Trepanier Creek Hydrological Risk Assessment

Prepared for:

BC Ministry of Environment

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EXECUTIVE SUMMARY

Grainger and Associates Consulting Ltd. and Streamworks Unlimited completed an analysis of Mountain Pine Beetle (MPB) and salvage harvesting-related risks to water quality, water supply, fish habitat and other infrastructure in Trepanier Creek Community Watershed. Trepanier Creek has an area of $255km^2$ and drains into Okanagan Lake just north of the Town of Peachland. It is a water source for the District of Peachland (DoP).

The hydrological effects of MPB and salvage harvest forest cover disturbance were analysed using recent research findings on snow accumulation and melt effects under different forest canopy conditions, including the effects of the dead pine trees, non-pine overstory, and understory seedlings, saplings and poles in MPB-attacked stands (Huggard and Lewis, 2008). Canopy change effects are expressed as equivalent clearcut area (ECA).

Stand structure data for ECA modelling was collected in 245 random plots in 30 accessible pine-leading stands (>40% pine) in the hydrologically sensitive upper watershed “snow zone”, in seven South Okanagan watersheds near and including Trepanier Creek. Over 70% of inventoried pine-leading stands had a non-pine overstory averaging 25 to 69% of total overstory basal area, and healthy understory averaging 560 to 1000 well-spaced stems/ha >1.3m tall. These stands will have a significant hydrological function, even if all pine in the stand is dead.

Stand data was used to model two watershed level management scenarios. In the “MPB/unharvested” scenario, all pine trees in pine-leading stands (>40% pine) are assumed to be killed by MPB, and no further forest harvesting activity takes place in the watershed. In the “full clearcut salvage” scenario all pine-leading stands are clearcut harvested, with the exception of riparian zones, old growth management and other areas designated as long-term reserves by forest licensees. For each of these scenarios, stand ECA data was rolled up into watershed or sub-basin ECA’s for Trepanier Creek watershed and its four sub-basins.

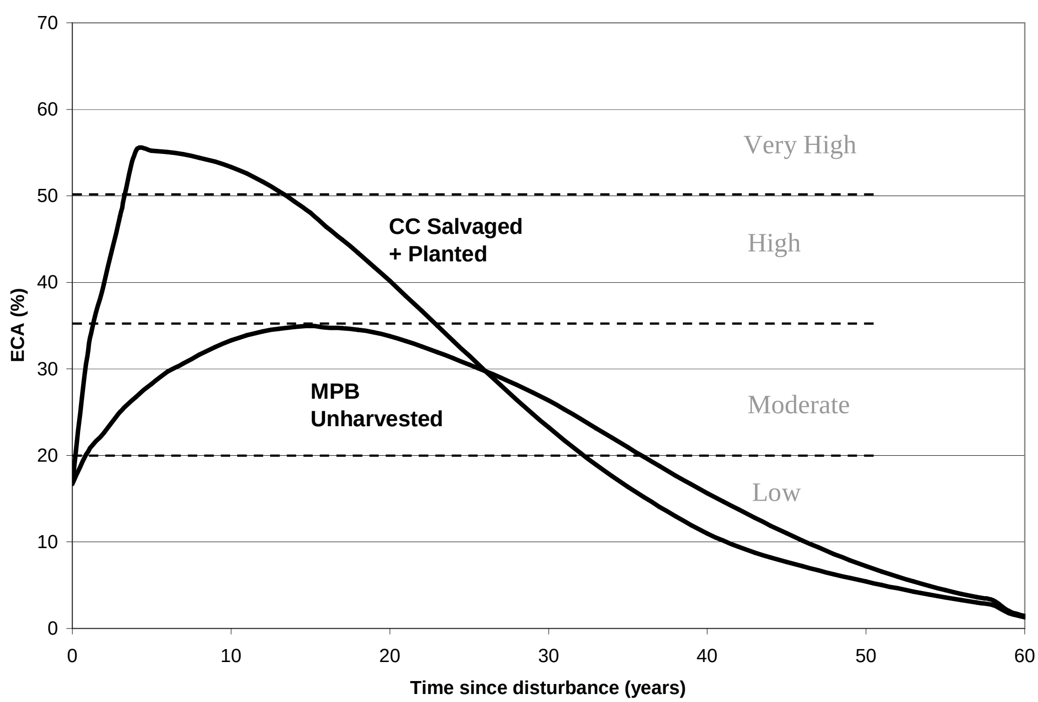


Figure 10. ECA hazard projections for Trepanier Creek Watershed above DOS intake.

The current watershed ECA is low. Following full pine mortality and no harvesting there is, on average, a moderate ECA hazard for approximately 25 years; and for the full pine salvage harvest scenario there is a high incremental ECA hazard lasting for 15 to 20 years. It is clear there is a much greater change in forest canopy and thus watershed ECA following total clearcut salvage harvesting, than if MPB-attacked stands are left unharvested.

Watershed characteristics afford little opportunity to attenuate forest cover changes (ECA) effects in producing changes in peak flows and sediment mobilization from channel beds and banks. These hydrologic hazards are Moderate and High following the unharvested MPB and total pine salvage harvest scenarios respectively. Based on previous studies in the Okanagan and elsewhere, the High hydrologic hazard following total pine salvage is expected to result in an increased occurrence of all size peak flows. For example, it is estimated that what has historically been the 50 year flood would occur, on average, every 15 year years. That is, an event the size of the current 50 year flood is about 3 times more likely to occur following full salvage harvesting; and this effect would last for 15 to 20 years. Also larger floods, with a greater than 50 year return period, which have not been experienced in recent times, are also more likely to occur in this period.

Most sub-basins in the watershed have lower or similar hydrologic hazards as the watershed as a whole, except for the MacDonald Creek sub-basin; which has ECA hazard values of High following the unharvested MPB scenario and Very High following the full salvage harvest scenario – due to significant cleared area for the closed Brenda Mine and a high proportion of forest type (ESSF) with significant non-pine canopy, that if harvested will show a large increase in ECA.

Potential qualitative risks to different watershed and sub-basin elements were determined by combining the hydrologic hazards for the two management scenarios with the consequence values for each of the four watershed elements of interest – municipal water quality, water supply, fish resources and infrastructure.

The water quality parameters most strongly linked to MPB infestation and salvage logging in Trepanier Creek watershed are increases in peak flows (floods) and associated mobilization of fine and coarse sediment from stream channel beds and banks. Following the complete mortality of all pine and no further harvesting in the watershed there is a Moderate Risk, which means some increase in fine and coarse sediment delivery to the DoP intake may or may not occur. Following the full salvage of pine-leading stands scenario there is a High risk. That is, a significant increase in peak flows and sediment delivery to the DoP intake is likely to occur. Source water turbidity levels will continue to present a problem at the DoP water intake, in terms of meeting Interior Health Authority water quality guidelines. MPB mortality alone may or may not result in noticeably increased turbidity, but high salvage harvest levels likely will.

There is little evidence of links between MPB/salvage effects and the water quality parameters of total organic carbon, true colour, metals and total phosphorous. Measurable changes in these parameters in Trepanier Creek are not expected. The effect of MPB and salvage mortality on growing season low flows will probably not be significant. A much greater change in decreased streamflows and freshet timing is expected due to global climate change-related temperature increases.

There are fish present and high habitat values along much of the lower Trepanier Creek mainstem. This results in a High Risk of negative impacts following MPB-related pine mortality, mainly due to increased sediment movement, channel aggradation and a reduction in habitat quality. If there is widespread salvage harvesting the risk of negative impacts on fish populations in these lower mainstem reaches will be Very High. The likelihood of negative impacts is even more likely in Reach 1 on the Trepanier Creek fan where fish habitat values are Very High due to it being Kokanee spawning habitat.

All social infrastructure values have a higher risk following the full salvage scenario than for the MPB/unharvested scenario; because of the increased hydrologic hazard associated with clearcut salvaging in the types of stands present in the Trepanier Creek watershed. Risks to housing developments on the Trepanier Creek fan, forestry roads, forest road-related "gentle-over-steep" landslides and public road crossings (Paradise Valley Road and Beach Avenue) are considered moderate and high for the MPB/unharvested and full salvage scenarios respectively. Risks to private water intakes and private stream crossings in the watershed are considered High to Very High respectively, because they are generally built to a lower standard than forestry or public works.

There are potentially High to Very High risks to water quality, infrastructure and fish values in lower Trepanier Creek, from failure of the MacDonald stream diversion channel around the Brenda Mine tailings pond. The risk rating is stated as potential because limited access prevented a detailed investigation of this area, and uncertainty remains about the vulnerability of the diversion to expected increases in peak flows following MPB infestation and possibly salvage harvesting. There is a history of severe erosion and mobilization of sediment from mine-related stream diversions in MacDonald Creek, and it remains sensitive to further disturbance due to past avulsions, erosion and stream aggradation. The capacity and integrity of the MacDonald Creek diversion around the mine tailings pond should be carefully reviewed, and improved as necessary.

Risk mitigation can focus on either protecting and strengthening risk elements, or reducing stand-level MPB and salvage effects. Forest For Tomorrow (FFT) program silviculture activities will promote long term health, economic value and hydrologic function in the forest. However, to date under-planting has not been successful and all ongoing FFT activities we are aware of involve canopy removal. These activities will not mitigate the short term hydrological impacts of MPB attack and salvage harvesting in Peachland Creek. Particularly where significant salvage harvesting is planned in any area, a review of trail and road drainage is recommended as described herein, to manage for potential gentle-over-steep landslide hazards.

Riparian management along streams during salvage harvesting will be important in maintaining short and long term temperature and large woody debris (LWD) recruitment levels, and in preserving stream stability and habitat quality. Research has found LWD input rates are similar for attacked and non-attacked Okanagan stands, suggesting that riparian zone forests have a significant non-pine component, and will continue to protect stream ecosystem values if left unharvested. At a minimum best riparian management practices for "green wood" harvesting in the Okanagan should be followed when salvage harvesting MPB-attacked stands. This will help to mitigate potential impacts on fish habitat. Since the effects of MPB-attack are uncertain and we don't know what level of harvesting will occur in the watershed, it would be prudent to periodically update on-site fish habitat assessments (last done in 1996), monitor channel and riparian conditions and carry out rehabilitation activities as necessary.

We know of no way to reduce the magnitude and duration of the ECA hazard in MPB-attacked unharvested stands, in the absence of an effective under-planting program for unharvested attacked stands. However the incremental risks related to unharvested MPB-related ECA hazards are only moderate to DoP water quality and water supply infrastructure, and low to water supply. Post unharvested MPB risks are low to moderate for most other infrastructure, and high for private water intakes and crossings, and fish values in lower mainstem stream reaches.

Incremental risks are higher for all elements at risk in the watershed following the hypothetical scenario of full salvage harvest of all pine-leading stands, compared to the potential risks if all pine-leading stands were all left unharvested. To reduce those risks to an acceptable level will require managing the amount and location of salvage harvesting in the watershed.

While it makes good hydrological sense to harvest attacked pine stands rather than "green" non-pine stands, removing too much MPB-attacked forest will increase watershed hazards and risks. To manage the incremental hydrologic impact of salvage harvesting it is recommended that:

- Licensees should use a hydrological risk assessment methodology that models the effects of non-pine overstory and understory stand structure in dead pine stands to get a more accurate picture of the hydrological condition of the watershed, and of the potential impacts of proposed salvage harvesting. Hydrological risk analyses that treat all MPB attacked stands as having little or no hydrological forest function (i.e., as having initial ECA values similar to clearcuts) will seriously underestimate the incremental hydrological risks associated with widespread clearcutting of attacked stands that have hydrologically significant stand characteristics.

- From a strictly hydrological perspective (and we recognize forest managers have to balance many different forest values), the least hydrological impact would result if pine-leading stands with the lowest non-pine overstory component and lowest understory stocking were preferentially targeted for salvage harvest. From the data collected here the stands in the snow zone with least hydrological function would be younger MSdm stands followed by older MSdm stands and then ESSF stands (see Figures 6-8 and Appendix B).

- We recognize that individual stands within these broader biogeoclimatic types will have different characteristics; site specific surveys of stand characteristics in areas proposed for harvesting are recommended. Salvage harvesting should be focused on those stands with the least non-pine overstory and little healthy understory.

- The widespread and severe MPB epidemic in B.C. is clear evidence that forests can be subjected to significant unforeseen disturbances, with potentially significant consequences. Because of the types of forests present, the expected hydrological effect of unharvested MPB infestation and pine tree mortality in Trepanier Creek Watershed is not expected to be catastrophic for any of the identified watershed values (risk elements). Salvage harvesting, if widespread enough, can increase those risks. With good management of harvesting rates and sites, which recognizes the hydrological function of different pine-leading stand types, some forest development should be possible with a level of risk that is acceptable to watershed stakeholders. However MPB infestation may not be the only significant source of stress on Trepanier Creek forests in the near future. Global warming and global warming-related disturbances such as other pathogens which could attack other tree types, and fire, etc., are not improbable. We think that part of the determination of what is an acceptable level of risk should include considering the potential hydrological (and other) effects of these other possible disturbances. To manage for them it would be prudent to apply the precautionary principle and preserve some hydrological function in the watershed above the minimum required to manage only for MPB and MPB-related salvage impacts.

1.0 INTRODUCTION

Grainger and Associates Consulting Ltd. and Streamworks Unlimited were retained by the B.C. Ministry of Environment to carry out an analysis of Mountain Pine Beetle (MPB) and salvage harvesting-related risks to water quality, water supply, fish habitat and other infrastructure in Trepanier Creek Community Watershed (Figure 1, in pocket); as part of a contract to complete similar risk analyses for seven south Okanagan Community Watersheds.

Trepanier Creek Watershed has an area of approximately 255km^2 and drains into Okanagan Lake just north of the town of Peachland, B.C. It is a municipal water source for the District of Peachland (DoP). Rainbow trout are present in many parts of the watershed and kokanee spawn in the lowest reach of Trepanier Creek near Okanagan Lake.

This report provides an analysis of risks to watershed values associated with potential changes in the forest following pine mortality due to MPB attack and/or salvage harvesting. Changes in forest cover affects watershed hydrology, and potentially water quality, quantity and timing.

The project was completed by the team of Bill Grainger, P.Geo. EngL., forest hydrology, risk analysis and project management; Alan Bates, P.Eng., hydrotechnical analysis, channel morphology, sensitivity and restoration; Jennifer Clarke, P. Geo.; background information and water quality, Michele Trumbley; R.P.Bio., fish population and habitat analysis, Dave Huggard, Ph.D., ECA modeling; Stuart Parker, RPF, forest stand data collection and silviculture mitigation options; and Chris Long of Integrated ProAction Corp, GIS data analyses and mapping.

2.0 METHODOLOGY

This report utilizes previously published materials on Trepanier Creek watershed conditions, as well as a helicopter overflight on October 27 and ground inspections on November 12 and 13, 2008. Forest overstory and understory were measured in 37 plots in five different areas in Trepanier Creek on December 16, 17 and 18, 2008, as part of a program of 245 plots taken in 30 areas in seven south Okanagan Community watersheds. This detailed stand information was use in modelling the projected hydrological effects of MPB pine mortality and salvage harvesting in Trepanier Creek and the six other watersheds.

This report also incorporates recent research findings regarding the hydrological effects of MPB-attacked stands over time, and research findings regarding potential stream flow regime changes due to large scale watershed disturbances such as those resulting from MPB and clearcut salvage harvesting.

The watershed risk analysis procedure is presented in Section 2.1. Sections 2.2 and 2.3 explain how forest cover changes, watershed conditions and channel conditions make up the hydrologic hazard. Section 2.4 discusses the linkages between MPB and salvage harvesting-related watershed processes and the various elements potentially at risk in the watershed. Current and potential future watershed conditions in Trepanier Creek are assessed in Section 3, to determine potential hydrologic hazards. Section 4 details the presence and/or vulnerability of specific Trepanier Creek watershed values (or consequences) that could be impacted by those hazards.

Section 5 combines the hazards and consequences discussed in Sections 3 and 4 to arrive at qualitative risk ratings for each of the consequences potentially at risk.

Section 6 summarizes the various qualitative risks and proposes mitigative measures and management strategies to reduce those risks, where necessary.

2.1 RISK ANALYSIS

Risk is a product of the incremental (increased) hydrologic hazard due to MPB and salvage harvesting, and each of the consequences which could be impacted by that hazard:

$$\text{Risk} = \text{Hazard} \times \text{Consequence}$$

This is done using a risk matrix, as shown in Appendix A, Risk Assessment Definitions.

Figure 2 shows the risk assessment procedure used in this investigation. The incremental hydrologic hazard starts with changes in the forest canopy, snow accumulation and snow melt. This is expressed as an Equivalent Clearcut Area hazard (ECA). Watershed characteristics – drainage density, slope and routing factors (reservoirs, lakes and swamps) determine how the watershed will respond to changes in watershed ECA. A change in the flow regime is expressed as the flow hazard. How the flow hazard will affect stream channels depends on the existing channel conditions, and how sensitive or robust the channel is to changes in stream flows. This is determined from field observations and previously published channel assessments. The channel sensitivity and flow hazard are combined to form the overall Hydrologic Hazard.

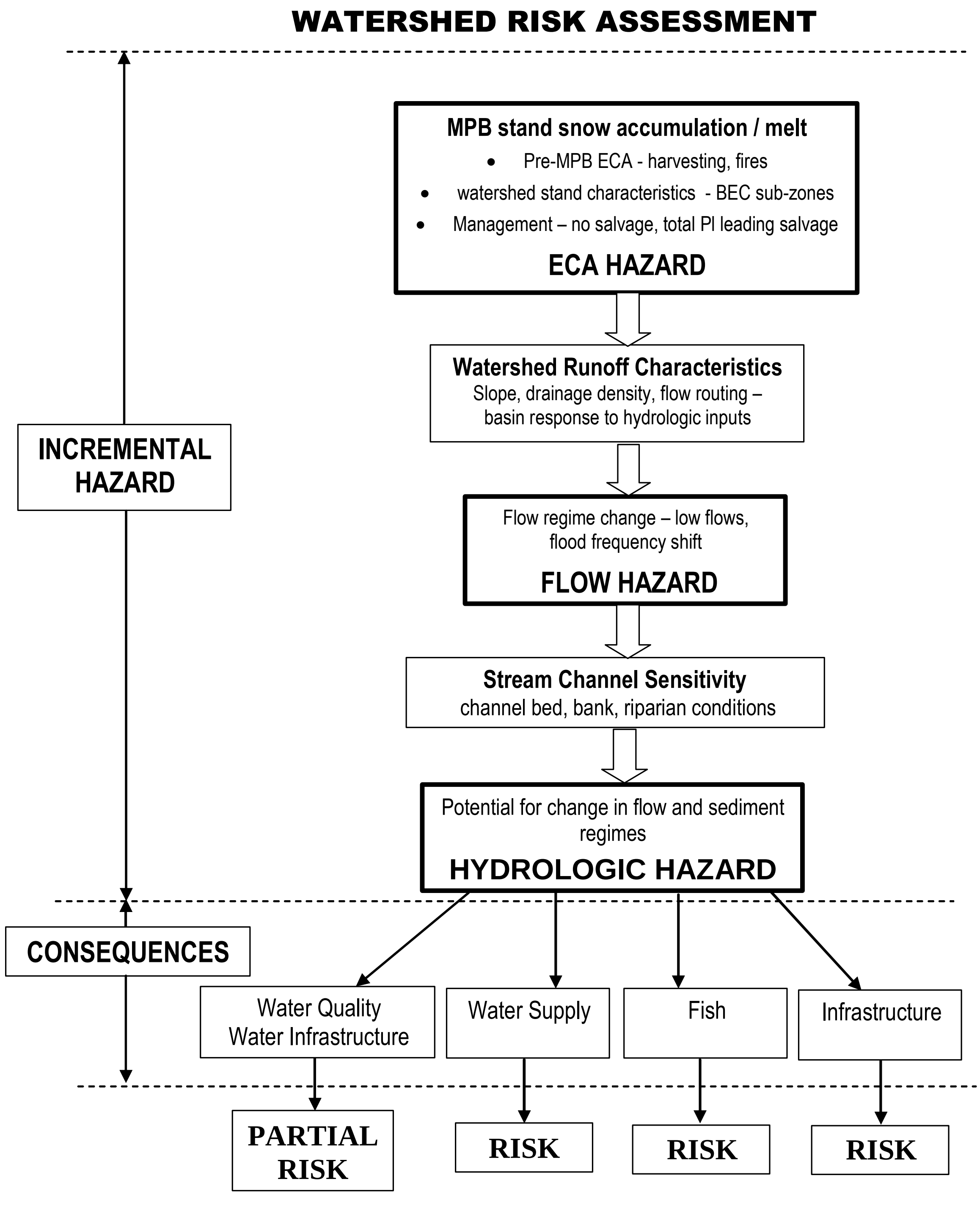


Figure 2. Risk Assessment Flow Chart

2.2 MPB AND SALVAGE HARVESTING HAZARDS

2.2.1 MPB and salvage stand hydrological effects

Mountain Pine Beetle and salvage harvesting primarily affect watershed hydrological processes through the loss of forest canopy and ground disturbance; when the pine beetle kills pine trees in a stand, and when clearcut harvesting removes all trees in a stand. These changes can alter the water balance at affected sites and, depending on actual weather and watershed characteristics contribute to: less evapotranspiration and interception losses, increased rain and snow reaching the ground, increased soil moisture and hillslope flow, changes in site level energy balances leading to earlier onset of spring snowmelt, more rapid streamflow response to storms, increased total stream flow and increased magnitude and frequency of peak flows (Winkler et al. 2008).

Ground disturbance and roads can lead to soil compaction, reduced infiltration to groundwater, shallow groundwater interception in road cuts and redirection of intercepted water to streams. These processes can increase the “flashiness” of watershed response to rain and snowmelt inputs, and contribute to elevated peak flows. Our experience with recent forest development in this area is that with current forest harvesting and road drainage practices and the mostly well-drained coarse textured soils found in the region, these effects are relatively small compared to the effect of canopy removal, and this is assumed to be the case in the following analysis.

Clearcut harvesting results in complete canopy removal and leads to the maximum hydrological effects mentioned above. In the nival (snow-melt dominated) watersheds of the southern interior, such as Trepanier Creek, these effects are caused primarily by the accumulation of higher snow packs (expressed as snow water equivalent, SWE) in clearcuts than in forests, and increased melt or ablation rates in clear cuts relative to forests.

There is a large volume of literature concerning the hydrological effects of clear-cutting, in which the extent of forest canopy removal or disturbance is often expressed as the Equivalent Clearcut Area (ECA); where a clear-cut initially has an ECA of 100%, a mature forest has an ECA of zero, and a regenerating forest has an ECA somewhere in between, that is proportional to tree height and stocking (Anonymous, 1999). A watershed ECA value is calculated by combining the ECA’s for various treatment and unharvested areas throughout the watershed.

Our experience with analyzing hydrological impacts to watersheds using the ECA concept is that because of the many simplifying assumptions necessary, there is always a large degree of uncertainty regarding the final result, and it is not meaningful to apply watershed ECA results with an accuracy of greater ±5%. In this report, when discussing the implications of ECA results they are generally rounded to the nearest 5%.

2.2.2 MPB and ECA

In this study we model watershed ECA using the Huggard method (Huggard and Lewis, 2008), which incorporates recent research findings on snow accumulation and melt effects of different forest canopy conditions in MPB attacked stands. This includes modelling the canopy effects of the dead pine, the non-pine overstory and understory seedlings, saplings and poles. Research throughout BC to quantify the hydrologic function of dead pine trees and secondary structure in pine-leading (>40% pine) MPB infested stands clearly demonstrates the important hydrologic function of unharvested MPB attacked stands, and supports the contention that these effects must be considered when evaluating the potential hydrologic risks associated with MPB related stand mortality relative to salvage logging (Winkler and Boon 2009, Rex et al. 2009, Boon 2008, Redding et al., 2008a, Redding et al. 2008b, Winkler, et al. 2008 and FPB, 2007).

The stand structure data used in modelling Trepanier Creek ECA was collected in 245 random plots in 30 accessible stands in seven South Okanagan watersheds[1] near Trepanier Creek, with similar biogeoclimatic (BEC) stand types as Trepanier Creek, and includes 64 plots taken in Trepanier Creek watershed. Appendix B, "Summary of Results from South Okanagan Stand Surveys for MPB-ECA Modeling" presents a summary of those field findings for secondary structure in high elevation BEC zones in this area, and compares those findings with similar secondary stand structure surveys taken elsewhere in the province. Where required this data was supplemented with secondary structure stand data from the North Okanagan and Thompson regions (Vyse et al. 2007), which showed similar results.

Huggard and Lewis (2008) found the ECA effects of the dead pine trees in a pure pine stand can initially contribute up to 60% ECA reduction in the grey-attack phase. ECA gradually increases over time as dead trees in the pine stand fall to the ground. The ECA of non-pine overstory is considered directly proportional to the percentage of mature non-pine trees in the stand, which is presumed to remain constant over the time period analysed; and which varies greatly between forest types (BEC variants). The understory components affecting ECA include existing poles, saplings and seedlings, and new seedlings, assuming a regeneration delay of 20 years before full stocking. As the understory grows over time, stand ECA is gradually reduced. The change in ECA contribution over time from these three factors is combined into a single curve representing the cumulative growth and/or decay of ECA of the dead pine stand over time. This was done for various BEC variants, percentages of pine in the stand, site productivity indices and other variables. Figure 3 is an ECA progression curve for an unharvested MPB attacked stand, showing the contribution of the three ECA reduction factors (dead pine, non-pine overstory and understory) and the cumulative ECA curve over a 60 year recovery period.

In Figure 3, and in all modelling of unharvested MPB-attacked pine-leading stands, 100% mortality of pine trees in the stand is assumed. However, recent research suggests that in the Okanagan Timber Supply Area the amount of pine mortality after the MPB infestation has largely subsided in 2019 will be about 68%; albeit with a substantial degree of uncertainty around that projection (Walton, 2009). If this turns out to be true, there will be 38% of pine trees left alive and with continuing hydrologic function. The distribution of mortality and survival in differing stand types is not known. A sensitivity analysis of watershed ECA with less than total pine mortality was carried out (see Section 3.2.1). Because of the significant uncertainty with the Walton (2009) estimates, stand and watershed analyses shown in this report assume total pine mortality. It should be kept in mind that these analyses may overstate the ECA effect of unharvested MPB attack, and underestimate the difference between retention of actual attacked pine stands and salvage harvesting, if pine mortality turns our to be significantly less than 100%.

1. The seven watersheds are Trout, Lambly, Trepanier, Peachland, Mission, Hydraulic and Penticton Creeks.

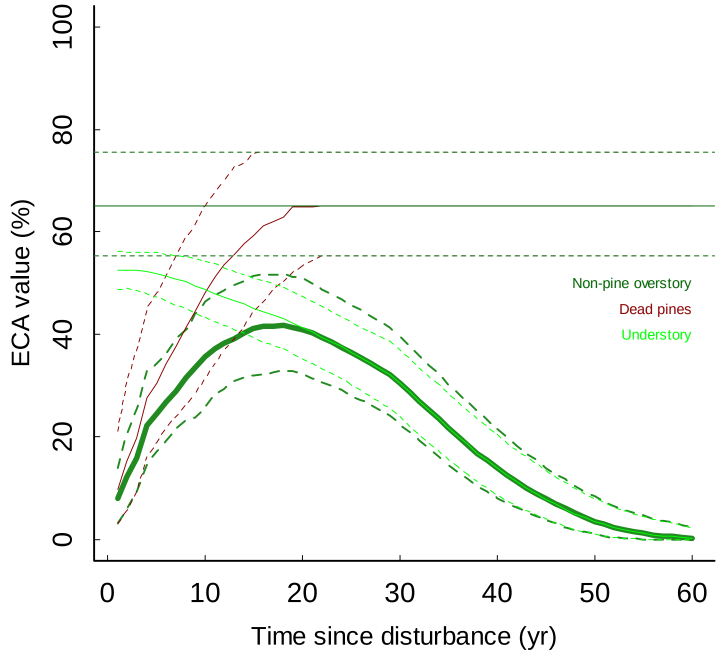


Figure 3. ECA projection (heavy green line) for unsalvaged older Montane Spruce BEC variant (MSdm, >110yr) showing the contributions over time of non-pine canopy (black line, showing a constant 35% ECA reduction over time) the dead pine (red line, showing decreasing ECA reduction as dead pines fall down over about 20 years) and understory (light green line). Dashed lines are 95% confidence intervals.

Huggard and Lewis (2008) also conducted sensitivity analyses on many of the critical input parameters, including percent mortality of natural understory, understory species composition, TIPSY vs. VDYP regrowth modeling, different regeneration stocking delays, and other modeling components/assumptions. Generally the salvage vs. non-salvage ECA curves were found to be most sensitive to the percentage of non-pine overstory, as shown in Figure 3.

It should be noted that the solid lines in Figure 3 are average values of the many different individual site conditions one would encounter in actual stands throughout a particular BEC variant.

ECA curves for clearcut harvested attacked stands were also developed, based on expected regrowth rates of planted stands. Figure 4 shows a comparison of the unharvested and harvested ECA progression over time, for the same stand type shown in Figure 3. Similar curves were developed for all major BEC zones or subzones in the hydrologically important upper portion of the watershed. To arrive at a watershed ECA the cumulative effect of the different ECA progressions in different BEC zones in the watershed is calculated.

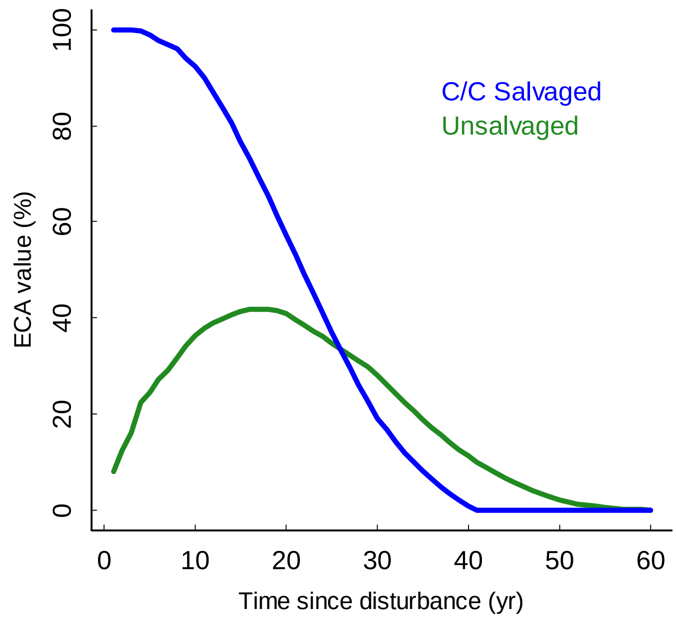


Figure 4. ECA projections for unsalvaged and clearcut salvaged and planted older MSdm, showing that ECA for unharvested MPB attacked stands never rises above about 40%. There is a 20 to 25 year period where the clearcut salvaged and replanted stand has a significantly higher ECA than the unharvested stand, after which the planted stand recovers slightly ahead of the unharvested stand.

It should be stressed that ECA hazard value alone is not necessarily a good indicator of potential watershed hazards. Each watershed and stream channel will respond differently to changes in forest canopy that ECA values represent, depending on watershed and channel characteristics, as discussed below.

2.3 WATERSHED AND CHANNEL SENSITIVITY

Where ECA levels are high, increased runoff is routed down slopes and is collected by channel systems, accumulating flows downward through the watershed. How or whether stand level changes translate into downstream watershed level impacts depends upon the physical attributes of the watershed and channels.

Drainage basin factors that affect runoff sensitivity include steepness, soil drainage properties, drainage density, soil depth (or proximity to an impervious layer), and natural storage (e.g. lakes, wetlands). Some of these characteristics are clearly interrelated; for example a steep basin with poor soil drainage usually has a higher drainage density. Storage features such as lakes and wetlands (either on the channel or floodplain) can attenuate peak flows and lessen the impact of an increased flow regime. As shown in Figure 2 the extent of forest cover disturbance (denoted by ECA) is combined with drainage basin properties to give a Peak Flow Hazard. Qualitative basin drainage characteristics were assessed for this project using orthophoto/contour maps, field observations and previously published reports.

Channel response to changes in flow regime depends on natural channel attributes, which are a reflection of grade, flow regime and the materials (soil and vegetation) that the channel passes through. Channels respond to increased flows by increasing their capacity, typically by widening through bank erosion (Church, 1993). Channels passing through coarser, erosion resistant materials will respond more slowly to flow regime change, taking decades or more to adjust. Conversely, channels with easily erodible banks will respond rapidly to increases in peak flows.

Channel sensitivities are described in response to increased peak flow/flood frequency, increased sediment delivery and decreased riparian function, and channel change can result from any one of or a combination of these stressors.

Loss of riparian cover due to MPB is not considered a major issue as the component of pine in wetter riparian zones tends to be less than elsewhere across the landscape. Wei et al, (2007) found similar large woody debris (LWD) input rates in the Okanagan for MPB-attacked and non-attacked stands. Hassan (2008) investigated sites in central BC and concluded that MPB infestation-related wood transfer to the channel in the next 25 years is likely to be relatively small and within the range of typical conditions found in the region. Therefore, in Trepanier Creek, MPB-related short term increases and long term decreases in LWD recruitment are not expected to be major or to have a significant effect on channel stability and/or fish habitat. If stream riparian zones are included in clearcut areas during timber salvage operations, this loss of riparian vegetation could lead to loss of LWD recruitment, channel stability, stream nutrient and stream temperature issues.

Channel sensitivities were interpreted according to the framework presented in Table C-1 (Appendix C, from Green, 2005) based on field observations, airphoto and map reviews, and observations and conclusions from previously completed channel assessments. Earlier assessments were typically aimed at documenting levels of disturbance in channels and observed indicators of disturbance were assumed to also be indicators of channel sensitivity or 'robustness'. These results were carried forward into this assessment. Channel sensitivities vary along the length of the stream. For the purposes of this assessment, sensitivities were assigned by sub-basin, based on the relative extent and location of sensitive reaches within that sub-basin.

Channel sensitivities are described in response to increased peak flow/flood frequency, increased sediment delivery and decreased riparian function, and channel change can result from any one or a combination of these stressors. In the broad gently sloping upland areas where most forest development has occurred, few significant sediment sources, such as landslides and road erosion, were identified outside of the stream bed and banks. Therefore most sediment is generated from channel beds and banks during high flows, and increased peak flows and sediment generation are closely related. Lower in the watershed where larger tributaries and the Penticton Creek mainstem are more deeply incised into the plateau with steeper valley walls, there is more potential for significant natural or forest development-related landslides which can introduce significant sediment to channels, which will also be mobilized by peak flows.

Once channel sensitivity has been determined, it is combined with the Peak Flow Hazard to give a Hydrologic Hazard for the drainage area (Figure 2). The Hydrologic Hazard therefore includes forest cover ECA effects, sub-basin drainage characteristics and channel sensitivity rolled up into a single hazard reflecting the potential for channel change, and is an expression of expectations regarding peak flows and sediment delivery at the drainage outlet.

2.4 ELEMENTS AT RISK

Watershed elements potentially at risk from the hydrological effects of MPB infestation and salvage harvesting are:

- Water quality and water intake infrastructure, primarily at the District of Peachland (DoP) water intake.
- Water supply (quantity) at the DoP intake.
- Fish populations and habitat
- Social infrastructure (infrastructure not related to municipal water supply)

2.4.1 Water quality and water intake infrastructure

The water quality element at risk can be expressed as "a sufficient and reliable supply of safe and aesthetically acceptable water" (MoH, 2005), at the District of Peachland (DoP) intake on Trepanier Creek. As well, potential damage and increased maintenance costs to the DoP intake are considered.

Table 1 shows the various parameters identified by Ministry of Health (MoH) and Ministry of Environment (MoE) stakeholders that, if compromised, could reduce drinking water aesthetic appeal, increase the risk of microbiological activity and impact on human health, and decrease the effectiveness of primary disinfection treatment.

The potential link to MPB and/or salvage effects is evaluated for each parameter, which is judged to be weakly linked, moderately linked, or strongly linked; and the rationale is provided as follows.

Trepanier Creek receives runoff from the now closed open-pit molybdenum Brenda Mine site through MacDonald Creek tributary. Metals, primarily copper and molybdenum from that source are managed under permit from B.C. Ministry of Environment. Molybdenum is the primary concern. The long term legacy of the mine site is that for the next 50 to 200 years, approximately 3.1 million litres of effluent from the mine per year will have to be treated prior to release into Trepanier Creek, to meet the water quality objectives of 0.05mg/l and 0.01mg/l molybdenum during the May to September irrigation season. Since 1998, a flocculation-sedimentation water treatment plant has reduced molybdenum concentrations in downstream receiving waters to between 0.005 to 0.015mg/l, as measured between 1999 and 2003 (Patterson 2004).

Other water quality parameters values in Trepanier Creek discussed below, including turbidity, temperature, pathogens, true colour and nitrate/nitrite are known from limited testing between 1996 and 1999 (MoE, 2008).

Table 1. Water quality and water supply infrastructure parameters

Element at Risk	Effects of Concern	Specific Parameter	Metric	Parameter or Watershed Sensitivity
Drinking Water Quality	Reduced aesthetic appeal and increased risk of microbiological activity. Decreased effectiveness of primary disinfection treatment	**FINE SEDIMENT** (Turbidity)	NTU	In Trepanier Creek source waters, turbidity (fine sediment) is being somewhat elevated during the freshet period and low during the rest of the year. The watershed is considered somewhat sensitive to disturbances that will increase fine sediment concentrations in source waters.
		FINE SEDIMENT (Total Suspended Solids)	concentration, mg/L	
		Temperature	^{o}C	Loss of riparian forest shade can result in increased stream temperatures. MPB effects are limited because there is less pine in riparian areas. Salvage will remove forest shade if riparian zone is harvested. With good riparian retention, salvage effects will be limited.
	Reduced aesthetic appeal and human health effects	True Colour	True Colour Units	Trepanier TCU regularly exceed water quality standards. Concentrations of metals in runoff from the closed Brenda Mine are managed under permit from BC Ministry of Environment. Little published evidence to link changes in these water quality parameters to MPB infestation or salvage harvesting.
		Total Organic Carbon	concentration, mg/L	
		Metals (select)	concentration, mg/L	
	Reduced aesthetic appeal and increased risk of microbiological activity	Total Phosphorous	concentration, mg/L	
		Nitrate & Nitrite	concentration, mg/L	Difficult to generalize effects on nitrogen cycle due to complexity. However, increased concentrations of dissolved inorganic nitrogen (nitrates and ammonium) are typical. Trepanier Creek nitrogen levels are low.
		Aquatic Flora (algae)	mg per m^2	Difficult to generalize due to complex interaction between canopy closure, stream temperature, nutrient concentrations, and sedimentation.
	Human health (waterbourne pathogens)	Microbiological Indicators	Fecal coliform, E. Coli bacteria	MPB infestation and salvage harvesting could have an indirect effect on microbiological indicators associated if there are changes in range use and recreational activities associated with salvage harvesting access. Microbial levels in Trepanier Creek are seasonally (May to September) elevated.
Water Supply Infrastructure	Treatment infrastructure damage	**COARSE SEDIMENT**	cubic metres	In Trepanier Creek, most sediment is mobilized from bed and bank erosion in the channel, so any sediment mobilized can be transferred downstream to intake and other values. Watershed is sensitive to disturbances that will increase coarse sediment production.

(blue)	Parameter not strongly linked to MPB effects, or lack of data to infer trends
(light cyan)	Parameter with some link to MPB effects; can infer potential trends
(white)	Parameter linked to MPB effects; partial risk analysis completed

Parameters weakly linked to MPB and salvage harvest effects
For True Colour, total organic carbon, metals, and total phosphorus there is no published evidence to link changes water quality to MPB infestation and mortality. In general, these parameters are watershed specific and are dependant upon the physical watershed characteristics (i.e. presence of wetlands, organic soils, geological and mineralogical conditions) as opposed to watershed process. Total phosphorous levels, where they might be linked to other potentially-harmful algae conditions in the watersheds, are unknown and the link to MPB and/or salvage effects is potentially complex and unknown.

Due to the presence and on-going treatment of discharge from the Brenda Mine into Trepanier Creek, there is a fair amount of water quality monitoring data that includes metals concentration. Metals and other above-listed parameter concentrations are weakly linked to MPB and salvage-related processes, particularly when riparian management is adequate; and they are not considered further in this study.

Parameters with some link to MPB and salvage harvest effects
The following parameters are considered to be moderately linked to MPB and/or salvage harvesting effects. There may be some information on particular levels in Trepanier Creek so that potential post-MPB and salvage trends may be inferred, although not with a high degree of certainty:

Temperature
In Trepanier Creek, MOE (2008) monitoring indicates that maximum temperatures at the community water intake generally meet the aquatic life water quality guidelines and are not considered to be a concern.

Although the loss of riparian forest shade can result in increased stream temperatures, as discussed in Section 2.3, loss of riparian cover due to MPB is not considered a major issue as the component of pine in wetter riparian zones tends to be less than elsewhere across the landscape.

The potential temperature effects of salvage harvesting will depend on appropriate riparian management strategies. Our understanding is licensees intend to maintain reserves zones and management zones along all major streams. Small headwater streams in cut blocks may still be vulnerable to temperature effects, depending on stand composition and riparian management.

MOE (2008) monitoring indicates that maximum temperatures at the DoP community water intake rarely exceed the drinking water guidelines maximum level of 15^{o} C. Dobson (2006) noted that during years with low flows and above seasonal air temperatures, water temperatures would likely exceed this level on occasion. While it is expected any change in Trepanier Creek stream water temperatures due to MPB and salvage will be small, any change would be an increase in temperatures already expected to periodically exceed maximum acceptable levels.

Nitrate/Nitrite

Limited source water monitoring from 1997 to 1999 found nitrate/nitrite concentrations in Trepanier Creek were well below guidelines established for the protection of drinking water and aquatic life in surface waters (MoE, 2008).

Following both MPB and salvage harvesting increased concentrations of dissolved inorganic nitrogen (nitrates and ammonium) could occur. While elevated stream water nitrate concentrations have been measured following MPB infestation, levels did not exceed drinking water standards (Stednick, 2007). The complexity and interactions of the terrestrial and aquatic nitrogen cycle makes it difficult to predict MPB infestation or salvage harvest effects with any degree of certainty; however, it is expected any change in nitrite/nitrate concentrations will be small and will not result in any significant increase above drinking water source standards.

Aquatic Flora (Algae)

MPB and salvage harvesting can affect the interrelated processes which can influence the abundance of aquatic flora in lakes and streams. These include changes in riparian canopy, stream temperature, nutrient concentration, and sedimentation rates. However, the complex interaction of these processes makes it difficult to predict how forest cover changes could affect algae growth in the watershed.

Neither chlorophyll *a*, nor periphytic algae, were measured as part of the 1996-1999 Trepanier Creek water quality monitoring program, nor is it considered necessary due to the lack of reservoirs in the watershed.

Microbiological Indicators

Elevated concentrations of fecal coliform and *E. coli* at the municipal intake on Trepanier Creek occur most frequently between May and September (during July-August); a time of year when livestock grazing on Crown range land seek out shade and water in riparian areas (MoE, 2008). The results suggest that elevated concentrations of microbiological indicators are common in Trepanier Creek.

MPB infestation and salvage harvesting are not expected to have a significant direct effect on fecal coliform and *E. Coli* levels in Trepanier Creek. However, changes in access due to a larger forest road network associated with salvage harvesting could have an indirect effect. For example, inadequate sanitary waste management by recreational users and the presence of livestock in stream channels or riparian corridors could contribute to elevated levels of coliform bacteria. Since activities are typically dispersed throughout the watershed and soils act as an effective filtration medium, water contamination may be mitigated through the use of suitable riparian buffers.

Given the fairly widespread road access that exists in the watershed, any increase in fecal coliform and E. Coli levels in Trepanier Creek due to MPB and salvage is expected to be small. However, it will be cumulative with measured existing elevated levels.

Parameters strongly linked to MPB and salvage harvest effects

The water quality parameters most-strongly linked to MPB infestation and/or salvage harvesting are changes in fine and coarse sediment production. Increased sediment production and transport to the DoP water intake is a concern, because the changes in forest canopy affected by MPB and salvage can be similar to the effects of forest harvesting; namely, changes in riparian vegetation, increased magnitude and frequency of peak flows (floods), and sediment production from landslides, surface erosion and stream channel bank and bed sediment mobilization.

Fine Sediment

Increased fine sediment production and transport to the water intake is a concern, because suspended sediment concentrations, measured as turbidity and total suspended sediment (or non-filterable residue) can act as a vector for pathogens that can affect human health, decrease primary disinfection treatment effectiveness, and decrease the aesthetic quality of water, placing additional stress on water treatment facilities.

Turbidity measurements in Trepanier Creek source waters near the DoP water intake showed that during the April to June freshet period the mean turbidity value was 35.4 NTU (MoE, 2008) exceeding the 1 NTU treatment standard set by Interior Health Authority. Turbidity in Trepanier Creek is a concern which will require considerable expense to address.

DoP is exploring a water supply and treatment option in which Peachland Creek supplies most of the districts water needs, and Trepanier Creek would eventually be abandoned as a drinking water source, and would only be used as an emergency supply (Urban Systems, 2007). One of the main reasons for increased reliance on Peachland Creek is that more advanced water treatment will be required to meet IHA 4-3-2-1-0 treatment standards, and this would allow the entire district to be serviced by one water treatment plant at the Peachland Creek source. The total cost of the above plan is estimated to be $55.4 M.

While the abandonment of Trepanier Creek as a municipal drinking water source would decrease the consequence and risk of fine sediment contamination, in the short term this transition to Peachland Creek has not been completed and Trepanier Creek is still part of the municipal water supply. Therefore in this study Trepanier Creek is considered sensitive to disturbances that will increase fine sediment concentrations in source waters.

Coarse Sediment

Coarse sediment production, measured as bed load, can disrupt or damage water intake infrastructure. We are not aware of any bed load measurements in Trepanier Creek near the DoP intake. As discussed in Section 2.3, most sediment is generated from channel bed and bank erosion during high flows. That is, any sediment mobilized is already in the channel and can be transported downstream, eventually to the community water intake and other values. Therefore, the watershed is considered sensitive to disturbances that will increase coarse sediment production.

Water Quality Risk Analysis Procedure

A complete risk analysis would consider not only the stream flow and sediment hazards, but also how vulnerable the entire water delivery system could be to sediment impacts, by looking at all the water supply system protection barriers from source to tap, including intake configuration, treatment processes, storage and distribution components, system maintenance, water quality monitoring, operator training, and emergency response planning.

Interior Health Authority B.C. requested we do not evaluate the robustness or vulnerability of the District of Peachland water intake or treatment facilities; rather that we look only at any incremental hazards due to MPB and salvage harvesting that could affect source water quality, supply and infrastructure integrity (Dale Thomas, *pers. comm*.). The source water quality findings of this investigation can be used as input to a more comprehensive "Source to Tap Risk Assessment" that water purveyors are required to complete (MoH, 2005).

Studies that determine potential hazards and identify the elements at risk from those hazards, but do not evaluate their vulnerability, are known as partial risk analyses (Wise, *et al.*, 2004). In this analysis the partial risk will be equal to the MPB-related hazardous conditions that could compromise water quality at the DoP intake, which are discussed in Section 3 of this report.

2.4.2 Water Supply

In the South Okanagan risks to water supplies come from changes in climate and watershed conditions that could compromise the ability to meet agricultural and domestic demands during the growing season, when there are large natural moisture deficits. MPB attacked stands lose some canopy function, or are salvage clearcut harvested, in which case 100% of the canopy is removed. Therefore snowmelt accumulation and melt effects similar to harvesting are expected in MPB and salvaged stands. These include changes in low flow discharge and in freshet runoff timing.

2.4.3 Fish

Rainbow trout (Oncorhynchus mykiss) are known to inhabit many parts of the Trepanier Creek watershed and Kokanee (Oncorhynchus nerka) have been identified in the lowest reach of Trepanier Creek. In a previous assessment, a Burbot (Lota lota) was also captured in the lower reach (Taylor and Wightman 1978). A series of cascades and a waterfall approximately 1km upstream from Okanagan Lake is considered a permanent barrier to upstream fish migration.

From a review of available published fish inventories and habitat assessments, stream reaches were assigned a consequence rating based on fish species presence, importance and fish habitat quality (Table 2).

Table 2. Stream reach fish consequence value criteria

Consequence Rating	Criteria			
	Fish Species Present	Channel Width (m)	Channel Gradient (%)	Habitat Quality
Very Low	fish absence	<1.5	>20%	fish absence confirmed, minimal fish habitat available, habitat degradation low risk to fish
Low	presence of RB	0-5	16% - 19%	fish absence confirmed and/or habitat with low rearing potential for the fish species present
Moderate	presence of RB, EB	0-5	8% to 15%	habitat quality low to moderate
High	presence of RB, EB, MW	0-20	0% to 8%	fish presence confirmed, habitat quality moderate to high
Very High	presence of RB, EB, BT, KO, MW	0-20	0% to 8%	fish presence confirmed, habitat quality high

Impacts to fish and fish habitat following changes in forest cover due to MPB and salvage harvesting are likely to be similar to forest harvesting effects. These include loss of riparian vegetation which can affect fish shelter, stream temperature, nutrient availability and large woody debris recruitment to streams. Increased peak flows and sediment can alter channel morphology, resulting in degraded spawning, rearing and over-wintering habitat. For each Trepanier Creek and tributary reach, hydrologic hazards (see Section 3) are combined with the consequence values for each reach (see Appendix C), and for cumulative downstream reaches, using a standard risk matrix (Appendix A).

There have been fish conservation flow concerns in Trepanier Creek during the summer low flow period in the past. Summit (2004) notes that " When current water usage is factored in (net flow), most of the streams experience flow deficits relative to the proposed conservation flows during some low-flow months under average climate conditions, and during nearly all low-flow months under 1-in-5 year dry conditions. Dobson (2006) notes that "Preliminary results to date indicate that even with the relocation of the DoP point of diversion [from Trepanier Creek], and supplementing flows with discharges from Brenda Mine, water extractions and other losses (infiltration) reduce the useable [fish] habitat in the lower reaches to 20-35% of its potential.

From a fish conservation perspective Trepanier Creek is considered sensitive to watershed disturbances that could reduce summer low flows.

2.4.4 Social Infrastructure

Social infrastructure refers to structures other than the DoP water supply infrastructure. In Trepanier Creek this includes numerous licensed water intakes and public, forestry and private road crossings of stream mainstems and tributaries. Highways 97 and 97C cross Trepanier Creek near the mouth, and there has been some residential development on the fan. Drainage and water treatment infrastructure also exists within the Brenda Mine site. Pipes and ditchlines have been installed to divert drainage around the mine site and keep separate clean and contaminated runoff. These constructed features will have a design limit and may be susceptible to increased volumes following MPB mortality and/or salvage harvesting.

For each of the elements present, a qualitative vulnerability or consequence rating was determined. This was combined with the hydrologic hazard in a risk matrix (Appendix A) to determine the qualitative incremental risk from increased flooding and sediment movement due to MPB and salvage logging.

3.0 WATERSHED CONDITIONS AND HAZARDS

3.1 WATERSHED CONDITION

3.1.1 Physiography, geology and terrain

The Trepanier Creek Community watershed drains portions of the Thompson Plateau into Okanagan Lake on the west side of the valley near Peachland, BC. The watershed encompasses an area of approximately 255 km^2 ranging in elevation from 342m at Okanagan Lake to a maximum of 1900m at the summit of Mount Gottfriedsen. Major tributaries to Trepanier are Jack Creek, MacDonald Creek, and Lacoma Creek. Smaller tributaries include Law Creek, Venner Creek, Pigeon Creek, Silver Creek and Clover Creek. Law Creek, Jack Creek and Pigeon Creek were not considered in this analysis as they join Trepanier Creek downstream of the DoP intake.

Silver Lake forms the headwaters of Silver Creek. Lake Lacoma is a small lake on Lacoma Creek between 900 and 1000m elevation. There are other smaller lakes and wetlands in the watershed, mostly on the upper plateau. While the storage provided by these waterbodies may help to sustain late season flows in Trepanier Creek, they are too small to provide significant peak flow attenuation during the freshet.

There are several small lakes in upper MacDonald Creek sub-basin as well as the Brenda Mines open pit (now used for mine effluent storage) and a large tailings pond. The pit and tailings pond are essentially isolated from the surrounding drainage system. Clean runoff upslope of the mine is diverted around the pit and tailings through a network of diversion ditches and pipelines into MacDonald Creek. Treated effluent from the tailings pond is currently released into MacDonald Creek.

Table 3. Trepanier Creek Watershed and sub-basin areas

Sub-basin Name	Sub-basin Area (ha)	Total Tributary Area (ha)	Elevation Range (m)	Reservoirs (area, elevation)
Upper Lacoma	3363	3363	950 – 1800m	None
Lower Lacoma	1438	4801	800 – 1900m	Lake Lacoma (5 ha, 950m)
Upper Trepanier	3579	8616	800 – 1900m	None
MacDonald Creek	3610	3610	780 – 1860m	George Lake (1.8 ha,1598m) Long Lake (4.6 ha, 1622m) MacDonald Lake (6.1 ha, 1738m)
Trepanier Residual	6456	18446	576 – 1560m	Silver Lake (11.9 ha, 1054m)
Total Trepanier Watershed (above DoP intake)	18446	184446	576 – 1900m	All of the above.

Bedrock is mapped mostly as Mesozoic granodioritic intrusives granitic rocks which commonly weather to coarse grained soils. Bedrock in the lower watershed (below the Jack Creek confluence) is predominantly Cenozoic volcanics of the Penticton Group (Land and Resource Data Warehouse).

Most of the Trepanier Creek watershed is dominated by a rolling, flat (<7%) to gentle (7 to 30%) sloping glaciated upland plateau between elevations of 1200 and 1800m, typical of the Okanagan Highlands Physiographic Region (Photo 1). Soils in the plateau areas of the watershed are typically moderately coarse to coarse-textured, moderately well-drained morainal material with some colluvium on steeper slopes (Kowall, 1986). Drainage density of streams on the plateau is low due to the relatively gentle terrain and adequate soil drainage. Some fluvial and glaciofluvial deposits occur along the valley bottoms.

Upland plateau tributaries are generally weakly incised and have relatively low gradients. Incision increases as the tributaries accumulate into mainstem channels. Three tributaries from the northeast side of Trepanier Creek in the Trepanier Residual (Figure 1), including Clover Creek, are moderately incised into the plateau and valley side. Lacoma Creek and Upper Trepanier Creek have formed well-incised valleys with moderately steep (50 to 70%) to steep (>70%) gradient side slopes (Photo 2). Along both creeks there are some exposed talus slopes on the lower valley walls. Some gullying and possible landslide activity is evident along steeper sections. Portions of Trepanier Creek and lower Lacoma Creek are partly disconnected from the hillslopes by areas of floodplain and/or glacio-fluvial terraces along the channel.

Few forestry road-related failures and/or sediment sources were noted in the previous sediment source survey (Dobson 1998). Forestry roads are mostly located in the upper plateau areas of the watershed, on gently sloping terrain away from mainstem channels. In the areas affected by forest development, no recent significant slope failures or erosion sites were noted during the watershed overflight or the ground based assessments in 2008.

A landslide occurred in the McDonald Creek sub-basin below Highway 97C in 1998 as a result of redirected runoff from the Brenda Mines site (Dobson 1998). It is apparent from the large scour in erodible sand and grave glaciofluvial sediments (Photo 3) and from 1998 photos that lower MacDonald Creek has been severely disturbed and the failure was a significant source of both fine and coarse sediment to the Trepanier Creek mainstem. Increased turbidity was noted all the way down to Okanagan Lake (WAC minutes 1998). Trepanier Creek immediately downstream of the failure site was observed in 2008 to be aggraded, and some material from the failure may still be moving downstream through the system. Sand deposits were observed in Trepanier Creek Reach 4, 10km downstream of MacDonald Creek, in an otherwise cobble bed channel (Photo 4).

Downstream of the MacDonald and Lacoma Creek confluences, Trepanier Creek follows a relatively broad-bottomed valley filled through fluvial and glacio-fluvial sediments. The current channel is ‘underfit’, flowing over materials deposited by larger streams during deglaciation. Downstream to the DoP intake the channel is more frequently confined by colluvial valley walls which are directly connected to the channel. Downstream of the Highway 97C crossing, the channel becomes more incised, eventually entering a bedrock controlled canyon. Approximately 1 km from Okanagan Lake, the canyon opens onto an alluvial fan. The channel on the fan has been confined to a narrow corridor by residential development (Photo 5).

3.1.2 Channel conditions and bank stability

Existing channel conditions in the Trepanier Creek watershed derived from field and office reviews are described in Table 4. Channel conditions are summarized by sub-basin although some issues may only apply to specific reaches within that sub-basin. Listed channel morphology types represent the predominant morphology of the mainstem channel within that sub-basin (Hogan 1997). Although erosion, transport and deposition typically occur everywhere in a channel system, the sediment regime descriptor provided in Table 4 gives an indication of the dominant sediment process for the mainstem channel in the sub-basin, whether it is overall a source area, a transport or a depositional zone.

In Upper Trepanier Creek sub-basin, the mainstem channel just above the Lacoma confluence was found to exhibit a stable riffle-pool morphology with moss covered bed materials and stable banks (Dobson 1998). Upstream in the sub-basin the channel is confined between talus deposits, and no channel is visible on aerial photography through a section of talus above a small lake on the mainstem (1130m elevation), indicating it may be flowing subsurface through the coarse deposits. There is little evidence of sediment accumulating in the small lake and sediment transfer is likely negligible through the large talus. Bank stability and sediment input and transfer are of low concern in this sub-basin. Riparian vegetation is discontinuous but undisturbed, along the mainstem as the valley bottom is not accessed for logging. Few tributaries are visible and/or mapped in the sub-basin indicating a low drainage density. The likelihood of discernible change at the DoP intake as a result of the disturbances in this sub-basin is Very Low.

Upper Lacoma Creek sub-basin is quite similar to Upper Trepanier Creek sub-basin. They are deeply incised into a broad gently sloping upland plateau with moderately steep to steep valley sidewalls, which are the source of numerous talus deposits directly connected to mainstem channels (see Photo 2). In some areas the channel may flow subsurface beneath coarse talus and sediment transfer is likely negligible. There is a small wetland complex and lake on the main channel at 1030m elevation, and Lacoma Lake defines the lower end of this sub-basin (Figure 1). There is little evidence of recent sediment collecting in these lakes. Bank stability and sediment input and transfer are of low concern in this sub-basin. The canyon of Trepanier Creek through the upper and lower Lacoma basins is protected by Trepanier Provincial Park (established in 2001) and there is no road access to the mainstem in this area.

Few tributaries are visible and/or mapped in these sub-basins, indicating a low drainage density. The likelihood of discernible change at the DoP intake as a result of the disturbances in this sub-basin is Very Low.

In the Lower Lacoma sub-basin the creek is protected from sediment entering from upstream by Lacoma Lake. Stable moss covered lag boulders and well-developed stone lines were observed in a previous assessment (Dobson 1998). The mainstem channel appears predominantly stable with occasional minor bank erosion. Talus inputs along the middle section are likely coarse-grained and minimal sediment transfer through the sub-basin is expected. Riparian areas appear intact and the mainstem channel in this sub-basin is protected by the Provincial Park. A similar low drainage density exists in this sub-basin with only one tributary has been mapped.

Drainage in the MacDonald Creek sub-basin has been significantly altered by the Brenda Mines development. A substantial portion of the sub-basin was cleared for the mine, including the development of a large tailings storage area (Photo 6). Since the pit was closed in 1990, it has also been used to store contaminated water. Treated water from the tailings pond is released into MacDonald Creek (see Section 2.4.1). Surface runoff above the pit, including drainage from several small lakes on the plateau, is diverted around the mine site and directed into MacDonald Creek below the tailings pond. It is not clear to what extent these changes have affected the runoff regime in the sub-basin.

Lower MacDonald Creek is moderately aggraded due to the mine-related slope failure below Highway 97C and the associated debris transported down the channel. Near its confluence with Trepanier Creek the channel is essentially an alluvial fan, with multiple channels flowing over cobble and gravel deposits previously transported down MacDonald Creek. Some finer sediment generated in MacDonald Creek may find its way to the DoP intake.

The Trepanier Creek mainstem channel downstream of MacDonald Creek is less confined than its tributaries, and is partly disconnected from the neighbouring hillslopes by a floodplain and/or glacio-fluvial terraces. Some aggradation, elevated bar surfaces, sand deposits and localized widening has been observed downstream of the MacDonald Creek confluence (Dobson 1998). Cobble/gravel deposits observed upstream of larger debris jams indicate significant bedload in the channel (Photo 7). There are occasional confined colluvial or bedrock sections through the sub-basin. Sediment is passed through the sub-basin with no lakes, wetlands or obvious gradient breaks. Riparian is mostly intact above the DoP intake with a mix of conifers and deciduous. Overall the sub-basin has a low drainage density.

Downstream of the DoP intake the channel is disconnected from the valley sides as it flows across relatively flat valley fill. Some localized bank erosion and evidence of high water were observed near the confluence with Jack Creek. Coarse sand deposits were noted in pools and eddies throughout this section, possibly an artefact of the MacDonald Creek failure. The channel is continuous cobble riffle (few pools) with lag boulders and minimal woody debris function (Photo 8). Downstream of Highway 97C, the channel moves to the south side of the valley and enters a bedrock canyon (Photo 9). Approximately 1 km from the lake it flows onto an alluvial fan supporting extensive residential development (see Photo 5). The creek has been straightened/channelized in the past and some bank protection has been installed. Riparian vegetation on the fan has been reduced to a single row of deciduous trees in some areas, and no substantial vegetation in others. Human activity and development on the fan has obscured evidence of channel change or long term stability.

Forest cover disturbances in the drainage areas below the District intake were not analysed. However any increases in stream flows and sediment from upstream of the DoP intake will be passed on to the lower reaches. Potential impacts in this section are included in the discussion below.

Table 4. Channel Characteristics and Conditions

Sub-basin Name	Reaches	Mainstem Channel Length (km)	Average Gradient (m/m)	Dominant Morphology Type*	Sediment Regime	Sub-basin/Channel Characteristics
Upper Lacoma	*2,3,4,5*	*8.5*	*0.07*	*SPc/b,CPc/b*	*Source*	Originating on high plateau, channel enters long confined section with steep-sided valley walls. Frequent talus slopes connected to channel. Small wetland complex on main channel at 1030m elevation. Robust channel type with coarse textured substrates. Low drainage density with few tributaries. Riparian protected by Provincial Park.
Lower Lacoma	*1*	*4.8*	*0.04*	*CPc, RPc/g*	*Source*	Sediment transfer controlled upstream by Lacoma Lake. Moss covered lag boulders and well-developed stone lines. Some low gradient sections. Channel predominantly stable with occasional minor bank erosion and sand deposits. Talus inputs along middle section. Riparian intact, mostly deciduous. Minimal LWD function. Low drainage density with only one mapped tributary.
Upper Trepanier	*9,10,11,12*	*8.5*	*0.05*	*CPc, RPc/g*	*Source*	Channel confined between talus deposits. Small lake on main channel at 1130m elevation, steep channel section upstream to plateau. Moss covered lag boulders. Gradient decreases from 20% below plateau to less than 2% near Lacoma confluence. Riparian intact and not accessed for logging. Low drainage density, few tributaries.
MacDonald	*1,2,3,4, 5,6,7,8*	*3.8*	*0.11*	*SPc/b*	*Source*	Sub-basin drainage significantly altered by Brenda Mines development including water filled pit and large tailings pond. Several small lakes on plateau. Moderately aggraded due to slope failure near Highway and associated debris movement down channel. Lower section is an unstable alluvial fan, with multiple channels over cobble/gravel deposits. Low drainage density.
Trepanier Residual	*5,6,7,8*	*18.2*	*0.02*	*RPb/c/g*	*Transport*	Less confined channel partly disconnected from hillslopes by valley fill. Moderate aggradation, elevated bar surfaces, sand deposits and some localized widening downstream of MacDonald confluence. LWD function limited to occasional span log and large debris jam. Cobble/gravel deposits upstream of larger debris jams indicate significant bedload. Frequent lag boulders, some mossy. Occasional bedrock control. Intact riparian of mixed conifers and deciduous. Low drainage density.
Trepanier below DoP intake	*1,2,3,4*	*7.0*	*.03*	*RPc/g/r*	*Transport*	Continuous cobble riffle with lag boulders and minimal woody debris function. Lengthy bedrock-controlled section. Relatively small fan at the mouth. Riparian reduced by residential development in some areas. Low drainage density.

*CP = cascade-pool; RP = riffle-pool; c=cobble, g=gravel, b=boulder

3.1.3 Channel Sensitivity

Using the assessment framework outlined in Table C1 Appendix C, channel sensitivities for the Trepanier Creek watershed are summarized in Table 5. Sensitivity to changes in peak flows, sediment regime and riparian condition are considered separately. Since changes in flow and sediment regime are considered the most likely impacts to occur following MPB and salvage harvesting, a combined sensitivity rating to peak flow and sediment is assigned to each sub-basin. For the purposes of this assessment, assigned ratings generally represent the sensitivity of the mainstem channel in that sub-basin. Potential outputs associated with potential channel changes are included in Table 5 to provide an indication of issues that may arise if changes to flow/sediment regimes were to occur.

Sensitivities of natural channels to increased peak flows in the Trepanier Creek watershed were considered to be low in previous assessments (Dobson 1998). We concur that mainstem channels in Upper Lacoma, Lower Lacoma and Upper Trepanier are robust and would not be sensitive to minor changes in flow and/or sediment regimes. Channels are generally stable with erosion resistant banks and coarse textured substrates with frequent lag boulders. Lacoma and Upper Trepanier Creeks are dominated by over-sized talus deposits, at times forcing the channel subsurface. Sediment transfer is restricted and significant movements of the large and coarse material are unlikely in these areas.

Channel widening and significant debris mobilization and deposition has occurred in MacDonald Creek and the channel remains somewhat sensitive to avulsion, particularly through the alluvial fan at the MacDonald/Trepanier confluence, where increased peak flows would mobilize sediment which would be a source of coarse sediment (bedload) to lower Trepanier Creek. Below the MacDonald Creek confluence Trepanier Creek has been affected by the influx of material and will continue to adjust. While naturally robust the Trepanier Creek mainstem below MacDonald Creek is somewhat aggraded and there is little opportunity for sediment capture/storage downstream to the DoP intake. For these reasons, a moderate sensitivity to peak flow changes and sediment input has been assigned to mainstem stream reaches in MacDonald Creek and the Trepanier Residual sub-basin above the DoP intake.

Riparian vegetation appears to be mostly intact along mainstem channels in the Trepanier watershed as few mainstem reaches are accessible by road. Much of Lacoma Creek is protected by Trepanier Provincial Park. A significant component of the riparian vegetation in the watershed is deciduous; therefore riparian conditions are not expected to change significantly with the invasion of MPB. Good riparian retention during salvage harvesting along tributaries in upland plateau areas will be required to ensure there are no negative impacts to channels due to loss of riparian vegetation.

Table 5: Channel Sensitivity

Sub-basin Name	To Increased Peak Flow	Comments/ Rationale	To Increased Sediment Delivery	Comments/ Rationale	To Decreased Riparian Function	Comments/ Rationale	Combined Channel Sensitivity	Potential Outputs Associated with Channel Change
Upper Lacoma	L	Stable, relatively steep channel with coarse substrates. Banks comprised of oversized colluvial deposits.	L	Little opportunity for deposition and/or storage until Lacoma Lake. Some ability to move sediment.	L	Predominantly coarse bank materials and deciduous riparian.	**L**	Cumulative effects limited near headwaters. No changes anticipated.
Lower Lacoma	L	Stable coarse textured substrates, well-vegetated banks, not subject to frequent flooding/bedload movement.	L	Some in-channel storage capacity for sediment, however most material will pass through.	L	Instream LWD plays a minor role in channel stability and controlling sediment transfer.	L	Increased mobilization of coarse sediment.
Upper Trepanier	L	Stable channel with coarse substrates. Some banks comprised of oversized colluvial deposits.	M	Little opportunity for deposition/sediment storage. Could become aggraded at lower end.	L	Instream LWD plays a minor role in channel stability and controlling sediment transfer.	L	Increased mobilization of coarse sediment. Channel may aggrade near confluence with Lacoma Creek.
MacDonald	*M*	Channel has been impacted by debris flow/flood resulting in broad aggraded sections and multiple channels at lower end.	M	Channel has little remaining storage capacity, additional sediment will cause further aggradation and avulsion.	M	Migration/avulsion of aggraded channel could be accelerated if riparian vegetation is removed or banks destabilized.	M	Additional fine and coarse textured sediment. Potential channel avulsion on alluvial fan near confluence with Trepanier Creek.
Trepanier Residual	*M*	Aggraded with coarse textured substrates with stable banks and functioning LWD. Minor floodplain. Some inherent capacity to withstand higher flows.	M	Banks erosion resistant and frequently decoupled from valley slopes. Bedload accumulations behind debris jams.	M	Instream LWD plays a role in channel stability and controlling sediment transfer.	M	Increased coarse sediment and/or bedload. *If widened fine texture sediment from colluvial and glaciofluvial bank erosion.*
Trepainer below DoP intake	L	Stable coarse textured substrates. Some bedrock controls.	M	Frequent coarse sand deposits noted in channel. Channel on fan near lake could aggrade.	M	Instream LWD plays a role in channel stability and controlling sediment transfer.	M	Increased coarse sediment and/or bedload. Aggradation of the channel in Reach 1 (fan).

3.2 WATERSHED HYDROLOGY

Trepanier Creek is a snow-dominated (nival) hydrologic system and peak flows occur from late April to June. Total annual precipitation is 400mm at 345m near Okanagan Lake, 650mm at 1500m elevation, and higher over the 20% of the watershed that is above 1500m. At higher elevations approximately 75% of annual precipitation falls as snow, and is largely stored until the spring freshet snowmelt. It is estimated that roughly 75% of annual runoff occurs between April and July in response to snowmelt (Summit 2004). All historic annual peak flows occur within this spring freshet period, and therefore it is almost exclusively snow melt or rain on snow that produces watershed peak discharges.

The total watershed area is approximately 255km^2 and the watershed area draining into Trepanier Creek upstream of the DoP water intake is approximately 185km^2.

3.2.1 Historic Flood Frequency

Daily discharge in Trepanier Creek has been gauged periodically (from 1919-1927 and 1960 to present) by the Water Survey of Canada at a site near the DoP (WSC #08NM041). The gauging record provides 54 annual peaks based on daily observations. Continuous recording was initiated in 1976, providing approximately 30 years of instantaneous flow data. Using the 'daily' record, annual peaks were plotted using various distributions to generate a flood frequency relationship. A Log-Pearson Type III distribution was found to exhibit the best fit and the results are graphed in Figure 5.

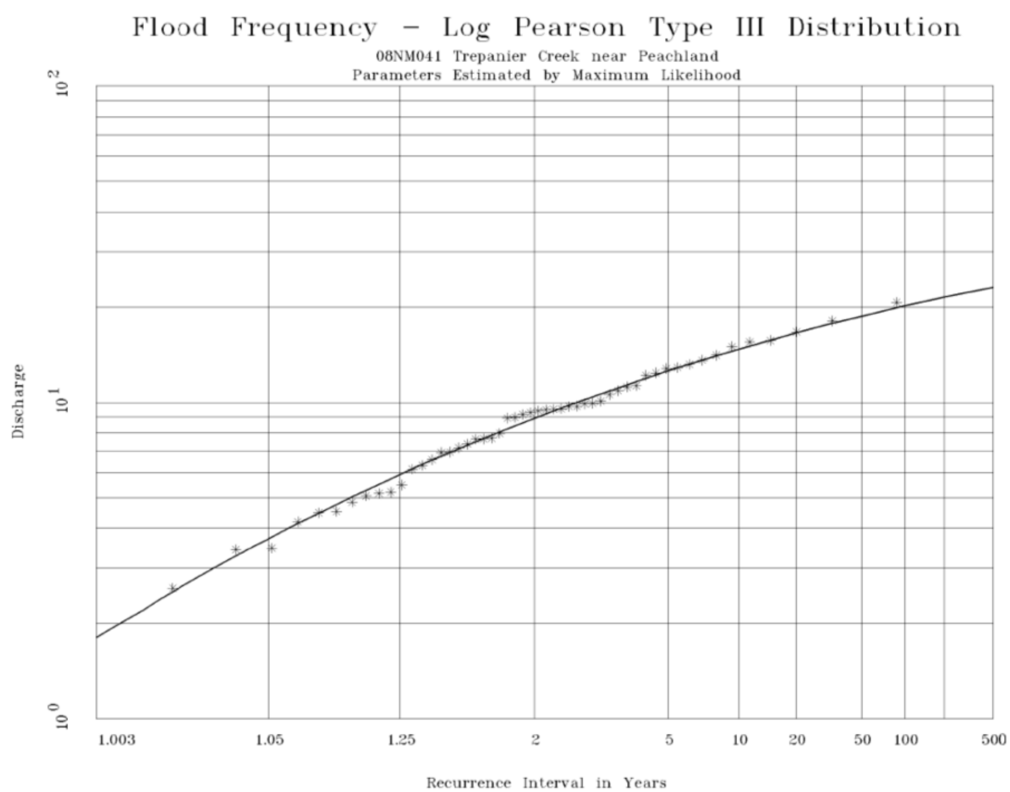


Figure 5. Trepanier Creek flood frequency near the DoP intake based on 54 Mean Annual Daily Flood Peaks (WSC # 08NM041).

There are some lakes in Trepanier Creek watershed, such as Silver, Lacoma and others (see Figure 1), which are not currently managed for storage (Dobson, 2006). Because of the small size of lakes and their location in the upper watershed they have little effect on flow attenuation, and Trepanier Creek stream flows are assumed to be uncontrolled.

3.2.2 Snow sensitive zone

It is widely accepted that for nival (snowmelt dominated) watersheds such as Trepanier Creek, it is largely the upper portion of the watershed that produces peak flows during the spring freshet melt - because snow in the lower watershed has typically melted prior to peak flows occurring in the lower mainstem (Gluns 2001; Schnorbus and Alila 2004). The H_{60} (the contour line above which 60% of watershed area is contained) is commonly used to define the watershed area that is contributing snow melt runoff at the time of peak discharge. It should be noted that the H_{60} concept was developed for graded mountain watersheds, and not watersheds with large upland plateaux, such as Trepanier Creek.

Measurements have been made of the elevation of the receding snowline at the time of peak flows in several south Okanagan watersheds (Dobson 2004a, 2004b, 2004c and 2004d). In almost all cases the contributing snow zone was less than 60%. Based on four years of observations (2001 to 2004), the position of the snow line in Peachland Creek (which is adjacent to and south of Trepanier Creek) during the freshet period was between 1350 and 1600m elevation (Dobson, 2004a).

It is reasonable to expect that, depending on snow pack and melt conditions, some variation in the contributing area will occur; and that a rapid melt when the snow line elevation is still relatively low would cause the highest peak flows. The very largest peak flows are likely caused by widespread radiation and/or other energy inputs (e.g., sensible and latent heat transfers and energy advected by rain) occurring simultaneously over a large area of the watershed. This is probably especially true in watersheds where mid and upper elevations consist of relatively low gradient plateaux, as in Trepanier Creek. In Trepanier Creek the 1375m elevation is considered the approximate lower limit of the snowmelt contributing zone to mainstem peak flows. The 1375m contour is approximately the H_{48} line for Trepanier Creek. That is, of the 185km^2 drainage area above the DPO intake, about 88km^2 (48%) will have a melting snowpack contributing to peak stream discharge during the spring freshet snowmelt. This is defined as the snow zone in this report.

3.2.3 Forest cover changes

Stand Level ECA

Figure 6 (in pocket) shows the biogeoclimatic (BEC) stand types in Trepanier Creek watershed, including Ponderosa Pine (PP), Interior Douglas Fir (IDF), Montane Spruce (MS) and Engelmann Spruce Sub-alpine fir (ESSF). MSdm and ESSF BEC variants located above the H_{48} line are coloured. These two variants comprise 67% and 31% respectively, and total over 98%, of the area of Trepanier Creek watershed in the snow zone above the H_{48} line. As discussed in Section 2, different ECA progression curves were developed for the different BEC units. Figures 7, 8 and 9 show unharvested and harvested ECA curves for three stand types above the snow line in Trepanier Creek.

As discussed in Section 2.2.2, the unsalvaged curves are based on field measurements taken for this project of secondary stand structure in Vegetation Resource Inventory (VRI) labelled pine-leading stands in seven south Okanagan watersheds (see Appendix B). The curves shown here assume full pine mortality, full understory survival and a site index (SI) of 15.

ESSF ECA curves (Figure 7) are based on 56 plots in 7 ESSFdc stands. In stands labelled as 100% pine or >80% pine, the actual measured overstory pine component averages 30.7%. The rest of the overstory was approximately equal amounts of spruce and balsam. The average understory has 1,000 well-spaced stems (>1.3m tall) per hectare (ha).

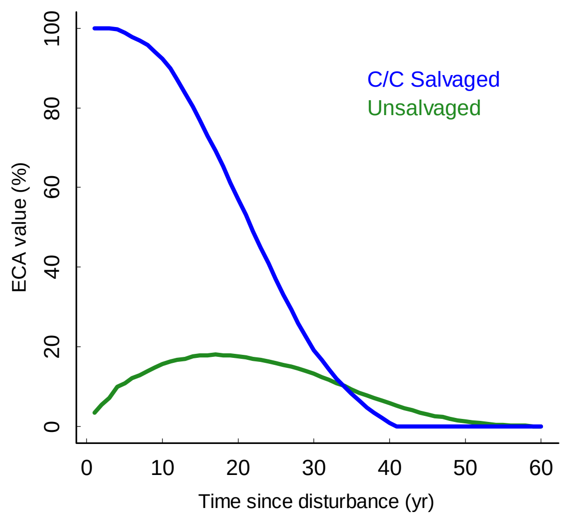


Figure 7. ECA progression in ESSF pine-leading stands.

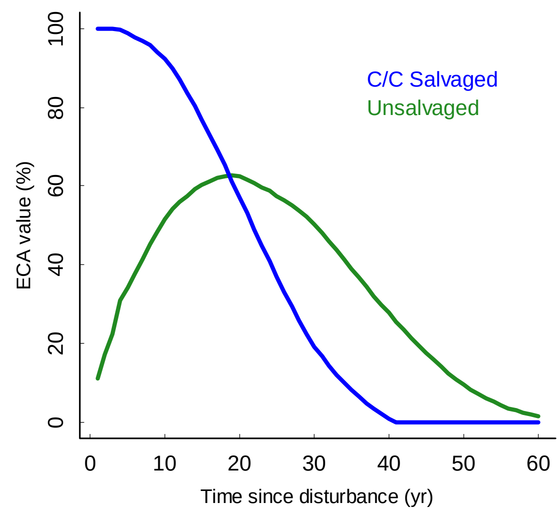


Figure 8. ECA progression in younger pine-leading MSdm stands (70 to 110 yr).

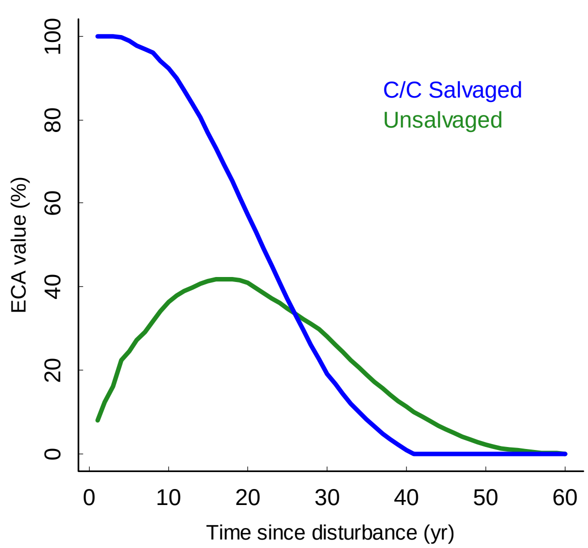


Figure 9. ECA progression in older pine-leading MSdm (> 110yrs) stands.

The younger MSdm ECA curves (Figure 8) are based on 64 plots in 8 pine-leading stands. The measured overstory pine component averages about 90%. Average understory is 280 well-spaced stems per ha (>1.3m tall) per ha. The older MSdm ECA curves (Figure 9) are based on 85 plots in 10 stands with an average overstory pine component of 74% and an average understory of 560 well-spaced understory stems >1.3m tall per ha.

Trepanier Creek Watershed ECA

Figure 6 shows the drainage area above the H_{48} line that defines the snow zone. The following discussion of Trepanier watershed ECA refers to that upper elevation area that still has some snow pack during spring freshet snow melt. Note that Trepanier Provincial Park, established in 2001, will not be harvested; but it is assumed the pine trees in it will be attacked by MPB. The park is about 29km^2 or about 16% of watershed area above the DoP intake. However most of it is located on the steeper valley sidewalls of Lacoma Creek, downslope of the plateau. Almost none of it is in the snow zone above the H_{48} line and management within the park does not affect snow zone ECA or watershed freshet peak flows.

These three stand type curves were used to generate cumulative harvested and unharvested ECA curves for the watershed area and all sub-basin areas. ECA calculations also included the existing harvesting and fire disturbances in the watershed as of December 2008, based on VRI data and information provided by major forest licensees operating in the watershed, which are held by Gorman Bros. Lumber Ltd. and Westbank First Nation.

In watershed ECA modelling, MPB attack was phased in over 5 years, and salvage harvesting followed 1 year behind the MPB. Two management scenarios were modelled as shown in Figure 10.

In the “MPB unharvested” scenario (green line) all pine trees in pine-leading stands are assumed to killed by MPB, no further forest harvesting activity takes place in the watershed and there is full survival of the measured understory. That is, all stands are retained and there is no salvage harvesting of pine-leading stands and no harvesting of non-pine green wood. In the “clearcut salvage” scenario (purple line) all pine-leading stands are clearcut harvested, with the exception of riparian zones, old growth management areas, unstable terrain and other areas designated as long-term reserves, as contained in GIS layers supplied by forest licensees. These areas are preserved, however if they are pine-leading it is presumed that the pine dies from MPB attack.

These two potential end points on the possible development continuum were chosen so that the maximum difference in hydrological effects between harvest and non-harvest options could be shown. It is not expected that forest licensees would be able to salvage harvest all non long-term reserve attacked pine; however there may be other interests in the wood, such as bio-fuel users or others we do not currently know about, who could conceivably be able to utilize more of the pine. And the authors have analysed watersheds in other areas where MPB infestation is more advanced, and where ECA values are as high as 75%, because almost all pine-leading stands in a watershed have been salvaged harvested. Showing the maximum possible hydrological effects of different management options gives forest managers information on the widest possible range of potential hydrological risks in the watershed.

Hazard ratings for different ECA levels are also shown in Figure 10. The low ECA hazard rating is based on findings that noticeable peak flow increases or peak flow effects are not generally experienced in watersheds with ECA values of 20% or less. Because of this watershed ECA is considered recovered, or a low ECA hazard, when the ECA level is 20% or less.

A moderate ECA hazard indicates that ECA (forest canopy) effects may or may not be noticeable, and if effects are noticeable, they are not expected to be large. A high ECA hazard rating indicates that significant ECA effects are likely; and a very high rating expresses an even greater certainty about the expected occurrence of very significant effects.

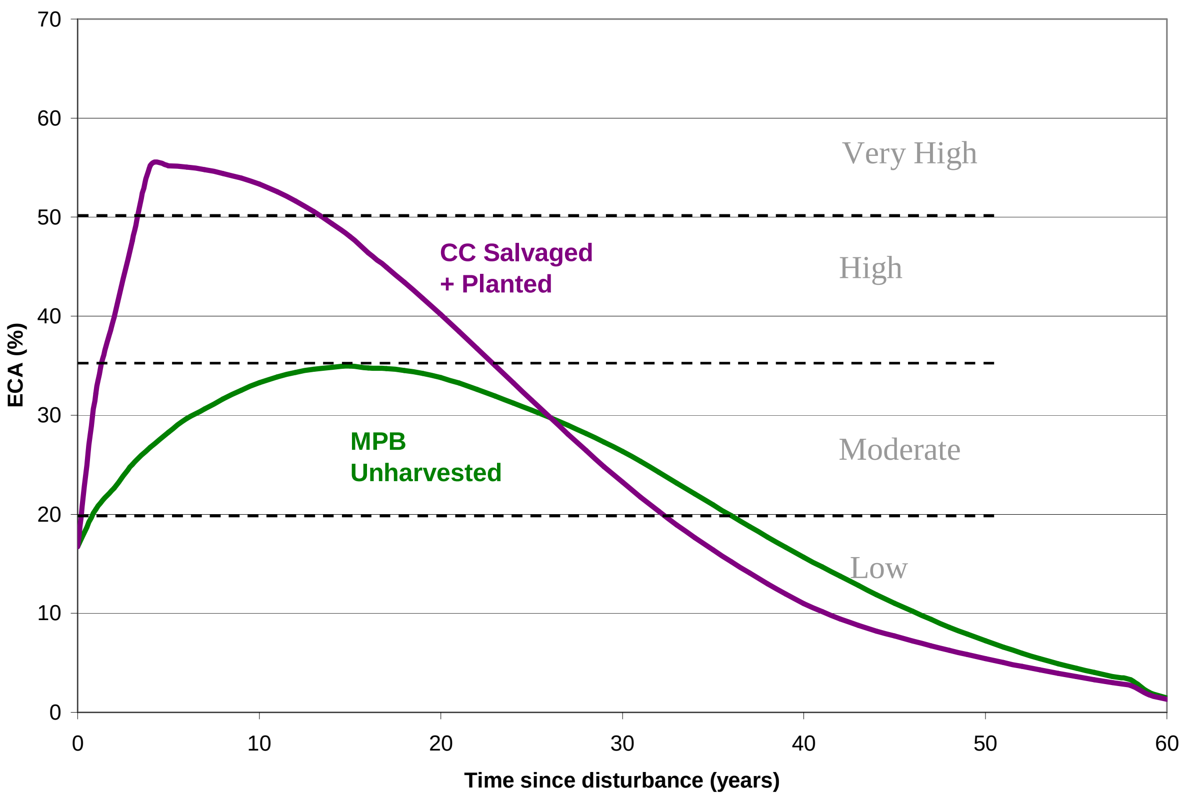


Figure 10. ECA and ECA hazard projections for Trepanier Creek Watershed above H_{48} elevation, assuming full pine mortality from MPB infestation, full understory survival and no harvest scenario (green) and full salvage harvest of all pine-leading stands scenario (purple).

In Figure 10, the sustained ECA hazard for the MPB/unharvested scenario is approximately the centre of the area under the curve above the low hazard level. The current watershed ECA is low. Following full pine mortality and no harvesting there is a Moderate ECA hazard for approximately 25 years. That is, with the overstory and understory survival assumptions made, the ECA effects of MPB mortality (and no further harvesting) there may or may not be noticeable ECA effects. Similarly, the centre of the area under the ECA curve for the hypothetical full pine-leading stand salvage scenario, relative to the MPB/unharvested curve, suggests there is a sustained a High ECA hazard for 15 to 20 years. That is, there is an incremental high hazard due to full salvage harvesting and within this time period significant ECA effects are considered likely.

In addition to these two scenarios, sensitivity analyses are carried out for a range of possible future forest recovery scenarios. These include modelling the effects of total and partial pine mortality in unharvested pine-leading stands in the watershed and of total and partial understory survival in unharvested attacked pine-leading stands. Modelling 50 to 20% less than full mortality in unharvested MPB-attacked stands decreased maximum ECA values by about 5% and watershed recovery (to 20% ECA) is about 5 years earlier. Since ECA for clearcut harvested stands did not change, the difference between retention and harvesting is greater than shown in Figure 10. As discussed in Section 2.2.2 actual total pine mortality following completion of the MPB infestation may be significantly less than 100%, but there is a great deal of uncertainty around that projection.

With only 50% understory survival in the MPB/unharvested scenario, the maximum ECA increased about 5% and recovery is approximately 5 years later. These changes are small compared to the difference between the MPB retention and the full-harvest scenario ECA values.

Sub-basin ECA Analyses

ECA analyses for the two ECA scenarios were also completed for the each sub-basin in the watershed, for the area in that sub-basin that is above the watershed H_{48} line (see Figure 6).

Table 6. Sub-basin ECA above watershed H_{48}

Sub-basin Name	Area (ha)	% Total Watershed Area >H48	Current ECA	Maximum ECA (%)		Sustained ECA (%)	
				MPB	Full Salvage	MPB	Full Salvage
Upper Lacoma	3363	28	18	30	57	Moderate	High
Lower Lacoma	1438	6	21	21	45	Low	Moderate
Upper Trepanier	3597	29	10	27	37	Low	Moderate
McDonald Creek	3610	29	26	51	85	High	Very High
Watershed (above DoP intake)	18446	100	17	35	59	**Moderate**	**High**

The Trepanier residual area is largely below the H_{48} elevation line, and thus does not make a significant contribution to freshet peak flows. It has also had less harvesting than higher elevation snow zone areas. The High to Very High ECA values in MacDonald Creek sub-basin are partly due to area of forest cover removed for development of Brenda Mine. The Very High post-full salvage ECA is due to the presence of much ESSF BEC zone forest labelled as pine-leading in the sub-basin. These types of stands have a relatively low initial stand ECA (see Figure 7), and hence a larger increase in ECA if clearcut harvested. The Low to Moderate post-MPB (and no further harvest) ECA values and the Moderate to High post-full salvage ECA values in the Lacoma and Upper Trepanier sub-basins reflect the amount of previous harvesting and pine-leading forest in these areas.

Finally it is worth remembering that ECA values are only an expression of forest canopy changes in the area being analysed, and the local snow accumulation and melt rate effects of those canopy changes. Whether the expected canopy changes will result in increased stream discharge and geomorphic effects in the watershed will depend on the particular watershed and channel characteristics of the watershed in question, as discussed below.

3.2.4 Flood frequency shift

If changes in forest canopy and increased snow accumulation and freshet snowmelt rates represented by ECA values result in increased frequency of floods (peak flows) of various magnitudes, this is known as a flood frequency shift.

Spring peak flow generation in nival watersheds is a complex process involving snow pack, forest cover, microclimatology and weather. This study uses the results of numerical modelling watershed studies for 11 nival, unregulated Interior B.C. watersheds, which look at changes in flood frequency following widespread watershed forest cover disturbances (Alila, et al. 2007, FPB 2007, Schnorbus et al. 2004). That is, computer models of watershed processes are used to predict changes in flood frequency following modelled changes in forest cover conditions in the study watersheds. The resulting flood frequency shifts from those studies are extrapolated to a typical uncontrolled, mid-sized Okanagan watershed, such as Trepanier Creek; as detailed in Appendix D. Figure 11 is a conceptual analysis of the expected change in flood frequency in a typical mid-sized (10's to 100's km^2) Okanagan watershed, given a high (45 %) ECA, as would occur for 15 to 20 years following full salvage harvest in Trepanier Creek.

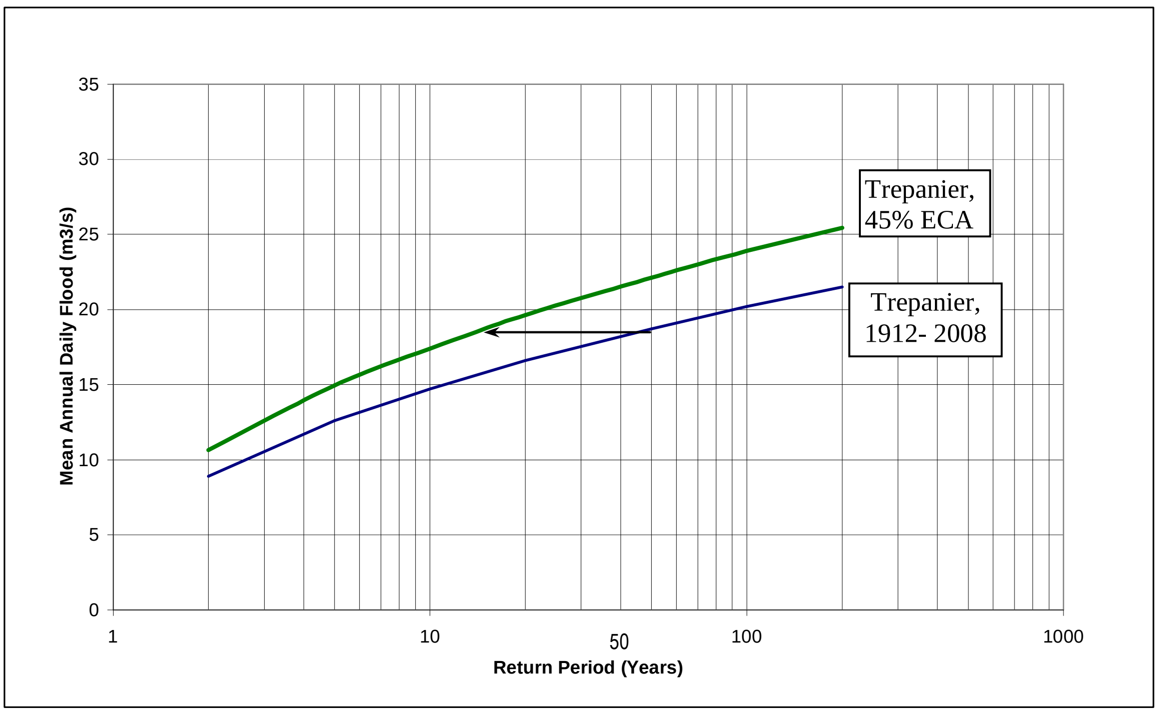


Figure 11. Estimated flood frequency shift in Trepanier Creek with a sustained 45% ECA for 15 to 20 years following the complete harvest of pine-leading stands; based on the expected response of an average, uncontrolled mid-sized Okanagan Watershed.

Figure 11 shows that following the full salvage harvesting scenario the historic 50 year flood is expected to occur approximately every 15 years; and all other magnitude floods would similarly be expected to occur more frequently. This also means that if there is full salvage harvest of pine-leading stands, floods larger than have been experienced in recent times are more likely to occur. This flood frequency shift is expected to last for 15 to 20 years in areas with unregulated flows, which is the case in Trepanier Creek. With a moderate ECA, such as that expected to last about 25 years after total MPB pine mortality and no further harvest, a noticeable increase in flood frequency, and shift in the flood frequency curve, may or may not occur.

This is the flood frequency shift expected for an average Okanagan watershed with the modelled forest canopy (or ECA) changes shown. Section 3.3 looks at the specific characteristics of Trepanier Ck watershed to determine if this expected flood frequency shift is reasonable, following particular management scenarios and the resultant change in forest canopy.

3.3 HYDROLOGIC HAZARD

3.3.1 Peak flow hazard

Peak flow hazard is the potential or likelihood that a sub-basin will develop an elevated flow regime following changes in forest cover. Prime factors when considering peak flow hazards are the extent of forest canopy loss (ECA) discussed in earlier sections, and the watershed or sub-basin characteristics that control how streamflow will respond to the canopy changes. Sub-basin factors that affect runoff sensitivity include steepness, soil drainage properties, drainage density, soil depth (or proximity to an impervious layer), and existing storage such as reservoirs, lakes, and wetlands. Sub-basin peak flow attenuation potentials are described as ‘Poor’ (not likely to attenuate peak discharge), ‘Moderate’ (some potential to attenuate peaks) and ‘Good’ (likely to significantly attenuate peak flows). Combining ECA hazards with sub-basin attenuation gives a peak flow hazard rating. Where Poor peak flow attenuation is anticipated in a sub-basin, ECA-related increases in runoff translate directly into increased flow regimes. Moderate or Good attenuation will result in peak flow hazards somewhat less than that denoted by ECA alone.

High ECA in a sub-basin with rapidly routed runoff and little opportunity for storage will result in a high likelihood or potential for increased peak flows. A lower ECA and/or opportunities for significant water retention in lakes, wetlands and/or reservoirs will reduce peak flow hazards.

Table 7 presents peak flow hazards for each sub-basin and the Trepanier watershed as a whole under the two forest management ECA scenarios of ‘MPB/unharvested’ and ‘Full-salvage’. The ECA progressions for the watershed over time and for the two management scenarios are shown in Section 3.2.3. ECA hazards in Table 7 are represented primarily by the qualitative sustained ECA hazard over time.

Table 7. Peak flow hazard ratings derived from sub-basin routing characteristics and modelled ECA levels

Sub-basin	Peak Flow Attenuation Potential	Projected Maximum ECA (Percent)	Sustained ECA Hazard Level	Projected Maximum ECA (Percent)	Sustained ECA Hazard Level	Peak Flow Hazard	
		MPB		Full Salvage		MPB	Full Salvage
Upper Lacoma	Poor	30	M	57	H	M	H
Lower Lacoma	Poor	21	L	45	M	L	M
Upper Trepanier	Poor	26	L	37	M	L	M
MacDonald	Poor	51	H	85	VH	H	VH
Trepanier Watershed at DoP intake	**Poor**	**35**	**M**	**59**	**H**	**M**	**H**

Results
There is little opportunity for flow attenuation in the Trepanier watershed. The existing lakes are considered too small to provide the storage necessary to absorb the volume of runoff generated during a typical peak freshet. In addition, most of the lakes are situated higher in the watershed, where they will have little effect on flood peaks at the DoP intake. The relatively gentle terrain of the plateau areas, good soil drainage and low drainage density may help to slow runoff, however the plateau snow zone occurs within a relatively narrow elevation band, and much of it will melt simultaneously, particularly in high peak flow years. Once flow is off the plateau and is concentrated into the mainstem channels, it will move quickly to the lower watershed and intake site with little attenuation. For this reason all sub-basins in Trepanier Creek and the watershed as a whole have been assigned a Poor potential for peak flow attenuation; and following the full salvage harvest of pine-leading stands the flood frequency shift predicted for the watershed in Section 3.2.4 would be expected to occur.

Combining this with the ECA levels in the Trepanier watershed following retention of MPB-attacked stands of Moderate, post-unharvested MPB peak flow hazards are Moderate. Anticipated ECA levels resulting from the full salvage scenario are High due to the increased ECA effects of harvesting relative to retention of MPB-attacked forests. Combining this with the Poor attenuation potential yields a post-total salvage peak flow hazard of High for the watershed.

3.3.2 Hydrologic Hazard

Hydrologic hazard represents the potential or likelihood of peak flow or sediment impacts to existing channel conditions in response to the projected change in flood regime. Hydrologic hazard ratings are derived from channel sensitivities (Table 5) and peak flow hazard ratings (Table 7), which are combined using a standard risk matrix (see Appendix A, Table A2). Table 8 shows the resulting Hydrologic Hazard values for each of the Trepanier Creek sub-basins and watershed as a whole.

Table 8. Hydrologic Hazards by Sub-basin

Sub-basin	Channel Sensitivity (from Table 5)	Peak Flow Hazard (from Table 7)		Hydrologic Hazard (Peak Flow Hazard Combined with Channel Sensitivity)	
		MPB	Full salvage	MPB	Full Salvage
Upper Lacoma	L	M	H	L	M
Lower Lacoma	L	L	M	VL	L
Upper Trepanier	L	L	M	VL	L
MacDonald	M	H	VH	H	VH
Trepanier Watershed at DoP intake	**M**	**M**	**H**	**M**	**H**
Trepanier below DoP Intake	M	M	H	M	H

As discussed in Section 3.1.3, channel sensitivities are generally low to moderate in the Trepanier Creek system. When combined with the unharvested MPB related peak flow hazards from Table 7, hydrologic hazards range from Very Low in the upper Trepanier and Lacoma sub-basins to High in the MacDonald Creek sub-basin. The High rating in MacDonald sub-basin is related to the High ECA levels and the moderately sensitive lower MacDonald Creek channel related previous disturbance and aggradation near the Trepanier confluence. The cumulative hydrologic hazard at the intake site is Moderate, representing the cumulative contributions of all four upper sub-basins and the Trepanier Residual sub-basin.

Under the full-salvage scenario, all of the hydrologic hazard ratings increase by one level over the non-salvage scenario. The cumulative hydrologic hazard at the intake becomes High. These finding suggest that there is a high likelihood of significantly increased peak flows and sediment delivery at the intake following full salvage. Peak flows would likely mobilize sediment in MacDonald Creek and Trepanier Creek downstream of their confluence. Subsequent channel adjustment in the Trepanier mainstem, such as widening and erosion of glaciofluvial and colluvial banks, would likely affect fine and coarse sediment loading at the DoP intake.

3.3.3 Low-flow hazard

It is widely accepted that clearcutting increases annual water availability, growing season soil moisture and potentially stream flows; because removing the trees decreases interception and evapotranspiration water losses associated with the forest. The effect of MPB mortality and salvage is expected to be similar.

The widespread removal of forest cover can expose the melting spring snow pack to greater energy inputs, causing it to melt faster so that the freshet melt and associated peak flows occur earlier. This shift in the hydrograph can result in earlier depletion of soil moisture and a longer and more severe soil moisture deficit later in the growing season. However this earlier drying due to freshet advancement is likely to be at least partially offset by the expected increase in available moisture due canopy loss and decreased interception and evapotranspiration losses.

A literature review and workshop attended by most research forest hydrologists in B.C. to address low flow issues in Interior B.C. snowmelt dominated hydrologic regimes, such as Lambly Creek, concluded that; "Forest management generally increases water volume - no case studies relevant to snowmelt-dominated regimes reported a decrease in water quantity as a result of forest harvesting" (Pike and Scherer, 2003). The likelihood of MPB mortality and salvage negatively affecting unregulated growing season low flow stream discharges in Terpanier Creek is considered low.

3.4 CLIMATE CHANGE

Studies of recent past and expected future climate change effects suggest there will be several major effects on DoP water demand, supply and timing.

Recent analyses of recent climate patterns suggest there will be less runoff. Rodenhuis et al. (2007) found that in nival Okanagan basins, annual mean streamflow decreased by -7 to -14% over the last 30 years. Modelling of various climate change scenarios on stream flows in Trepanier Creek resulted in a predicted decrease in natural annual flows of 20% by 2020 and 39% by 2050. (Summit, 2004). There is also expected to be a decrease in freshet peak flows, as more precipitation falls as rain in the winter and there is less stored snow at the start of the freshet.

Secondly, there will be increased agricultural demand. It is estimated climate change related increased temperature and dryness during the growing season will increase water use for agriculture and residential irrigation (which comprise 85% of DoP water use) by 16% in 2020 and 30% in 2050 (Summit, 2004).

Higher temperatures will also result in earlier snowmelt and annual spring hydrograph peak. As discussed in Section 3.3.3, earlier spring runoff results in earlier hydrograph recession, and possibly earlier and more severe growing season moisture deficits. The magnitude of the combined effects of climate change-related decreased water availability, increased demand and earlier storage depletion are not known.

Changes in forest cover can also affect water supply. Decreased snow sublimation and evapotranspiration losses will mean more water availability for runoff, both as accumulated snow for the freshet and water availability during the growing season. As well, models predict canopy loss will mean an earlier onset to the freshet. As discussed in Section 3.3.3 the MPB/salvage effect growing season low flows is not expected to be significant; and in general is expected to be small relative to climate change effects.

3.5 WILDFIRE

Concerns have been raised about increased risks of wildfires and severe wildfires in stands and watersheds where there is widespread MPB mortality, presumably because dead pine trees are seen as increased fuel load relative to live pine stands. Extensive wildfire, and locally severe wildfires, can create changes in the hydrological functioning of forests, and increase flood and other hydrogeomorphic risks to downstream values (Scott and Pike, 2003).

It has been noted, in a study of fire occurrence and effects in MPB attacked and non-attacked stands in Colorado, that: "Although it is widely believed that insect outbreaks set the stage for severe forest fires, the few scientific studies that support this idea report a very small effect, and other studies have found no relationship between insect outbreaks and subsequent fire activity. Based on current knowledge, the assumed link between insect outbreaks and subsequent forest fires are the norm . . . is not well supported, and may in fact be incorrect or so small an effect as to be inconsequential for many or most forests" (Romme et al. 2007).

The reason proposed for this finding is that weather may be a more important factor than stand condition, and where drought has increased the fire hazard in all stands, both live and dead fuels will carry fire (Romme et al. 2007). In lodgepole pine stands in the 1988 Yellowstone fires, Lynch (2006) found that MPB-affected areas had only an 11% higher probability of burning compared to un-infested areas.

There is some agreement that for the one to two-year period following attack, when the trees still retain their needles, there is an increased crown fire hazard. After the needles have fallen, the risk of crown fire and fire behaviour potential is reduced for one to several decades. Fire risk may then return to pre-fire intensity levels as dead trees fall and fast growing understory vegetation provide fuels. (Romme et al. 2007; Duffy, C.D., Superintendent, Fuel Management, Fire Management Section, Protection Branch, MoF, Victoria, pers. comm. 2008).

Presumably for these reasons, advice to the Chief Forester of BC Forest Service regarding MPB-related salvage harvesting has been: "Increased risk of fire in MPB-affected stands has been postulated by many, but evidence in the literature is equivocal (e.g., Turner and Carroll 1999). Conducting salvage operations based on the premise of reducing fire risks is not recommended, except in the wildland-uban interface" (Eng 2004). We agree with this statement and recommend that, except in the wildland-urban interface, and possibly in small tributary watersheds (<10 to 20km^2) with high property or infrastructure values on the fan, widespread salvage of MPB attacked stands should not be carried out if the prime management objective is to reduce fire risk.

4.0 CONSEQUENCES

4.1 WATER QUALITY AND INFRASTRUCTURE

Trepanier Creek is a community watershed supplying drinking water to the Municipality of Peachland. The Corporation of the District of Peachland is the local water authority that services approximately 2,000 Peachland residents and provides irrigation for approximately 500 hectares of orchard, field crops, and vineyards. Of the total annual licensed volume of water consumption, approximately 38% is allocated to agricultural irrigation and 47% to domestic outdoor use. While the District of Peachland holds 28 water licenses, the remaining 48 water licenses are privately held (domestic and irrigation). In addition to Trepanier Creek, the DoP also withdraws water from Peachland Creek, Okanagan Lake and several groundwater wells. As discussed in Section 2.4.1 the long-term plan is to abandon Trepanier Creek as a municipal water source except in the case of emergencies; but in the short term it is a significant source, meeting approximately 37% of DoP average annual water demand (Dobson, 2006).

The DoP domestic water intake on Trepanier Creek is located approximately 7 km upstream from Okanagan Lake. At the intake site, there is a small dam on Trepanier Creek, behind which there is minimal settling. Water is directed into a small reservoir and then into the gas chlorination facility prior to distribution.

Limited water storage has been developed on Lacoma Lake and Silver Lake to increase the available water in the Trepanier Creek system, but it is understood that this storage capability is not currently being utilized.

As discussed in Section 2.4.1, the water quality parameters most-strongly linked to MPB infestation and/or salvage harvesting are those related to peak flows and fine and coarse sediment production. At the request of IHA this study looks only at the flooding and sediment hydrologic hazards that could impact a sufficient and reliable supply of safe and aesthetically acceptable water at the DoP intake, and does not consider the vulnerability of the DoP water supply and treatment system. Those impacts at the DoP water intake are considered the consequence in the partial risk analysis completed below.

4.2 WATER SUPPLY

There is little storage capacity available or utilized in Trepanier Creek watershed. While the long term plan is for DoP to abandon Trepanier as a significant municipal water source, in the short term is meets over a third of average annual demand and is an important source of supplies. Impacts to water supply would be considered a high consequence.

4.3 FISH

Sport-fish species within the Trepanier Creek watershed include Rainbow trout (Oncorhynchus mykiss) and Kokanee (Oncorhynchus nerka). Burbot (Lota lota) have also been captured in lower Trepanier, about 200m upstream of Okanagan Lake (Taylor and Wightman 1978). Trepanier Creek is fish bearing through to Reach 10 of the mainstem. Reach 11 of the mainstem is an unnamed lake which is documented as non-fish bearing and the headwaters are also non-fish bearing. A falls located 1.1km upstream of Okanagan Lake on Trepanier Creek in Reach 1 is a fish-barrier and is considered the upper limit of Kokanee spawning. Rainbow Trout are documented upstream of this barrier.

Law Creek, Jack creek, Venner Creek, Hill Creek, and Pigeon Creek are confirmed as non-fish bearing. Lacoma Creek and Lacoma Lake contain rainbow trout. Upstream of the lake, Lacoma Creek is noted as non-fish bearing. Silver Lake, Trepanier Creek and MacDonald Creek have been stocked with rainbow trout for many years, including as recently as 2008.

Trepanier Creek fish presence and habitat values for all reaches are presented in Appendix E, along with a fish consequence ranking for that reach, based on criteria presented in Table 2 (Section 2.4.3).

Figure 12 (in pocket) summarizes fish habitat consequence ratings for each macro-reach. Where reaches within one sub-basin have different consequence values, the highest value is assigned to that reach. Where there was no fish information available for a reach, it is given a similar or one consequence class lower value, based on reach characteristics from available published material.

High to Very High fish habitat consequence ratings have been assigned for the mainstem of Trepanier Creek (below Reach 11), Silver Creek and Lacoma Creek (up to and including Lacoma Lake). Silver Lake and MacDonald Lake also have high fish habitat consequence ratings. Habitat values are decreased in McDonald Creek resulting in a moderate consequence rating.

4.4 Social Infrastructure

Table 9 outlines the assumptions used to develop expected infrastructure vulnerability, and the assigned vulnerability ratings.

Table 9. Social Infrastructure Vulnerability Rating

Item at Risk	Key Post MPB/salvage Issues	Comments	Vulnerability Rating
Licensed Water Intakes	Increased peak flows, local aggradation, increased turbidity, increased debris movement, low flows (availability).	Intakes are often 'home-made' and unable to withstand flooding/debris impact. Constructed weirs susceptible to burial by bedload. Most will have no provision for filtering of suspended fines.	**H**
Forestry Roads	Increased peak flows, increased scour, increased debris movement. Drainage redirection on plateau and gentle-over-steep landslides on steeper stream sidewalls.	Few road crossings of streams, mostly on the plateau where cumulative effects will be low. Some structures may not have capacity for post MPB/salvage increased peak flow + debris. Overflows will be on gentle terrain, with potential for GoS landslides if near stream escarpments. Forestry bridge over mainstem appears to have good clearance	**M**
Private Bridge Crossings (Driveways)	Increased peak flows, increased scour, increased debris movement.	Many constructed to a low standard without hydrologic and/or engineering input. Often poorly founded on abutments. Area of relatively low banks.	**H**
Public Road Crossings (including Beach Avenue and Paradise Valley Road)	Increased peak flows, increased sediment leading to local aggradation, increased debris movement.	Better constructed than private crossings, however still relatively low clearance. Potential for aggradation on the beach at the Beach Avenue crossing.	**M**
Highway 97 & 97C Overpasses	Increased peak flows, increased sediment leading to local aggradation, increased debris movement.	Current bridge capacity appears more than adequate. Clearances determined by elevated highway grade rather than channel capacity. Some risk of damage to abutments or piers.	**L**
Residences on Fan	Increased peak flows and flooding potential, increased sediment leading to local aggradation, increased debris movement causing jams.	No evidence of recent flooding. Current channel appears well-incised but flood potential could increase with higher peak flows, aggradation and/or debris jams.	**M**
MacDonald Creek mine by-pass	Increased peak flows and flooding potential, increased sediment movement leading to local aggradation	Not investigated but history of drainage diversion and sediment mobilization, and potential for further sediment delivery to Trepanier mainstem.	**Potentially H**

Most water licenses belong to either the District of Peachland or Noranda Mines. Several permits exist on Lacoma Lake, including four privately held water licences for storage, but it does not appear that lake outlets are managed in a controlled manner. Private domestic water licenses exist on Silver Lake and Venner Creek.

Downstream of the DoP intake there are numerous water licences, including privately held permits for domestic and irrigation use of water from Trepanier Creek, Pidgeon Creek and Jack Creek. Approximately 200m upstream of the Highway 97C crossing (off Trepanier Road), a community intake serving approximately 15 domestic and irrigation users had been set up complete with gate valves and a lock block weir. Although well-built compared to typical private water intakes, this structure may be sensitive to increases in peak flows. Inspections of other individual water licence 'points of diversion' were not made.

Many kilometres of forestry road have been developed in the Trepanier watershed, mostly associated with harvesting in the upper plateau areas. The number of crossings estimated in the watershed above the DoP intake was 47 in 1998, including all tributaries (Dobson 1998). This number has likely increased with continued development. No comprehensive review of bridge capacities or forest road crossings, etc., was undertaken. Most of the crossings are likely minor culverts high on the plateau and detailed inspections and analyses of these existing crossings were not conducted. Cumulative runoff effects will be less nearer the headwaters on the upper plateau. Where existing or proposed forest roads within several hundred metres of steep-walled streams incised into the plateau, such as Lacoma and Upper Trepanier, inadequate road drainage structures could lead to drainage redirection on the plateau and "gentle-over-steep" landslides on the steeper stream sidewalls.

There is one forestry bridge crossing of the Trepanier Creek mainstem located approximately 1.4 km upstream of the DoP intake. This crossing consisted of a steel span on lock block abutments armoured with riprap (Photo 10) and the bridge appears to have good clearance. There are no crossings of Lacoma Creek below the plateau level.

The Coquihalla Connector (Highway 97C) crosses MacDonald Creek just below the Brenda Mine site on a high concrete overpass. Downstream of the DoP intake, there are several other public road crossings. Paradise Valley Road crosses Trepanier Creek approximately 1.5 km downstream of the DoP intake. The bridge is a timber structure with concrete abutments, with less clearance due to reduced channel incision. Floating debris at high water may be an issue at this crossing.

Several properties along Trepanier Road in the vicinity of Paradise Valley Road have constructed bridge crossings for private access (driveways). The quality and capacity of these structures are likely quite variable and some are probably quite vulnerable to changes in flow regime and/or debris transport (Photo 11).

The Coquihalla Connector (Highway 97C) crosses Trepanier Creek approximately 3 km downstream of the intake over a high concrete overpass. Issues with increased peak flows are unlikely. Similarly, Highway 97 crosses Trepanier Creek approximately 300m upstream of Okanagan Lake over a high concrete and steel bridge. Just upstream of the highway crossing, a steel frame pedestrian bridge is quite a bit lower, but nonetheless appeared to have good clearance. Beach Avenue crosses Trepanier Creek over a concrete bridge with riprapped banks near the shoreline of Okanagan Lake (Photo 12). The clearance at this crossing is fairly low, and capacity will decrease if the channel aggrades at all in this depositional zone.

The Trepanier Creek fan near the outlet on Okanagan Lake is highly developed with residential housing on both banks (see Photo 5). Over time, sediment transported from upstream will be deposited on the fan, leading to aggradation and reduced channel capacity. Increased sedimentation combined with changes to the flow regime could increase the frequency of flooding on the fan.

Upper MadDonald Creek is diverted around the tailings pond, so that tailings pond effluent can be introduced into the creek after treatment in a controlled manner. There is limited public access to the closed Brenda Mine site and it is not know how robust this drainage diversion is, or how vulnerable it would be to increased peak flows and/or sediment. There is a history of serious channel disturbances due to drainage from the mine site, both in lower MacDonald Creek, and in upper Peachland Creek (GACL, 2010). In the absence of greater certainty around this feature, it is given a Potentially High vulnerability rating.

5.0 RISK ANALYSIS

5.1 WATER QUALITY AND INFRASTRUCTURE

Table 10 summarizes the partial risk analysis for water quality at the DoP water intake. The hydrologic hazard, which includes both incremental peak flow and channel erosion sediment hazards, is the cumulative watershed Hydrologic Hazard at the lower end of the Trepanier Residual, at the DoP water intake (Table 8).

Table 10. Partial risk analysis for DoP water intake.

Reach	Hydrologic Hazard (peak flow and sediment)		Water Quality Element at Risk: DoP Water Intake		**Partial Risk**	
	MPB	Full Salvage	Fine sediment impacts	Coarse sediment impacts	**MPB**	**Full Salvage**
Trepanier Residual	Mod	High	less aesthetic appeal, more microbiological activity, less effective primary treatment	Intake damage, maintenance	**Mod**	**High**

For the MPB infestation scenario (with no salvage harvesting) there is a Moderate Risk. In other words, following full MPB-related pine mortality some increase in fine and coarse sediment delivery to the DoP intake may occur. With the full salvage of pine-leading stands scenario there is a High risk. That is, a significant increase in peak flows and sediment delivery to the DoP intake is considered likely.

5.2 WATER SUPPLY

The consequence of potential decreases in later growing season water flows is considered high. However, as discussed in Section 3.3.3, earlier drying due to MPB and salvage-related freshet advancement is likely to be at least partially offset by the expected increase in available moisture due to canopy loss and decreased interception and evapotranspiration losses. On balance the effect of MPB and salvage mortality on growing season low flows will probably not be significant. Therefore the MPB-related risk to water supplies in Trepanier Creek is considered low.

As discussed in Sections 3.4, a much greater change in decreased streamflows and freshet timing is expected due to global climate change-related temperature increases, depending on the temperature increases that occur in the Okanagan over time.

5.3 FISH

For each sub-basin, hydrologic hazards (Table 8) are combined with the fish consequence values (Appendix E, Table 2) using a standard risk matrix (Appendix A, Table A1), to arrive at the fish habitat risk ratings in Table 11.

Note that risks to fish values only occur where fish populations and habitat exists and this risk rating may not represent the entire sub-basin. Since hydrologic hazard is generally cumulative to the downstream end of the sub-basin, risk ratings in tributary basins generally represent risks near the lower end of the sub-basin. Risks in residual sub-basins represent risks to habitat values along the Trepanier Creek mainstem within that sub-basin.

Table 11. Risks to Fish Values by Sub-basin

Sub-basin Name	Hydrologic Hazard (From Table 8)		Fish Consequence Rating	Risks to Fish habitat	
	MPB	Full Salvage		MPB	Full Salvage
Upper Lacoma	L	M	H	**M**	**H**
Lower Lacoma	VL	L	H	**M**	**M**
Upper Trepanier	VL	L	VL	**VL**	**VL**
MacDonald	H	VH	M	**H**	**H**
Trepanier Residual	M	H	H	**H**	**VH**
Trepanier Below the DoP Intake	M	H	H to VH	**H** **VH (R1)**	**VH**

Risks to fish habitat are generally High in lower mainstem sub-basins following the MPB/unharvested scenario, because mainstem consequence values are High to Very High and even the possibility of negative impacts (moderate hydrologic hazard) yields a High potential risk. Risks are Very High in lower mainstem reaches under the full salvage scenario. Upper mainstem and tributary reaches generally have Very Low to Moderate Risks following either scenario.

A Very High consequence rating was assigned to Reach 1 of the mainstem near the mouth of the creek at Okanagan Lake, which is considered Kokanee spawning habitat. When combined with Moderate (post-MPB) and High (post-Full salvage) hydrologic hazards, the risk to fish habitat in this reach becomes Very High following either scenario.

Degradation to fish habitat in the lower reaches would likely result from increased sedimentation, causing aggradation, reduction in pool depths, cementing of substrates and generally a reduction in habitat quality, especially in spawning areas.

5.4 SOCIAL INFRASTRUCTURE

To determine infrastructure risk ratings the hydrologic hazard derived for the watershed is combined with infrastructure vulnerability ratings presented in Table 9, as summarized in Table 12.

Table 12. Social Infrastructure Risk Ratings

Item at Risk	Consequence Vulnerability Rating	Hydrologic Hazard		Infrastructure Risk Ratings	
		MPB	Full Salvage	MPB	Full Salvage
Licensed Water Intakes	**H**	M	H	**H**	**VH**
Forestry Roads and road-related gentle-over-steep landslides	**M**	M	H	**M**	**H**
Private Bridge Crossings (Driveways)	**H**	M	H	**H**	**VH**
Public Road crossings (Beach Avenue and Paradise Valley Road)	**M**	M	H	**M**	**H**
Highway 97 & 97C Overpasses	**L**	M	H	**L**	**M**
Residences on Fan	**M**	M	H	**M**	**H**
MacDonald Creek Brenda Mine by-pass	**Potentially H**	M	H	**H**	**VH**

Risks to infrastructure range from Low to High following the unharvested MPB attack scenario, and Moderate to Very High following the hypothetical full salvage scenario.

High to Very High risks have been assigned to private water intakes and private bridge crossing licenses as a result of an inferred sensitivity of these installations to increases in peak flows and sediment. Most privately constructed works are done to a lower standard than forest or provincial roads, or municipal water intakes.

Forestry road drainage structures may have no excess capacity for increased flows or debris movement, which, particularly following the full salvage scenario, may result in redirected drainage and if near steeper incised stream escarpments, and High “gentle-over-steep” landslide risks.

Public crossings for the Paradise Valley Road and Beach Avenue have a Moderate risk of problems post-MPB, potentially increasing to High risk under the hypothetical full-harvest scenario. Increased debris movement and/or aggradation (reducing bridge capacity) are the most likely mechanisms for problems at these crossings.

Similarly, residences on the fan would be subject to a Moderate risk of flooding post-MPB, potentially increasing to High risk under the hypothetical full-harvest scenario.

Risk ratings for the higher Highway 97 and 97C crossings may be overstated by this methodology. Unless piers or abutments are threatened by channel destabilization and erosion, impacts to these structures are unlikely, even under the full harvest scenario.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The water quality parameters most strongly linked to MPB infestation and salvage logging in Trepanier Creek watershed are increases in peak flows (floods) and associated mobilization of fine and coarse sediment from stream channel beds and banks. Following the complete mortality of all pine and with no further harvesting in Trepanier Creek watershed there is a Moderate Risk, which means some increase in fine and coarse sediment delivery to the DoP intake may or may not occur. Following the full salvage of pine-leading stands in the watershed an increase in the size and frequency of floods is expected to last for 15 to 20 years, and there is a High risk of a significant increase in peak flows and sediment delivery to the DoP intake. Source water turbidity levels have been and will continue to present a problem at the DoP water intake, in terms of meeting Interior Health Authority water quality guidelines. MPB mortality along may or may not result in a noticeable increase turbidity, but high salvage harvest levels will likely exacerbate turbidity problems.

There is little evidence of links between MPB and salvage effects and the water quality parameters of total organic carbon, true colour, metals and total phosphorous, and measurable change in these parameters in Trepanier Creek are not expected. The effect of MPB and salvage mortality on growing season low flows will probably not be significant. Therefore the MPB and salvage harvest-related risk to water supplies in Trepanier Creek is considered low. A much greater change in decreased streamflows and freshet timing is expected due to global climate change-related temperature increases.

There are fish present and high habitat values along much of the lower Trepanier Creek mainstem. This results in a High Risk of negative impacts following MPB-related pine mortality, mainly due to increased sediment movement, channel aggradation and a reduction in habitat quality. If there is widespread salvage harvesting the risk of negative impacts on fish populations in these lower mainstem reaches will be Very High. The likelihood of negative impacts is even more likely in Reach 1 where fish habitat values are Very High due to it being Kokanee spawning habitat.

All social infrastructure risk values have a higher risk for the full salvage scenario than for the MPB/unharvested scenario; because of the increased hydrologic hazard associated with clearcut salvaging in the types of stands present in the Trepanier Creek watershed. Risks to housing developments on the Trepanier Creek fan, forestry roads, forest road-related “gentle-over-steep” landslides and public road crossings (Paradise Valley Road and Beach Avenue) are considered moderate and high for the MPB/unharvested and full salvage scenarios respectively. Risks to private water intakes and private stream crossings in the watershed are considered High to Very High respectively, because they are generally built to a lower standard that forestry or public works.

There are potentially High to Very High risks to water quality, infrastructure and fish values in lower Trepanier Creek reaches from failure of the MacDonald stream diversion channel around the Brenda Mine tailings pond. The risk rating is stated as potential because limited access prevented a detailed investigation of this area, and uncertainty remains about its vulnerability. There is a history of severe erosion and mobilization of sediment from mine-related stream diversions in MacDonald Creek, and it remains sensitive to further disturbance due to past avulsions, erosion and stream aggradation. As well, there are high to very high levels of canopy change and ECA hazards following the unharvested MPB and total salvage harvest scenarios respectively.

6.2 RISK MITIGATION

Recommendations to reduce risks focus on either protecting and strengthening risk elements, or reducing stand-level MPB and salvage effects.

6.2.1 FOREST FOR TOMORROW ACTIVITIES

The Forest For Tomorrow program was created to respond to the MPB infestation in B.C. Its mandate is to improve the future timber supply and address risks to other forest values. Discussions with program administrators and others involved in the program in the Okanagan provided information on FFT activities being carried out the Southern Interior. These are:

- rehabilitation of MPB attacked immature or small diameter stands (>70% pine, <50yrs) with some economic recovery (clearcut harvest, site prep, replanting)
- rehabilitation of attacked plantations (site preparation, which destroys the plantation, and replanting)
- rehabilitation of attacked mature stands with no commercial value (cut, pile, burn, plant). This is expensive and is considered unlikely to be widely implemented.

Hydrologically, these treatments are the same as clearcutting and have the same effect in removing stand hydrologic function, if the treated stands have some hydrological function at the outset. However, it is our understanding that overstory and understory composition in stands proposed for treatment are assessed, and stands with significant non-pine overstory and healthy understory are not treated, but are left to recover naturally. Therefore these treatments will not significantly increase the short term ECA the watershed. On the other hand the treatments promote more rapid recovery and a healthier and more economically viable stand.

It appears that activities that could increase forest health and productivity, while maintaining the existing hydrological function of the attacked stand, such as under-planting mature attacked stands, have had little success. This is due to the expense and to high seedling mortality from hares and rodents, which apparently can survive better in the attacked forest than in a clearcut (Stuart Parker, pers. comm.). Other trials are underway (Doug Lewis, pers. comm.) which may address outstanding under-planting issues. Currently we know of no operational under-planting of attacked stands being done by FFT or others.

FFT activities that are being implemented will improve the long term health and economic value of the forest, and in the long term help restore hydrological forest function; but they will not mitigate the potential short term hydrological impacts of MPB attack and salvage harvesting in Trepanier Creek, as discussed in this report.

6.2.2 RISK MITIGATION RECOMMENDATIONS

MacDonald Creek mine by-pass
The capacity and integrity of the MacDonald Creek by-pass of the mine tailings pond should be carefully reviewed, and improved as necessary.

Riparian Management
As discussed in Section 2.3, riparian management along streams during salvage harvesting will be important in maintaining short and long term temperature and large woody debris recruitment levels, and to preserve stream stability and habitat quality. Given that research has found LWD input rates are similar for attacked and non-attacked Okanagan stands, at a minimum best riparian management practices for “green wood” harvesting in the Okanagan should be followed when salvage harvesting MPB-attacked stands.

Fish Habitat Management
Maintaining good riparian condition and instream LWD throughout the watershed will help to mitigate potential impacts on fish habitat. Since the effects of unharvested MPB-attack are uncertain and we don’t know what level of harvesting will occur in the watershed, it would be prudent to periodically update on-site fish habitat assessments (last done in 1996), monitor channel and riparian conditions and carry out rehabilitation activities as necessary.

Forest Road Drainage Management
No significant forest road-related landslide impacts were noted in this or previous watershed assessments. However the potential for “gentle-over-steep” (GoS) landslides exists where trail and road drainage diversions on the gently sloping plateau could divert water onto the moderately steep (50 to 70%) gradient escarpments of the upper Lacoma and upper Trepanier mainstems. Particularly if significant salvage harvesting is planned in any area, a review of

trail and road drainage structures (ditches, ditch blocks, culverts, cross-ditches, bridges, etc.) located within 200 to 400m of steeper stream escarpment slopes is recommended. Any structure which appears to be operating near its capacity, to be damaged or otherwise compromised so that it is not working at its design capacity, or is otherwise insufficient to accommodate some increase over historic flows, should be upgraded to accommodate larger flows. Reviews and drainage plans should be completed by a geotechnical professional with expertise in mitigating GoS landslides.

Stand and Watershed ECA Hazard Management

In the absence of an effective under-planting program for MPB attacked stands, we know of no way to reduce the MPB-related ECA hazard at the stand level. However the incremental risks related to unharvested MPB-related ECA hazards are moderate to DoP water quality and water supply infrastructure and low to water supply. Post unharvested MPB risks are low to moderate for most other infrastructure, and high for private water intakes and crossings and fish values in lower mainstem stream reaches.

Incremental risks are higher for all elements at risk in the watershed following the hypothetical scenario of full salvage harvest of all pine-leading stands, compared to risks if pine-leading stands were all left unharvested; because of the expected stand characteristics of pine-leading stands in the watershed. To reduce those risks to an acceptable level will require managing the amount and location of salvage harvesting in the watershed.

While it makes good hydrological sense to harvest attacked pine stands rather than “green” non-pine stands, removing too much MPB-attacked forest will increase watershed hazards and risks. To manage the incremental hydrologic impact of salvage harvesting it is recommended that:

- licensees use a hydrological risk assessment methodology that models the effects of non-pine overstory and understory stand structure in dead pine stands to get a more accurate picture of the hydrological condition of the watershed, and of the potential impacts of proposed salvage harvesting. Hydrological risk analyses that treat all MPB attacked stands as having little or no hydrological forest function (ie., as having initial ECA values similar to clearcuts) may seriously underestimate the incremental hydrological risks associated with widespread clearcutting of attacked stand that have hydrologically significant stand characteristics.

- From a strictly hydrological perspective (and we recognize forest managers have to balance many different forest values), the least hydrological impact would result if pine-leading stands with the lowest non-pine overstory component and lowest understory stocking were preferentially targeted for salvage harvest. From the data collected here the stands in the snow zone with least hydrological function would be younger MSdm stands followed by older MSdm stands and then ESSF stands (see Figures 6-8 and Appendix B).

- We recognize that individual stands within these broader BEC types will have different characteristics; site specific surveys of stand characteristics in areas proposed for harvesting are recommended. Salvage harvesting should be focused on those stands with the least non-pine overstory and little healthy understory.

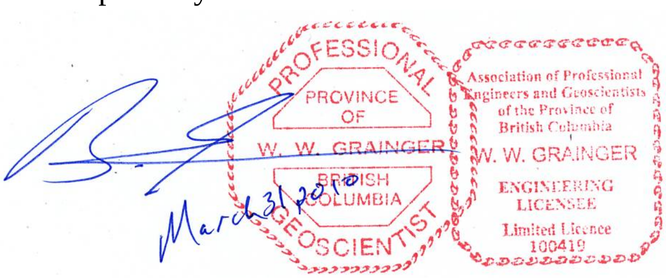
- The widespread and severe MPB epidemic in B.C. is clear evidence that forests can be subjected to significant unforeseen disturbances, with potentially significant consequences. Because of the types of forests present, the expected hydrological effect of MPB infestation and pine tree mortality in Trepanier Creek Watershed is not expected to be catastrophic for any of the identified watershed values (risk elements). With good management of harvesting rates and sites that recognizes the hydrological function of different pine-leading stand types, forest development should be possible with a level of risk that is acceptable to watershed stakeholders. However MPB infestation may not be the only significant stressor on Trepanier Creek forests in the near future. Global warming and global warming-related disturbances such as other pathogens which could attack other tree types (spruce or fir beetle and others) and fire, etc., are not improbable. We think that part of the determination of what is an acceptable level of risk would include considering the potential hydrological (and other) effects of these other possible disturbances. To manage for them it would be prudent to apply the precautionary principle and preserve some hydrological function in the watershed above the minimum required to manage only for MPB and MPB-related salvage impacts.

7.0 CLOSURE

This investigation has been carried out in accordance with generally accepted Geoscience and Engineering practice. Geoscience and Engineering judgement have been applied in developing the conclusions and recommendations in this report. No other warranty is made, either expressed or implied.

We trust that this report satisfies your present requirements. Should you have any questions or comments, please contact our office at your convenience.

Prepared by: and



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References:

Alila, Y., Lou, C. and Maloney, D., 2007. Peak Flow and Water Yield Responses to Clearcut Salvage Logging in Meso-scale Mountain Pine Beetle Infested Watersheds. Unpublished manuscript.

Anonymous. 1999. Watershed Assessment Procedure Guidebook, Second edition, Version 2.1. Forest Practices Branch, Ministry of Forests, Victoria, BC. Forest Practices Code of British Columbia Guidebook.

Boon, S., 2009. Impact of Mountain Pine Beetle Infestation and Salvage Harvesting on Seasonal Snow Melt and Runoff. Mountain Pine Beetle Working Paper 2008-4. Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C.

Church, M. 1993. Environmental Change and Rivers in Cordilleran Canada. Department of Geography. University of British Columbia.

Coates, D.K., Glover, T., and B. Henderson, 2009. Abundance of Secondary structure in Lodgepole Pine Stands Affected by the Mountain Pine Beetle in the Cariboo-Chilcotin. Final Report 2008/2009. MPB Project 7.22. Forest Sciences, British Columbia Forest Service.

Dobson Engineering Ltd., 1998. Watershed Assessment Report for the Trepanier Creek Watershed. Gorman Bros. Limber Ltd.

Dobson Engineering Ltd., 2004a. Extent of Snow Cover During the 2004 Spring Freshet for the Trepanier Creek Watershed. Fourth Year of Snowline Data. Riverside Forest Products and Gorman Bros. Lumber Ltd.

Dobson Engineering Ltd., 2004b. Extent of Snow Cover During the 2004 Spring Freshet for the Mission Creek Watershed. Fourth Year of Snowline Data. Riverside Forest Products and Gorman Bros. Lumber Ltd.

Dobson Engineering Ltd., 2004c. 2004 Snowline Survey in Selected Watersheds of the Central and South Okanagan. Extent of Snow Cover During the 2004 Spring Freshet. Weyerhaueser Company Ltd. Okanagan Falls Division.

Dobson Engineering Ltd., 2004d. Extent of Snow Cover During the 2004 Spring Freshet for the Trout Creek Watershed. Fourth Year of Snowline Data. Riverside Forest Products and Gorman Bros. Lumber Ltd.

Dobson Engineering Ltd., 2006. District of Trepanier Water Availability Analysis. District of Trepanier.

Forest Practices Board (FPB), 2007. The Effects of Mountain Pine Beetle Attack and Salvage Harvesting on Streamflows. Special Investigation Report 16.

Green, K. 2005 A Qualitative Hydro-Geomorphic Risk Analysis for British Columbia's Interior Watersheds: A Discussion Paper. Streamline Watershed Management Bulletin Vol. 8/No. 2 Spring 2005.

Hassan, M., D. Hogan, and S. Bird. 2008. Mountain Pine Beetle Impacts on Channel Morphology and Woody Debris in Forested Landscapes. Mountain Pine Beetle Working Paper 2008-07. Mountain Pine Beetle Initiative Project #8.40. Natural Resources Canada, Canadian Forest Service. Victoria, BC.

Huggard, 2009. Summary of Results from South Okanagan Stand Surveys for MPB-ECA Modeling. GACL. Included as Appendix B of this report.

Kowall, R. 1986 Soils & Slopes, Penticton Soil Project FRBC_9A, Digital Terrain Map Library Projects, B.C. Ministry of Energy and Mines.

Ministry of Environment, 2008. Water Quality Assessment and Objectives for Trepanier Creek Watershed (draft – not issued). Environmental Protection Division, Water Stewardship Branch, Ministry of Environment. Victoria, BC.

Ministry of Health Services and Ministry of Water, Land and Air Protection, B.C. (MoH), 2005. Comprehensive Drinking Water Source to Tap Assessment Guideline, Draft for Pilot Assessments. Introduction and Modules 1 through 8.

Patterson, M. 2004 Water management and Molybdenum Treatment at the Closed Noranda Inc - Brenda Mines Site, Peachland BC. Noranda Inc./Falconbridge Ltd., Westbank BC.

Pike, Robin G., and Rob Scherer, 2003. Overview of the potential effects of forest management on low flows in snowmelt dominated hydrologic regimes. BC Journal of Ecosystems and Management. Vol. 3, No. 1.

Redding, T., R. Winkler, P. Teti, D. Spittlehouse, S. Boon, J. Rex, S. Dubé, R.D. Moore, A. Wei, M. Carver, M. Schnorbus, L. Reese-Hansen, and S. Chatwin. 2008a. Mountain pine beetle and watershed hydrology. In Mountain Pine Beetle: From Lessons Learned to Community-based Solutions Conference Proceedings, June 10–11, 2008. BC Journal of Ecosystems and Management 9(3):33–50.

Redding, T., Rita Winkler, David Spittlehouse, R.D. Moore, Adam Wei and Pat Teti, 2008b. Mountain Pine Beetle and Watershed Hydrology: A Synthesis focused on the Okanagan Basin. Can. Water Res. Ass., One Watershed - One Water conference proceedings. Oct 21 to 23, 2008. Kelowna, B.C.

Rex, John and Stephane Dube, 2009. Hydrologic effects of mountain pine beetle infestation and salvage-harvesting operations. Mountain Pine Beetle working paper 2009-05. Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C.

Rodenhuis, D., Bennett, K.E., Werner, A.T., Murdock, T.Q. and D. Bronaugh. Climate Overview 2007. Hydro-climatology and Future Climate Impacts in British Columbia. Pacific Climate Impacts Consortium. University of Victoria, B.C.

Schnorbus, M., Alila, Y., Beckers, J., Spittlehouse, D. and Winkler, R. 2004. Peak flow regime changes following forest harvesting in a snow-dominated basin: An exploratory analysis using numerical modeling. Unpublished manuscript.

Schnorbus, M., and Alila, Y. 2004. Forest Harvesting Impacts on the Peak Flow Regime in the Columbia Mountains of South-Eastern British Columbia: An Investigation Using Long-Term Numerical Modeling. Water Resources Research, doi:10.1029/2003WR002918.

Scott, D., and Pike, R. 2003. Wildfires and Watershed Effects in Southern B.C. Interior. Streamline Watershed Management Bulletin. Vol.7, No.3.

Stednick, J. 2007. Preliminary assessment of water quantity and quality changes in beetle-killed catchments in north-central Colorado. In T. Redding (Ed.), Proc. Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary results from research from BC, Alberta and Colorado, July 10, 2007. Kelowna, B.C.

Summit Environmental Consultants Ltd., 2004. Trepanier Landscape Unit Water Management Plan. Regional District of Central Okanagan and B.C. Ministry of Sustainable Resource Management.

Urban Systems Ltd., 2007. District of Peachland Water Master Plan. District of Peachland.

Vyse, A., C. Ferguson, D. Huggard, J. Roach and B. Zimonick. 2007. Regeneration below lodgepole pine stands attacked or threatened by mountain pine beetle in the Kamloops Timber Supply Area. Thompson Rivers University, Kamloops, BC.

Wei, A., Chen, X., and Scherer, R. 2007. Assessment of the impacts of wildfire and MPB infestation on in-stream wood recruitment and transportation processes in the B.C. Interior. In T. Redding (Ed.), Proc. Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary results from research from BC, Alberta and Colorado, July 10, 2007. Kelowna, B.C.

Winkler, R., J. Rex, P. Teti, D. Maloney, and T. Redding. 2008. Mountain pine beetle, forest practices, and watershed management. B.C. Min. For.Range, Victoria, B.C. Exten. Note 88.

Winkler, R. and S. Boon, 2009. A summary of Research into the Effects of Mountain Pine Beetle Related Stand Mortality on Snow Accumulation and Ablation in BC. Paper presented at Western Snow Conference

Wise, M.P., G.D., Moore, and D.F. VanDine (editors), 2004. Landslide risk case studies in forest development planning and operations. B.C. Min. For. Res. Br., Victoria, B.C. Land Management Handbook No. 56.

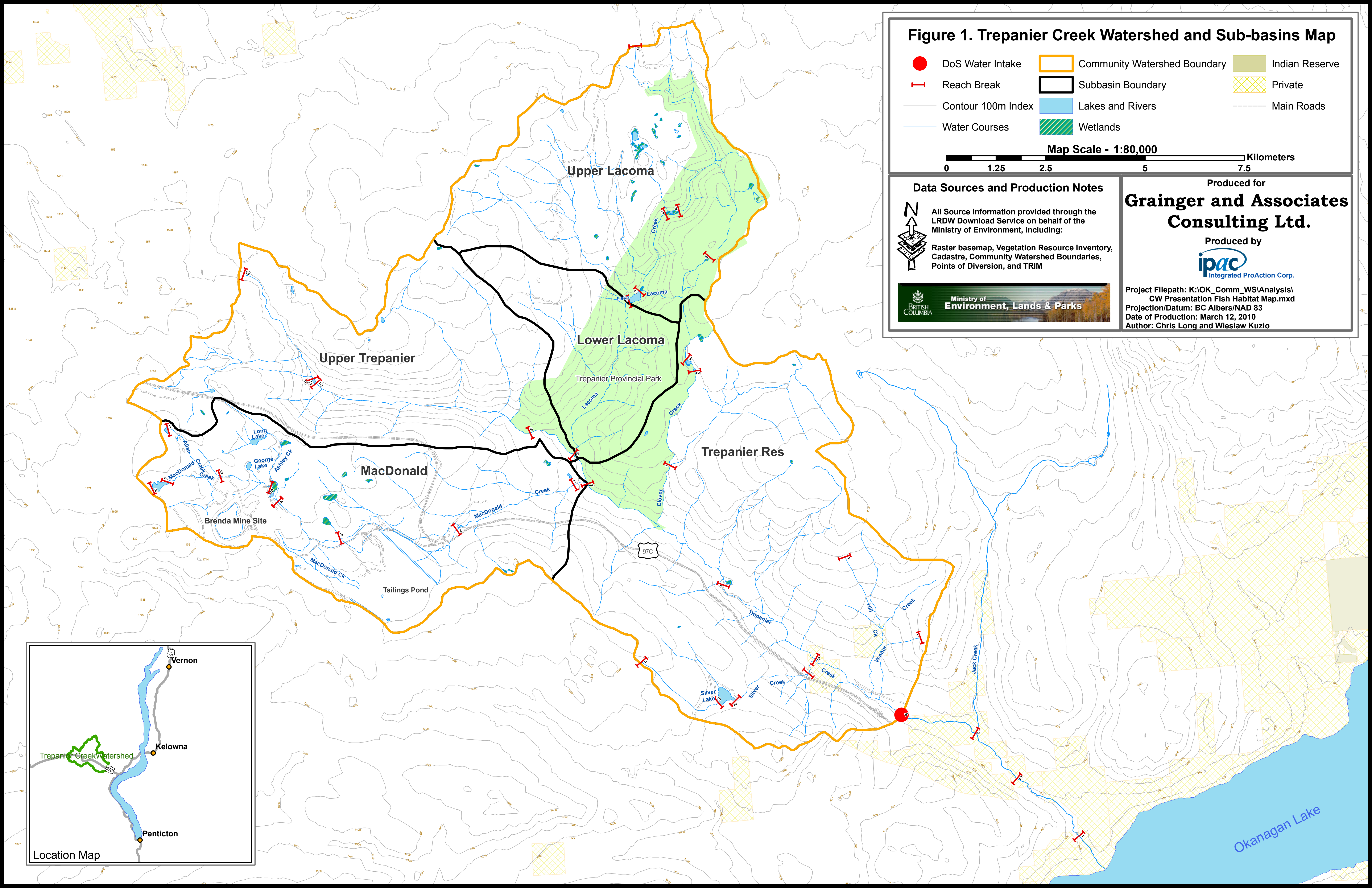

Figure 1. Trepanier Creek Watershed and Sub-basins Map
DoS Water Intake
Reach Break
Contour 100m Index
Water Courses
Community Watershed Boundary
Subbasin Boundary
Lakes and Rivers
Wetlands
Indian Reserve
Private
Main Roads
Map Scale - 1:80,000
0
1.25
2.5
5
7.5
Kilometers
Data Sources and Production Notes
N
All Source information provided through the LRDW Download Service on behalf of the Ministry of Environment, including:
Raster basemap, Vegetation Resource Inventory, Cadastre, Community Watershed Boundaries, Points of Diversion, and TRIM
British Columbia
Ministry of Environment, Lands & Parks
Produced for
Grainger and Associates Consulting Ltd.
Produced by
ipac
Integrated ProAction Corp.
Project Filepath: K:\OK_Comm_WS\Analysis\CW Presentation Fish Habitat Map.mxd
Projection/Datum: BC Albers/NAD 83
Date of Production: March 12, 2010
Author: Chris Long and Wieslaw Kuzio
Upper Lacoma
Lower Lacoma
Upper Trepanier
MacDonald
Trepanier Res
Trepanier Provincial Park
Lacoma Lake
Lacoma Creek
Clover Creek
Long Lake
George Lake
Ashley Ck
Allan Creek
MacDonald Creek
MacDonald Ck
Brenda Mine Site
Tailings Pond
97C
Trepanier Creek
Hill Ck
Venner Creek
Silver Lake
Silver Creek
Jack Creek
Okanagan Lake
Location Map
Vernon
Kelowna
Penticton
Trepanier Creek Watershed

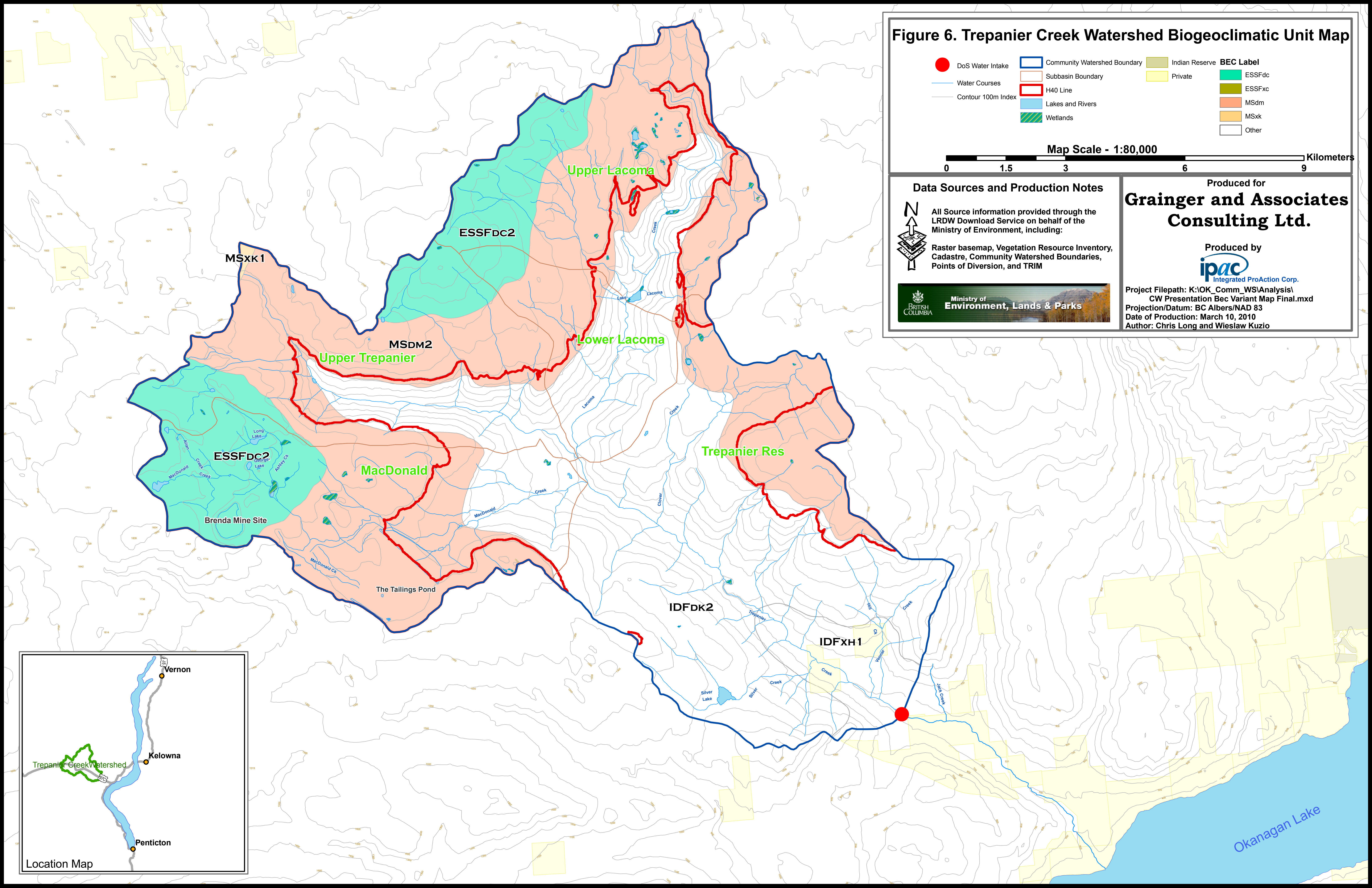

Figure 6. Trepanier Creek Watershed Biogeoclimatic Unit Map

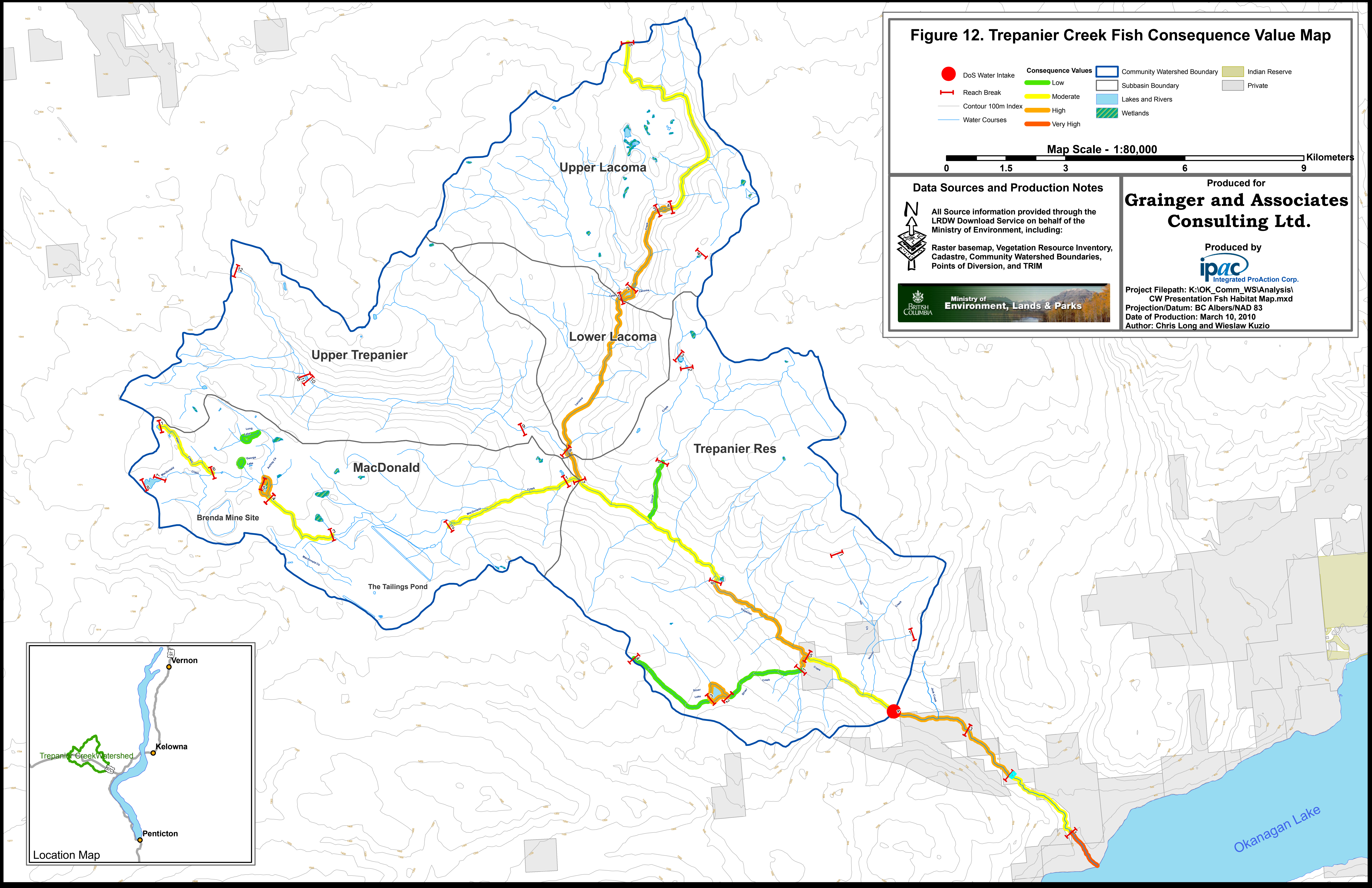

Figure 12. Trepanier Creek Fish Consequence Value Map
DoS Water Intake
Reach Break
Contour 100m Index
Water Courses
Consequence Values
Low
Moderate
High
Very High
Community Watershed Boundary
Subbasin Boundary
Lakes and Rivers
Wetlands
Indian Reserve
Private
Map Scale - 1:80,000
0
1.5
3
6
9
Kilometers
Data Sources and Production Notes
N
All Source information provided through the LRDW Download Service on behalf of the Ministry of Environment, including:
Raster basemap, Vegetation Resource Inventory, Cadastre, Community Watershed Boundaries, Points of Diversion, and TRIM
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Projection/Datum: BC Albers/NAD 83
Date of Production: March 10, 2010
Author: Chris Long and Wieslaw Kuzio
Upper Lacoma
Lower Lacoma
Upper Trepanier
Trepanier Res
MacDonald
Brenda Mine Site
The Tailings Pond
Okanagan Lake
Location Map
Vernon
Kelowna
Penticton
Trepanier Creek Watershed

PHOTOS

Photo 1. Broad gently sloping upland plateau of Trepanier Creek watershed.

Photo 2. Lacoma Lake and Upper Lacoma Creek in Trepanier Provincial Park (Reach 5) incised into surrounding plateau, with some talus sideslopes.

Photo 3. Deep scour in erodible sand and gravel glaciofluvial sediments caused by redirected drainage from Brenda Mine site in MacDonald Creek drainage.

Photo 4. Sand deposits in cobble stream bed in Trepanier mainstem Reach 4, 10km downstream of MacDonald Creek confluence.

Photo 5. Trepanier Creek on inhabited fan, Hwy 97 in foreground. Note riparian vegetation zone of one tree on north side of channel (right side in photo) and little substantial vegetation on south side.

Photo 6. Brenda Mines tailings pond in MacDonald Creek sub-basin, looking east towards Okanagan Lake. Trepanier Creek valley is on upper left of photo.

Photo 7. Trepanier Creek Reach 7. Moderately aggraded with elevated bars and intact riparian vegetation.

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Photo 8. Trepanier Creek Reach 4. Cobble bed with lag boulders (and sand – see Photo 4).

Photo 9. Trepanier Creek Reach 2, bedrock canyon.

Photo 10. Forestry road crossing of Trepanier Creek 1.4 km upstream of DOP intake. Steel span bridge with lock block abutments.

Photo 11. Private bridge with collapsed stringer visible under bridge deck compromising crossing capacity. Note gravel pushed into the creek from private property.

Photo 12. Beach Avenue bridge on the shoreline of Okanagan Lake. Limited bridge capacity could be reduced by channel aggradation on the fan

Appendix A:

Risk Analysis Definitions

Appendix A: Risk Analysis Definitions

Risk is defined as the product of hazard and consequence:

Hazard x Consequence = Risk

In this report, hazards are the likelihood of specific hydrological changes in the watershed due to MPB infestation and salvage harvesting-related modifications in watershed forest cover.

Consequences are the presence of some element of value, such as a "sufficient and reliable supply of safe and aesthetically acceptable water" at the District of Summerland intake, which could be impacted by a specific hydrologic hazard. Where the risk analysis focuses on a hazard which will impact a particular element, but does not include details of the vulnerability, robustness or economic value of the element, it is known as a "partial risk analysis" (Wise, *et al.,* 2004).

Where the vulnerability and/or the value of the element are considered, the analysis is referred to in this report as the incremental risk. For instance in this report the vulnerability of infrastructure such as bridges, etc., are considered. Incremental means an increase in risks due to the specific hazard and its ultimate source, which in this case are MPB-related stand mortality and associated salvage harvesting.

In all cases the hazards and consequence ratings are qualitative. Hazard ratings are expressed as very low, low, moderate, high or very high. As shown in Table 1, these can be understood as meaning the specific hazardous event is rare, unlikely - but possible, possible - may or may not occur, likely to occur and very likely or almost certain to occur, respectively. Consequence ratings are also expressed as very low to very high (5 classes - Table A1) or as low to high (3 classes), if there is not enough known about the element at risk to realistically discern more than 3 levels of its environmental or social value and/or vulnerability.

Table A1. Risk matrix with 5 hazard and consequence classes.

Hazard - Likelihood of Occurrence	**Consequence**				
	Very Low (insignificant)	**Low** (minor)	**Medium** (medium)	**High** (major)	**Very High** (catastrophic)
Very High (almost certain)	Moderate	High	High	Very High	Very High
High (likely)	Moderate	Moderate	High	Very High	Very High
Moderate (possible)	Low	Low	Moderate	High	High
Low (unlikely, but possible)	Very Low	Very Low	Low	Moderate	Moderate
Very Low (rare or unknown)	Very Low	Very Low	Low	Low	Moderate

Adapted from Wise, *et al*., 2004.

Table A2. Risk matrix with 5 hazard and 3 consequence classes.

Hazard	**Consequence**		
	Low	**Moderate**	**High**
Very High	High	Very High	Very High
High	Moderate	High	Very High
Moderate	Low	Moderate	High
Low	Very Low	Low	Moderate
Very Low	Very Low	Very Low	Low

The description of qualitative risk terms are similar to hazard descriptions; a very low risk means any impact or damage to the element at risk is very unlikely, a low risk means minor impact or damage could occur but is not considered likely, a moderate risk means some impact or damage may or may not occur, a high risk means that significant impact or damage to the element at risk is considered likely, and a very high risk means very significant impacts or damage are considered very likely.

There are other risk matrices in common use. Table A3 is a 5 x 5matix used by B.C. Ministry or Health and B.C. Ministry of Environment is the Comprehensive Drinking Water Source to Tap Assessment Guideline (MoH, 2005). In that matrix risk ratings are weighted towards the consequence values and the resulting risk ratings are more conservative (higher risk rating) than Tables A1 and A2, which are used in this report.

Table A3. Risk matrix suggested in Comprehensive Drinking Water Source to Tap Assessment Guideline

		Consequence				
Hazard - Likelihood of Occurrence		Insignificant (1) VL	Minor (2) L	Medium (3) M	Major (4) H	Catastro-phic (5) VH
Almost Certain (A)	VH	M	H	VH	VH	VH
Likely (B)	H	M	H	H	VH	VH
Possible (C)	M	L	M	H	VH	VH
Unlikely (D)	L	L	L	M	H	VH
Rare (E)	VL	L	L	M	H	H

Adapted from MoH, 2005.

The accompanying report provides a qualitative evaluation of potential hydrologic hazards associated with MPB attack and salvage harvesting. Suggestions as to qualitative values that could be applied specific consequences are made in this report, so that a risk analysis procedure for the specific hazards can be presented. However the final determination of consequence values, the risk analysis methodology and risk matrix used are the responsibility of watershed stakeholders. Risk assessment, which uses the risk analysis results and includes a determination of what level of risk is acceptable, and what steps should be taken to mitigate that risk, is entirely the responsibility watershed stakeholders.

Appendix B:

Summary of South Okanagan Stand Survey Results.

Prepared by Dave Huggard.

Summary of Results from South Okanagan Stand Surveys for MPB-ECA Modeling

Data summary by David Huggard (Jan 2009). From field data collection by Stuart Parker (Nov-Dec 2008) for Grainger and Associates Consulting Ltd.

Executive Summary

This field study measured overstory composition and understory density in 30 stands, representing 6 major pine-leading stand types in MSdm and ESSFdc forest, which comprise most of hydrologically important upper elevations of the south Okanagan watersheds studied. The field study is one component of projecting effects of mountain pine beetle (MPB) and salvage on hydrological equivalent clearcut area (ECA). At least 8 plots per stand, for a total of 245 plots, were used to measure total and well-spaced densities (stems per hectare, sph) of seedlings, saplings and poles by species, and basal area of overstory by species, following suggested provincial methods for surveying “secondary structure”. MPB attack status of overstory pines was also recorded.

In ESSF, the 7 surveyed stands labelled as pure pine or pine-leading were found to have only 30% pine basal area, with spruce and subalpine fir equally common. [This is not due to MPB mortality, because MPB-killed pine were included in these surveys.] Older (>110 yr) pine-leading stands in the MS averaged 65% pine, with a mix of subalpine fir, spruce and Douglas-fir. Mid-seral (<110 yr) pine-leading stands in MS were closer to 90% pine.

Understory densities ranged from high in ESSF to moderately high in older MS to moderately low in mid-seral MS. Counting only trees >1.3m tall that meet spacing and acceptability criteria for good stocking, and excluding lodgepole pine poles (>7.5cm dbh) because these may be killed by MPB, understory densities in ESSF averaged nearly 1000 sph. In MS stands >110yr old, density of these well-spaced understory trees averaged 560 sph, while mid-seral MS stands had 280 sph.

In terms of stocking of individual plots, 60% of ESSF plots had at least 1000 well-spaced sph, somewhat higher than the 40% of plots stocked at this level in Kamloops area ESSFdc (Vyse et al. 2007). In MS >110 yr, 30% of plots had at least 1000 well-spaced sph, while 65% had at least 400 well-spaced sph. Only 11% of mid-seral MS plots were stocked at 1000 well-spaced sph, while 32% were stocked at 400 well-spaced sph. These MS values are also comparable to results from Vyse et al. in Kamloops area MS stands (15-39% of plots stocked at 1000 sph, 40-70% at 400 sph).

Overall, these surveys suggest that ESSF stands should show little effect of MPB on ECA, because of dominant non-pine overstory and high understory stocking. Older pine-leading MS stands will also receive a substantial contribution to reducing post-MPB ECA from non-pine overstory and a substantial understory. Mid-seral (<110 yr) MS stands will have only a small initial contribution due to limited non-pine overstory and moderately low understory levels, although the existing understory will help speed up post-MPB recovery. As in other areas that have been surveyed in the Southern Interior, non-pine overstory and existing understory are important components of pine-leading stands in the southern Okanagan highlands.

The effects on ECA projections of non-pine overstory and existing understory – along with other stand components – are presented in detail in a separate report. An example of a plot showing the ECA projections for MPB attacked stands and clearcut salvaged attacked stands used in modeling watershed ECA projections for South Okanagan Community Watersheds follows this summary.

Summary of Results from South Okanagan Stand Surveys for MPB-ECA Modeling

Purposes: This study was undertaken to provide information on:

1. Canopy composition,
2. Understory trees,
3. Current status of mountain pine beetle (MPB) attack,

in pine-leading stands in the south Okanagan highlands[1], as part of a project evaluating the effects of MPB and salvage options on hydrological equivalent clearcut area (ECA). The project focused on 6 combinations of age and reported pine percentages in mature pine-leading stands in ESSFdc1 and 2, and MSdm1 and 2. Canopy composition and existing understory are important parameters in projecting MPB effects on ECA and the relative short- and long-term benefits of salvaging and planting versus leaving affected stands unsalvaged. Information on percentages of pine and non-pine canopy species is provided by forest cover maps, but can be of low reliability. Understory surveys in pine-leading stands have been conducted in MS and ESSF in adjacent areas, but in the absence of local surveys, opinions about understory were diverse for the south Okanagan pine-leading stands. The information on current MPB attack allows ECA projections to start at current conditions in each watershed.

Methods

Sample design

Six stand types compose the majority of the pine-leading stands in the hydrologically important upper elevations of the south Okanagan watersheds (Table 1).

Table 1. Six stand types sampled in the higher elevations of south Okanagan watersheds.

BEC subzone	Pine (VRI %)	Age (yr)	Percent of total Pl area	Polygons	Plots
ESSFdc	100	70-130	6.7	4	32
	<80	>130	4.7	3	24
MSdm	100	70-110	22.9	8	64
	100	>110	25.2	10	85
	<90	70-90	2.4	2	16
	<80	>150	6.0	3	24
			68.0	30	245

A total of 30 forest cover polygons to sample were chosen randomly from the set of relatively accessible stands of these types, with effort roughly proportional to the area of each type. Polygons were on both sides of Okanagan Lake (ESSFdc1 and MSdm1 on the east side, ESSFdc2 and MSdm2 on the west side).

Field measurements

At least eight plots spaced 50m apart were surveyed in each polygon for a total of 245 plots. In each plot, seedlings (0.3-1.3m tall), saplings (>1.3m tall to 7.5cm dbh) and poles (7.5-15cm dbh) were measured in 3.99m-radius plots. Total and well-spaced undamaged stems were tallied by species for each layer. With the size of the plot, there is a maximum of 8 well-spaced stems per plot (=1600 stems per hectare). Canopy trees (≥15 cm dbh) were counted by species using a BAF 2 prism. Status of attack by mountain pine beetles was recorded for canopy pines: none, green attack, red attack or grey attack.

[1] The study area includes the Mission, Hydraulic, Penticton, Lambley, Trepanier, Peachland and Trout Creek Community Watersheds.

Analysis

Results from the two variants of each subzone were combined, because there were limited samples in each and no obvious differences in the results.

Species composition of the canopy was summarized for each plot, then averaged for each polygon, and finally the polygons were averaged within a stand type. Percent composition was based on basal area (BA), because that was provided by the prism plots. BA is assumed to provide a reasonable representation of canopy composition, which is directly relevant to ECA.

Density of each species, of all non-pine species, and of all species combined was calculated for each plot, then averaged for the polygon, separately for seedlings, saplings and poles, for sapling+poles combined and for all three layers combined. Averages and standard errors (SE) in a stand type were calculated. For saplings and poles, these values were calculated separately for all trees, and for well-spaced trees. Additionally, the density of all species of saplings plus all species of poles *except* lodgepole pine were also summarized, for all trees and just well-spaced trees. This value is probably the most relevant for regeneration after MPB (which is assumed to kill the pole-size lodgepole pine). This total density was summarized by stand type, and also by the combination of stand type and watershed (allowing watersheds to be compared within any stand types that they share).

Following the approach of Coates et al. (2006) and Vyse et al. (2007)[2], we also summarized the proportion of plots in each stand type that were stocked at minimum levels from 200 stems per hectare (sph), 400 sph…through 1600 sph. This was done separately for all understory layers combined (seedlings, saplings, poles), saplings+poles combined, and for well-spaced saplings+poles. These values were compared to results from Vyse et al. in ESSF and MS subzones in the Kamloops area, and to stocking results from Nigh et al. (2008)[3].

The percentage of canopy lodgepole pine in four MPB attack stages – no attack, green, red and grey attack – was summarized by stand type and also by the combination of stand type and watershed.

Results

Canopy composition

The two ESSF stand types, including stands labelled 100% pine, had roughly equal basal areas of pine, spruce and subalpine fir (Table 2). Even in stands labelled as pure pine, the maximum percentage of pine in the canopy was 63.7%, while one of these stands had no pine. The prevalence of non-pine canopy suggests that MPB will have only small effects on ECA in ESSF stands in this area. [Note: Pines killed by MPB were included in these canopy surveys, so the results are not due to pine being removed by MPB.]

In the MS, stands labelled as 100% pine had 86.3% and 74.0% pine basal area, for mid-seral and mature stands, respectively. The stands >110 years had a larger component of

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[2] Coates, K.D., C. Delong, P. Burton and D. Sachs. 2006. Draft Interim Report. Abundance of Secondary Structure in Lodgepole Pine Stands Affected by the Mountain Pine Beetle. Bulkley Valley Centre for Natural Resources Research and Management 22 p.
Vyse, A., C. Ferguson, D. Huggard, J. Roach and B. Zimonick. 2007. Regeneration below lodgepole pine stands attacked or threatened by mountain pine beetle in the Kamloops Timber Supply Area. Thompson Rivers University, Kamloops, BC. Available from Alan Vyse or Dave Huggard.

[3] Nigh, G.D., J.A. Antos and R. Parish. 2008. Density and distribution of advance regeneration in mountain pine beetle killed lodgepole pine stands of the Montane Spruce zone of British Columbia. Can. J. For. Res. 38:2826-2836. They present total trees for each of their plots, but include trees down to 10cm height. They also provide information on the overall proportions of trees in each height class. An approximate idea of the stocking of saplings+poles in each plot was obtained by assuming that the overall proportion of trees 1-10m tall (24.8% of understory trees) applied to each plot. Results were combined for dry, mesic and wet sites, as these shared a similar range of variation in plot-level stocking.

subalpine fir and spruce than the 70-100year stands. Mid-seral stands labelled as having <90% pine averaged 91.1% pine, with Douglas-fir being the other substantial component in the two sampled stands. In contrast, the three mature stands labelled as <80% pine averaged 33.0% pine basal area, with subalpine fir, spruce and Douglas-fir all common. The non-pine components will make at least a moderate contribution to reducing ECA effects of MPB in MS, even in "pure pine" stands.

Table 2. Canopy composition in six pine-leading stand types.

	Stand type		Canopy composition (%BA)				Pl range (%)		
BEC	Pine (%)	Age (yr)	Pl	Bl	Sx	Fd	Min	Max	n
ESSFdc	100	70-130	33.3	35.5	31.2	0.0	0.0	63.7	4
ESSFdc	<80	>130	26.8	31.2	42.0	0.0	25.0	29.7	3
MSdm	100	70-110	86.3	8.6	3.9	0.2	62.9	100.0	8
MSdm	100	>110	74.0	11.0	12.3	2.6	30.6	100.0	10
MSdm	<90	70-90	91.1	1.8	0.8	6.3	83.7	98.4	2
MSdm	<80	>150	33.0	36.4	19.0	11.5	24.7	39.2	3

Notes: MSdm 100% 70-110yrs and >110yrs contained 0.9% and 0.2% aspen, respectively

Stage of mountain pine beetle attack

MPB appears to have begun to attack the surveyed mid-seral ESSF stands only recently, with 89.8% of mature pines not attacked, and more green attack than red or grey (Table 3). Attack rates are also still low in the older ESSF stand type, with 73.3% of pines not attacked. In older ESSF, though, the attack began a few years ago, with equal amounts of grey and red attacked trees.

Attack rates are somewhat higher in most MS stands, with a mix of older versus more recent attack stages in the different types. The old, mixed species stands, despite not having a high percentage of pine, had high rates of attack, with only 15.5% of pines not attacked.

Table 3. Percentage of canopy lodgepole pine (Pl) in different stages of mountain pine beetle attack, by stand type.

	Stand type		Pl Attack status (%)			
BEC	Pine (%)	Age (yr)	None	Green	Red	Grey
ESSFdc	100	70-130	89.8	5.0	1.4	3.8
ESSFdc	<80	>130	73.3	1.8	12.3	12.7
MSdm	100	70-110	68.5	13.7	10.6	7.1
MSdm	100	>110	64.0	9.1	16.2	10.7
MSdm	<90	70-90	73.6	0.9	15.1	10.4
MSdm	<80	>150	15.5	19.2	39.4	25.9

Much of the variation in attack rates in MS stand types seems to be due to different amounts of MPB in different watersheds (and the fact that stand types are not equally spread across the watersheds.) The Bear Lambly watershed had very few pines that were not attacked, even in ESSF where MPB activity was otherwise low (Table 4). Except in the ESSF, the Trepanier watershed also had high attack rates, but with a higher percentage of recent green attacked pines than Bear Lambly. The Peachland watershed had moderate attack rates, while attack rates are still low in the Hydraulic, Mission and Trout watersheds. Although, these results are based on only 1 or 2 stands in each stand type in each watershed, they agree with MPB survey results for the watersheds provided by Ministry of Forests and Range.

Table 4. Percentage of canopy lodgepole pine (Pl) in different stages of mountain pine beetle attack, by stand type and watershed.

BEC	Stand type Pine (%)	Age (yr)	Watershed	Pl Attack status (%) None	Green	Red	Grey
ESSFdc	100	70-130	Penticton	84.6	7.5	2.1	5.8
			Trepanier	100.0	0.0	0.0	0.0
ESSFdc	<80	>130	Bear Lambly	31.6	5.3	36.8	26.3
			Mission	100.0	0.0	0.0	0.0
			Penticton	88.2	0.0	0.0	11.8
MSdm	100	70-110	Hydraulic	70.0	14.3	7.9	7.8
			Trepanier	43.8	25.2	17.3	13.7
			Trout	92.2	2.0	5.8	0.0
MSdm	100	>110	Bear Lambly	5.6	0.0	61.1	33.3
			Hydraulic	95.7	0.0	2.2	2.2
			Mission	71.4	22.2	3.2	3.2
			Peachland	47.6	14.2	19.9	18.3
			Trepanier	0.0	34.5	41.4	24.1
			Trout	92.1	2.1	4.0	1.9
MSdm	<90	70-90	Peachland	100.0	0.0	0.0	0.0
			Trepanier	47.2	1.9	30.2	20.8
MSdm	<80	>150	Bear Lambly	13.2	10.5	39.5	36.8
			Peachland	33.3	25.0	41.7	0.0
			Trepanier	0.0	22.2	37.0	40.7

Densities of understory trees

Saplings were roughly 3 times as abundant as pole-sized understory trees overall, except in mid-seral MS stands where saplings were rarer (Table 5). Saplings tend to be clustered more than poles, so that *well-spaced* saplings and poles are about equally common.

Non-pine understory trees were most common in ESSF, with about 2500 stems per hectare, of which almost 1000 sph are well-spaced (Table 5). Subalpine fir is dominant. The understory in these stands is close to “well-stocked”. There are few understory pines in these stands.

Well-spaced non-pine understory is fairly sparse in mid-seral MS stands, with 213 or 281 well-spaced sph in the two mid-seral stand types (Table 5). There is, however substantial pine understory in these types, raising the density of well-spaced understory trees to 413 or 688 sph. Well-spaced understory trees are denser in older MS, dominated by subalpine fir. Well-spaced totals for all species are 600 and 726 sph in the two types of older MS. All these values only include trees >1.3m height.

Table 5. Densities of poles, saplings and poles+saplings combined (with SE), total and well-spaced (WS), by species and stand type.

Stand type				Lodgepole pine (/ha)		Subalpine fir (/ha)		Spruce (/ha)		All non-pine (/ha)		All species (/ha)	
BEC	Pine (%)	Age (yr)	Layer	Total	WS	Total	WS	Total	WS	Total	WS	Total	WS
ESSFdc	100	70-130	poles	13 (13)	6 (6)	544 (112)	319 (28)	106 (41)	44 (12)	650 (126)	363 (30)	663 (139)	369 (26)
			saplings	0	0	1663 (444)	513 (82)	131 (62)	75 (42)	1794 (484)	588 (118)	1794 (484)	588 (118)
			combined	13 (13)	6 (6)	2206 (384)	831 (90)	238 (51)	119 (37)	2444 (407)	950 (117)	2456 (401)	956 (113)
ESSFdc	<80	>130	poles	50 (29)	17 (17)	442 (51)	308 (58)	108 (85)	100 (76)	550 (52)	408 (22)	600 (80)	425 (38)
			saplings	0	0	1833 (639)	508 (60)	208 (123)	67 (55)	2067 (517)	583 (68)	2067 (517)	583 (68)
			combined	50 (29)	17 (17)	2275 (652)	817 (106)	317 (205)	167 (131)	2617 (467)	992 (88)	2667 (443)	1008 (101)
MSdm	100	70-110	poles	647 (285)	397 (152)	75 (26)	59 (23)	69 (42)	56 (32)	153 (67)	119 (55)	800 (275)	516 (147)
			saplings	206 (120)	9 (7)	225 (130)	109 (52)	131 (58)	53 (23)	356 (162)	163 (64)	563 (170)	172 (62)
			combined	853 (403)	406 (155)	300 (153)	169 (72)	200 (75)	109 (39)	509 (222)	281 (110)	1363 (408)	688 (161)
MSdm	100	>110	poles	276 (129)	177 (95)	148 (67)	120 (54)	41 (14)	35 (14)	189 (69)	155 (56)	465 (127)	332 (92)
			saplings	25 (11)	5 (5)	934 (252)	366 (85)	36 (13)	23 (7)	970 (257)	390 (85)	995 (255)	395 (84)
			combined	301 (130)	182 (95)	1081 (288)	487 (124)	77 (23)	58 (18)	1159 (299)	545 (127)	1459 (259)	726 (114)
MSdm	<90	70-90	poles	325 (250)	188 (138)	150 (150)	117 (117)	13 (13)	13 (13)	225 (100)	150 (25)	550 (350)	338 (163)
			saplings	25 (25)	13 (13)	525 (475)	50 (25)	88 (88)	13 (13)	613 (563)	63 (38)	638 (588)	75 (50)
			combined	350 (275)	200 (150)	675 (625)	138 (113)	100 (75)	25	838 (663)	213 (63)	1188 (938)	413 (213)
MSdm	<80	>150	poles	8 (8)	0	225 (66)	175 (66)	50 (29)	50 (29)	275 (88)	225 (88)	283 (92)	225 (88)
			saplings	0	0	1458 (512)	358 (179)	92 (92)	17 (17)	1550 (603)	375 (189)	1550 (603)	375 (189)
			combined	8 (8)	0	1683 (567)	533 (243)	142 (96)	67 (33)	1825 (663)	600 (277)	1833 (660)	600 (277)

Notes: MSdm <90% pine, 70-90yrs also included 63 Fd poles/ha, with 50/ha well-spaced
A few cedars and aspens (not shown) occurred in the understory at a few sites.
WS = well-spaced

A heavy MPB infestation can kill pole-sized lodgepole pine. The best summary of surviving understory densities expected after severe MPB is therefore sapling and poles of non-pine species, plus saplings only of lodgepole pine. Densities of this group are around 2500 sph in ESSF, 1800 sph in old MS, declining to about 800 in mid-seral MS (Table 6). ESSF has nearly 1000 well-spaced sph of this group, older MS has about 600 sph and mid-seral MS has 250 sph. These levels could be described as “almost stocked”, “half stocked” and “mostly unstocked”, respectively.

Table 6. Total and well-spaced (WS) densities of saplings+poles combined, but excluding lodgepole pine poles (with SE).

Poles+Saplings total density (no Pl poles)

	Stand type		Pole+Sapling density (/ha; no Pl poles)	
BEC	**Pine (%)**	**Age (yr)**	**Total**	**WS**
ESSFdc	100	70-130	2444 (407)	950 (117)
ESSFdc	<80	>130	2617 (467)	992 (88)
MSdm	100	70-110	716 (215)	291 (107)
MSdm	100	>110	1184 (298)	550 (126)
MSdm	<90	70-90	863 (688)	225 (75)
MSdm	<80	>150	1825 (663)	600 (277)

Note: WS = well-spaced

Plot-level stocking distribution

The above values are stand-level averages. It is also important to look at what proportions of individual plots are stocked to different stocking levels. The summaries include results for all understory layers (seedlings+saplings+poles), for just saplings+poles, and for well-spaced saplings+poles.

With all understory trees, or all saplings+poles, the majority of ESSF stands are stocked to the highest levels examined (1600 sph; Table 7). Over half of the plots in ESSF stand types are stocked to 1000 sph with well-spaced trees[4]. The stocking levels are moderately higher than levels reported by Vyse et al. for ESSFdc3 stands in the Kamloops area. [Note: Vyse et al. reported on “acceptable trees”, based on height, stem form and lack of disease, but no spacing criterion, so these results are not completely comparable to the well-spaced densities reported here.]

Table 7. Percentage of individual plots in ESSF that are stocked to different levels (stems per hectare, SPH), for all understory layers (seedling+sapling+poles), saplings+poles only, and well-spaced saplings+poles, with comparison to results from Vyse et al.

ESSF						Percent of plots with understory density >= specified SPH							
Study	**BEC**	**Pine (%)**	**Age (yr)**	**Plots**	**Layers**	**200**	**400**	**600**	**800**	**1000**	**1200**	**1400**	**1600**
This study	ESSFdc	100	70-130	32	All	97	97	94	91	91	91	91	91
					Saplings+Poles	97	97	91	84	81	78	66	66
					Saplings+Poles well-spaced	97	97	88	66	56	34	28	9
This study	ESSFdc	<80	>130	24	All	100	100	100	100	100	100	100	100
					Saplings+Poles	100	96	96	96	92	92	92	88
					Saplings+Poles well-spaced	96	92	83	79	63	46	25	13
Vyse et al	ESSFdc3	Pl leading	>60		All	100	100	100	100	100	100	100	100
					Saplings+Poles	100	92	72	64	56	48	36	36
					Saplings+Poles acceptable	84	64	56	48	40	36	20	20

[4] Given the plot size and the minimum spacing for a well-stocked tree, the maximum physically possible value for well-spaced stocking is 1600 sph.

In mid-seral MS stands, half the plots are stocked at 800 sph with all understory layers, but more than half the plots have <400 sph of well-spaced saplings+poles (Table 8). Older MS stands have more than half their plots stocked to 1600 sph with all layers, but half the plots have less than 600-800 sph of just well-spaced saplings+poles. 29% of plots in these older MS stands had <200 well-spaced sph. Vyse et al. found similar plot-level stocking distributions for the drier MSxk2, and moderately higher stocking in MSdm3 plots. Nigh et al. reported generally lower understory stocking in mature MS stands in the Merritt area[5].

Table 8. Percentage of individual plots in MS that are stocked to different levels (stems per hectare, SPH), for all understory layers (seedling+sapling+poles), saplings+poles only, and well-spaced saplings+poles, with comparison to results from Vyse et al. and Nigh et al.

MS Study	BEC	Pine (%)	Age (yr)	Plots	Layers	Percent of plots with understory density >= specified SPH: 200	400	600	800	1000	1200	1400	1600
This study	MSdm	100	70-110	64	All	73	66	53	50	47	38	33	25
					Saplings+Poles	69	58	44	36	30	22	19	16
					Saplings+Poles well-spaced	48	31	20	16	14	13	3	0
This study	MSdm	100	>110	85	All	86	75	69	64	61	58	55	53
					Saplings+Poles	76	67	58	48	46	44	39	32
					Saplings+Poles well-spaced	71	64	45	41	32	19	6	5
This study	MSdm	<90	70-90	16	All	81	69	56	50	44	31	31	25
					Saplings+Poles	81	63	44	38	31	31	19	19
					Saplings+Poles well-spaced	75	38	0	0	0	0	0	0
This study	MSdm	<80	>150	24	All	100	92	88	83	83	79	75	67
					Saplings+Poles	96	88	75	75	71	58	50	42
					Saplings+Poles well-spaced	71	67	54	46	25	17	13	8
Vyse et al	MSdm3	Pl leading	>60		All	97	96	96	95	92	92	92	89
					Saplings+Poles	91	82	69	58	55	51	49	43
					Saplings+Poles acceptable	88	70	57	45	39	27	26	22
Vyse et al	MSxk2	Pl leading	>60		All	94	83	75	64	56	51	46	42
					Saplings+Poles	81	62	48	40	31	23	18	14
					Saplings+Poles acceptable	60	40	29	24	15	11	7	5
Nigh et al	MS	>70	Mature	28	Saplings+Poles (approx)	61	39	25	14	7	7	7	7

[5] The Nigh et al. values are approximate calculated values that may not be equivalent to the survey results from this study or Vyse et al.

Appendix C:

Channel Sensitivity Methodology

Appendix C: Channel Sensitivity Methodology

Table C-1 (adapted from Green, 2005) is a framework for assigning channel sensitivity ratings based on characteristics from field, airphoto and map observations.

Alteration	Channel Sensitivity Rating (H, M, L)	Channel Attributes that May Contribute to Channel Sensitivity
Increased Peak Discharge and/or Flood Frequency	Low	▪ Channel experiences frequent natural, large peak flow events (e.g. steep watershed, rapid runoff, high snow pack). ▪ Channel has endured high flow events in the past with little evidence of long term change. ▪ Channel exhibits a natural resiliency to bank and bed scour/erosion (e.g. bedrock controls, extensive colluvial or lag deposits, well-vegetated, deep-rooted riparian vegetation). ▪ Abundant instream LWD, debris jams and lag boulders that augments channel and bank stability through energy dissipation. ▪ Frequent sizeable lakes, wetland areas and/or broad floodplain able to store significant water volume and attenuate flood peaks.
	Moderate	▪ Range or combination of attributes listed above and below.
	High	▪ Channel does not experience frequent flood events (dark mossy substrates, mature vegetation to high water mark). ▪ Relatively recent flood events (past 20 years) have caused significant disruption of channel and/or bank stability. ▪ Channel segments with fine textured banks and substrates that are susceptible to scour/erosion. ▪ Lacking in channel structure (e.g. instream LWD, lag boulders, bedrock) that would absorb flow energy. ▪ Little or no lakes, overflow channels, floodplain or low gradient wetland segments that would attenuate/store flood peaks.
Increased Sediment Delivery [Fine suspended and Coarse bedload sediment should be considered separately]	Low	▪ Channel experiences frequent high volumes of sediment delivery from upstream/upslope sources (e.g. numerous natural landslides, ravelling banks, naturally aggraded channel). ▪ Evidence of older, connected landslides and/or debris flows with minimal evidence of long term changes to channel stability. ▪ Abundant locations for sediment storage, such as frequent functioning debris jams or low gradient, unconfined sections that arrest bedload movement. ▪ Slow-flowing, meandering stream with insufficient power to transport bedload and allow some settling/filtering (e.g. frequent wetland segments). ▪ Stable/resilient banks that will resist widening following sediment storage/aggradation. ▪ Coarse sediment is easily passed through the channel system with minimal accumulations (in context of watershed, may lead to issues downstream – see notes).
	Moderate	▪ Range or combination of attributes listed above and below.
	High	▪ Channel does not experience frequent high volumes of sediment delivery from upstream/upslope sources (e.g. dark mossy substrates, deep pools, broadly graded substrates). ▪ Evidence of channel destabilization in response to isolated sediment events (e.g. older, connected landslides have caused aggradation/channel widening downstream). ▪ Channel has little or no sediment storage capacity such that increases in sediment delivery are likely to cause channel aggradation, lateral erosion and/or avulsion. ▪ Fine sediment is rapidly passed through with little opportunity for settling/filtering (reducing water quality downstream). ▪ Channel has frequent erodible banks that will allow channel widening in response to aggradation and contribute further sediment to the channel.
Decreased Riparian Function	Low	▪ Channel flows through area of naturally low-growing riparian vegetation (e.g. wetland, alpine area or avalanche pathway). ▪ Channel is not dependant on LWD to provide channel or bank stability (e.g. bedrock controlled, colluvial and/or lag deposits, steeper Step-Pool or Cascade-Pool morphology types). ▪ Channel has experienced localized decreased riparian condition in the past (e.g. wildfire, harvesting) with little indication of long term instability. ▪ Channel is not dependant on LWD to control bedload movement. ▪ Channel is not dependant on riparian vegetation to maintain fish habitat values, including instream LWD, food sources and/or stream temperature moderation.
	Moderate	▪ Range or combination of attributes listed above and below.
	High	▪ Channel is dependant on LWD to provide channel or bank stability (e.g. erodible banks, Riffle-Pool morphology type). ▪ Channel has experienced localized decreased riparian condition in the past (e.g. wildfire, harvesting) resulting in local destabilization. ▪ Channel is dependant on LWD to control bedload movement. ▪ Channel is dependant on riparian vegetation to maintain fish habitat values, including instream LWD, food sources and/or stream temperature moderation.

Appendix D:

Okanagan Flood Frequency Shift Analysis

Appendix D: Okanagan Flood Frequency Shift Analysis

Flood generation in nival watersheds is a complex process involving snow pack, forest cover, microclimatology and weather. Flood frequency curves may change with time due to changes in climate, land use (e.g., drainage improvement) and forest cover. Extensive literature reviews of research findings on the relationship between harvesting and peak flows, largely through paired-watershed studies, show great variability in results. There is no single variable – such as the amount of forest cover removed, harvesting system, etc. that allows for a quantitative description of changes in peak flows associated with timber harvesting (Scherer and Pike, 2003). This is because of the wide range of forest management histories, weather conditions and events, physical properties, forest cover types, watershed drainage characteristics, etc., as well as different analytical and statistical methods used in the many studies.

This study uses the results of several recent numerical modeling-based analyses of the relationship between forest canopy changes due to harvesting, MPB infestation, or both, and runoff regime. Numerical modeling removes some of the uncontrolled variables inherent in paired-watershed studies, such as weather history, and allows testing of various treatment hypotheses. In all cases, watershed models were calibrated using some period of existing climate and runoff data. Nonetheless, modeling watershed processes requires making many assumptions, which introduce uncertainties, especially when extrapolating from experimental watersheds to operational situations in different watersheds.

The modelling results for 11 nival Interior B.C. modelled watersheds were reviewed. Nine are in the south Okanagan: (Whiteman (112km^2), Vaseaux above Dutton (255km^2), Bellevue (73km^2), Camp (34km^2), Dave (31km^2), Vaseaux above Solco (112km^2), Pearson (74km^2), Ewer (53km^2) Creeks (Alilla et al. 2007) and 240(5 km^2) Creek (Schnorbus et al. 2004). Two are in the upper Fraser River basin (Naver Ck.(658 km^2 - Allila et al. 2007) and Baker Ck. (1570 km^2 – FPB 2007). They have different sizes, geographic locations, physical and climatic characteristics and treatments. Baker Ck. and 240 Ck. were modelled with the Distributed Hydrology Soil Vegetation Model (DHSVM) and the rest with the UBC Watershed Model (UBCWM).

Figures C-1 to C-3 show some of the watersheds modelled and the expected flood frequency shifts. 240 Creek is about 1/50 the size of Trepanier Creek and Baker Creek about six times as large.

Camp Creek results are similar to results for Naver Creek and the other mid-sized Okanagan watersheds modelled (Whiteman, Vaseaux 1 and 2, Bellevue, Dave, and Ewer Creeks). Camp Creek is a tributary of Trout Creek and is located about 9 km south of Trepanier Creek.

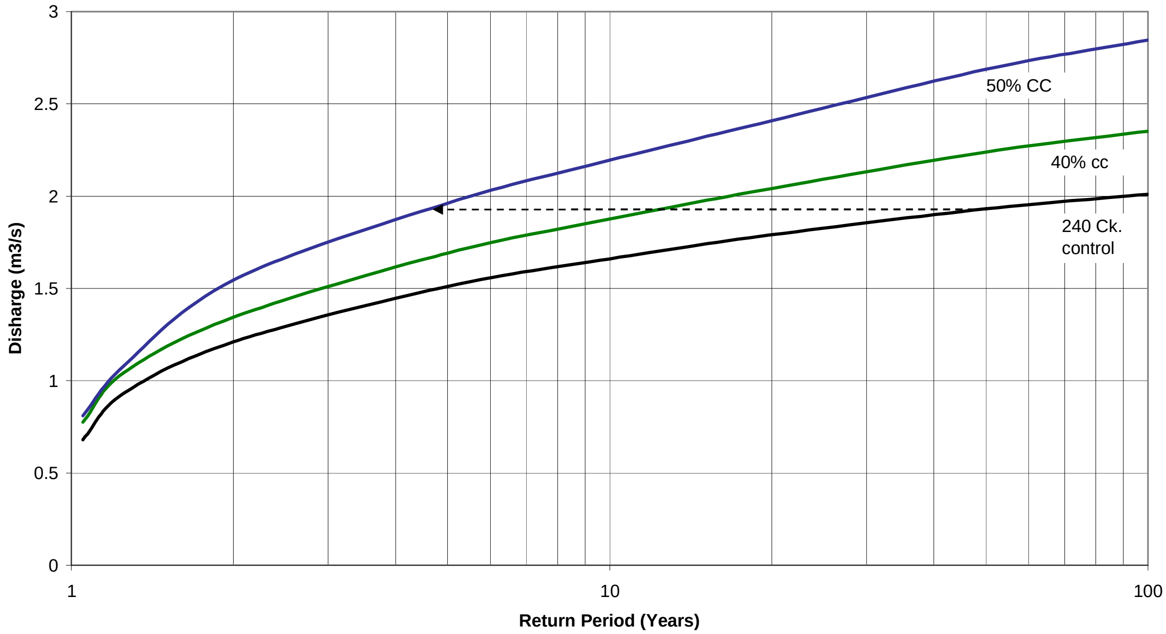

Figure C-1. Modelled flood frequency for 240 Creek, a 5km^2 tributary of Penticton Creek, with 40% and 50% clearcutting of upper watershed. With 50% clearcutting the 50 year flood would be expected to occur on average every 5 years. Data from Schnorbus *et al.* 2004.

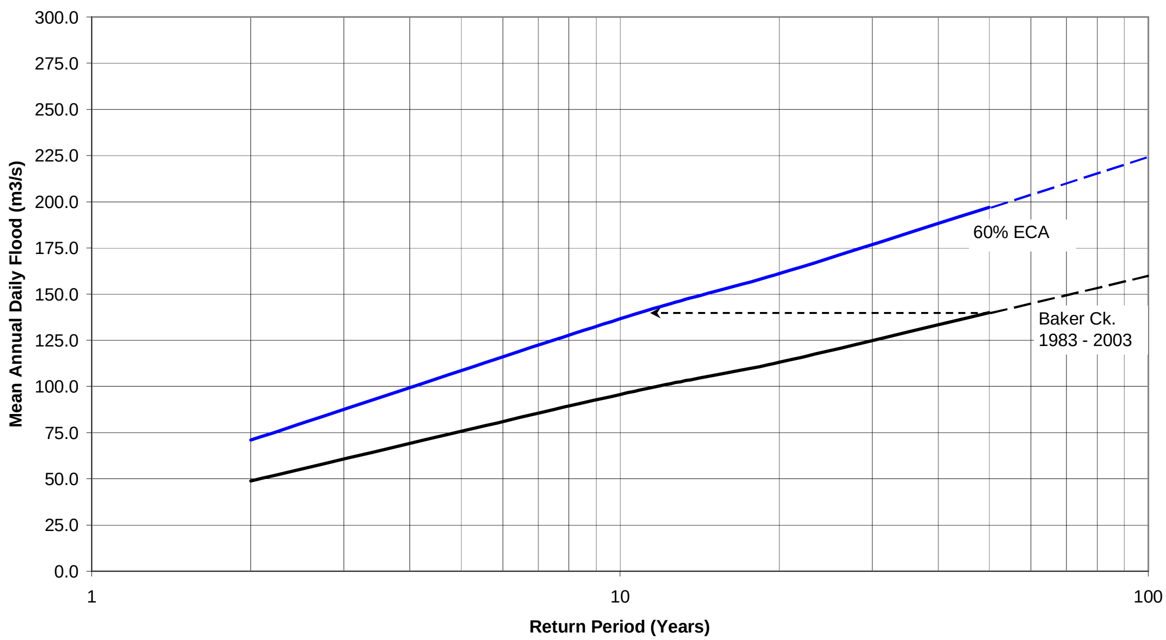

Figure C-2: Modelled flood frequency shift for Baker Creek (1570km^2) with approximately 60% ECA, from clearcutting and MPB pine mortality. The 50 year flood becomes about the post-treatment 11 year flood. Data from FPB 2007.

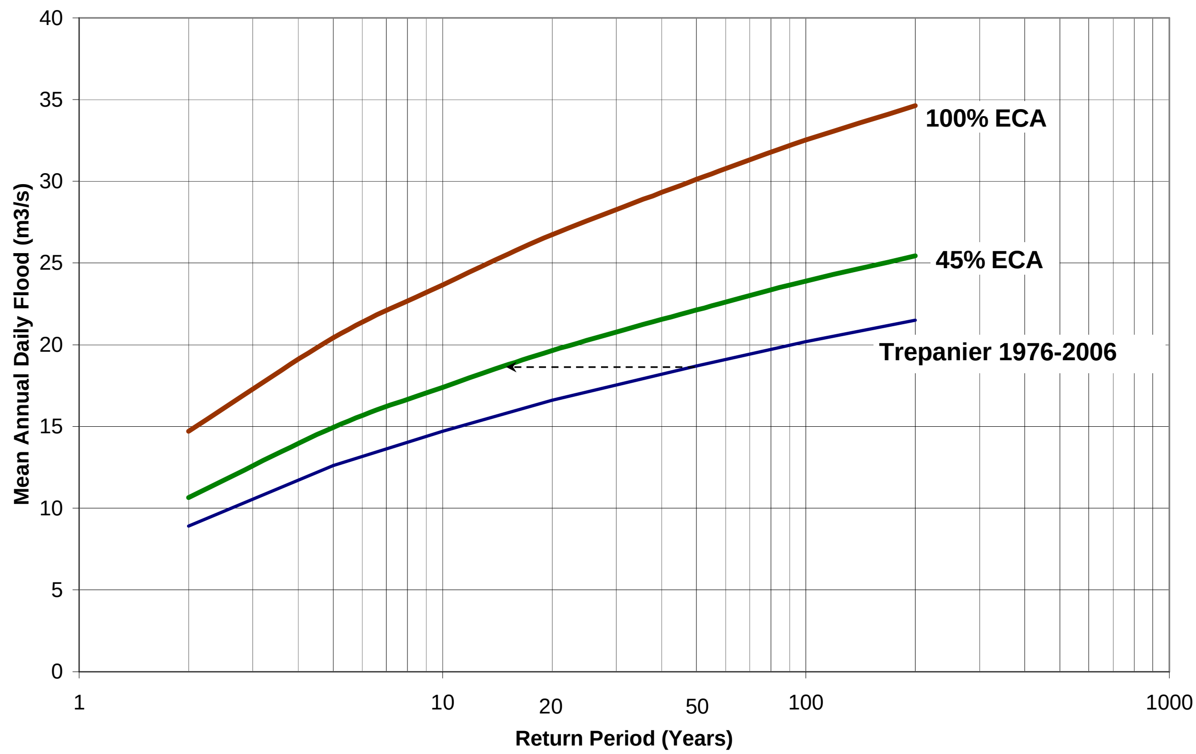

Figure C-3. Modelled flood frequency shift for Tepanier Creek, extrapolating from a "typical" Okanagan watershed (Allila, 2007) with a high (45%) ECA. The historic 50 year flood becomes the 15 year post-treatment flood for the 15 to 20 year period of sustained high ECA

To extrapolate to the expected flood frequency shift in Trepanier Creek, with the total salvage scenario having an extended ECA of around 45% (see Figure 10) all the modelled results would have to be scaled down (the amount of flood frequency shift reduced); because either the amount of clearcutting and the corresponding ECA is higher in the modelled watersheds, or the watershed area is smaller than Trepanier Creek. Smaller watersheds are generally more "flashy" than larger watersheds, and all else being equal, one could expect a smaller change in flood regime in larger watersheds. We also note the slight divergence between the control and treatment flood regimes, such that larger (longer return period) floods show somewhat larger increases in magnitude than smaller floods (Alila, *et al.* 2009)

Figure C-3 shows the expected flood frequency shift in Trepanier Creek if 100% of the watershed were clearcut (Allila et al. 2007); and the expected shift following salvage harvesting of all pine-leading stands in the watershed, which would result in a sustained ECA of 45% for 15 to 20 years. It is estimated that following total salvage harvesting the 50 year return period flood would be expected to occur on average every 15 years.

Appendix E:

Trepanier Creek Fish Values by Reach

Prepared by Michele Trumbley, R.P. Bio.

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March 31, 2009

RE: Fisheries Information on the Trepanier Creek Watershed as one of Seven Identified Okanagan Community Watersheds

TREPANIER CREEK WATERSHED

The Trepanier Creek watershed is situated on the west side of Okanagan Lake, north of the Peachland Watershed. The watershed has been delineated in to six sub-basins consisting of Trepanier Residual, Jack Creek Sub-basin, Lower Lacombe, Upper Lacombe, MacDonald Creek Sub-basin and Upper Trepanier Residual. Trepanier Creek (WSC[1] 310-742200) flows directly into Okanagan Lake and is fish bearing through to reach 10 of Trepanier Creek. Reach 11 of the mainstem is an unnamed lake which is documented as non-fish bearing and the headwaters as non fish bearing. A falls located 1.1km upstream of Okanagan Lake on Trepanier Creek is a barrier and considered the upper limit of Kokanee spawning. Rainbow Trout are documented upstream of the falls barrier in reach 1 of Trepanier. Law Creek, Jack creek, Venner Creek, Hill Creek, and Pigeon Creek are confirmed as non-fish bearing. Lacoma Lacoma Lake contains rainbow trout however; upstream of lake is noted as non fish bearing. Silver Lake (WBID 00954OKAN) has been stocked with fry rainbow trout annually from 1929-2008 with the exception of 1930, 1948, 1986, 1987. Trepanier Creek was also stocked with rainbow trout from 1928-1954 and with Kokanee in 1941. MacDonald Creek was stocked from 1940 to 2008 with the exception of 1959-1961, 1965, 1967-1970, 1981-81, 1983-85, 1990-1993 and 2001.
The fish and fish habitat investigation is one component of several factors used to develop an overall risk rating for MPB[2].

FISH SPECIES

Sport-fish[3] species within the watershed include Rainbow trout (*Oncorhynchus mykiss*) and Kokanee (*Oncorhynchus nerka*) have been identified in the lower reach of Trepanier Creek. Burbot (*Lota lota*) was captured in the lower reaches (200m upstream of Okanagan Lake) of Trapanier Creek (Taylor and Wightman 1978). Burbot are primarily lake spawners however, there is documentation of Burbot occasionally spawning in rivers (Scott and Crossman 1985).

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[1] WSC- Watershed code
[2] MPB – Mountain Pine Beetle
[3] Sport-fish as defined by the Forest Practices Code, Fish-Stream Identification Guidebook. pg 4.

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OBSTRUCTIONS

Obstructions to upstream fish migration include a falls located 1km upstream from Okanagan Lake, in reach 1 of Trepanier Creek which is the upstream limit of Kokanee spawning. A falls on reach 4 of Trepanier Creek may limit the upstream movement of fish; however rainbow trout are confirmed in the upper reaches of the watershed. A 1.5m falls is documented at the confluence of Trepanier Creek and MacDonald Creek that may restrict the upward migration of fish into MacDonald Creek; however MacDonald Creek has been stocked. The headwaters of MacDonald Creek have been impacted by mining activities, channelization and the creation of dams. An 8m dam at the outflow of Silver Lake (UTM 11-96075-5526672) restricts the upstream and downstream migration of fish in and out of the lake. The 1.5m falls in reach 1 of Lacoma Creek will restrict the upward migration of fish, however Lacoma Lake, is upstream of the falls and is known to contain Rainbow trout.

RISK ASSESSMENT

A consequence table was developed to identify reaches of special concern because the likely effect of MPB on fish and fish habitat within the Trepanier Watershed is largely unknown. The sub-basins were delineated into macro-reaches which were used to target sensitive areas (Table 2). Therefore mitigation strategies can be developed in target areas where negative impacts are probable.

MITIGATION STRATEGIES

Mitigations to maintain fish presence is often difficult to determine. The impacts of MPB will ultimately reduce riparian cover. The dynamics of stream ecosystems are dependent on the presence of intact multi stage riparian zones. The LWD[4] and CWD[5] supplies organics to the channel thereby enabling the growth of invertebrates used as food for fish. Insect drop from adjacent riparian vegetation also provides a valuable food source for fish. In addition, riparian vegetation provides important value in maintaining stream temperatures and limiting bank failure and sloughing. The influx of sediment into a channel increases turbidity which aside from having detrimental effects by clogging fish gills; it also inhibits feeding which is sight dependent. Therefore, an important mitigation strategy is to encourage the growth of riparian vegetation in areas where very high and high value consequences were identified. Planting of a mixed stand will provide habitat in areas where MPB has removed the adjacent riparian vegetation.

In addition, point sources of sediment should be targeted and rectified. Water flows should be monitored to ensure minimal flows during critical periods which include summer months where fish may be stranded.

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[4] LWD – large woody debris
[5] CWD – coarse woody debris

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Table 1 outlines the criteria utilized in determining the consequences for fish and fish habitat.

Priority	1	2	3	4
Consequence Rating	**Fish Species Present**	**Habitat Quality**	**Channel Gradient %**	**Average Channel Width (m)**
VL	fish absence	fish absence confirmed, minimal fish habitat available, habitat degradation low risk to fish	>20%	<1.5
L	presence of RB	Fish Absence Confirmed and/or habitat with low rearing potential for the fish species present	16% - 19%	0-5
M	presence of RB, EB	habitat quality low to moderate	9% to 15%	0-5
H	presence of RB, EB	fish presence confirmed, habitat quality moderate to high	0% to 8%	0-20
VH	presence of RB, EB, KO	fish presence confirmed, habitat quality high	0% to 8%	0-20

Note: VL – Very Low
L – Low
M – Moderate
H – High
VH – Very High

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Table 2 – Trepanier Creek Watershed Consequence Rating

Stream Name	WSC	Reach	Average Channel Width (m)	Gradient (%)	Species Present	Habitat Quality	Consequence Rating
Trepanier Creek	310-742200	1	11	1	RB, KO, BB	Falls located 1.1km from Okanagan Lake, Good kokanee spawning habitat over 1100m of reach. Riffle Pool, debris and cobble	**VH -** presence of KO, good spawning habitat.
Trepanier Creek	310-742200	3	10	1	RB	Reservior with 1m high outflow impedes fish passage, Frequent pools, staging for RB, good instream cover	**H -** high habitat quality
Trepanier Creek	310-742200	4	5-10	1	RB	1m falls at junction of Pigeon Creek	**H -** RB upstream and downstream.
Trepanier Creek	310-742200	6	6	4	RB	Site 1. Cobble, step-pool morphology, side channels quality rearing habitat for juvenile RB	**H -** presence of RB, side channels, high quality habitat.
Trepanier Creek	310-742200	8	5-10	<5	RB	1.5m falls at the confluence of MacDonald Creek.	**H –** rearing habitat in mainstem
Law Creek	310-742200-03600	1	n/a	>20%	Non fish	Intermittent flow with gradients >20% Intermittent flow	**VL-** No fish, >20% gradients.
Jack Creek	310-742200-18400	1	3.5	4	Non fish	1m boulder falls impeding migration to reaches 1-9 Sites 3 and 4	**VL-** Fish absent, poor habitat.
Jack Creek	310-742200-18400	2	N/A	N/A	Non Fish	Site 5, intermittent tributary, minimal flow	**VL-** Fish absent, low habitat quality.
Pigeon Creek	310-742200-22700	1	1	7	No fish, barrier in reach 1	underground flow prevents fish passage Fish habitat poor, infrequent pools and low flow	**VL -** Fish absent, low habitat quality, low habitat availability.
Venner Creek	310-742200-28500	1	n/a	12	No fish	Dry channel All reaches dry	**VL-** no fish presence, dry channel.
Hill Creek	310-742200-28500-6100	1	n/a	24	No fish	Dry channel All reaches dry	**VL-** no fish presence, dry channel
Silver Creek	310-742200-35000	1	1	10	RB	Reach is 300m and exhibits low flows, valuable staging habitat and instream cover	**H-** confirmed RB, provides staging habitat

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Table 2 – Trepanier Creek Watershed Consequence Rating

Stream Name	WSC	Reach	Average Channel Width (m)	Gradient (%)	Species Present	Habitat Quality	Consequence Rating
Silver Creek	310-742200-35000	2	4	>20	n/a	Downstream from silver Lake gradient >20%, No downstream migration of fish from Silver lake due to 8m dam at outflow. Gradient >20%	**L**->20% gradients, limited downstream or upstream movement of fish.
Silver Lake	00954OKAN	3	N/A	N/A	RB	Overwintering habitat and rearing in lake, lake stocked with RB.	**H**- Overwintering and rearing habitat.
Silver Creek	310-742200-35000	4	2	1	(RB)	Dry/ intermittent Reach 4 located upstream of Silver Lake. Good staging and over stream cover, Deciduous trees in early sucession.	**L -** suspected RB, moderate habitat.
Clover Creek	310-742200-54900	1	2.5	22	Non Fish	Minimal flow, runoff from precipitation, abundant LWD. Site 6 Debris-boulder step pool morphology	**L -** low flow, habitat for 100m upstream of confluence with Trepanier Creek
MacDonald Creek	310-742200-62600	1	3.5	3	RB	1.5m falls Cobble-boulder step-pool	**M -** confirmed RB presence, low gradients and proximity to Trepanier Creek
MacDonald Creek	310-742200-62600	2	2.5	10	(RB)	Channel dry due to re-channelization Created channel with no flow	**M-** assumed fish presence, low habitat quality due to degradation, channelization. Creek has been previously stocked.
MacDonald Creek	310-742200-62600	4	3	7	RB	Dam at outflow to MacDonald Lake is barrier to fish migration, Site 7. Low flow and sparse staging habitat	**M-** low habitat quality, low flows

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Table 2 – Trepanier Creek Watershed Consequence Rating

Stream Name	WSC	Reach	Average Channel Width (m)	Gradient (%)	Species Present	Habitat Quality	Consequence Rating
MacDonald Lake	00887OK AN	5	N/A	N/A	RB	Overwintering habitat.	**H –** Overwintering habitat for MacDonald Creek and tributaries.
George Creek (George Lake)	310-742200-62600-000, 00884OK AN	1	0-5	8	(RB)	Trib is 500m long and dry at time of sampling	**L**- low habitat value, suspectedfish presence.
Ashley Creek	310-742200-000	1	2.5	2	No fish, low flow, impassa ble falls	Tributary 3000m length, flows into MacDonald reservoir. Site 8	**VL**- fish absent, minimal habitat available.
(Long Lake)	00876OK AN	2	N/A	N/A	No fish data	Disturbed area, from open pit mine.	**L**- no fish data was available and the lake is within a disturbed area.
Allan Creek	310-742200-000	1	n/a	9	(RB)	Tributary to MacDonald Creek dry at time of sampling	**M**- suspected fish presence.
Lacoma Creek	310-742200-64800	1	N/A	N/A	RB	1.5m Falls	**H**- tributary is lake headed, good upstream habitat, overwintering potential in Lacoma Lake.
Lacoma Lake	00842OK AN	2	N/A	N/A	RB	Overwintering and rearing potential in lake	**H**- overwintering, rearing habitat.
Lacoma Creek	310-742200-64800	3	6	4	RB	Reach 3 covered by a rockslide, Sites 10, 11, 12, and 13. Reach one cobble step pool morphology, pools infrequent and sparse staging, side channel provided valuable rearing areas for juvenile RB	**H**- high habitat with side channels for rearing. Connection to Lacoma Lake for overwintering.

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Table 2 – Trepanier Creek Watershed Consequence Rating

Stream Name	WSC	Reach	Average Channel Width (m)	Gradient (%)	Species Present	Habitat Quality	Consequence Rating
Lacoma Creek	310-742200-64800	5	5	5	(RB)	adquate flow, good staging for RB, Sites 14, 15	**M**- RB suspected

Fish Species Codes:
RB- Rainbow trout
BB- Burbot
KO- Kokanee
(species) - suspected fish presence.
NFC – No fish caught
NS – Not Sampled

SUMMARY OF RISKS TO FISH HABITAT:

This summary is to be used in conjunction with the Channel Evaluation Table and summarized according to sub-basin. Rainbow trout were the only species identified within the watershed and tend to be resilient to sedimentation for a short duration.

Trepainer Residual: The lower reaches (2-7) and the tributaries flowing into Trepanier Creek downstream of reach seven are included within the trepanier residual. Venner, Hill, Clover and Pigeon Creeks are non-fish bearing due to gradients >20%. Habitat quality is confined to the mainstem.

Jack Creek Sub-Basin: A 1m falls located at the confluence of Jack Creek is a barrier to fish migration upstream therefore this sub-basin has a low fisheries value.

Lower Lacoma Sub-Basin: Rainbow trout are documented in this sub-basin. Rainbow trout can endure short periods of time with increased sedimentation.

Upper Lacoma Sub-Basin: Fish presence has not been confirmed upstream of Lacoma Lake.

MacDonald Creek Sub-Basin: The headwaters of this sub-basin has been altered by mining. Rainbow trout are present, and may be resilient to limited spans of increased sedimentation.

Upper Trepanier: The upper Trepanier residual consists of reaches 8-12 of Trepanier Creek and its tributaries. Fish have not been confirmed in the upper reaches of Trepanier Creek and no habitat information was available.

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REFERENCE MATERIAL

- FISS 8002, 01-Jan-95 Lacoma Lake (00842OKAN), Silver Lake (00954OKAN)
- FISS HQ0879, Fish and Fish Habitat Operational Inventory, Wildstone Resources Ltd, 1996, Jack Creek (310-742200-18400), Trepanier Creek (WSC 310-742200)
- FISS 8405 Region 8 High Value Fish Stream 1:100 000 Map Series, MELP, 1995, Silver Creek (WSC 310-742200-3500), Trepanier Creek (WSC 310-742200)
- FISS BCLKS-3363 Silver Lake (00954OKAN)
- FISS BCLKS-3360, BCLKS 3733 Silver Lake (00954OKAN)
- FISS 8324 Silver Lake (00954OKAN)
- FISS 8341, 8349 Trepanier Creek (WSC 310-742200)
- FISSBCLKS 3730 MacDonald Lake (00887OKAN)
- FISS HQ1992 Trepanier Creek (WSC 310-74220), Jack Creek (310-742200-18400), MacDonald Creek (310-74200-62600)

Scott W.B, E.J. Crossman. 1985. *Freshwater Fishes of Canada*. Minister of Supply and Services Canada. The Bryant Press Limited. Ottawa Ont.

Taylor, G.D., J.C. Wightman. 1978. *Overview and Rating of Production Capabilities and Enhancement Opportunities for Rainbow Trout and Kokanee in Tributaries to Upper Okanagan Basin Lakes*. Fish Habitat Improvement Section. Fish and Wildlife Branch. Ministry of Recreation and Conservation. Victoria BC. (FISS reference 8341)

Trumbley Environmental Consulting Ltd. 1996. Peachland/Trepanier Creek Watershed, Fisheries Habitat Assessment Procedure, District of Peachland, Peachland B.C.

Trumbley Environmental Consulting Ltd, 1994. Hotspot Fish Inventory, FISS 8090

Trumbley Environmental Consulting Ltd., 1996, Kokanee Enumeration Report, MELP

Should you have any questions regarding the content of this report, please contact the undersigned at your convenience.

Thank-you

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