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An Inventory of Watershed Conditions

Affecting Risks to Fish Habitat

in the

CARIBOO, COTTONWOOD & HORSEFLY WATERSHEDS

VOLUME I

Cariboo River Watershed

(Sections 1 to 5 & 6)

Prepared for

CARIBOO REGION INTERAGENCY MANAGEMENT COMMITTEE

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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.

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

4. 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.

5. 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.

6. 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.

7. 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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6.0 CARIBOO RIVER WATERSHED

Watershed Characteristics

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. The characteristics of these nine sub-basins *[Figure C1]* are summarized in Table 1. Locations of the sub-basins within the Cariboo River watershed are shown on Figure 2.

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.

With the exception of the Spanish Lake sub-basin, the Cariboo watershed is underlain by Precambrian and Paleozoic age sedimentary rocks. Spanish Lake and other lower watershed areas are underlain by extrusive volcanics of Triassic and Jurassic age.

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.

Significant climate variability exists over the watershed area. Precipitation generally increases and mean annual temperature decreases from west to east, as elevation increases. At Kersley (located approximately 150 km west of the watershed[1]), annual precipitation amounts to approximately 520 mm with over 35% occurring as snow. At Barkerville (located approximately 10 km north of the upper watershed area), annual precipitation amounts to 1,050 mm with 50% occurring as snow. Daily mean annual temperature decreases from 4.2° C at Kersley to 1.7° C at Barkerville.

A Water Survey of Canada hydrometric station known as Cariboo River below Kangaroo Creek operated for the period 1926-1964 *[Table 2]*.

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

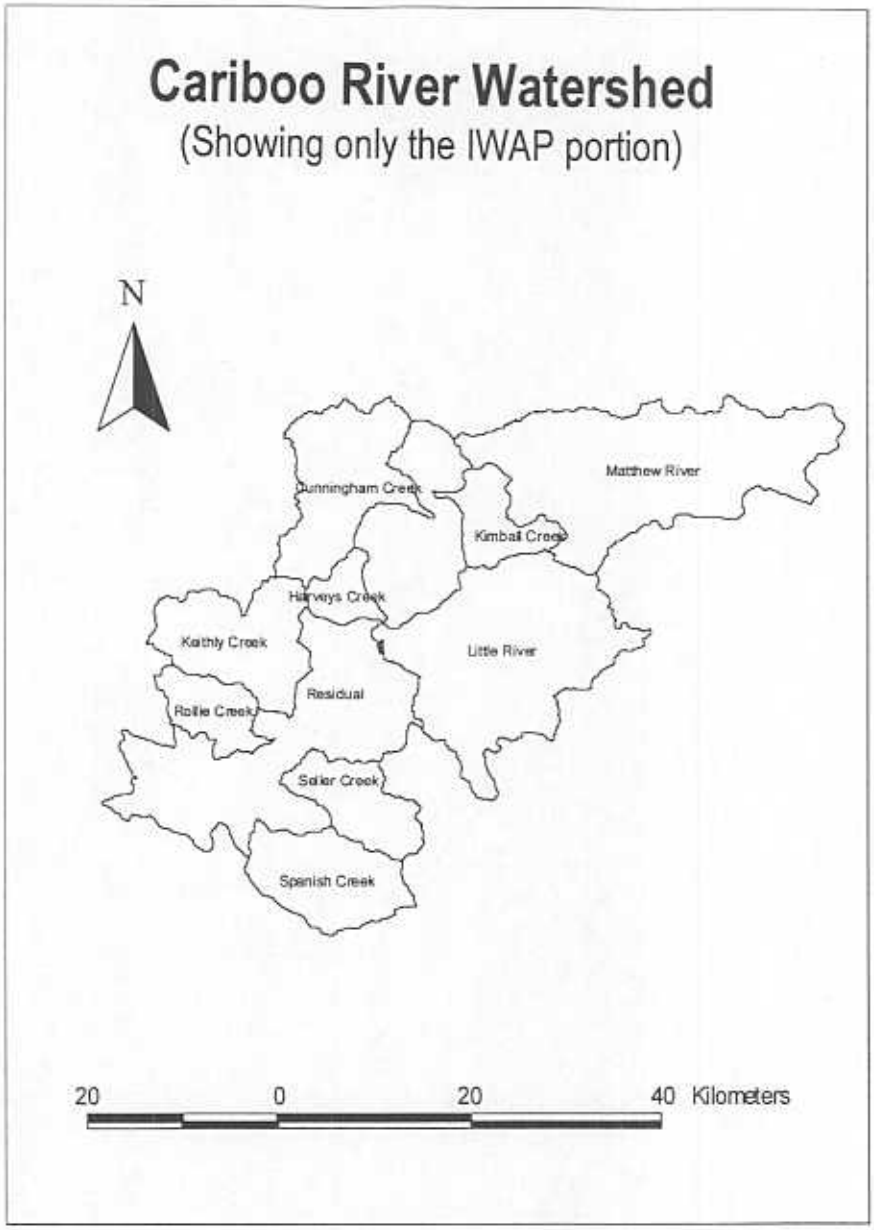


FIGURE C1

Major watersheds and map units of the Cariboo River watershed.

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.

TABLE 2

Water Survey of Canada Gauge on the Cariboo River

Gauge Name	WSC No.	Drainage Area km^2	Mean Annual Discharge (m^3/s)	Mean Annual Runoff (mm)
Cariboo River below Kangaroo Creek	08KH003	3,260	93.3	902

The Cariboo River watershed has a long history of mining exploration and development. Mineral extraction has been confined to placer mining involving the use of either hydraulic techniques or excavation and sluice boxes. 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[2].

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.

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

Background Information

Background information is presented in Table 3 and summarized as follows:

Tenure

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.

Watershed Restoration

Several watershed restoration initiatives funded by Forest Renewal BC 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.

Past Forest Development

Approximately 13.8% of the watershed area has been logged to 1996[3]. The equivalent clearcut area (ECA) for the total drainage area within the nine IWAP sub-basins 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. These differences are expected, based on the coarse data used in the FTRA inventory and conservative nature of the results. For the purpose of this inventory, the IWAP ECA values have been used.

[3] Rowland, D.E., and L.B. MacDonald, 1996. Salmon Watershed Planning Profiles for the Fraser River Basin within the Cariboo-Chilcotin Land Use Plan (CCLUP) Area, Department of Fisheries and Oceans, Vancouver.

Interior Watershed Assessment Procedure

The results of the Interior Watershed Assessment Procedure (IWAP) indicate a low potential for increased peak flows in all of the nine major sub-basins.[4]

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 done for the IWAP.

The IWAP underestimates the overall road length in the watershed as a result of using TRIM maps derived from mid-1980s air photos as the information source, rather than more recent forest cover maps.

Agency Concerns

Agency concerns in the Cariboo River watershed relate primarily to the extensive amount of both historic and active 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. Ten-metre riparian reserves are currently being applied to placer mining operations. It is believed, though, that additional riparian protection measures are required to maintain or improve overall channel and riparian stability.

The Department of Fisheries and Oceans (DFO) recognizes that the lower channels of the tributaries to the Cariboo River are important salmonid stream reaches. They are utilized as spawning and rearing habitat by salmon, and they also serve as refuge areas for fry and smolts during freshet period in the Cariboo River mainstem.

Concern by DFO and BC Environment over riparian logging and channel instability in tributaries such as Harveys Creek, Keithley Creek, Matthew River and Little River was noted.

[4] Watershed Assessment of the Cariboo Watershed, Carmanah Research Ltd., August 1997.

The final agency concern noted is the generation and transport of sand-size sediment from forest roads to stream channels. It is believed that sand-size sediment (which is especially detrimental to spawning redd excavation and salmon egg survival) is being generated from logging roads and transported to streams, where it potentially infills and cements spawning gravel.

Proposed Harvesting 1997-2001

A total of 7,179 ha of forest development is proposed within the sub-basins inventoried as part of this project *[Table 3]*. This calculation accounts for the majority of proposed development in the Cariboo River watershed, but may be a conservative estimate based on the exclusion of some small sub-basins and residual areas.

With proposed development, ECA in the sub-basins will increase to highs of 28% in Keithley Creek and 27% in Spanish Creek, but will remain under 20% in the remaining sub-basins.

Inventory Observations

Stream Channels

The Cariboo River watershed contains numerous large lakes on the mainstem channel system, which provide a partial buffer to downstream channels from sedimentation and potential increases in peak flows. In addition, with the upper 40% of the watershed protected in a park, the impact of logging in the lower 60% of the watershed is minimal with respect to peak flow increases in the mainstem of the Cariboo River.

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 watershed ECA of approximately 13%, 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.

Moderately sized tributary channels to the Cariboo River (Rollie, Keithley, Frank, Pine, Harveys, Kimball, Cunningham) all have lower alluvial fan reaches that are also inherently 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 historic and ongoing placer mining activity. The fans of Cunningham Creek, Frank Creek and Rollie Creek are all recovering from historic placer 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.

Proposed levels of forest development *[Table 3]*, ranging from an ECA increase of 1.2% in Harveys Creek to an increase of 11.5% in Cunningham Creek, are not expected to exacerbate existing instabilities or initiate disturbance in stable situations on any of the aforementioned alluvial fans.

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 *[Photo C1]*.

Significant overall channel disturbance, both recent and historic, was observed in Keithley Creek, Pine Creek (a small tributary to Cariboo Lake between the Harveys Creek and Keithley Creek alluvial fans) and Harveys Creek. These disturbances are the result of a substantial increase in coarse sediment supply to the streams from placer mining activity in and adjacent to stream channels. The extent of placer mining disturbance to channels in other basins (Rollie Creek, Spanish Creek and Seller Creek) was less.

Active and abandoned placer mining operations contain large areas of exposed soil sites, which continue to be chronic contributors of fine and coarse sediment to streams.

Some channel 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).

By comparing aerial photographs from 1958 and 1992 for selected stream channel reaches, the following observations were made:

1. Some restabilization of banks has occurred on both the Rollie Creek and Keithley Creek lower mainstem channels, and on the Keithley Creek alluvial fan (refer to basin reports for aerial photograph inventory details). Recent destabilization resulting from placer mining (within the last 25 years) has occurred on the Pine Creek alluvial fan, which is built into Cariboo Lake between Keithley and Harveys creeks.

2. Channel instability concerns on the lower Little River appear to be the result of natural occurrences. Measurable changes in channel morphology, rates of lateral channel migration, or sediment supplies from stream banks are not evident over the inventory period for the lower Little River (refer to basin report for aerial photograph inventory). Mid-channel bars and large woody debris jams on the apex of the alluvial fan appear on both the 1958 and 1992 photographs. Multiple active channels exist on the low gradient alluvial fan.

3. Riparian harvesting and the subsequent loss of root stability on the lower Matthew River have resulted in minor increases in bank erosion. However, it also appears that significant tree regeneration in many of the older blocks adjacent to the mainstem channel may have helped to restabilize the banks.

Landslides

In addition to the high natural sediment source from the Cariboo River headwaters, the aerial reconnaissance (refer to aerial reconnaissance data forms) indicates 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 *[Photo C2]*.

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 falling boundary and generally terminated in the mainstem channel.

Several natural and cutblock-related landslides were observed in the Seller Creek watershed, with the failures directly affecting mainstem channels. It should be noted, however, that lower Seller Creek has been disturbed by placer mining, and that the only failures related to forest development along the lower channel were associated with an old windthrow salvage block.

Additional forest development related landslides were observed in the Kimball Creek watershed. Cutblocks on a large glacio-fluvial outwash deposit were situated along the break in the slope of the incised river valley. At least one failure that impacted the mainstem channel was initiated by ditch line runoff that had been directed onto a steep hillslope.

Roads

Rain was common during the initial field inventory (July 1997) and many streams were flowing at bankfull by the end of the inventory period. Erosion of exposed soils along road systems was readily observed, however, in some cases discharge levels did restrict stream access, necessitating a follow-up field visit in September 1997.

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, several common factors emerged:

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. Access roads to placer mines in the Keithley Creek, Harveys Creek and Cunningham Creek watersheds have been constructed with limited drainage works. 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.

Extremely 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.

Inventory Interpretation

Alluvial 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:

1. 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.

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

3. 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 practice (including forest development).

If fish habitat is to be improved in these systems, many stream channel sites or reaches will require rehabilitation. However, unless there is a major change in the way that placer mining is undertaken, any channel rehabilitation will be unsuccessful.

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.

At the present, forestry effects on tributary streams in the Cariboo River watershed are limited.

It is unlikely that peaks flows have been altered by past forest development, or that the channel disturbances noted in a number of the tributary channels are related to peak flow increases.

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.

Active road construction was observed in the Little River watershed during a high rainfall event. High concentrations of suspended sediment were evident in runoff from recently exposed soils and eroding ditch lines. Capping of the running surface was in progress but sediment was being generated by equipment travelling back and forth on "green roads." 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.

Recommendations

The following recommendations are provided (based on the field inventory results) to either reduce, remediate or avoid impacts on the water resource from forest development in the Cariboo River watershed:

1. In order to avoid potential peak flow impacts from harvesting, develop total chance plans for the sub-basins that would determine if/or when future harvesting ECA's might affect stream flows. The following sub-basins have channels that are classed as highly sensitive:

    - Rollie Creek, Keithley Creek, Harveys Creek, Kimball Creek, Cunningham Creek, Little River, Matthew River, and Cariboo River from Sandy Lake to Cariboo Lake.

2. 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.

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

    - 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.

4. Complete terrain mapping for the Provincial forest lands within the Cariboo River watershed as soon as possible.

5. 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.

6.1 SPANISH CREEK

Watershed Characteristics

Spanish Creek has a watershed area of 13,200 ha with one large lake (>7km^2) (Spanish Lake) in the upper watershed and one main tributary channel (Blackbear Creek) that joins the mainstem approximately 1.0 km upstream of the mouth *[Figure 3]*. Spanish Creek is a tributary to the Cariboo River with the confluence approximately 10 km below Cariboo Lake. The watershed has a relief of 885 m, with rolling topography in the upper basin and steep coupled valley slopes along the lower sections of both Spanish and Blackbear Creeks. Spanish Creek below the lake has a low gradient channel with a broad alluvial floodplain. The lower reaches of the channel are incised into glacio-fluvial and glacio-lacustrine deposits where many natural hillslope failures have occurred.

Background Information

Results of the 1997 IWAP indicate moderate potential hazards for surface erosion and landslides in the Spanish Creek watershed *[Table 3]*. The moderate surface erosion hazard rating is based on the density of roads on erodible soils and slopes >60%. Terrain hazard mapping is not yet available. The lack of accurate surficial materials mapping may underestimate the extent of erodible soils, since much of the lower basin contains fine textured glacio-fluvial and glacio-lacustrine materials. The current (1997) ECA in the Spanish Creek watershed is 22%.

The moderate landslide hazard rating is the result of the road density on potentially unstable terrain (>60). This may be an underestimation of the actual hazard based on the exclusion of a landslide count in the IWAP calculations, and the amount of observed bank failures on lower valley slopes.

Regulatory agencies are concerned about continued sediment input from Spanish Creek into the Cariboo River.

Inventory Observations

Observations made during the aerial reconnaissance were as follows (refer to aerial reconnaissance data forms):

1. Old placer mining activity was evident along the lower mainstem channels of both Spanish and Blackbear Creeks *[Site S1] [Photo SP1].*

2. Moderate levels of forest development have occurred in the major northern tributary draining into Spanish Lake. Suspended sediment from road and ditch line erosion was evident as a sediment plume in Spanish Lake *[Site S5] [Photo SP2].*

3. Both natural and placer mining induced bank failures were noted along lower Spanish and Blackbear Creeks.

4. There was limited evidence of harvesting in riparian zones.

5. Spanish Lake is providing a buffer to increases in sedimentation resulting from forest development in the upper watershed.

Field inventories were carried out in the Spanish Creek watershed in early July 1997. Weather conditions were clear and dry, and stream flows were low allowing for easy access into the channels. Four channel reaches, two on Spanish Creek and two on Blackbear Creek, were assessed using the reconnaissance channel inventory procedure *[Figure 3]* (refer to field inventory forms). No aerial photograph inventories were undertaken on the Spanish Creek channel system.

Observations made at stream channel inventory sites:

1. Lower Spanish Creek appears to be stable with boulder and bedrock control *[Site S1] [Photos SP3 and SP4].* Riparian conditions are good with mixed old growth vegetation and stable stream banks. No evidence of increased bedload supply from upstream bank failures was noted.

2. Spanish Creek in the middle basin area is a low gradient alluvial channel with a broad floodplain *[Site S2] [Photos SP5 and SP6].* Stream banks are stable with some control being provided by beaver dams and large woody debris. The minor increases noted in channel bar development were attributable to recent upstream beaver dam failures.

3. Lower Blackbear Creek is stable with boulder, bedrock and large woody debris control *[Site S3] [Photos SP7 and SP8].* Abandoned placer mining claims are located adjacent to the channel. Narrow riparian buffers have been retained (approximately 5.0 m in width) which appear to have been adequate for stream protection from placer mining activity. No instream mining activity was evident. However, some evidence of fine sediment input from abandoned placer mine sites was noted.

4. Upper Blackbear Creek shows evidence of moderate increases in fine and coarse bedload materials that are derived from natural hillslope and gully processes (inventory site is located above all areas of forest development and placer mining activity) *[Site S4] [Photos SP9 and SP10].*

Roads in the lower watershed are constructed from fine-textured native materials. Surface erosion was noted on all adverse roads inspected in the lower watershed (within fine-textured surficial material areas). Sumps were generally absent at cross-drains and stream crossings. Fine sediment input is being directed into streams at road crossings. Long uninterrupted ditch lines also contribute sediment to streams.

Proposed Harvesting 1997-2001

Approximately 1,000 ha of logging is proposed for the Spanish Creek basin during the period 1997-2001, corresponding to 7.5% of the drainage area. The current ECA in the watershed is 21.6%, which will increase to approximately 27% with the proposed development (and including hydrologic recovery on previously logged blocks). Detectable increases in peak flows are not anticipated at this ECA.

Inventory Interpretation

1. No evidence of channel instability as a result of past forest development was noted during the aerial and ground based inventories.

2. Bank erosion and bank failures have occurred on the lower mainstem channels of Spanish Creek and Blackbear Creek, both naturally and as a result of placer mining disturbance. Forest development has not affected bank erosion rates.

3. Running surface erosion is contributing fine sediment to channels at stream crossings. Long, uninterrupted ditch lines and a general lack of sediment control structures are increasing sediment loads in streams.

4. The ECA level in the watershed will increase from 21.6% to approximately 27% by 2001. Spanish Lake is providing a buffer to any downstream effects of increased sedimentation that may result from the proposed development above the lake. The proposed forest development should have a minimal effect on downstream water quality or fish habitat.

Recommendations

1. Upgrade active roads in the watershed, particularly those located on erodible soil types in the lower basin, focusing on:

   - Increased cross-drain frequency on long, uninterrupted ditch lines.

   - Construction of settling ponds on ditch lines at all active stream crossings, and sumps at the inlet to cross-drains.

6.2 SELLER CREEK

Watershed Characteristics

Seller Creek is a fourth-order stream with a watershed area of 8,900 ha. Topographic relief is moderate at 1,220 m. Hillslopes in the watershed are directly coupled to the streams and the sediment delivery potential from hillslope failures is high. Forest development is the prime land-use in the watershed with one large placer mining claim located along the lower 2.0 km of the mainstem channel. Seller Creek is tributary to the Cariboo River with the confluence approximately 6.0 km below Cariboo Lake *[Figure 3]*.

Background Information

The results of the IWAP suggest that there are no forestry-related hazards of concern in the watershed *[Table 3]*. However, the frequency of forest development and placer mining related hillslope failures in the lower watershed observed during the aerial reconnaissance is of concern. One large windthrow salvage block exists in the lower watershed, below which several landslides have occurred. The current ECA in the Seller Creek watershed is 10%.

Regulatory agencies are concerned about the potential for bedload delivery to the Cariboo River from Seller Creek resulting from forest development.

Inventory Observations

Observations made during the aerial reconnaissance were (refer to aerial reconnaissance data forms):

1. Numerous large hillslope failures and large placer mining scars are present along the lower mainstem channel *[Site Sel1] [Photo S1]*. Several slope failures are located adjacent to or below harvested blocks and/or forest roads along the break in slope above the lower incised channel. The majority of slope failures have directly impacted the lower mainstem channel.

2. Several small veneer type hillslope failures were noted on steeper slopes, both within old cutblocks and in old growth forest in the middle watershed. All the small failures impacted the stream channels.

3. Small natural bank failures were also noted along the middle mainstem channels.

Field inventories were completed in early July 1997 under extremely wet conditions. Stream flows were low enough to allow channel inventories to be completed and road conditions were optimal for the observation of surface erosion problems. Two channel reaches were assessed using the reconnaissance channel inventory procedure *[Figure 2]*. No aerial photograph inventories were undertaken on the Seller Creek channel system.

Observations made at stream channel inventory sites include:

1. Lower Seller Creek is a boulder and channel gradient controlled stream. Moderate levels of aggradation were noted as a result of upstream placer mining activity, bank instabilities, and large slope failures *[Site Sel2] [Photos S2 and S3]*. Sections of the lower mainstem channel have been harvested to the bank with minor instabilities resulting from the loss of riparian vegetation. Lower Seller Creek is moderately sensitive to channel changes that may result from harvesting in the riparian zone, increases in bedload and increased peak flows.

2. Upper Seller Creek is a stable riffle-pool channel with large woody debris and channel gradient control *[Site Sel4] [Photos S4 and S5]*. Riparian conditions are rated as good in the upper watershed, with a good source of future LWD to the channel. No forest development or mining activity has occurred above the uppermost inventory location. Upper Seller Creek is also classed as having a moderate sensitivity rating.

Roads in the watershed are well drained and show little evidence of surface erosion in spite of the extremely wet conditions. Coarse materials have been used to surface the roads (derived from local materials) and adequate drainage is in place. Extensive deactivation of block and spur roads has reduced the potential for increased peak flows and surface erosion.

Very few major stream crossings have been constructed in the watershed. Grass seeding of inactive road running surfaces and ditches was evident over the entire watershed, which has reduced surface erosion hazards *[Site Sel3] [Photo S6]*.

Proposed Harvesting 1997-2001

Approximately 900 ha of logging is proposed in the Seller Creek watershed over the period 1997 to 2001. The current ECA of 10.1% will increase to approximately 19% in 2001, accounting for hydrologic recovery on previously harvested blocks.

Inventory Interpretation

1. Lower Seller Creek has experienced elevated bedload supply and transport levels as a result of natural and forest development related bank failures, and placer mining on the lower mainstem channel. The channel is moderately aggraded and has a moderate sensitivity rating.

2. Forest roads in the watershed are in good condition based on: extensive deactivation of old block and spur roads; the use of coarse textured road construction materials; and the adequate number of cross-drains that maintain natural hillslope drainage patterns. Limited stream crossings have been constructed in the basin to date.

3. The current ECA of 10.1% will increase to approximately 19% by 2001. Detectable increases in peak flow are not anticipated in the Seller Creek watershed.

Recommendations

1. Assess hillslope drainage patterns in older blocks (located along the break in slope of the lower Seller Creek valley) to determine the risk of further hillslope failures.

2. Restore natural drainage patterns within these blocks as determined in the assessment.

6.3 ROLLIE CREEK

Watershed Characteristics

Rollie Creek has a drainage area of 6,400 ha and a relief of 1,190 m. The channel enters the eastern end of Cariboo Lake over a large alluvial fan *[Figure 4]*. The lower mainstem channel is incised into thick glacio-fluvial and glacio-lacustrine deposits. Several active and abandoned placer mine claims exist along the lower mainstem. Forest development is now the primary land-use activity in the basin.

Background Information

The current ECA in the Rollie Creek watershed is 11.1%. The 1997 IWAP calculations indicate low potential hazard levels from past forest development in all categories *[Table 3]*.

Regulatory agencies are concerned about increased sediment transport (both suspended sediment and bedload) in the main channel that might impact the quality and quantity of fish habitat.

Inventory Observations

Observations made during the aerial reconnaissance were (refer to aerial reconnaissance data forms):

1. Several landslides have occurred below the block boundaries of past logging above lower mainstem channel *[Site Rol3] [Photo R1]*.

2. Suspended sediment concentrations were low compared to other Cariboo River sub-basins, suggesting a minimal input of fine textured sediment to the channels from all natural and/or human induced sources.

3. Riparian zones had not been affected by past logging.

4. Coarse bedload carried by Rollie Creek is deposited on the alluvial fan but is not available to the Cariboo River. Some suspended sediment is transported beyond the outlet of Cariboo Lake into the Cariboo River.

5. Limited road construction has taken place adjacent to the lower mainstem channel. Road access to the upper Rollie Creek watershed is via the Rollie Creek mainline, which begins east of the alluvial fan but adjacent to the Cariboo River mainstem channel.

Inventory work on roads and channels was carried out in early July 1997 under moderately wet conditions. Running surfaces were wet and discharges in the mainstem channels were too high to allow for channel assessments. Channel inspections were completed in lower Rollie Creek in September 1997 *[Figure 3]*. Channel inspections were also completed on the alluvial fan and in the upper headwaters area.

The results of the observations made at stream channel inventory sites were:

1. Mainstem channel conditions on the Rollie Creek alluvial fan indicate moderate aggradation, and minor channel widening and riparian disturbance. Increases in bedload are the result of natural and forest development related bank failures that have occurred upstream, and from placer mining disturbance to the channel and banks. Cobble and boulder mid-channel bars are present with lateral flow over the bar surfaces *[Site Rol2] [Photos R2 and R3]*. An active placer claim is being worked on the lower hillslopes at the apex of the alluvial fan. A large debris jam is present approximately 50 m above the mouth, which may be a barrier to spawning salmon. The jam does not appear to be related to forest development since no saw-cut pieces were noted.

2. The channel on the alluvial fan is recovering from a historically high bedload supply. Deposition on the alluvial fan appears to be less than in previous years, in spite of high 1997 freshet flow conditions. Historic alluvial fan deposits are beginning to stabilize, as evidenced by the presence of a sparse but invading vegetation cover *[Site Rol1] [Photo R4]*.

3. Channels in the upper Rollie Creek watershed have a low gradient and pass through broad alluvial meadows with thick alder and willow cover *[Site Rol4] [Photos R5 and R6]*. Stream channels and banks are stable. Fine sediment derived from road surface erosion is entering the channels at bridge crossings. Long uninterrupted ditch lines terminate at stream crossings with no sediment traps, so sediment is carried into the streams.

The Rollie mainline leading up from the main Cariboo River valley cuts through fine-textured glacio-lacustrine materials *[Site R11, Figure 5] [Photo R7]*. Continual bank failures in both the cutbanks and fillslopes require ongoing maintenance and are a chronic source of fine sediment to the Cariboo River.

Roads at middle and upper elevations that have been either constructed of, or surfaced with, coarse materials are well-drained and reasonably resistant to surface erosion *[Site R10, Figure 5] [Photo R8]*.

In the upper watershed, recently deactivated roads were undergoing considerable surface erosion. The roads have been constructed of glacial till materials that to have a high silt content and are easily eroded. Fords have not been armoured and are easily eroded. Direct sediment delivery to a small headwater stream was noted *[Site Rol5] [Photo R9].*

Based on the low level of suspended sediment observed in streams during the aerial reconnaissance and the absence of road construction adjacent to the lower Rollie Creek channel, surface erosion was not a concern in the watershed at the time of inspection.

A comparison of aerial photographs from the 1950s and 1990s indicated that the channels on lower Rollie Creek had not changed from the 1950s to the present. Some re-vegetation of old placer mining scars on the lower mainstem channel has occurred since the 1950s, indicating that Rollie Creek has had increased bedload in the past (refer to aerial photographs). Some residential development has occurred on the upper alluvial fan over the inventory period, with minor reductions in riparian forest cover. No obvious changes in channel morphology were noted on the fan.

Proposed Harvesting 1997-2001

Approximately 150 ha of logging is proposed between 1997 and 2001. The current ECA of 11.1% (1996) will increase to approximately 12% by 2001. The proposed forest development poses no hydrologic concern for increased peak flow levels or channel instability.

Inventory Interpretation

1. Surface erosion concerns in the watershed include:

    - The section of the Rollie mainline where it climbs through fine-textured glacio-lacustrine materials is a chronic source of fine sediment to the Cariboo River.

    - Fine sediment is entering channels in the upper watershed at stream crossing due to infrequent cross-drains on long ditch lines and a lack of sediment control structures.

    - Surface erosion is occurring on recently deactivated roads built on fine-textured glacial till in the upper watershed.

2. Channel disturbance in the basin appears to be low, with recovery of disturbed sites and a reduction in bedload supply to the lower mainstem channel since the 1950s.

3. The Rollie Creek alluvial fan is sensitive to disturbance from increased peak flows or bedload.

4. Proposed forest development should have no impact on peak flows or bedload transport.

5. Relatively clear freshet flows in Rollie Creek are the partial result of an absence of road construction adjacent to the lower mainstem channel.

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 the recovery from historic placer mining disturbances or destabilize the alluvial fan at the mouth of the creek.

2. In order to maintain the low suspended sediment levels in Rollie Creek as observed in July 1997, it is recommended that a road upgrading and deactivation program be undertaken with the following objectives:

   - To minimize sediment delivery stream crossings by increasing the frequency of cross-drains installing sediment control structures at all active road crossings.

   - To reduce surface erosion on recently deactivated roads in sensitive soils by armouring fords and cross ditches where necessary, and grass seeding all exposed soils.

3. Develop and implement remedial measures to control cut and fill failures, and surface erosion on the lower Rollie mainline where it has been constructed in the fine-textured, glacio-lacustrine deposits.

6.4 KEITHLEY CREEK

Watershed Characteristics

Keithley Creek is a fourth-order stream with a drainage area of 15,000 ha *[Figure 4]*. Topographic relief in the watershed ranges from 810 m to 1805 m ASL, and hillslopes are coupled to the mainstem channels throughout the basin. Keithley Creek flows directly into Cariboo Lake over a large alluvial fan.

There is a small mining community and minor amounts of agricultural land development on the alluvial fan. Extensive historic placer and hydraulic mining have occurred throughout the watershed. Numerous active placer claims are present in many of the tributary valleys and along the lower mainstem channel.

Background Information

The results of the 1997 IWAP indicate moderate potential hazard ratings for surface erosion and landslides in the basin. Both ratings are based on road densities on erodible soils and unstable terrain. Since there is no terrain mapping available, unstable terrain is defined as any area with slopes >60%. This is the least accurate method for determining a landslide hazard rating so the results should be used with caution. The current ECA in the watershed is 10%.

The Department of Fisheries and Oceans is concerned about ongoing channel disturbances, and increases in bedload supply and transport through the system.

Inventory Observations

Observations made during the aerial reconnaissance were as follows (refer to aerial reconnaissance data forms):

1. There has been a very high level of placer mining activity throughout the watershed.

2. Significant channel disturbance from upstream and adjacent placer mining has occurred on the alluvial fan *[Site K1] [Photo K1]*.

3. It was noted that entire tributary channels have been extensively disturbed by placer mining. Bank instabilities continue to occur along many of the disturbed channel reaches, since regeneration of riparian vegetation is limited.

4. Forest development has occurred in the middle and upper watershed. Active running surface erosion was occurring during spring melt. High suspended sediment levels were observed in runoff in long uninterrupted ditch lines that were connected to stream channels at road crossing locations.

5. There had been some harvesting in riparian zones in the upper basins, resulting in bank instability.

Aerial photographs of the lower mainstem channel and alluvial fan were compared from the 1950s and 1990s. The 1950s photographs show high levels of disturbance on the alluvial fan as a result of large increases in bedload from upstream placer mining (refer to aerial photographs). The 1992 photography indicated that considerable restabilization has taken place over the intervening 40 years that included:

1. Re-vegetation of braided channel deposits on the alluvial fan and of placer mining sites along the lower mainstem channel.

2. Minor stabilization as a result of riparian zone regeneration along the banks on the fan.

3. A reduction in the number of active channels on the fan utilized during high flow conditions.

The air photo inventory results indicate a significant reduction in bedload supply and transport levels over the 40-year period. The reduction in bedload supply has been assumed to be the direct result of a reduction in placer mining activity, which has reduced the overall channel disturbance.

Observations made at channel inventory sites are as follows:

1. The Keithley Creek fan is highly disturbed *[Site K2] [Photos K2 and K3]* due to elevated bedload transport, which has resulted in channel widening and the formation of mid-channel bars. Large debris piles with very little logging related debris (saw-cut) are scattered along the channel. Aggradation and unstable conditions will continue until the bedload supply and transport is reduced.

2. Upper Keithley Creek is a stable boulder and bedrock controlled channel. This upper reach is a sediment transport zone which shows no evidence of aggradation or bank instabilities *[Site K5] [Photos K4 and K5].*

3. The three main upper tributaries (Snowshoe, French Snowshoe and Little Snowshoe Creeks) all show evidence of large increases in bed load supply and movement *[Sites K8 and K9] [Photos K6 to K9].* Placer mining and a minor amount of harvesting in the riparian zone have occurred upstream on all of these tributaries.

4. Upper Rabbit Creek has been disturbed by harvesting in the riparian zone which has increased bank erosion, sediment movement and channel widening *[Site K6] [Photos K10 and K11].*

Road inspections in the watershed were carried out under extremely wet conditions. The following surface erosion concerns were noted:

1. Long ditch lines with significant downcutting as a result of infrequent cross-drains on both mining and logging roads *[Site K7] [Photo K12].*

2. High suspended sediment concentrations in ditch runoff discharging into streams at road crossings.

Proposed Harvesting 1997-2001

Approximately 990 ha or 6.6% of the watershed area is proposed for development over the five-year plan period. The current ECA of 22.5% will increase to approximately 28% by 2001, representing a rate of cut of 1.3% per year. There is potential for increases in peak flows at the proposed ECA levels. However, any channel impacts due to minor peak flow increases would be difficult to detect, given the extensive amount of placer mining disturbance throughout the watershed.

Inventory Interpretation

1. There has been a large increase in bedload supply and transport in the Keithley Creek watershed as a result of placer mining, which has resulted in channel changes in all major tributary streams and the entire mainstem channel.

2. In spite of the high levels of channel disturbance on the lower mainstem channel and fan of Keithley Creek, considerable recovery from historic levels has occurred. Based on a review of 1950s aerial photography, bank re-vegetation and stabilization is evident in the lower watershed and on the fan.

3. Logging (pre-FPC) in the riparian zones has resulted in some bank erosion in the upper watershed.

4. There is a need for more cross-drains on the active forest and mining access roads inspected, including sediment control structures to reduce the amount of sediment entering streams.

5. Downcutting was evident on ditch lines with insufficient cross-drains.

6. The proposed development of 990 ha will increase the current ECA of 22.5% to approximately 28% by 2001, which could result in peak flow increases.

Recommendations

1. Consider preparing a total forest development plan that could be used to determine if or when proposed harvesting might affect peak flows. The objective would be to maintain peak flows in the low hazard range (as defined in the IWAP) to permit continued natural channel bed and bank recovery from historic placer mining disturbance.

2. Forest development beyond a low peak flow hazard level could be approved contingent upon favourable results from detailed stream channel and riparian condition assessments.

3. Consideration should be given to developing and implementing remedial plans for those sections of channel in the Keithley Creek watershed that have been impacted by placer mining and may be constraining future forest development in the watershed. The objective would be to stabilize impacted banks and reduce the erosion potential.

4. Upgrade drainage works on active forest and mining roads by increasing the frequency of cross-drains.

5. Install sediment control structures (sumps and settling ponds) at all culverts and stream crossings on active forest and mining roads.

6. Deactivate inactive roads where there is a potential for sediment transport into streams.

6.5 HARVEYS CREEK

Watershed Characteristics

Harveys Creek is a third-order stream with a drainage area of 3,700 ha *[Table 3]*. Harveys Creek flows into the Cariboo River approximately 6.0 km above Cariboo Lake *[Figure 6]*. Hillslopes in the basin are all directly coupled to the channel system and the sediment delivery potential from mass wasting is high. The watershed has a relief of 1,110 m. The lower watershed contains thick glacio-fluvial deposits.

Background Information

The results of the IWAP suggest a moderate potential hazard for surface erosion and landslides in the watershed. Both ratings are based on road densities on erodible soils and unstable terrain. Since there is no terrain mapping available, unstable terrain is defined as any area with slopes >60%. This is the least accurate method for determining a landslide hazard rating so the results should be used with caution. The current ECA is 10%. Regulatory agencies are concerned about increased sediment transport into the Cariboo River.

Inventory Observations

Observations made during the aerial reconnaissance (refer to aerial reconnaissance data forms) were:

1. Lower Harveys Creek is incised into glacio-fluvial sand and gravel deposits.

2. Suspended sediment concentrations are high during freshet flows *[Site H1] [Photo H1]*.

3. Large volumes of sidecast and fill materials have been transported into lower Harveys Creek at an old road crossing (immediately above the alluvial fan) constructed through thick glacio-fluvial deposits.

4. Placer mining disturbances are present on the lower mainstem valley slopes below the large natural failures (refer to aerial photographs) *[Site H1] [Photo H2]*.

5. Recent impacts from ongoing high levels of sediment transport onto the alluvial fan include channel avulsions, aggradation, mid-channel bar formation, channel bank erosion, riparian large woody debris input and burial, and overall channel widening.

6. At least one forest road related landslide has impacted the Harveys Creek mainstem channel immediately above the Simlock Creek confluence.

7. The Harveys mainline crossing on the upper channel is constructed in fine-textured materials and is a source of fine sediment to the channel system *[Site H2] [Photo H3].*

8. Numerous bank failures (both natural and forest development related) were noted along Simlock Creek.

9. Harvesting in the riparian zone was noted along Simlock Creek, resulting in bank erosion and small woody debris input.

The field inventory was undertaken during wet weather conditions that made the observation of soil erosion and mass wasting much easier. Stream discharges were high and channel assessments on the upper Harveys Creek alluvial fan and middle Simlock Creek were difficult *[Figure 6].*

The following is a summary of the observations made at stream channel inventory sites:

1. The alluvial fan of Harveys Creek is highly sensitive to increases in bedload input and peak flows. Inspection of channel conditions on the fan indicated very high impact levels due to channel and bank instability, large increases in bedload from upstream bank failures, landslides, road sidecast failures and active placer mining. Elevated mid-channel bars are present, the channel is actively eroding stream banks and widening, and riparian vegetation and logging debris is present in the channel *[Site H1] [Photos H4 and H5].*

2. Harvesting in the riparian zones (pre-FPC) has occurred along upper Simlock Creek which has resulted minor bank erosion and woody debris input *[Site H5] [Photos H6 and H7].*

3. Numerous bank failures on Simlock Creek (both from past logging and natural sources) have increased the bedload supply to Harveys Creek.

Roads in the lower watershed are constructed in well-drained glacio-fluvial deposits. Surface erosion along roads in the lower watershed was limited. Active and abandoned access roads (to the Harveys Creek fan) used for placer mining have been built on steep gravel and cobble hillslopes, which have contributed large amounts of sediment to Harveys Creek.

Upper and middle watershed roads are generally constructed using coarse textured materials which have minor levels of surface erosion *[Site H4] [Photo H8]*. A lack of sediment control structures in ditch lines at stream crossings (sumps), and long uninterrupted ditch lines, allow sediment to enter streams *[Site H3] [Photo H9]*. The Harveys mainline crossing on upper Harveys Creek is a chronic source of fine sediment to the channel and has caused at least one slope failure into Simlock Creek.

Proposed Harvesting 1997-2001

Approximately 1.2% of the Harveys Creek watershed is proposed for development from 1997 to 2001. The current ECA level of 10.3% will increase to approximately 11% with the inclusion of forest development and estimated hydrologic recovery on old cutblocks.

Inventory Interpretation

1. Channels on the fan are highly sensitive to increases in bedload and peak flows.

2. Placer mining has impacted much of the channel on lower Harveys Creek.

3. Logging in the riparian zone (pre-FPC) and road construction have caused bank failures in the upper basin, and increased bank erosion and bedload transport. Increased small and large woody debris input to the upper and lower channels has resulted from riparian logging activities.

4. Forest roads in the upper basin are generally coarse-surfaced in nature and resistant to surface erosion. However, insufficient sediment control structures in ditch lines permits sediment to enter streams at road crossings.

5. At the watershed level, hydrologic impacts due to forest development on the lower channel system are difficult to identify due to channel impacts from placer mining activity.

6. Increased bedload due to channel instability has impacted the fisheries resource in lower Harveys Creek and the Cariboo River.

7. Proposed forest development over the next five years (which would increase the ECA by approximately 1.2% to 11%) should not result in additional channel instability.

Recommendations

1. Complete a total forest development plan in the watershed to provide a basis for determining if/or when proposed development might affect peak flows. The objective would be to maintain peak flows at a low hazard rating (as defined in the IWAP) until impacted channels have returned to a stable condition. Proposals for forest development beyond a low peak flow hazard level should be considered only upon favourable results from detailed stream channel and riparian condition assessments.

2. The impacts from current placer mining operations in the watershed should be assessed by the regulating agency to determine if additional protection measures are required to eliminate further impacts on the water resource.

3. Restoration plans should be developed and implemented to address the impacts on the channels from placer mining, which will ultimately constrain future forest development.

4. Revegetating the site should stabilize the hillslope failure below the road into Simlock Creek (at the Harveys mainline crossing on upper Harveys Creek).

5. Upgrade the road drainage on all active roads in the Harveys Creek watershed to minimize sediment input to streams. This should include installing additional cross-drains on long uninterrupted ditch lines, with sediment control structures (sumps) at all culvert inlets and at stream crossings.

6.6 LITTLE RIVER

Watershed Characteristics

The Little River has a drainage area of 35,400 ha. The watershed is characterized by a deeply incised lower alluvial channel with a broad low gradient alluvial fan *[Figure 7]*. Terrain in the upper watershed is rugged with high relief and directly coupled hillslopes.

Background Information

IWAP results indicate low levels of concern in all hazard categories. The current ECA in the Little River watershed is 5.0%.

High stream discharge levels have been noted in the Little River watershed as a result of steep terrain and directly coupled hillslopes in the upper watershed. The Little River watershed is described as "flashy" with extreme peak and low flow responses to wet and dry weather conditions[5]. Relatively high rates of forest development have occurred over the last 10 to 15 years. It is thought that channel widening has occurred as a result of riparian harvesting.

The lower 20 km of mainstem channel is utilized by both chinook and coho salmonid species.

Inventory Observations

The aerial reconnaissance was limited to the lower 15 km of the basin (refer to aerial reconnaissance data forms). Harvesting in the riparian zone has occurred adjacent to the lower channel resulting in minor increases in bank erosion *[Sites L4 and L5] [Photos L1 and L2]*.

Aerial photographs of the lower 10 km were compared using 1950s and 1992 coverage. The lower mainstem channel is low gradient and has a naturally high bedload of sand and gravel. Extensive bank erosion has contributed large quantities of sediment and woody debris to the channel. A large debris jam at the apex of the fan on both sets of photographs suggests that the fan has been stable for the past forty years. Natural debris jams and historic channel avulsions have created multiple active channels on the fan. However, the assessment indicated that there had been no measurable changes in sediment supply to the channel, rates of lateral channel migration, or channel morphology over the inventory period.

Field conditions were wet with high stream discharges during the inventory work that was conducted in July 1997. Follow-up channel inventories were completed in September 1997 on three reaches on the Little River and two on Ishkloo Creek *[Figure 7]*.

Observations made at the stream channel inventory sites are summarized below:

1. The alluvial fan at the apex of the Little River is characterized by elevated sand and gravel bars, and large woody debris jams *[Site L2] [Photos L3 and L4]*. No logging related debris (saw-cut pieces) was present in the debris jam, indicating limited debris from past forest development *[Site L2] [Photo L5]*.

2. A large bank failure into the mainstem channel was identified below a riparian leave strip at the G road crossing *[Site L3] [Photos L6 and L7]*. Large bank failures such as this are chronic sources of sediment and debris to the channel.

3. Channels above the J road crossing (in the middle watershed) have been impacted by natural bank erosion and woody debris input from an old growth riparian zone *[Site L6] [Photos L8 and L9]*.

4. In the upper watershed, both the Little River and Ishkloo Creek are stable boulder and bedrock controlled channels *[Sites L8 and L9] [Photos L10 to L13]*. Old growth riparian zones are present along both channels with no signs of instability. Channels in the upper Little River watershed serve as transport reaches for sediment into the sensitive lower alluvial reaches.

Running surface erosion on active roads in the upper watershed is a concern during heavy rainfall events *[Site L10] [Photo L14]*. Suspended sediment from the running surface and ditch lines is being transported into the upper channel at stream crossings *[Site L9] [Photo L15]*. Long uninterrupted ditch lines with a lack of sediment control structures are conveying sediment into stream channels. Surface erosion resulting from forest road construction and use in this watershed (as in the other watersheds) is having a cumulative effect on water quality.

New road construction was occurring in the Ishkloo Creek basin during the field inventory work. New roads were being constructed from native till materials; surfacing was in progress. Construction work during ongoing rain was resulting in high rates of surface erosion and sedimentation in Ishkloo Creek *[Site L11]*.

Proposed Harvesting 1997-2001

Approximately 1,400 ha of harvesting are proposed in the Little River watershed over the next five-year development plan period. The current ECA of 4.6% will increase to approximately 8.0% by 2001.

Inventory Interpretation

1. The lower and middle mainstem reaches of the Little River are incised alluvial channels that are sensitive to increases in peak flow or direct riparian disturbance. Bank erosion and associated debris input from the riparian zone is a natural process in alluvial channels.

2. There may be some minor increases in bank erosion and debris input as a result of inadequate riparian leave strips from past forest development along the lower and middle mainstem channels.

3. No measurable changes in channel morphology, sediment supply from channel banks or rates of lateral channel migration were noted in the aerial photograph comparison of the lower and middle mainstem channels.

4. The upper Little River watershed is characterized by steep rugged terrain, and boulder and bedrock controlled cascade-pool and step-pool channels.

5. The watershed is said to have a "flashy" response to rainfall events, which can exacerbate already high levels of bank erosion and bedload movement in the lower channels.

6. Most roads in the watershed have a coarse running surface, however, surface erosion is still a problem during extreme rainfall events. Long uninterrupted ditch lines with a lack of sediment control structures at stream crossings allow for sediment to be transported into stream channels. High rates of erosion into streams were observed at road construction sites where equipment was working during heavy rains.

7. Proposed forest development will increase the ECA in the Little River watershed from 5.0% to 8.0% by 2001. This increase should not affect peak flows in the mainstem channel.

Recommendations

1. Complete a total forest development plan in the watershed to provide a basis for determining if/or when proposed development might affect peak flows. The objective would be to maintain peak flows at a low hazard rating (as defined in the IWAP) due to the high sensitivity of the lower alluvial mainstem channel. Development beyond a low peak flow hazard level could initiate rapid rates of lateral channel migration and bedload movement. Alternative harvesting techniques that remove less than 30% of the basal area and have no hydrologic impact could be considered for development beyond the low peak flow hazard level.

2. Road drainage and sediment control measures on active roads should be upgraded to reduce sediment transport to channels. Long uninterrupted ditch lines should have additional cross-drains installed to re-establish natural hillslope drainage patterns and reduce the rates of sedimentation.

3. Road construction activities that may cause elevated sediment transport to streams should be suspended during wet conditions, unless sediment can be controlled through the use of silt fences, sumps and settling ponds.

6.7 CUNNINGHAM CREEK

Watershed Characteristics

Cunningham Creek is a third-order tributary of the Cariboo River with a drainage area of 10,800 ha *[Figure 6]*. The watershed is characterized by a deeply incised middle and lower mainstem channel with a steep gradient. Placer mining in the upper watershed over the last century has caused extensive impacts to the channels. Several claims remain active on the mainstem and headwater channels. Numerous natural bank failures exist along the steep valley slopes of the middle and lower channels. Several steep first and second-order major tributaries join the middle and lower mainstem channel in the incised reaches. Glacio-fluvial and glacio-lacustrine materials are present along the steep banks of the lower mainstem channel.

Background Information

The results of the 1997 IWAP suggest low potential hazards from past forest development. Mass wasting hazards may have been underestimated based on the exclusion of a landslide count from the IWAP calculations. Surface erosion hazards may also have been underestimated based on the use of TRIM information for road density calculations, rather than updated forest cover data. The current ECA in the Cunningham Creek watershed is 3.0%.

Lower Cunningham Creek is utilized by chinook salmon up to the confluence with Tinsdale Creek, approximately 10 km above the mouth. The Department of Fisheries and Oceans is concerned about the high levels of forest development concentrated in the lower watershed area and the encroachment of blocks on the stream channels. Logging on steep slopes may also be a source of sediment.

Low stream flows in the winter months are a concern to the Department of Fisheries and Oceans. Applications for water licenses on Cunningham Creek are currently being opposed by DFO until minimum flow and water management options are reviewed.

Inventory Observations

Poor weather conditions during the aerial reconnaissance limited basin access to the lower mainstem channel and fan (refer to aerial reconnaissance data forms). Suspended sediment concentrations were high during the freshet and new bedload deposition was observed on the fan. Vegetation cover is intact on the fan and is providing some stability to the banks.

Field inventory procedures were carried out in July 1997 during wet weather, which was an asset with regards to identifying surface erosion concerns. Stream discharges were too high in the lower watershed to permit channel assessments. A reconnaissance of the lower channels was completed in September 1997.

Results of the stream channel inventory are summarized below:

1. The fan of lower Cunningham Creek has undergone moderate aggradation and channel widening *[Site C1] [Photos CN1 to CN3]*. Mid-channel bars are present and woody debris is scattered along the banks and is accumulating on mid-channel islands. Multiple channels are present on the middle and lower fan. The main channel on the fan is sensitive to increases in bedload and/or discharges.

2. Bank instability and an increased supply of woody debris resulting from harvesting in the riparian zone is a concern in Tinsdale Creek (tributary to Cunningham Creek) *[Site C3] [Photos CN4 and CN5]*. Mid-channel bars and woody debris jams are present and minor channel widening has occurred. Bedload supply has increased from Tinsdale Creek into the Cunningham Creek.

3. Upper Cunningham Creek is moderately unstable as a result of placer mining disturbances on the floodplain. Increased bedload from upstream and adjacent placer mining disturbance has resulted in channel aggradation and widening, which in turn has caused increases in bank erosion and the supply of woody debris from the riparian zone *[Site C5] [Photos CN6 and CN7]*. Overall, riparian vegetation along the upper mainstem channel is sparse (due to extensive historic placer mining of the floodplain deposits) and is providing limited bank stability.

4. Roundtop Creek above the break in slope of the main Cunningham Creek valley is stable with low suspended sediment levels. Harvesting has occurred in the riparian zone (pre-FPC) but bank stability is not a concern since the banks are composed of boulders and bedrock *[Site C5] [Photo CN8]*. There have been some minor increases in woody debris input from the adjacent forest development.

Some of the older roads in the watershed are armoured, as fine sediments have been washed from the running surface. Some roads (pre-FPC) are rutted and have undergone running surface erosion *[Site C4] [Photo CN9]*. Sumps are usually absent on pre-FPC roads at crossdrain and stream crossings allowing sediment to enter streams. New roads in the upper watershed (constructed to Forest Practices Code standards) are well drained and exposed soils have been grass seeded *[Photo CN10]*.

Proposed Harvesting 1997-2001

Proposed forest development over the next five years will increase the current ECA (3.0%) by approximately 11.5% to 14%. No changes in peak flow are anticipated with the proposed level of forest development.

Inventory Interpretation

1. There has been no harvesting in the riparian zones nor any placer mining on the fan. However, increased bedload from upstream placer mining disturbances and numerous natural hillslope failures has resulted in channel aggradation, bank erosion and channel widening on the Cunningham Creek fan.

2. Harvesting in the riparian zones (pre-FPC) on tributary channels has caused minor increases in bank erosion and woody debris input.

3. There was limited evidence of surface erosion and sediment delivery from roads into the channels in the watershed. Sediment control structures are absent at cross-drains and stream crossings, increasing the risk of sediment input into the channels.

Recommendations

1. Based on the fish values of the lower mainstem channel, observed channel disturbances and high channel sensitivity on the alluvial fan, future forest development should be planned to maintain a low peak flow hazard rating as defined in the IWAP. Development beyond the low hazard level should be contingent upon favourable results from channel and riparian stability assessments, and a determination that any flow increase will not increase the channel instability concerns in the disturbed placer mined reaches in the upper watershed.

2. Restoration plans should be developed and implemented to address the impacts on the channels from placer mining, which will ultimately constrain future forest development.

3. The impacts from current placer mining operations in the watershed should be assessed by the regulating agency to determine if additional protection measures are required to eliminate further impacts on the water resource.

4. Restoration of channel reaches disturbed by past placer mining activity should not be undertaken unless there is a process in place that will eliminate similar impacts from re-occurring because of other placer activities.

5. Road drainage and sediment control measures should be upgraded on active roads to minimize the delivery of sediment to the channels. Additional cross-drains and sumps are required on long uninterrupted ditch lines to reduce sediment input to streams.

6.8 KIMBALL CREEK

Watershed Characteristics

Kimball Creek drains directly into the middle Cariboo River between Cunningham Creek and Matthew River. Kimball Creek is a third-order stream with a drainage area of 6,700 ha *[Figure 8]*. It has one major tributary (Windlass Creek) that joins the mainstem in the lower watershed. Topographic relief in the basin is 1,205 m. Hillslopes are coupled in the areas of the lower and middle mainstem, and partially coupled in the upper watershed. Both the lower mainstem and lower Windlass Creek are deeply incised into glacio-fluvial and glacio-lacustrine deposits, with high sediment delivery potentials from hillslope failures. Limited forest development has taken place in the watershed and placer mining activity is confined to one recently developed claim on the apex of the fan.

Background Information

The 1997 IWAP results indicate no past forest development related concerns in the watershed. The current ECA is 2.6%. There are fisheries concerns in Kimball Creek regarding increases in the bedload to the Cariboo River[6].

Inventory Observations

The results of the aerial reconnaissance were limited due to poor weather which restricted access to the watershed (refer to aerial reconnaissance data forms). Recent bedload deposition was evident on the fan, and bank erosion with associated increases in woody debris was noted.

Field inventory observations were made in early July and mid-September 1997. Weather conditions during the initial visit were extremely wet and provided an excellent opportunity to assess surface erosion and mass wasting hazards. Stream discharges were high in July, so the lower mainstem channel inspections were completed in September 1997. Reconnaissance channel inventory procedures were completed on the alluvial fan approximately 100 m above the mouth, and on Windlass Creek above the incised lower reaches *[Figure 8]*.

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

Observations made at stream channel inventory sites are as follows (refer to field data forms):

1. Significant channel disturbance was noted on the Kimball Creek fan including considerable bank erosion and large woody debris input *[Site Kim1, 2 and 3] [Photos KB1 to KB4]*. Large elevated mid-channel bars are present and moderate levels of channel widening have occurred. Channel disturbances were recent and could possibly be attributable to high spring runoff conditions in 1997. Unfortunately, stream discharge data is no longer available for the Cariboo River watershed so the magnitude and return period of the 1997 freshet is not known.

2. Windlass Creek in the middle watershed is stable and shows no signs of major disturbance *[Site Kim6] [Photos KB5 and KB6]*. Forest development has occurred in the drainage, including some harvesting (pre-FPC) in riparian zones. Small woody debris accumulations are present that may be attributable to harvesting in riparian zones.

Two mainline roads (on either side of the incised lower channel reach) lead up from the Cariboo River valley through fine-textured surficial deposits into the middle watershed. Running surface and ditch line erosion is occurring, but it does not appear that there is any direct connection to the mainstem channel system. In the middle watershed roads are either constructed of, or surfaced with, coarse materials and are stable *[Site Kim3] [Photo KB7]*. Semi-permanent road deactivation of block and spur roads has occurred in the middle watershed.

Several landslides have occurred into the lower mainstem channel of Kimball Creek. Numerous pre-FPC landings are located at the break in slope to the incised lower river valley *[Site Kim5] [Photo KB8]*. One of the landslides occurred as a result of a long ditch line which drained onto a landing at the break in slope, then into a steep gully triggering the failure *[Site Kim4] [Photo KB9]*. Numerous other landings are located close to the break in slope above the deeply incised lower channel, which are a concern with regards to initiating future landslides.

Increases in bedload from landslides have contributed to instabilities on the alluvial fan. The increase in bedload and subsequent aggradation has also resulted in increased bank erosion, channel widening and riparian woody debris input.

Proposed Harvesting 1997-2001

Proposed development over the next five years will increase the ECA (2.6%) by approximately 8.2% to 11%.

Inventory Interpretation

1. Several landslides have directly impacted the lower mainstem channel from the steep, coupled valley slopes. At least one slope failure resulted from ditch line runoff draining onto a landing adjacent to the break in slope. Increases in bedload have resulted from failures on the steep valley slopes.

2. Recent high freshet discharges have increased bedload and channel instabilities on the fan, as well as contributing more sediment to the Cariboo River.

3. The lower Kimball Creek alluvial fan is sensitive to disturbances resulting from increased peak flows or increases in bedload.

4. Roads climbing out of the Cariboo River valley have been constructed through fine-textured soils and are experiencing moderate levels of surface erosion. Direct connections to the drainage network were not noted, since roads are located away from the mainstem valley.

5. Since there has been limited forest development in the watershed, proposed development which would increase the ECA by 8.2% to 11% should not affect peak flows in Kimball Creek.

Recommendations

1. It is recommended that block and spur roads be assessed to determine if the natural drainage patterns are intact.

2. Landings adjacent to the break in slope above Kimball Creek should be assessed to determine if there is any potential of slope stability.

3. If the natural drainage patterns on the steep valley slopes has been impacted by past forest development, drainage works on active roads should be upgraded, and any inactive roads should be semi-permanent or permanently deactivated.

4. A detailed channel assessment should be undertaken on the lower and middle reaches of Kimball Creek to determine what impacts landslides might have had on channel stability and the alluvial fan.

6.9 MATTHEW RIVER

Watershed Characteristics

The Matthew River is a large fourth-order channel draining a basin area of 39,800 ha *[Figure 8]*. The lower basin is characterized by a broad U-shaped valley with a wide alluvial floodplain and hanging tributary valleys. The river meanders through thick glacio-fluvial and fluvial deposits from below Ghost Lake to a bedrock canyon approximately 3.0 km above the confluence with the Cariboo River. The upper watershed above Ghost Lake is rugged with glacier fed first-order tributary streams and a broad, low gradient floodplain adjacent to the mainstem channel.

Approximately 60% of the Matthew River watershed is located in a newly formed Provincial Park. The park begins near the lower end of Ghost Lake and includes the entire upper watershed. Considerable forest development has taken place in the lower watershed as a result of a large spruce and pine beetle salvage operation in the early 1980s. The rate of growth of regeneration on the old cutblocks on floodplain has been very significant, reducing the impact of earlier harvesting in the riparian zone.

Background Information

The results of the IWAP indicate limited concern with past forest development activity. However, considering the concentration of forest development in the lower third of the watershed, some potential surface erosion concerns may exist. There are concerns in the Matthew River watershed regarding the level of riparian harvesting, and the potential for increased bank erosion and sediment load to the mainstem channel.

Inventory Observations

Aerial reconnaissance observations made are summarized below (refer to aerial reconnaissance data forms):

1. Large progressive clearcuts dominate the floodplain to the stream edge and lower slopes of the lower basin (below Ghost Lake). The majority of blocks in the lower watershed are old and considerable riparian regeneration has occurred along the mainstem channel. Forest development has occurred adjacent to, but not above, Ghost Lake.

2. The concentration of forest roads in the lower watershed is a concern for surface erosion, which is currently being addressed through the completion of a sediment source survey in the Cariboo River watershed.

3. Surface erosion from inventoried road networks in the lower basin, however, appeared to be minimal.

4. Suspended sediment levels in lower tributary streams was low.

5. The broad alluvial floodplain of the Matthew River is characterized by multiple terrace levels. Development to the river banks (riparian harvesting) has occurred on the alluvial terraces with only a minor increase in bank erosion.

6. Several large bank failures have occurred in the lower incised canyon reach approximately 3.0 to 4.0 km above the mouth. Forest development has occurred on the terrace above the failures and may have increased the rate of bank erosion and mass wasting.

7. The mainstem river channel is a low gradient meandering stream that appears to be stable.

Field inventories were undertaken in July 1997 during wet weather. Although river discharges were high, two sites were visited: one on the lower Matthew River and the other on lower Connection Creek *[Figure 8]*.

Observations made at stream channel inventory sites are presented below:

1. Stream banks along much of the lower mainstem channel appear to be stable, in spite of significant riparian harvesting *[Site M1] [Photos M1 to M3]*. Vigorous alder and conifer regeneration is improving bank stability bank and providing some cover for fish. Bed and bank materials of the mainstem channel below Ghost Lake are sand and silt, which are sensitive to increases in peak flow or riparian disturbance.

2. Connection Creek, which enters the Matthew River approximately 3.0 km below Ghost Lake, is a stable low gradient stream with beaver ponds and marshlands on the lower floodplain *[Site M4] [Photos M4 and M5]*. Increases in large woody debris input on the lower channel are the result of blowdown in the riparian reserves. No bank disturbance was noted from riparian harvesting or blowdown.

Lower slope mainline roads in the lower basin are constructed of coarse-textured materials and show minimal evidence of surface erosion. Semi-permanent deactivation has been completed on inactive block and spur roads in the lower basin. However, some of the deactivated roads show evidence of past surface erosion and rutting *[Site M2] [Photo M6]*.

Using aerial photography, the lower Matthew River was assessed to determine areas of significant bank instability. In spite of a history of harvesting in the riparian zones on the floodplain and alluvial terraces, the river appears to be stable with bank erosion and sediment transport in a state of equilibrium.

Proposed Harvesting 1997-2001

Proposed development over the next five years will increase the ECA (11.4%) by approximately 1.7% to 12% by 2001. No increase in peak flow is anticipated in the Matthew River as a result of the proposed development.

Inventory Interpretation

1. Large progressive clearcuts dominate the lower third of the Matthew River watershed. No forest development has taken place above Ghost Lake.

2. The lower Matthew River is considered to be sensitive to forest development impacts, since it flows through a broad alluvial floodplain flanked by numerous alluvial terraces.

3. In spite of significant harvesting on the floodplain and lower alluvial terraces, the mainstem channel appear to be stable. Several large bank failures have occurred from the alluvial terraces above the incised canyon reach approximately 3.0 km above the mouth.

4. Mainline roads in the basin are constructed of coarse-textured materials and are stable. Deactivation has taken place on many of the older block and spur roads, although there is evidence of past surface rutting and erosion.

5. An overall concern with road density and potential surface erosion in the lower watershed is being addressed through the completion of a sediment source survey.

6. Proposed for development of approximately 1.7% over the next five years poses no hydrologic concern with regards to increases in peak flow.

Recommendations

Due to the overall good condition of the Matthew River watershed, there are no watershed scale recommendations at this time. Site specific recommendations to address an overall road density and potential surface erosion concern in the lower watershed may be developed as a result of the sediment source survey that is being completed as part of the Watershed Restoration Program funded by Forest Renewal BC.

MM/dd/jb

7.0 COTTON RIVER WATERSHED

[Volume II: Pages 57-90]

8.0 HORSEFLY RIVER WATERSHED

[Volume III: Pages 91-121]

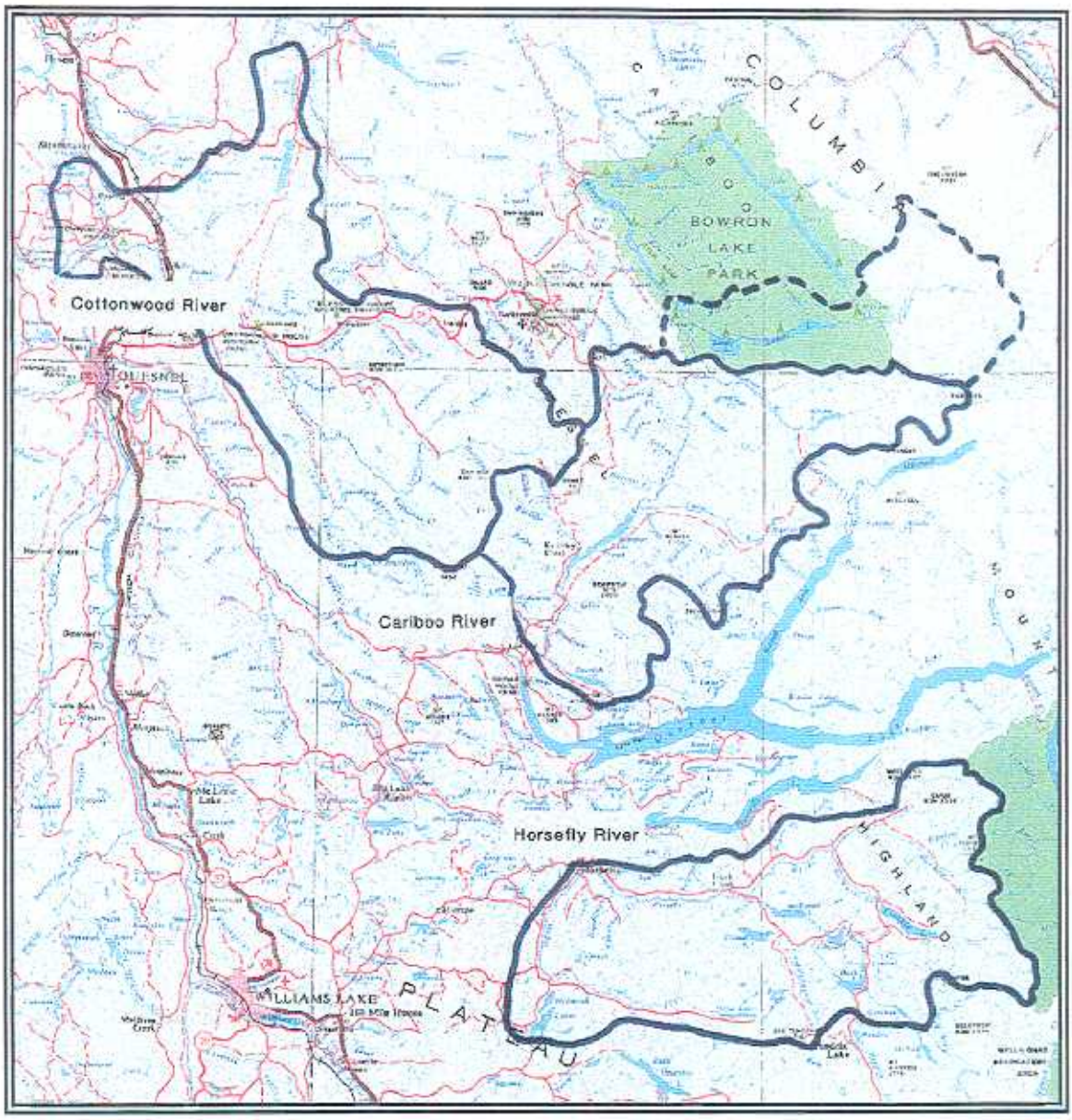
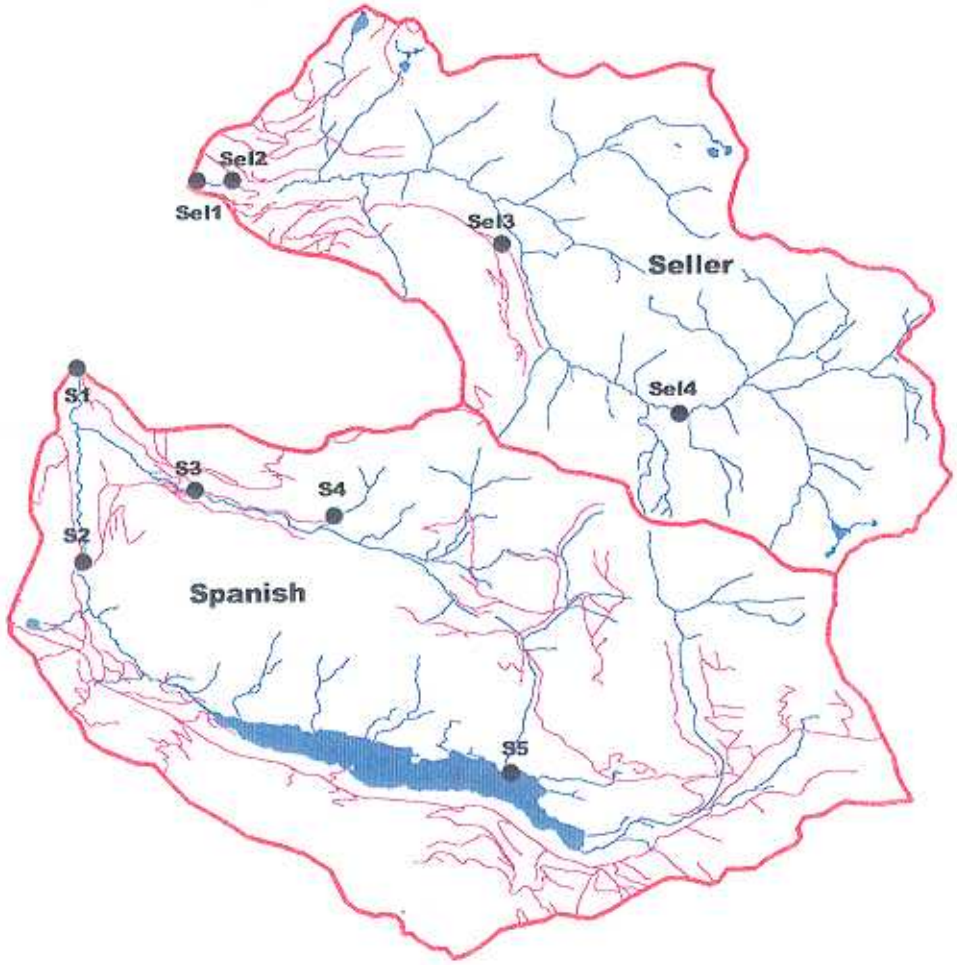


FIGURE 1

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.

CARIBOO REGION WATERSHED INVENTORY



CARIBOO RIVER WATERSHED
Spanish and Seller Sub-basins

FIGURE 3

N

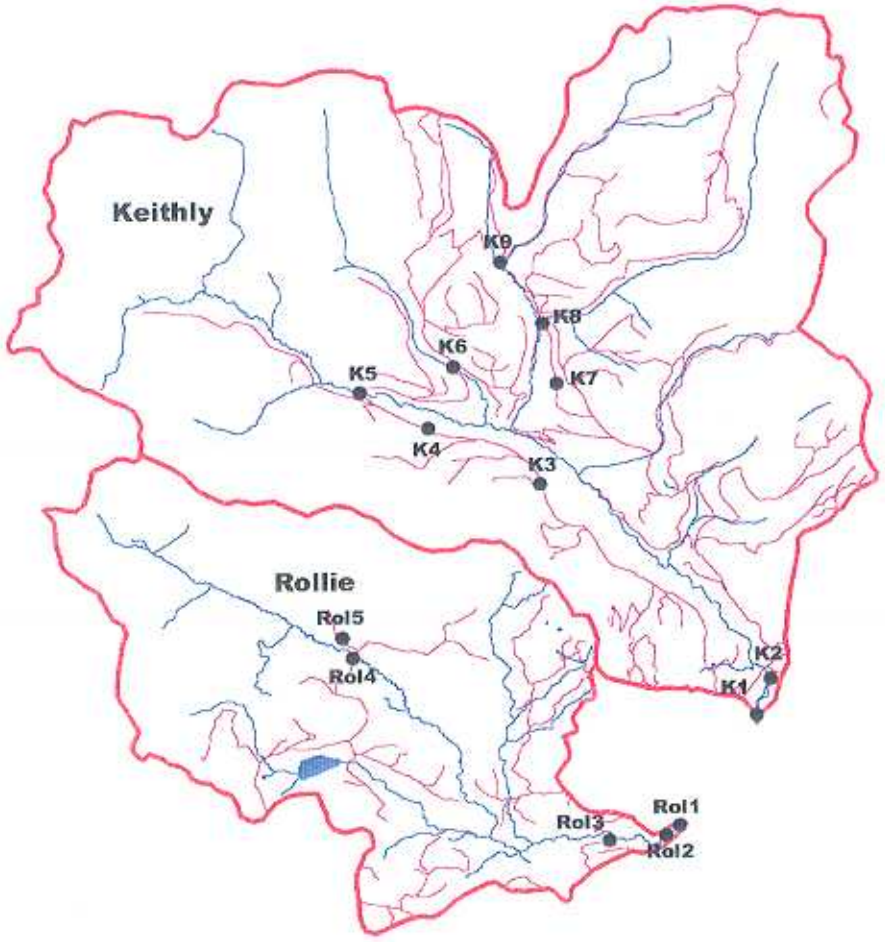
2 0 2 Kms

Roads

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

Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by Carmanah Research Ltd. (Victoria, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY



CARIBOO RIVER WATERSHED
Keithly and Rollie Sub-basins
FIGURE 4

N

1 0 1 2 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 Carmanah Research Ltd. (Victoria, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

CARIBOO RIVER WATERSHED
Residual Area

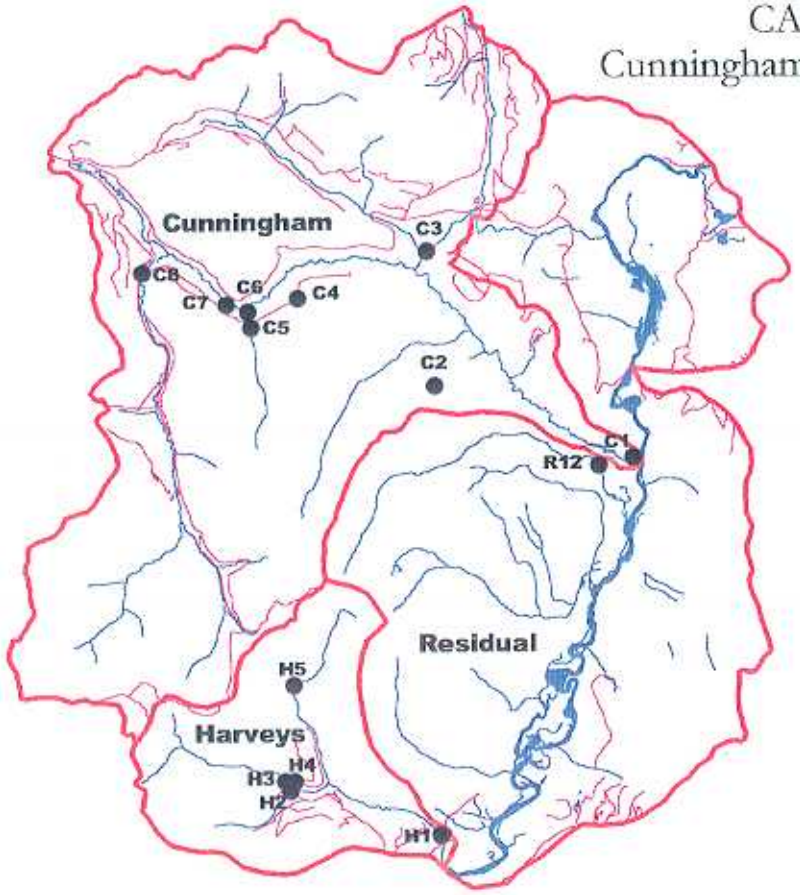
FIGURE 5

Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by Carmanah Research Ltd. (Victoria, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

CARIBOO RIVER WATERSHED
Cunningham & Harveys Sub-basins, and Residual Area

FIGURE 6



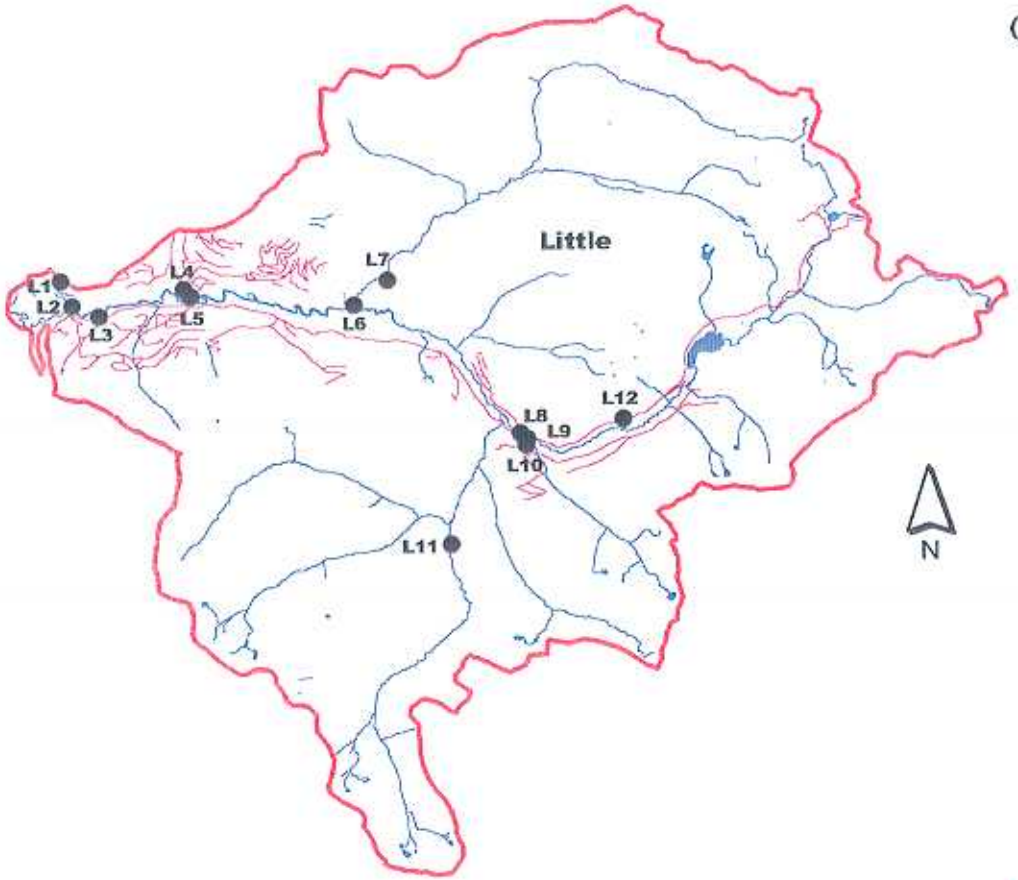
2 0 2 4 Kms

Roads

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

Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by Carmanah Research Ltd. (Victoria, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY



CARIBOO RIVER WATERSHED

Little Sub-basin

FIGURE 7

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 Carmanah Research Ltd. (Victoria, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

CARIBOO RIVER WATERSHED
Kimball and Matthew Sub-basins

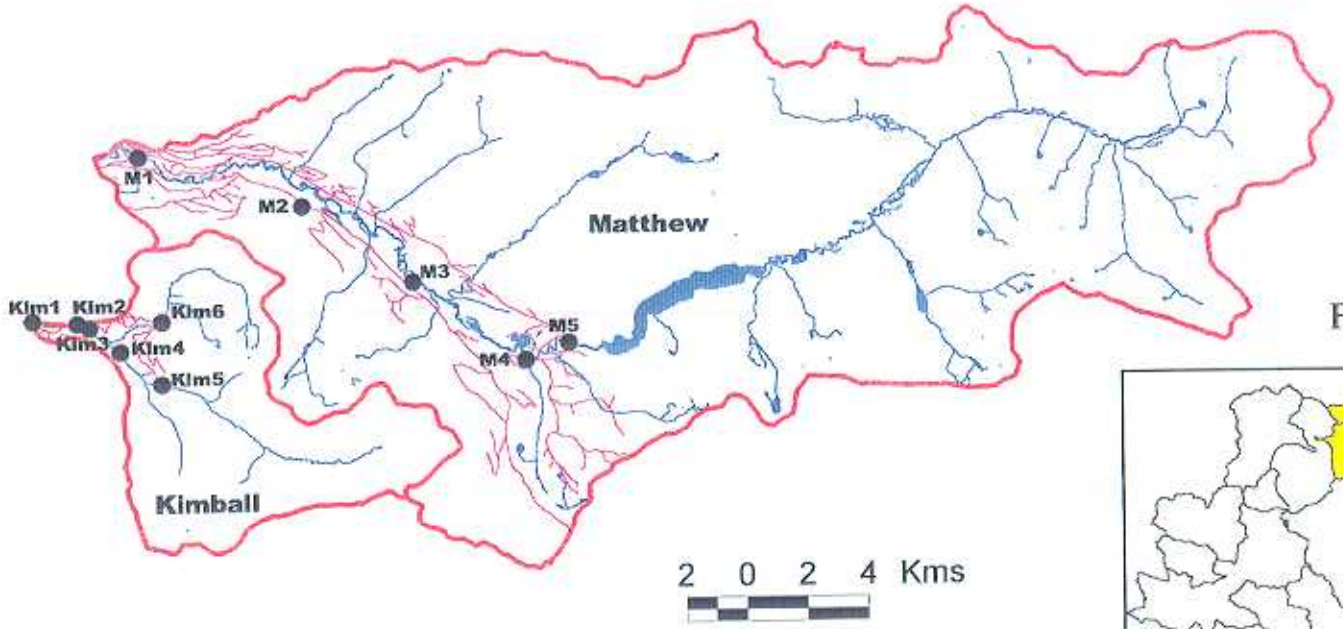


FIGURE 8

Roads

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

Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by Carmanah Research Ltd. (Victoria, BC)
October 31, 1997

Cariboo Stakeholders - Comment List

Contact	Firm/Agency	Position	Phone/Fax	Project Input
Adrian Wall	DFO - Lillooet	Habitat Technician	256-4525	Met with contractor June 4, 1997 - See meeting minutes for details
Al Balogh	MoF Region - Williams Lake	Regional Staff Manager	398-4247	Met with contractor and contract officer and monitor to develop terms of reference for the project
Bill Chung	McElhanney Consulting	Technician	561-2229	Provided information on the Bridge Creek IWAP. Identified the 100 Mile House water intake (at Horse Lake) as a POI location that was treated similar to a community watershed. Identified fine textured eroding banks around 100 Mile House, and high sportfishing values in the lakes of the Bridge Creek watershed.
Bill Young	MoF Horsefly	District Manager	620-3229	Refered the contractor to Wendy McRae of Tech Drafting for 5 year development plan information. Refer to meeting minutes for details of telephone conversation.
Bruce MacDonald	DFO - Prince George	Regional Manager	561-5367	Met with contractor June 3, 1997 - See meeting minutes for details
Doug Cooper	MoF 100 Mile	GIS/LIS Coordinator	395-7848	Provided 5 year development plan mapping to the contractor
Doug Flintoft	MoF Quesnel	District Manager	992-4400 Fax:992-4403	Assisted in providing 5 year development plan mapping to the contractor. Commented on the project with reference to its potential usefulness for reviewing 5 year development plans.
Doug Konkin	MoF 100 Mile	District Manager	395-7804	Assisted in providing 5 year development plan mapping to the contractor. Provided information regarding the status of IWAP reports for the Bridge and Bonaparte watersheds.
Gordon Kosakoski	DFO - Kamloops Region	Head - Southern BC Region	851-4959	Met with the contractor May 22, 1997 - See meeting minutes for details.
Herb Langin	MOE Region - Williams Lake		398-4563	Met with contractor and contract officer and monitor to develop terms of reference for the project.
John Mansell	Weldwood Forest Products	Chair of Major Licensees Fisheries Committee		Spoke with the contractor regarding the scope and use of the project results. Offered to organize any licensee meetings with the contractor that were deemed necessary. Requested that the Licensees be kept informed of the preliminary project results.
Ken Gilbert	MoF Horsefly	WRP Coordinator	620-3239	Referred the contractor to Mike Parker for IWAP information.
Ken Soneff	MoF Region - Williams Lake	Research Manager		Met with contractor and contract officer to develop initial terms of reference and final work plan.
MIke Parker	MOE Fish & Wildlife	WRP Fisheries Specialist	398-4530	Confirmed IWAP status in project watersheds
Mike Romaine	DFO - Vancouver	Chief - Integrated Resource Management and Planning	666-3856	Met with contractor May 22,1997 - See meeting minutes for details
Pat Teti	MoF Region-Williams Lake	Regional Hydrologist	398-4752 Fax:398-4380	Met with contrator, contract officer and MOE and MoF regional representatives to determine initial project objectives. Provided technical input in developing aerial reconnaissance and field-based assessment techniques. Met with contractor and contract officer to develop final work plan.
Peter Baggs	MoF 100 Mile	WRP Coordinator	395-7825	Provided information on the status of IWAP, FHAP and Sediment Source Survey assessments in the Bridge Creek and Bonaparte River watersheds.
Ray Jungaro	MoF Quesnel	WRP Coordinator	992-4487	Provided information on the status of the Cottonwood River IWAP.
Wendy McRae	Tech Drafting - Williams Lake	Drafting Tech	398-9000 Fax:398-9045	Provided 5 year development plan information for the Horsefly and Cariboo watersheds.
Ron Beasley	MoF Regional Fire Centre	Flight coordinator	989-2611	Provided aircraft suitability information for the aerial reconnaissance
Rob Dolihan	MOE Williams Lake - Region	Fisheries Officer	398-4554	Provided information on Horsefly River stream temperature monitoring program. Meeting scheduled with the contractor to discuss temperature trends in various sub-basins and to provide a temperature monitoring location map.
Mae Burrows	T Buck Suzuki Foundation	Executive Director	(604) 255-8819	Spoke with contractor on July 22, 1997. Refer to meeting minutes for details.

MEETING MINUTES - CARIBOO WATERSHED PROJECT

Date:	**June 25, 1997**
Location:	**Telephone Interview**
Contact:	**Marty Beets**
Position:	**Designated Environmental Officer** **Ministry of Environment, Lands and Parks**
Area of Interest	**Horsefly, Cottonwood and Cariboo Watersheds**
Interviewer:	**Michael Milne**
Others Present:	**None**

- WRP funded assessments have generally proven to be somewhat limited in their use at the operational level.
- The Designated Environmental Officer (DEO) is responsible for signing off five year development plans in the Ministry of Environment, Lands and Parks.
- Information (field based) is required on the current state of the watersheds and sub-basins according to the IWAP categories. The DEO needs to know where we are now in order to judge the geographic suitability of proposed five-year development plans. Comments on proposed development should focus on not exacerbating existing conditions. If development is found to be inappropriate in certain drainages, direction should be given as to where a more suitable location may be and why.
- We do not want to make things worse in any of the drainages.
- The Horsefly River watershed is the most contentious drainage in the Region. Sierra Legal Defense has identified that no terrain stability mapping has been completed in the Horsefly.
- A draft report should be circulated to the DEO for review prior to project completion.
- Watershed report format should identify problems and concerns with proposed development then allow the DEO, District Managers and DFO to decide on the level of risk that they are willing to accept in each drainage.

MEETING MINUTES - CARIBOO WATERSHED PROJECT

Date:	**May 22, 1997**
Location:	**Department of Fisheries and Oceans Suite 1220 - 555 West Hastings Vancouver, BC**
Contact:	**Mike Romaine and Gordon Kosakoski**
Position:	**Chief, Integrated Resource Management Planning - Pacific Region and Head, Southern B.C. Interior Section respectively.**
Area of Interest	**All watersheds involved in the Cariboo Watershed Project**
Interviewer:	**Allan Chapman**
Others Present:	**None**

- 1:500 000 scale map was provided which identifies areas in Horsefly, Cottonwood, Cariboo, Bonaparte and Bridge watersheds for anadromous fish.
- Resource profiles for Cariboo/Chilcotin report by Rowland and MacDonald were also provided.
- Mike Romaine recommended getting touch with Ian Williams, ex-DFO living in Nanaimo. Williams carried out fish habitat work in the Horsefly River watershed.
- Mike Romaine wants to see specific, applicable results and recommendations similar to those provided by Ken Rood in his reports (Horsefly River). He does not believe that general, inapplicable results (such as IWAP's) are useful.
- Mike Romaine and Bruce MacDonald will be the key DFO contacts.
- DFO would like to be kept informed but does not want to be involved at every stage or phase.

- DFO would like regular communication regarding the:

  1. work plan
  2. interim results
  3. draft final report or interim report
  4. presentation

- DFO would like to see a discussion regarding the contribution of agricultural land clearing to the ECA. What is the ECA now (i.e. why the discrepancy between IWAP and the Ken Rood reports)?

- A discussion on the topic of hydrologic recovery could be incorporated into the final report.

- Unit number 8 on the Bonaparte River is very important anadromous fish habitat. Gordon will be the contact for this watershed.

MEETING MINUTES - CARIBOO WATERSHED PROJECT

Date:	**July 2, 1997**
Location:	**Telephone Interview**
Contact:	**Maurice Lirette**
Position:	**Senior Fisheries Biologist** **Cariboo Region**
Area of Interest	**All watersheds involved in the Cariboo Watershed Project**
Interviewer:	**Michael Milne**
Others Present:	**None**

- Bonaparte and Bridge watersheds are of lesser concern than the Horsefly, Cottonwood and Cariboo watersheds.
- Bonaparte and Bridge have had lower rates of harvest and are genearlly more benign watersheds.
- Objectives of the Cariboo Watershed Inventory are to identify relative risks to the impairment of fish habitat and their geographic extent in each basin or watershed.
- Results are needed for direction in the short term - five to 20 years.
- Horsefly watershed has the most significant salmonid fish resources.
- Cottonwood watershed has been effected by placer mining more than either Horsefly or Cariboo.
- In the Cariboo watershed, sub-basins and their mainstem channels are the highest concern. Little River, Keithly Creek, Rollie Creek and lower Matthew Creek are the sub-basins of highest concern. Upper Cariboo is well buffered from hydrologic effects by a significant protected area and several lakes.
- The problem in the Cariboo Region is how to meet the annual cut while minimizing forestry related effects over the long-term. Streams in the Cariboo are not as heavily damaged as some in the Coastal regions, but proactive planning at this stage will prevent degradation beyond unrecoverable levels.

- Results of the Cariboo Watershed Inventory should filter down through all levels of all agencies responsible for land and resource management in the region - DFO, MOE and MoF.

- Problems with past forest and land management relate to the scope or scale of the management focus. Specific cutblocks and prescriptive requirements have been dealt with rather than a watershed systems approach. There is a significant need for "bigger picture" direction on appropriate levels and types of land-use practice.

- CCLUP has been written such that ongoing monitoring is undertaken while development is occurring. No assessment procedures are laid out by which to identify current conditions or specific risks resulting from various land-use types.

- Rob Dolihan - MOE Williams Lake - was recommended as a contact for water temperature monitoring information in the Cariboo Region.

- No research or information is in place to directly link physical habitat changes to overall fish productivity.

- Cariboo Region is at the level where physical parameters that relate to fish habitat need to be identified, and the effects of various land-use practices on those parameters documented. Forest, Environment and Fisheries managers can assimilate information and assume appropriate risk levels when commenting on proposed development.

- The key issue is forest development, but final reports must still identify other land-use related effects on the stream systems. Recommendations regarding other land-use regulation would be useful.

- Report results should identify present risk levels and the potential effects that proposed forest development may have on those risks. Recommendations should direct both the timber companies and agencies into areas where forest development is most suitable now and in the long term.

- Recent Fisheries Protection Act may prove very useful for managing agriculture in riparian zones. Preliminary ideas relate to landowner compensation (tax breaks) for giving up some productive lands in riparian areas to establish riparian management zones.

- Bridge and Bonaparte watersheds - the final report should mention the lesser concerns in these watersheds, the budgetary limitations and reasons for only looking at three watersheds, and the potential for similar inventory work to be undertaken on the remaining watersheds in the future. According to the CCLUP, inventories must be done in these watersheds to fulfill requirements. Agricultural development in riparian areas is of prime concern in Bridge and Bonaparte.

- Norm Zirnhelt (398-4545) was recommended regarding the Bridge Creek watershed. He is a source of water quality monitoring information, and reports on the effects of agriculture in the riparian zone. Bridge Creek watershed contains numerous lakes with significant recreational value. Water quality is of prime concern as it relates to agricultural land-use.

- Sixty percent of the angling effort in the Cariboo Region is concentrated in the 100 Mile Forest District - Bonaparte and Bridge watersheds.

- Sportfish are the management concern in the Bridge and Bonaparte. No red or blue listed species are present in either watershed. Salmonid use is confined to only the lower Bonaparte mainstem channel.

- The MOE does not want just another assessment. A risk assessment is required that provides direction regarding appropriate levels and types of land-use in each sub-basin or watershed.

MEETING MINUTES - CARIBOO WATERSHED PROJECT

Date:	**June 3, 1997 1:00 P.M.**
Location:	**Department of Fisheries and Oceans** **3690 Massey Drive** **Prince George, BC**
Contact:	**Bruce MacDonald**
Position:	**Head, Habitat Management**
Area of Interest:	**Prince George Region - Horsefly, Cottonwood, Cariboo Watershed s**
Interviewer:	**Michael Milne**
Others Present:	**None**

- Aware that the Level 1 IWAP's have been completed for the watersheds.
- Not sure what the status is with updates to the Horsefly and Cottonwood IWAP reports.
- Cariboo IWAP is underway.
- General concern with regard to the Forest Service's motive for undertaking the Cariboo Watershed Project.
- DFO requires basin specific information for each of the above mentioned watersheds.
- DFO would like to see a ground-truthing of the IWAP hazard ratings. Examine the IWAP ratings and provide actual hazards as observed in the field.
- Most concerned with the IWAP hazards that are in the moderate range (0.5 to 0.7) where they are open to more arbitrary interpretation by various stakeholders. It is much easier to comment on the low and high ratings. Some focus on moderates would be helpful to determine the trend of either increasing or decreasing hazards.
- Forest Districts will be able to provide current WRP status in each of the watersheds.

- Main fisheries effects are from the input of fine sediment to channel systems. The above watersheds span four distinct biogeoclimatic zones - Cariboo Mountains, Quesnel Highlands, Quesnel Plateau, Fraser Basin. Highest fish values in the Quesnel Highlands zone with Quesnel Plateau used mainly for migration to spawning habitat.

- DFO is currently looking into riparian reserve zone and management zone requirements for placer mining operations. Forest Practices Code standards will basically shut down all mining operations which is unrealistic at this time. Information is required from the Cariboo Watershed Project to document the current stability of riparian zones along many of the tributary and mainstem channels. Land-use effects need to be documented and possibly some recommendations could be given as to appropriate riparian buffer widths for both damaged and undamaged reaches.

- DFO would like information at the sub-basin level with emphasis in the following areas:

    1. Is the basin stable with regard to peak flow levels and sediment budgets? If so - DFO is willing to accept development at acceptable levels (i.e. rate of cut).

    2. Where are the bad spot in the sub-basin or on the mainstem channels, and what can be done to restore these areas?

    3. What are the current riparian conditions and what have been the effects of various land-use practices? Attempt to identify the cause and effect on riparian zones and channel instability.

- Larger reaches in the watersheds (i.e. lower mainstem channels of the Horsefly, Cottonwood and Cariboo) are less sensitive to the effects of increased sedimentation and peak flow levels.

- Data is required at the basin specific level.

- The Cottonwood mainstem channel is a concern from the Lightning Creek confluence downstream. An aerial photograph channel change assessment, similar to that done by Ken Rood on the lower Horsefly River, could be undertaken. Focus should be directed to the middle mainstem channel and adjacent placer mining developments.

- The Cariboo mainstem channel is of lower concern to DFO. Main focus should be on tributary basins, specifically lower mainstem channels in each sub-basin.

- Salmonid species generally use the lower mainstem channels in the sub-basins to spawn and also hide during peak flows in the watershed mainstem. Some species rear in the lower mainstems of the sub-basins before entering either lake habitat or heading downstream to the ocean. Many lower tributary basins melt out earlier than upper basins, providing a less turbid refugia for salmonids during freshet flows in the watershed mainstem.

- Concerned with riparian management and placer development. Tenures do not lapse but may be simply abandoned due to economics and limitations of current technology. Tenures can be reactivated and/or sold at any time, with subsequent effects on the riparian zone. Restoration of disturbed riparian areas therefore can be worthless if the potential exists for reactivation. For this reason some form of riparian reserve zone designation is essential to re-establish some level of riparian function along many mainstem and tributary reaches.

- DFO concern in the Horsefly River relates to the potential infilling of the middle mainstem channel, from Patenaude Lake downstream to the bedrock and valley wall confined reach. Aerial photograph assessment could be done in an attempt to determine if channel aggradation is occurring and if so why? Lower tributary channels are also of concern as in the other two watersheds. The Cariboo Watershed Project could determine where sediment is being introduced to the channel and what is the cause.

- Sand size sediment is the main concern to potential impairment of fish habitat. Salmon can flush silt and clay size particles from the bed during redd construction. Many of the mainstem channels are turbid during active spawning periods for this reason. Sand size particles are not easily entrained in the late summer or fall flows, and tend to infill spawning beds and reduce permeability of gravels.

- DFO would like to see a report format that addresses each sub-basin, makes recommendations for viable restoration opportunities where applicable (regardless of land tenure) and identifies where restoration efforts are not applicable and why.

- General report format will address Horsefly River and Cottonwood mainstem channels with respect to placer mining operations and channel stability, and address issues in each sub-basin of all watersheds with respect to IWAP hazard ratings.

- Reports for each sub-basin should include a description of background concerns identified by IWAP, Sediment Source Survey, Suspended Sediment Monitoring programs, other agency reports and specific agency concerns. Field observation results should then be presented identifying current levels of channel and riparian stability, types of land-use activities (both historic and present) in the sub-basin, potential restoration alternatives and a description of land tenure types.

- A useful exercise would be to observe heavily damaged stream reaches and unaltered natural systems to develop a relatively objective rating system.

- Ministry of Environment contacts include Rob Dolihand - Horsefly River, Roger Stewart and Chris Guppy.

- District Managers will require similar ground-based information on sub-basins to attempt to meet identified CCLUP targets.

- Expressed interest in spending time in the field with both Michael Milne and Allan Chapman during the field assessment phase of the project.

Summary

- Ground-based information is required by DFO in all sub-basins and on selected mainstem channels.
- IWAP hazard ratings need to be ground-truthed.
- Moderate IWAP ratings should be a focus to determine either increasing or recovering trends.
- Current channel and riparian stability conditions along with recommended restoration alternatives will be most useful.
- Sand-size particles are of highest concern, specifically in watershed mainstem reaches flowing through the Quesnel Highlands biogeoclimatic zone and other depositional areas.
- Riparian condition assessments are necessary to devise a riparian management zone requirement for placer mining operations.
- Bruce MacDonald expressed interest in spending time in the field with the contractor during the field assessment phase.

MEETING MINUTES - CARIBOO WATERSHED PROJECT

Date:	**June 4, 1997**
Location:	**Department of Fisheries and Oceans** **859 Main Street** **Lillooet, BC**
Contact:	**Adrian Wall**
Position:	**Habitat Technologist**
Area of Interest	**Bonaparte River**
Interviewer:	**Michael Milne**
Others Present:	**None**

- Initial confusion regarding the Bridge River and Bridge Creek watersheds. The Bridge Creek watershed, which is part of the Cariboo Watershed Project, is under the jurisdiction of the Clearwater District where Tim Panko is the contact person with DFO (674-2578).
- DFO Lillooet only concerned with the Bonaparte River watershed.
- Habitat Technologists' responsibilities with DFO (Lillooet) includes the review of five-year development plans (FDPs).
- Concern with regard to having no field-based information in the watershed on which to base FDP comments on.
- DFO (Lillooet) has a desire for some Level 2 results (IWAP, CAP) along with sub-basin and sub-sub-basin ECA values.
- To effectively process FDP's, there needs to be field based assessment information for smaller units than those used in the IWAP process. Many of the sub-sub-basin concerns (i.e. road density) can be diluted by calculating hazard ratings for a much larger area (i.e. 50 000 ha).

- DFO requires a clear picture of what is happening in the watershed - current channel, hillslope, forest development, regeneration and riparian conditions.
    - The main problems in each sub-basin need to be identified to relate to FDP reviews. IWAP hazards need to be directly linked to field-based results in an attempt to determine what a high, moderate and low hazard rating actually translates to on the ground.
- A copy of the Assessment of the Bonaparte River Relevant to Anadromous Fish Production Potential by C.D. Tredger (Fisheries Biologist - MOE - August 1980) was given to the interviewer.
- In the Bonaparte watershed, 97% of all spawners (salmonid species) utilize the channels below Young Lake. Two to three percent spawn below Bonaparte Lake.
- The dam at Bonaparte Lake was constructed to maintain consistent flow levels for salmonid and sportfish species and provide water to downstream water users throughout dryer seasons.
- Riparian logging is a concern for DFO in the Bonaparte River tributary streams with respect to increases in water temperatures. Approximately 18°C is the upper limit for salmonid survival.
- The most useful report format for the Cariboo Watershed Project would include:
    1. A description of riparian conditions along mainstem channels
    2. An identification of problem sites on channels, hillslopes and riparian zones with recommendations for viable restoration activities.
    3. Clear rationale provided for restoration recommendations where applicable.
- Riparian education programs should be developed for private landowners along the Bonaparte River. FRBC could be a source of funding for this type of program.

Summary

- DFO requires ground-based information for the Bonaparte River watershed on which to based five-year development plans comments.

- Field assessments should identify current channel and riparian conditions, and identify sources of identified problems.

- Aerial photograph channel assessment procedures could be carried out on identified reaches, specifically the lower mainstem channel downstream of the Chasm Creek, Fifty-seven Creek and Fifty-one Creek confluences.

MEETING MINUTES - CARIBOO WATERSHED PROJECT

Date:	**July 29, 1997**
Location:	**Telephone interview**
Contact:	**Bill Young**
Position:	**District Manager - Horsefly Forest District**
Area of Interest	**Horsefly and Cariboo watersheds**
Interviewer:	**Michael Milne**
Others Present:	**None**

- Appreciated the information that was provided by the contractor following the field assessment phase regarding any observed "high risk" sites in the watersheds.
- Wanted to know if recommendations from the Cariboo Watershed Inventory project will be used in the formation of operational guidelines from the IAMC that are to be developed by November. Feels that the contractor's field-based information should be used by the various Cariboo planning boards to assist in the formation of guidelines.
- Expressed interest in the contractor's recent observations in the watersheds and whether final recommendations would contradict other research (overview, Level 1 assessments and DFO documents) that has been undertaken in the watersheds.
- Would like to see some definitions of what "best management practices" are in the subject watersheds. Feels that this direction should come from the IAMC board with input from the Cariboo Watershed Inventory project.
- Expressed interest in contractor's intent to present field-based recommendations regarding current watershed conditions and proposed development on a sub-basin and sub-sub-basin basis.
- Would like to review the draft document prior to presentation to the IAMC and RRB.
- Recommends that the contractor continue with open communications among various agencies and stakeholder groups.

MEETING MINUTES - CARIBOO WATERSHED PROJECT

Date:	**July 22, 1997**
Location:	**Telephone Interview**
Contact:	**Mae Burrows**
Position:	**Executive Director - T Buck Suzuki Foundation**
Area of Interest	**General Environmental**
Interviewer:	**Michael Milne**
Others Present:	**None**

- Explained that her background was not "scientific" but that she would be interested in making some general comments.
- Has visited the Cariboo region and Horsefly River watershed.
- Expressed concern regarding stream temperatures and possible changes as a result of forest development. Does not know how much timber can be taken out before temperature increases will result.
- Feels that in watersheds like the Horsefly River, forestry related effects are hard to detect until a significant change has occurred. After significant change it is too late to rehabilitate the system.
- Sees the Horsefly River system as one of the most important sockeye salmon spawning and rearing habitats in the Province.
- Referred to research done on stream temperature increases from forest development by Dr. Hartman.
- Sees increased stream temperatures as the major threat to sockeye salmon stocks in the Horsefly River.
- Is very interested in using the "Ecosystem Approach" to resource management and planning at the watershed level.
- Wanted the Cariboo Watershed Inventory project to address as many factors as possible in the ecosystem when making recommendations.

- Concerned with the CCLUP process and the fact that timber has been determined to be the most important resource in the region. Fears that timber values (targets) will be met without proper consideration of the other resources and concerns.
- Interested in the current and proposed ECA values in the watersheds. Feels that an ECA of 20% is acceptable, but thinks that some of the proposed development will raise ECA in some basins to approximately 40%.
- Concerned with regeneration rates in the Cariboo Region and the rate of cut. Feels that the AAC in the Province and the Region should be scaled back in consideration of other resource values and regeneration rates.
- Would like to review the draft document (from Ken Soneff) and attend the presentation in September.
- Was pleased to hear that the contractor had been in contact with all agencies and various stakeholder groups in the region.
- Appreciated the opportunity to make general comments on the project.

TABLE 1
Cariboo River Watershed

Watershed or Sub-basin	Drainage Area (ha)	Elevation (m)		Relative Relief Relief/Area$^{1/2}$	Physiographic Region	Biogeoclimatic Zone	Fish Resource	Tenure (%)	
		Min	Max					Crown	Private
Cariboo River at the mouth	362,000	600	2800	37	Quesnel Highlands Cariboo Mountains Cariboo Plateau	ESSF AT ICH SBS	chinook		
Spanish Creek	13,200	730	1615	77	Quesnel Highlands	ESSF ICH SBS	chinook	75.6	24.4
Seller Creek	8,900	790	2010	129	Quesnel Highlands	ESSF ICH SBS	chinook	100	0
Rollie Creek	6,400	810	2000	149	Quesnel Highlands	ESSF ICH SBS	chinook	99	1
Keithley Creek	15,000	810	1905	89	Quesnel Highlands	ESSF ICH AT	chinook	99.4	0.6
Little River	35,400	810	2130	70	Quesnel Highlands	ESSF ICH AT	chinook	100	0
Harveys Creek	3,700	810	1920	182	Cariboo Mountains Quesnel Highlands	ESSF AT	chinook	100	0
Cunningham Creek	10,800	830	2140	126	Quesnel Highlands	ESSF AT	chinook	99.6	0.4
Kimball Creek	6,700	835	2040	147	Quesnel Highlands	ESSF AT	chinook	100	0
Matthew River	39,800	870	2743	94	Quesnel Highlands Cariboo Mountains	ESSF AT	chinook	98	2

TABLE 3
Cariboo River Watershed

Watershed or Sub-basin	Drainage Area (ha)	FTRA ECA %	ECA 20.0 %	Proposed Development %	ECA 2001 %	Rate of cut %/Year	IWAP (1997 data)					Private Land Use[3]	
							Road Density km/km^2	Peak Flow	Surface Erosion	Riparian	Mass Wasting	Agriculture	Placer
Cariboo River at the mouth	326,000	19	n/a[1]	n/a[2]	n/a[2]	n/a[2]	n/a[1]	n/a[1]	n/a[1]	n/a[1]	n/a[1]	Low	High
Spanish Creek	13,200		21.6	7.5	27	1.5	1.2	Low	Moderate	Low	Moderate	Low	Moderate
Seller Creek	8,900		10	10.1	19	2	0.5	Low	Low	Low	Low	Low	Low
Rollie Creek	6,400		11.1	2.3	12	0.4	0.8	Low	Low	Low	Low	Low	Moderate
Keithley Creek	15,000		22.5	6.6	28	1.3	1.06	Low	Moderate	Low	Moderate	Low	High
Little River	35,400	18	4.6	4.6	8	0.9	0.3	Low	Low	Low	Low	Low	Low
Harveys Creek	3,700		10.3	0	9	0	0.6	Low	Moderate	Low	Moderate	Low	High
Cunningham Creek	10,800	14	3.2	11.5	14	2.3	0.7	Low	Low	Low	Low	Low	High
Kimball Creek	6,700		2.6	8.2	11	1.6	0.2	Low	Low	Low	Low	Low	Low
Matthew River	39,800	14	11.4	1.7	12	0.3	0.3	Low	Low	Low	Low	Low	Low

Note: 1. Cariboo watershed and residual area calculations not included in 1997 IWAP report
2. Five year development data only available for sub-basins used in the IWAP
3. Levels imply areal exent of land-use practice within each watershed or sub-basin

WATERSHED: CARIBOO **SUB-BASIN:** MAINSTEM (Below Cariboo Lake)

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Into Quesnel River.	Not evident	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Large natural bank failures in glacio-fluvial deposits.		Channel incised into glacio-fluvial deposits.	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	Unknown			
COMMENTS	No major problems noted.			

WATERSHED: CARIBOO **SUB-BASIN:** MAINSTEM (From park to Cariboo Lake)

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Turbid flow into Cariboo Lake.	Not evident	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Appeared stable.		Not evident	Channel confined in upper area and broad floodplain in lower.
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	Unknown			
COMMENTS				

WATERSHED: CARIBOO **SUB-BASIN:** MAINSTEM (In Bowron Park)

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Into Lanezi Lake	Not evident	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Appeared stable.		Large amount of bedload movement.	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	No harvest.			
COMMENTS	Several avalanches in upper basin.			

WATERSHED: CARIBOO **SUB-BASIN:** SPANISH CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	From major NE. tributary to Spanish Lake.	Very little evidence.	Not evident	Some minor road erosion in major north tributary to Spanish Lake.
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	All were active.	Many bank failures, cause undetermined.
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Many bank failures in fluvial gravel/cobbles.	Possibly placer. Reserves on lower Spanish and Blackbear.	Bank instability.	Bank instability likely due to old placer operations.
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	<10%			Caution in Blackbear Creek.
COMMENTS	Large amount of logging on south side of Spanish Lake. Logging effects above lake are minimal. Concern with increased coarse bed load input from lower mainstem into Cariboo River. Do not increase bed load movement in Blackbear Creek through mass wasting or increased flow.			

WATERSHED: CARIBOO **SUB-BASIN:** SELLER CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Not evident	Not evident	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	All stream failures were active.	Small failures within cutback.
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Large bank failures into lower mainstem.	Placer on lower mainstem.	Coarse bedload input into Cariboo mainstem.	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	<10%			
COMMENTS	Large bank failures are significant and contribute moderate to high amounts of coarse material to lower Seller Creek. Placer proximal to logged blocks. Concern with increased bed load movement.			

WATERSHED: CARIBOO **SUB-BASIN:** ROLLIE CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Clear flow.	Not evident	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Failures into mainstem from falling boundary.	Placer along lower mainstem.	High bed load movement.	Possible natural bank failures along mainstem.
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	10 - 25%			
COMMENTS	Stream cutting through glacio-fluvial deposits. Natural incision and erosion with deposition in large fan building into Cariboo Lake. Concern with increased bed load movement from lower mainstem and fan. Possible high natural bed load movement and deposition.			

WATERSHED: CARIBOO **SUB-BASIN:** KEITHLEY CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Not evident	Turbid ditch flow. Channels cut through regen.	Not evident	High surface erosion in upper Snowshoe and French Snowshoe Creeks.
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Appeared stable	Placer evident. Logging in upper basin.	High bedload volume.	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	10 - 25%			
COMMENTS	Placer all the way up the mainstem and up Snowshoe Creek. Concern about potential salmonid use of lower mainstem.			

WATERSHED: CARIBOO **SUB-BASIN:** KEITHLEY CREEK (Snowshoe Creek)

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Not evident	Flow in ditches with channel cut into regen.	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Appeared stable.	Logging and placer.		
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	10 - 25%			
COMMENTS	Question regarding salmonid use of basin.			

WATERSHED: CARIBOO **SUB-BASIN:** HARVEY'S CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Into Cariboo River	Turbid Flow in Ditches	Not evident	Submerged culverts above Simlock confluence.
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Landslides into Harvey's, slide directly connected to mainstem above Simlock confluence.	Not evident	Slide into mainstem above Simlock still active sediment source.	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Many slumps in Simlock Cr..	Placer in lower channel.	Coarse gravel aggradation on fan.	Lower Stream Disturbance = High.
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW				
COMMENTS	Concern with coarse sediment into Cariboo mainstem near park. Major placer disturbance in lower mainstem. Large natural bank failures above placer disturbance.			

WATERSHED: CARIBOO **SUB-BASIN:** HARVEY'S CREEK (Simlock Creek)

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Not Evident	Not Evident	Not Evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Into Simlock Creek.	Several from falling boundary.		
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Appeared stable.		Not evident	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW				
COMMENTS	Concern about additional coarse sediment input to mainstem.			

WATERSHED: CARIBOO **SUB-BASIN:** LITTLE RIVER

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Into Cariboo mainstem.	Not evident	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident.	Not evident.	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Large slumps along mid to lower mainstem.	Logging on lower and mid mainstem.	Debris in lower mainstem.	No placer noted.
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	Scoured gully noted from air.			
COMMENTS	Debris in lower mainstem, source unknown but likely riparian logging debris. High DFO fish value channel up to middle mainstem. * Low cloud cover limited flight to lower 12 km of mainstem.			

WATERSHED: CARIBOO **SUB-BASIN:** CUNNINGHAM CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Highly turbid water into Cariboo mainstem.	Not evident	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Appeared stable	Inconclusive	Fresh coarse sediment on fan.	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	10 - 25%			
COMMENTS	Flight limited due to low ceiling. DFO concern with riparian logging and placer.			

WATERSHED: CARIBOO **SUB-BASIN:** KIMBALL CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Not evident	Not evident	Not evident	
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	Not evident	Not evident	n/a	
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Not evident	Not evident	Not evident	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	Unknown			
COMMENTS	Weather did not permit flight of this basin.			

WATERSHED: CARIBOO **SUB-BASIN:** MATTHEW RIVER

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Into Cariboo River	Very limited	Not evident	Minimal overall erosion observed.
	Road Related	**Cut-block Related**	**State Active/Healed**	**Other**
LANDSLIDES	One large slide from road on fluvial terrace, into mainstem.	Not evident	Road related slide re-vegetated.	No other slides affecting creeks. One other slide terminating mid-slope near Ghost Lake.
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN	Very minor slumping evident.	Riparian logging.	None related to riparian logging noted. Incised channel on lower fan, broad floodplain above.	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	10 - 25 %			
COMMENTS	No logging above Ghost Lake, overall riparian seem relatively undisturbed.			

WATERSHED: CARIBOO **SUB-BASIN:** SPANISH CREEK

Stop 1. Approximately 200 metres upstream of confluence with Cariboo River.
(Map 93A/11, Photos C3 and C4)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Step-Pool boulder/wood	Stable	Boulders and gradient.	Boulder and LWD, stable
DISTURBANCE INDICATORS: None			
COMMENTS: LWD is very sparse and not providing much control, if any. Channel constriction is occurring at this location due to adjacent road and hill slopes are coupled. Spanish Lake is acting as a sediment buffer.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer adjacent to lower mainstem.	Vegetation consists of mature mixed wood forest with potential recruitable LWD.
COMMENTS: Riparian reserve of at least one channel width seems acceptable.	

WATERSHED: CARIBOO **SUB-BASIN:** SPANISH CREEK

Stop 2. Approximately 200 metres upstream of Blackbear main crossing.
(Map 93A/11, Photos C5 and C6)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, cobble/gravel/wood	Slightly aggraded, but stable.	LWD	Stable fluvial deposits.
DISTURBANCE INDICATORS: None			
COMMENTS: Bed load sand/gravel. LWD providing pool and bank cover. Slopes partially coupled.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Low shrub-grass with conifers. Roots of conifers and grass providing bank stability.
COMMENTS: Riparian conditions appear natural. Riparian buffer of at least three channel widths should be left intact.	

WATERSHED: CARIBOO **SUB-BASIN:** SPANISH CREEK (Blackbear Creek)

Stop 3. Approximately 400 metres upstream of Blackbear main crossing.
(Map 93A/11, Photos SP7 and SP8)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Step-pool, boulder/wood	Slightly aggraded, but stable.	Bedrock and boulders.	Boulder and LWD.
DISTURBANCE INDICATORS: None			
COMMENTS: Appears stable and hill slopes coupled.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer adjacent to stream, but a 5-10 metre riparian buffer is intact.	Vegetation consists of a mixed mature forest providing potential future LWD.
COMMENTS: Sediment sumps are incorporated in the placer operation. Riparian reserve of 5-10 metres seems appropriate.	

WATERSHED: CARIBOO **SUB-BASIN:** SPANISH CREEK (Blackbear Creek)

Stop 4. Middle Blackbear Creek. (Map 93A/11, Photos SP9 and SP10)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel/wood	Moderately aggraded.	Gradient.	Well rounded materials.
DISTURBANCE INDICATORS: (S3) Sediment wedges, (B2) Eroding banks, (B3) Avulsions, (C3) Elevated mid-channel bars.			
COMMENTS: LWD exists but not providing much control. Hill slopes partially coupled. High bed load of shale and slate derived from surrounding hill slopes.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None at this site.	Vegetation is mature forest and shrub.
COMMENTS: Perhaps placer upstream delivering sediment to channel.	

WATERSHED: CARIBOO **SUB-BASIN:** SELLER CREEK

Stop 1. Lower Seller Creek. (Map 93A/11, Photos S2 and S3)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel/wood.	Stable.	Gradient and LWD.	Stable.
DISTURBANCE INDICATORS: None.			
COMMENTS: Moderate coarse bed load from natural slides upstream.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Forest development.	Old growth conifers.
COMMENTS: Existing 15-20 metre buffer from harvest appears to be adequate.	

WATERSHED: CARIBOO **SUB-BASIN:** SELLER CREEK

Stop 2. Lower mainstem approximately 50 metres upstream from Seller main crossing. (Map 93A/11, Photo S4 and S5)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, boulder/wood.	Slightly aggraded.	Gradient.	Banks consist of glacio-fluvial sand and gravel with lacustrine silt and clay.
DISTURBANCE INDICATORS: (C1) Extensive riffles or cascades; (C5) Disturbed stone lines.			
COMMENTS: LWD is present, but stream size and power prevent LWD control. Numerous slides into mainstem causing minor aggradation. Hill slopes are coupled.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None.	Mature conifers with alder and willows.
COMMENTS: Riparian reserves should be to the top of the gorge on steep sides.	

WATERSHED: CARIBOO **SUB-BASIN:** ROLLIE CREEK

Stop 1. Rollie Creek on alluvial fan. (Maps 93A/11 and 93A/13, Photos R2-R4)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, cobble/wood	Stable	Gradient	Appear stable
DISTURBANCE INDICATORS: (S3) Sediment wedges, (B2) Eroding banks, (B3) Avulsions, (C4) Multiple channels or braids.			
COMMENTS: Hill slopes are de-coupled. Some stone line development is present.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Vegetation is a mixed mature forest with shrub layers.
COMMENTS: Blocks are proposed along the face units of Cariboo River. Riparian reserve on fan should be at least three times channel width.	

WATERSHED: CARIBOO **SUB-BASIN:** ROLLIE CREEK

Stop 2. Approximately 50 metres upstream 1400 Road crossing.
(Map 93A/11 and 93A/13, Photos R5 and R6)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel	Stable	Gradient	Gravel and fines stable.
DISTURBANCE INDICATORS: None			
COMMENTS: Local surface erosion is directly delivering fine sediment to the stream. LWD is absent from the channel on this broad floodplain area.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Shrub, grass and conifers present.
COMMENTS: Appears stable. Riparian reserve of at least three channel widths should be left intact.	

WATERSHED: CARIBOO **SUB-BASIN:** KEITHLEY CREEK

Stop 1. Keithley Creek at upper Keithley mainline crossing (Map 93A/13-14, Photos K5, K6)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, cobble/wood	Slightly aggraded.	Boulder, bedrock and LWD control.	Stable
DISTURBANCE INDICATORS: None			
COMMENTS: Some stone lines present and covered with moss. No evidence of increased flow levels, even with numerous blocks upstream.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Old growth conifer with willow and alder.
COMMENTS: Riparian appears very stable.	

WATERSHED: CARIBOO **SUB-BASIN:** KEITHLEY CREEK (Rabbit Creek)

Stop 2. Approximately 50 metres upstream of 1500 Road crossing.
(Map 93A/13-14, Photos K10, K11)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, cobble	Slightly degraded	Gradient	Eroded and unstable.
DISTURBANCE INDICATORS: (C1) Extensive riffles or cascades, (C2) Minimal pool area, (D2) LWD does not span the channel, (B2) Eroding banks.			
COMMENTS: Banks eroding from lack of LWD stabilization. Disturbed boulder and cobble lines. Channel used to braid through willows at high flow. Possible increased flow levels.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Riparian logging has occurred.	Riparian cover is gone at this location.
COMMENTS: Riparian logging has de-stabilized banks and possibly removed LWD pieces and jams. Riparian reserve of 2-3 channel widths would be adequate to allow for natural meander.	

WATERSHED: CARIBOO **SUB-BASIN:** KEITHLEY

Stop 3. Approximately 200 metres downstream of main road crossing.
(Map 93A/13-14, Photos K2, K3)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, cobble/wood	Moderately aggraded.	Gradient and LWD.	Eroding
DISTURBANCE INDICATORS: (B1) Abandoned channels, (B2) Eroding banks, (C4) Multiple channels or braids, (D3) Recently formed debris jams, (S3) Sediment wedges and (S4) Extensive bars.			
COMMENTS: Bed consists of gravel and cobble with sand deposits. Channel appears to have recently shifted and recent debris piles and sediment wedges exist. Significant placer operations exist upstream.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None at this location.	Vegetation consists of deciduous dominated pole sapling forest.
COMMENTS: Riparian reserve of at least three channel widths should be left intact to allow for natural meander.	

WATERSHED: CARIBOO **SUB-BASIN:** KEITHLEY (Little Snowshoe)

Stop 4. Approximately 20 metres downstream of the road crossing at the confluence of Little Snowshoe and Snowshoe Creeks. (Map 93A/13-14, Photos K6 - K9)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, cobble	Slightly aggraded.	Gradient	Appear stable.
DISTURBANCE INDICATORS: (C1) Extensive riffles or cascades, (C4) Multiple channels, (C5) Disturbed stone lines and (D2) LWD parallel to channel.			
COMMENTS: LWD is present in small jams adjacent to the banks. Active bed load due to placer disturbance and riparian logging upstream. Upper snowshoe has organic coloring. Turbid flow from placer site and road erosion.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Placer mine adjacent to stream. Buffer of 10-15 metres in place.	See Photos
COMMENTS: See Photos	

WATERSHED: CARIBOO **SUB-BASIN:** KEITHLEY (French Snowshoe)

Stop 5. Approximately 50 metres downstream of French Snowshoe and Snowshoe confluence. (Map 93A/13-14, Photos K6 - K9)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
See Photos	See Photos	See Photos	See Photos
DISTURBANCE INDICATORS: None			
COMMENTS: Mining roads are not well maintained and surface erosion from these roads as well as placer slopes is occurring.			
RIPARIAN INFORMATION			
LAND USE		**CONDITIONS**	
Placer mines present.			
COMMENTS:			

WATERSHED: CARIBOO **SUB-BASIN:** KEITHLEY (Weaver Creek)

Stop 6. Weaver Creek crossing. (Map 93A/13-14)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
See Photos	See Photos	See Photos	See Photos
DISTURBANCE INDICATORS:			
COMMENTS: Significant bedload movement from riparian harvest and possibly placer. See Photos			
RIPARIAN INFORMATION			
LAND USE		**CONDITIONS**	
Logging has occurred and possibly placer.		See Photos	
COMMENTS:			

WATERSHED: CARIBOO **SUB-BASIN:** HARVEY'S CREEK (Simlock Creek)

Stop 1. Below pulled bridge crossing. (Map 93A/14, Photos H6 and H7)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Step-pool, boulder/wood	Stable.	Boulder and rock.	Appear stable.
DISTURBANCE INDICATORS: None.			
COMMENTS: Clear flow in creek and moss on rocks. Pulled creek crossing is seeded and stable. Active erosion on cut and fill slopes, seeding may reduce surface erosion. Road related slide into Harvey's Creek, silty till slopes exposed.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logging above site.	Stable conifer and alder vegetation.
COMMENTS: Riparian vegetation appears stable.	

WATERSHED: CARIBOO **SUB-BASIN:** HARVEY'S CREEK

Stop 3. Harveys mainline at Harveys Creek crossing (Map 93A/14)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Step-pool, boulder/wood	Stable.	Boulder and rock.	No instability noted.
DISTURBANCE INDICATORS: None			
COMMENTS: Road surface and ditch erosion is a concern.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Harvested to one bank.	Existing vegetation appears stable.
COMMENTS: Riparian reserves on step-pool channels could be minimal.	

WATERSHED: CARIBOO **SUB-BASIN:** HARVEYS CREEK

Stop 4. Harveys Creek alluvial fan. (Map 93A/14, Photos H4 and H5)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, boulder/cobble.	Moderately degraded.	Gradient	Unstable.
DISTURBANCE INDICATORS: (B2) Eroding banks, (C4) Multiple channels or braids, (D2) LWD oriented parallel to channel.			
COMMENTS: Incised channel possibly due to high ECA. LWD scattered over channel and not offering much control.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None.	Vegetation is mature deciduous dominated forest.
COMMENTS:	

WATERSHED: CARIBOO **SUB-BASIN:** LITTLE RIVER (Ishkloo Creek)

Stop 1. Approximately 50 metres upstream of road crossing.
(Map 93A/14 15, Photos L10-L13)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, boulder.	Stable.	Gradient.	Stable.
DISTURBANCE INDICATORS: None.			
COMMENTS: All appears to be in a natural state. Hill slopes coupled. Significant proposed development upstream of this point.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None.	Old growth coniferous forest.
COMMENTS: Riparian is in a natural state.	

WATERSHED: CARIBOO **SUB-BASIN:** LITTLE RIVER

Stop 2. Approximately 50 metres upstream of Maeford Lake main.
(Map 93A/14 15, Photos L10-L13)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, boulder.	Stable.	Bedrock and boulder.	No instability noted.
DISTURBANCE INDICATORS: None.			
COMMENTS: Low turbidity in the creek. LWD is present but offers very little channel control.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Harvested on one bank.	Buffer on one bank, old growth on the other.
COMMENTS: Stable riparian vegetation and buffer.	

WATERSHED: CARIBOO **SUB-BASIN:** LITTLE RIVER

Stop 3. Lower Little River at J road crossing. (Map 93A/14 15, Photos L8 and L9)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
See Photos	See Photos	See Photos	See Photos
DISTURBANCE INDICATORS: None.			
COMMENTS: High flows from recent storms. Bank failures present along majority of lower mainstem in old lacustrine or overbank silt/clay deposits.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None.	None.
COMMENTS:	

WATERSHED: CARIBOO **SUB-BASIN:** LITTLE RIVER

Stop 4. Little River at G road crossing. (Map 93A/14 15, Photos L6 and L7)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel.	Aggraded.	Gradient.	Eroding, unstable gravel, silt and sand.
DISTURBANCE INDICATORS: (B2) Eroding banks.			
COMMENTS: LWD is made up of whole trees derived from bank erosion. Alluvial banks are naturally eroding and hill slopes are partially coupled.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
See Photos	See Photos
COMMENTS: See Photo's	

WATERSHED: CARIBOO **SUB-BASIN:** LITTLE RIVER

Stop 1. (Map 93A/14 15, Photos L3 and L4)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool		Gradient and LWD	Sand and Gravel
DISTURBANCE INDICATORS: Elevated channel bars, large woody debris jams, eroding banks, avulsions			
COMMENTS: Naturally dynamic channel. Large woody debris pieces all have complete root wads and no young regeneration is present in the jams.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Riparian logging upstream	Eroding
COMMENTS: Very limited evidence of logging induced riparian instability.	

WATERSHED: CARIBOO **SUB-BASIN:** CUNNINGHAM CREEK

Stop 1. Downstream of Cunningham/Nolaka FSR crossing. (Map 93A/14, Photos C1 to C3)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, cobble.	Moderately aggraded.	Gradient and LWD jams	Eroding Fluvial sand and gravel.
DISTURBANCE INDICATORS: (B1) Abandoned channels, (B2) Eroding banks, (C4) Multiple channels or braids.			
COMMENTS: LWD is swept out and adjacent to the channel. Flow was turbid and too high to do further inventory in first visit. Lateral flow over elevated channel bars. Bedload increase. Some disturbance as a result of high spring 1997 discharge levels. Aggraded and slightly widened channel from increased bedload transport (sourced from upstream slides and placer mining.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None.	Mixed old growth forest with shrub layers.
COMMENTS: Riparian is undisturbed.	

WATERSHED: CARIBOO **SUB-BASIN:** CUNNINGHAM (Tisdale Cr.)

Stop 2. Tisdale Creek at Cunningham FSR. (Map 93A/14, Photos C4 and C5)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, cobble/wood.	Slightly aggraded.	Gradient.	Unstable cobble and pebble.
DISTURBANCE INDICATORS: (B1) Abandoned channels, (C3) Elevated mid-channel bars, (D3) Recently formed debris jams.			
COMMENTS: Beaver dams are present and hill slopes are coupled on one side.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Riparian harvest has occurred.	Unstable.
COMMENTS: Instability has resulted from riparian harvest, debris jams resulting. Riparian reserves of 2-3 channel widths would be appropriate for alluvial floodplain.	

WATERSHED: CARIBOO **SUB-BASIN:** CUNNINGHAM CREEK

Stop 3. Upper Cunningham Creek approximately 100 metres upstream of Cunningham/Keithley FSR crossing. (Map 93A/14 , Photos C6 and C7)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel/cobble/wood.	Slightly aggraded.	Gradient, LWD.	Fluvial gravel and cobble. Eroding.
DISTURBANCE INDICATORS: (B1) Abandoned channels, (B2) Eroding banks, (B3) Avulsions, (D3) Recently formed debris jams, (S2) Sediment fingers.			
COMMENTS: LWD providing moderate control, debris jams present causing multiple channels, banks moderate instability but well vegetated with willow alder and small conifer.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Willow and alder with small conifers.
COMMENTS:	

WATERSHED: CARIBOO **SUB-BASIN:** ROUNDTOP CREEK

Stop 4. PHOTO SITE ONLY. (Map 93A/14, Photo C8)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Step-pool, boulder/wood.	Stable		
DISTURBANCE INDICATORS: None			
COMMENTS:			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Harvested to one bank.	
COMMENTS:	

WATERSHED: CARIBOO **SUB-BASIN:** KIMBALL CREEK

Stop 1. Approximately 100 metres upstream of Cariboo confluence. (Map 93A/14, Photos KB1 to KB4)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel/cobble/wood.	Slightly degraded.	LWD and gradient.	Eroding cobble gravel and sand.
DISTURBANCE INDICATORS: (B2) Eroding banks, (C1) Extensive riffles, (C2) Minimal pool area, (C4) Multiple channels or braids, (D3) Recently formed debris jams, (S3) Sediment wedges.			
COMMENTS: LWD is abundant and providing moderate control. Fresh coarse bed load input to Cariboo River is derived from eroding banks. Forest development minimal upstream. High 1997 freshet flows are partially attributable for disturbance.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Undisturbed old growth conifer.
COMMENTS: Fan vegetation is undisturbed old growth.	

WATERSHED: CARIBOO **SUB-BASIN:** WINDLASS CREEK

Stop 2. Windlass Creek upstream of confluence. (Map 93A/14, Photos KB5 and KB6)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel/sand/wood.	Stable	Gradient and LWD.	Stable sand and gravel.
DISTURBANCE INDICATORS: None			
COMMENTS: All appears in a natural state. Hill slopes are partially coupled.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Undisturbed old growth conifer with alder and willow.
COMMENTS:	

WATERSHED: CARIBOO **SUB-BASIN:** MATTHEW RIVER

Stop 1. Connection Creek approximately 50 metres upstream of crossing. (Map 93A/14, Photos M4 and M5)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, sand/wood.	Slightly aggraded.	Gradient and LWD.	Stable silt and sand.
DISTURBANCE INDICATORS: (B1) Abandoned channels, (D3) Recently formed LWD jams.			
COMMENTS: Very limited recruitable LWD left on banks, existing LWD providing significant control. Hill slopes de-coupled.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Riparian logging has occurred.	Unstable.
COMMENTS: Blowdown has occurred in small reserve after harvest.	

WATERSHED: CARIBOO **SUB-BASIN:** MATTHEW RIVER

Stop 2. Lower Matthew River. (Map 93A/14, Photos M1 to M3)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool	Stable	Gradient and bedload	Stable.
DISTURBANCE INDICATORS:			
COMMENTS: Appears to be within natural range of lateral channel migration for this channel type.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Riparian harvest to both banks.	Regeneration of Pine
COMMENTS: Bank shading reduced due to harvest. Bank stability appears to be good.	

PHOTO C1. Avalanche in upper Cariboo River watershed above Matthew River confluence.

PHOTO C2. Large bank failures in fine textured glacio-fluvial and glacio-lacustrine sediment in lower Cariboo River watershed.

PHOTO SP1. Old placer mining scar at the mouth of Spanish Creek on the Cariboo River [Site S1].

PHOTO SP2. Sediment plume into Spanish Lake from road and ditchline erosion in upper tributary [Site S5].

PHOTO SP3. Lower Spanish Creek - downstream [Site S1]

PHOTO SP4. Lower Spanish Creek - upstream [Site S1]

PHOTO SP5. Middle Spanish Creek below Spanish Lake showing broad alluvial floodplain and beaver dam - upstream [Site S2].

PHOTO SP6. Middle Spanish Creek below Spanish Lake showing low gradient channel - downstream [Site S2].

PHOTO SP7. Middle Blackbear Creek showing stable boulder/bedrock channel - upstream [Site S3].

PHOTO SP8. Middle Blackbear Creek showing blowdown from adjacent placer mine site - downstream [Site S3].

PHOTO SP9. Upper Blackbear Creek - upstream [Site S4].

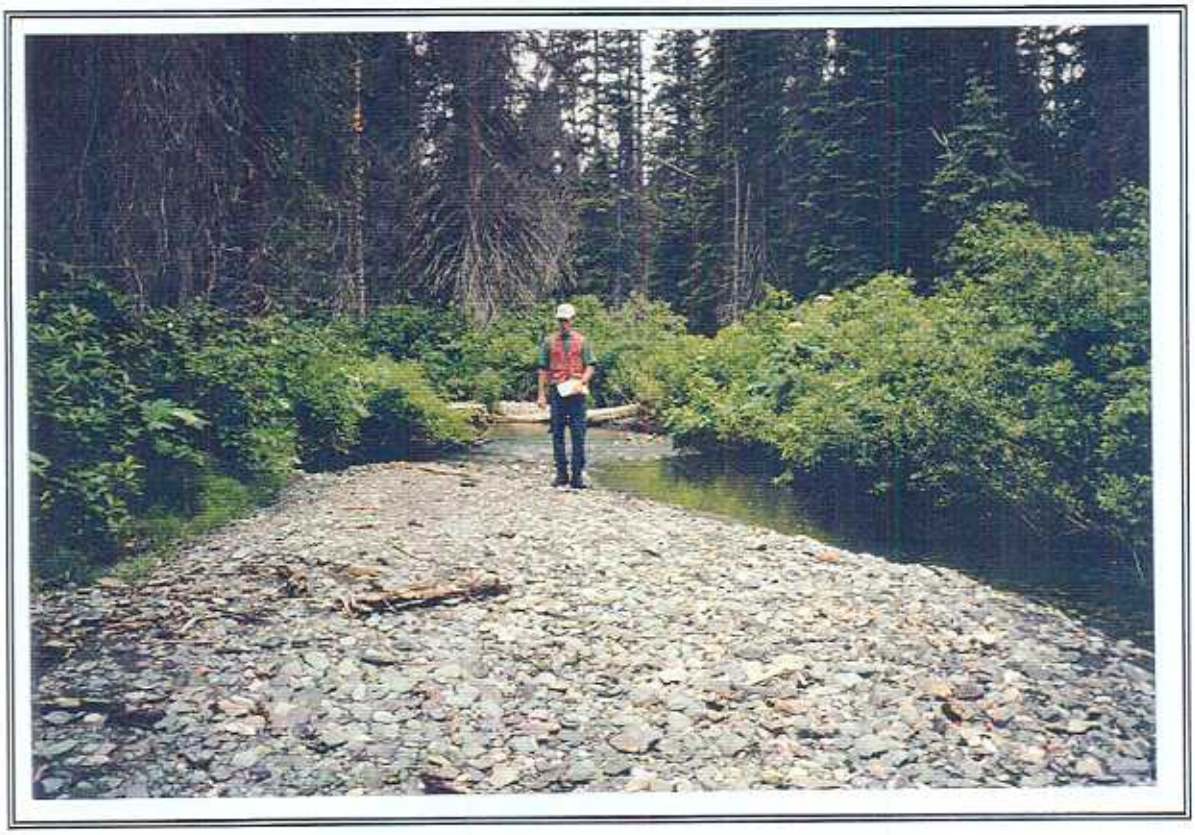


PHOTO SP10. Upper Blackbear Creek showing elevated bar material - downstream [Site S4].

PHOTO S1. Bank failures and placer mining scars on Seller Creek [Site Sel1].

PHOTO S2. Lower Seller Creek - upstream [Site Sel2].

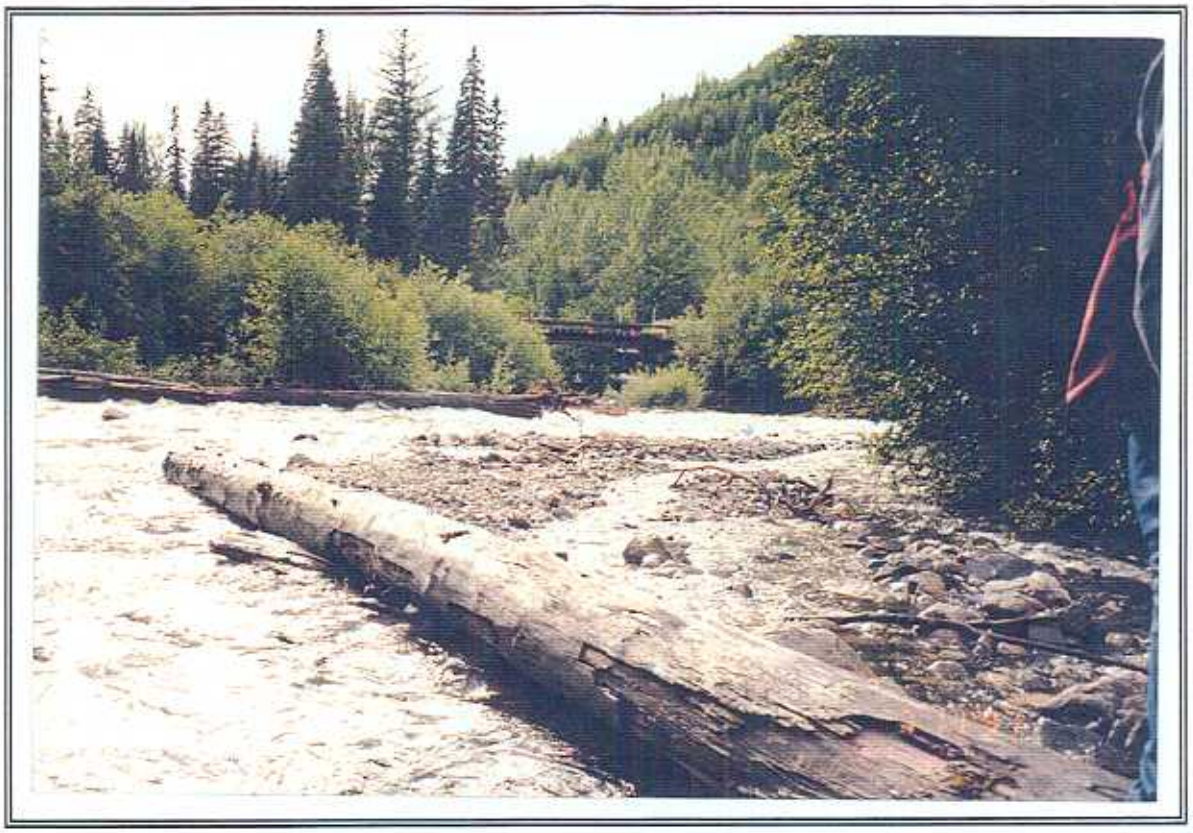


PHOTO S3. Lower Seller Creek showing aggradation from upstream bank failures and landslides - downstream [Site Sel2].

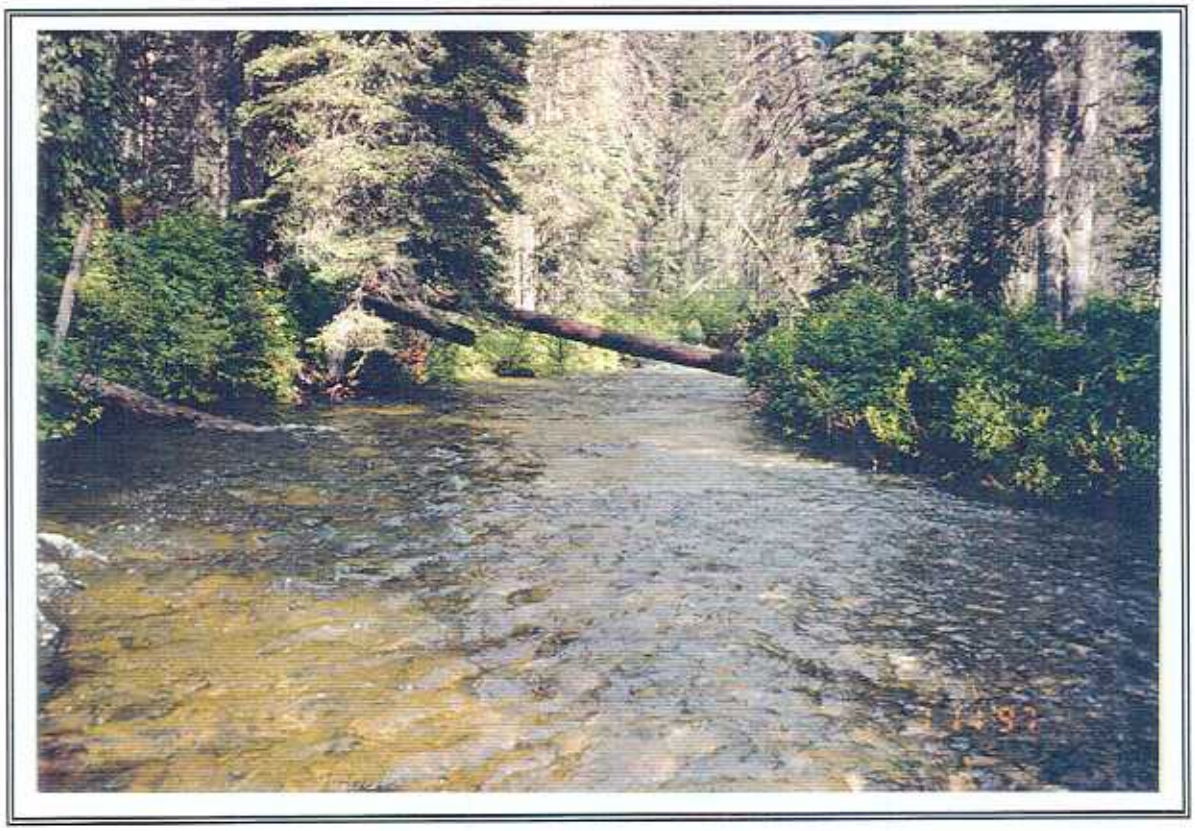


PHOTO S4. Upper Seller Creek with stable old growth riparian zone - upstream [Site Sel4].

PHOTO S5. Clear flow in undisturbed upper Seller Creek [Site Sel4].

PHOTO S6. Stable road in middle Seller Creek watershed with grass seeding and ditchline vegetation [Site Sel3].

PHOTO R1. Bank failures below old cutblocks in the lower Rollie Creek watershed [Site Rol3].

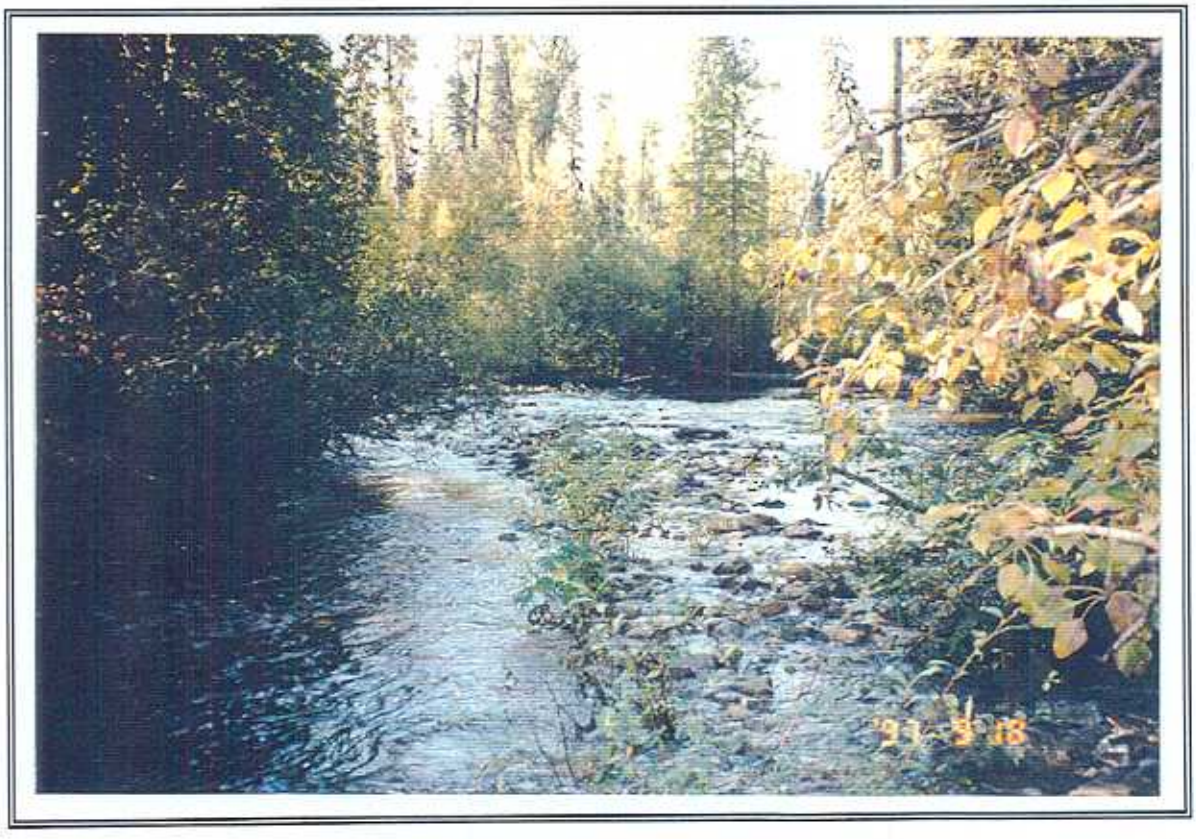


PHOTO R2. Rollie Creek on the alluvial fan showing lateral streamflow over elevated mid-channel bar - upstream [Site Rol2].

PHOTO R3. Rollie Creek on the alluvial fan - downstream [Site Rol2].

PHOTO R4. Invasive vegetation on old alluvial fan deposit at the mouth of Rollie Creek on Cariboo Lake [Site Rol1].

PHOTO R5. Upper low gradient reach of Rollie Creek with stable alder and willow riparian vegetation - upstream [Site Rol4].

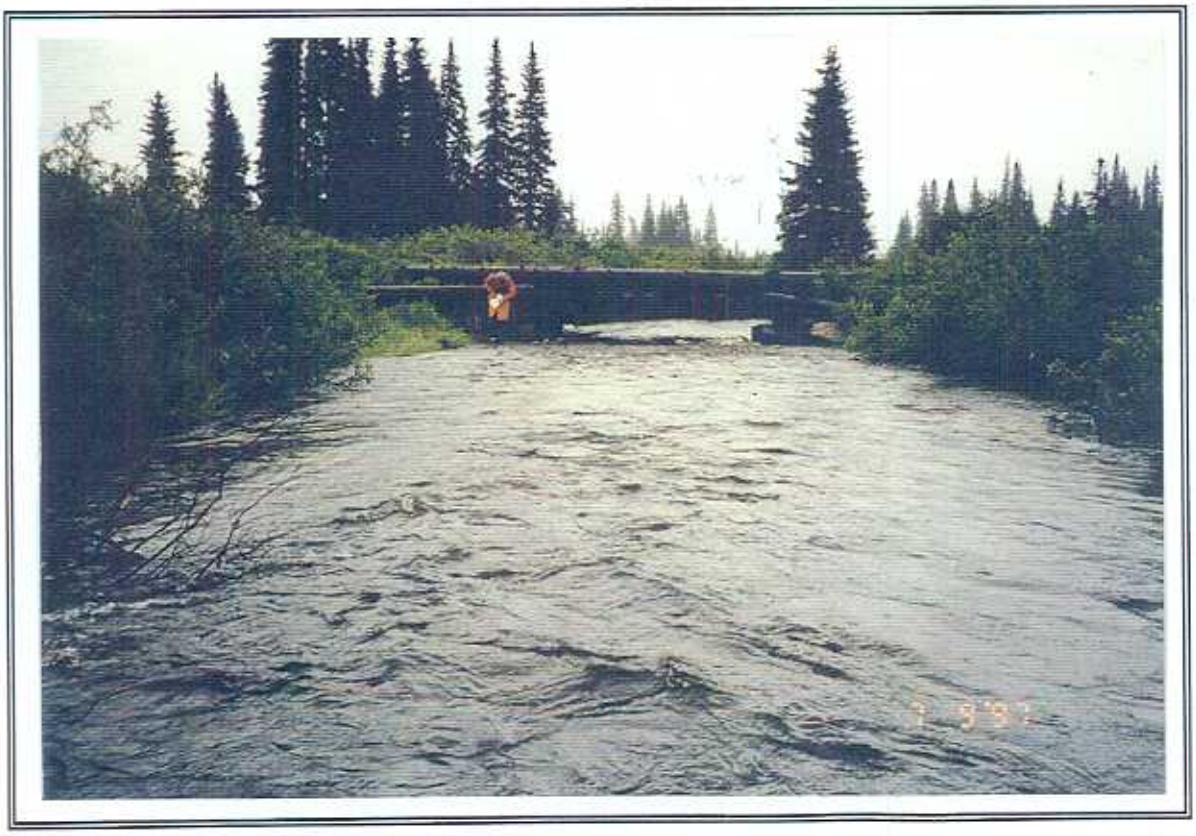


PHOTO R6. Upper Rollie Creek - downstream [Site Rol4].

PHOTO R7. Rollie mainline road climbing out of the main Cariboo River valley through fine textured glacio-lacustrine sediments [Site R11].

PHOTO R8. Stable coarse surfaced section of the Rollie mainline [Site R10].

PHOTO R9. Surface erosion and direct input of suspended sediment to the upper Rollie Creek system at an un-armoured ford [Site Rol5].

PHOTO K1. Lower Keithley Creek alluvial fan showing multiple channels, aggraded conditions and sediment plume into Cariboo Lake [Site K1].

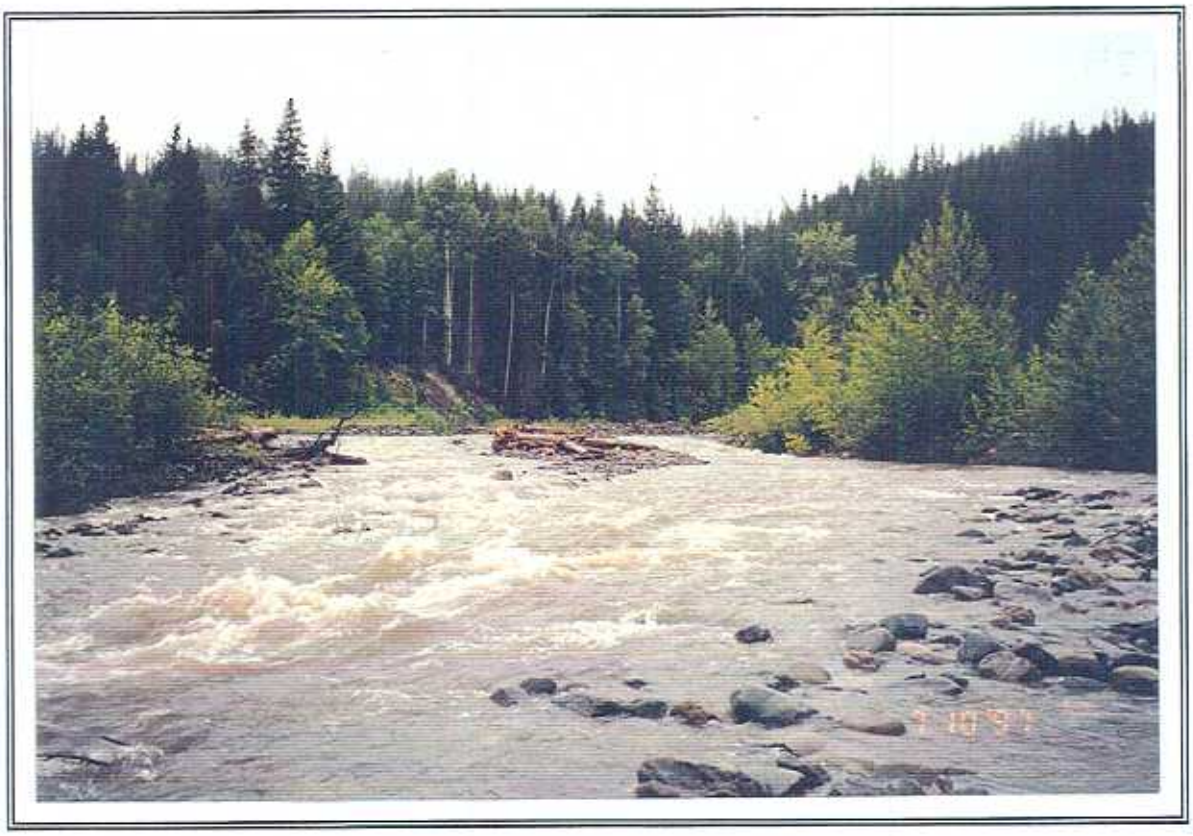


PHOTO K2. Turbid flow in multiple channels on Keithley Creek alluvial fan - upstream [Site K2].

PHOTO K3. Aggraded Keithley Creek channel with fresh large woody debris piles eroded from upstream banks - downstream [Site K2].

PHOTO K4. Upper Keithley Creek showing high suspended sediment level - upstream [Site K5].

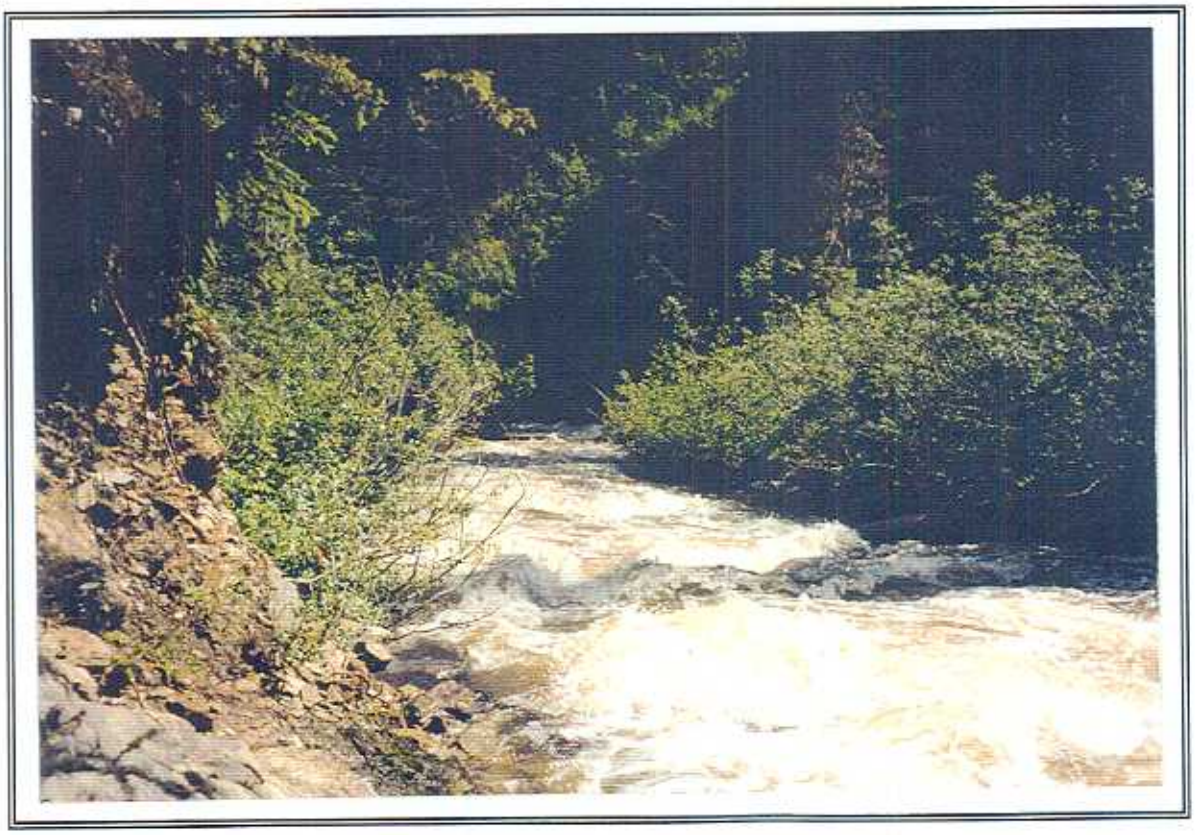


PHOTO K5. Upper Keithley Creek - downstream [Site K5].

PHOTO K6. French Snowshoe Creek at the confluence with Snowshoe Creek - upstream [Site K8].

PHOTO K7. Confluence of Little Snowshoe and Snowshoe Creeks showing increased bedload transport in both systems - upstream [Site K9].

PHOTO K8. Snowshoe Creek below confluence with Little Snowshoe Creek showing aggraded conditions resulting from increased bedload supply and transport - downstream [Site K9].

PHOTO K9. Increased bedload in Weaver Creek resulting from channel bank disturbance in upstream placer mines - upstream [at mainline crossing on east side of Keithley Creek].

PHOTO K10. Bank erosion resulting from harvesting in the riparian zone on upper Rabbit Creek - upstream [Site K6].

PHOTO K11. Bank erosion on upper Rabbit Creek - downstream [Site K6].

PHOTO K12. Incised ditch line on mainline road leading into upper Snowshoe and Little Snowshoe basins [Site K7].

PHOTO H1. Sediment plume from Harveys Creek into Cariboo River during freshet [Site H1].

PHOTO H2. Active placer mine site and road sidecast input to Harveys Creek at apex of alluvial fan [Site H1].

PHOTO H3. Hillslope failure from mainline road into Harveys Creek and exposed soil sites at stream crossing location [Site H2].

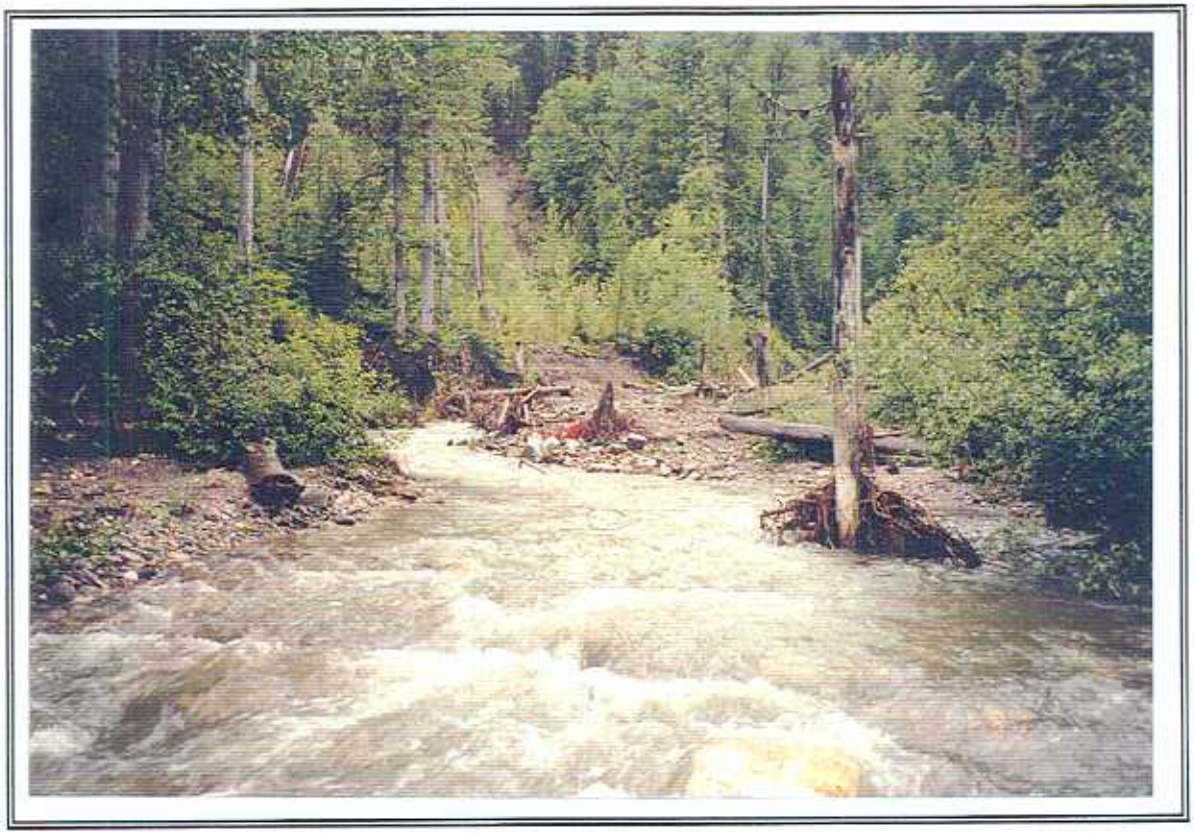


PHOTO H4. Unstable channel on Harveys Creek alluvial fan showing recent widening and aggradation - upstream [Site H1].

PHOTO H5. Harveys Creek at alluvial fan apex showing recent bank erosion and logging debris in the channel - downstream [Site H1].

PHOTO H6. Bank instability and erosion resulting from harvesting in the riparian zone on upper Harveys Creek - downstream [Site H3].

PHOTO H7. Small woody debris accumulations in upper Simlock Creek introduced during pre-FPC harvesting in the riparian zone - upstream [Site H5].

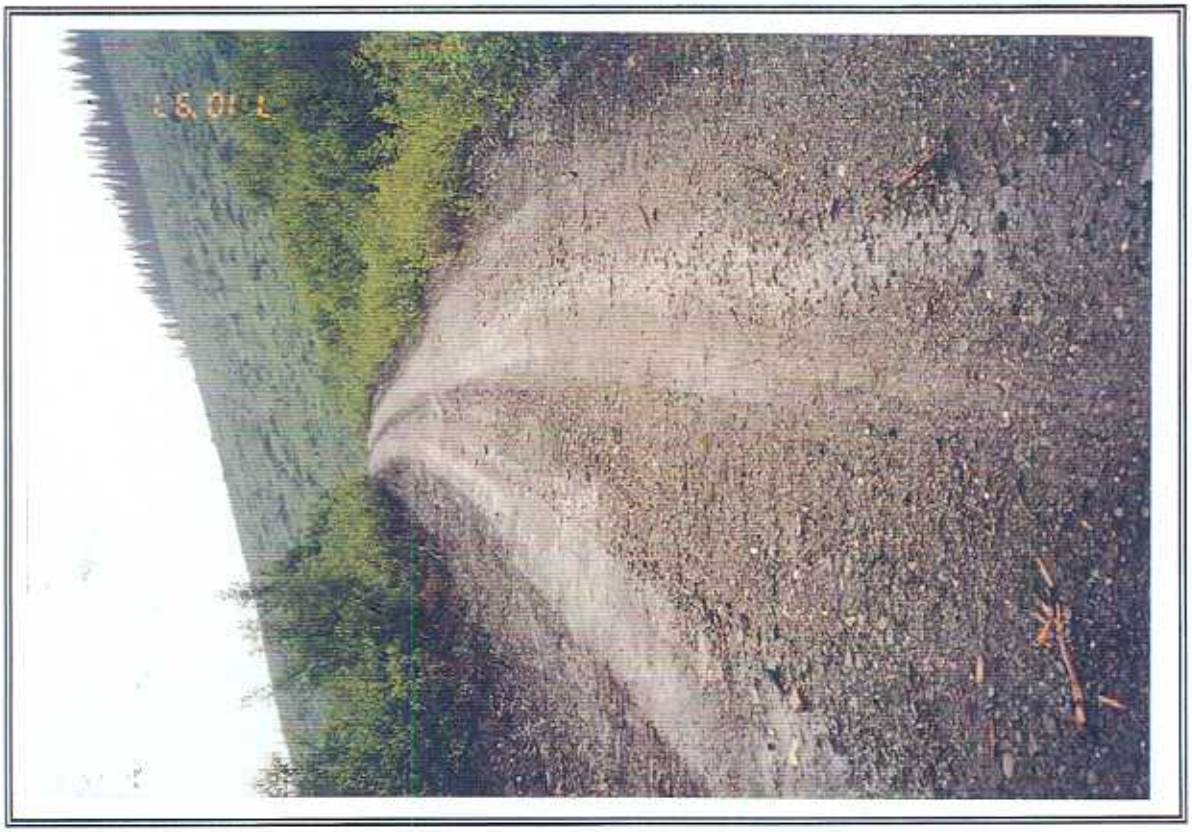


PHOTO H8. Coarse surfaced mainline road in upper Harveys Creek showing limited evidence of surface erosion [Site H4].

PHOTO H9. Turbid ditch flow into upper Simlock Creek from long uninterrupted ditch line on mainline road [Site H4].

PHOTO L1. Bank failures into lower Little River below harvesting boundary [Site L4].

PHOTO L2. Bank failure into lower Little River on outside of meander bend below harvesting boundary [Site L5].

PHOTO L3-4. Lower Little River above alluvial fan showing elevated gravel and sand bar deposits and multiple channels - upstream [Site L2].

PHOTO L5. Large debris jam on lower Little River above alluvial fan. No evidence of logging related debris. [Site L2].

PHOTO L6. Turbid flow during field inventory on Lower Little River - upstream [Site L3].

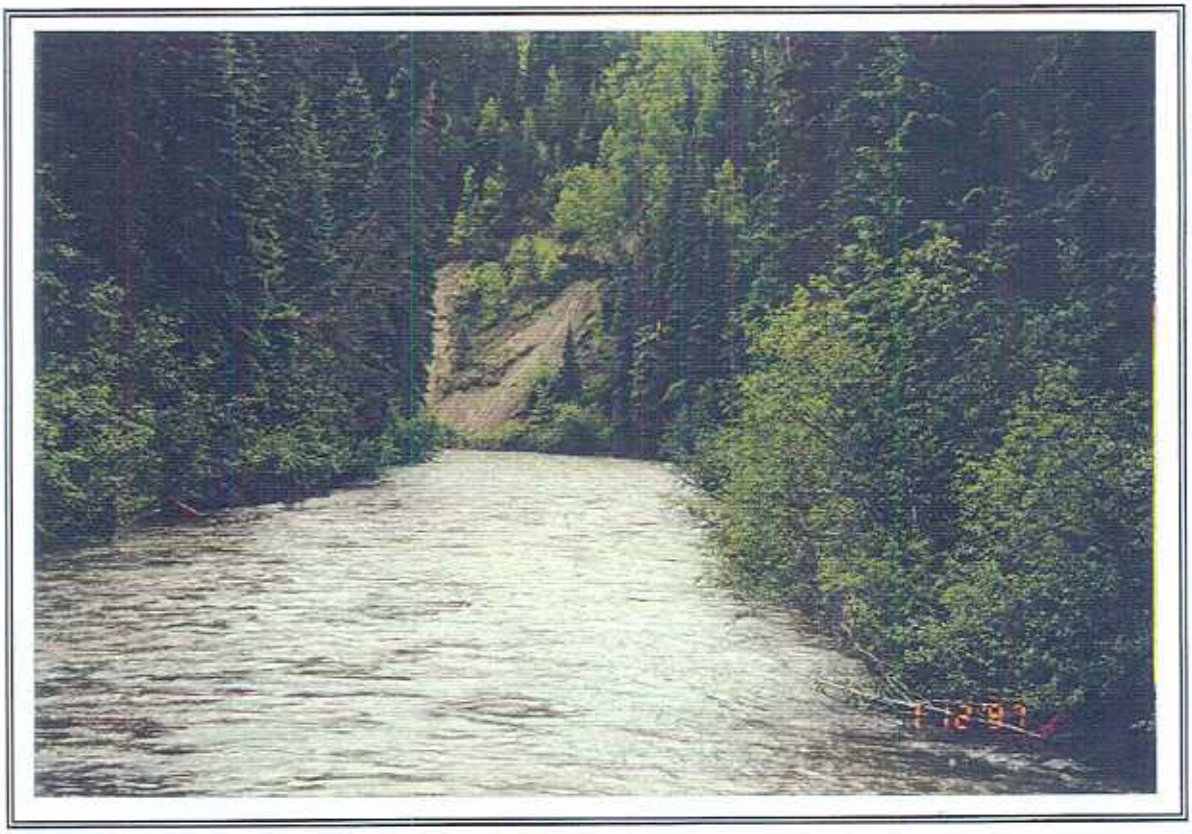


PHOTO L7. Large bank failure below harvesting boundary into lower Little River - downstream [Site L3].

PHOTO L8 . Freshly eroded banks and natural large woody debris input to the lower Little River - upstream [Site L6].

PHOTO L9. Fresh bank erosion and large woody debris input to the lower Little River - downstream [Site L6].

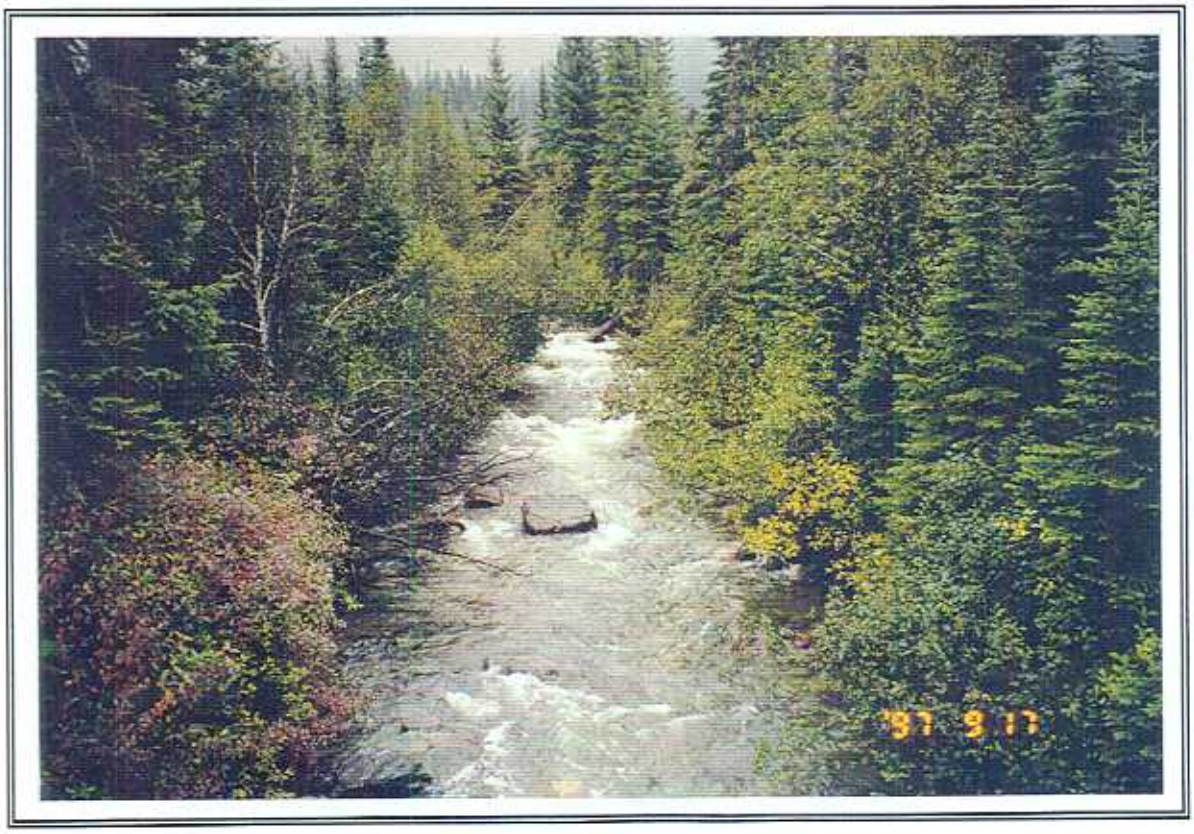


PHOTO L10. Middle Little River channel with stable riparian zone - upstream [Site L9].

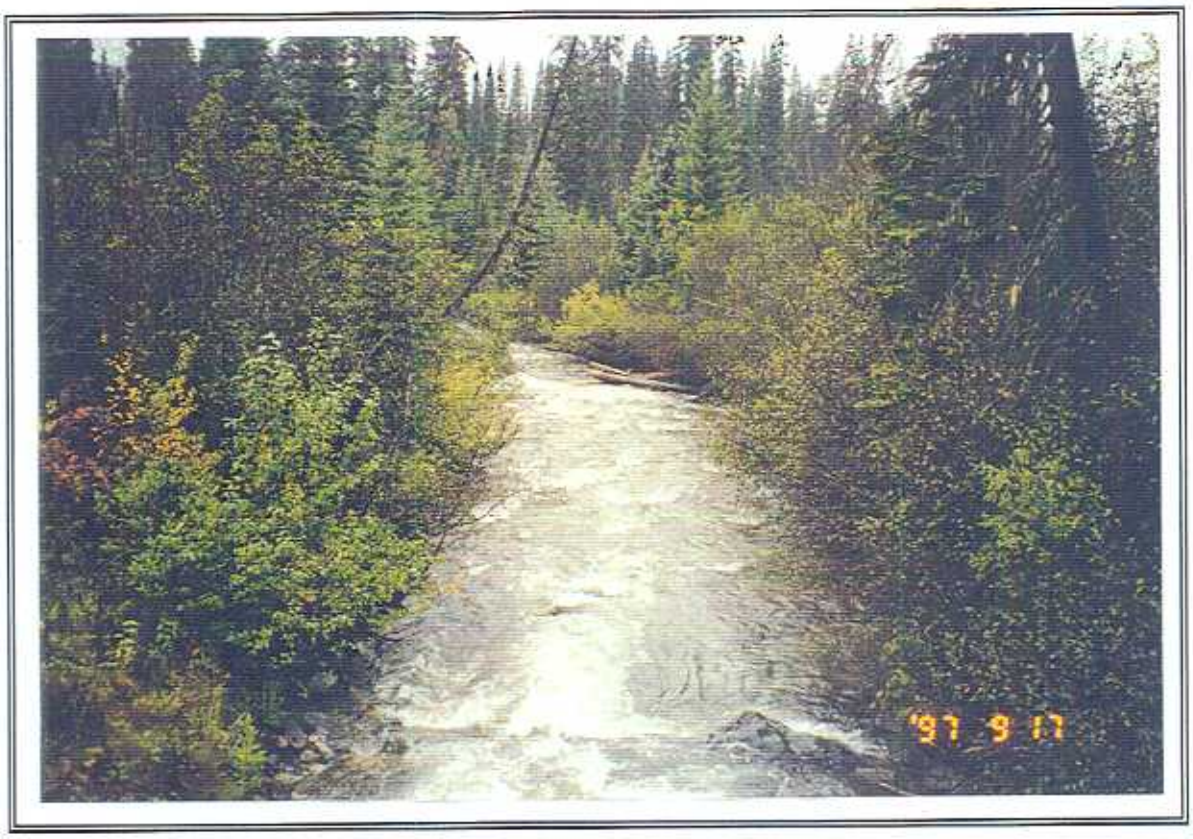


PHOTO L11. Middle Little River channel with stable channel bed and banks - downstream [Site L9].

PHOTO L12. Lower Ishkloo Creek with stable old growth riparian zone - upstream [Site L8].

PHOTO L13. Lower Ishkloo Creek with stable boulder channel - downstream [Site L8].

PHOTO L14. Running surface erosion from fine textured road leading into the Ishkloo Creek drainage [Site L10].

PHOTO L15. Direct turbid ditch flow input to Little River at Maeford Lake road crossing [Site L9].

PHOTO CN1. Lower Cunningham Creek on the alluvial fan showing aggradation and bank erosion - upstream [Site C1].

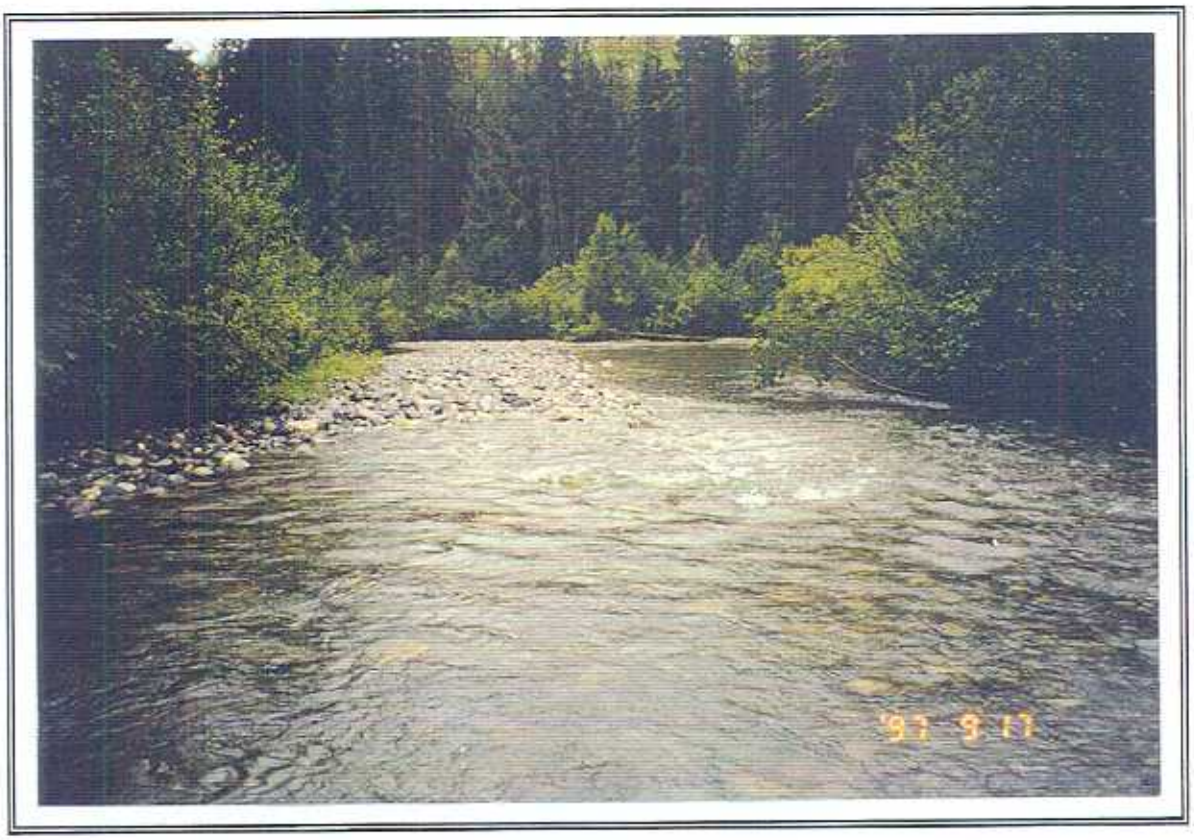


PHOTO CN2. Cunningham Creek on the alluvial fan showing bar formation - downstream [Site C1].

PHOTO CN3. Multiple channels and channel widening on the Cunningham Creek alluvial fan - downstream [Site C1].

PHOTO CN4. Harvesting in the riparian zone of Tisdale Creek and large woody debris input - upstream [Site C3].

PHOTO CN5. Increased large and small woody debris from pre-FPC harvesting in the riparian zone of Tisdale Creek - downstream [Site C3].

PHOTO CN6. Increased large woody debris input from bank erosion in upper Cunninham Creek - upstream [Site C8].

PHOTO CN7. Bank erosion in placer mined floodplain materials in upper Cunninham Creek - downstream [Site C8].

PHOTO CN8. Boulder channel with increased woody debris supply from adjacent harvesting on Roundtop Creek [Site C5].

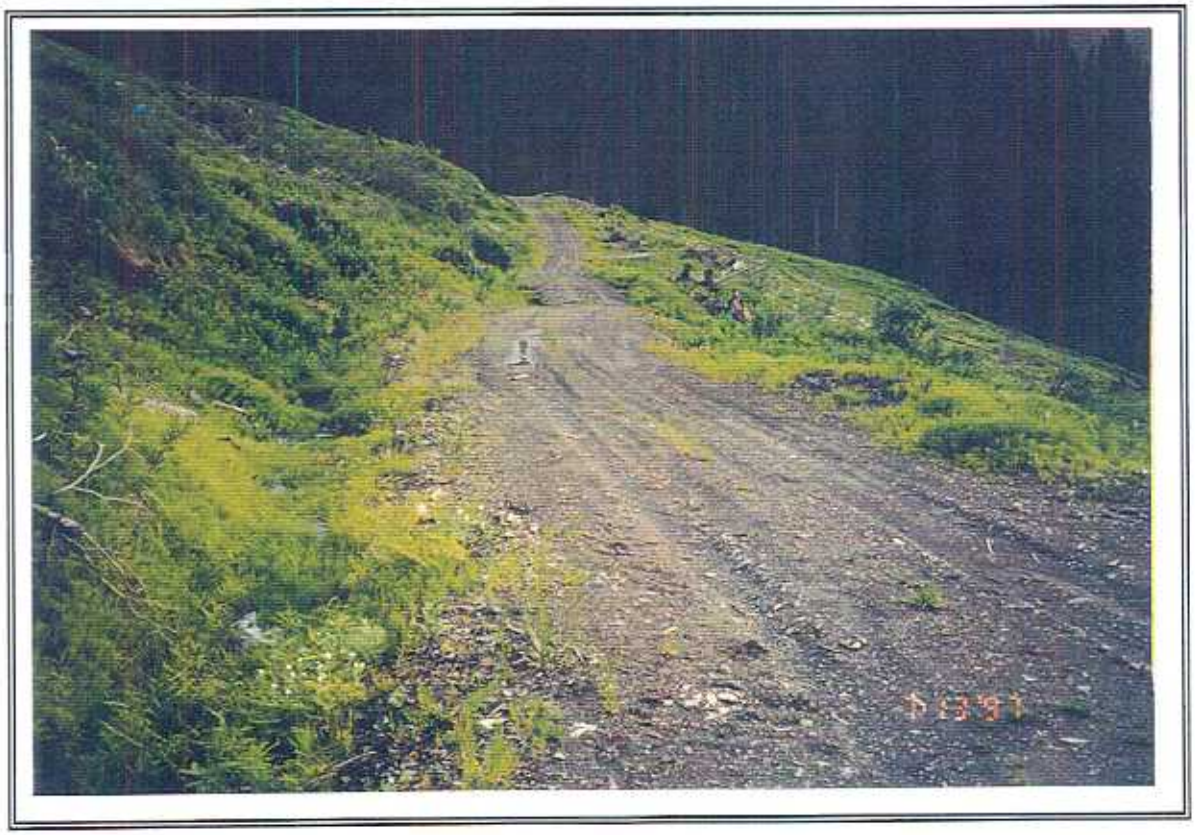


PHOTO CN9. Ruts in fine textured pre-FPC road surface in the middle watershed [Site C4].

PHOTO CN10. New road built to Forest Practices Code standards with outsloping, grass seeding and frequent cross drain installation [Upper Cunningham Creek watershed].

PHOTO KB1. Recent channel disturbance on the Kimball Creek alluvial fan - upstream [Site Kim1].

PHOTO KB2. Channel disturbance from 1997 freshet flows on Kimball Creek alluvial fan - downstream [Site Kim1].

PHOTO KB3. Bank erosion and large increase in woody debris input to lower Kimball Creek [Site Kim1].

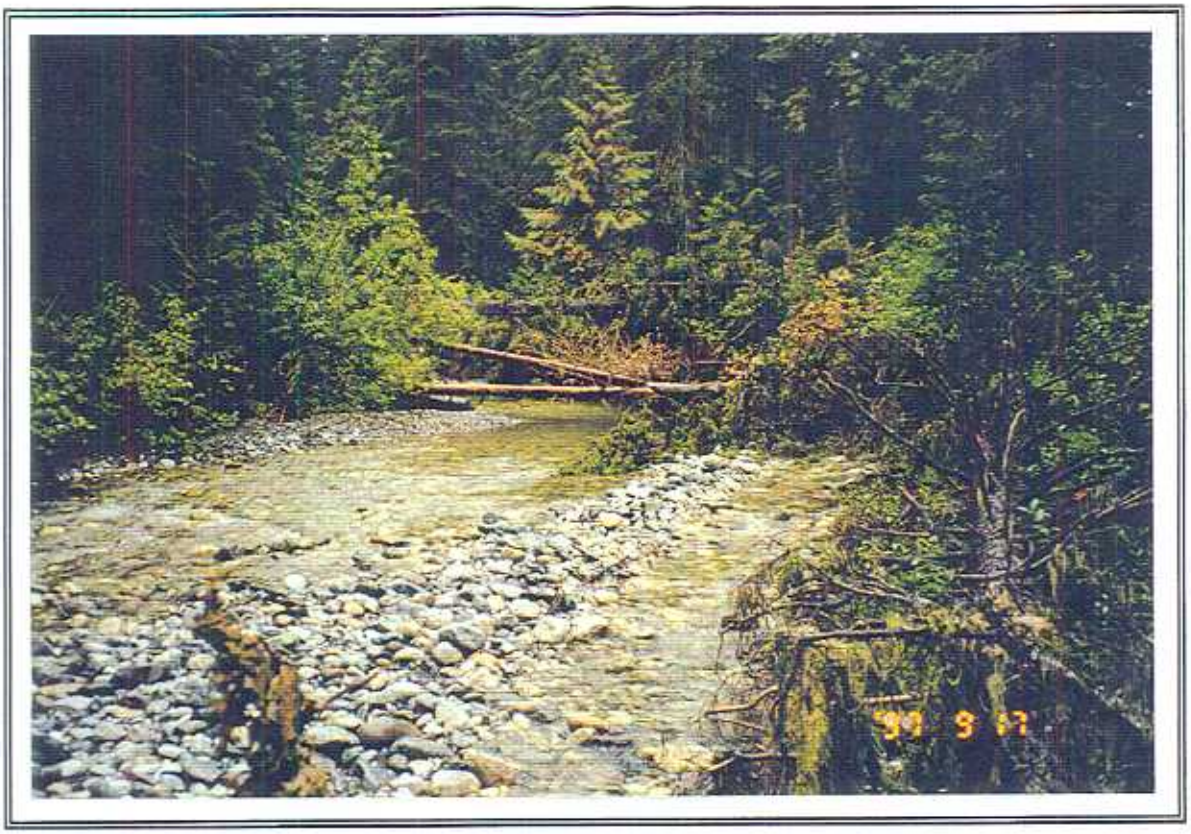


PHOTO KB4. Woody debris input from old growth riparian zone on lower Kimball Creek [Site Kim1].

PHOTO KB5. Stable channel in Windlass Creek with minor increase in small woody debris from adjacent forest harvesting - upstream [Site Kim6].

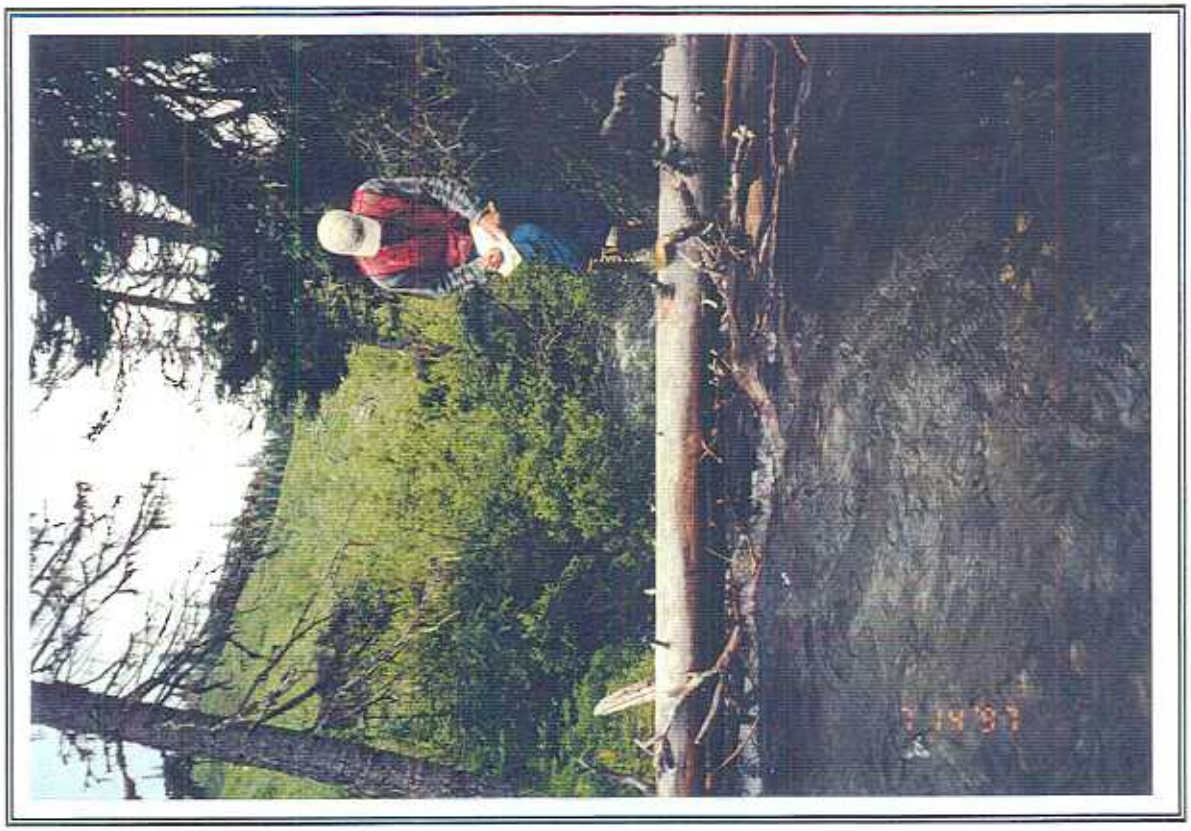


PHOTO KB6. Windlass Creek showing adjacent cutblock - downstream [Site Kim7].

PHOTO KB7. Stable, coarse surfaced road with grass and shrub vegetation to reduce surface erosion [Site Kim2].

PHOTO KB8. Pre-FPC landings and harvesting to the break in slope above Kimball Creek [Site Kim5].

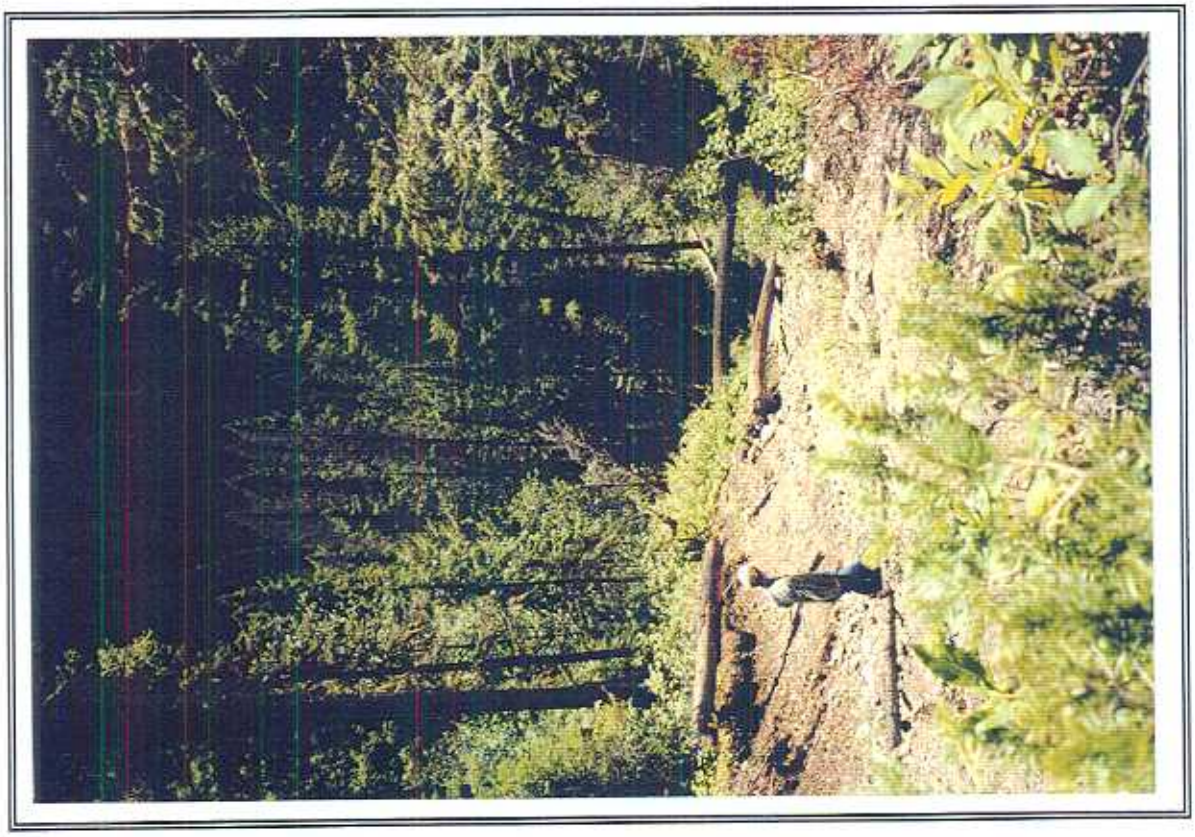


PHOTO KB9. Landslide initiated by ditchflow concentration and diversion across a landing onto the steep slope above Kimball Creek. Direct sediment delivery to the channel [Site Kim4].

PHOTO M1. Extensive riparian harvesting along the lower mainstem channel of the Matthew River [Site M1].

PHOTO M2. Low gradient reach of the lower Matthew River showing alder and willow regeneration on the banks - upstream [Site M1].

PHOTO M3. Bankfull discharge on the lower Matthew River during field inventory (July 1997). Alder and willow regeneration in the riparian zone [Site M1].

PHOTO M4. Lower Connection Creek with a large woody debris increase from blowdown in the riparian zone - upstream [Site M4].

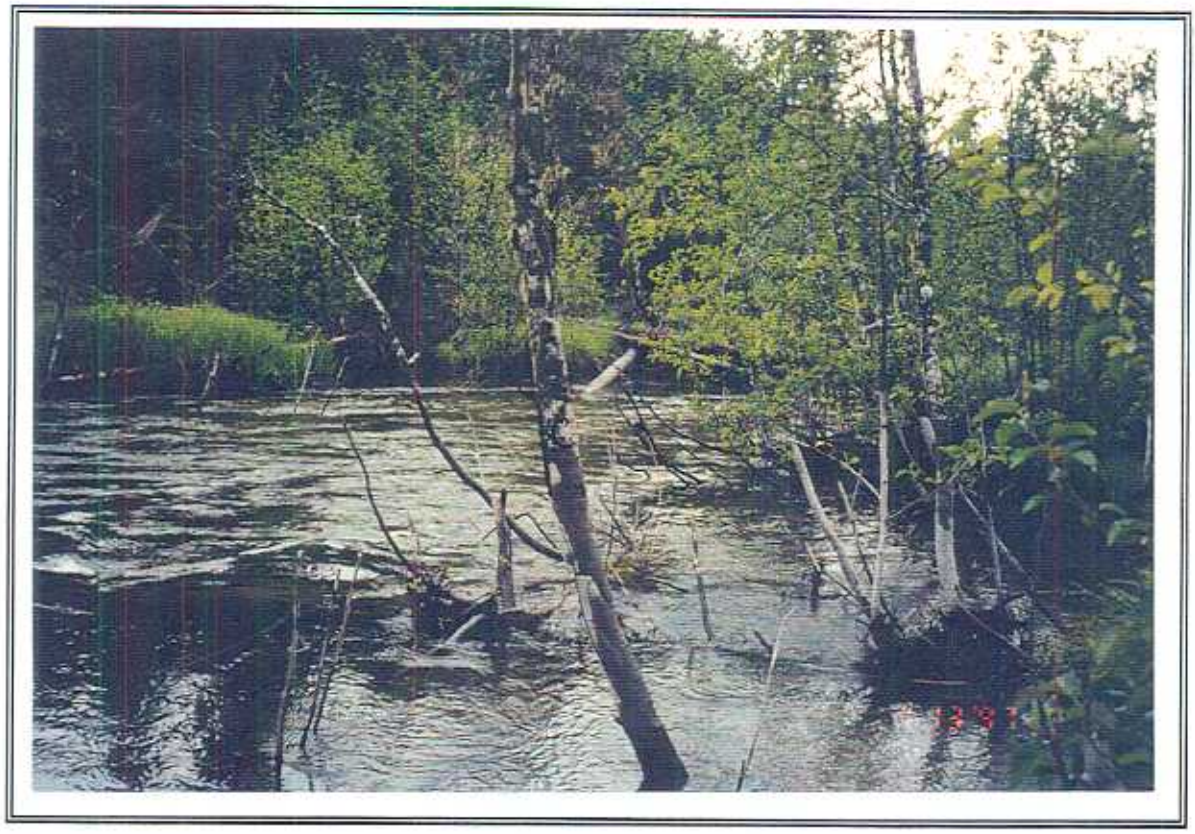
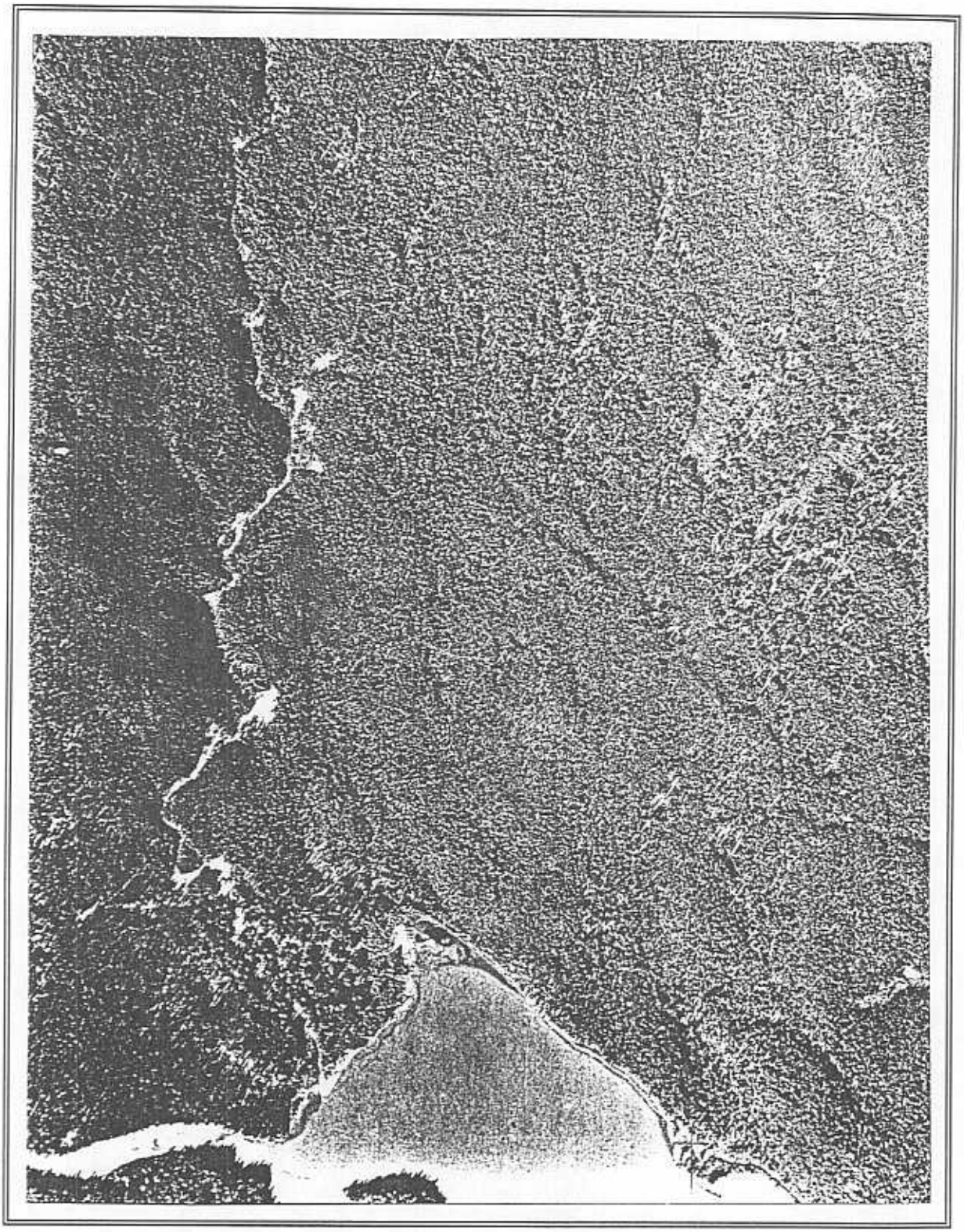


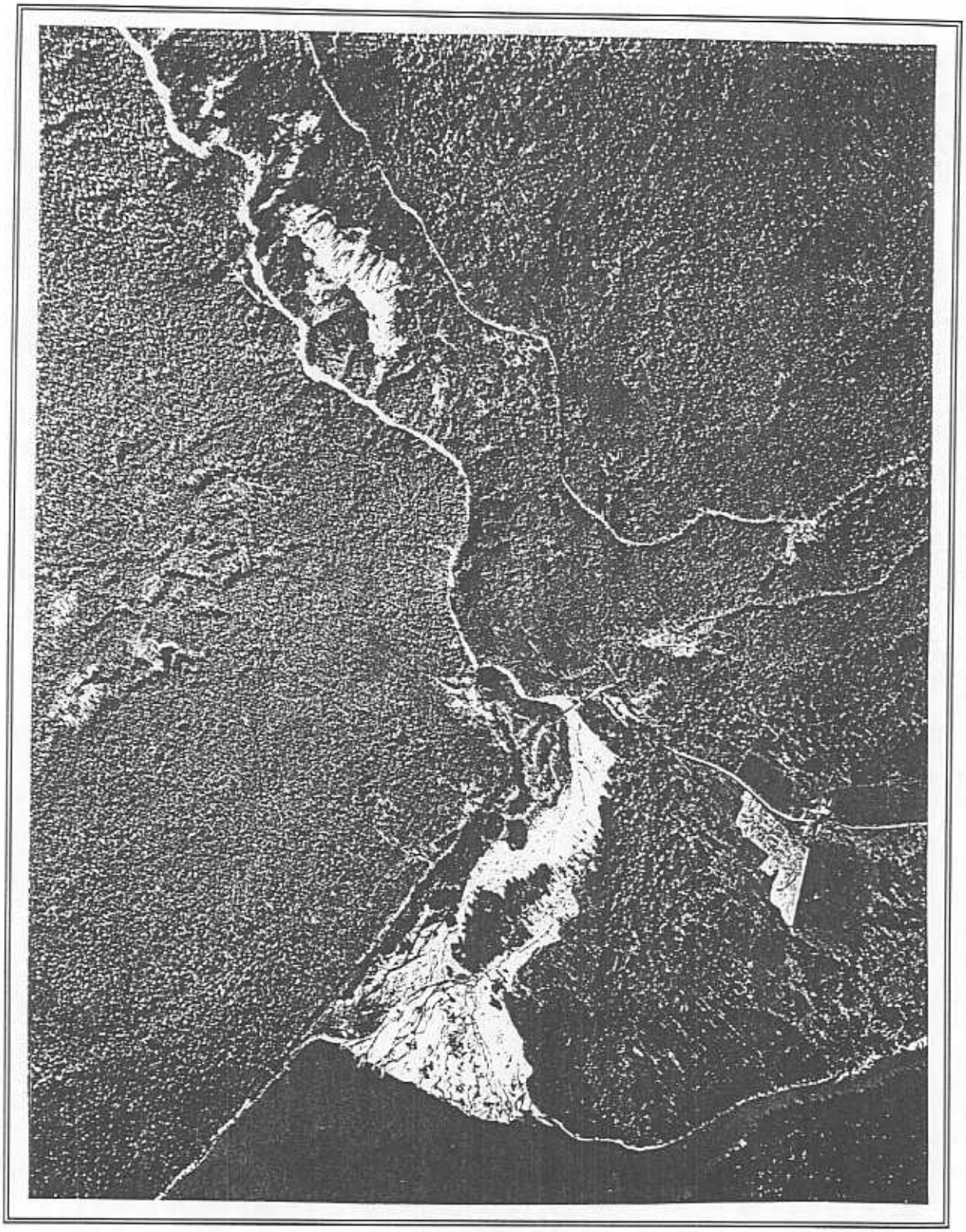
PHOTO M5. Low gradient reach on lower Connection Reach showing stable banks - downstream [Site M4].

PHOTO M6. Pre-FPC fine textured road with long uninterrupted ditch line and tire ruts [Site M2].

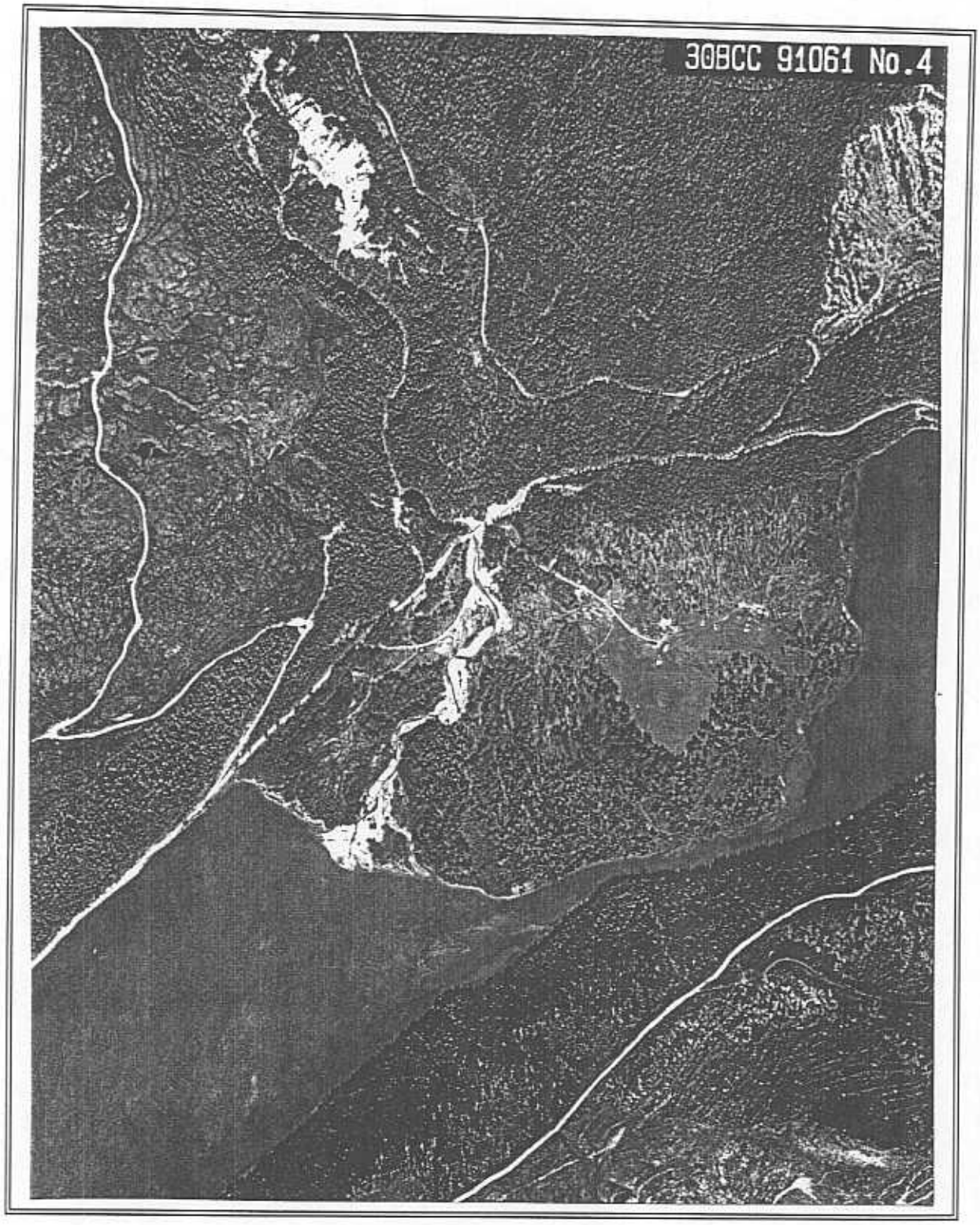


1955 - Lower Rollie Creek and the Rollie Creek alluvial fan showing actively eroding placer mining scars, and channel bar development immediately above the alluvial fan *[BC2342:20].*

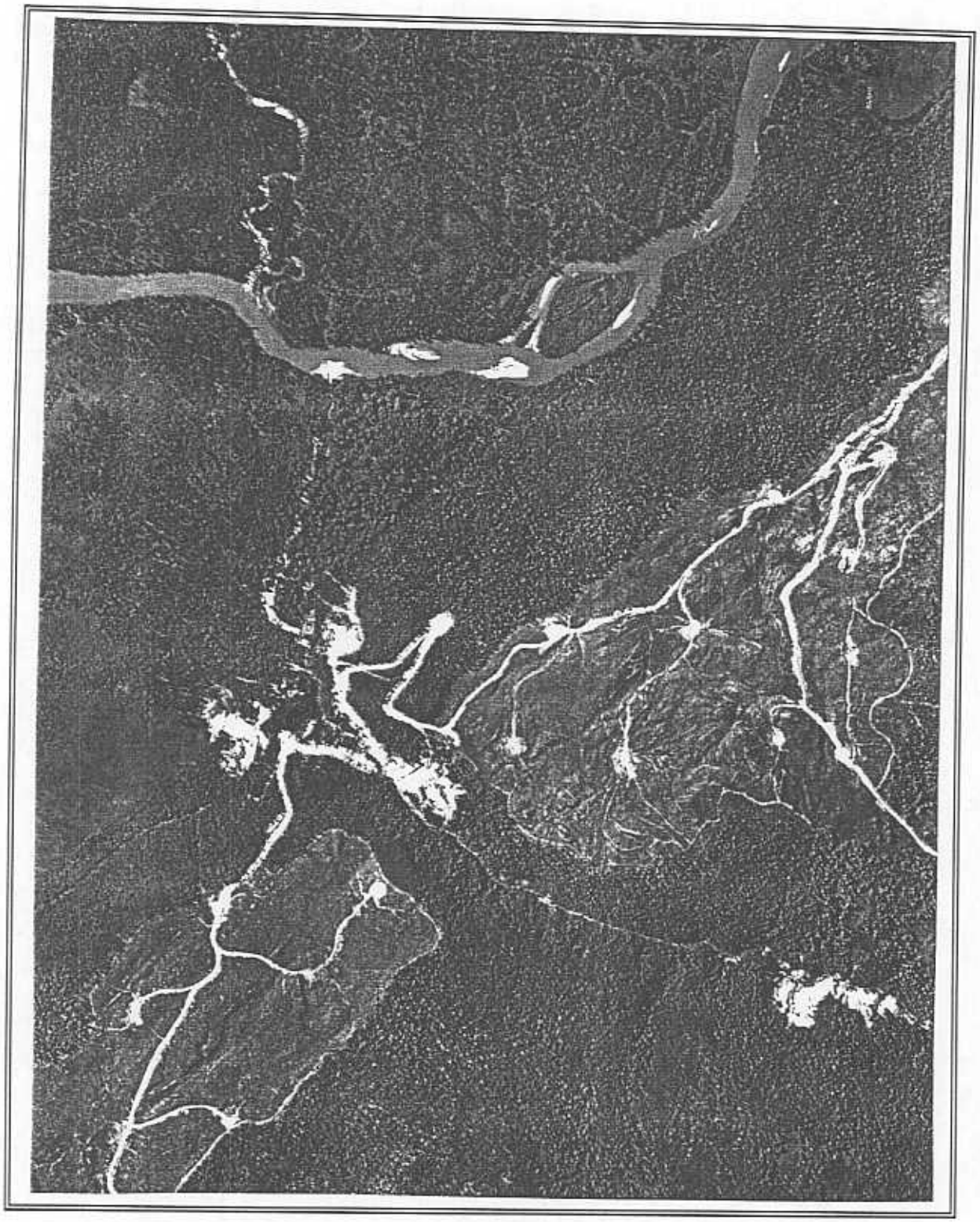
1992 - Lower Rollie Creek and the Rollie Creek alluvial fan showing partial revegetation of placer mining scars, a reduction in channel bar development immediately above the alluvial fan, and some riparian vegetation loss as a result of residential development on the fan
[30BCC 92051 No.88]



1955 - Extremely active channel on the Keithley Creek alluvial fan with multiple channels and limited riparian vegetation. Large active placer mining site on lower channel upstream of the alluvial fan *[BC 2343:67]*.



1991 - Revegetation on the active placer mining site upstream of the Keithley Creek alluvial fan, and a reduction in the number of active channels used during freshet flow. Some bank stability has returned to the system as a result of riparian zone regeneration on the fan and an overall reduction in bedload supply *[30BCC 91061 No.4]*.



1992 - Harveys Creek lower mainstem channel and alluvial fan. Large placer mining scars and active mines on the steep valley slopes and glacio-fluvial terrace. Pre-FPC forest road constructed in erodible soils. Visible channel disturbance on the alluvial fan *[30BCC 91061 No.4].*