Recommended operational procedures to address hydrological concerns.

The AAC's of three TSAs (Quesnel, Lakes and Prince George) were recently increased by 27% in response to the mountain pine beetle attack. Modelling assumptions made in the timber supply review included, turning off the adjacency requirements and increasing retention within harvest areas to an average of 20%. This increase in AAC has raised concerns about practices that need to be employed to address the hydrological issues associated with the expedited harvest.

Current Mountain Pine Beetle Hydrology Issues

Large scale (watershed level) infestations will affect watershed hydrological process such as canopy interception, transpiration, soil moisture storage, groundwater levels and recharge, snowfall, snow melt, runoff and peak flows, flood estimation, stream and stream bank stability, erosion and sedimentation.

For example, the Vanderhoof Forest District has reported the occurrence of a raised water table in MPB affected areas. The raised water table has turned what was previously summer logging ground, into winter logging ground potentially resulting in increased operational and regeneration costs for the forest operator. A change in the water table, may mean low ground pressure harvesting equipment will be necessary to summer log, and mounding site preparation may be considered. It must be noted that the cause for the change in site conditions has not been confirmed.

Operational Concerns

Hydrological research and practices are usually conducted at the watershed scale - a definable unit. Consequently, the identification of an area for any particular input, output, treatment or planning activity should be completed at a watershed scale. The hydrological concerns and responses are sub-divided into the following topic areas:

1. Peak flows
2. Riparian
3. Fish
4. Surface erosion
5. Water temperature

1) Peak flows

Peak flow refers to the maximum flow rate that occurs within a specified period of time, usually on an annual or event basis. In the interior it usually occurs between May and June and occurs due to spring snow-melt. Forest harvesting can increase peak flows as it can allow for greater accumulations of snow, reduced sublimation and accelerated snow melt. Increased peak flows can cause stream channel de-stabilization leading to decreased water quality. The Watershed Assessment Procedure (WAP), lists the two primary factors considered in an evaluation of the potential effects of past or proposed forest harvesting on peak flows. These are equivalent clearcut area (ECA) or the area considered to be in (equivalent to) a clearcut state and, road density. The WAP provides a description and rationale for the assessment of these two primary factors.

Snow accumulation and melt control peak flows in the interior. The elevation, above which 60% of the watershed occurs, also referred to as the H60 line, is considered to be the source area for the major snowmelt peak flows. When peak flow occurs, the creeks are usually near bankful and snowmelt from the area above the H60 line is contributing directly to peak runoff. In the southern interior, research has found peak flow might be controlled by a H20 line. In the northern interior there are indications it might be a H70 line. If peak flows are a concern, research might be needed to provide guidance to harvesting activities.

Issues

It is anticipated that large cutblocks, exceeding 1000 hectares in size will be utilized for the salvage harvesting. The increased harvest rate plus the large cutblock size will require increased retention levels, however there is still potential for very high ECA levels. Research at Penticton Creek in south central BC indicates that for local watersheds, a 75% ECA can potentially increase daily peak flows. For example, an event with a:

- 2 year return period can increase in magnitude by 22%;
- 10 year return period can increase by 28%;
- 50 year return period can increase by 36%.

MSRM data indicates that for many watersheds in the province, the multiplier ratio to scale up from a 10 year peak flow event to a 100 year peak flow event is between 1.1 and 1.5. That is, the difference in magnitude between a peak flow event classified as a 10 year event and a peak flow event classified as a 100 year event can be as low as 10%. The magnitude of a peak flow event with a return period of 100 years is between 10% to 50% greater than an event with a return period of once in 10 years.

Research at Penticton Creek indicates that a watershed with a 75% ECA, and no roads, can expect a 30% increase in daily peak flows. Based on the MSRM research, a 30% increase in daily peak flows would mean that peak flow events experienced every 10 years would now have a magnitude exceeding those experienced once every 100 years. Therefore pre-harvest peak flow events that have a return period of >10 years would now, post-harvest, have a magnitude that exceeds the 100 year return period magnitude.

The above information can have considerable importance to the maintenance of drainage infrastructure. For example under FRPA regulations (Table 1), the design of a bridge or a culvert depends on how long it will remain at a site.

Table 1

Anticipated period for the structure	**Peak flow return period**
Bridge/culvert: 3 yrs.	10 yrs.
Bridge: 3 – 15 yrs.	50 yrs.
Bridge: >15 yrs.	100 yrs.
Culvert: >3 yrs	100 yrs.
Bridge/culvert in community w/s: >3yrs	100 yrs.

If a 75% ECA can increase the magnitude of daily peak flows by 22% or greater, and this increase can be equivalent to or greater than that of a 100 year event, it might be prudent to consider a reduced ECA. By comparison, a 50% ECA will increase the magnitude of a 10 year daily peak flow event by 14%. The 14% increase is close to the lower limit of the multiplier ratio to go from a 10 year event to a 100 year event.

Recommendations:

1. Recommend licensees to use MSRM streamflow data or regional unit area runoff estimates to calculate peak flows in proposed salvage watersheds to plan drainage structures.
2. Recommend licensees to perform watershed assessments in salvage watersheds to monitor / assess hydrologic change and have a record for future comparison.
3. Recommend prompt re-forestation of logged sites.
4. Recommend leaving logging slash on site. The slash will slow snow melt, reduce wind speeds (and thus sublimation), maintain soil moisture, and aid in site regeneration.
5. Recommend, where possible, minimizing forest harvesting on south facing slopes.
6. Recommend licensees plan harvesting on a watershed or landscape scale to minimize road construction and road density. No incremental harvesting as this leads to ad hoc road systems and drainage networks. Where possible winter log.

2) Riparian

Riparian areas are those adjacent to streams that experience repeated cycles of erosion and deposition of materials. These areas:

- contribute nutrients to the stream,
- provide a source of food for fish,
- regulate stream temperature,
- supply large woody debris,
- help maintain stream bank integrity,
- are areas that are frequently flooded,
- are locations of sediment deposition, and
- are directly adjacent to fish habitat (they can act as fish habitat during very high flows).

Issues

There is no information to indicate all riparian vegetation is 100% pine.

The Vanderhoof Forest District has identified a concern about raised water tables, potentially in these areas.

There may be concern about maintaining larger than standard width riparian management areas to help mitigate any potential increase in water temperature of fish bearing streams, to maintain fish habitat, provide future supplies of LWD, and flood protection.

Recommendations

7. Where possible, retain all green vegetation (under-story and over-story) both in and outside of the riparian area. If ECA's are high, consider doubling current buffer widths and make them reserves. Evidence indicates dead trees can stand for 30-40 years – if the water table is lower than the root mat. If riparian area has a larger percentage of live wood to dead wood, it is better to leave the dead than to disturb the whole site by removing the dead ones. By 30-40 years after disturbance, the regeneration will take care of any issue regarding sediment sources due to blowdown. If the sites are primarily dead pine (>60%), licensees should considering discussing with local DFO staff the benefits of harvesting the site and replanting a new forest..

3) Surface erosion

Most surface erosion issues associated with forest harvesting are linked to road and drainage structures - their construction, installation , maintenance, and de-activation.

Issues:

With increased harvest levels there is potential for increased road density within a watershed. The concern here is to prevent:

- loss of soil productivity,
- increased permanent access structures,
- increased number of stream crossings and associated potential to limit fish access,
- the introduction of sediment into streams,
- fan de-stabilization and mass wasting.

Recommendations

8. Recommend development of erosion control plans by a qualified specialist to minimize erosion and movement of sediment from areas of exposed mineral and organic soils, the management of overland and channelized drainage water, and the maintenance of drainage systems / structures.

Summary of Background References and Relevant Research.

Bethlahamy, Nedavia. 1975. A Colorado Episode: Beetle Epidemic, Ghost Forests, More Streamflow. Northwest Science. 49(2), 95-105.

In 1939 a severe wind storm in the high plateaus of Colorado created ideal breeding conditions for the Engelmann spruce beetle. By 1946, the beetle had killed trees covering hundreds of square miles. When the epidemic finally ran its course, it killed up to 80% of the forest trees in the affected area. Before the outbreak, the forest consisted of Engelmann spruce and sub-alpine fir in a 4:1 ratio, with a basal area of $34m^2$/ha and a volume of $343m^3$/ha. Twenty five years later, dead trees are still standing, and the spruce to fir ratio was 1:4 with a basal area and volume of $10m^2$/ha and $60m^3$/ha respectively.

Water yields 25 years after the outbreak were approximately 10% greater than expected yields. The variable hydrologic effects of the epidemic in the studied watersheds reflect differences in their exposures.

Research focused on 4 watersheds, 2 treatment (White and Yampa) and 2 control (Elk and Plateau) watersheds. Average water yield increases for a 15 year (1946-60) post epidemic period were 22% (28.2 – 18) for the White watershed and 14% (24.8 - 2.9) for the Yampa watershed. The higher water yields in the treatment watersheds was attributed to their exposure. The Yampa drained primarily to the north (lower solar energy) whereas the White drained to the west (higher solar energy). Maximum annual instantaneous rate of flow for the White watershed increased 27% whereas no significant change occurred for the Yampa. The variable response was again attributed to watershed exposure. Interestingly, spring thaw was delayed for all watersheds, both for the treatment and control during the post epidemic period. The delay was attributed to "general climatic conditions." Overall, the increased discharge from the White and Yampa watersheds was due to greater accumulations of snow that melted in the spring to produce more water. Watershed exposure was determined to influence runoff.

Potts, D.F., 1984. Hydrologic Impacts of a Large-Scale Mountain Pine Beetle Epidemic. Water Resources Bulletin, 20(3), 373-377.

A mountain pine beetle outbreak in 1975-77 killed an estimated 35% of total timber in a 133 km^2 drainage in southwestern Montana. Analysis of data for 4 years prior to and 5 years after mortality indicated a 15% post-epidemic increase in water yield, a 2-3 week advance in the annual hydrograph, and a 10% increase in low flows and little increase in peak flows.

The drainage is snowmelt dominated. The advance in snowmelt timing was due to reduced springtime soil moisture recharge requirements and changes in the forest canopy cover from the tree mortality. Because of the de-synchronization, the 15% increase in average annual water yields did not produce a large difference in water yield for the month of June (highest month). The data indicates that, in the absence of major site degradation by soil compaction, timber harvesting spread uniformly throughout a drainage may not increase peak flows. However, the pre- and post epidemic discharge records indicate that the highest daily discharges occur during the last 2 weeks of May and the first 2 weeks of June. Therefore caution must be used before drawing absolute conclusions about impacts on peak discharges.

Beaudry, P. 1997. Research Note: The Bowron River Watershed. Prince George Forest Region. Forest Resources and Practices Team. January 1997, Note #PG-09.

The Bowron watershed has an area of 340,300 ha and is located 50km east of Prince George. In 1975 a wind storm in the Bowron Lakes Park, located in the headwaters of the Bowron watershed, created scattered blowdown patches that made ideal habitat for spruce bark beetles. The beetle population exploded and resulted in an epidemic infestation. Between the mid-1970's to the mid-1980's a salvage operation was undertaken to control the spread of the beetle and reduce the fire hazard. The salvage operation created a 50,000 ha clearcut – approximately 30% of the upper Bowron watershed. Extensive harvesting also occurred in the middle and lower portions of the watershed, but at a slower rate

In 1994 the Bowron watershed was assessed to determine the potential cumulative impacts of the salvage operation. Due to the watershed's large size it was divided into 43 smaller sub-basins. The assessment involved the completion of a Level 1 Watershed Assessment which included a peak flow, surface erosion, riparian and landslide analysis, a sediment source survey and a channel assessment. The channel assessment was performed for the unstable reaches of the Bowron and Haggen mainstems (at their confluence).

Level 1 Watershed Assessment results found that the equivalent clear cut area of the sub-basins ranged from 1% to 76%. While the Level 1 assessment found that only 14% of the waterheds had a high potential for increased peak flows and a high risk for stream bank erosion and flooding, the high risk was attributed to high road densities and extensive harvesting. Similarly, the surface erosion component of the Level 1 assessment found that much of the watershed was at risk due to a combination of high road densities and an extensive layer of easily erodible lakebed silts. This combination indicated there was a potential for a substantial increase in the delivery of fine sediment to the tributary and mainstem channels. The riparian component of the Level 1 found that many watersheds in the Bowron experienced riparian harvesting. The loss of riparian forests resulted in a high potential risk for stream bank de-stabilization and loss of fish habitat. The Level 1 landslide component found that most of the landslide activity and large sediment sources occurred in areas with steeper terrain, unstable soils and higher precipitation. The sediment source survey identified 550 sediment sources, including landslides. Approximately one third of the sediment sources were directly attributable to forest harvesting activities. The channel assessment found that the greatest change occurred along the lower reaches of Haggen Creek where it joins with the Bowron mainstem. The creek increased in width and became straighter since 1966. The widening and loss of sinuosity are typical responses to increases in increased sediment supply.

Recommendations from the assessments were:

- For areas with high IWAP indices, limit future forest development plans to very stable sites not adjacent to stream channels until there is further green-up.
- For areas with a high riparian buffer score, limit harvesting on unstable alluvial fans, and conduct intensive reforestation.
- For areas with a high peak flow index, recommend special road construction techniques to maintain drainage networks and minimize erosion and sedimentation.
- Areas with high erosion hazard should be assigned a high priority for future road surveys, road de-activation programs and slope stabilization activities.
- Areas with medium to high riparian and landslide index scores should be targeted as a priority for more detailed hydrological analysis and watershed restoration activities.

Schnorbus, M., Winkler, R., and Alila, Y., 2004. Modelling Forest Harvesting Effects on Maximum Daily Peak Flow at Upper Penticton Creek. B.C. Ministry of Forests, Research Branch, Victoria, B.C., Extension Note 67.

Evidence from snow dominated watersheds in the southern interior of BC indicates that streamflow generating processes can be altered because of logging. At Penticton Creek, research suggests that forest harvesting will increase peak flows and that the magnitude of those increases is greater for larger return periods. For the Penticton Creek watersheds, the predicted increases are less than 50% regardless of the level of forest harvesting. Investigations in the West Kootenays indicate that watersheds with greater elevation gradients have greater sensitivity to harvesting. The presence of a large sub-alpine area can substantially mitigate peak flow changes.