Extension Note

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Considerations for rehabilitating naturally disturbed stands: Part 1 –Watershed hydrology

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Abstract

This extension note is the first of a two-part series involving watershed management considerations when planning stand rehabilitation activities following large-scale natural disturbances in the Interior of British Columbia. Despite the potential benefits and good intentions of stand rehabilitation following natural disturbance, these activities can have negative effects on water and water-related resources. Negative effects can include incremental increases in runoff and streamflow, increases in stream sedimentation, and reductions in riparian function. These effects can be minimized or avoided in most cases by establishing clear objectives for both timber and non-timber values and incorporating good planning and best management practices. It is recommended that practitioners involved in planning and implementing stand rehabilitation activities utilize a qualified professional to:

- understand current watershed condition, resources at stake in the watershed, and their connection to watershed processes;
- use a risk analysis approach to evaluate the potential consequence(s) of proposed stand rehabilitation activities before implementation; and
- discuss and co-ordinate activities with other tenure holders and watershed stakeholders.

KEYWORDS: *Forests For Tomorrow program; management considerations; mountain pine beetle; rehabilitation; risk analysis; watershed hydrology.*

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Introduction

This extension note is the first of a two-part series involving watershed management considerations when planning stand rehabilitation activities following large-scale natural disturbances in the Interior of British Columbia.[1] It provides practitioners involved in reforestation of naturally disturbed stands under the "Current Reforestation" investment category of the B.C. Ministry of Forests, Mines and Lands' Land-based Investment Program with information to increase the likelihood of a positive effect of stand rehabilitation activities on water and water-related resources. In Part 1 of this series, we explore watershed-level considerations when planning stand rehabilitation activities. Part 2 (see Huggard [2011], page 66 in this issue) provides a more detailed summary of the effects of different stand-level treatment options on the rate of hydrologic recovery using stand-level equivalent clearcut area (ECA) as an index under a range of pre-treatment forest conditions (i.e., site index, pine mortality, and existing understorey regeneration).

This extension note is the first of a two-part series involving watershed management considerations when planning stand rehabilitation activities following large-scale natural disturbances in the interior of British Columbia.

Stand rehabilitation activities under the Land-based Investment Program are aimed at improving future timber supply and addressing risks to other forest values in areas affected by mountain pine beetle, wildfire, and other natural forms of disturbance (see ***http://www.for.gov.bc.ca/hcp/fia/landbase***). The following stand-level treatments are used to reforest naturally disturbed stands.

- Clearcutting or overstorey removal using a Forest License to Cut followed by planting: applicable to stands affected by mountain pine beetle that will not be dealt with by major forest licensees for economic and (or) timing-related reasons (B.C. Ministry of Forests, Mines and Lands 2010). Overstorey tree removals also include knockdown or mulching.
- Partial overstorey removal (> 40% basal area retention) with planting: removal of single trees or patches affected by mountain pine beetle with planting of openings created by removal.
- Underplanting and fill planting with no removal of affected pine or other species.
- Planting of burns and other natural disturbance related openings.

Selection of eligible stands for stand rehabilitation treatment follows a Multiple Accounts Decision Analysis framework, a cumulative scoring exercise used to identify candidate areas for treatment that considers timber and non-timber values (see ***http://www.forestsfortomorrow.ca/ModellingDecisionSupportTools/MultipleAccounts/MultipleAccounts.html***). Under this framework, water and water-related resources are reviewed in a cursory manner, and it is assumed that rehabilitation treatment will generally be positive for hydrologic recovery,[2] restoration of riparian function, and potential effects on water quality and fish habitat.

Although stand rehabilitation treatments can increase the rate hydrologic recovery in naturally disturbed stands,[3] the watershed-level effect of misdirected stand rehabilitation treatments may exacerbate water-related concerns (Burton 2006). Stand rehabilitation activities in areas with extensive natural disturbances, such as mountain pine beetle infestations, often coincide with large-scale commercial salvage operations involving multiple, overlapping, volume-based tenures. Under the *Forest and Range Practices Act*, licensees involved in large-scale salvage activities are required to outline results and strategies to protect forest resources within

[1] See Burton (2006) for a discussion of the terminology behind "stand rehabilitation" and application of stand rehabilitation activities in naturally disturbed forest.

[2] In this case, we refer to hydrologic recovery as re-growth of trees to a height where the hydrologic function of the stand, in terms of effects on snow accumulation and ablation, is similar to that of a mature forest. A height of 12 m is used to represent the point at which the stand approaches full hydrologic recovery (see Lewis and Huggard 2010). We recognize that full recovery may never occur as second-growth stands often do not approximate structural conditions of old forest (B.C. Ministry of Forests 2001).

[3] The assumption that planted forests recover faster generally holds true for sites affected by wildfire but may vary in beetle-attacked stands. See Lewis and Huggard (2010) for modelled comparisons between beetle-attacked stands and planted regeneration following clearcut.

forest stewardship plans (FSPs) and consider enhanced stand- and landscape-level retention (Snetsinger 2005; Klenner 2006). Even so, lack of planning and co-ordination among tenure holders can result in extensively harvested areas with limited retention (Forest Practices Board 2009), which may lead to unintended negative effects on biodiversity, wildlife habitat, and water-related resources (Lindenmayer et al. 2008). The challenge for practitioners involved in stand rehabilitation activities, which may operate in the absence of results and strategies associated with an approved FSP, is to be careful that their activities, combined with effects of other resource tenures, do not increase the likelihood of a negative effect on other forest resources. In particular, adequate consideration must be given to the potential watershed-level effects of stand rehabilitation treatments, such that a practitioner's activities are consistent with and do not compromise or jeopardize objectives set by government for community watersheds,[4] fisheries-sensitive watersheds,[5] and other water and water-related resources.

To assist practitioners involved in planning stand rehabilitation treatments, we discuss potential stand rehabilitation treatment effects on watershed processes, such as runoff and streamflow, stream sedimentation, and riparian function. We provide an introduction to the watershed risk analysis approach to watershed management. Also provided are links to existing reports available to Land-based Investment Program delivery agents and procedures to be followed to complete risk analyses where no equivalent information is in place. We close with a discussion of monitoring requirements to determine the appropriateness and effectiveness of stand rehabilitation treatments and provide feedback for future rehabilitation.

Watershed management and stand rehabilitation activities

Forests play a role in watershed processes by:

- intercepting incoming precipitation and regulating snow accumulation, snowmelt, and runoff rates;
- directly using water for ecosystem function, plant growth, and transpiration;
- providing bank stability for alluvial channels;
- providing a source of wood to channels for sediment regulation and fish habitat purposes; and
- providing shade to streams and a source of organic material for fish and other aquatic organisms.

When forests are affected by natural disturbances (e.g., beetle infestations) they continue to provide some hydrologic function such as intercepting precipitation and providing shade (Winkler and Boon 2010). Where present, unaffected overstorey and secondary structure also contribute to hydrologic function[6] over both the short and longer term. Thus, the hydrologic function of beetle-affected stands lies somewhere between that of a mature forest and a clearcut depending on the severity of the beetle attack, proportion of unaffected overstorey, and amount of understorey trees.

Stand rehabilitation treatment that involves clearcutting (overstorey removal)[7] in juvenile or mature beetle-affected stands can significantly reduce or eliminate any hydrologic function remaining in the stand after beetle attack and mortality. At the watershed level, this difference can result in measurable differences in ECA over time depending on stand type (Grainger and Bates 2010) and potentially affect peak flows (Forest Practices Board 2007) and total water yield. Construction, re-activation, and (or) increased use of forest roads by light and heavy industrial traffic to access treatment sites can also affect roads and road-related stream sedimentation. Rehabilitation treatment in or near riparian areas can also potentially affect function (e.g., large woody debris recruitment, shade, organic inputs) and both short- and long-term channel stability. Negative effects could be realized if trees required for these processes are removed or compromised as a result of treatment within or adjacent to these areas.

To avoid potential negative effects on resources or elements at risk, stand rehabilitation activities should be guided by clear objectives for both timber and non-timber values. To accomplish this, planning and application of stand rehabilitation treatments must be informed by an understanding of:

4 See *Forest and Range Practices Act*, Forest Planning and Practices Regulation, Section 8.2: ***http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/12_14_2004#section8.2***

5 See *Forest and Range Practices Act*, Forest Planning and Practices Regulation, Section 8.1: ***http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/12_14_2004#section8.1***

6 As measured by stand-level equivalent clearcut area; see Lewis and Huggard (2010) or Huggard (2011).

7 We assume clearcutting and overstorey removal are synonymous, as most treated stands would have little secondary forest structure to be eligible for treatment, and this structure would be removed or damaged during overstorey tree removal.

Consequence Rating	Hazard Rating: Low	Hazard Rating: Moderate	Hazard Rating: High
Low	Very low	Low	Moderate
Moderate	Low	Moderate	High
High	Moderate	High	Very high

Figure 1. Risk matrix used in watershed risk analysis (adapted from Wise et al. 2004).

- the potential consequences of treatment on watershed resources at stake at the site level and in downslope and downstream areas;
- the hydrologic and geomorphic processes that can affect the resources at stake and the likelihood that such effects may occur;
- the expected effect of access and treatment on hydrologic and geomorphic processes and ultimately the resources at stake; and
- the landscape locations where rehabilitation treatments can be planned to benefit hydrologic recovery associated with forest regeneration and the appropriate treatments.

Watershed risk analysis procedures can be used to consider stand rehabilitation treatment effects on watershed-level hazards and resources at stake, or consequences. Risk of negative effects on resources at stake is the product of hazard and consequence defined by the risk equation (Risk = Hazard × Consequence) and applied using the matrix in Figure 1 (see above).

Hazards in this case are a source of potential harm, or a situation with a potential for causing harm in terms of human injury, damage to property, the environment, and other things of value, or some combination of these (Wise et al. [editors] 2004). Hazard ratings are the measurement or expression of the likelihood or probability of hazard occurrence. In watershed management, hazards can include:

- effects on runoff and streamflow, such as:
  - increases in the frequency and magnitude of hydrogeomorphic events (floods, bank erosion, channel instability, debris floods, and debris flows); and
  - reductions in water yield, low flow, and water supply;
- reduced water quality as a result of sediment or other deleterious material input to streams from roads, landslides, or other upslope sources; and
- reductions in riparian function and aquatic habitat.

Consequence refers to the resources at stake (human well-being, property, the environment, drinking water quality, or other things of value) and the change, loss, or damage to the resource(s) that may result from hazard occurrence.

Potential stand rehabilitation treatment effects on runoff and streamflow

In most southern and central Interior watersheds, streamflow (particularly peak flows) is controlled by snowmelt in the upper portion of the watershed. The area of the watershed that contributes snowmelt at the time of peak flow is often referred to as the "area above the snowline," "peak flow contribution zone," or "snow-sensitive zone," and ranges in elevation depending on aspect, topography, and snow accumulation and melt patterns (Toews and Gluns 1986). In mountainous watersheds, the snowline elevation is typically represented by an "H60 line," or elevation above which 60% of the watershed is located. In plateau-type watersheds of the southern Interior, the snowline can be as high as H45 or H40 (Smith et al. 2008). In watersheds with low relative relief, such as those in the central Interior, the area above the snowline at the time of peak flow can be the entire watershed.

Stand rehabilitation treatments that involve overstorey removal in beetle-affected forests are most likely to result in reductions in forest cover in the portion(s) of a watershed that contribute snowmelt runoff at the time of peak flow. Modelling suggests that loss of forest cover often results in earlier runoff and an increase in the frequency and severity of flood events (Alila et al. 2009). Both have potential negative effects on downstream resources such as life and property, infrastructure, water quality, water quantity, and fish habitat. Overstorey removal, or clearcutting, to expedite planting and hydrologic recovery decreases forest cover and increases snow accumulation and snowmelt rates (Winkler et al. 2008). The result is an increase in ECA over the untreated situation. In some cases, long-term hydrologic recovery can be accelerated through clearcutting beetle-affected stands and planting in stands with a high proportion of pine, severe mortality, and little to no secondary structure. In cases where affected pine occurs with other overstorey or understorey species, clearcutting can result in a higher short-term hydrologic hazard as non-pine species that regulate snow accumulation and snowmelt are removed along with dead pine.

Based on these considerations, where increases in runoff and peak flow are a concern for downstream values based on existing risk analysis reports or other information, clearcutting for stand rehabilitation above the snowline (as defined in existing reports or with expert input) should only be used where the incremental effect on ECA is small and a benefit can be shown from a long-term recovery perspective—that is, less time to hydrologic recovery if clearcut and planted.

Clearcutting below the snowline does not usually have a significant effect on peak-flow levels, but access and treatment effects on stream sedimentation and riparian function can occur. Above the snowline, partial overstorey removal can be used to remove affected pine from mixed or otherwise green stands with little to no incremental effect on stand-level ECA. Remaining green stems and both non-pine overstorey and understorey must be protected to achieve this outcome. Underplanting can also be used to promote hydrologic recovery where overstorey treatment is not applied and secondary structure is absent.

Extensive cutting and the creation of large openings (i.e., aggregates) in watersheds, which results in large portions of the watershed regenerating in a single seral stage, may also lead to reductions in water supply and low flow levels over the medium to long term. Although considerable uncertainty and speculation surrounds this effect, young trees generally use (i.e., transpire) more water than old trees (Yoder et al. 1994), which can make water less available for runoff and streamflow, particularly in wetter biogeoclimatic zones and variants such as the Sub-Boreal Spruce and the dry, mild Montane Spruce. In locations where water supply and low flows are a concern for downstream resources, the creation of large aggregated cutblocks should be avoided for precautionary reasons; rather, a mosaic of openings in various stages of regeneration should be created by dispersing harvesting/restoration efforts by aspect and elevation, where possible (Winkler et al. 2008).

Potential stand rehabilitation treatment effects on sedimentation and other contamination

Application of stand rehabilitation treatments requires the use of existing forest roads and in some cases construction of new roads. Forest road construction and use can be a chronic source of fine sediment to streams depending on road location, construction methods, surface material type, amount and timing of use, maintenance regimes, and weather-related considerations (Gucinski et al. 2001). Road-related effects on drainage are also linked closely with the occurrence of landslides on steep slopes, particularly where water diversion and concentration occurs within gentle over steep areas (Grainger 2002; Jordan 2002). Mapping of natural drainage patterns is a basic planning step in ensuring such water diversion and concentration does not occur. Even subtle changes have resulted in significant landslides (e.g., Hummingbird Creek [Anderson et al. 1997]).

Although sediment input to streams is a naturally occurring process (i.e., natural landslides), chronic inputs of sediment associated with road use and failing road infrastructure can potentially affect water quality for domestic water users and fisheries resources. Input of fine sediment to drinking water can reduce water quality and pose an increased health risk, particularly where water treatment infrastructure is inadequate to ensure potable water. Often, the outcome may be increased treatment costs borne by water purveyors (Redding and Bladon 2009). Chronic inputs of fine sediment can also negatively affect aquatic ecosystems and fish, depending on the concentration and duration of exposure (Newcombe and MacDonald 1991; Newcombe and Jensen 1996; Birtwell 1999). Fine sediment is particularly harmful in spawning areas, filling interstitial spaces in gravels and thereby reducing supply of dissolved oxygen to eggs, which can reduce spawning success (Slaney et al. 1977; Anderson 1996).

Where water quality is a concern based on existing risk analysis reports or other information, limits on road construction and use are recommended. Where only light use of forest roads will occur for rehabilitation activities like planting, no formal agreement is required, but the local forest district or forest licensee should be notified to pass along direction and any applicable road safety information. Where roads are required to move equipment to rehabilitation treatment sites, some form of tenure or authorization is required from the road permit holder (i.e., the B.C. Ministry of Forests, Mines and Lands) or forest licensee. Where industrial hauling is required, a formal road use permit, road use agreement, or road maintenance agreement with the permit holder is required. Where industrial hauling will occur, upgrading of drainage infrastructure and surfaces according to current legislation may also be required. Older roads were often built to lower standards (from both a drainage and a road-prism perspective) than those required by current legislation; re-activation or use without appropriate upgrades can result in serious accidents, landslides, surface erosion, changes in drainage patterns, and effects on downslope and downstream resources.

Non-status roads[8] for use in Forests For Tomorrow activities should be managed similarly for light use but must be put under tenure (usually a Special Use permit), upgraded accordingly, and maintained or deactivated after use. Even where light use occurs on non-status roads, improvements may be required to facilitate safe passage and meet environmental requirements.

Downstream drainage infrastructure (i.e., culverts, bridges) capacities and downslope stability are important considerations where clearcutting is the proposed rehabilitation treatment in upstream or upslope areas and if any road improvement work is planned. Increases in runoff and streamflow, and changes in drainage patterns can occur. Road upgrade and (or) terrain stability assessments should be completed by qualified professionals where treatment and road upgrade or use is to occur on steep terrain or within gentle-over-steep areas.

Stand rehabilitation treatment effects on riparian function

Treatments that remove overstorey trees in riparian areas result in a decrease in the volume of wood potentially available to channels, an increase in exposure to solar radiation, a decrease in other organic material inputs to the channel (leaf litter), and a possible decrease in bank stability. The input of wood to channels is a natural process from adjacent riparian areas. Instream wood plays a role in the regulation of sediment in channels, creation of fish habitat, and dissipation of energy and sediment in alluvial fan and floodplain environments (Robison and Beschta 1990; Smith et al. 1993; Wilford et al. 2005). Stream channels with sufficient power to rework their beds and banks (generally > 1.5 m bankfull width) require instream wood and mature riparian vegetation for stability. Streams less than 1.5 m wide have less energy and most often remain stable despite removal of riparian vegetation. All fish-bearing streams require some riparian vegetation for fish habitat reasons, the amount of which depends on the size of the stream and fish values.

With these considerations, stand rehabilitation activities near streams should be consistent with existing riparian management legislation.[9] Clearcut or partial overstorey removal for stand rehabilitation may be acceptable in riparian areas where pine composition is nearing 100%, pine mortality is high, and little secondary structure exists. Removal of overstorey trees in a riparian area may have limited adverse effect on small streams (< 1.5 m), where channels are not dependent on riparian vegetation for stability or instream wood supply purposes, and fish habitat values are low as determined by a qualified professional. Applicable streams are often ephemeral in the central and southern Interior of British Columbia, limiting development-related effects on stream temperature.

Clearcutting for stand rehabilitation adjacent to riparian areas where a riparian reserve is required can also increase post-harvest windthrow. Where a riparian reserve is required for channel stability or fish habitat reasons, increased retention in windthrow-prone areas within and adjacent to riparian areas will achieve the best result. Where riparian reserves have a high proportion of beetle-affected pine and little understorey, underplanting using either coniferous or deciduous trees (or both) can expedite riparian vegetation establishment and growth. For safety reasons, underplanting may be most appropriate either during the red attack stage or after deadfall occurs, and should be a high priority for stand rehabilitation.

Riparian reserves, particularly with beetle-affected stems that fall down, can further protect streams by

[8] Roads for which no permit or other obligation on the part of government or a forest licensee is in place (i.e., there are no inspection, maintenance, or repair-related activities occurring).

[9] See *Forest and Range Practices Act*, Forest Planning and Practices Regulation, Sections 47, 50–53: ***http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/12_14_2004#part4_division3***

Case Study – Tranquille Creek Community Watershed

The Tranquille River drains an area of roughly 40 000 ha west of Kamloops, B.C. The watershed has two large basins with opposite orientations, Upper Tranquille and Watching Creek, each with several sub-basins. Tranquille is a designated community watershed and likely candidate for future fisheries-sensitive watershed designation based on high salmon spawning values. Water quality, water quantity, and salmon spawning habitat in the lower reaches of the Tranquille mainstem channel are key elements at risk. Private land and both public and private infrastructure are also elements at risk in the lower watershed and lower reaches of the east–west-oriented Upper Tranquille basin. Public safety is a high consequence at several highways crossings in the Upper Tranquille basin and on a mid-basin alluvial fan. Consequences are less in the north–south-oriented Watching Creek basin. Increases in runoff, peak flow, and stream sedimentation are the hazards of concern in the lower mainstem and lower reaches of Upper Tranquille. The potential exists to desynchronize flows from the two basins by focussing licensee-driven salvage and Forests For Tomorrow program overstorey removal in both juvenile and mature beetle-affected stands in the Watching Creek basin and conducting limited additional salvage or other forms of overstorey removal in the Upper Tranquille basin. In the short term, opportunities for underplanting exist in the Upper Tranquille basin to expedite recovery where sufficient non-pine overstorey or understorey species are absent. This recommended treatment would advance snowmelt and runoff in the Watching Creek basin and leave the Upper Tranquille basin less affected over the short term, possibly desynchronizing runoff and reducing peak flow magnitude in the lower mainstem where resources are at stake.

creating a natural barrier to livestock. Removal of riparian vegetation can also facilitate access for range cattle with negative effects on bank stability and water quality (Chatwin et al. 2001; Forest Practices Board 2002). Where active range use occurs near fish-bearing streams or where downstream values such as water quality are a concern, avoidance of riparian areas is most appropriate for stand rehabilitation as deadfall can impede cattle access, protecting resources at stake. Again, underplanting is an option to expedite riparian vegetation establishment and growth, if required.

Using watershed risk analyses to support management decisions

The previous sections have provided general watershed management guidance that professionals involved in stand rehabilitation should consider when planning treatments. Unfortunately, no clear "rules of thumb" can be consistently applied in watershed management. Forest management effects on watershed processes vary considerably based on topography, climate, geology, sensitivity, historic disturbances and existing condition (hazards), and the connection to resources at stake (consequences). Thus, decisions on the extent of area to be treated and type of treatments prescribed should be considered at both the watershed and basin levels. In any circumstance, delivery agents should direct their stand rehabilitation activities based on a risk analysis completed by a qualified professional, particularly in community watersheds and fisheries-sensitive watersheds.

Recently, watershed risk analyses have been completed in several community watersheds and fisheries-sensitive watersheds by (or for) the B.C. Ministry of Environment and are available to other agencies, forest licensees, and stand rehabilitation delivery agents.[10] The Tranquille River Watershed Risk Analysis is an example (see above). Risk analyses may have also been completed by major licensees to address forest stewardship plan requirements and may be made available to stand rehabilitation delivery agents on request. Most watershed risk analyses related to mountain pine beetle rehabilitation activities completed by the Ministry of Environment in recent years were funded by Forests For Tomorrow and provide recommendations for:

- types of stand rehabilitation activities aimed at restoring or recovering watershed function;

[10] Individual reports by watershed can be found by searching the Ecological Reports Catalogue or "EcoCat" using the watershed name (*http://www.env.gov.bc.ca/ecocat/*), or type "MOE FFT" as a keyword.

- direction around the location of beneficial treatment(s) and areas to be avoided; and
- priority areas for treatment by type.

Where formal risk analyses are not available other information can be used in combination with expert advice to better understand candidate treatment sites, methods, and potential hydrologic effects. It is important to recognize that because of the mountain pine beetle outbreak watershed information is most likely out of date and will require updating to provide meaningful direction around hazard and risk. Other information could include:

- Interior Watershed Assessment reports available from forest districts and major licensees;
- terrain stability mapping and reports available from forest districts, forest regions, and major licensees;
- other government or forest licensee planning and assessment documents, such as hydrologic assessments, road risk assessments, road rehabilitation plans, and watershed management plans;
- watershed and water intake and treatment infrastructure information available from water purveyors; and
- fisheries inventory and fish habitat assessments.

Sources for existing watershed risk analyses and other supporting information include:

- B.C. Ministry of Forest, Lands and Natural Resource Operations (contact Doug Lewis: ***Doug.W.Lewis@gov.bc.ca***)
- EcoCat – Ecological Reports Catalogue (***http://www.env.gov.bc.ca/ecocat/***)
- *Streamline Watershed Management Bulletin* (***http://www.forrex.org/streamline/streamline.asp***)
- *BC Journal of Ecosystems and Management* (***http://jem.forrex.org/index.php/jem***)
- Forest licensees

Monitoring

Watershed conditions need to be closely monitored before large-scale forest rehabilitation activities are undertaken. The rate of forest cover change on the land base is increasing; conditions resulting from new commercial harvesting, wildfires, and extent and severity of insect attacks may be significantly different than when the last watershed analysis occurred. Recent evidence suggests that the severity and extent of mountain pine beetle attack may be less than originally predicted in areas of the province on the periphery of the outbreak (i.e., Okanagan or Merritt timber supply areas; Walton 2010). Thus, pre-emptive removal of pine-leading stands, even when existing attack levels are low, may not be appropriate given uncertainties around attack and effects of treatment on watershed condition and values. Where Forests For Tomorrow rehabilitation activities occur in high-value watersheds, process-based and effectiveness monitoring should consider the following points.

Process-based monitoring

- Is the rate of mountain pine beetle attack and mortality as expected? Should Forests For Tomorrow rehabilitation be ramped up or scaled back accordingly?
- Is a watershed risk analysis report or equivalent information in place to guide Forests For Tomorrow activities? If so, have recommendations been followed to date?
- Were appropriate treatments employed considering hazard and consequence?
- Were Forests For Tomorrow activities strategically planned with other activities (i.e., commercial salvage) to result in a positive outcome for watershed values and elements at risk?

Effectiveness monitoring

- Conduct survival surveys to determine the success, survival, and growth of seedlings in underplanted stands.
- Evaluate the rate of recovery in untreated areas with naturally stocked understorey.
- Determine retreatment requirements (i.e., replanting) in clearcut, fill-planted, and underplanted stands.
- Develop and publish case studies around treatment versus no treatment to guide future activities.

Summary

Despite the potential benefits and good intentions of stand rehabilitation following natural disturbance, these activities can have negative effects on watershed-related resources. Negative effects on water and water-related resources can be minimized or avoided in most cases by establishing clear objectives for both timber and non-timber values and by incorporating good planning and best management practices. We recommend that practitioners involved in planning and implementing stand rehabilitation activities utilize a qualified professional to:

- understand current watershed condition, resources at stake in the watershed, and their connection to watershed processes;
- use a risk analysis approach to evaluate the potential consequence(s) of proposed stand rehabilitation activities before implementation; and
- discuss and co-ordinate activities with other tenure holders and watershed stakeholders.

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Test Your Knowledge . . .

Considerations for rehabilitating naturally disturbed stands: Part 1 – Watershed hydrology

How well can you recall some of the main messages in the preceding Extension Note?
Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. What stand-level treatments are available under the Land-based Investment Program to reforest naturally disturbed stands?
   A) Clearcutting or overstorey removal with planting
   B) Planting only
   C) Partial overstorey removal with planting
   D) Underplanting and fill planting
   E) All of the above

2. What water-related role(s) do non-pine overstorey and understorey species play in stands affected by mountain pine beetle?
   A) Slope stability
   B) Regulation of snow accumulation and snowmelt rates
   C) Fire suppression
   D) A and C only
   E) B and C only

3. Watershed risk analysis procedures consider which of the following points?
   A) Forest and non-forest resources at stake in a watershed
   B) Water-related hazards from a streamflow, sedimentation, and riparian function perspective
   C) Connection between hazards and resources at stake
   D) None of the above
   E) All of the above

ANSWERS

1. E 2. B 3. E