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An Inventory of Watershed Conditions Affecting Risks to Fish Habitat

in the

CARIBOO, COTTONWOOD & HORSEFLY WATERSHEDS

VOLUME III

Horsefly River Watershed

(Sections 1 to 5 & 8)

Prepared for

CARIBOO REGION INTERAGENCY MANAGEMENT COMMITTEE

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TABLE OF CONTENTS

TABLE OF CONTENTS/Continued

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Executive Summary

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

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

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

The following observations were common to all of the watersheds:

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

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

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

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

Summaries for each of the three watersheds follow.

Cariboo River Watershed

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Cottonwood River Watershed

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Horsefly River Watershed

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

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

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

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

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

- Moffat Creek 6.0%
- Woodjam Creek 4.0%

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Consideration should be given to the following:

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

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

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

- For S6 streams, apply the RMA Guidelines.

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

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

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

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

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

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

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

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

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

DD/jb

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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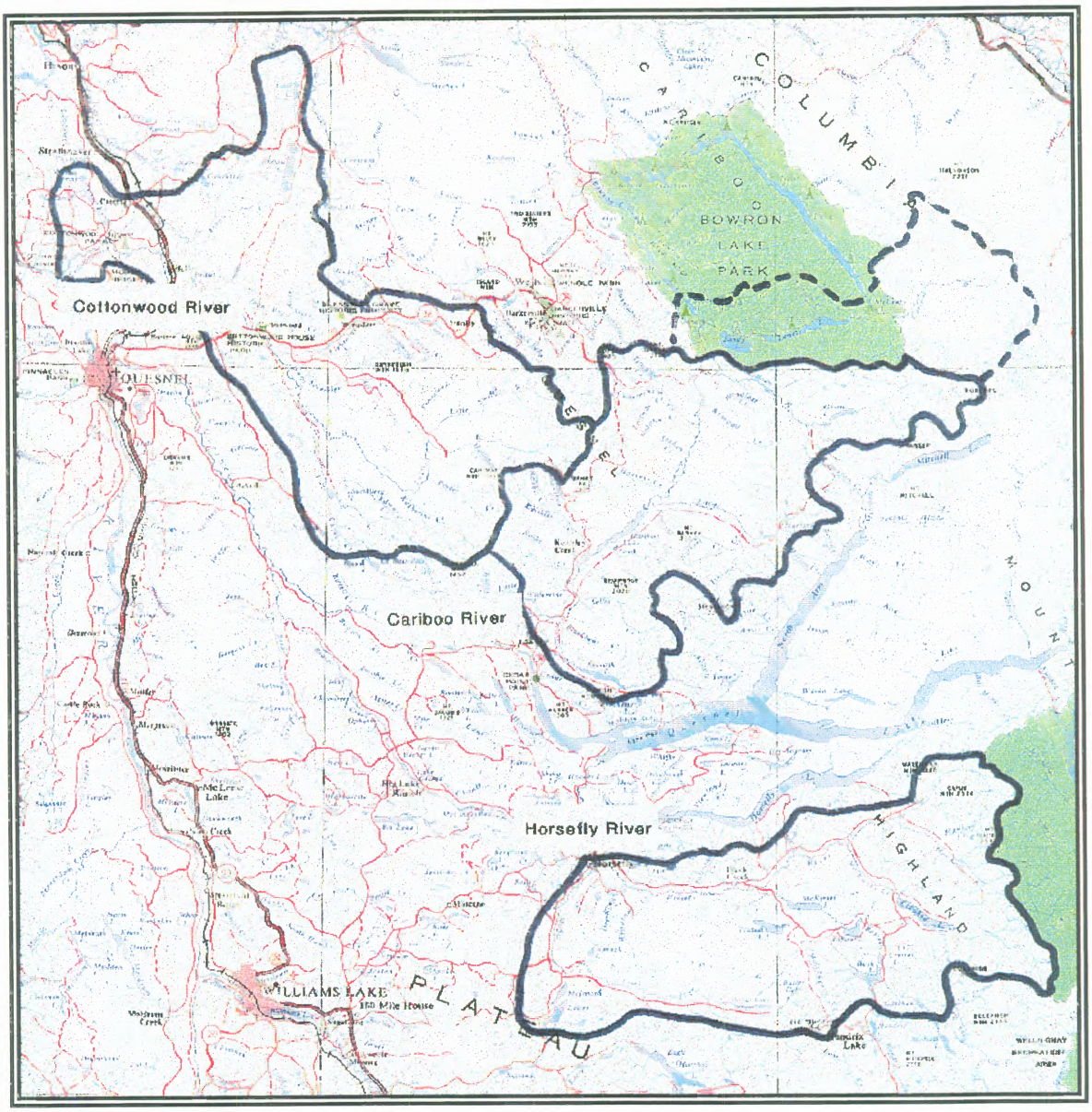


FIGURE 1

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 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.

8.0 HORSEFLY RIVER WATERSHED*

Watershed Characteristics

The Horsefly River has a watershed area of 286,000 ha (2,860 km^2) located southeast of Williams Lake *[Figure H1]*. The Horsefly River drains into Quesnel Lake, which in turn drains through the Quesnel River to the Fraser River.

This inventory was restricted to that portion of the Horsefly River watershed upstream of the confluence with the Little Horsefly River, including the Moffat Creek basin (2,120 km^2). For simplicity for this report, the "Horsefly River watershed"* refers only to that portion of the Horsefly River watershed upstream of the Little Horsefly River.

Watershed and sub-basin characteristics are presented in Table 1. The location of sub-basins in the Horsefly River watershed is shown on Figure 2.

The Horsefly River watershed is important for sockeye, coho and chinook salmon. It is one of the most productive sockeye rivers in British Columbia[1]. 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[2].

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

Climate varies over the watershed. Precipitation increases and annual temperature decreases from west to east, as elevation increases. Climate data is available for Williams Lake, Barkerville (not in the watershed) and Boss Mountain. Annual precipitation ranges from 430 mm at Williams Lake to 1,050 mm at Barkerville (which is located some distance north of the Horsefly River)[3] and 1,180 mm at Boss Mountain (located at 1,530 m of elevation south of McKinley Creek)[4]. Daily mean temperature decreases from 4.1° C at Williams Lake to 1.7° C at Barkerville and 1.1° C at Boss Mountain.

[1] Personal communication, Bruce MacDonald, Department of Fisheries and Oceans, Prince George.
[2] Personal communication, Rob Dolighan, Ministry of Environment, Lands and Parks, Cariboo Region.
[3] Canadian Climate Normals, 1961-1990, Environment Canada, Atmospheric Environment Service., 1993.
[4] Canadian Climate Normals, 1951-1980, Environment Canada, Atmospheric Environment Service., 1983

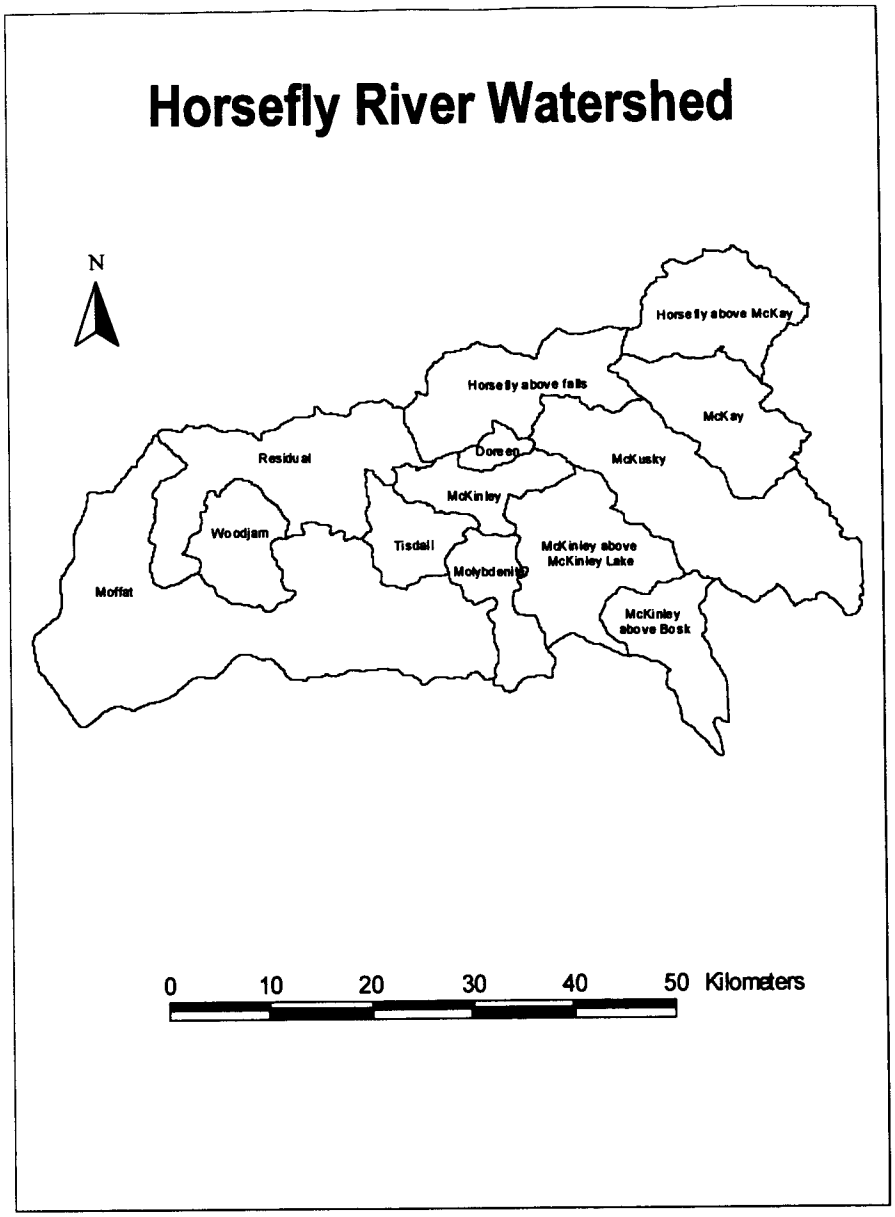


FIGURE H1

Major watersheds and map units of the Horsefly River watershed above the town of Horsefly.

The Water Survey of Canada currently operates three hydrometric stations in the Horsefly River watershed. Two additional stations have been discontinued. The annual discharge and runoff data for these stations are summarized in Table 2. The higher mean annual runoff in millimetres for the upper Horsefly River above McKinley Lake and MacKay Creek reflects higher precipitation in the Quesnel Highlands physiographic region.

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). Biogeoclimatic characteristics of the watershed and sub-basins are summarized in Table 1.

TABLE 2

Water Survey of Canada in The Horsefly River Watershed

Station Name	WSC No.	Period of Record	Drainage Area km^2	Mean Annual Discharge (m^3/s)	Mean Annual Runoff (mm)
Horsefly River at Horsefly	98KH007	1946-59	2,310	29.2	399
Moffat Creek near Horsefly	08KH019	1964-	539	3.26	191
McKinley Creek below McKinley L	08KH002	1964-	430	4.97	365
Horsefly River above McKinley C.	08KH010	1955-	785	19.4	780
MacKay River at the mouth	08KH022	1971-85	144	4.57	1,000

Background Information

Background information for the Horsefly River watershed is summarized in the following sections *[refer also to Table 3].*

Land Tenure

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.

Private Land

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.

Mining

A placer mining operation exists on Black Creek approximately 2.0 km upstream from the Horsefly River. This mine site may be contributing sediment to the Black Creek alluvial 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.

Harvesting and Equivalent Clearcut Area

As of 1996, the equivalent clearcut area (ECA) in the Horsefly watershed was 13%[5]. 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% *[Table 4]*.

These ECA values are lower than those used in the Fish Target Risk Assessment (FTRA) report.

[5] Based on a GIS analysis completed by Inland Timber Management Ltd., for the Horsefly Watershed Monitoring Committee, March 1997.

Interior Watershed Assessment Procedure (IWAP)

In 1996, an IWAP was completed for the Horsefly River watershed for BC Environment by Dobson Engineering Ltd. In 1997, IWAP calculations were redone by Inland Timber Management Ltd. for the Horsefly Watershed Monitoring Committee[6].

The 1997 IWAP calculations included:

1. Low potential peak flow hazards in the watershed and all of the sub-basins.

2. 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.

3. Low potential riparian buffer hazard ratings in the watershed and all sub-basins, but Molybdenite Creek and the 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.

4. High potential landslide hazard ratings in the Horsefly River above the Falls and the McKusky Creek sub-basins. Moderate potential landslide hazard ratings in the McKinley Creek above Bosk Lake and MacKay River sub-basins. Low potential landslide hazard ratings 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.

5. Overall, 1997 IWAP results indicate minimal past forest development related concerns in the Horsefly River watershed above the confluence with the Little Horsefly River.

[6] Personal Communication, Patrick Teti, Research Hydrologist, Cariboo Forest Region. The Horsefly Watershed Monitoring Committee includes representation from the Ministry of Forests (Cariboo Region and Horsefly District), the Ministry of Environment, Lands and Parks, the Department of Fisheries and Oceans, major forest licensees, and others.

Hydrometric Trend Analysis (Eugene Hetherington)

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.

Channel Assessment

A channel assessment of 54 km of the Horsefly River mainstem channel and McKinley Creek was completed by Dobson Engineering Ltd. 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.

Department of Fisheries and Oceans Reports

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).

The report objectives were to:

1. Apply DFO's strategies and goals to the respective units.

2. Analyze existing resource development plans for their consistency with DFO's goals and strategies.

3. Recommend specific resource management approaches to comply with these goals and strategies.

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.

Forest Renewal BC

The following inventory, assessment and upgrading work is in progress or has been completed in the Horsefly River watershed under Forest Renewal BC[7]:

- 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.

[7] Information supplied by the Horsefly Forest District.

Watershed Planning

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[8]. 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.

Inventory Observations

Stream Channels

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. Channel inventory observations summarizing areas of concern are as 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.

[8] Personal communication, Patrick Teti, Research Hydrologist, Cariboo Forest Region.

5. The following two small sub-drainages in MacKay River and the McKusky Creek have been effected by past forest development:

   - 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.

   - 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.

Roads

Three locations of new road (post-FPC) were examined in the watershed. These were in Molybdenite Creek, Bassett Creek and Woodjam Creek. In all cases, running surface erosion, and cut- and fill-slope erosion was noted, related to the following conditions:

1. Sub-grades were constructed from local surficial materials (commonly fine-grained till).

2. Capping of the road was either underway or had not been done.

3. Road surfaces were deeply rutted with truck and caterpillar tracks.

4. Extensive erosion of the road surface and cut and fill slopes was evident.

5. The use of sediment control measures to minimize the input of road sediment to streams was absent.

6. Old roads (pre-FPC) were generally stable and armoured. Some general characteristics were noted, with implications for water quality:

   - Cross drain frequencies were low.
   - Long uninterrupted ditch lines permit sediment transport into streams at road crossings.

Landslides

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).

Mining

The old open-pit mine located at the upper end of the Molybdenite Creek sub-basin (in the McKinley Creek sub-basin) was observed to be contributing large amounts fine sediment during spring freshet to Molybdenite Creek and McKinley Creek.

Proposed Harvesting 1997-2001

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 *[Table 4]*. Assuming some hydrologic recovery on previously harvested blocks, this ECA increase translates into a rate of cut of approximately 2.0% of the watershed area 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).

Inventory Interpretation

1. Based on the observations made in this inventory (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.

2. 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.

3. 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.

    - Surface erosion concerns on roads inventoried in the Horsefly River watershed are:

    - Fine-grained local surficial materials are used to construct road sub-grades. Capping of the road surface with coarse-textured, erosion resistant material is not commonly done.

    - Erosion control measures such as ditch blocks and sumps, geotextile filter cloth fences or hay bales in ditch lines, or grass seeding of cut- and fill-slopes are not common.

    - Green roads, in spite of commonly being built in fine-textured native materials, are used by trucks and machinery. Road surfaces are deeply rutted and generate large amounts of fine sediment.

4. The extent of past forest development in the Horsefly River watershed is low.

5. 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.

6. 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:

    - 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.

    - 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.

7. Landslides have occurred from pre-FPC roads on unstable terrain in the McKusky Creek and MacKay River sub-basins.

8. 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.

Recommendations

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. Maintain a 5.0 m no-machine buffer (along all S4, S5 and S6 stream channels), and protect all immature and non-merchantable species in the riparian management zones to maintain channel bank stability and stream shading.

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. 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 following steps should be considered:

   - Develop and implement a riparian zone awareness program for private landowners.
   - Establish riparian reserve zones along the channel according to the ***Riparian Management Area Guidebook.***
   - 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.

8.1 MOFFAT CREEK

Watershed Characteristics

Moffat Creek is located on the Cariboo Plateau physiographic unit and has a watershed area of 52,620 ha *[Figure 3]*. SubBoreal Spruce and Engelmann Spruce Subalpine Fir biogeoclimatic zones cover the sub-basin from west to east. The mainstem channel of Moffat Creek, and some larger tributaries, are used by sockeye salmon.

Background Information

Ninety-four percent of the sub-basin is Crown land and the remaining 6.0% is private. Private land used for agriculture occupies the lower sub-basin area. The 1996 ECA in Moffat Creek was 11%. Private land was not included in the ECA calculation. The 1997 IWAP calculated low potential hazard ratings in all IWAP categories. Clearing of land in the riparian zone for private agricultural purposes was not considered in the riparian buffer calculation.

DFO and BC Environment are concerned with land clearing and cattle grazing in the riparian zone along lower Moffat Creek between the Horsefly River and McIntosh Creek. The Horsefly Water Monitoring Committee reports that lower Moffat Creek has the highest suspended sediment concentrations in the Horsefly River watershed[9]

Inventory Observations

Stream Channels

1. The lower mainstem channel of Moffat Creek (below the waterfall located about 6.0 km from the Horsefly River) contains large, naturally-eroding banks where the creek is eroding through old glacio-fluvial gravels.

2. Six channel inventory sites were visited in the Moffat Creek sub-basin, two on the lower alluvial channel (below the waterfall) and four in the forested part of the basin.

3. Channel aggradation, bank erosion and channel widening has occurred as a result of riparian vegetation removal and cattle grazing on private land *[Sites M1 and M2]*. Eroding glacio-fluvial gravel banks on the lower reaches are contributing large amounts of bedload to Moffat Creek.

[9] Personal communication, Patrick Teti, Research Hydrologist, Cariboo Forest Region.

4. Moffat Creek is stable upstream of private land *[Sites M4, M5, M6 and M7].* All inspected reaches are alluvial, cobble and gravel bed with forested riparian zones. No bed or bank disturbance was noted at any of these sites.

5. The mainstem channel upstream of the waterfall was not field inventoried, but was assessed on air photographs and during the aerial reconnaissance. Large glacio-fluvial gravel banks do not exist on this reach. Reaches flowing through cleared agricultural land show evidence of channel aggradation, bank erosion, channel widening and lateral shifting.

6. There was a natural organic load in Upper Moffat Creek that caused the water to have a dark colour.

7. The mainstem channel of Moffat Creek (with the exception of a bedrock-controlled reach in the vicinity of the waterfall located 6.0 km upstream of the Horsefly) is alluvial with fine-textured gravel banks and bed.

8. The air photo comparison carried out for Moffat Creek, from the confluence with Horsefly River to McIntosh Creek (a distance of about 25 km), using 1:15 840 photos from 1958 and 1:20 000 photos from 1992 indicated that:

   - Reaches within the lower 20 km of Moffat Creek have undergone channel widening (in places by 100-200%), avulsions and straightening through mechanical exacavation.

   - Disturbance was limited in 1958 and increased significantly by 1992.

   - Disturbance is concentrated on private agricultural land, however, some channel widening and point bar formation was evident on 1992 photos upstream of all private land activities. Increased bank erosion and deposition is possibly attributable to a large freshet peak discharge event that occurred in 1990. The relative magnitude of this event on Moffat Creek is unknown, as the Water Survey of Canada stream gauge was damaged and did not record this event. Data from other stream gauges within the Horsefly River watershed indicate a return period of 10-20 years.

   - The rate of bank erosion in the large glacio-fluvial banks of the lower Moffat Creek has not changed over the 34-year study period. This observation indicates that they are not responsible for the increased bedload that has aggraded lower Moffat Creek.

   - Extensive channel widening has occurred on cleared private land upstream of the waterfall and upstream of the large, naturally eroding banks. Riparian disturbance in this area has increased the bedload supply to Moffat Creek which is ultimately being transported to the Horsefly River.

Roads

About 50 km of road in the Moffat Creek basin were assessed. All these roads were old (pre-FPC). Some isolated problems were noted, such as culvert wash-outs and road surface erosion. No recently-constructed roads were assessed.

Proposed Harvesting 1997-2001

The harvesting proposed in the watershed for the 1997-2001 period would be approximately 12-14% of the watershed area. The ECA would increase from 10.5% (1996) by 11.6% to a maximum of 22.1% by 2001. This corresponds to a rate-of-cut of about 2.5% per year.

Inventory Interpretation

The Moffat Creek sub-basin exhibits a high level of stream disturbance associated with agricultural land clearing and cattle activity in riparian zones. Extensive bank disturbance and channel widening has occurred. The disturbance appears to be concentrated in the lower 20 km of the mainstem channel. It is likely that the fish resources of Moffat Creek have been impacted.

The channel disturbance along the lower 20 km of Moffat Creek may result from an unusually large stream discharge event during snowmelt in 1990. Water Survey of Canada data indicates that the 1990 freshet peak might have a 10-20 year return period. The channel disturbance attributed to this peak flow might be the result of a relatively common event eroding stream banks that had been destabilized by removal of riparian vegetation.

Effects from forest development appear to be minimal at this time. Moffat Creek downstream of past harvesting appeared to be undisturbed.

The mainstem channel has a gravel bed with an active floodplain that is sensitive to riparian disturbance. Removal of riparian vegetation (for forestry, agriculture, etc.) will result in bank erosion and channel widening due to loss of bank stability.

There is a significant amount of logging proposed in the sub-basin during the 1997-2001 period. This harvesting may contribute to additional channel disturbances, with negative effects on fish in the mainstem channel as a result of the following.

1. The increased rate of new road construction required will likely result in increased fine sediment supply (i.e., sand-sized and smaller) to Moffat Creek. This may result in increased suspended load and sand accumulation in the low gradient alluvial reaches (including sand infilling of spawning gravel).
2. The ECA at the end of the five-year plan period would be 22.1%, which could result in a risk of increased peak flows during the spring freshet. Because the gravel bed and banks of the alluvial reaches are sensitive, there is a moderate probability that increased bank erosion and channel disturbance will occur.

Recommendations

Refer to the recommendations provided for the Horsefly River in Section 8.0.

8.2 WOODJAM CREEK

Watershed Characteristics

Woodjam Creek has a drainage area of 8,600 ha and is located on the Cariboo Plateau physiographic unit. Topographic relief in the watershed is low *[Figure 4]*. The basin is located within the SubBoreal Spruce biogeoclimatic zone, but contains some areas of Engelmann Spruce Subalpine Fir at higher elevation.

Background Information

Ninety-six percent of the sub-basin is Crown land and the remaining 4.0% is private. Both crop production and livestock grazing occurs on the private land in the lower sub-basin.

The 1996 ECA for Woodjam Creek was 3.4%, not including cleared private land. Assuming that the majority has been cleared for agricultural, the estimated ECA would be 6.0%. Low potential hazards were calculated for Woodjam Creek in all IWAP categories.

DFO and BC Environment are concerned with land clearing and cattle grazing in the riparian zone along the lower mainstem channel. Additional concerns regarding the proposed rate of cut in the five-year development plan have been expressed by DFO.

Inventory Observations

Stream Channels

Woodjam Creek was assessed on the lower alluvial channel near the Horsefly River *[Site W1]* and in the upper forested part of the basin *[Site W3]*.

The lower mainstem channel has been disturbed by clearing in the riparian zone. Farming to the stream bank has occurred, resulting in increased bank erosion and sediment input to the channel.

Channels in the upper sub-basin are stable, however, sediment input from roads was noted *[Site W3]*.

Roads

Twenty kilometres of road was assessed in the sub-basin. In the middle and upper sub-basin, new roads have been constructed using fine-textured native material on wet sites *[Site W2]*. The running surface is not stable, resulting in surface erosion and sediment transport to streams. Old roads (pre-FPC) were armoured and stable.

Proposed Harvesting 1997-2001

Approximately 20% of the Woodjam Creek sub-basin is proposed for development over the 1997-2001 period. The 1996 ECA of 3.5% would increase to 22.1% in 2001, representing a rate of cut of 3.7% per year.

Inventory Interpretation

Lower Woodjam Creek has been disturbed by land clearing in the riparian zone on private land. Farming to the stream bank has occurred, resulting in increased bank erosion and sediment input to the channel.

Lower Woodjam Creek is an alluvial channel and sensitive to increases in peak flow and bedload supply, and riparian disturbance.

Erosion from roads and sediment delivery to channels is occurring from new roads constructed in fine-textured soils.

Twenty percent of the Woodjam Creek sub-basin is proposed for development over the next five years. The current ECA of 3.5% would increase to 22.1% at a rate of 3.7% per year. This rate of forest development is a concern with regards to potential increases in peak flow, and surface erosion from new road construction that would affect streams.

Recommendations

In addition to the recommendations provided in Section 8.0, the following recommendation is provided.

1. The proposed rate of cut (3.7%/year) should be reduced to minimize:

    - Site disturbance and potential sedimentation concerns from surface erosion off new roads (post-FPC).
    - The presence of erodible soils in the middle and upper sub-basin.
    - The rate of new road construction that will be required to access proposed blocks.

8.3 MCKINLEY CREEK

Watershed Characteristics

The McKinley Creek sub-basin has a drainage area of 44,300 hectares *[Figure 5].* Topographic relief is moderate with rolling terrain in the middle and lower drainage area. There are several large lakes in the watershed.

Background Information

The lower McKinley Creek is important for salmonid spawning and the entire watershed has been designated as an enhanced stream by DFO (i.e. accessible reaches are used by salmon or trout to spawn and rear). Any activity that would increase bedload supply and peak flow increases would be a concern.

DFO has installed a wier at McKinley Lake to maintain minimum flows. Stream temperatures in the summer months in the lower McKinley system, which can approach levels causing salmonid mortality, are a concern.

The 1997 IWAP calculated hazard ratings for the McKinley Creek sub-basin above McKinley Lake and also above Bosk Lake. The results indicate no concerns regarding past forest development in the McKinley Creek sub-basin above McKinley Lake. However, moderate potential riparian buffer and landslide hazard ratings were calculated for the watershed above Bosk Lake. These moderate ratings resulted from the length of fish-bearing streams logged and the overall landslide density.

Inventory Observations

In addition to the aerial reconnaissance overview (refer to aerial reconnaissance forms) and field inventory procedures (field data forms), a helicopter overview of the sub-basin, specifically the McKinley Creek mainstem channel above Bosk Lake, was conducted in September 1997. No channel disturbance was noted on the lower, middle or upper mainstem channel reaches. McKinley Creek below McKinley Lake is a stable, irregular channel with a confined meander pattern *[Photo McKin1].* Bed materials are coarse gravel and small cobbles, and showed no indications of increased sedimentation or bank disturbance *[Site McKin1] [Photos McKin2 and McKin3].*

There was a minor amount of bank erosion and increased large woody debris input on the mainstem channel above Molybdenite Creek *[Site McKin3] [Photos McKin4 and McKin5].* This disturbance resulted from recent blowdown in the riparian zone. Cobble and gravel bed materials were found to be moderately compacted with fine sediment.

Harvesting in the riparian zone has taken place on upper McKinley Creek above Bosk Lake *[Site McKin9] [Photos McKin6 to McKin9].* No channel instability or disturbance was observed during the helicopter overview from Bosk Lake to Gotchen Lake.

A large sediment plume was observed in Elbow Lake originating from Bassett Creek. Erosion was noted on roads and ditch lines in the watershed. Some semi-permanent deactivation has been undertaken in the Bassett Creek drainage, however, some ditch blocks have failed and ditch erosion is occurring *[Site McKin6] [Photos McKin10 and McKin11].*

Ditch line and running surface erosion was also observed on roads with long, uninterrupted ditch lines, infrequent cross-drains *[Site McKin9] [Photo McKin12]* and where the running surface was composed of fine-textured soils. Sumps are infrequent at stream crossings, allowing sediment to be transported into streams.

Proposed Harvesting 1997-2001

The 1996 ECA in the McKinley Creek sub-basin at the mouth was 13.8%. Five percent of the sub-basin is proposed for development over the next five years, increasing the ECA to 18.5% by 2001.

Inventory Interpretation

The mainstem channel of McKinley Creek is stable and shows only minor evidence of disturbance. Minor aggradation and compaction of stream bed materials was evident upstream of Molybdenite Creek, as a result of blowdown in the riparian zone.

Road surface and ditch line erosion is occurring in the Bassett Creek drainage, contributing sediment to the channel. The large lakes on the system are providing a buffer to the lower channels from sedimentation in the upstream areas.

Peak flow increases as a result of the proposed development are not expected. However, there are surface erosion concerns related to new road construction, and sedimentation into channels resulting from long, uninterrupted ditch lines with infrequent sumps at stream crossings.

Recommendations

The following recommendation is provided in addition to those in Section 8.0.

1. Complete a road assessment in the Bassett Creek basin to:

   - Determine if and where improvements are required to the previous deactivation work.

   - Identify those sections of roads where ditch line and running surface erosion are contributing sediment to channels.

8.4 MOLYBDENITE CREEK

Watershed Characteristics

Molybdenite Creek is a third-order tributary to McKinley Creek with a watershed area of 7,900 ha. The Molybdenite drainage is a long, linear sub-basin with a broad low gradient floodplain, and wetland complexes throughout the system *[Figure 5]*. One steep incised channel reach exists in the lower sub-basin.

Background Information

Molybdenite Creek, a tributary to McKinley Creek, is an important habitat for salmon spawning and rearing. Fisheries agencies are concerned about any activity that could affect McKinley Creek, such as increases in sediment input to channels, peak flows and stream temperatures.

The 1997 IWAP calculated a moderate potential riparian hazard rating resulting from the length of stream logged.

Inventory Observations

Suspended sediment was high during freshet *[Photo Moly1]*. The source of sediment in the channel was traced to an old open pit mine in the upper sub-basin *[Photo Moly2]*.

Harvesting in the riparian zone has occurred below the incised reach in the lower sub-basin. Bank erosion, aggradation and channel widening has occurred as a result *[Site Mol1] [Photos Moly3 and Moly4]*. Surficial materials (soils) in the lower sub-basin consist of erodible glacio-fluvial sand and gravel deposits (kame terrace).

Surface erosion concerns were observed on post-FPC roads in the lower sub-basin *[Site Mol2]*. The road at this location was constructed using fine-textured native materials, had not been capped, contained infrequent cross-drains creating long, uninterrupted ditch lines, and showed evidence of running surface, and cut- and fill- slope erosion. The roads were also rutted causing additional running surface erosion.

Proposed Harvesting 1997-2001

The 1996 ECA in Molybdenite Creek was 12.7%. Proposed development of another 13-15% for the 1997-2001 period (a rate of cut of 2.8% per year) would increase the ECA to 25.3% by 2001.

Inventory Interpretation

The old open pit mine in the upper sub-basin is the major cause of high suspended sediment levels in Molybdenite Creek.

Harvesting in the riparian zone along the mainstem channel in the lower sub-basin has caused bank erosion, channel widening and aggradation. The lower mainstem channel is sensitive to direct riparian disturbance, and increases in peak flow and bedload.

Rutting and surface erosion on post-FPC roads in the lower sub-basin is occuring as a result of: the use of fine-textured native materials in the sub-grade and running surface; infrequent cross-drains resulting in ditch line erosion; no coarse erosion resistant surfacing; lack of grass seeding on exposed cut and fill slopes; and active use during wet weather.

The proposed 2.8% per year rate of cut is a concern due to the potential of increased sediment transport to streams associated with the amount of new road that may be required to access the proposed development in the five-year plan. The extent of fine-grained soils in the watershed (which are easily eroded) and the frequency of erosion on existing roads (e.g. sedimentation in Molybdenite Creek) underscores this problem.

The proposed ECA increase of 13-15% to 25.3% is also a concern with regards to increased peak flows and bank erosion that could result in additional disturbance to the lower mainstem channel.

Recommendations

The following recommendations are provided in addition to those in Section 8.0.

1. The rate of cut should be reduced, based on observed surface erosion conditions on new roads (post-FPC), and the amount of new road construction that would be required to access the proposed blocks.

2. A restoration plan should be prepared to address surface erosion at the old open pit mine site in upper Molybdenite Creek and to reduce suspended sediment levels in the channel.

8.5 MCKUSKY CREEK

Watershed Characteristics

The McKusky Creek sub-basin has a watershed area of 31,000 ha and contains Crooked Lake *[Figure 6]*. Topographic relief is high on the northeast side of Crooked Lake and in the upper sub-basin.

Background Information

Past forest development extends to upper Crooked Lake. A large wildfire covers much of the northeast portion of the sub-basin, including some steep terrain above Crooked Lake, and in several tributary basins of lower McKusky Creek.

An impassable barrier upstream of McKinley Creek restricts access for salmon into the sub-basin. Fisheries agencies are concerned about the risk of increased peak flows, and sediment input from surface erosion and landslides.

The 1997 IWAP indicated a high potential landslide hazard rating in the sub-basin as a result of the landslide density.

Inventory Observations

In addition to the aerial reconnaissance overview (refer to aerial reconnaissance data forms) and field inventory procedures (field data forms), a helicopter overview was conducted in September 1997. Natural landslides have originated in the old burn along the northeast side of the sub-basin. Cosmosky Creek, the first major northern tributary downstream of Crooked Lake, has an increased bedload and debris supply from these natural landslides. A debris flow that has occurred in the channel caused an avulsion on the fan. Increased bedload particle size and volume was noted in McKusky Creek below the confluence. Wetland complexes on lower McKusky Creek will prevent this coarse sediment from reaching the Horsefly River.

The second major northern tributary downstream of the lake has an increase in bedload due to landslides. Elevated gravel and cobble bars were noted in the lower channel *[Site McKus4] [Photos McKus1 and McKus2]*. Coarse bedload will eventually reach McKusky Creek, however, no detectable change in bedload size or volume has occurred to date.

Extensive forest development (approximately 85% of the watershed area) has taken place in this small basin and numerous development related landslides have occurred *[Site McKus2] [Photo McKus3]*. The semi-permanently deactivation of roads in the basin appears to be satisfactory *[Site McKus3] [Photo McKus4]*.

McKusky Creek below Crooked Lake has a stable irregular channel. The riparian reserve is intact from Crooked Lake to the Horsefly River. With the exception of a minor, natural bedload input from Cosmosky Creek, the lower McKusky Creek channel is undisturbed.

Proposed Harvesting 1997-2001

Five percent of the McKusky Creek sub-basin is proposed for development from 1997 to 2001. The 1996 ECA of 15% would increase to 20%. Proposed road and blocks are concentrated on the lower and middle slopes of the sub-basin above Crooked Lake.

Inventory Interpretation

McKusky Creek below Crooked Lake is a stable, irregular channel. Besides a minor amount of coarse bedload introduced to the system from natural landslides in Cosmosky Creek, the lower channel is undisturbed.

Based on the frequency of observed landslides within logged and areas burned by wildfires, unstable terrain may exist on middle and upper slopes in the sub-basin.

Proposed forest development would increase the ECA from 15% to 20% by 2001. Roads and blocks are concentrated on lower valley slopes upstream of Crooked Lake. Increased peak flows in McKusky Creek are not anticipated.

New road construction on lower slopes close to the mainstem channel is a concern with regards to increased surface erosion and sediment transport to streams.

Recommendations

Refer to recommendations provided in Section 8.0.

8.6 MACKAY RIVER

Watershed Characteristics

The MacKay River sub-basin has drainage area of 14,400 ha, and a broad U-shaped glacial valley with numerous hanging tributary valleys. Hillslopes in the lower and middle sub-basin are de-coupled and partially coupled from the mainstem channel, respectively, and alluvial fans are present on all lower tributary streams *[Figure 7]*. Topographic relief is high, and the sediment delivery potential from landslides is high in the upper sub-basin and tributary valleys.

Background Information

There is no salmonid access to the MacKay River because of an impassable barrier 3.0 km upstream of McKinley Creek

Agency concern in the MacKay River sub-basin relates to minimizing the risk of increased peak flow and sediment supply levels. DFO is also concerned with an inactive Frasergold project (Eureka Gold Mine) on Eureka Brook regarding water quality impairment from cyanide, copper sulfate and sediment.

The 1997 IWAP calculated moderate potential surface erosion and landslide hazard ratings in the MacKay River sub-basin. The moderate surface erosion rating resulted from the length of road within 100 m of a stream and the number of active stream crossings, while the moderate landslide rating resulted from the density of landslides in the sub-basin.

Inventory Observations

In addition to the initial aerial reconnaissance overview (refer to aerial reconnaissance data forms) and field inventory procedures (field data forms), a helicopter overview was conducted in September 1997.

Large progressive clearcuts dominate the lower and middle slopes of the MacKay River sub-basin *[Photo MacKay1] [Site MacKay1]*. A riparian leave strip is present along the mainstem channel, however, tributary fans have been harvested.

Several natural and one pre-FPC road related bank failure has occurred on the lower incised mainstem channel above the Horsefly River confluence. Ditch line runoff from the MacKay mainline (built above the break in slope) was flowing onto the steep valley slope *[Site MacKay1]*. This drainage problem has been addressed.

The MacKay River above the incised reach is stable with boulder and bedrock control. Minor harvesting in the riparian zone has occurred at this location, however, no evidence of bank instability was noted *[Photos MacKay2 and MacKay3] [Site MacKay2].*

Past forest development has occurred in two of the main tributary valleys, Hawkley Creek and Pegasus Creek. The Hawkley Creek channel has remained stable in spite of logging on the alluvial fan and on steep slopes above the MacKay River valley *[Photo MacKay4] [Site MacKay3].*

In Pegasus Creek, landslides resulting from pre-FPC road construction and logging on unstable terrain has caused channel disturbance *[Photos MacKay5 and MacKay6] [Site MacKay7].* Increased bedload and woody debris has caused channel avulsions, and increased bank erosion. Coarse sediment and debris has deposited on the alluvial fan and no direct disturbance to the MacKay River was observed *[Photo MacKay7] [Site MacKay6].*

Semi-permanent road deactivation has been completed on pre-FPC access and spur roads in the sub-basin. Roads in the middle and upper sub-basin are built well away from the mainstem channel. Tension cracks were noted along roads in the Pegasus Creek drainage that have been semi-permanently deactivated.

Proposed Harvesting 1997-2001

Approximately 1.4% of the MacKay River sub-basin is proposed for harvesting from 1997 to 2001. The 1996 ECA of 14% will increase to approximately 15% by 2001. Proposed forest development is concentrated on lower valley slopes in the upper sub-basin.

Interpretations

The MacKay River is stable bedrock and boulder controlled channel.

Landslides have occurred in Pegasus Creek as a result of forest development on unstable terrain. Coarse sediment and debris was deposited in the channel, causing increased bank erosion and avulsions on the alluvial fan. No direct impact on the MacKay River was observed.

Based on observed landslides and the geomorphology of the sub-basin, potentially unstable kame terrace deposits may exist along the middle and lower slopes of the main valley, and on middle slopes in each tributary valley.

Considerable semi-permanent road deactivation has been completed in the sub-basin. Tension cracks were, however, observed on deactivated roads in Pegasus Creek.

Several failures have occurred on the lower mainstem of the MacKay River, one of which was related to the MacKay mainline road built above the break in slope.

The proposed level of forest development (1.4%) is low, however, proposed road construction on lower valley slopes is a concern for sedimentation in the MacKay River.

Recommendations

The following recommendations are provided in addition to those in Section 8.0.

1. Complete a road assessment in Pegasus Creek to determine deactivation requirements to restore natural hillslope drainage.

2. Complete a road assessment on the lower MacKay mainline to determine if adequate drainage structures are in place to maintain the natural hillslope drainage.

8.7 UPPER HORSEFLY RIVER (aka Horsefly River above MacKay Creek)

Watershed Characteristics

The Upper Horsefly River sub-basin has a drainage area of 14,100 ha and is dominated by steep slopes that are directly coupled to the mainstem channel *[Figure 7]*. Potential sediment delivery to the channel from landslides is high.

Background Information

Agencies are concerned about the risk of increased peak flows and sediment from landslides. There is no access for fish to the upper sub-basin due to an impassable barrier 3.0 km above McKinley Creek. The 1997 IWAP does not indicate any potential hazards from past forest development.

Inventory Observations

Suspended sediment in the upper Horsefly River was low during freshet. Large avalanches occur in the upper sub-basin, introducing woody debris and some sediment to the channel. No harvesting was observed in the riparian zone.

The channel, at the second road crossing upstream of the McKusky Creek confluence *[Site H3]*, is a stable sinuous channel with an old growth riparian zone. Lower reaches of the upper Horsefly River are sediment transport reaches *[Site H2] [Photos H1 and H2]*.

In the middle sub-basin, the channel is also stable, and the riparian zone is intact *[Sites H4 and H5] [Photos H3 and H4]*. The upper channel is alluvial and sensitive to increases in peak flow, sediment supply and riparian disturbance.

Roads in the sub-basin are built on the lower valley slopes close to the mainstem channel. Running surfaces are composed of fine-textured sand and gravel, and show evidence of surface erosion. Sediment sumps are infrequent at cross-drains or stream crossings, and where present, require maintenance *[Site H6] [Photo H5]*. The input of sediment (sand) to the channel was noted at cross-drain locations *[Site H7] [Photo H6]*

Two small road-related landslides were observed in a post-FPC block *[Site H7]*. Both slides originated at spur roads or landings, but did not terminate in the channel.

Proposed Harvesting 1997-2001

Based on the proposed development, the 1996 ECA of 3.0% would increase to 6.0% by 2001. Proposed blocks would be concentrated on lower and middle slopes. Access would be developed adjacent to the channel.

Inventory Interpretation

The mainstem channel in the upper Horsefly River sub-basin is stable and the riparian zone is intact. Suspended sediment concentrations were low during freshet.

Roads on lower valley slopes contribute fine sediment to the mainstem channel. Sumps at cross-drains and stream crossings are infrequent, and where present, require maintenance.

Two road-related landslides have occurred in the sub-basin but did not impact any streams. Unstable terrain may exist on middle and upper slopes.

Three percent of the sub-basin is proposed for development over the next five years. Road construction on lower slopes adjacent to the channel is a concern with regard to potential increased sedimentation.

Recommendations

Refer to recommendations provided in Section 8.0.

MM/ac/dd/jb

CARIBOO REGION WATERSHED INVENTORY

HORSEFLY RIVER WATERSHED ABOVE HORSEFLY

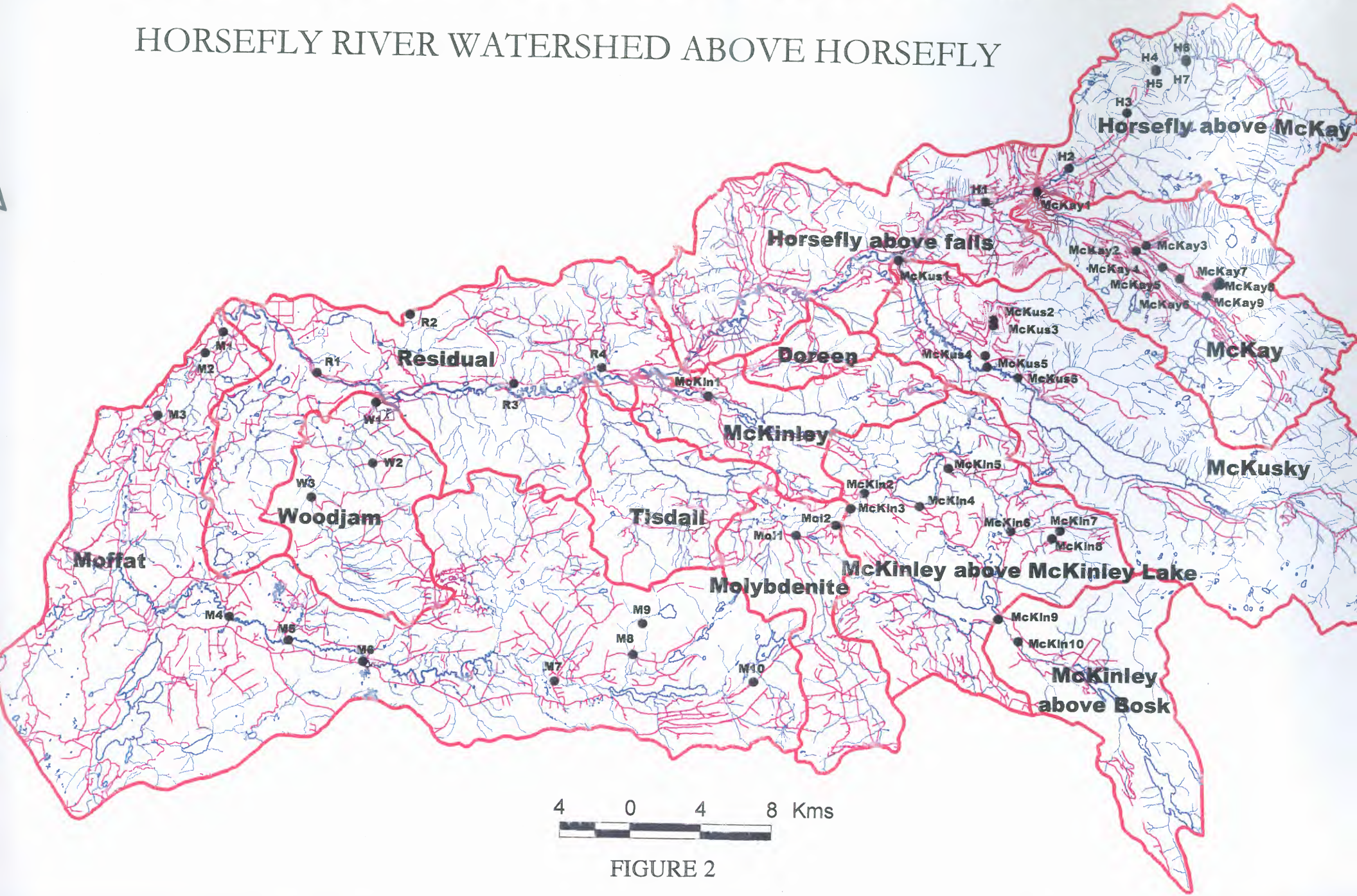


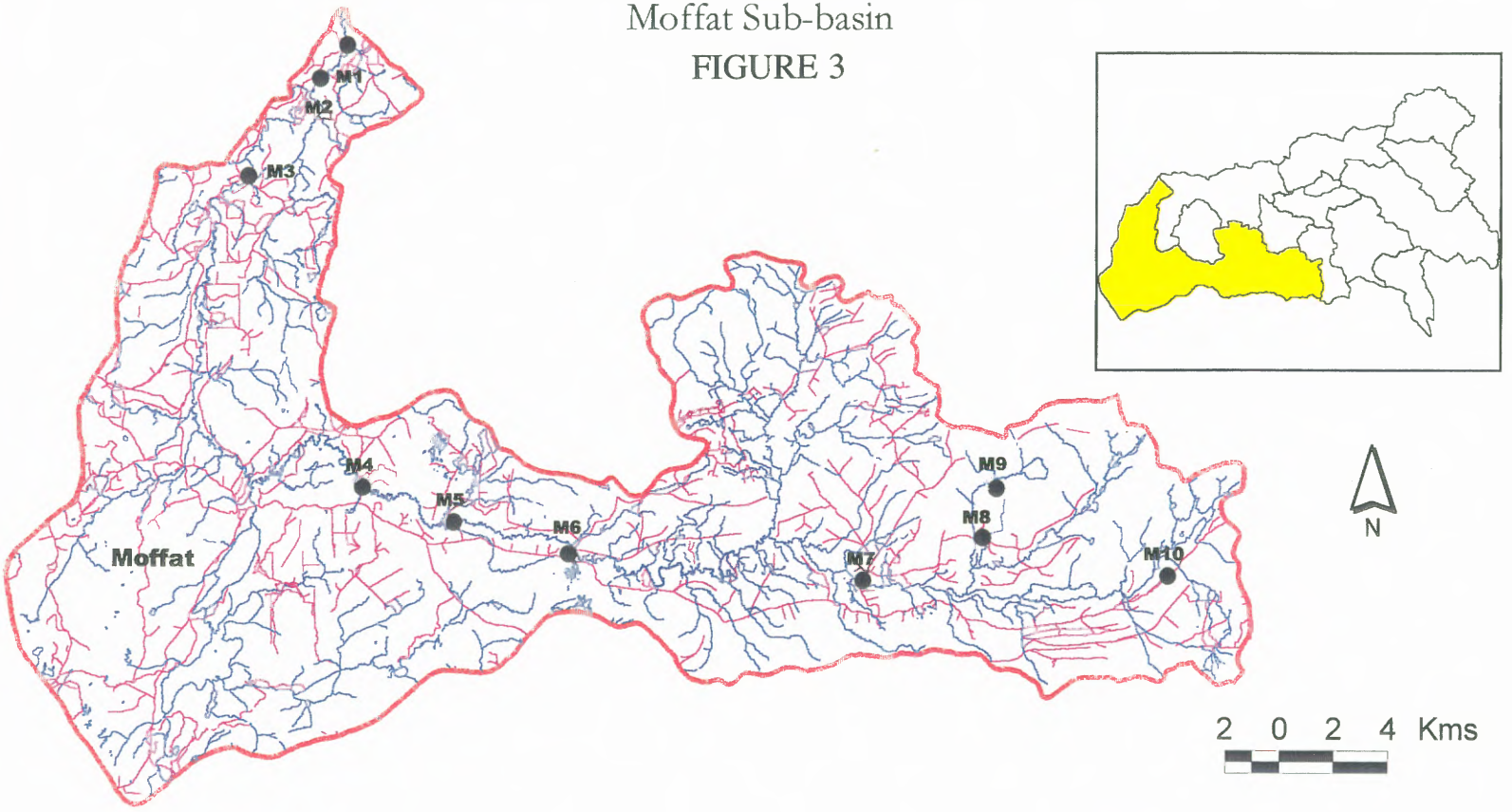
FIGURE 2

CARIBOO REGION WATERSHED INVENTORY

HORSEFLY RIVER WATERSHED ABOVE HORSEFLY

Moffat Sub-basin

FIGURE 3



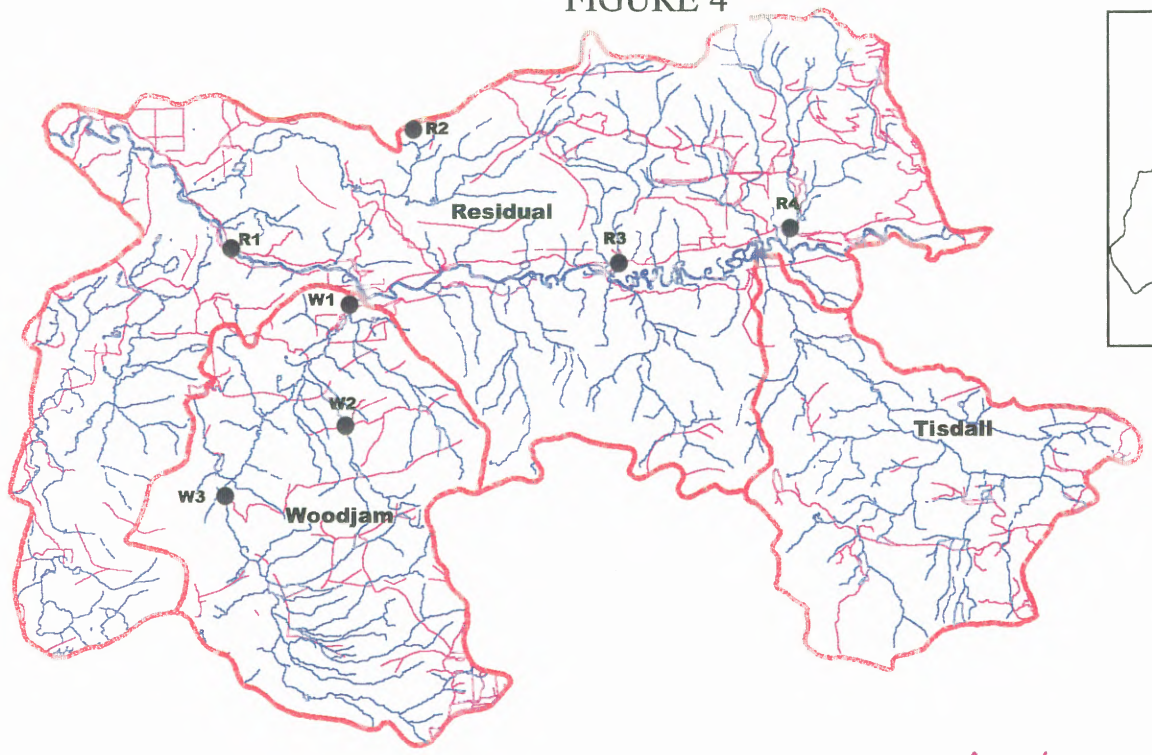
Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by Inland Timber Management Ltd. (Williams Lake, BC)
October 31, 1997

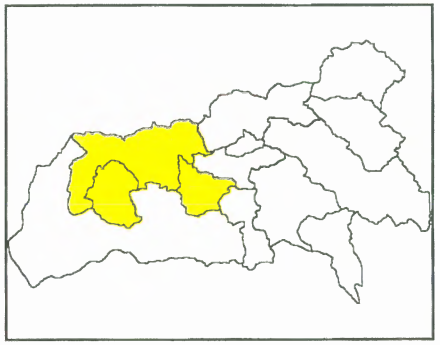
CARIBOO REGION WATERSHED INVENTORY

HORSEFLY RIVER WATERSHED ABOVE HORSEFLY

Woodjam, Tisdall, and Residual Sub-basins

FIGURE 4





N

2 0 2 4 Kms

Roads

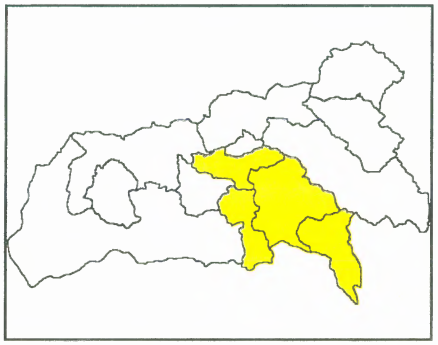
Location of channel and road assessments, and photos referenced within text

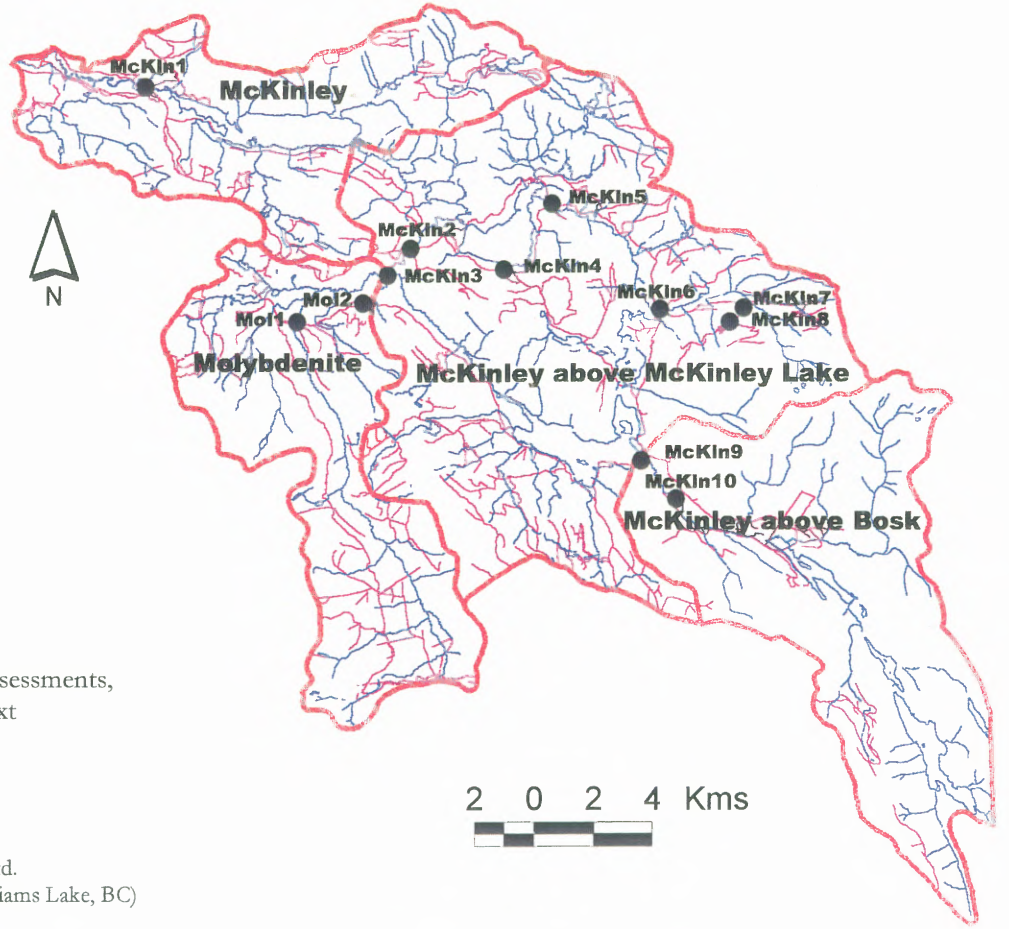
Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by Inland Timber Management Ltd. (Williams Lake, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

HORSEFLY RIVER WATERSHED ABOVE HORSEFLY
Molybdenite and McKinley Sub-basins

FIGURE 5





Roads

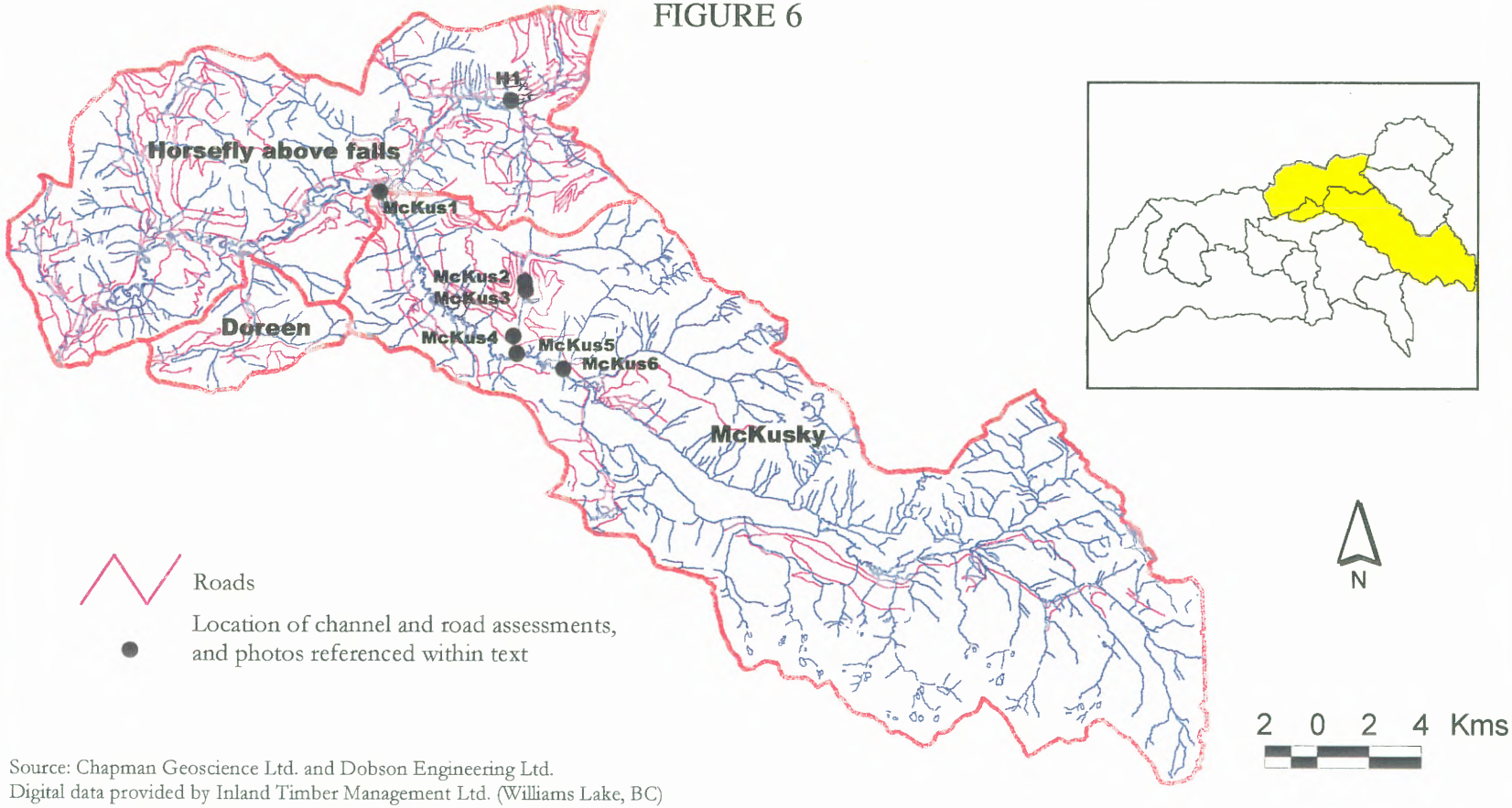
Location of channel and road assessments, and photos referenced within text

Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by Inland Timber Management Ltd. (Williams Lake, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

HORSEFLY RIVER WATERSHED ABOVE HORSEFLY
Doreen, McKusky, and Horsefly (above falls) Sub-basins

FIGURE 6



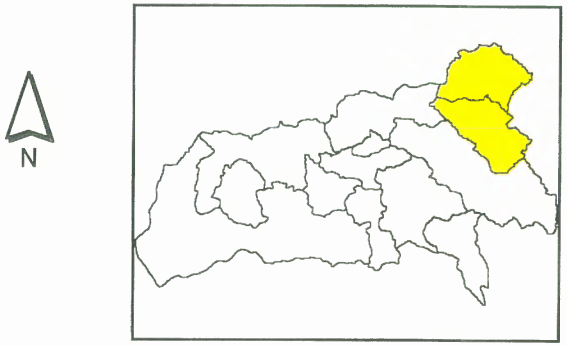
Source: Chapman Geoscience Ltd. and Dobson Engineering Ltd.
Digital data provided by Inland Timber Management Ltd. (Williams Lake, BC)
October 31, 1997

CARIBOO REGION WATERSHED INVENTORY

HORSEFLY RIVER WATERSHED ABOVE HORSEFLY

McKay and Horsefly (above McKay) Sub-basins

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 Inland Timber Management Ltd. (Williams Lake, BC)
October 31, 1997

TABLE 1
Horsefly River Watershed

Watershed or Sub-basin	Drainage Area (ha)	Physiographic Region	Biogeoclimatic Zone	Fish Resource	Tenure (%)[1]	
					Crown	Private
Horsefly River above town of Horsefly	212,000	Cariboo Plateau 50%) Quesnel Highland (50%)	SBS (40%) ICH & ESSF	sockeye, coho chinook, trout	97	3
Horsefly River above falls	78,500	Quesnel Highland	ICH ESSF	trout	100	0
Horsefly River above McKay	14,100	Quesnel Highland	ICH & ESSF AT (50%)	trout	100	0
McKay River at the mouth	14,400	Quesnel Highland	ICH & ESSF AT (30%)	trout	100	0
McKusky Creek at the mouth	31,100	Quesnel Highland	ICH (50%) ESSF(50%	trout	100	0
McKinley Creek above McKinley Lake	36,800	Quesnel Highland	ICH (60%) ESSF(40%)	sockeye, coho chinook, trout	100	0
McKinley Creek above Bosk Lake	10,700	Cariboo Plateau	ESSF		100	0
Moffat Creek at the mouth	52,200	Cariboo Plateau	SBS (70%) ESSF (30%)	sockeye	94	6
Woodjam Creek at the mouth	8,600	Cariboo Plateau	SBS (80%) ESSF (20%)	sockeye	96	4

1. The land tenure information presented here is as reported in the Horsefly River IWAP.

TABLE 3
Horsefly River Watershed

Watershed or Sub-basin	IWAP (1996 data)						Other Land Use [1]		
	ECA %	Road Density km/km^2	Peak Flow	Surface Erosion	Riparian	Mass Wasting	Agriculture	Placer	Other
Horsefly River above town of Horsefly	13	0.74	L	L-M	L	M	M[2]	M[3]	
Horsefly River above falls	17	0.66	L	L-M	L	H	L	L	
Horsefly River above McKay	3	0.25	L	L	L	L	L	L	
McKay River at the mouth	14	0.92	L	M	L	M	L	L	mine
McKusky Creek at the mouth	15	0.41	L	L	L	H	L	L	
McKinley Creek above McKinley Lake	15	0.84	L	L	L	L	L	L	
Molybdenite C. above McKinley R.	13	0.91	L	L	M	n/a	L	L	mine
McKinley River above Bosk Lake	5	0.41	L	L	M	M	L	L	
Moffat Creek at the mouth	11	0.92	L	L	L	L	H	L	
Woodjam Creek at the mouth	4	0.21	L	L	L	L	M	L	

1. The hazards as presented in the Level 1 IWAP are shown as L=low, M=moderate, and H=high.
2. The categories of "Other Land Use" are qualified as L=low, M=moderate, or H=high concern for thre activity, as expressed by various agency representatives.

TABLE 4
Horsefly River Watershed

Watersheds and Sub-Basins	Drainage Area	1996 ECA		Proposed Harvesting 1997-2001 2001 ECA		ECA Change 1997-2001
	ha	ha	%	ha	%	%
Horsefly River above town of Horsefly	212,400	27,500	12.9	44,500	21.0	8.0
Horsefly River above the Falls	78,500	13,200	16.8	16,700	21.3	4.5
Horsefly River above McKay River	14,100	400	2.8	900	6.4	3.5
McKay River at the mouth	14,400	2,000	13.9	2,200	15.3	1.4
McKusky Creek at the mouth	31,100	4,700	15.1	6,200	19.9	4.8
McKinley Creek at the mouth	44,300	6,100	13.8	8,200	18.5	4.7
McKinley Creek above McKinley Lake	36,800	5,400	14.7	7,100	19.3	4.6
Molybdenite Creek at the mouth	7,900	1,000	12.7	2,000	25.3	12.7
McKinley Creek above Bosk Lake	10,700	500	4.7	500	4.7	0.0
Moffat Creek at the mouth	52,600	5,500	10.5	11,600	22.1	11.6
Woodjam Creek at the mouth	8,600	300	3.5	1,900	22.1	18.6

WATERSHED: HORSEFLY **SUB-BASIN:** MOFFAT CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion
SURFACE EROSION	Not evident	Not evident	Not evident
	Road Related	**Cut-block Related**	**State Active/Healed**
LANDSLIDES	Not evident	Not evident	n/a
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**
STREAM AND RIPARIAN	Natural bank failures; channel widening,	Agricultural clearing on lower channel	Wide, shallow channel; Cleared riparian; Livestock access; Large, elevated bars
	% Harvest (Low <0, Mod 10-25, High >25)		
PEAK FLOW	Low.		
COMMENTS	Highly unstable in lower agricultural reaches; extensive bank erosion and channel widening; large bars are evident. Appears stable in forested reaches.		

WATERSHED: HORSEFLY **SUB-BASIN:** MAINSTEM (From McKusky to top end)

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	No instability noted.			Avalanche impacts upstream.
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	Level of harvest undetermined.			
COMMENTS	Clean flow in Horsefly River upstream of McKay River.			

WATERSHED: HORSEFLY **SUB-BASIN:** MCKAY RIVER

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	One failure a block boundary into mainstem.	Active	Failures into Pegasus Creek.
	Bank Stability	**Riparian Land Use**	**Disturbance Evidence**	**Other**
STREAM AND RIPARIAN		Hawkley Creek logged to banks.		
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	Level of harvest undetermined.			
COMMENTS				

WATERSHED: HORSEFLY **SUB-BASIN:** MCKINLEY CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Into McKinley Creek.	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	No bank failures noted.	Agriculture at lower end.	McKinley aggraded at inlet to Horsefly River.	
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	Level of harvest undetermined.			
COMENTS				

WATERSHED: HORSEFLY **SUB-BASIN:** MOLYBDENITE CREEK

WAP CATEGORY HAZARDS	Sediment Plume	Road Surface Erosion	Landslide Erosion	Other
SURFACE EROSION	Into McKinley Creek.	Not evident	Not evident	Turbid flow out of inactive mine area at top end of creek.
	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	No instability noted.			
	% Harvest (Low <0, Mod 10-25, High >25)			**Other**
PEAK FLOW	Level of harvest undetermined.			
COMMENTS				

WATERSHED: HORSEFLY **SUB-BASIN:** MOFFAT CREEK

Stop M1. Moffat Creek, approximately 1.5 upstream of the Horsefly mainstem.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool	Aggraded, unstable.	Gradient.	Fluvial, glaciofluvial, gravel.
DISTURBANCE INDICATORS: Extensively eroding banks; large, elevated mid-channel bars.			
COMMENTS: Extremely disturbed. Is a low gradient deposition reach upstream of the Horsefly, heavily aggraded. Land use-related bank erosion is occurring. Cattle trampling of banks is evident.			

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

WATERSHED: HORSEFLY **SUB-BASIN:** MOFFAT CREEK

Stop M2. Moffat Creek, approximately 4 km upstream of the Horsefly River.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel	Moderately aggraded.	Gradient.	Fluvial, gravel.
DISTURBANCE INDICATORS: Eroding banks, large point bar, mid-channel bar.			
COMMENTS: Disturbed; extensive bank erosion is apparent; cattle trampling of banks is evident.			

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

WATERSHED: HORSEFLY **SUB-BASIN:** MOFFAT CREEK

Stop M3. Upper Moffat Creek.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, cobble	Stable.	Gradient.	Fluvial.
DISTURBANCE INDICATORS: None.			
COMMENTS: No disturbance evident.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Forested.
COMMENTS: Appears natural and undisturbed.	

WATERSHED: HORSEFLY **SUB-BASIN:** MOFFAT CREEK

Stop M4. Upper Moffat Creek, approximately 6 km upstream of M3

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, cobble	Stable.	Gradient.	Fluvial
DISTURBANCE INDICATORS: None.			
COMMENTS:.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None.	Forested.
COMMENTS: Appears natural and undisturbed.	

WATERSHED: HORSEFLY **SUB-BASIN:** MOFFAT CREEK

Stop M5. Upper Moffat Creek, approximately 7 km upstream of M4

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool, cobble	Stable.	Gradient.	Fluvial
DISTURBANCE INDICATORS: None.			
COMMENTS: No disturbance evident			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Forested
COMMENTS: Appears natural and undisturbed.	

WATERSHED: HORSEFLY **SUB-BASIN:** MOFFAT CREEK

Stop M6. Moffat Creek, approximately 10 km upstream of M5.

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-Pool, cobble/boulder	Stable.	Gradient.	Fluvial, till.
DISTURBANCE INDICATORS: None			
COMMENTS: No disturbance is apparent.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Forested
COMMENTS: Appears natural and undisturbed.	

WATERSHED: HORSEFLY **SUB-BASIN:** WOODJAM CREEK

Stop W1. Woodjam Creek, approximately 200 m upstream of the Horsefly River

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-Pool	Stable.	Gradient.	Fluvial, sand
DISTURBANCE INDICATORS: Some bank erosion is evident, related to proximal clearing and agriculture.			
COMMENTS: The riparian areas have been cleared and used for crop production. Bank disturbance has occurred.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Private, agriculture (crop)	Cleared.
COMMENTS:	

WATERSHED: HORSEFLY **SUB-BASIN:** WOODJAM CREEK

Stop W2. Upper Woodjam Creek

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel	Stable.	Gradient.	Fluvial, gravel.
DISTURBANCE INDICATORS: Extensive sand aggradation behind LWD.			
COMMENTS: The sand appears to be coming from the upstream road. Sand was much less evident upstream of the road.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Forested, except at road crossing.
COMMENTS:	

WATERSHED: HORSEFLY **SUB-BASIN:** UPPER HORSEFLY RIVER

Stop 2. Upper Horsefly River. (Map 93A/7 - 8, Photos 3 and 4)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Sinuous - gravel bed	Stable	Gradient and LWD.	Stable sand and gravel.
DISTURBANCE INDICATORS: None			
COMMENTS: Banks stable for the most part, but some minor natural slumps noted. Debris jams frequently spaced from avalanche delivery. Overbank sand deposition from this years flood.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Old growth conifer and willow layer.
COMMENTS:	

WATERSHED: HORSEFLY **SUB-BASIN:** UPPER HORSEFLY RIVER

Stop 1. Lower mainstem in upper Horsefly River. (Map 93A/7 - 8, Photos 1 and 2)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Sinuous - boulder bed	Stable	Gradient	Stable fluvial boulder and cobble.
DISTURBANCE INDICATORS: None			
COMMENTS: Limited sediment input at the crossing, but some sand deposition in the backwater areas.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Stable
COMMENTS: Riparian reserve of one channel width would be appropriate.	

WATERSHED: HORSEFLY **SUB-BASIN:** MCKAY RIVER

Stop 1. First road crossing above the mouth (Map 93A/7, Photos 2 and 3)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Sinuous - Regular - Boulder bed	Stable	Gradient and bedrock and boulder.	Stable bedrock and boulder.
DISTURBANCE INDICATORS: None			
COMMENTS: Sand deposition in lower gradient sections. Bed materials are stable bolder and cobble. Some fines input from roads.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Harvest to one bank.	Stable
COMMENTS: Although harvest has occurred to one bank, all appears stable.	

WATERSHED: HORSEFLY **SUB-BASIN:** PEGASUS CREEK

Stop 1. Pegasus Creek fan. (Map 93A/7, Photos 5 - 7)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Step-pool, cobble/wood.	Moderately aggraded.	Gradient and LWD.	Unstable.
DISTURBANCE INDICATORS: (B1) Abandoned channels, (B3) Eroding banks, (B3) Avulsions, (D3) Recently formed debris jams.			
COMMENTS: Significant debris buildup from upslope slides. Jams have caused avulsions into abandoned channels. Bank scour is adding coarse sediment to McKay mainstem.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logging	Harvested to both banks and rest of fan.
COMMENTS: Almost entire fan had been logged.	

WATERSHED: HORSEFLY **SUB-BASIN:** MCKUSKY CREEK

Stop 2. Second major tributary to McKusky Creek. (Map 93A/7, Photos 1 and 2)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, boulder.	Moderately aggraded.	Gradient and LWD.	Unstable.
DISTURBANCE INDICATORS: Many logging related slides into mainstem.			
COMMENTS: Moderate amount of logging input woody debris.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logging to both banks.	Logged to both banks.
COMMENTS:	

WATERSHED: HORSEFLY **SUB-BASIN:** MCKINLEY CREEK

Stop 1. McKinley Creek at the 500 road crossing. (Map 93A/6, Photos 2 and 3)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, gravel.	Stable	Gradient	Stable fluvial gravel and cobble.
DISTURBANCE INDICATORS: None			
COMMENTS: Bed materials dark oxidized materials and stable.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Undisturbed mixed wood forest.
COMMENTS: All appears stable.	

WATERSHED: HORSEFLY **SUB-BASIN:** MCKINLEY CREEK

Stop 2. McKinley Creek downstream of Molybdenite Creek confluence.
(Map 93A/6, Photos 4 and 5)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, cobble/wood.	Slightly aggraded.	Gradient and LWD.	Eroding till and fluvial gravel and cobble.
DISTURBANCE INDICATORS: (B2) Eroding banks, (D2) LWD parallel to channel.			
COMMENTS: Recent blowdown input, imbercated gravel and cobble bed, high sand load possibly from road erosion and/or mine site input from Molybdenite drainage.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Intact conifer and deciduous shrub.
COMMENTS: Recent blowdown has occurred along banks.	

WATERSHED: HORSEFLY **SUB-BASIN:** BASSETT CREEK

Stop 1. Bassett Creek downstream of 500 road crossing. (Map 93A/6)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Step-pool, boulder/wood.	Slightly aggraded.	Gradient, bedrock and boulder.	Eroding
DISTURBANCE INDICATORS: (B2) Eroding banks.			
COMMENTS: Banks below bridge are unstable, possibly due to high flows this year. Sand bed load present.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Old growth forest.
COMMENTS: Old growth exists below bridge crossing.	

WATERSHED: HORSEFLY **SUB-BASIN:** BASSETT CREEK

Stop 2. Upper Bassett Creek. (Map 93A/6)

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

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Logging	Stable
COMMENTS: Where harvest has occurred, intact riparian reserves exist.	

WATERSHED: HORSEFLY **SUB-BASIN:** MCKINLEY CREEK

Stop 3. McKinley Creek upstream of Bosk Lake. (Map 93A/6, Photos 6-9)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, sand/gravel/wood.	Stable	Gradient and LWD.	Unstable
DISTURBANCE INDICATORS: None			
COMMENTS: LWD providing minor control, some minor bank slumping occurring at this site. Small woody debris derived from beaver activity and logging.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
None	Stable coniferous deciduous forest.
COMMENTS: Riparian stable at this site.	

WATERSHED: HORSEFLY **SUB-BASIN:** MCKINLEY CREEK

Stop 4. Upstream of Bosk Lake. (Map 93A/6, Photos 6-9)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Riffle-pool, sand/gravel/wood.	Stable	Gradient and LWD.	Stable
DISTURBANCE INDICATORS: None			
COMMENTS:			

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

WATERSHED: HORSEFLY **SUB-BASIN:** MOLYBDENITE CREEK

Stop 1. Approximately 100 metres downstream of 550 South road crossing.
(Map 93A/2 , Photos 3 and 4)

CHANNEL INFORMATION			
CHANNEL TYPE	**CONDITION**	**CONTROL**	**BANKS**
Cascade-pool, cobble/gravel/wood	Moderately aggraded.	Gradient and LWD.	Eroding gravel and cobble.
DISTURBANCE INDICATORS: (B1) Abandoned channels, (B2) Eroding banks, (C3) Elevated mid channel bars, (C4) Multiple channels or braids, (D1) Small woody debris, (S2) Sediment fingers.			
COMMENTS: Increase in coarse bed load movement resulting from eroding banks. LWD providing moderate to high channel control. Fresh overbank sand deposits.			

RIPARIAN INFORMATION	
LAND USE	**CONDITIONS**
Harvested to both banks at this site.	Alder and willow with small conifers.
COMMENTS: Alder and willow not providing adequate bank stability.	

SITE M1A. Lower Moffat Creek. Bank erosion into fine-grained fluvial sediment is extensive. Channel widening and lateral shifting is occurring.

SITE M1B. Lower Moffat Creek. Extensive bank erosion along a reach used for livestock grazing.

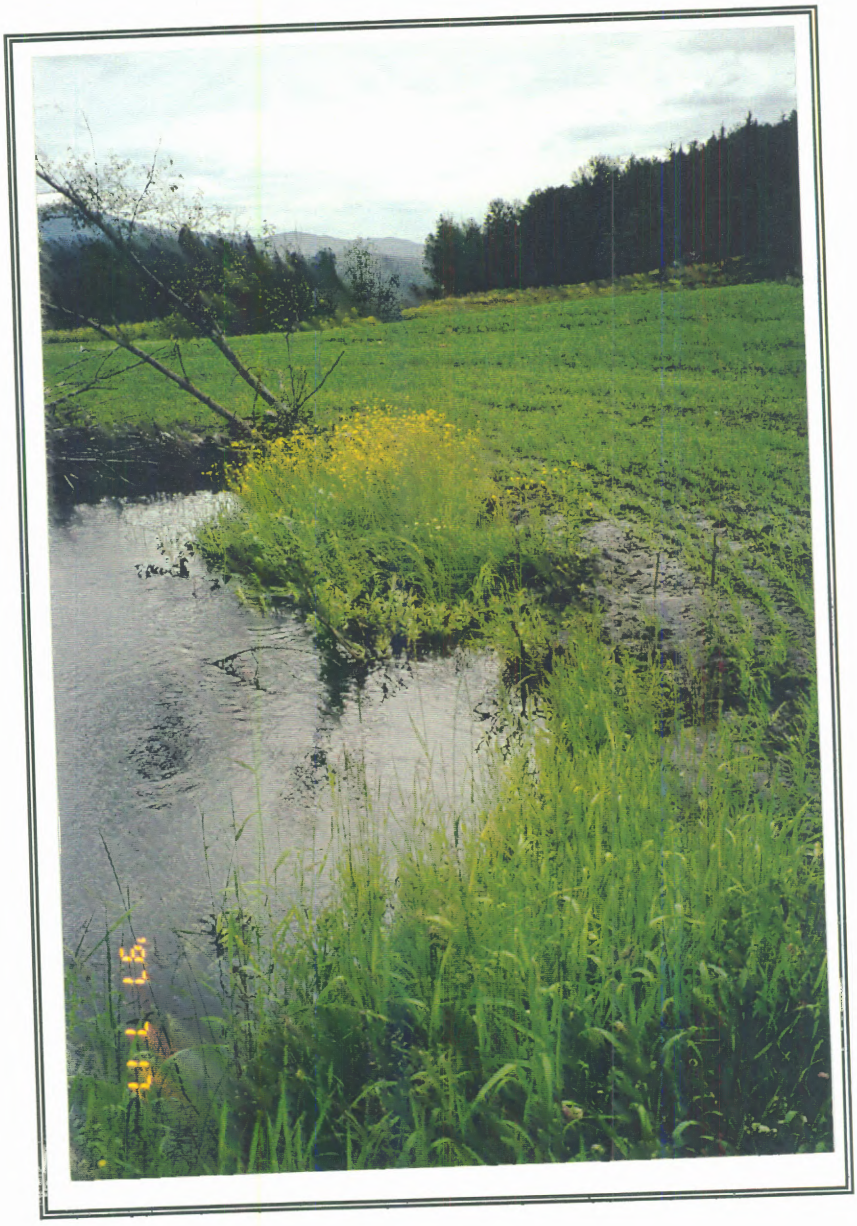
SITE M2. Moffat Creek, approximately 2 km upstream of site M1. Note the bank erosion.

SITE M5. Mid Moffat Creek. A stable, undisturbed alluvial reach

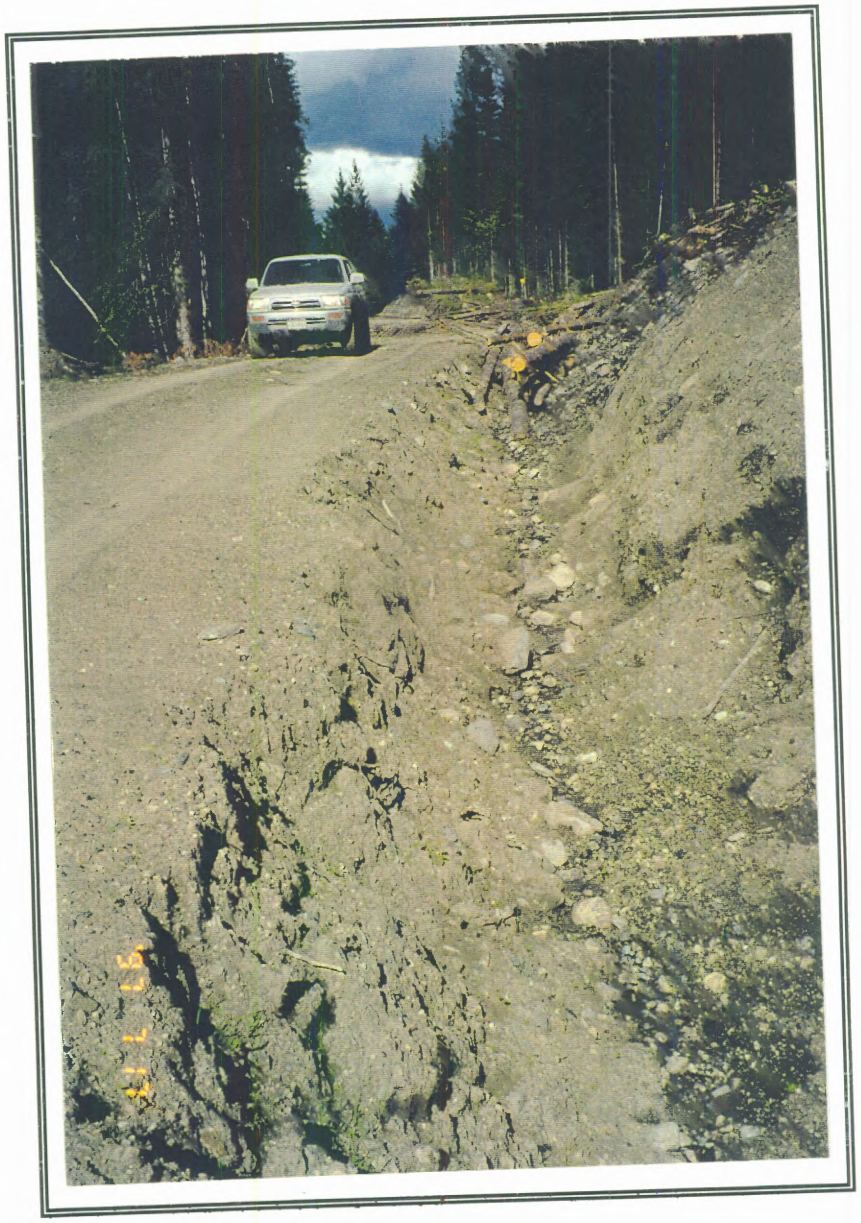
SITE R3. Horsefly River below Black Creek. Bank erosion is occurring along alluvial, floodplain reaches cleared for agricultural purposes.

SITE R4A. Black Creek, on its alluvial fan about 300 m upstream of the Horsefly River. Note the bank erosion.

SITE R4B. Aerial view of the mouth of the Black Creek fan. Note the aggradation of gravel. This material has eroded from the fan immediately upstream, and from the placer mining operation about 1 kilometre upstream.



SITE W1. Lower Woodjam Creek, about 300 m upstream of the Horsefly River. Crop production within a metre of the stream bank has caused bank erosion. In addition, the loss of riparian vegetation along this reach allows sediment to enter directly from the adjacent field, and has resulted in a loss of shading.



SITE W2. Ditch scour on new road in Woodjam creek.

SITE MCKIN1. McKinley Creek mainstem, below McKinley Lake. Abundant sockeye salmon.

PHOTO MCKIN1. Overview of lower McKinley Creek below McKinley Lake. Stable old growth riparian zone and no evidence of channel instability.

PHOTO MCKIN2. Lower McKinley Creek below McKinley Lake - upstream *[Site McKin1].*

PHOTO MCKIN3. Lower McKinley Creek with stable banks and in tact riparian zone *[Site McKin1].*

PHOTO MCKIN4. McKinley Creek above Molybdenite Creek - upstream *[Site McKin3].*

PHOTO MCKIN5. Recent blowdown and bank erosion on McKinley Creek above Molybdenite Creek - downstream *[Site McKin3].*

PHOTO MCKIN6. Harvesting in the riparian zone with no bank instability on McKinley Creek immediately above Bosk Lake - upstream *[Site McKin9].*

PHOTO MCKIN7. Stable, low gradient reach on McKinley Creek above Bosk Lake - downstream *[Site McKin9].*

PHOTO MCKIN8. McKinley Creek above Bosk Lake - upstream *[Site McKin10].*

PHOTO MCKIN9. McKinley Creek above Bosk Lake showing stable, old growth riparian zone *[Site McKin10].*

PHOTO MCKIN10. Severe ditch erosion as a result of ditch block failure on deactivated road in the Bassett Creek basin *[Site McKin6]*.

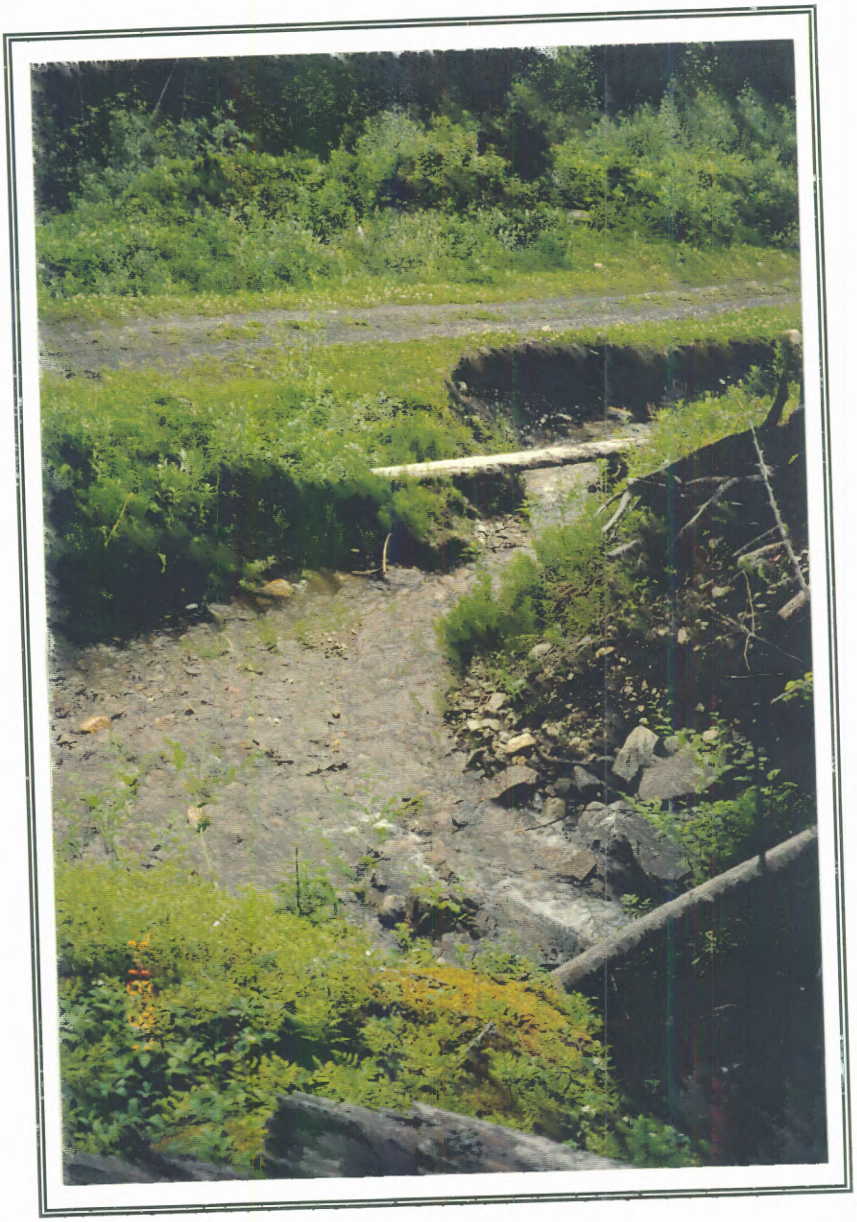


PHOTO MCKIN11. Erosion of the road grade in Bassett Creek basin *[Site McKin6].*

PHOTO MCKIN12. Ditch erosion resulting from infrequent cross drain use and long uninterrupted ditch line *[Site McKin9].*

PHOTO MOLY1. Overview of middle and lower Molybdenite sub-basin showing high suspended sediment concentration during freshet.

PHOTO MOLY2. Old open pit mine in upper Molybdenite Creek showing bank and bed scour in tributary stream.

PHOTO MOLY3. Lower Molybdenite Creek showing unstable banks, harvesting in the riparian zone and aggradation (mid-channel bar) *[Site Mol1].*

PHOTO MOLY4. Aggradation, channel widening and multiple channels on lower Molybdenite Creek *[Site Mol1].*

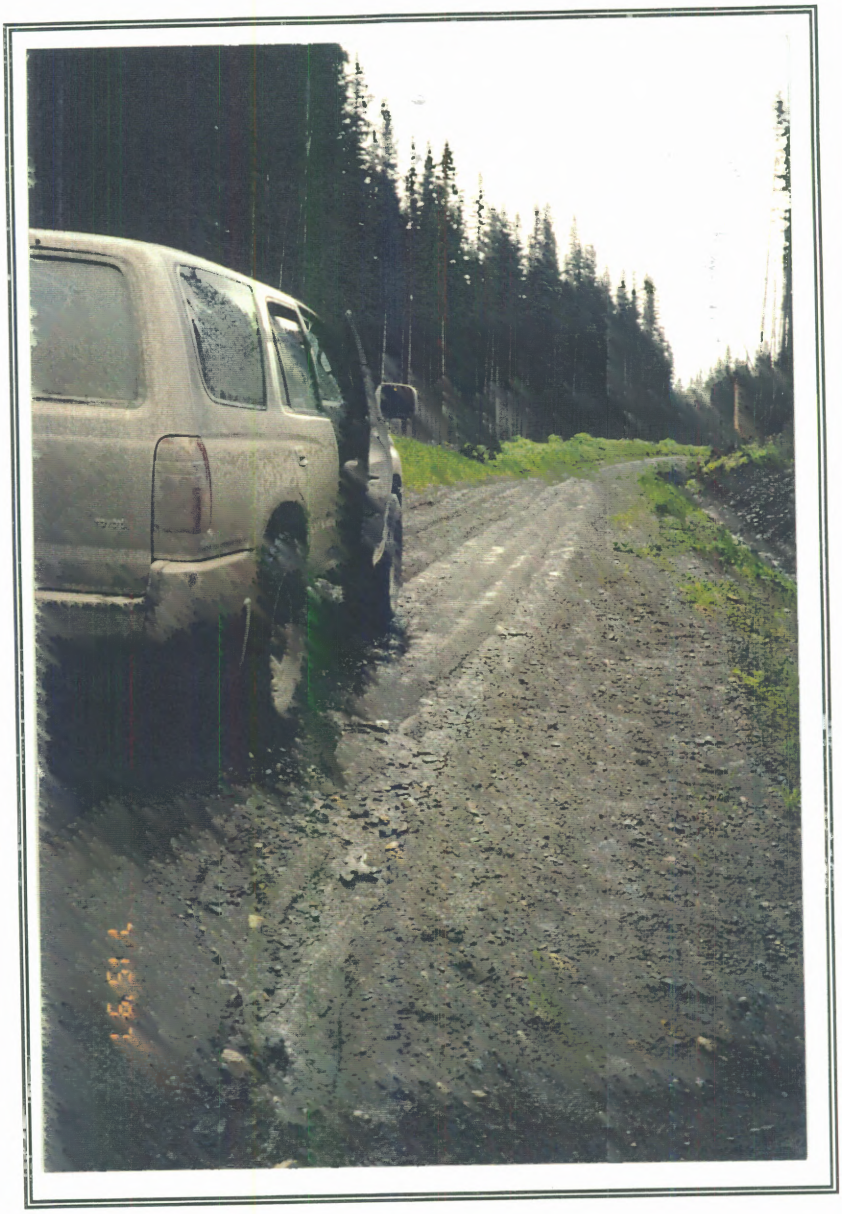


PHOTO MOLY5. Eroding running surface on road built with fine textured native material in lower Molybdenite Creek *[Site Mol2].*

PHOTO MCKUS1. Second northern tributary downstream of Crooked Lake in the McKusky Creek sub-basin. Increased bedload from upstream landslides *[Site McKus4].*

PHOTO MCKUS2. Buried large woody debris from increased bedload supply in second northern tributary downstream of Crooked Lake *[Site McKus4].*

PHOTO MCKUS3. Extensive harvesting and multiple bank slumps and landslides in second northern tributary downstream of Crooked Lake *[Site McKus2].*

PHOTO MCKUS4. Semi-permanent deactivation on road in second major northern tributary downstream of Crooked Lake *[Site McKus3].*

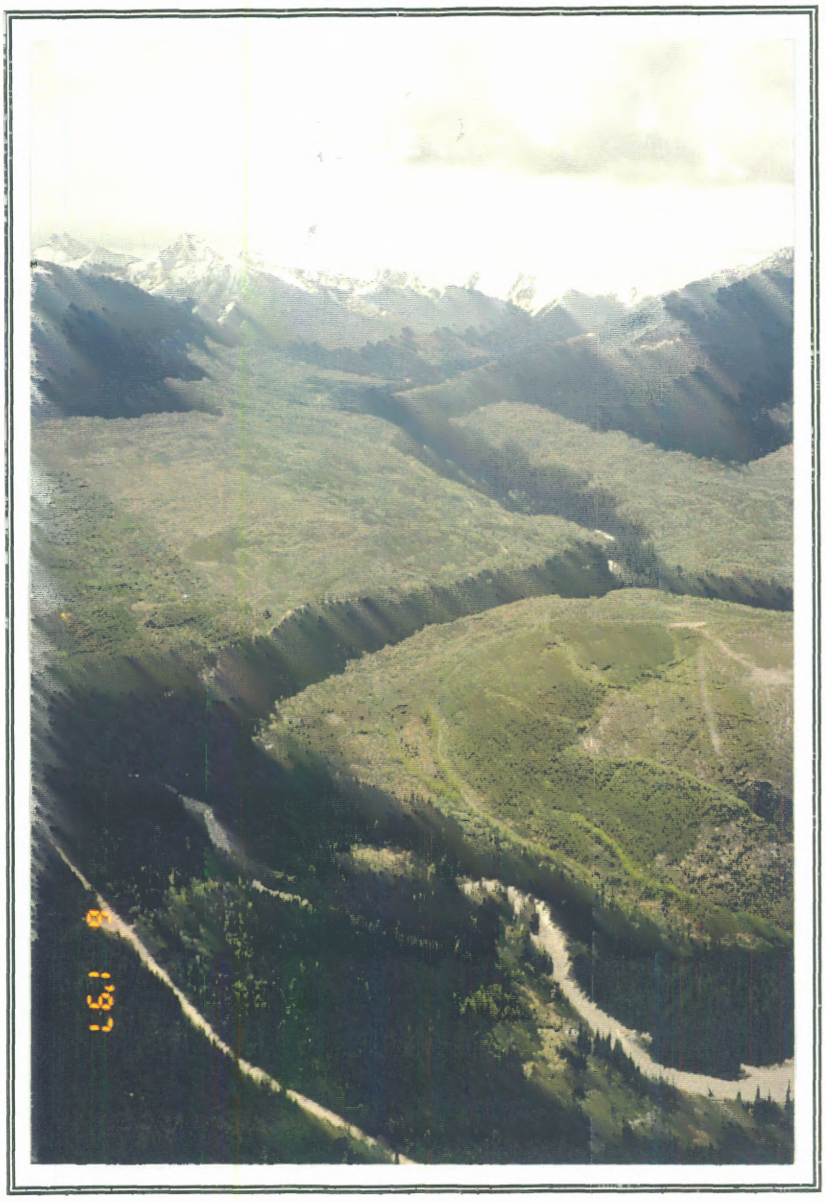


PHOTO MCKAY1. Lower McKay River showing riparian leave strip along mainstem channel and large progressive clearcuts in the lower basin *[Site McKay1].*

PHOTO MCKAY2. Stable boulder and bedrock controlled reach of the lower McKay River - upstream *[Site McKay2].*

PHOTO MCKAY3. Old growth riparian zone and stable banks on lower McKay River - downstream *[Site McKay3].*

PHOTO MCKAY4. Lower Hawkley Creek - stable in spite of harvesting in upstream riparian zone*[Site McKay3]*.

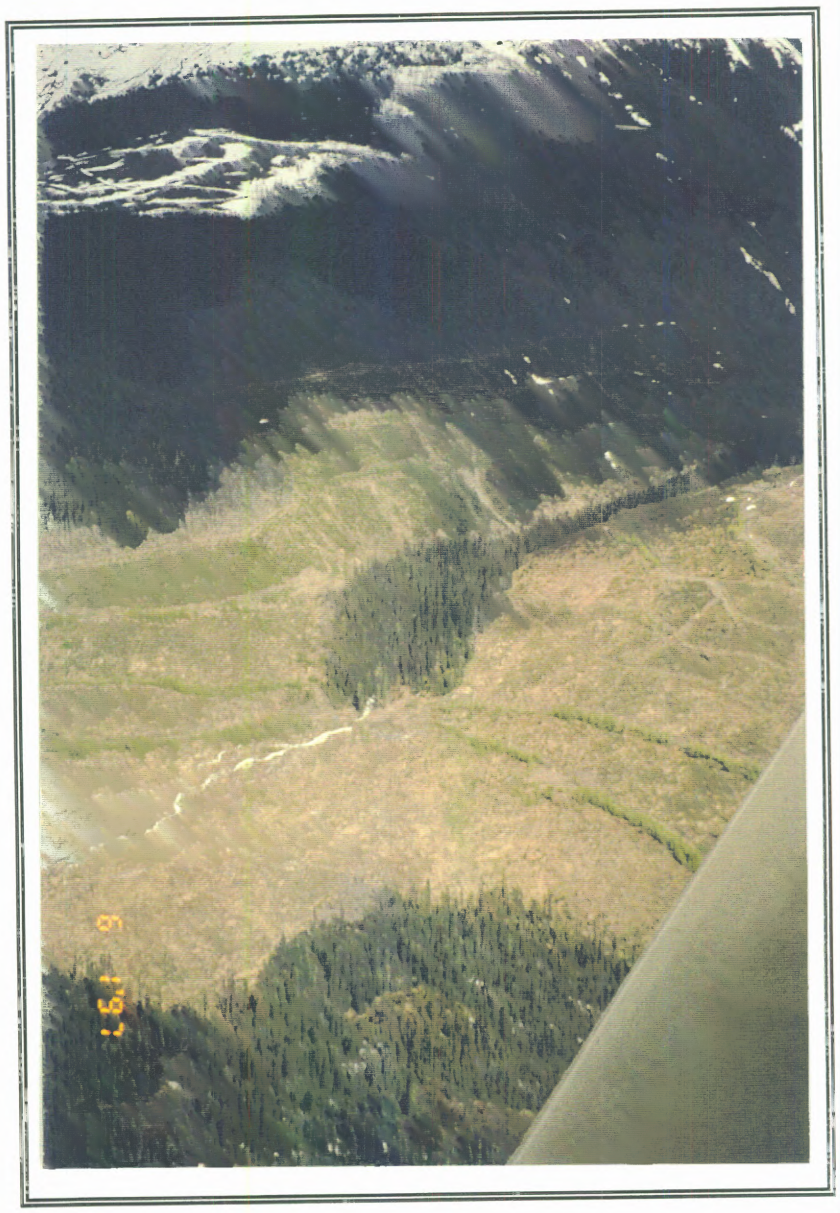


PHOTO MCKAY5. Extensive development on unstable terrain in Pegasus Creek. Multiple landslides into channel and riparian harvesting on the alluvial fan *[Site McKay8].*

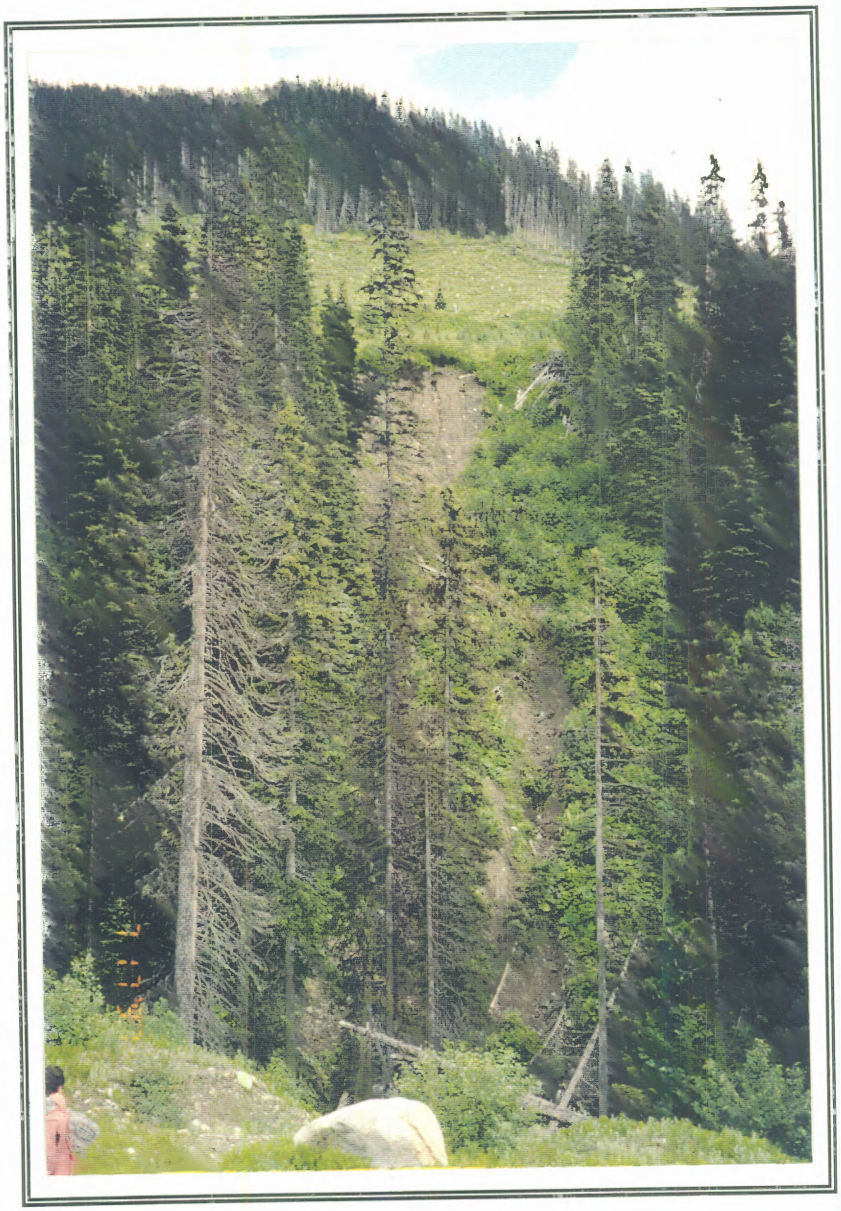


PHOTO MCKAY6. Landslide from old landing into Pegasus Creek *[Site McKay9].*

PHOTO MCKAY7. Pegasus Creek alluvial fan with two active channels *[Site McKay 6].*

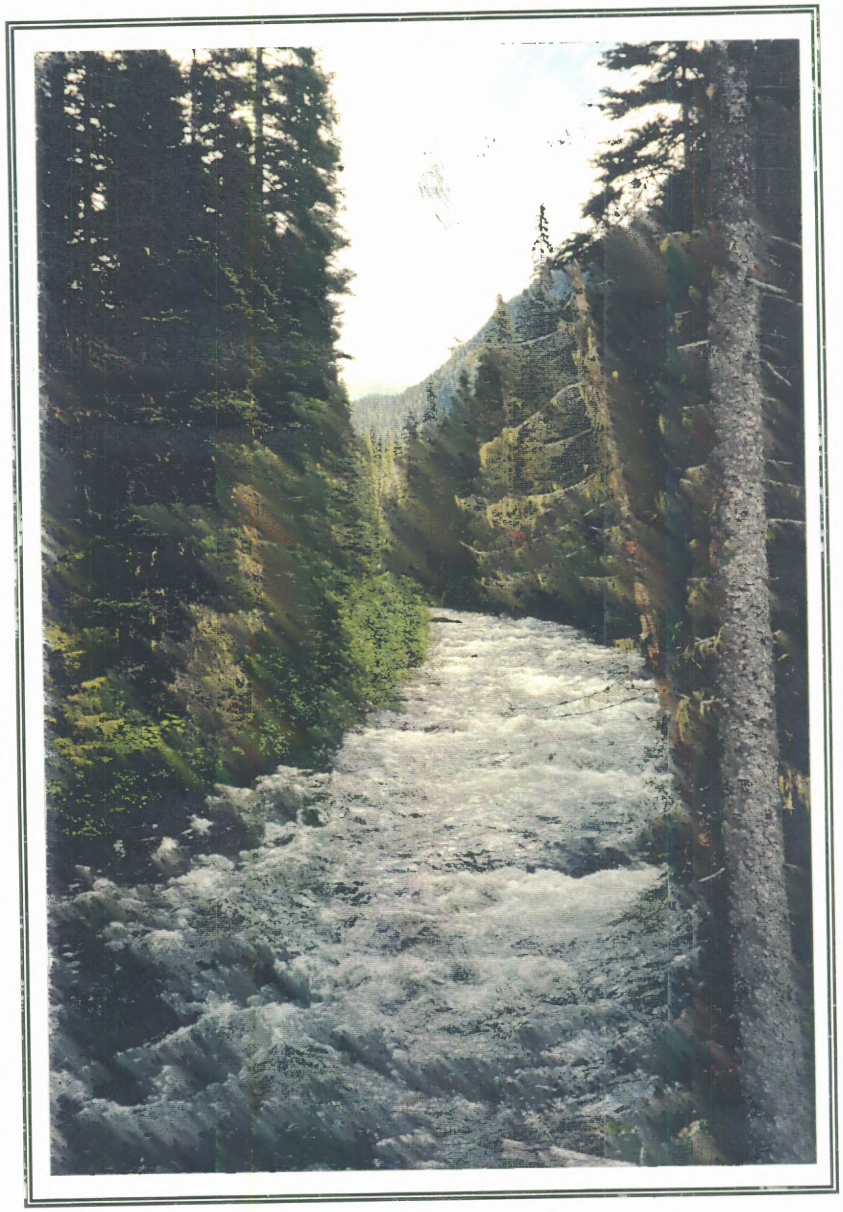


PHOTO H1. Stable boulder channel in the upper Horsefly at second road crossing above McKay River - upstream *[Site H2].*

PHOTO H2. Horsefly River at second crossing above the McKay River showing stable old growth riparian zone *[Site H2].*

PHOTO H3. Low gradient mainstem channel in upper Horsefly River above McKay sub-basin - upstream *[Site H4].*

PHOTO H4. Alluvial bed and banks of the upper Horsefly River - downstream *[Site H4].*

PHOTO H5. Sand road adjacent to the mainstem channel with full sump above cross drain *[Site H7].*

PHOTO H6. Input of sand and silt to the upper Horsefly River from a road within 30 metres of the channel.