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An Inventory of Watershed Conditions Affecting Risks to Fish Habitat

in the

CARIBOO, COTTONWOOD & HORSEFLY WATERSHEDS

VOLUME II
Cottonwood River Watershed
(Sections 1 to 5 & 7)

Prepared for
CARIBOO REGION INTERAGENCY MANAGEMENT COMMITTEE
Williams Lake, BC

by
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Executive Summary

The Cariboo River, Cottonwood River and Horsefly River watersheds were identified in the Cariboo Chilcotin Land-use Plan (CCLUP) as priority watersheds where hydrologic stability should be a land and forest management consideration. To assist in the implementation of the CCLUP, an integration process was initiated and a Fisheries Target Risk Assessment (FTRA) was completed. The FTRA determined that the potential risks to fish habitat in the Cottonwood and Horsefly River watersheds were high, and in the Cariboo River watershed the risks were moderate. In response to the FTRA report and CCLUP requirements, the Cariboo Region Interagency Management Committee (IAMC) identified the need for an independent assessment of the three watersheds to inventory current physical conditions, define potential risks to fish resources, assess and interpret land use impacts that may affect fish resources, and interpret watershed conditions with regard to current forest development plans.

In May 1997, a contract funded by Forest Renewal BC (FRBC) was issued to Dobson Engineering Ltd. and Chapman Geoscience Ltd. to complete an inventory of watershed conditions affecting risks to fish habitat in the Cariboo, Cottonwood and Horsefly watersheds.

Background information on watershed characteristics and land-use concerns was assembled from Watershed Restoration Program reports, Department of Fisheries and Oceans reports, and other agency reports, and from interviews with stakeholders. Aerial overview, air photo and ground-based assessments were completed in the watersheds. A sample of roads and channels was assessed in each of the watersheds based on the results of the aerial overview.

The following observations were common to all of the watersheds:

1. Where placer mining had occurred, stream channels have been disturbed resulting in increased sediment supply that overwhelmed the potential effects from other land use activities. Channel re-stabilization was observed and the supply of coarse sediment was reduced at locations where mining had been abandoned.

2. Access roads to placer mining operations have been constructed to a low standard with inadequate drainage works. As a result, sediment is transported off the roads into adjacent streams.

3. Where private land has been developed for agricultural uses and the land has been cleared to the edge of streams, subsequent bank erosion and channel migration was common. The primary cause of the channel instability was the loss of stream bank integrity due to the removal of the stream side vegetation. A secondary factor was the effect of cattle disturbance along stream banks.

4. Erosion of road running surfaces and ditch lines was observed on all active forest roads inspected, as a result of the use of fine-textured native materials in the sub-grade, and minimal use of sediment control structures both during and after construction. Where drainage and sediment control works were absent at stream crossings, sediment impacted the streams.

Summaries for each of the three watersheds follow.

Cariboo River Watershed

The Cariboo River is a tributary to the Fraser River and has a watershed area of approximately 326,000 ha (3,260 km^2). Approximately 40% of the watershed (131,000 ha) is either contained within Bowron Lake Provincial Park or located upstream of the park. The remaining 60% is mostly Crown forest land where the two principal land uses are forest development and placer mining. The Interior Watershed Assessment Procedure identified nine sub-basins within the Provincial forest land that account for 75% of the land base. The remainder (25%) is contained within "residual" areas that drain directly into the Cariboo River.

Topographic relief in the watershed ranges from 800 m ASL at Quesnel Forks to over 2,500 m in the Cariboo Mountains beyond Bowron Lake Provincial Park. The lower watershed is located within the Quesnel Highlands physiographic region characterized by moderate to high relief and dissected valleys. The upper headwaters are situated in the Cariboo Mountains region characterized by high relief, deeply incised valleys and glaciers.

Surficial materials range from glacial till and colluvial veneers on steeper slopes in the upper watershed, to thick glacio-fluvial and glacio-lacustrine deposits in lower tributary valleys and the Cariboo River mainstem valley. Perched deltaic and kame deposits (fine-textured sand and gravel) are common at major tributary confluences, and along much of the lower mainstem valley slopes.

The Cariboo River watershed contains four biogeoclimatic zones: Alpine Tundra (AT); Englemann Spruce/Sup-Alpine Fir (ESSF); Interior Cedar/Hemlock (ICH); and Sub-Boreal Spruce (SBS). AT is confined to high elevations in all of the upper sub-basins; ESSF covers the majority of the watershed area; ICH is confined to lower tributary valleys such as Keithley Creek and Rollie Creek; and SBS is found in the lower portions of the Spanish Creek sub-basin and along the lower mainstem channel below Cariboo Lake.

Placer activity began in the mid to late 1800s and continues (to a much lesser extent) today. Active mineral claims are present throughout the watershed, but concentrated along the Cariboo River mainstem and lower tributary valleys. Any placer claim that remains in good standing has the potential to be re-activated at any time, dependent upon the economic value of the resource[1].

Forest development has become the primary land-use activity in the watershed over the last 50 years. Major timber licensees operating in the area include Riverside Forest Products Limited, Weldwood of Canada Ltd., Slocan Forest Products Ltd. and Lignum Forest Products Ltd.

The majority of the Cariboo watershed is Crown land with only small private land holdings in some of the lower tributary basins. Private land amounts to less than 7.0% of each of the sub-basins. About 40% of the watershed is contained within or above the Bowron Lake Provincial Park, where mining and logging activities have not occurred.

Several watershed restoration initiatives funded by FRBC have already been undertaken in the Cariboo River watershed, or are proposed in the 1998 and 1999 seasons. Approximately 32 km of forest roads have been upgraded to improve hillslope drainage in 1997. A landslide inventory is currently underway to address problems of slope instability and surface erosion. Harveys Creek watershed is currently being assessed as part of the Watershed Restoration Program to address the concerns with sediment input. Forty thousand dollars was spent in 1997 on road fill removal to minimize sediment input into Harveys Creek and Simlock Creek at the confluence. Also under FRBC, a sediment source survey, a road inventory and an access management strategy are currently being completed. Site prescriptions for high risk sites will be completed in 1998, and an estimated $250,000 is proposed for road deactivation next year. Terrain stability mapping is scheduled to be completed in 1998.

According to the results of the IWAP, the equivalent clearcut area (ECA) for the total drainage area is 10.3%. ECA's vary within the sub-basins from a high of 22.5% for Keithley Creek to a low of 2.7% for Kimball Creek. Estimates of ECA values for some of the Cariboo River sub-basins were completed as part of a Fisheries Target Risk Inventory (FTRA) in 1996. The IWAP ECA values are generally lower than those presented in the FTRA.

[1] MacDonald, B., 1997. Personal Communication, Department of Fisheries and Oceans, Prince George.

The results of the IWAP indicate a low potential for increased peak flows in all of the nine major sub-basins. Low surface erosion hazards were determined for all basins with the exception of Keithley Creek, Harveys Creek and Spanish Creek, where moderate hazard ratings were determined. All moderate surface erosion hazard ratings resulted from the length of road on erodible soils. Harvesting within the riparian zones has been limited in the watershed, resulting in low riparian hazard ratings for all basins. Moderate landslide hazard ratings were determined for Harveys Creek, Keithley Creek and Spanish Creek, with low ratings in the other six basins. The moderate landslide hazard ratings were based on the density of roads on slopes >60% used as a surrogate for potentially unstable terrain, since terrain mapping is not available. An actual landslide count was not carried out for the IWAP.

The Department of Fisheries and Oceans (DFO) and BC Environment are concerned about the amount of placer mining activity on sections of the lower Cariboo mainstem channel and Keithley Creek, Harveys Creek, Cunningham Creek, Spanish Creek, Block Creek and Little River tributaries and the production of sediment. Ten-metre riparian reserves are currently being applied to placer mining operations but this reserve did not apply to earlier activity. The lower reaches of the tributaries to the Cariboo River are important stream reaches as spawning and rearing habitat for salmon. There is also a concern that sand-size sediment is being generated from logging roads and transported to streams where it potentially infills and cements spawning gravel (which is especially detrimental to spawning redd excavation and salmon egg survival). DFO and BC Environment are also concerned about riparian logging and channel instability in Harveys Creek, Keithley Creek, Matthew River and Little River.

A total of 7,179 ha of forest development (2.2% of the watershed) is proposed over the next five years (1997-2001). With proposed development, ECA's in Keithley Creek would increase to 28% and in Spanish Creek to 27%, but would remain under 20% in the remaining sub-basins.

The mainstem of the Cariboo River from Sandy Lake to Cariboo Lake, the lower Matthew River and the lower Little River are all low gradient alluvial channels that are naturally sensitive to increased peak flow levels and direct riparian disturbances. At the present ECA level for most of the sub-basins (excluding Keithley Creek and Spanish Creek), there is a low probability that peak flows have been altered from past forest development. The proposed level of forest development in the sub-basins and overall watershed (approximately 2.2% over the next five years) will not increase this probability.

The mainstem channels of Little River, Matthew River and Cariboo River between Sandy Lake and Cariboo Lake are low gradient, with alluvial beds that are sensitive to changes in peak flow or riparian disturbances (pre-FPC) that might result from forest development. It is unlikely that the Cariboo River mainstem or Matthew River mainstem would be impacted by cumulative peak flow effects from forest development, due to the large proportion of their watershed areas under protected area status. However, for the Little River, a total chance plan would assist in determining if there is a potential for harvesting-related peak flow increases that might result in channel destabilization that could affect downstream fish habitat.

Moderately sized tributary channels to the Cariboo River (Rollie, Keithley, Frank, Pine, Harveys, Kimball, Cunningham) all have lower alluvial reaches that are sensitive to disturbance from changes in peak flow and sediment supply. The fans of Keithley, Frank, Pine and Harveys Creeks have all been disturbed by placer mining activity. The fans of Cunningham Creek, Frank Creek and Rollie Creek are recovering from mining disturbances. The Kimball Creek fan indicates moderate disturbance as a result of high 1997 freshet flows and a sediment supply increase from forest development related landslides.

The upper Cariboo River tributaries are glacier-fed streams that naturally carry high levels of silt and bedload. Large amounts of woody debris are introduced to the system each winter from snow avalanches in the upper watershed.

Active and abandoned placer mining operations include large areas of exposed soil which continue to be chronic sources of sediment to streams. Some bank instability was noted as a result of riparian logging along the lower Little River and upper Keithley Creek tributaries (Rabbit Creek, French Snowshoe, Snowshoe and Little Snowshoe creeks).

In addition to the high natural sediment source from the Cariboo River headwaters, the aerial surveys indicated that significant amounts of fine-textured sediment (silt, sand and gravel) are introduced through large natural bank failures on the Cariboo River mainstem channel below Cariboo Lake. The majority of the sub-basins have a high natural rate of coarse sediment input from bank failures in steep, glacio-fluvial deposits. In a number of cases, forestry-related bank failures have occurred where blocks are situated along the break in slope. These failures occurred below the block boundary and terminated in the mainstem channel.

Forest development related landslides were observed in the Kimball Creek and Sellers Creek watersheds. Some failiures were the result of the location of cutblocks along the break in slope of large glacio-fluvial outwash deposit along the incised river valley. Some were the result of blowdown, and at least one failure was initiated by ditch line runoff that had been directed onto a steep hillslope.

The results of the overview road inventory indicate that both construction and use of logging and mining roads contribute fine-textured sediment to the streams. While the severity of surface erosion varies considerably by sub-basin, elevation and surficial materials, the following common factors were observed:

1. Sumps and sediment traps are not commonly used at cross-drains or stream crossings. These locations were observed to be chronic sites for fine-textured sediment (sand and silt) to enter stream channels during precipitation events and when roads are in active use.

2. Many roads were observed to have long, uninterrupted ditch lines that accumulate too much runoff and permit sediment laden water to discharge directly into streams at crossing locations. Additional culverts with sumps would reduce this surface erosion concern.

3. Many of the older mine access roads built with steep grades (usually adjacent to streams) are now initiation zones for landslides, as well as sources of erosion resulting in further sediment loading to streams.

4. Mainline roads climbing out of the Cariboo River valley into the sub-basins are constructed through highly erodible glacio-fluvial and glacio-lacustrine deposits. The highest levels of surface erosion and sediment delivery to stream channels were observed in these lower valley slope locations.

5. High levels of surface erosion were observed on roads under construction in the upper Little River watershed (specifically Ishkloo Creek) during a significant summer rainfall event. Running surface capping had not been completed and trucks were hauling on sub-grade constructed from native soils. Sediment control structures were not in place and ditch line runoff containing high levels of suspended sediment were flowing directly into streams.

Where road deactivation had been implemented on block and spur roads, it appeared to be effective in reducing ditch line and running surface erosion, and re-establishing natural hillslope drainage patterns.

Fans on lower sub-basin mainstem channels are readily impacted by increases in peak flows and/or bedload. Riparian vegetation on the fans contributes to stream bank integrity and channel stability. Increases in either peak flow or bedload can cause increased bank erosion and large woody debris input from the riparian zone. Debris jams may then form in the stream and force it to cut a new channel, or avulse, around the obstruction. Channel avulsions on alluvial fans increase sediment transport that can impair fish habitat in downstream channels.

Bedload supply and transport is high in the Cariboo River and its tributaries as a result of:

- Large natural bank failures into the mainstem channel and tributary channels from glacio-fluvial outwash and kame terrace deposits along much of the lower valley slopes in the watershed.

- Coarse sediment and debris input from avalanches in the upper watershed.

- High levels of fine and coarse sediment from glaciers in the headwater regions.

Channel disturbances from placer mining activity are common in many tributary channels of the Cariboo River system. Large increases in bedload supply due to placer operations have occurred in the Keithley Creek mainstem and tributary channels, the lower mainstem of Harveys Creek, the lower mainstem of Pine Creek and, to a lesser degree, the lower mainstem channels of Rollie Creek, Spanish Creek and Seller Creek. The alluvial fans that are present on the lower reaches of several of these basins have been, or are currently being, disturbed. Overall, the impacts of placer mining on stream channels in Keithley Creek, Harveys Creek and Pine Creek watersheds overwhelm those that may be attributable to any other land-use activities including forest development.

If fish habitat is to be improved in these systems, many stream channels will require rehabilitation. Unless there is a change in the way that placer mining is undertaken, any channel rehabilitation will be unsuccessful.

There has been an increased contribution of coarse sediment to some streams as a result of slope failures initiated at cutblocks situated at the edge of unstable glacio-fluvial terraces. In several of these streams (Keithley Creek and Seller Creek), the sediment load from placer disturbance was already high and it is uncertain what the incremental effect of the forestry-related slides might be. Surface erosion from road running surfaces and ditch lines was observed on all roads traveled in the watershed (approximately 10% of total road network). High suspended sediment loads were observed in all major tributaries to the Cariboo River system. The primary location where fine sediment is being delivered to the streams is at active road crossings. Long, uninterrupted ditch lines flowing into streams at road crossings are common on most roads.

High concentrations of suspended sediment were evident in runoff from recently exposed soils and eroding ditch lines where new road construction was underway. Capping of the running surface was in progress, but sediment being generated by construction equipment was impacting streams since no sediment control structures were in place.

Roads from the main Cariboo River valley climb glacio-fluvial and glacio-lacustrine deposits to access the sub-basins. The highest levels of road surface erosion noted in the watershed were observed on these roads. In many cases, the sediment delivery to either the sub-basin mainstem channel or the Cariboo River is high, resulting in large and rapid increases in suspended sediment concentrations.

Based on the results of the inventory work completed in the Cariboo River watershed, the following recommendations are provided that would either reduce, remediate or avoid impacts on the water resource from forest development.

1. Avoid potential peak flow impacts from proposed development by completing total development plans for the sub-basins that would determine if/or when future harvesting ECA's might affect stream flows.

2. Proposed development in Rollie Creek, Keithley Creek, Harveys Creek, Kimball Creek, Cunningham Creek, Little River, Matthew River, and the Cariboo River from Sandy Lake to Cariboo Lake that might result in increased peak flows should be reviewed since the channels in the watersheds are classed as highly sensitive.

3. Control of sediment production from roads should be a priority. For active roads this would involve installing additional cross-drain culverts with sumps, and upgrading sediment control measures at all existing cross-drains and stream crossings. Inactive roads should be deactivated to the level appropriate to an access plan.

4. For new road construction, consideration should be given to implementing the following sediment control measures:

    - Use temporary structures such as sumps, silt fences, waterbars, cross-ditches, etc. to contain sediment during the period of road construction.

    - Consider operational shutdown guidelines for road construction during wet weather.

5. Complete terrain mapping for the Provincial forest lands within the Cariboo River watershed as soon as possible, and use the terrain maps to assist in the layout and design of roads and cutblocks. Cutblock boundaries should be set back from the break in slope at the terrace faces to reduce the potential for logging-related mass wasting into streams in the valley bottom. The actual setback distance for a block should be determined by a Professional Engineer/Geoscientist with local experience.

6. Where roads are proposed on highly erodible soils that are identified from the terrain maps, the following measures should be considered:

    - Install cross-drains at sufficient spacing to minimize ditch line erosion and to minimize runoff.
    - Use ditch blocks and sumps at cross-culverts.
    - Grass seed and plant local brush species on cut and fill slopes following construction for erosion control.
    - Armour ditch lines with coarse, non-erodible material.
    - Cap running surfaces as required to reduce erosion into streams.

7. Consider remedial plans to address channel disturbance/instability concerns related to placer mining activity. The objective of any restoration work should be to improve channel stability, and the quality and quantity of impacted fish habitat.

Cottonwood River Watershed

The Cottonwood River watershed has a drainage area of 2,474 km^2. The watershed is important for anadromous fish (including chinook salmon and pink salmon), and contains important bull trout and rainbow trout populations.

Relief in the watershed is generally low, varying between about 800 m at the confluence with the Fraser River to about 2,000 m at the extreme eastern end in the Little Swift and McMartin sub-basins. The watershed is situated mostly within the Cariboo Plateau physiographic region where the terrain is gently rolling, mostly undissected uplands. Much of the plateau is underlain by volcanic bedrock covered with blankets of glacial till, glacio-fluvial and glacio-lacustrine deposits. The eastern portions of the Lightning, Little Swift, McMartin and upper Swift sub-basins are located within the Quesnel Highlands physiographic region which has much greater relief. The terrain in this area is comprised of highly dissected valleys.

Ninety-eight percent of the Cottonwood River watershed is Crown forest land, with only 2.0% of the land base privately owned. Private land is concentrated in the Nelson Kenny watershed which is 82% private land, and in the Ahbau watershed where approximately 6.0% is private holdings.

According to the IWAP completed in 1995, the ECA for the total watershed was calculated to be 18%. This did not include cleared private land, which may account for approximately 1.0-2.0%. By including private land and 1996 and 1997 harvesting, the ECA for the watershed is estimated be to 20-22% at present. This ECA is lower than that estimated during the Fish Target Risk Assessment process. Some sub-basins have had more extensive logging than others. The three sub-basins with the highest ECA's are:

- John Boyd Creek 40% ECA
- Sovereign Creek 36% ECA
- Reddish Creek 29% ECA.

The IWAP indicated that the potential hazard for increased peak flows as a result of past harvesting in the total watershed was low, but was high for John Boyd Creek, Reddish Creek, and Sovereign Creek. The surface erosion hazard potential was low-moderate for the total watershed, high for John Boyd Creek and Reddish Creek, and moderate for a number of other sub-basins. Only John Boyd Creek had a road density greater than low. The riparian buffer hazard potential was high for the entire Cottonwood River watershed. The mass wasting hazard potential was low for the watershed overall. Very few natural or forestry-related hillslope landslides were noted in the watershed.

The principal forestry-related concerns in the Cottonwood watershed are related to:

1. Stream channel disturbance from past logging in the riparian zone.
2. Potentially increased peak flows in some sub-basins.
3. Increased rates of sediment transport from hillslopes to streams along the road network, with the greatest concern at stream crossings.
4. The recent high rate-of-cut.

The Department of Fisheries and Oceans (DFO) has indicated concerns regarding the effects of placer mining on fish habitat in Lightning Creek, John Boyd Creek, Sovereign Creek, Umiti Creek, and along the Cottonwood River mainstem. Extensive placer mining operations are found throughout the Cottonwood River watershed. There are also concerns regarding the impacts that private land use activities may be having on streams in the Ahbau Creek and Nelson Kenny Creek sub-basins. Both DFO and BC Environment have expressed concerns about sediment transport into Lightning Creek from the ski hill.

The Watershed Restoration Program under Forest Renewal BC is funding the following work in the Cottonwood River watershed:

- Overview and Level 1 Fish Habitat Assessments
- Sediment Source Mapping
- Access Management Planning.

Stream channels were assessed through the aerial reconnaissance surveys and during a field inspection of 30 stream reaches throughout the watershed. The inventory results indicated that channel disturbance related to land use is common in portions of the Cottonwood River watershed. Channels in Lightning Creek have been disturbed by placer mining and in John Boyd Creek the disturbance is associated with harvesting in the riparian zone (pre-FPC). The impact of these disturbances were noted in the field through:

- Increased sediment from stream banks and riparian areas
- Increased bank erosion
- Elevated gravel bar formation and channel dewatering
- Increased rates of bed load transport.

Sovereign Creek, upper Umiti Creek, Ahbau Creek and Fontaine Creek (a tributary of Reddish Creek) all indicated some degree of channel disturbance from placer mining (and possibly harvesting) in the riparian zone.

A comparison of air photographs for the mainstem of the Cottonwood River determined that although the river moves very large amounts of bed load and has a very high rate of natural sediment supply from eroding stream banks, no channel shifting was noted over the 35-year period covered by the air photos.

Approximately 300 km of pre-Forest Practices Code and post-Forest Practices Code roads were assessed (representing 15% of the roads in the watershed). Five new roads (circa 1996) were also examined in the Cottonwood River watershed, upper Reddish Creek, Little Swift River and McMartin Creek sub-basins. Old roads (pre-FPC) were generally stable, with compacted running surfaces and stable ditch lines. Some of the typical road conditions common throughout the watershed that were of concern are:

- Sub-grades were constructed from local surficial materials (commonly fine-grained till).
- Coarse surfacing material was not common.
- Some roads were deeply rutted.
- Extensive erosion of the road surface, and cut and fill slopes was evident.
- The use of sediment-control measures to minimize the input of sediment from roads into streams at crossings was usually absent. Cross-drains rarely had ditch blocks or sumps at the culvert inlets. Long, uninterrupted ditch lines terminating at streams were common. Grass seeding of disturbed soils to reduce erosion was absent.
- Concentration of surface runoff by roads was common and cross-drains were rare, allowing water to flow along the running surface and ditch lines for long distances.
- Ditches discharge directly into streams at stream crossings.
- On a few abandoned, but non-deactivated spurs, surface erosion has been severe with the sediment transported to the ditch lines of active roads.

A total of 14,200 ha (5.7% of the Cottonwood River watershed) is proposed for harvesting during the 1997-2001 period. Approximately 9.0% (10,160 ha) of the total proposed cut is located in the Swift River sub-basin, which includes Sovereign Creek, Reddish Creek, McMartin Creek, Victoria Creek and Little Swift River sub-basins. In the remainder of the watershed, the proposed harvesting varies from lows of 0.4% and 0.8% in the Nelson Kenny Creek and Ahbau Creek sub-basins (respectively), to a high of 11.6% in the Victoria Creek sub-basin.

Land use activities have resulted in channel disturbances with probable fisheries impacts in portions of the Cottonwood River watershed. The principal channel disturbance is related to placer mining in Lightning Creek and John Boyd Creek, and possibly Sovereign Creek. For Lightning Creek and John Boyd Creek, especially, the extent of placer-related disturbance is severe. Other streams have also been disturbed by placer mining but the extent of the mining was often limited to a small, specific site.

Channels have also been impacted by forest development but these effects have been less than those from placer mining. Harvesting in the riparian zone (pre-FPC) may have contributed to stream bank destabilization and channel aggradation in John Boyd Creek, Umiti Creek and Sovereign Creek. Since there may have been impacts from placer mining as well as possible peak discharge increases related to high ECA values in these sub-basins, linking impacts to a specific activity would be difficult. Throughout much of the rest of the watershed, channels appeared to be in good condition with limited effects on fish.

Sediment transport into streams at crossings along most roads is a concern. Old roads were found to be producing less sediment than newer roads, as would be expected. But the dispursed sediment generated from all roads is an issue that requires attention.

Based on the results of the inventory work completed in the Cottonwood River watershed, the following recommendations are provided:

1. A total development plan should be prepared to determine if it is necessary to consider development constraints to limit increases in peak flows that might affect channel stability. The sub-basins of specific concern are John Boyd Creek, upper Umiti Creek, Sovereign Creek and the Fontaine Creek sub-basin of Reddish Creek.

2. In the Lightning, John Boyd, Sovereign and Umiti sub-basins, all low gradient alluvial channels (including S1-S5 channels) should have the riparian zone protected from harvesting in order to minimize any further increases in bedload transport.

3. Pre-FPC roads that are still active should have drainage works upgraded to reduce sediment transport into streams at crossings.

4. For new roads recently constructed (and for new construction), improved sediment control measures should be considered, including more cross-drains, sumps and ditch blocks, the use of silt fence, and grass seeding of disturbed cut and fill areas.

5. During periods of wet weather when it may not be possible to control sediment on new construction, work should be suspended.

6. Remedial plans should be considered to address channel disturbance/instability concerns related to placer mining activity in the John Boyd Creek, Umiti Creek and Sovereign Creek sub-basins. The objective of any restoration work should be to improve channel stability, and the quality and quantity of impacted fish habitat.

7. Consideration should be given to establishing a water quality monitoring program in the Swift River watershed to establish a baseline. The goal would be to determine the effects, if any, on water quality associated with land use practices, and to identify any change in water quality that might be related to altered road construction and use practices.

Horsefly River Watershed

The Horsefly River has a watershed area of 286,000 ha (2,860 km^2) located southeast of Williams Lake. The Horsefly River drains into Quesnel Lake, which in turn drains through the Quesnel River to the Fraser River. This inventory project was restricted to that portion of the Horsefly River watershed upstream of the confluence with the Little Horsefly River, including Moffat Creek. For this report, the "Horsefly River watershed" refers only to that portion of the Horsefly River watershed upstream of the Little Horsefly River.

The Horsefly River watershed is important for sockeye, coho and chinook salmon. It is one of the most productive sockeye rivers in British Columbia. In addition, the watershed is valuable for rainbow trout and kokanee, which are part of the Quesnel Lake sports fishery. The rainbow trout are among the largest in the world for wild stock, and rely on the Horsefly River for spawning and juvenile rearing.

Topographic relief is low on the west side of the watershed (on the Cariboo Plateau physiographic unit) and moderate to high in the east (on the Quesnel Highlands physiographic unit). The terrain in the plateau consists of rolling, undissected uplands underlain by volcanic bedrock covered by blankets of glacial till, glacio-fluvial and glacio-lacustrine deposits. The Quesnel Highlands (MacKay River, McKusky Creek, etc.) are characterized by steep terrain and highly dissected valleys.

Much of the lower elevation western portions of the Horsefly River are located in the SubBoreal Spruce biogeoclimatic zone (SBS). The higher elevation eastern portions of the watershed are located in the Interior Cedar Hemlock (ICH) and Engelmann Spruce Subalpine Fir biogeoclimatic zone (ESSF). In addition, at elevation in MacKay River and the upper Horsefly River above MacKay River, there are large areas of Alpine Tundra (AT).

Ninety-seven percent of the watershed is Crown land, and the remaining 3.0% is private. The private land is mostly used for agricultural. The highest concentrations of private land are in:

- Moffat Creek 6.0%
- Woodjam Creek 4.0%

Although these private land holdings are small, they are important with respect to channel stability and fisheries resources. The private land in Moffat Creek and Woodjam Creek is located in the lower sub-basin along low gradient mainstem channels. For the Horsefly River, the private land is concentrated along the mainstem channel, between Black Creek and the town of Horsefly. Agriculture, specifically livestock grazing and crop production, is common along the lower 15-20 km of Moffat Creek, the lower 2.0-3.0 km of Woodjam Creek, and the Horsefly River mainstem below Black Creek.

A placer mining operation exists on Black Creek approximately 2.0 km upstream from the Horsefly River. Channel disturbances related to the mining activity may be contributing sediment to the Black Creek fan which is used as a spawning area, and as a refuge by salmon fry and smolts and Horsefly River. An old open pit mine at the upper end of Molybdenite Creek is a concern for sedimentation in Molybdenite and McKinley Creeks. The Frasergold Project (formerly Eureka Gold) is located in the MacKay watershed and has been noted as a water quality concern by DFO.

As of 1996, the equivalent clearcut area (ECA) in the Horsefly watershed was 13%. This excluded private land. Assuming that a portion of the private land has also been cleared, the overall ECA estimate is 14-15% (which is low). ECA values for the sub-basins range from a low of 3.0% to a high of 17%. These ECA values are lower than those used in the Fish Target Risk Assessment (FTRA) report.

In 1997, IWAP calculations were computed for the Horsefly Watershed Monitoring Committee. Overall the results indicate minimal past forest development related concerns in the Horsefly River watershed above the confluence with the Little Horsefly River. The results indicated low potential peak flow hazards in the watershed and all of the sub-basins. There were moderate potential surface erosion hazards in the watershed, and in the MacKay River and Horsefly River above the falls sub-basins. Surface erosion concerns result from the density of road-stream crossings and the length of road located within 100 m of streams. All other sub-basins in the watershed have low potential surface erosion hazard ratings. Overall road density was considered to be of low concern for suspended sediment problems in the sub-basins inventoried.

The potential riparian buffer hazard ratings in the watershed and all sub-basins were low, except for Molybdenite Creek and McKinley Creek above Bosk Lake where the potential riparian buffer hazards were moderate. Low and moderate riparian hazard ratings are the result of limited overall harvesting in riparian zones. Potential landslide hazard ratings were high in the Horsefly River above the Falls and the McKusky Creek sub-basins. They were moderate in the McKinley Creek above Bosk Lake and MacKay River sub-basins, and low in the remaining sub-basins. It should be noted that some of the features noted as landslides in the 1997 IWAP are sections of eroding stream bank along the mainstem channels in glacio-fluvial gravels.

Based on the results of the 1997 IWAP, proposed development would increase the ECA for the Horsefly River from 13% to 21% over the next five years, or a rate of cut of approximately 2.0% per year. The highest rates of cut are proposed in Woodjam Creek (18.6% ECA increase in five years), Molybdenite Creek (12.6% ECA increase in five years) and Moffat Creek (11.6% ECA increase in five years).

A streamflow trend analysis for the Horsefly River was completed in 1996 by Eugene Hetherington, Ph.D., P.Eng. The goal of the analysis was to determine any discernible trends or changes in trend in the discharge of gauged streams in the Horsefly River watershed over the period of streamflow record; and to distinguish, if possible, any effects of land use activity on those streamflow regimes. Analysis was completed for annual water yield, summer low flows, annual peak flows, and the timing of peak flow occurrence for the Horsefly River at McKinley Creek, the MacKay River, McKinley Creek and Moffat Creek. Streamflow data from the Clearwater River and Mitchell River, along with snow data from the Boss Mountain mine snow course and precipitation data from Barkerville were used as "controls". The results indicated that few statistically significant shifts in the hydrological relationships between the Horsefly River data and the control stations exist. Dr. Hetherington concluded that any fluctuations in flow patterns relate primarily to variations in climate, and that there was no clear evidence of any trend suggesting that past forest harvesting had affected runoff in the Horsefly River watershed.

A channel assessment of 54 km of the Horsefly River mainstem channel and McKinley Creek was completed in 1996 using a draft version of the Forest Practices Code guidebook ***Channel Assessment Procedure.*** The assessment was an office exercise completed by comparative air photo analysis, using photos from 1955, 1959 and 1992. The results were inconclusive since large differences in the stage of the river between the various flights masked channel morphology (the 1958 photos were collected during flood stage on the Horsefly River). The report concluded that small changes in channel pattern had occurred over the study period in six reaches of the Horsefly River and one reach of McKinley Creek, involving a total of 1.5 km of channel. The report recommended field verification of areas where channel change might have occurred. In addition, the report identified channel straightening on Moffat Creek and recommended the completion of a detailed channel assessment.

The following reports addressing CCLUP salmon fisheries targets and strategies have been prepared for the Department of Fisheries and Ocean's, Fraser River Action Plan, by Northwest Hydraulics Ltd. and Coast River Environmental Services Ltd.:

- "Applying CCLUP Salmon Fisheries Targets and Strategies: A Hydraulic and Channel Analysis of the McKinley Assessment (Draft Landscape) Unit" (dated March 1996).

- "Applying CCLUP Salmon Fisheries Targets and Strategies: A Hydraulic and Channel Analysis of the Black Creek Assessment (Draft Landscape) Unit" (dated February 1996).

For the McKinley Creek unit (which is all of the McKinley Creek sub-basin upstream of the Horsefly River), the report concludes that the spawning reaches of McKinley Creek are sensitive to increased peak flows. It was recommended that the sub-basin be managed for a low risk of peak flow increase. Detailed recommendations are also included with respect to ECA targets in the sub-basin, riparian management, sediment control, and rehabilitation and management of the Molybdenite Creek sub-basin.

For the Black Creek unit (which includes the Horsefly River mainstem between Moffat Creek and the Horsefly Falls, and Woodjam Creek, Black Creek, Tisdall Creek, and other small tributaries), the conclusions and recommendations were:

1. Manage ECA for a low risk of peak flow increase in the mainstem of the Horsefly River, and in Woodjam Creek and Black Creek.

2. Improve terrain and riparian management in areas upstream of the Black Creek unit, particularly in the MacKay River, Doreen Creek and Club Creek.

3. Riparian management to maintain stream bank stability along all alluvial, floodplain reaches.

4. Restoration in harvested riparian zones to improve riparian function.

Stream temperature in the spawning reaches of the lower Horsefly River, lower McKinley Creek and Moffat Creek approach salmon and trout mortality levels in the late summer. Reductions in stream shading as a result of the removal of riparian vegetation for agricultural purposes or during forest harvesting is a concern.

The following inventory, assessment and upgrading work is in progress or has been completed in the Horsefly River watershed under Forest Renewal BC:

- A sediment source survey, road inventory, overview fish habitat assessment, and access management plan.
- Stream channel assessments in some reaches of the McKinley Creek, MacKay River and McKusky Creek sub-basins.
- Assessment of potential landslide concerns from past road construction in the Pegasus Creek sub-basin.
- Terrain stability mapping for the upper Horsefly River, MacKay River and McKinley Creek sub-basins will be completed in 1997.
- Completed semi-permanent and permanent road deactivation, and road upgrading in the upper Horsefly River, McKinley Creek, MacKay River and Moffat Creek areas.
- Three hundred thousand dollars to be spent on road deactivation in the watershed, following completion of the access management plan.

The Horsefly Watershed Monitoring Committee, an interagency group, has been requested by the district manager of the Horsefly Forest District to use the IWAP process to provide management recommendations for forestry activity in the Horsefly River watershed. Representation includes the Ministry of Forests (Cariboo Region and Horsefly District), the Department of Fisheries and Oceans, BC Environment and major forest licensees. Information available for watershed management includes the results of the IWAP, channel assessments being completed in selected stream reaches, and suspended sediment data collected by Pat Teti (Research Hydrologist, Cariboo Forest Region). It is expected that this watershed inventory report will also provide additional information for the planning group to assist the district manager with recommendations for forest development.

Stream channel and watershed conditions in the Horsefly River watershed are rated as good. However, evidence of land-use related disturbance are apparent on some channel reaches. A summary of channel inventory observations follows:

1. The lower 20 km of Moffat Creek is heavily disturbed. The channel is wider (by as much as 200% in some reaches), and has experienced bank erosion and increased lateral channel migration. Elevated mid-channel gravel and cobble bars are common. Practices on private land, which includes clearing of riparian zone vegetation and unrestricted cattle access to the channel, is the main cause of disturbance on the lower 20 km of Moffat Creek. A comparison of 1958 and 1992 air photos indicates that the noted disturbance spans the entire length of Moffat Creek from McIntosh Creek to the Horsefly River.

2. The mainstem channel of the Horsefly River, downstream from Black Creek, is experiencing bank erosion in floodplain areas cleared for agriculture. A comparison of 1958 and 1992 air photos did not, however, detect measurable channel widening or increased lateral channel migration.

3. The lower reach of Black Creek (located on the alluvial fan) is disturbed. The stream has avulsed on the fan, and bank erosion and channel are occurring. The riparian zone has been cleared for agriculture and a placer mine exists 1.0-2.0 km upstream.

4. Natural and forest development related bank failures have occurred along the MacKay River, however, any debris deposits have been washed away by subsequent freshet flows.

5. Pegasus Creek (in the MacKay River sub-basin) has been affected by landslides from roads constructed across unstable slopes. Sediment and debris has entered Pegasus Creek from these landslides and has been transported downstream to the alluvial fan. The fan is extensive and most of the coarse sediment deposited on the fan before reaching MacKay River. No evidence of direct disturbance in the MacKay River was noted.

6. An unnamed tributary to the McKusky Creek (below Crooked Lake) has experienced numerous landslides from roads. These slides have entered the tributary channel. There was no evidence of disturbance in McKusky Creek itself (see McKusky Creek basin report for details).

Alluvial channels in the Horsefly River watershed are sensitive to increased peak flow and bed load levels, and direct riparian zone disturbance. Sensitive alluvial channels include: the mainstem of the Horsefly River, from the town of Horsefly to Black Creek; portions of the mainstem of McKinley Creek, from the Horsefly River to Bosk Lake; Moffat Creek; the lower reaches of Woodjam Creek; the lower alluvial fan reach of Black Creek; and other small alluvial fan reaches along the lower Horsefly River.

Three locations of new road (post-FPC) were examined in Molybdenite Creek, Bassett Creek and Woodjam Creek. The concerns noted with these roads were similar to those for new roads in the other watersheds.

Both road failures and open slope debris slides were noted in the MacKay River and McKusky Creek sub-basins. Some road-related slides have occurred on elevated glacio-fluvial or glacio-lacustrine terraces (kame terraces).

With the exception of Moffat Creek and the lower reaches of some tributary streams to the Horsefly River mainstem, channel conditions in the Horsefly River watershed are rated as good.

Agricultural land clearing and cattle grazing in the riparian zone have disturbed Moffat Creek, Woodjam Creek, and the lower Horsefly River between Black Creek and the town of Horsefly.

Past forest development (pre-FPC) has caused landslides on unstable terrain in the MacKay River and McKusky Creek sub-basins. The landslides have directly impacted tributary channels, but had limited effect on the MacKay River and McKusky River.

The extent of past forest development in the Horsefly River watershed is low. Based on the proposed development plans, the ECA in the Horsefly River watershed above the town of Horsefly would increase to 22-23% (including cleared private land) by 2001. Current literature indicates for ECA greater than 20%, measurable increases in peak flow can occur. If peak flows do increase, it is possible that the Horsefly River downstream of Black Creek will experience increased bank erosion and channel widening. The extent of proposed forest development in the Woodjam Creek, Moffat Creek and Molybdenite Creek sub-basins is a concern with regard to peak flow increase, bank erosion and sedimentation.

The following concerns represent a risk to the impairment of fish habitat:

1. Proposed ECA levels in Woodjam Creek, Moffat Creek and Molybdenite Creek, could initiate increased bank erosion, channel widening and avulsion. Moffat and Molybdenite are both used for sockeye spawning, while lower Woodjam is used as a refuge by salmon fry and smolts during conditions of high flow in the Horsefly.

2. The proposed rate-of-cut is also a concern in the Woodjam Creek, Moffat Creek and Molybdenite Creek sub-basins. Based on observed road surface erosion and sediment delivery to channels (particularly during new road construction and use of green-roads), the extent of road construction required to access proposed blocks in these sub-basins will result in increased sedimentation in channels.

Moffat Creek is highly disturbed, with the majority of the disturbance resulting from agricultural land-use (land clearing and livestock grazing in the riparian zone) along the lower 20 km of Moffat Creek that has caused increased bank erosion and channel widening (up to a 200% in width). The disturbance is concentrated in the sockeye spawning reaches below the waterfall and alluvial reaches above the waterfall. The quality of fish habitat has been impaired by agricultural land use.

Based on the results of the inventory work completed in the Horsefly River watershed, the following recommendations are provided that should address the concerns noted in the report:

1. Complete a total development plan for the Horsefly River watershed above the Little Horsefly River to assist in managing forest development for a low peak flow hazard rating as defined in the IWAP. The objective would be to minimize the risk of peak flow increases and subsequent bank erosion and channel widening.

2. To minimize the potential for direct disturbance, it is recommended that some streams receive an enhanced level of riparian protection to ensure that long-term bank and bed stability is maintained. For most streams, this means applying the RMA Guidelines of the Forest Practices Code. Where an emphasis on channel stability and riparian integrity is paramount, ie. for all alluvial channels (S1-S5), it is recommended that these streams be managed with forested RMA's and that the forested zones be expanded as necessary to maintain their stability in areas potentially subject to blowdown.

Consideration should be given to the following:

- For S4 streams, the RMA Guidelines of the Forest Practices Code recommends retaining all trees within 10 m of the stream bank. These forested RMA's should be expanded as necessary to ensure that a windfirm buffer is created.

- For low gradient, alluvial S5 streams (ie. with gravel bed and banks, and possible floodplain areas), enhance stream protection by maintaining all trees within 10 m of the stream bank. These forested RMA's should be expanded as necessary to ensure that a windfirm buffer is created.

- For non-alluvial S5 streams, apply the RMA Guidelines.

- For S6 streams, apply the RMA Guidelines.

1. Deactivate roads that are no longer required (as determined by an access management strategy) to standards appropriate to the terrain sensitivity.

2. Upgrade drainage on active roads including increasing cross-drain frequencies on long, uninterrupted ditch lines and constructing sumps in ditch lines at all stream crossings.

3. Implement sediment control measures to control erosion during road construction. These should include the following:

   - Use temporary structures such as sumps, silt fences, waterbars, cross-ditches, etc. to contain sediment.

   - Install sediment control structures such as sumps, geotextile filter fences, etc. in ditch lines (and especially in ditch lines proximal to streams) during the period of road construction and early use.

   - Consider operational shutdown guidelines for road construction during wet weather.

4. Complete overview terrain mapping for portions of the Horsefly River watershed above the confluence of Black Creek, and use the terrain maps to assist in forest development plans for roads and cutblocks.

5. A riparian zone rehabilitation program should be considered for private land along the lower 20 km of Moffat Creek, and the Horsefly River between Black Creek and the Little Horsefly River. The plan should include the following:

   - Develop and implement a riparian zone awareness program for private landowners.
   - Establish an appropriate riparian reserve zone along the channel.
   - Fence the reserve zones to control livestock access.
   - Plant native shrubs and trees in the riparian reserve zone.
   - Stabilize disturbed channel reaches using bioengineering techniques.

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CARIBOO REGION INTERAGENCY MANAGEMENT COMMITTEE
Williams Lake, BC

An Inventory of Watershed Conditions Affecting Risks to Fish Habitat

in the

CARIBOO, COTTONWOOD AND HORSEFLY WATERSHEDS

1.0 INTRODUCTION

Purpose of This Inventory

The potential impacts of development on fish habitat has been a concern in the Cottonwood, Cariboo and Horsefly watersheds for many years. Forest development has been a particular concern due to the amount of the landbase that is disturbed. The purpose of this inventory of watershed conditions with respect to fish habitat risks for the watersheds is to provide an objective data base that can be used by the agencies (Ministry of Forests, BC Environment, Department of Fisheries and Oceans) and the forest licensees to address these issues.

Background

The Cariboo Chilcotin Land Use Plan (CCLUP) identified the Cottonwood River, Cariboo River, Horsefly River, Bonaparte River and Bridge Creek as priority watersheds where hydrologic stability[1] should be a land and forest management consideration.

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[1] The term *hydrologic stability* is somewhat ambiguous and difficult to define precisely. For this inventory, though, hydrologic stability is defined rather broadly as a combination of channel hydrology (i.e., stream flow) and geomorphology (i.e., the characteristics of the stream banks, bed and riparian areas). Hillslope hydrology and geomorphology processes that affect in-stream conditions are also included within the definition. In addition, for this inventory the concept of hydrologic stability clearly involves the examination of existing conditions and potential future conditions relative to what would be expected in a natural, background state.

To assist in the implementation of the CCLUP, an *Integration Process* was initiated to identify and help reconcile potential resource conflicts. Part of this process involved an assessment of potential risks to fish habitat at the landscape level, as identifed in the Fisheries Target Risk Assessment (FTRA) report[2] prepared by the Fisheries Target Committee.

The FTRA committee reviewed watersheds throughout the Cariboo Forest Region and concluded, in part, that high potential risks to fish habitat exist in the Horsefly River, Cottonwood River and Bridge Creek watersheds, while moderate potential risks exist in the Cariboo River and Bonaparte River watersheds. It was recognized that because of the uncertainties in the simplified methods used, and the conservative interpretation of the information, the potential risks to fish habitat identified in the report were possibly higher than actual risks. The committee recommended that more detailed, field-based assessments be completed in the five watersheds to define the current watershed conditions that might affect fish habitat.

In response to the FTRA report, the Cariboo Region Interagency Management Committee (IAMC) identified the need for an independent study of the five watersheds. With the support of the IAMC, the Cariboo Regional Resource Board (RRB) and the Major Licensee Steering Committee (MLSC), a proposal for funding was made to the Resource Inventory Program of Forest Renewal BC to complete ***An Inventory of Conditions Affecting Risks to Fish Habitat.*** Based on the funds approved, the project was restricted to the Cottonwood River, Cariboo River and Horsefly River watersheds *[Figure 1].*

This report summarizes the results of the inventories and assessments that have been completed in these watersheds, based on the requirements in the Forest Practices Code and procedures in the Watershed Restoration Program guidebooks (e.g. Interior Watershed Assessment Procedure, Channel Assessment Procedure, Fish Habitat Assessment Procedure).

[2] Fisheries Target Risk Assessment: Prepared for the CCLUP Integration Process. By the Fisheries Target Committee (Coral DeShield, Department of Fisheries and Oceans; Maurice Lirette, BC Environment; and Patrick Teti, BC Forest Service). August 15, 1996.

2.0 INVENTORY OBJECTIVES

The general objectives of the inventory were to:

1. Inventory current physical conditions in the Cottonwood, Cariboo and Horsefly watersheds that might affect fish habitat.
2. Define potential risks to fish resources.
3. Assess and interpret the land use impacts in each watershed that could potentially result in a risk to the fish resource.
4. Assess and interpret the watershed conditions with regards to proposed harvesting as outlined in the current five-year Forest Development Plans.

Specific objectives for the inventory were to:

1. Compile and interpret available information pertaining to fisheries, hydrology and land use including:
   - Interior Watershed Assessment Procedure (IWAP) reports
   - Fisheries Target Risk Assessment (FTRA) report
   - Fish Habitat Assessment reports
   - Department of Fisheries and Oceans reports
   - Sediment Source inventories
   - Five-Year Development Plan information.
2. Gather information from major stakeholders (Meeting Minutes and Stakeholder List), including:
   - Department of Fisheries and Oceans
   - Ministry of Forest (region and district)
   - BC Environment
   - Major forest licensees.

3. Undertake aerial and ground-based field inventories of forest development or other land uses to provide detailed information on the potential impacts to the fisheries resource.

4. Prepare summary reports providing detailed information that can be used to address forest resource planning on Crown land, as well as the issues identified in the CCLUP report.

3.0 METHODOLOGY

The three watersheds encompass a total area of approximately 756,000 ha. Since there was neither the funds nor the time available to inventory all of the area, sub-basins or portions of sub-basins were selected for detailed field inventory that were considered to be representative of the larger watersheds.

Locations for detailed field assessment were determined through two processes. First, all available relevant material pertaining to watershed conditions was reviewed, including land use history, fisheries utilization, forest development planning, etc. Second, an aerial overview using a fixed-wing aircraft was completed during the spring freshet in early June. The results of the overview flights were then used to identify specific locations in the watersheds for ground-based inventory work that focused on specific watershed and stream channel conditions, and land use effects.

The multi-step method involved:

Step 1. Pre-Field Inventory of Existing Information

The following documents pertaining to the three watersheds were reviewed:

1. Interior Watershed Assessment Procedure (IWAP) report (produced by Dobson Engineering Ltd., 1996) for the Cottonwood River watershed. This IWAP was completed as a component of Watershed Restoration Program inventory through the Ministry of Environment, Lands and Parks.

2. IWAP report (produced by Carmanah Research Ltd., 1997) for the Cariboo River watershed. This IWAP was completed as a component of Watershed Restoration Program inventory through the Ministry of Environment, Lands and Parks.

3. IWAP report (produced by Carmanah Research Ltd., 1997) for the Cariboo River watershed This IWAP was completed as a component of Watershed Restoration Program inventory through the Ministry of Environment, Lands and Parks.

4. IWAP report (produced by Dobson Engineering Ltd., 1996) for the Horsefly River watershed above the town of Horsefly. This IWAP was completed as a component of Watershed Restoration Program inventory through the Ministry of Environment, Lands and Parks.

5. IWAP data summaries (produced by the Inland Timber Management Ltd., 1997) for the Horsefly River watershed above the town of Horsefly. This was completed for the Horsefly Watershed Monitoring Committee.

6. "Salmon Watershed Planning Profiles for the Fraser River Basin within the Cariboo-Chilcotin Land Use Plan Area" (produced by D.E. Rowland and L.B. MacDonald for the Department of Fisheries and Oceans, Fraser River Action Plan, 1996).

7. Fisheries Target Risk Assessment (FTRA) report (produced by the Fisheries Target Committee, 1996).

8. "Applying CCLUP Salmon Fisheries Targets and Strategies to the Black Creek Assessment Unit" (produced by Northwest Hydraulic Consultants Ltd. and Coast River Environmental Services Ltd. for the Department of Fisheries and Oceans, Fraser River Action Plan, 1996).

9. "Applying CCLUP Salmon Fisheries Targets and Strategies to the McKinley Assessment Unit" (produced by Northwest Hydraulic Consultants Ltd. and Coast River Environmental Services Ltd. for the Department of Fisheries and Oceans, Fraser River Action Plan, 1996).

10. Sediment source summaries for the Cottonwood River and Horsefly River watersheds.

The information contained within these documents was summarized by sub-basin and interpreted with regards to locations where specific land use effects on streams or fish habitat might be assessed in the field. These locations were noted on 1:100 000 NTS topographic maps (or 1:50 000 NTS topographic maps where 1:100 000 maps were not available).

Step 2. Aerial Reconnaissance

Aerial reconnaissance surveys of the three watersheds were conducted in early June 1997 during spring freshet. The purpose of the aerial reconnaissance was to:

1. Identify specific locations in the watersheds where land use might have affected fish habitat, based on the interpretation of the existing information collected in Step 1.

2. Identify hillslope and road conditions as snowmelt was occurring, with specific reference to road-related erosion impacts on streams.

   - Observe water quality and the extent of road, hillslope and channel erosion during a period of high steamflow.

   - Refine the list of specific sub-basins or portions of sub-basins in which to conduct detailed ground-based assessments.

A fixed-wing aircraft with a three-person assessment team was used to carry out the reconnaissance. Information was compiled on videotape, 35-mm film (photographs) and field notes. The flight path was plotted on topographic maps, noting the locations of still photos and compiling location-specific notes based on the observations of all three team members. The results of the aerial reconnaissance have been recorded on field forms and summarized later in this report.

Step 3. Air Photo Interpretation

Certain mainstem stream channels were selected for interpretation using historic and recent air photos. The historic photos were 1:15 840 black and white photos flown in 1958, while the recent photos were 1:20 000 colour photos from the 1992 - 1995 period (refer to Table 1 for a listing of reaches assessed, and air photo date, flight line and photo numbers). Stereo pairs were examined to assess channel stability in the study reaches. The purpose of the historic air photo assessment was to define the extent and magnitude (if any) of gross changes in channel morphology that might be related to riparian disturbance or upstream land use changes.

The mainstem channels selected for assessment were:

Horsefly River Watershed
(Horsefly River upstream of Little Horsefly River)

- Moffat Creek, from the Horsefly River to approximately the confluence with McIntosh Creek.

- Horsefly River mainstem, between the McKinley River and Woodjam Creek.

Cottonwood River Watershed

- Cottonwood River mainstem, between the Fraser River and Lightning Creek.

Cariboo River Watershed

- Little River, between the Cariboo River and Ishkloo Creek.
- Keithly Creek, between Cariboo Lake and kilometre 10.
- Rollie Creek alluvial fan and lower mainstem channel.

Step 3. Ground-Based Assessments

Phase 1 of the ground-based assessment was conducted during early July 1997. Allan Chapman, P.Geo. completed assessments in the Cottonwood River watershed and the lower portion of the Horsefly River watershed (including Moffat Creek). Conditions while working in the Cottonwood and lower Horsefly were dry and streams were at relatively low flow. Michael Milne, M.E.S. completed assessments in the Cariboo River watershed and the upper portion of the Horsefly River watershed. During the assessment in the Cariboo and upper Horsefly, conditions were wet and streams were at high flow.

The Phase 1 ground-based assessments required approximately 22 days (an average of one day per 340 km^2 of watershed).

Approximately half of the field work was reconnaissance stream channel assessments. The other half of the time was focused on slope and road assessments, specifically with respect to assessing road-related erosion.

Phase 2 of the field work involved an additional three days by Chapman and Milne in September 1997, completing a final reconnaissance of the three watersheds to confirm results of the July field work and to fill in any gaps. Those channels that were not assessed in July (due to high flows) were visited during this trip.

Step 4. Information Reporting

The information collected through this inventory is presented in summary reports for each watershed in total and by sub-basin, according to the following outline:

Watershed Characteristics

- Watershed and sub-basin locations and areas.
- Physiography.
- Climatology and hydrology.
- Biogeoclimatic characteristics.

Background Information

- Summary of IWAP, FTRA and sediment source assessments.
- Land use and land use concerns, as identified in MOF and DFO reports, and from MoF, DFO and BCE interviews (refer to interview meeting minutes and stakeholder list).

Inventory Observations

- Summary of overview aerial reconnaissance information.
- Description of field work (i.e. locations of roads and channels assessed).
- Description and summary of road and channel conditions.
- Summary of the results of that field work.
- Description and summary of air photo analysis.
- Description and summary of five-year forest development plans.

Mapping

- The inventory information is presented on maps of the watersheds and sub-basins.

Interpretation

- Interpretation has been made of current watershed and sub-basin conditions with respect to potential impacts on the fish resources, and the impact of different land uses in the watersheds on those conditions.

- Interpretation of watershed and sub-basin conditions incorporating potential effects of five-year forest development plans.

Recommendations

- Recommendations are provided that address specific forest practices, such as road construction, use and maintenance, riparian management, etc.

- Recommendations are provided regarding the potential impacts of proposed harvesting by watershed and sub-basin.

- Recommendations have been made concerning other land uses that may be impacting fish resources (e.g. placer mining and agriculture).

4.0 DEFINITIONS

The following terms used in the report have been defined to reduce possible misinterpretations or misunderstandings.

Equivalent Clearcut Area (ECA)

Equivalent clearcut area or ECA is a measure of the area that has been harvested in a watershed adjusted for the tree height of regenerating stands on a cutblock basis. As the stand increases in height, the effective area of the block is gradually reduced to zero when the stand reaches normal full tree height. The ECA value is important in understanding the hyrologic impacts of harvesting.

ECA is often used as a surrogate for all the cumulative effects of forest development in a watershed. However, in this report the term ECA is used to link potential peak flow increases related to harvesting, with possible risks of channel disturbance resulting from those increases.

In snow dominated forested watersheds, changes in forest cover affects snow accumulation. On clearcuts, snow accumulations are higher due to loss of interception, and snow will melt more rapidly due to a loss of shade. There is evidence in the scientific literature that peak flow rates increase in streams during the spring snowmelt freshet, due to changes in forest cover (e.g. harvesting, land clearing, wild fires) relative to undisturbed conditions when the ECA would be zero. As the ECA increases, so does the potential impact on stream flows. Conversely, the ECA (and any effects on stream flow) is reduced as tree heights increase on the harvested blocks.

ECA's have a cumulative effect on peak flow changes. Changes in peak flow may be a concern in certain types of channels where increased rates of bank erosion and bed mobilization may occur. The channels most sensitive to flow-related morphology changes are low gradient alluvial channels flowing through erodible, fine-textured floodplain sediments (i.e. fine gravels). Impacts from peak flow increases resulting from timber harvesting can occur well-removed from the site of the harvesting.

Rate-of-Cut

The term rate-of-cut is a measure of the area harvested (either proposed or actual) as a percentage of the watershed area on an annual basis. For example, if 10% of the watershed is proposed for harvesting in the five-year forest development plan period, the corresponding rate-of-cut would be 2.0% per year.

In this report, rate-of-cut has been used as a surrogate for the combination of the amount of new road construction and the amount of harvesting (i.e. rate of overall site disturbance).

Total Development Plan

The term total development plan refers to a long-term forest development plan for a watershed. The plan would identify, in general terms, the potential annual development including potential cutblocks. Based on the terms of the Forest Practices Code, plans can be prepared for periods up to 200 years. A key piece of information that can be derived through this process is a long-term estimate of ECA's which can be used to review various harvesting scenarios and the potential impact on peak flows. The total development plan does not consider such factors as visual quality, wildlife, biodiversity, etc.

5.0 RESULTS OF THE WATERSHED INVENTORY

The detailed reports prepared for each of the three watersheds contain inventory and assessment information for the total watershed, as well as each of the major sub-basins. The reports also include sections on the interpretation of the data and recommendations regarding future development and restoration.

Each watershed report is included under separate cover: Volume I – Cariboo (Section 6.0), Volume II – Cottonwood (Section 7.0) and Volume III – Horsefly (Section 8.0). The preceding five sections are common to all three.

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7.0 COTTONWOOD RIVER WATERSHED

Watershed Characteristics

The Cottonwood River watershed has a drainage area of 2,474 km^2. The watershed is located east of Quesnel, with the confluence with the Fraser River situated north of Quesnel *[Figure CW1]*. The characteristics of the watershed and its sub-basins are presented in Table 1. The sub-basins are shown on Figure 2.

The watershed is important for anadromous fish (including chinook salmon and pink salmon), and contains important bull trout and rainbow trout populations.

Relief in the watershed is generally low, varying between about 800 m at the confluence with the Fraser River to about 2,000 m at the extreme eastern end in the Little Swift and McMartin sub-basins. The watershed is situated mostly within the Cariboo Plateau physiographic region where the terrain is gently rolling, mostly undissected uplands. Much of the plateau is underlain by volcanic bedrock covered with blankets of glacial till, glacio-fluvial and glacio-lacustrine deposits. The eastern portions of the Lightning, Little Swift, McMartin and upper Swift sub-basins are located within the Quesnel Highlands physiographic region which has much greater relief. The terrain in this area is comprised of highly dissected valleys.

Climate varies considerably in the watershed. Precipitation generally increases and annual temperature decreases from west to east, and with increasing elevation. Annual precipitation in the west is 540 mm at Quesnel (with about one-third occurring as snow) and increases to 1,050 mm (where about half occurs as snow)[1] in the east at Barkerville. (Although not in the watershed, Barkerville is the closest climate station representative of the eastern zone.) Daily mean temperature similarly decreases from about 4.9° C at Quesnel to 1.7° C at Barkerville.

Water Survey of Canada operates two hydrometric stations in the Cottonwood watershed *[Table 2]*. The higher mean annual runoff for Lightning Creek reflects the higher precipitation received in the Quesnel Highlands physiographic region.

TABLE 2

Water Survey of Canada Gauges in the Cottonwood River Watershed

Water Survey of Canada Station Name	Statn. No.	Drainage Area (Km^2)	Mean Annual Discharge (m^3 /s)	Mean Annual Runoff (mm)
Cottonwood River near Cinema	08KE009	1,910.00	24.1	398
Lightning Creek at Wingdam	08KE004	243.00	5.0	649

[1] Canadian Climate Normals, 1961-1990, Environment Canada, Atmospheric Environment Service, 1993.

Much of the lower elevation western portion of the watershed is located in the SubBoreal Spruce biogeoclimatic zone (SBS), while the higher elevation eastern portion of the watershed is located in the Engelmann Spruce Subalpine Fir biogeoclimatic zone (ESSF). The biogeoclimatic characteristics of the watershed and sub-basins are summarized in Table 1.

Background Information

Background information is summarized as follows *[Table 3]:*

Tenure

For the entire Cottonwood watershed, approximately 98% is Crown land with the remaining 2.0% private land used principally for agriculture. The largest concentrations of private land are in:

- Nelson Kenny watershed 82%
- Ahbau watershed 6.0%

Past Forest Development

According to the IWAP completed in 1995 the ECA for the total watershed was calculated to be 18%. This did not include cleared private land, which may account for approximately 1.0-2.0%. By including private land and 1996 and 1997 harvesting, the ECA for the watershed is estimated be to 20-22% at present. This ECA is lower than that estimated during the Fish Target Risk Assessment process.

Some sub-basins have had more extensive logging than others. The three sub-basins with the highest ECA's are:

- John Boyd Creek 40% ECA
- Sovereign Creek 36% ECA
- Reddish Creek 29% ECA.

Agency Concerns

The Department of Fisheries and Oceans has indicated concerns regarding the effects placer mining on fish habitat in Lightning Creek, John Boyd Creek, Sovereign Creek, Umiti Creek, and along the Cottonwood River mainstem. Extensive placer mining operations are found throughout the Cottonwood River watershed.

There are also concerns regarding the impacts that private land use activities may be having on streams in the Ahbau Creek and Nelson Kenny Creek sub-basins.

Both DFO and BC Environment have expressed concerns about sediment transport into Lightning Creek from the ski hill.

Forest Renewal BC

The Watershed Restoration Program under Forest Renewal BC is funding the following work in the Cottonwood River watershed:

- Overview and Level 1 Fish Habitat Assessments
- Sediment Source Mapping
- Access Management Planning.

Inventory Observations

Stream Channels

Stream channels were assessed through the aerial reconnaissance surveys and during a field inspection of 30 stream reaches throughout the watershed.

The inventory results indicated that channel disturbance related to land use is common in portions of the Cottonwood River watershed. Channels in Lightning Creek have been disturbed by placer mining activity *[Sites L1, L2, L3, L4 and L5] [Figure 2]* and in John Boyd Creek the disturbance is associated with harvesting in the riparian zone (pre-FPC) *[Sites JB1, JB2, JB3, JB4 and JB5]*. The impact of these disturbances was indicated by:

1. Increased sediment from stream banks and riparian areas.
2. Increased bank erosion.
3. Elevated gravel bar formation with possible channel dewatering during low flow periods.
4. Increased rates of bed load transport.

Old roads (pre-FPC) in the Cottonwood River watershed were generally stable, with compacted running surfaces and stable ditch lines. However, the following concerns were *[Sites SOV2, U5, L11, JB6, LS5 and V2]:*

1. Concentration of surface runoff by roads was common and cross-drains were rare, allowing water to flow along the running surface and ditch lines for long distances.

2. Ditches discharge directly into streams at stream crossings.

3. On a few abandoned but non-deactivated spurs, surface erosion has been severe with the sediment transported to the ditch lines of active roads.

Proposed Harvesting 1997-2001

A total of 14,200 ha (5.7% percent of the Cottonwood River watershed) is proposed for harvesting during the 1997-2001 period. Approximately 9.0% (10,160 ha) of the total proposed cut is located in the Swift River sub-basin, which includes Sovereign Creek, Reddish Creek, McMartin Creek, Victoria Creek and Little Swift River sub-basins. In the remainder of the watershed, the proposed harvesting varies from lows of 0.4% and 0.8% of the Nelson Kenny Creek and Ahbau Creek sub-basins (respectively), to a high of 11.6% in the Victoria Creek sub-basin.

Inventory Interpretation

Land use activities have resulted in channel disturbances with probable fisheries impacts in portions of the Cottonwood River watershed. The principal channel disturbance is related to placer mining in Lightning Creek and John Boyd Creek, and possibly Sovereign Creek. For Lightning Creek and John Boyd Creek, especially, the extent of placer-related disturbance is severe. Other streams have also been disturbed by placer mining but the extent of the mining was often limited to a small, specific site.

Channels have also been impacted by forest development but these effects have been less than those from placer mining. Harvesting in the riparian zone (pre-FPC) may have contributed to stream bank destabilization and channel aggradation in John Boyd Creek, Umiti Creek and Sovereign Creek. Since there may have been impacts from placer mining as well as possible peak discharge increases related to high ECA values in these sub-basins, linking impacts to a specific activity would be difficult. Throughout much of the rest of the watershed, channels appeared to be in good condition with limited effects on fish.

Sediment transport into streams at crossings along most roads is a concern. Old roads were found to be producing less sediment than newer roads, as would be expected. But the dispursed sediment generated from all roads is an issue that requires attention.

Recommendations

1. A total development plan should be prepared to determine if it is necessary to consider development constraints to limit increases in peak flows that might affect channel stability. The sub-basins of specific concern are John Boyd Creek, upper Umiti Creek, Sovereign Creek and the Fontaine Creek sub-basin of Reddish Creek.

2. In the Lightning, John Boyd, Sovereign and Umiti sub-basins, all low gradient alluvial channels (including S1-S5 channels) should have the riparian zone protected from harvesting in order to minimize any further increases in bedload transport.

3. Pre-FPC roads that are still active should have drainage works upgraded to reduce sediment transport into streams at crossings.

4. For new roads recently constructed (and for new construction), improved sediment control measures should be considered, including more cross-drains, sumps and ditch blocks, the use of silt fence, and grass seeding of disturbed cut and fill areas.

5. During periods of wet weather when it may not be possible to control sediment on new construction, work should be suspended.

6. Remedial plans should be considered to address channel disturbance/instability concerns related to placer mining activity in the John Boyd Creek, Umiti Creek and Sovereign Creek sub-basins. The objective of any restoration work should be to improve channel stability, and the quality and quantity of impacted fish habitat.

7. Consideration should be given to establishing a water quality monitoring program in the Swift River watershed to establish a baseline. The goal would be to determine the effects, if any, on water quality associated with land use practices, and to identify any change in water quality that might be related to altered road construction and use practices.

4. Approximately 30 km of road in the Ahbau sub-basin were traveled and assessed. The roads were stable and no particular problems were noted.

Proposed Harvesting 1997-2001

Approximately 335 ha of logging is proposed for the Ahbau sub-basin for the 1997-2001 period, corresponding to 0.8% of the watershed area. This extent of harvesting is low.

Inventory Interpretation

1. Ahbau Creek has been disturbed by agricultural land clearing and cattle activity in riparian zones. Some bank disturbance and channel widening has occurred in the lower portions of the basin.

2. Forestry-related impacts are minimal. Most of the logging has occurred upstream of Ahbau Lake, where downstream impacts would be buffered by the lake.

3. The mainstem channel has a gravel bed with an active floodplain that is sensitive to riparian disturbance. Harvesting/land clearing in the riparian zone would likely result in increased bank erosion and channel widening.

4. Harvesting proposed in the five-year plan is not a concern, provided that adequate stream and riparian protection measures are implemented (i.e. FPC requirements).

Recommendations

1. Maintain channel stability by protecting riparian zones and restricting increases in peak flow to no more than a moderate level, as defined in the IWAP.

2. Consider restoration work in the riparian zones on private land to reduce bank erosion and channel migration.

7. All the roads assessed in the John Boyd Creek sub-basin were pre-FPC and found to be stable with compacted running surfaces and stable ditch lines.

8. The following list summarizes the road-related concerns that impact streams *[Site JB6]:*

   - Concentration of runoff on running surfaces was common.
   - Cross drains were infrequent, allowing water to flow in ditch lines for long distances.
   - Ditch lines discharge into streams at crossings.

Proposed Harvesting 1997-2001

Approximately 790 ha of logging is proposed for the John Boyd Creek sub-basin for the 1997-2001 period, corresponding to 7.2% of the watershed area.

Inventory Interpretation

John Boyd Creek has been highly disturbed by placer mining, harvesting in the riparian zones and peak flow increases.

- The mainstem channel is gravel bed with an active floodplain and is sensitive to increased peak flows, and accelerated bank erosion and bed load transport.
- The proposed harvesting will increase ECA's that are already high (40%+/-) and increase the potential for higher peak flows, which would in turn increase the risk of additional channel disturbance.

7.3 LIGHTNING CREEK

Watershed Characteristics

Lightning Creek has a drainage area of 25,940 ha. Most of the watershed is located on the Cariboo Plateau *[Figure 4]*. The eastern watershed also contains high relief terrain in the Quesnel Highlands portion of the sub-basin. Relief is moderate to steep. The watershed traverses the SubBoreal Spruce and Engelmann Spruce Subalpine Fir biogeoclimatic zones. The mainstem channel of Lightning Creek (and some of its larger tributaries) are utilized by chinook salmon, bull trout and rainbow trout.

Background Information

The majority of the sub-basin is Crown land. According to the IWAP completed in the mid-1995, the ECA was approximately 16%. The potential hazard ratings in the IWAP were low-moderate peak flows, surface erosion and riparian buffers, and low for landslides. The impacts from placer mining are major concern in the sub-basin. Historic and current placer mining operations are common throughout the watershed, and are most common in the lower basin.

In addition to the placer mining activity, the Department of Fisheries and Oceans is also concerned about harvesting in the riparian zone in the Peters Creek sub-basin, which could increase sediment production into Lightning Creek.

Inventory Observations

A summary of the field observations is as follows:

1. Almost the entire length of the mainstem stream channel in the sub-basin, and many of the tributary channels, have been disturbed by placer mining. Disturbance indicators are channel aggradation, channel widening and bank erosion *[Sites L1, L2, L6, L3, L4 and L5]*.

2. Floodplain areas have been disturbed by placer mining resulting in a loss of fish habitat such as side channels. Many tributaries may be chronic sources of gravel to Lightning Creek.

3. Fill slope failures on steep terrain in Peters Creek and stream bank disturbance *[Site L11]* may be contributing sediment to the creek.

4. The ski hill on the north side of Lightning Creek (near Wingdam) is a chronic source of sediment to Lightning Creek, resulting in increased bed material and increased turbidity in Lightning Creek *[Site L8]*.

7.4 LITTLE SWIFT RIVER

Watershed Characteristics

The Little Swift River has a drainage area of 13,118 ha. While part of the watershed is located on the Cariboo Plateau *[Figure 5]*, the majority of the watershed is situated on the Quesnel Highlands, which is high relief and high precipitation terrain. Relief is moderate. The watershed is primarily within the Engelmann Spruce Subalpine Fir biogeoclimatic zones. It is understood that anadromous fish do not utilize the Little Swift River but that resident trout are present.

Background Information

The Little Swift River is 100% Crown land. According to the 1995 IWAP, the ECA at that time was approximately 15%. The IWAP results suggest that the potential for cumulative impacts is low. No specific concerns were noted during the agency interviews.

Inventory Observations

The following is a summary of the observations made in the sub-basin:

1. Stream channels were assessed at four locations.
2. The mainstem stream channel is undisturbed by past development
3. Placer mining activity has occurred on some lower reaches of the Little Swift River, however, limited channel disturbance was noted *[Site LS1]*.
4. The Little Swift River had a high suspended sediment load during spring freshet. Some of sediment originated from roads in the upper sub-basin.
5. The field-based channel reconnaissance did not identify any channel disturbance from development activities.

Road assessments indicated that both old and new roads are contributing sediment to the Little Swift River. Some ditch erosion and running surface erosion was noted on old but active roads *[Site LS5]*. Recently constructed roads *[Sites LS6, LS7 and LS8]* were the main concerns and a major source of fine sediment to the Little Swift River.

Recommendations

1. Pre-FPC roads should have the road drainage works upgraded, particularly at stream crossings to reduce sediment transport into streams.

2. Sediment control needs to be improved for roads recently constructed (and for future road construction) and should include:

   - More cross-drains.
   - The installation of sumps and ditch blocks at culverts.
   - The use of silt fences to capture sand-sized sediment.
   - Grass seeding of cuts.
   - Wet weather restrictions for industrial use of roads where sediment transport is a concern.

3. A total development plan should be prepared for the watershed that will assist in maintaining the peak flow hazard at no more than a moderate level in order to maintain channel stability.

7. At two new road locations (circa 1996), extensive erosion was occurring *[Sites M5 and M6]*. The erosion was related to the fine-grained local till used to construct the sub-grade, the lack of surfacing with coarse material to armour the road, the absence of erosion or sediment control measures in the construction, and the use of the road during wet conditions.

Proposed Harvesting 1997-2001

Approximately 926 ha of logging is proposed for the McMartin Creek sub-basin for the 1997-2001 period (corresponding to 5.8% of the watershed), which would increase the ECA to approximately 15% by 2001.

Inventory Interpretation

1. There are few problems in the McMartin Creek sub-basin and stream channels appear undisturbed.

2. The principal problem noted in the sub-basin is new road construction and lack of sediment control measures sediment transport into the Little Swift River.

Recommendations

1. Pre-FPC roads should have the drainage works upgraded to reduce sediment transport into streams.

2. For recently constructed roads (and for future road construction), improved sediment controls should include:

   - More extensive cross-drains.
   - Sumps and ditch blocks at culverts.
   - The use of silt fences in ditch lines to capture sand-size sediment.
   - Grass seeding of cuts and fills.
   - Wet weather restrictions for industrial use of roads where sediment transport is a concern.

3. A total development plan should be prepared for the watershed that will assist in maintaining the peak flow hazard at no more than a moderate level in order to maintain channel stability.

Inventory Interpretation

1. The sub-basin is predominantly private agricultural land. No problems were noted on the Crown land.

2. The harvesting proposed for the Nelson Kenny Creek sub-basin is unlikely to result in any problems.

Recommendations

None.

6. The road assessment in the Fontaine Creek basin indicated that new roads are a source of sediment.

7. Pre-FPC roads were generally stable with instances of long lengths of ditch line with running water *[Site R5].*

8. One new road site visited *[Site R7]* had severe cut and fill slope erosion as well as erosion from the uncompacted sub-grade. There was a lack of sediment control measures. Cut slopes had not been grass seeded or stabilized, and were rilled or gullied.

Proposed Harvesting 1997-2001

Approximately 379 ha of logging is proposed for the McMartin Creek sub-basin for the 1997-2001 period, corresponding to 5.2% of the watershed. About one-third is located in the Reddish Creek sub-basin and two-thirds in Fontaine Creek. ECA's for Reddish Creek will increase from 29%to approximately 34% by 2001.

For Fontaine Creek, the ECA would increase to approximately 38% at 2001.

Inventory Interpretation

1. Disturbances from placer operations and erosion from some new roads are a concern.

2. ECA values for Reddish Creek and Fontaine Creek are at levels where increases in peak flows may occur. However, no channel disturbance that might be related to increased peak flows was noted on the Fontaine Creek mainstem.

Recommendations

1. A total development plan should be prepared for the watershed that will assist in maintaining the peak flow hazard at no more than a moderate level in order to maintain channel stability.

2. Consideration should be given to reducing the extent of harvesting in the Fontaine Creek basin within the 1997-2001 period.

7.8 SOVEREIGN CREEK

Watershed Characteristics

Sovereign Creek has a watershed area of 11,249 ha located on the Cariboo Plateau *[Figure 7]* physiographic unit. Relief is moderate. The watershed is situated in the SubBoreal Spruce and Engelmann Spruce Subalpine Fir biogeoclimatic zones. The mainstem channel of Sovereign Creek, and some of its larger tributaries, are used by chinook salmon.

Background Information

The sub-basin is 100% Crown land. The ECA in the 1995 IWAP was 36%. The potential hazard ratings were high for peak flows and riparian buffers, moderate for surface erosion and low for landslides. Placer mining impacts were a concern. The Department of Fisheries and Oceans is also concerned about the rate of cut.

Inventory Observations

Inventory observations are summarized as follows.

1. Placer mining has impacted the riparian zone resulting in increased bank erosion *[Sites SOV1 and SOV3].*

2. Pre-FPC roads were generally stable and well armoured, although erosion was noted on some non-deactivated spur roads *[Site SOV2].*

Proposed Harvesting 1997-2001

Approximately 935 ha of logging is proposed for the Sovereign Creek sub-basin for the 1997-2001 period, corresponding to 8.3% of the watershed. The ECA would increase from 36% to about approximately 45% by 2001.

Inventory Interpretation

1. Dispersed placer operations have resulted in bank erosion and disturbance to the riparian zones.

2. Channel disturbances have resulted from placer mining, disturbances to the riparian zone and increases in peak flow.

3. The high ECA proposed by 2001 will further impact channel stability.

7.9 SWIFT RIVER

Watershed Characteristics

The Swift River has a watershed area of 113,918 ha and includes the Victoria Creek, Reddish Creek, Sovereign Creek, Little Swift River, and McMartin Creek sub-basins *[Figures 5 and 8].* (Note: the watershed area of 36,277 ha for the Swift River sub-basin referred to in Tables 1 and 3 of this report is for the residual area only.) Most of the lower watershed is located on the Cariboo Plateau phyiographic unit where relief is low. The upper watershed (including portions of the Little Swift, McMartin and Reddish sub-basins) is located on the Quesnel Highland physiographic unit where relief is greater and valleys more dissected The watershed is primarly within SubBoreal Spruce biogeoclimatic zones.

The lower Swift River (to about 8.0 km upstream of Victoria Creek) is utilized by chinook salmon. The upper watershed is used by resident trout.

Background Information

The Swift River sub-basin is 100% Crown land. The ECA in 1995 was approximately 16%. The potential hazard ratings for the Swift residual area were low for surface erosion and landslides, moderate for peak flows and high for riparian buffers.

Inventory Observations

A summary of the inventory observations for the Swift residual area is presented below. (Refer to separate sections in this report for the Little Swift River, Reddish Creek, McMartin Creek and Sovereign Creek sub-basins.)

1. The following concerns were identified for roads:

    - Sub-grades were constructed from local surficial materials (commonly fine-grained till).
    - Coarse surfacing material was not common.
    - Some roads were deeply rutted.
    - Erosion of the running surface, and cut and fill slopes was evident.

Recommendations

1. A total development plan should be prepared for the watershed that will assist in maintaining the peak flow hazard at no more than a moderate level in order to maintain channel stability.

2. Pre-FPC roads require improvements to road drainage works to reduce sediment transport into streams at stream crossings.

3. For new roads (and for future road construction), improvements to control sediment transport should include:

   - More cross-drains.
   - Sumps and ditch blocks at culvert inlets.
   - The use of silt fences in ditch lines to capture sand-size sediment.
   - Grass seeding of disturbed cuts and fills.
   - Wet weather restrictions for industrial use of roads where sediment transport is a concern.

Proposed Harvesting 1997-2001

Approximately 693 ha of logging is proposed for the Umiti Creek sub-basin for the 1997-2001 period, corresponding to 4.7 percent of the watershed. ECA would increase from 23% to 26 % by 2001. Most of the harvesting is proposed in the upper watershed, where the ECA is >30 percent.

Inventory Interpretation

1. Channel disturbances have occurred related to placer mining and forest development.

2. Alluvial channels in the upper watershed have been disturbed by harvesting in the riparian zone and possibly due to high ECA's (>30%).

3. The amount of harvesting proposed in the upper watershed in the five-year plan may result in further instability in the alluvial channels, which are sensitive to increases in peak flow.

Recommendations

1. A total development plan should be prepared for the watershed that will assist in planning forest development so as to maintain the peak flow hazard at no more than a moderate level in order to maintain channel stability.

2. Distribution of harvesting over the Umiti Creek sub-basin would reduce the cumulative impacts.

Recommendations

1. A total development plan should be prepared for the watershed that will assist in planning forest development particularly proposed road development.

2. For new roads (and for future road construction), improvements to control sediment transport should include:

   - More cross-drains.
   - Sumps and ditch blocks at culvert inlets.
   - The use of silt fences in ditch lines to capture sand–size sediment.
   - Grass seeding of disturbed cuts and fills.
   - Wet weather restrictions for industrial use of roads where sediment transport is a concern.

AC/dd/jb

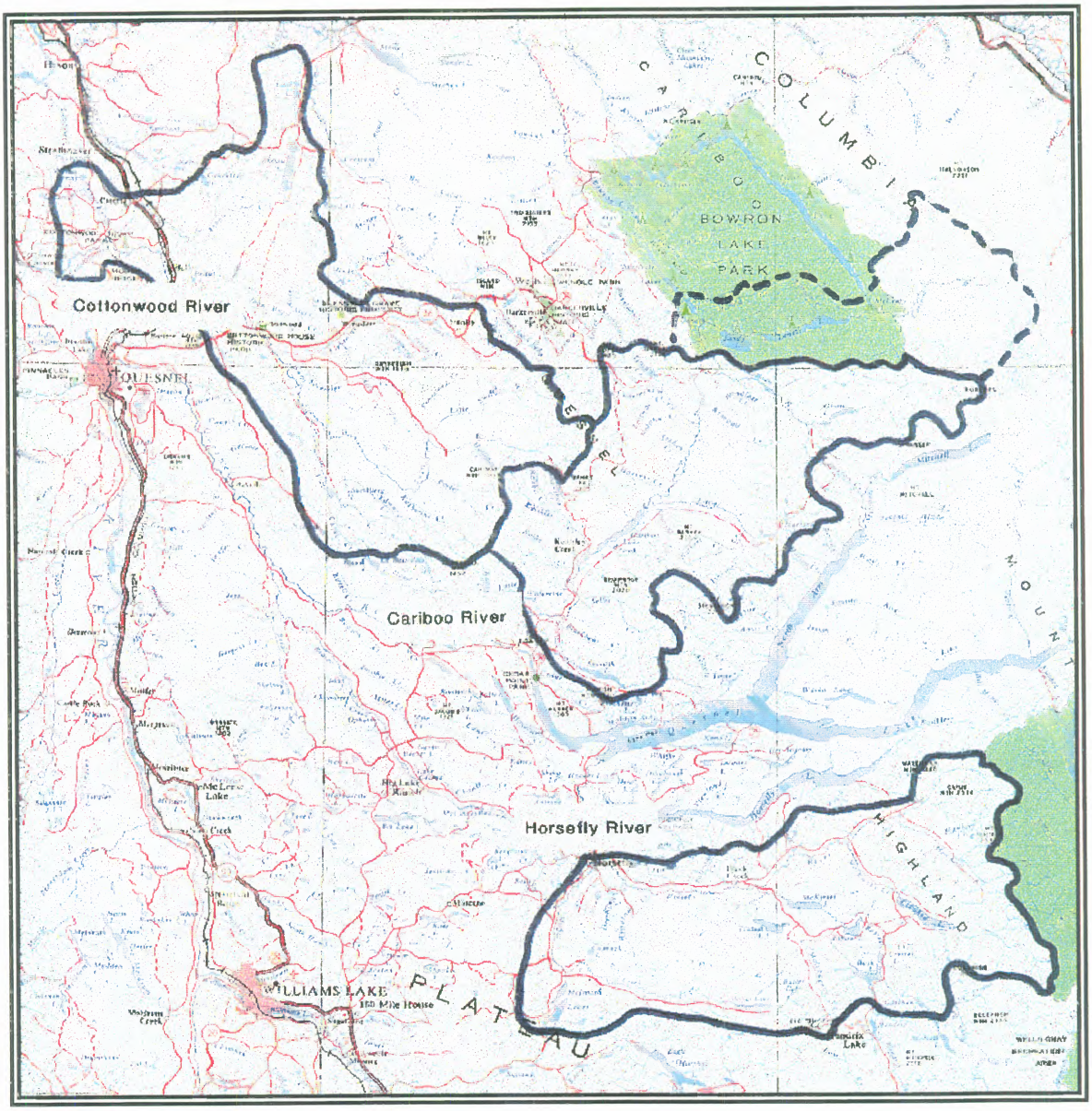


FIGURE 1

The study area showing the locations of the Cottonwood River watershed, the Cariboo River watershed and the Horsefly River watershed above the town of Horsefly.

COTTONWOOD RIVER WATERSHED

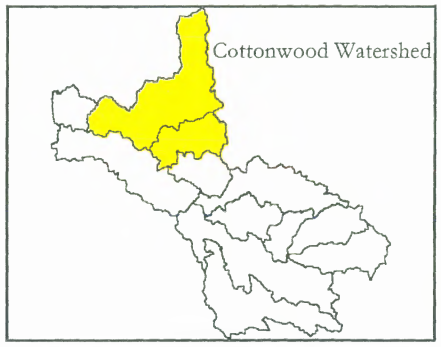
FIGURE 2

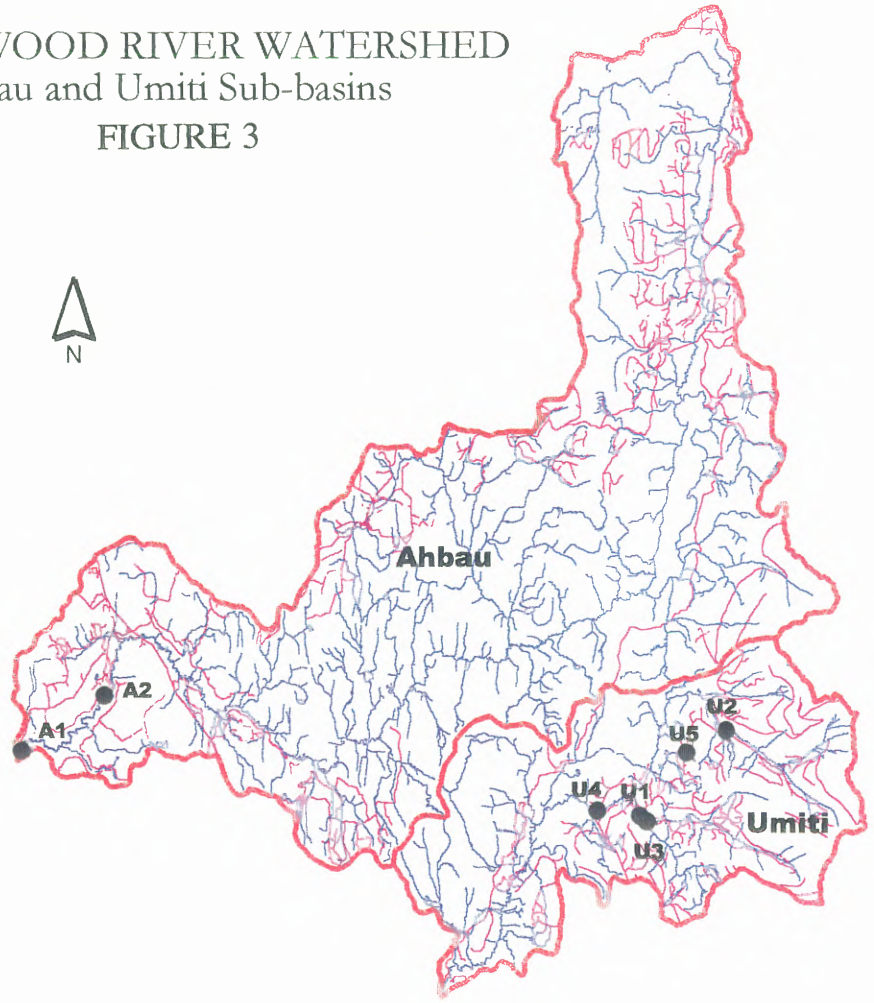
• Location of channel and road assessments, and photos referenced within text

Roads

CARIBOO REGION WATERSHED INVENTORY

COTTONWOOD RIVER WATERSHED
Ahbau and Umiti Sub-basins
FIGURE 3





2 0 2 4 Kms

Roads

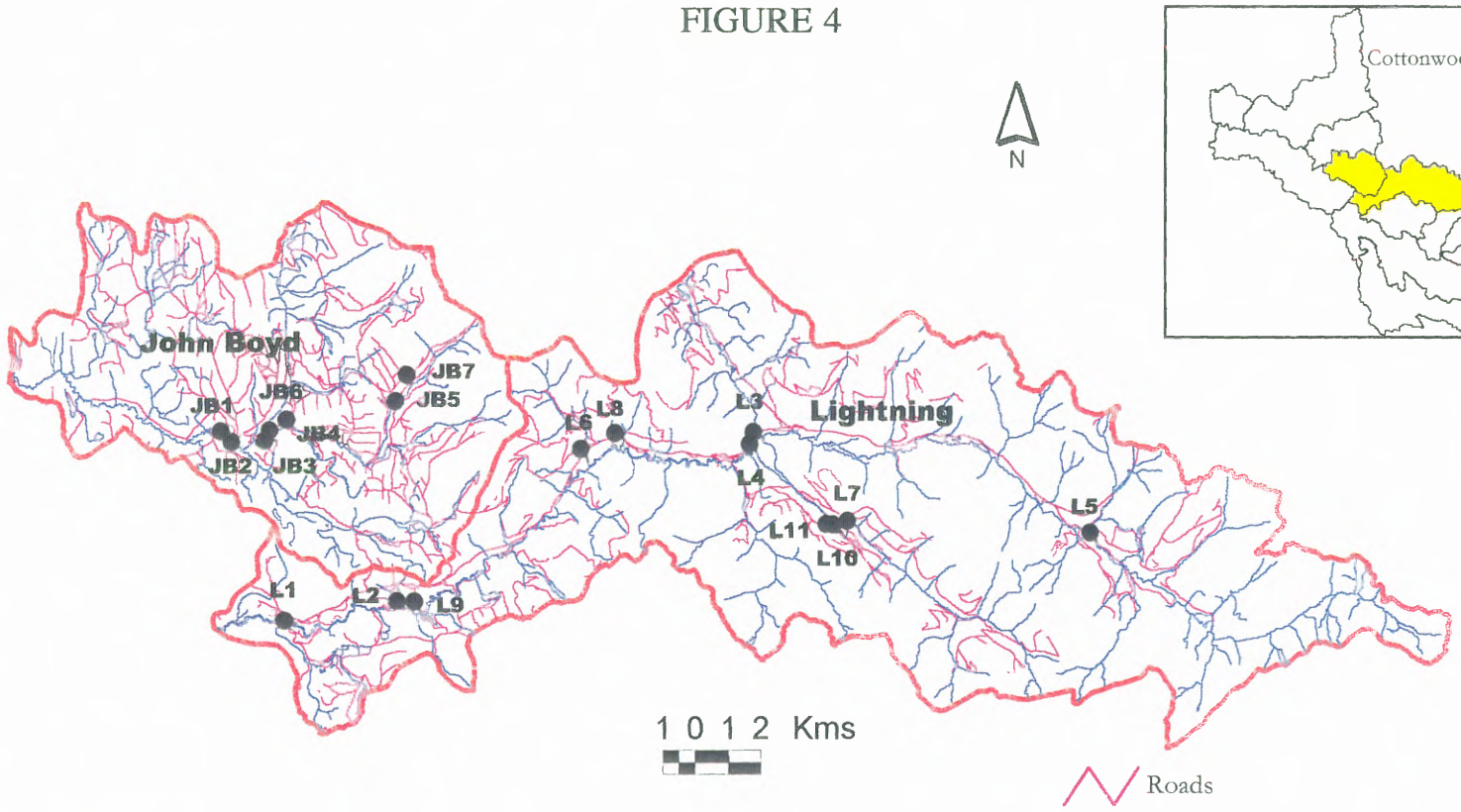
Location of channel and road assessments, and photos referenced within text

Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by West Fraser Mills Ltd. (Quesnel, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

COTTONWOOD RIVER WATERSHED
John Boyd and Lightning Sub-basins

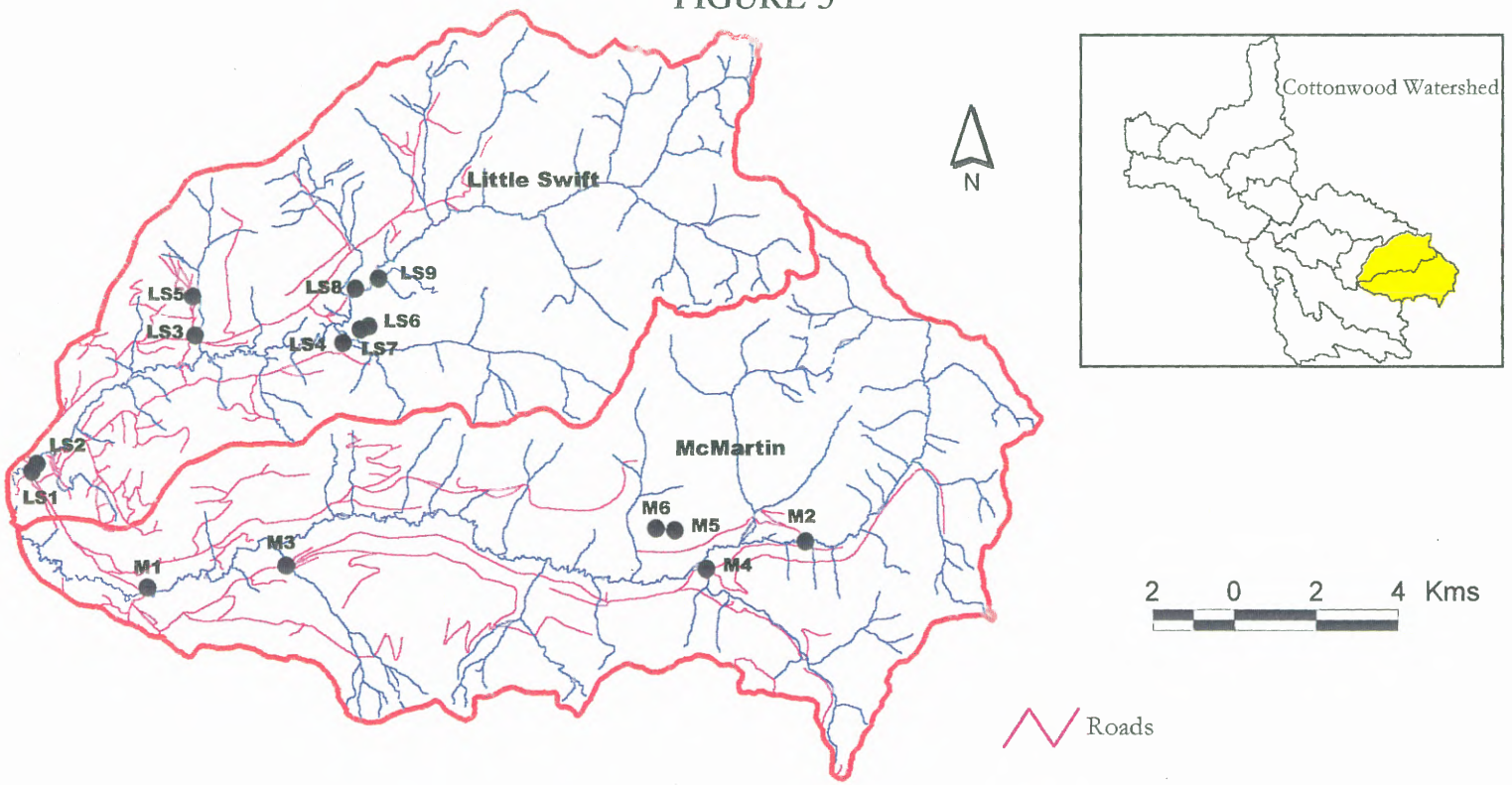
FIGURE 4



Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by West Fraser Mills Ltd. (Quesnel, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

COTTONWOOD RIVER WATERSHED
Little Swift and McMartin Sub-basins
FIGURE 5

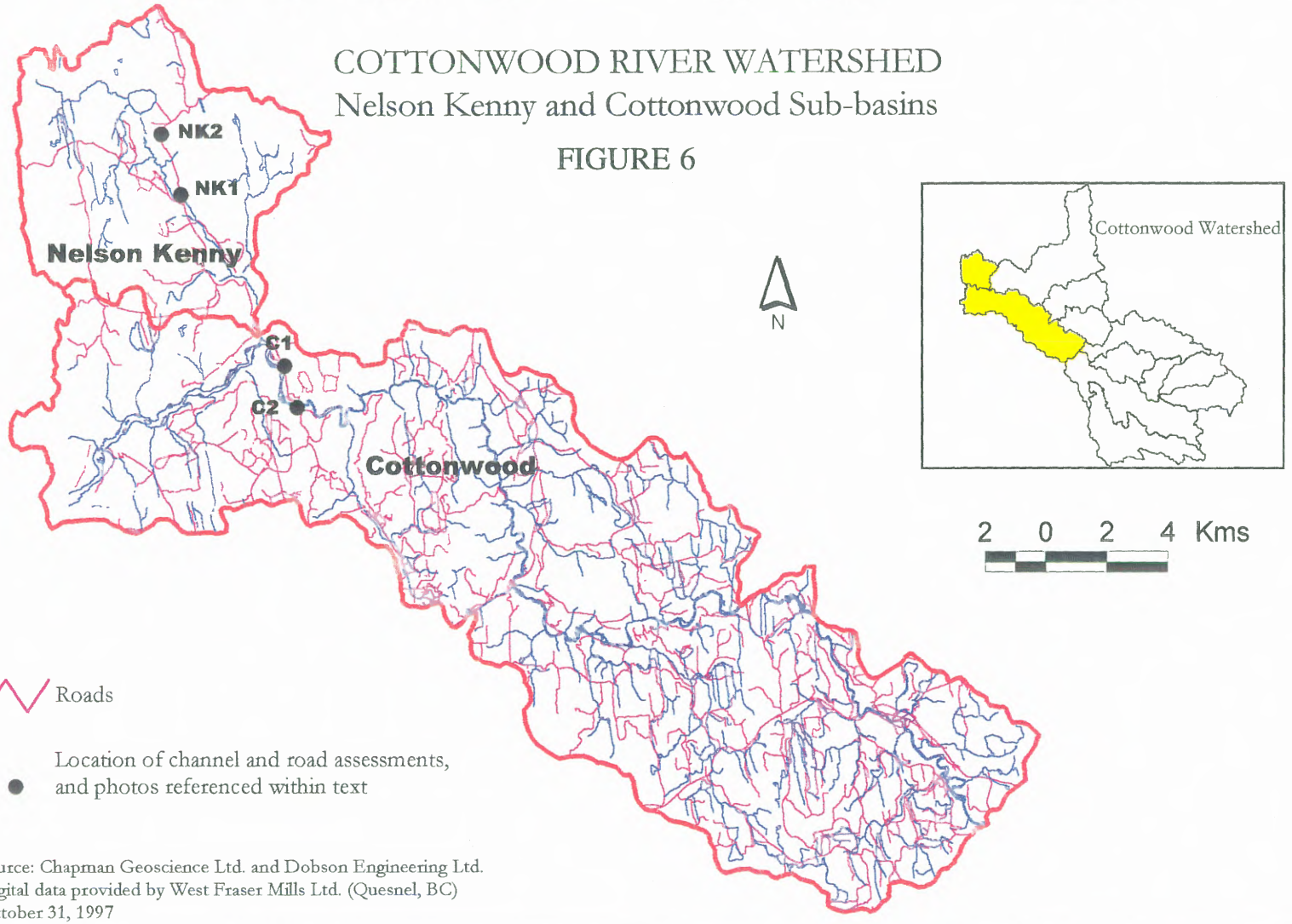


Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by West Fraser Mills Ltd. (Quesnel, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

COTTONWOOD RIVER WATERSHED
Nelson Kenny and Cottonwood Sub-basins

FIGURE 6

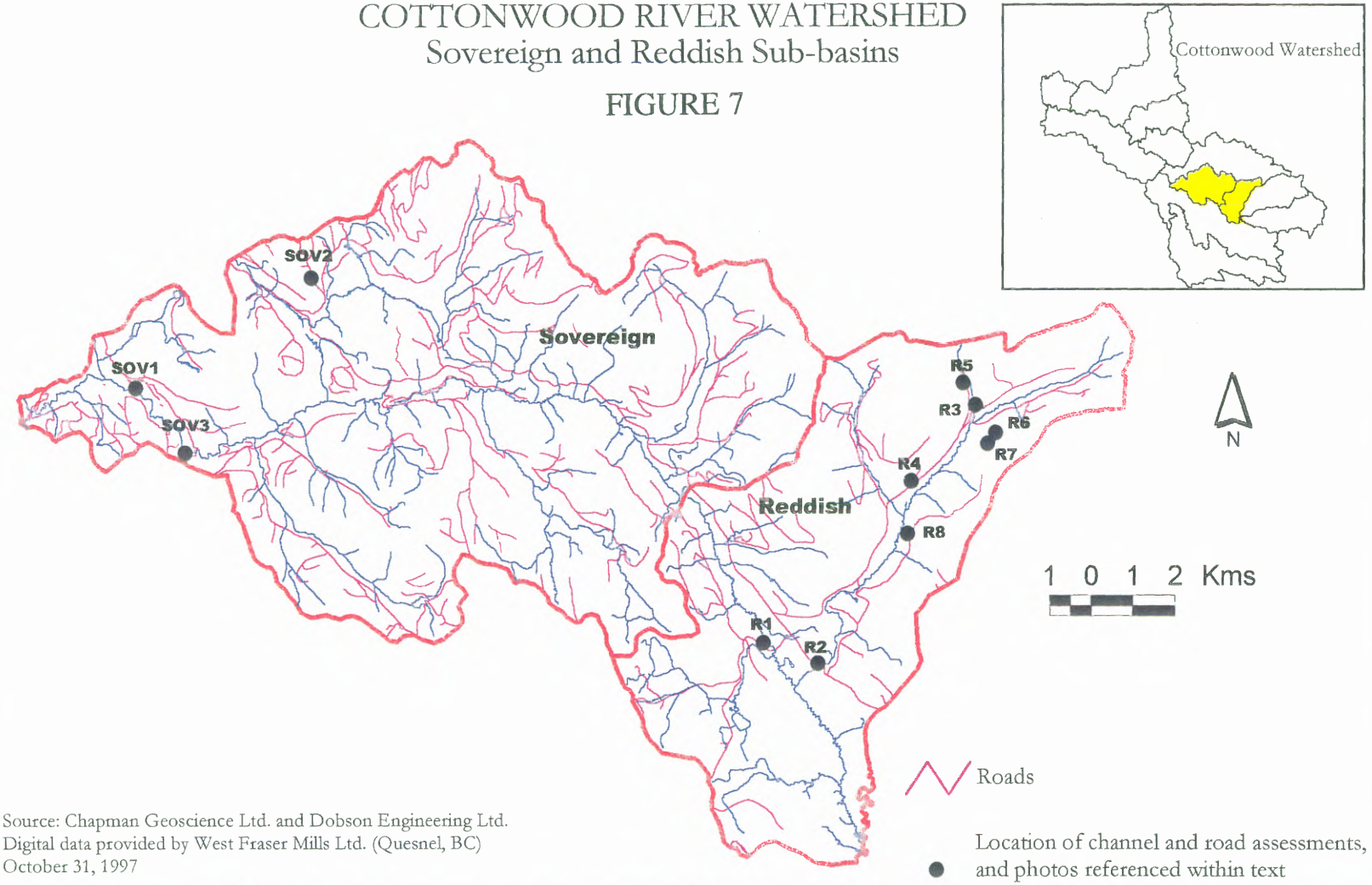


Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by West Fraser Mills Ltd. (Quesnel, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

COTTONWOOD RIVER WATERSHED
Sovereign and Reddish Sub-basins

FIGURE 7

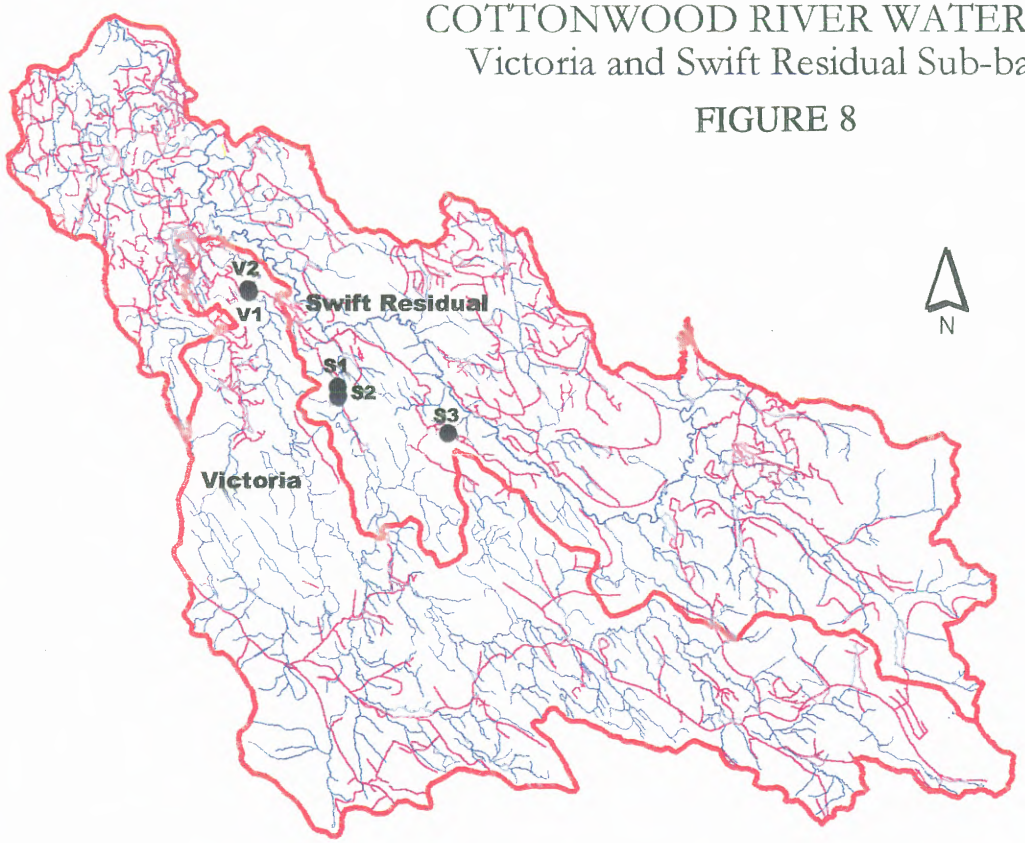


Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by West Fraser Mills Ltd. (Quesnel, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

COTTONWOOD RIVER WATERSHED
Victoria and Swift Residual Sub-basins

FIGURE 8



3 0 3 6 Kms

Roads

Location of channel and road assessments, and photos referenced within text

Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by West Fraser Mills Ltd. (Quesnel, BC)
October 31, 1997

TABLE 1
Cottonwood River Watershed

Watershed or Sub-basin	Drainage Area (ha)	Elevation (m)		Relative Relief	Physiographic	Biogeoclimatic	Fish	Tenure (%)[1]	
		Min	Max	Relief/Area$^{1/2}$	Region	Zone	Resource	Crown	Private
Cottonwood River at the mouth	247,363	500	2010	30	Cariboo Plateau (80%)	SBS (70%)	chinook, trout	n/a	n/a
Nelson Kenny Creek	7,923	550	800	28	Cariboo Plateau	SBS		18	82
Ahbau Creek	42,920	550	1580	50	Cariboo Plateau	SBS	chinook, trout	94	6
John Boyd Creek	11,046	800	1560	72	Cariboo Plateau	SBS	chinook, trout	26	74
Lightning Creek	25,940	790	1990	75	Cariboo Plateau (90%)	SBS (90%)	chinook, trout	n/a	n/a
Umiti Creek	14,876	790	1610	67	Cariboo Plateau	SBS	chinook, trout	100	0
Swift River	113,918	790	2010	86	Cariboo Plateau		chinook, trout	n/a	n/a
Little Swift River	13,118	1030	2010	77	Cariboo Plateau (25%)	SBS (15%)	chinook, trout	100	0
McMartin Creek	16,080	1030	2010	77	Cariboo Plateau (25%)	SBS (77%)	chinook, trout	100	0
Reddish Creek	7,245	1030	1690	78	Cariboo Plateau	SBS (80%)	chinook, trout	n/a	n/a
Soverign Creek	11,249	790	1680	84	Cariboo Plateau	SBS (60%)	chinook, trout	100	0
Victoria Creek	29,949	870	1600	42	Cariboo Plateau	SBS	chinook, trout	n/a	n/a
Swift River residual	36,277	790	1930	60	Cariboo Plateau (90%)	SBS (95%)	chinook, trout	n/a	n/a
Cottonwood residual	30,741	530	1030	29	Cariboo Plateau	SBS	chinook, trout	81	19

Note. 1. The land tenure information presented here is as reported in the Cottonwood River IWAP. The Crown / private land breakdown has not been verified. The 74 percent private land reported for John Boyd Creek appears to be incorrect, and is likely substantially smaller.

2. Relative relief is a measure of the steepness of a watershed. The higher the value, the greater the average steepness.

TABLE 3
Cottonwood River Watershed

Watershed or Sub-basin	Area Logged (1995)[4]		FTRA ECA	IWAP (1995 data)						Other Land Use[5]		
	ha	%	%	ECA %	Road Density km/km²	Peak Flow	Surface Erosion	Riparian	Mass Wasting	Agriculture	Placer	Other
Cottonwood River at the mouth	54,123	22	26	18[3]	0.78	L	L-M	H	L[2]	L	H	
Nelson Kenny Creek	650	8		7[3]	0.75	L	M[1]	H	L	H	L	
Umiti Creek	3,836	26	51	23	0.8	M	L-M[1]	M	L		M	
Ahbau Creek	8,760	20	27	17[3]	0.67	L	L	M	L	H	L	
John Boyd Creek	5,607	51		40[3]	1.6	H	H[1]	H	L	L	H	
Lightning Creek	4,150	16	19	16	1	L-M	M[1]	L-M	L	L	H	ski hill
Swift River	20,235	18		16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Little Swift River	1,710	13		15	0.74	L	L	L	L	L	L	
McMartin Creek	1,384	9		9	0.47	L	L	L	L	L	L	
Reddish Creek	2,328	32		29	1.1	H	H[1]	H	L	L	L	
Soverign Creek	4,461	40		36	1	H	M[1]	H	L	L	M	
Victoria Creek	1,943	6	16	6	0.31	L	L	L	L	L	L	
Swift River residual	8,409	23	12	21	0.59	L-M	L	H	L	L	L	
Cottonwood residual	11,170	36		21[3]	1.2	L	H[1]	H	H[2]			

Note:

1. The moderate and high surface erosion scores indicated by the IWAP assessment result from the density of road-stream crossings and from the density of roads located within 100 m of streams. In all the sub-basins, with the exception of John Boyd Creek, the total road density did not exceed the low category.
2. The high mass wasting score for the Cottonwood residual area results from the classification of bank slumps along the mainstem river channel as landslides. There are a very small number of hillslope failures such as debris slides or debris flows in the watershed.
3. These ECA values do not incorporate land clearing for agriculture purposes. It is likely that the ECAs are underestimates.
4. Area logged was calculated using data current to 1995. It is estimated that an additional 2% of the watershed has been harvested during 1996 and 1997, for a total of about 24 percent.
5. For other land use, we have made a very general interpretation of Low, Moderate or High concern, based on available information and interviews.

TABLE 4
Cottonwood River Watershed

Watershed or Sub-basin	Drainage Area (ha)	Crown Land			Proposed Harvesting 1997-2001		
		Area Logged (1995)[1]		ECA[2]	Area[3]		Rate-of-Cut
		ha	%	%	ha	%	%/yr
Cottonwood River at the mouth	247,364	54,123	22	18[3]	14,200	5.7	1.1
Ahbau Creek	42,920	8,760	20	17[3]	335	0.8	0.2
Nelson Kenny Creek	7,923	650	8	7[3]	35	0.4	0.1
Umiti Creek	14,876	3,836	26	23	693	4.7	0.9
John Boyd Creek	11,046	5,607	51	40[3]	791	7.2	1.4
Lightning Creek	25,940	4,150	16	16	1,700	6.6	1.3
Swift River	121,841	20,885	17	16	10,193	8.4	1.7
Little Swift River	13,118	1,710	13	15	1,060	8.1	1.6
McMartin Creek	16,080	1,384	9	9	926	5.8	1.2
Reddish Creek	7,245	2,328	32	29	379	5.2	1.0
Soverign Creek	11,249	4,461	40	36	935	8.3	1.7
Victoria Creek	29,949	1,943	6	6	3,484	11.6	2.3
Swift River residual	36,277	8,409	23	21	3,374	9.3	1.9
Cottonwood residual	30,741	11,170	36	21[3]	488	1.6	0.3

WATERSHED: COTTONWOOD **SUB-BASIN:** AHBAU CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	Not evident	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	Not evident	n/a
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	Natural bank failures.	Agricultural clearing on lower channel	
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Level of harvest undetermined.		
COMMENTS	Ahbau Creek runs through glacio-fluvial deposits, banks eroding. High bed load and some woody debris.		

WATERSHED: COTTONWOOD **SUB-BASIN:** JOHN-BOYD CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	Not evident	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	One slide into John-Boyd Cr.	Active
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	Bank erosion noted on lower John-Boyd Cr.	Upper John-Boyd logged, placer is common.	
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Level of harvest undetermined.		
COMMENTS	Potential source of gravel to Cottonwood mainstem. Appears to be placer and riparian logging disturbance. Some natural bank erosion noted.		

WATERSHED: COTTONWOOD **SUB-BASIN:** LIGHTNING CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	From ski hill	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	Not evident	n/a
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	Some bank failures noted.	Placer all the way up the mainstem.	Mid-channel islands noted.
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Level of harvest undetermined.		
COMMENTS	High levels of bed load in upper watershed, but appears to have limited harvest. Extensive placer upstream.		

WATERSHED: COTTONWOOD **SUB-BASIN:** REDDISH CREEK (Fontaine Creek)

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	Turbidity from Fontaine Creek	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	Not evident	n/a
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	No instability noted.	Heavy logging in Fontaine and Reddish.	
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Level of harvest undetermined.		
COMMENTS	Fontaine serves as sediment source to Reddish due in part to heavy placer. Reddish has clear flow upstream of Fontaine Creek.		

WATERSHED: COTTONWOOD **SUB-BASIN:** SOVEREIGN CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	Not evident	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	Not evident	n/a
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	No instability observed.	Heavy riparian logging. Placer below Moustique Creek.	High bed load.
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Level of harvest undetermined.		
COMMENTS	No mass wasting or major bank failures noted. Turbid flow out of Sovereign Creek.		

WATERSHED: COTTONWOOD **SUB-BASIN:** SWIFT RIVER

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	Not evident	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	Not evident	n/a
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	Banks eroding upstream of Victoria Creek confluence.		Debris jams noted.
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Level of harvest undetermined.		
COMMENTS	Many blocks in upper Swift, but no riparian logging. Placer in lower Little Swift, also small bank slumps.		

WATERSHED: COTTONWOOD **SUB-BASIN:** UMITI CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	Not evident	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	Not evident	n/a
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	Some observed.	Logging of some tributary channels.	Some bank disturbance from riparian logging
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Level of harvest undetermined.		
COMMENTS	Some areas appear to have potentially high natural instability. Also, possible placer and riparian logging disturbance.		

WATERSHED: COTTONWOOD **SUB-BASIN:** VICTORIA CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	Dark brown organic looking flow from Victoria into Swift.	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	Not evident	n/a
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	No instability noted.	Harvest south of Sundberg Lake. Some agriculture.	Channel widening south of Sundberg Lake.
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Level of harvest undetermined.		
COMMENTS	No extensive riparian logging or bank instability noted.		

WATERSHED: COTTONWOOD **SUB-BASIN:** RESIDUAL

Stop C1. Approximately 12.5 km upstream of Fraser River confluence, and 1 km upstream of Ahbau Creek confluence.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Stable and dynamic	Gradient.	Fluvial, gravel
DISTURBANCE INDICATORS: Bank erosion, large mid-channel bars			
COMMENTS: Very wide, anastomosed channel, carrying high bed load, eroding banks of glaciofluvial gravels.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Agriculture adjacent to mainstem.	Some land clearing for agriculture.
COMMENTS: 1958 - 1995 air photo comparison did not indicate significant erosion or channel change related to land use. Note the large, natural erosion on right bank.	

WATERSHED: COTTONWOOD **SUB-BASIN:** RESIDUAL

Stop C2. Approximately 13.5 km upstream of Fraser River confluence, and 2 km upstream of Ahbau Creek confluence.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Mostly stable.	Gradient	Fluvial, eroding
DISTURBANCE INDICATORS: Bank erosion adjacent to cleared reaches			
COMMENTS: Very wide, anastomosed channel, carrying high bed load, eroding banks of glaciofluvial gravels.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Private, some agricultural clearing	Bank erosion proximal to cleared riparian
COMMENTS: 1958 - 1995 air photo comparison did not indicate significant erosion or channel change related to land use. However, note the active bank erosion on left bank, adjacent to cleared agricultural field.	

WATERSHED: COTTONWOOD **SUB-BASIN:** RESIDUAL

Stop C3. Cottonwood River mainstem, upstream of John Boyd Creek

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Stable, dynamic	Gradient	Eroding
DISTURBANCE INDICATORS: Large eroding glaciofluvial banks			
COMMENTS: The wide, mainstem channel has a series of large sections of eroding bank. Photo is taken from placer operation on disturbed floodplain.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Clearing on far bank; placer on photo bank	Substantially disturbed
COMMENTS: Placer operation has disturbed the floodplain. Eroding bank is probably unrelated to the riparian clearing	

WATERSHED: COTTONWOOD **SUB-BASIN:** AHBAU CREEK

Stop A1. Ahbau Creek, approximately 500 metres upstream of the Cottonwood mainstem.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool	Aggraded, unstable.	Gradient.	Fluvial, glaciofluvial, gravel.
DISTURBANCE INDICATORS: Eroding banks; large, elevated mid-channel bars.			
COMMENTS: Is a low gradient deposition reach upstream of the Cottonwood, heavily aggraded. Both natural and land use-related bank erosion is occurring.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Private, agriculture (livestock)	Partially cleared.
COMMENTS: Some erosion apparent along cleared banks, related to land use. Some natural bank erosion through glaciofluvial gravels is also occurring.	

WATERSHED: COTTONWOOD **SUB-BASIN:** AHBAU CREEK

Stop A2. Ahbau Creek, upstream of Hwy 97.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel	Moderately aggraded.	Gradient.	Fluvial, gravel.
DISTURBANCE INDICATORS: Eroding banks, large point bar, mid-channel bar.			
COMMENTS: Bank erosion is apparent.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Private, agriculture.	Some clearing has been done.
COMMENTS: Private land upstream of this reach. Both natural and land use-related bank erosion has occurred, resulting in the aggradation here and downstream.	

WATERSHED: COTTONWOOD **SUB-BASIN:** JOHN BOYD CREEK

Stop JB1. John Boyd Creek mainstem, approximately 8 km upstream of the Cottonwood River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Unstable	Gradient, LWD	Alluvial, gravel
DISTURBANCE INDICATORS: Extensive bank erosion, channel widening, large elevated gravel bars, recent woody debris input, placer activity			
COMMENTS: This alluvial reach is substantially disturbed, probably by placer.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer mining	Unstable, disturbed
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** JOHN BOYD CREEK

Stop JB2. John Boyd Creek mainstem, approximately 9 km upstream of the Cottonwood River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Unstable, disturbed	Gradient, LWD	Alluvial, gravel
DISTURBANCE INDICATORS: Extensive bank erosion and channel widening, large mid-channel and point bars, riparian logging, possible placer at the reach, upstream placer.			
COMMENTS: One of the most heavily disturbed channels in the Cottonwood.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer, riparian logging	Disturbed
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** JOHN BOYD CREEK

Stop JB3. John Boyd Creek mainstem, approximately 9.2 km upstream of the Cottonwood River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Unstable, disturbed	Gradient, LWD	Alluvial, gravel
DISTURBANCE INDICATORS: Extensive bank erosion and channel widening, large mid-channel and point bars, riparian logging, possible placer at the reach, upstream placer.			
COMMENTS: The aggrading stream bed is deflecting John Boyd Creek against a forested bank, triggering substantial bank erosion.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer, riparian logging on one bank	Disturbed
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** JOHN BOYD CREEK

Stop JB4. John Boyd Creek mainstem, approximately 9.3 km upstream of the Cottonwood River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Unstable, disturbed	Gradient, LWD	Alluvial, gravel
DISTURBANCE INDICATORS: Extensive bank erosion and channel widening, large mid-channel and point bars, riparian logging, possible placer at the reach, upstream placer.			
COMMENTS: Note the erosion at the logged bank.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer, riparian logging	Disturbed
COMMENTS: It appears that a riparian buffer was left at the time of logging, but was subsequently burnt.	

WATERSHED: COTTONWOOD **SUB-BASIN:** JOHN BOYD CREEK

Stop JB5. Upper Mary Creek tributary to John Boyd.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
	Now a wetland	Beavers	Flooded
DISTURBANCE INDICATORS: Flooded valley bottom			
COMMENTS: Substantial stand conversion to deciduous after logging. Beavers have since converted the valley bottom into a wetland.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logged	Deciduous regen - beaver food
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** LIGHTNING CREEK

Stop L1. Approximately 2 km upstream of Swift confluence, upstream of 1300 Road crossing.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Disturbed	Gradient	Alluvial, gravel
DISTURBANCE INDICATORS: Substantial aggradation, large mid-channel bars, eroding banks			
COMMENTS: Most of Lightning Creek is alluvial, and has been placer mined. Channel disturbance is substantial.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer, cleared	2^{nd} growth deciduous and coniferous
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** LIGHTNING CREEK

Stop L2. Approximately 6 km upstream of Swift River confluence.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Unstable	Gradient	Alluvial, gravel
DISTURBANCE INDICATORS: Eroding banks, aggraded bed, large bar development			
COMMENTS: This photo is looking across Lightning Creek at an active placer mining operation.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer, cleared	Very disturbed
COMMENTS: The floodplain and riparian area has been cleared and mined.	

WATERSHED: COTTONWOOD **SUB-BASIN:** LIGHTNING CREEK

Stop L3. Mainstem of Lightning Creek, upstream of Peters Creek

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Unstable	Gradient	Alluvial, gravel, unstable
DISTURBANCE INDICATORS: Heavily aggraded with gravel; eroding banks; large mid-channel bars.			
COMMENTS: This reach is downstream of a recently active placer operation. The channel is heavily aggraded.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer	Unstable
COMMENTS:	

WATERSHED: Cottonwood **SUB-BASIN:** Lightning Creek

Stop L4. 100 m downstream of previous stop

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Unstable	Gradient	Alluvial, gravel, unstable
DISTURBANCE INDICATORS: Heavily aggraded with gravel; eroding banks; large mid-channel bars.			
COMMENTS: Significantly disturbed by gravel input from placer mining.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer	Disturbed.
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** LIGHTNING CREEK

Stop L5. Upper Lightning Creek

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel/cobble	Unstable	Gradient	Alluvial, gravel
DISTURBANCE INDICATORS: Eroded banks. Widened channel, large mid-channel bar			
COMMENTS: This is the site of a currently-inactive placer mining operation.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer	Unstable
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** LIGHTNING CREEK

Stop L6. Pinegrove Creek below ski hill

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool	Unstable	Gradient	Alluvial, gravel
DISTURBANCE INDICATORS: Heavily aggraded with small gravel; has been excavated with a back-hoe.			
COMMENTS: This small stream drains a ski hill that is a chronic source of gravel and silt to Lightning Creek.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Recreation	Unstable
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** LITTLE SWIFT RIVER

Stop LS1. Little Swift River, approximately 3 km upstream of McMartin Creek confluence.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, cobble	Slightly channelized.	Gradient	Appear stable.
DISTURBANCE INDICATORS: Historic placer on floodplain. Banks have been leveed.			
COMMENTS: There is evidence of an old placer operation on the floodplain. Stream banks appear to have been leveed with cobbles and boulders.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer operation adjacent to stream	2^{nd} growth deciduous
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** LITTLE SWIFT RIVER

Stop LS2. Approximately 3.1 km upstream of McMartin confluence

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, cobble		Gradient, banks	Till, some bedrock
DISTURBANCE INDICATORS: None			
COMMENTS: This is the Water Survey reach.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None, except Water Survey gauge	Coniferous forest
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** LITTLE SWIFT RIVER

Stop LS3. Tributary of Little Swift River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-Pool, cobble/boulder		Bed, gradient	Till, stable
DISTURBANCE INDICATORS: None			
COMMENTS: A small, undisturbed tributary stream flowing into the Little Swift River; 3 m wide, 3-4% gradient.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Coniferous forest
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** LITTLE SWIFT RIVER

Stop LS4. Tributary to Little Swift River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, alluvial, gravel	Fine	Gradient, LWD	Alluvial, gravel
DISTURBANCE INDICATORS: None			
COMMENTS: A geotextile silt fence has been installed at ditch approach to stream.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Coniferous forest
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** MCMARTIN CREEK (upper Swift River)

Stop M1. McMartin Creek approximately 4.5 km upstream of the Swift River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, cobble	Stable	Gradient, LWD	Stable; cobble,gravel
DISTURBANCE INDICATORS: None.			
COMMENTS: 15 m wide; alluvial; looks great			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Undisturbed coniferous forest.
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** MCMARTIN CREEK

Stop M2. Upper McMartin Creek

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel, cobble	Undisturbed.	Gradient, LWD.	Stable, alluvial, gravel/cobble
DISTURBANCE INDICATORS: None			
COMMENTS: Abundant LWD, floodplain on both banks, 10-15 m wide.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Coniferous forest.
COMMENTS: Some blowdown into stream from riparian.	

WATERSHED: COTTONWOOD **SUB-BASIN:** MCMARTIN CREEK

Stop M3 Haliday Creek (McMartin tributary)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, cobble/boulder	Stable	Gradient, bed material	Till, stable.
DISTURBANCE INDICATORS: None.			
COMMENTS: Undisturbed 3 m wide, boulder-bed stream.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logged at road, forest upstream of road.	Coniferous forest.
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** MCMARTIN CREEK

Stop M4. Upper tributary to McMartin Creek.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel/cobble, LWD	Undisturbed.	Gradient and LWD.	Alluvial, stable
DISTURBANCE INDICATORS: None			
COMMENTS: 10 m wide, alluvial, gravel/cobble bed stream, quite lovely.			

RIPARIAN INFORMATION	
LAND USE	CONDITIONS
None.	Coniferous forest.
COMMENTS: Riparian reserve of at least three channel widths should be left intact to allow for natural meander.	

WATERSHED: COTTONWOOD **SUB-BASIN:** NELSON KENNY

Stop NK1. Approximately 5.5 km upstream of confluence with Ahbou Creek.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel	Stable	Gradient	Gravel, sand.
DISTURBANCE INDICATORS: None at this location			
COMMENTS: Very low energy stream draining low gradient plateau.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Private, agriculture (livestock)	Some clearing.
COMMENTS: No disturbance was noted at this reach, but erosion of reaches cleared and used for livestock is expected.	

WATERSHED: COTTONWOOD **SUB-BASIN:** REDDISH CREEK

Stop R1. Reddish Creek upstream of the Fontaine Creek confluence

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Wetland	Boggy		
DISTURBANCE INDICATORS: None			
COMMENTS: This is Reddish Creek upstream of the Fontaine Creek confluence. The valley bottom is wetland.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Wetland
COMMENTS: Natural, undisturbed	

WATERSHED: COTTONWOOD **SUB-BASIN:** REDDISH CREEK

Stop R2 - Fontaine Creek, approximately 800 m upstream of Reddish.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, cobble	stable	Gradient	Alluvial, gravel/cobble, stable
DISTURBANCE INDICATORS: Possible old placer at this site; no LWD; no hydraulic variability; channel is 5 m wide, 2% gradient			
COMMENTS: It appears that this reach has been placer mined. The banks are slightly leveed and the channel is a long run or riffle.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logged riparian	2^{nd} growth deciduous
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** REDDISH CREEK

Stop R3. Font Creek, a small tributary of Fontaine Creek.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, LWD	Stable	Gradient, LWD	Till, stable
DISTURBANCE INDICATORS: None			
COMMENTS: Logged at road crossing, but undisturbed upstream of road.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logged at road, coniferous forest upstream	
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** SOVEREIGN CREEK

Stop SOV1. Sovereign Creek mainstem, approximately 3.5 km upstream of the Swift River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, gravel	Unstable	Gradient	Alluvial, gravel
DISTURBANCE INDICATORS: Eroding banks, aggraded channel, large point bars and mid-channel bars.			
COMMENTS: An eroding, unstable channel. Riparian logging is a contributor, possibly also placer disturbance.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logging, placer	2^{nd} growth deciduous and coniferous
COMMENTS: Accelerated erosion proximal to logged banks.	

WATERSHED: COTTONWOOD **SUB-BASIN:** UMITI CREEK

Stop U1. Small tributary of Umiti Creek

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, cobble	Unstable	Gradient	Gravel, cobble
DISTURBANCE INDICATORS: scoured, bank erosion			
COMMENTS: Bank erosion possibly related to logged riparian.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logged	2^{nd} growth coniferous, deciduous
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** UMITI CREEK

Stop U2. Tributary to Umiti Creek

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-Pool	Unstable	Gradient	Gravel, cobble
DISTURBANCE INDICATORS: Severely eroded banks, channel widening			
COMMENTS: Has been placer mined. The channel appears to have widened substantially, and scoured.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer	Disturbed, no vegetation
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** UMITI CREEK

Stop U3. Tributary to Umiti Creek

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
		Beaver	Flooded
DISTURBANCE INDICATORS: Extensive beaver activity has turned this stream into a wetland.			
COMMENTS:			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Some logging	Deciduous
COMMENTS:	

WATERSHED: COTTONWOOD **SUB-BASIN:** VICTORIA CREEK

Stop V1. Victoria Creek, 2.5 km upstream of the Swift River.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, LWD, gravel	Stable	Gradient, LWD	Alluvial, gravel/cobble
DISTURBANCE INDICATORS: None			
COMMENTS: Undisturbed, low gradient reach			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Coniferous Forest
COMMENTS:	

SITE A1. Lower Ahbau Creek, upstream of the Cottonwood River. This is an aggradingreach. Note the large, elevated mid-channel bar. Some bank erosion is evident here.

SITE C2. Cottonwood River mainstem channel, below Ahbau Creek. This is a wide, low gradient alluvial channel. Note the erosion into glaciofluvial gravels on the left bank.

SITE JB4A. John Boyd Creek. A narrow riparian fringe of trees was apparently left during harvesting. The trees subsequently have been killed by fire. Note the bank erosion just below the dead trees, where John Boyd Creek is incising into a fluvial bank deposit.

SITE JB4B Large eroding fine textured bank on lower John Boyd Creek.

SITE JB5. John Boyd Creek. This reach has severe bank erosion and lateral shifting through fine-grained fluvial sediment. This erosion is partly the result of the riparian logging (circa 1980).

SITE JB6. Ditch erosion in the John Boyd Creek basin. This ditch drains about 150-200 m of road, and discharges directly into John Boyd Creek. The road itself is stable, but the ditch erosion transfers fine sediment into the creek.

SITE JB7. Panorama across the Mary Creek sub-basin of John Boyd Creek, indicating the extensive harvesting that has occurred.

SITE JB3. John Boyd Creek. This reach is experiencing severe bank erosion, widening, and aggradation.

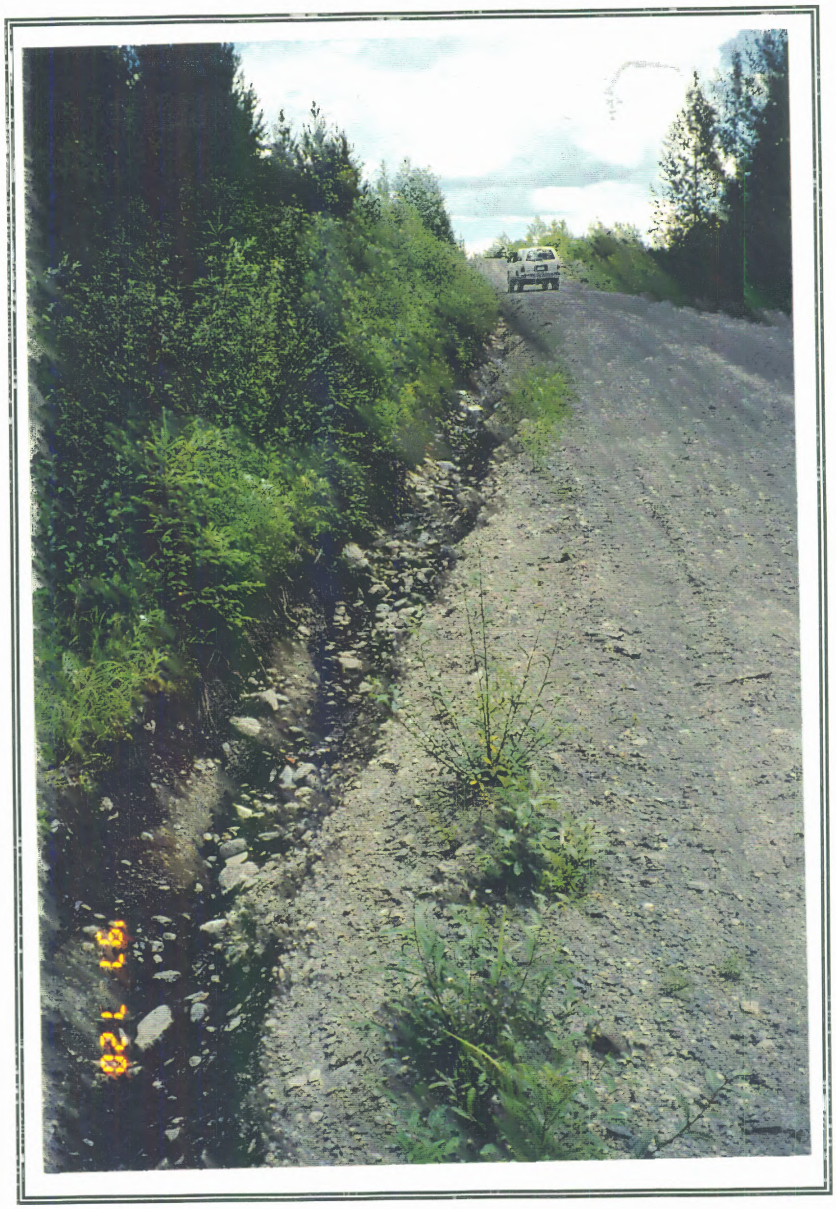
SITE L2. Active placer mining operation on Lightning Creek. A narrow band of riparian vegetation has been maintained along the stream bank, providing some stability. However, gravel and sand still enter Lightning Creek from the operation, from locations where there is no riparian vegetation.

SITE L3. Lightning Creek. This reach is about 200-400 m downstream of a floodplain with historic placer mining. The channel is aggraded.

SITE L11. Cut slope slumping and ditch erosion in the xxx sub-basin of Lightning Creek. This piece of road needs increased cross-drain frequency to remove the runoff water from the ditch.

SITE L9. Ditch erosion along a mining road in the lower Lightning Creek watershed. This ditch discharges directly into Lightning Creek.

SITE LS1. The lower mainstem channel of the Little Swift River. This reach has been placer mined. Channel disturbance is minimal.



SITE LS5. Ditch erosion in the Little Swift River basin.

SITE LS6. A recently constructed road in the upper Little Swift River basin. The site disturbance and lack of erosion control has resulted in large amounts of fine sediment being transferred to a tributary stream.

SITE LS7. A recently constructed road in the upper Little Swift River basin. At this site the fine-textured road fill is being eroded by water flowing along the road surface and ditch. The eroded sediment discharges directly into a tributary to the Little Swift River.

SITE LS8. An aggrading ditch line in the Little Swift basin. There is active erosion along the ditch and cut slope, and sediment is infilling the culvert.

SITE M1. The rather lovely mainstem channel of McMartin Creek.

SITE M4. A small, undisturbed tributary of McMartin Creek.

SITE M5A. Extensive cut slope erosion through a fluvial terrace. An attempt has been made to deal with this erosion by grass seeding the sandy cut slope. However, this has failed and the slope is continuing to slough large amounts of sand-sized material into the ditch. This sediment enters a tributary to McMartin Creek.

SITE M5B. The road fill is fine textured, and is not stable. An attempt has been made to control erosion by applying grass seed, but this has not succeeded. This slope is supplying large amounts of fine sediment to a tributary of McMartin Creek.

SITE M6. A recently constructed road in the upper McMartin Creek basin. Erosion of the road surface and the cut and fill slopes was very evident. No sediment control measures had been used.

SITE R1. Reddish Creek upstream of Fontaine Creek. This is more of a wetland than a stream.

SITE R2. The lower mainstem channel of Fontaine Creek. This reach has had placer mining activity. Disturbance appears low at this time.

SITE R5. A ditch line in the Fontaine Creek sub-basin. Water is being concentrated in the ditch and some erosion is occurring.

SITE R8. A panorama across the Fontaine Creek valley, showing the extensive harvesting and the riparian buffer.

SITE R7A. A recently constructed road in the Fontaine Creek sub-basin. This site is experiencing extensive erosion. No sediment control measures have been used.

SITE R7B. A recently constructed road in the Fontaine Creek sub-basin. This site is experiencing extensive erosion. Note the rutting and the eroding running surface and cut slope.

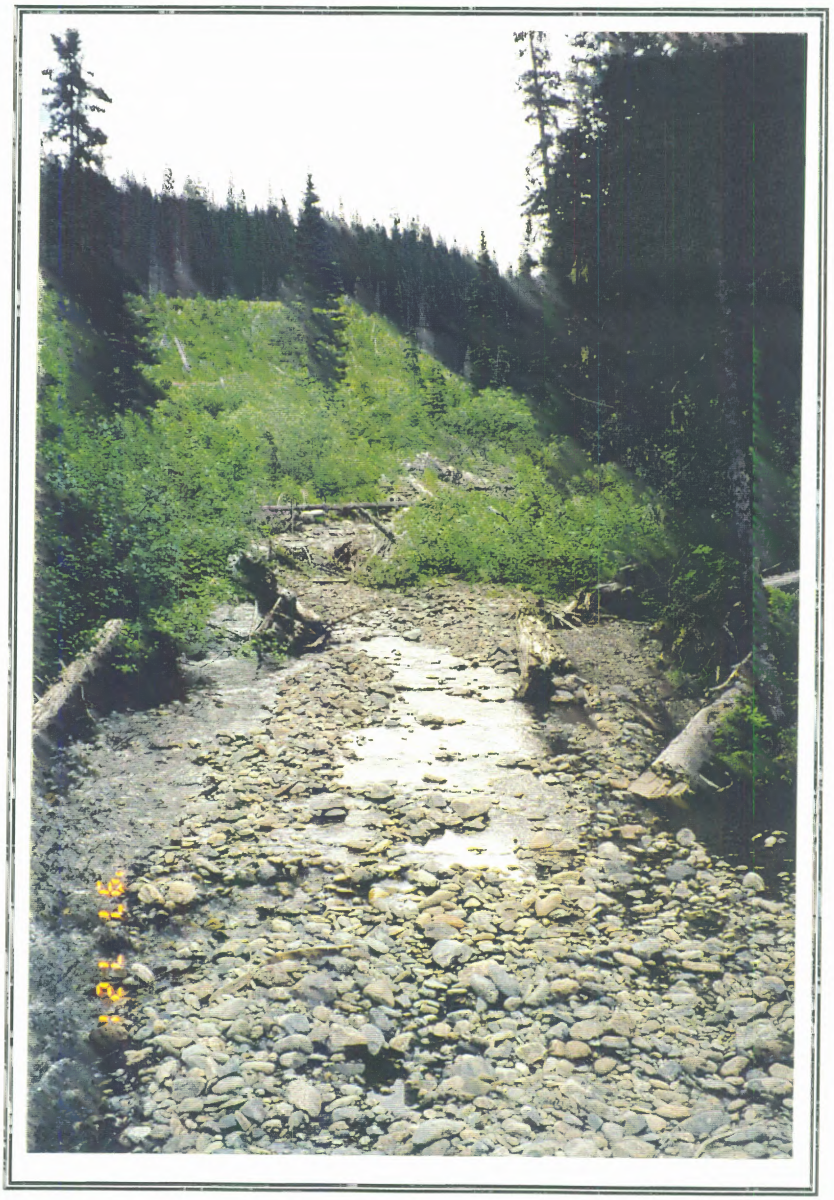
SITE SOV1. Sovereign Creek, showing bank erosion along a harvested and placer mined reach.

SITE SOV2. Deep gullying and erosion on an undeactivated road. The erosion occurred some time in the past and the site is stable now.

SITE U2. Upper Umiti Creek. This reach has widened and has extensive bank erosion. Proximal land uses are placer mining and riparian logging.

SITE U5. Road and ditch erosion in the Umiti Creek basin. The road itself is stable. However, the infrequent cross-drains allows surface runoff to concentrate and occasionally trigger extensive erosion. At this site, the ultimate discharge point was a tributary stream channel.

SITE S1. A small, undisturbed tributary of the Swift River.



SITE S2. A small tributary stream that has been aggraded by bank erosion related to riparian logging (pre-FPC).

SITE S4. A stable road on flat terrain in the Swift River watershed.

SITE V1. The mainstem channel of Victoria Creek. This river is undisturbed. Discharge during spring freshet was clear.

SITE V2. Erosion of fill material at a bridge crossing of Victoria Creek.