	3 (10 year)	0	3 (10 year)	1 (3 year)	1 (5 years)	X	X
		PI	3 (10 year)	1 (10 year)	0	1 (12 year)	0	0	0	X	X
		Sx	2 (5 year)	0	0	1 (5 year)	0	0	0	X	X
		Cw	0	0	0	0	1 (10 year)	0	0	X	X
		Lw	1 (10 year)	1 (10 year)							
Cottonwood-shrub	IDF, ICH	Sx	0	0	0	0	0	0	0	X	X

^a Manual cutting = using motorized or non-motorized tools to cut vegetation

- ^b Partial manual = using motorized tools to cut vegetation, leaving a designated density of standing broadleaves.
- ^c Girdling = using a chain girdler to cut through the bark around the circumference of each broadleaf stem
- ^d Glyphosate spray = broadcast or spot application of glyphosate solution (usually 1.4-2.1 kg ai/ha) using backpack sprayers or broadcast aerial application
- ^e Cut stump glyphosate = manual cutting followed by the application of glyphosate solution to cut stumps
- ^f Cut and spray glyphosate = manual cutting one year, followed by application of glyphosate solution to sprouts the following year
- ^g Basal triclopyr = wiping triclopyr in an oil carrier onto broadleaf stems
- ^h Grazing = the use of sheep or cattle to reduce the abundance of vegetation around seedlings
- ⁱ Mulch mats = mats are laid around seedlings to prevent growth of vegetation
- ^j Simard et al. 2001
- ^k Heineman et al. 2005
- ^l Heineman et al. 2007
- ^m Simard et al. 2004
- ⁿ Heineman et al. 2009

Appendix A-8. A summary of location, complex, BEC unit, brushing treatment and measurement history for individual PROBE sites (P= PROBE experiment established; numbers are measurement years post-treatment; PMP= Permanent measurement plot established; PMP-R-1 = first remeasurement completed at PMP; M = Maintenance, TERM=terminated; R=only silviculture survey done)

[illegible]

PROBE No.	Location	Mapsheet/op ening	Vegetation complex	BEC subzone/ variant	Crop speci es	Treatment	Year PROBE site estab	Year PMP estab	Year PMP remeas	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
55	Ross Lake	92I050-270	Dry Alder	MSxk	PI	Manual	1994	2005					P		2	3		5						11,PMP						
10	Penticton Creek	82E053-3	Dry Alder	ESSFdc1	PI	Manual	1991	none		P	1		3		5									M						
31	Crown Bench	92I082-214	Dry Alder	MSxk	PI	Glyph spray	1993	2005				P	1				5						11	PMP						
85	Upper McKay Creek	92J100-42	Dry Alder	ESSFdv	Se	Manual	1997	none								P	1		3						9					
18	Nicoamen River	92I014-17	Dry Alder	IDFdk2	Sx	Manual	1992	none			P	1		3		5									13					
24	Miner Creek	92I005-27	Wet Alder	ESSFmw	Se	Manual	1992	none			P	1		3		5					10									
57	Palmer Creek	82L073-43	Wet Alder	ESSFdc2	Se	Manual	1995	none						P		1		3		5						10				
104	Beaverfoot River	82K099-103	Wet Alder	ICHmk1	Se	Manual	1992	none			P	1		3		5														
17	Nicoamen River	92I014-11	Willow	IDFdk2	Fd	Glyphosate spray	1992	none			P	1		3		5									14					
20	West Gorge	82M006-21	Ericaceous Shrub	ESSFwc2	Se	Manual		none			P	1		3		5					10									
106	Corbin Pass	82N012-7	Ericaceous Shrub	ESSFvc	Se	Manual	1992	none			P	1		3		5														
110	Ladybird Creek	82F044-14	Ericaceous Shrub	ESSFwc4	Se	Manual	1992	none			P	1		3		5														
111	Howell Creek	82G027-32	Ericaceous Shrub	ESSFdk	Se	Manual	1992	none			P	1		3		5														
128	Bannock Creek	82F072-532	Ericaceous Shrub	ESSFwc4	Se	Manual	1997	none								P	1		3											
129	Berry Creek	82F062-517	Ericaceous Shrub	ESSFwc4	Se	Manual	1997	none								P	1		3											
43	Craigellachie Creek	82M006-11	Ericaceous Shrub	ESSFwc2	Se	Glyphosate spray	1993	none				P	1		3		5					10								
120	Glenogle Creek	82N036-27	Ericaceous Shrub	ESSFwm	Se	Glyphosate spray	1993	none				P	1	3				6												
19	Legerwood Creek	82L097-2	Fern	ICHwk1	Sx	Manual	1992	none			P	1		3		5														
102	Bigmouth Creek #2	82M088-2	Fern	ICHvk1	Se	Glyphosate spray	1992	none			P	1		3		5					10									
44	Ratchford River	82M037-9	Fern	ICHwk1	Sx	Glyphosate spray	1994	none					P	1		3		5												
45	Ratchford River	82M037-8	Fern	ICHwk1	Sx	Glyphosate spray	1994	none					P	1		3		5												
50	Eagle Bay	82L094-35	Fireweed	ICHmw3	PI	Manual	1994	none					P	1		3		5												
65	Birk Creek	82M031-24	Fireweed	ICHmw3	PI	Manual	1995	none						P	1			4	R											
49	Trophy Mountain	82M071-5012	Fireweed	ESSFwc2	PI	Manual	1994	none					P	1		3		5												
35	Kate Creek	82L048-30	Fireweed	ICHmw2	PI	Glyphosate spray	1993	none				P		1		3		5												
11	Chase Creek	82L063-4	Fireweed	ESSFwk2	PI & Se	Glyphosate spray	1991	none		P	1		3		5					10										
59	Tillis Landing	82I085-53	Fireweed	ICHmw2	Fd	Manual	1995	none						P	1			4	5											
78	Longridge	82M036-46	Fireweed	ICHmw3	Fd	Manual	1997	none								P	1		3											
63	Simard Road	82L068-43	Fireweed	ICHmw2	Fd	Glyphosate spray	1995	none						P	1			4												
79	Bowler Creek	82M003-82	Fireweed	ICHwk1	Sx	Manual	1997	none								P	1		3				7							
112	Murphy Creek	82F011-29	Fireweed	ICHmw2	Sx	Manual	1992	none			P	1		3		5										M				
56	Craigellachie Creek	82M007-80	Fireweed	ICHwk1	Sx	Manual	1995	none						P	1			4	5					M						
37	Coldwater Creek	92H065-21	Fireweed	MSdm2	Se	Manual	1993	none				P	1		3		5													
108	Bugle Creek	82F021-70	Fireweed	ESSFwc1	Se	Manual	1992	none			P	1		3		5														
124	O'Brien Creek	82K075-15	Fireweed	ESSFwc1	Se	Manual	1993	none				P	1		3				7											
82	McIntyre Creek	82L008-48	Fireweed	ICHmw2	Se	Glyphosate spray	1997	none								P	1					6								
122	Bush River	83C004-1	Fireweed	ICHmw1	Se	Glyphosate spray	1994	none				1	P			3		5							12					
47	Torrent Creek	82L057-35	Fireweed	ESSFwc2	Se	Glyphosate spray	1994	none					P	1		3		5												
13	Caribou Mtn	82M053-5114	Fireweed	ESSFdc2	Se	Cattle graze	1992	none			P	1		3		5								M						
48	Otter Creek	82M064-4093	Fireweed	ESSFwc2	Se	Cattle graze	1994	none					P	1		3		5												

Appendix A-8 continued.

PROBE No.	Location	Mapsheet/op ening	Vegetation complex	BEC subzone/ variant	Crop speci es	Treatment	Year PROBE site estab	Year PMP estab	Year PMP remeas	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
73	Patricia Creek	92P079-5118	Fireweed	ESSFwc2	Se	Sheep graze	1997	none								P	1		3											
109	Scott Road	82K082-11	Fireweed	ESSFwc1	Se	Sheep graze	1992	none			P	1		3		5														
70	Mosquito Creek	82M053-8045	Fireweed	ESSF	Se	Mulch mat	1997	none								P	1		3											
107	No-Name Creek	82F088-14	Fireweed	ESSFwm	Se	Mulch mats	1992	none			P	1		3		5														
16	Mt McLennan	82M061-4054	Mixed Shrub	ICHmw3	Fd	Manual	1992	none			P	1		3		5								M						
103	Smith Creek	82N072-23	Mixed Shrub	ICHwk1	Fd	Glyphosate spray	1992	none			P	1		3		5														
60	Finn Creek	83D005-4009	Mixed Shrub	ICHvk1	Sx	Manual	1995	none						P	1			4	5											
42	Brash Creek	82L066-289	Mixed Shrub	ESSFwc2	Se	Manual	1993	none				P	1		3		5					10								
123	Westfall River	82K074-5	Mixed Shrub	ESSFwc1	Se	Manual	1993	none			P	1			3			6							M					
71	Lower Saskum	82M052-5429	Mixed Shrub	ICHmw3	Sx	Sheep graze	1997	none								P	1		3		5									
72	Upper Saskum	82M052-5430	Mixed Shrub	ICHmw3	Sx	Sheep graze	1997	none								P	1		3		5									
38	Doug Creek	83D034-7046	Mixed Shrub	ESSFwc2	Se	Sheep graze	1993	none				P	1		3		5					10								
61	Finn-Tum Tum	82M095-4057	Mixed Shrub	ICHvk1	Cw	Manual	1995	none						P	1			4	R					M						
101	Bigmouth Creek #1	82M089-4	Mixed Shrub	ICHvk1	Cw	Glyphosate spray	1992	none			P	1		3		5								M						
14	Camp Creek	82M084-6007	Subalpine-Herb	ESSFmw2	Se	Sheep graze	1992	none			P	1		3		5								M						
83	Pennask Lake	92I009-?	Pinegrass	IDFdk1	Pl	Manual	1997	none								P	1													
127	Meadow Lake	82G001-9	Pinegrass	MSdk	Pl	Glyphosate spray	1996	none							P	1		3												
34	Cottonwood Creek	82L068-65	Dry Shrub	ICHmw2	Pl	Manual	1993	none				P	1		3		5													
22	Bowler Creek						1992				p	1	TERM																	
25	Cherry Ridge						1992				P	1	TERM																	
26	Star Pass						1992				P	1	TERM																	
32	Amphitheatre Lake						1993					P	1		3		5				TERM									
36	Kathleen Lake						1993					P	TERM																	
125	Rory Creek						1993					P	1		3										TERM					

Appendix A-9. Description of data collected at PROBE sites

PROBE form 1 and EM-1: Project description

Characteristics of study site, including location, mapsheet, opening #, treatment history, administration history, slope, aspect, elevation, soil information, and a subjective evaluation of the need for brushing. This information was recorded on both a standardized PROBE project form and on a MOF EM-1 form. The information was recorded only in the establishment year.

PROBE form 2: Crop tree growth

The crop tree at each of the 72 subplots was assessed for total height, leader length, crown width and length (± 1 cm), and basal stem diameter (± 0.1 cm). Tree vigour (4=good, 3=moderate, 2=poor, 1=moribund, 0=dead) and damage causes were visually assessed according to Simard (1993).

PROBE form 3: Target non-crop vegetation

Target vegetation was assessed at each of the 72 subplots, regardless of whether the centre crop tree was alive or dead. Prior to brushing, species were selected as target species if they were considered to be potential competitors and were present in $\geq 80\%$ of the subplots in both treatment and control main plots. Up to 5 target species were selected at each site. Target non-crop vegetation was assessed in subplots that had 1.78-m radius (10 m^2) or 2.52-m radius (20 m^2), with the smaller subplot size used when trees were $< 2\text{m}$ tall (on average) and the larger size used when they had grown to ≥ 2 m tall (on average). Cover and modal height were assessed for all vegetation, broadleaf trees, shrubs, herbs, and each of the target species. Broadleaf density was also determined in each plot. The approach to assessing broadleaf density was somewhat variable between contractors and it also changed over time. At present, the accepted approach is to count broadleaf stems within a 3.99 m radius of the crop tree, assigning them to categories of “shorter than the crop tree” or “taller than the crop tree”. Stems are counted for plots where the crop tree is dead, but cannot be assigned taller or shorter status. For the 2011 assessment of site 130, broadleaf density was assessed in a 2.52 m radius plot for consistency with the original approach that was used.

PROBE form 4: Target specimens

Prior to brushing, a healthy stem of each woody target species was tagged in each of the 72 subplots. The closest healthy stem to the crop tree was selected and distance and azimuth from the crop tree were recorded. At each assessment, the following were assessed: total height, height increment, number of sprouts, average sprout length, vigour, condition, damage cause, and ECW (for herbicide treatments). This approach was somewhat unsatisfactory because we ended up with some treated and some untreated stems in the brushed plot. As a result, a different approach was used for the birch variable density studies (sites 86, 87, 88, and 130). At those sites, a target birch was tagged and measured prior to treatment in the untreated plot. In the treated plots, selection was done in the first year post-treatment, with the closest cut and uncut birch stems to each crop conifer being tagged.

PROBE form 4 was used for the cut birch and PROBE form 2 (i.e, the same measurements as for the crop conifer) was used for the uncut birch.

PROBE form 5: Silviculture survey form

In years 0, 5, and 10, counts and density calculations are done in a 3.99 m radius around each crop tree to determine total, well-spaced, and free-growing conifer densities by species, according to B.C. Ministry of Forests (2000) criteria. This approach has never been ideal because it is crop tree-centred, which skews results for comparison with operational silviculture surveys. Originally we used sheets that had been designed for the PROBE project, but in recent years, most contractors used standard FS658 forms.

EM-3 habitat monitoring forms

At 4 randomly selected subplots in each of the treated and untreated plots, detailed vegetation surveys were conducted in 3.99 m radius plots. This data was collected prior to brushing and at each post-brushing assessment. Cover and distribution were estimated for each vascular species, and a modal height was estimated for each layer. Photos were taken at these plots that included an overview and a photo of the crop tree and each target species. Distance and azimuth from the camera to the crop tree and azimuth for the photo were recorded so that photos would show development over time.

Appendix A-10. Description of data collected at Permanent Measurement Plots

Site and soil descriptions

A full soil pit is described (B.C. Min. For. 1998) in each of the control and treatment plots. Photos are taken from each PMP centre towards the N, S, E, and W. Site description information has already been collected for each PROBE site.

Tree measurements

Each conifer and broadleaf tree ≥ 2 m tall was tagged with a uniquely numbered aluminum tag and painted at DBH. The following measured and descriptive variables were assessed: species, total height (cm), DBH (cm), percent live crown, tree vigour, damaging agent, severity of damage, pathological indicators, position of pathological indicators on tree. Trees less than 2 m tall were counted according to species and height was measured for 5 randomly selected stems of each species.

Site index measurements

Site index (SI) was determined according to standard methodology using four (minimum three) stems in the 0.1 ha plots and one stem in the 0.04 ha plots. If the largest DBH stems were not acceptable for SI determination, SI was determined using SIBEC ecosystem correlation (B.C. Min. For. 1997).

Non-crop vegetation and regeneration data (Habitat Monitoring Plots)

Habitat monitoring plots are circular plots with an area of 50 m^2 ($r=3.99 \text{ m}$) that were already been established for the original PROBE assessments. Information about individual species and regeneration was collected in these plots. For every vascular and non-vascular species in each vegetation layer, the following was recorded: percent cover, distribution code, vigour, and modal height. Regeneration data collected was: total number of conifers and broadleaves by species, number of well-spaced trees of each species, and number of free-growing trees of each species.

