HORSEFLY RIVER WATERSHED STEWARDSHIP REVIEW: A SYNTHESIS OF REPORTS AND STAKE HOLDER INITIATIVES

FINAL REPORT

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DEFINITION OF ACRONYMS

ASAP **As soon as possible**
CTC **Cariboo Tribal Council**
DFO **Department of Fisheries and Oceans Canada**
DM **District Manager**
ECP **Erosion Control Plan**
FDP **Forest Development Plan**
FEN **Forest Ecosystem Network**
FPC **Forest Practices Code**
HIATC **Horsefly Interagency Technical Committee**
HWMC **Horsefly River Watershed Monitoring Committee**
IWAP **Interior Watershed Assessment Procedure**
IAMC **Interagency Management Committee**
IPSFC **International Pacific Salmon Fisheries Commission**
MEM **Ministry of Energy and Mines**
MELP **Ministry of Environment, Lands, and Parks**
MOF **Ministry of Forests**
RMZ **Riparian Management Zone**
RMA **Riparian Management Area**
QRWA **Quesnel River Watershed Alliance**
WRP **Watershed Restoration Program**
TOR **Terms of Reference**

HORSEFLY RIVER WATERSHED STEWARDSHIP REVIEW: A SYNTHESIS OF REPORTS AND STAKE HOLDER INITIATIVES

1.0 INTRODUCTION

The Horsefly River Watershed has a long history of studies designed to understand, enhance, restore, and protect the salmon fishery. The most recent studies have focused on assessing current and past land use impacts (logging, grazing, mining, road building, and recreation) upon its aquatic ecosystems. A principle objective has been the recovery and protection of the sockeye fishery, but chinook, coho, rainbow, kokanee, and trophy size Quesnel Lake trout are also considered. The first studies were conducted in the 1940's, 50's and 60's by the International Pacific Salmon Fisheries Commission (IPSFC), but the main goal for this review is the recent watershed level assessments produced under the Provincial Watershed Restoration Program (WRP), funded by Forest Renewal B. C. Most of these watershed assessments have been initiated by the Horsefly River Watershed Monitoring Committee (HWMC).

Using a watershed perspective and a natural processes approach, the WRP program is designed to restore, maintain, and protect stream and forest resources that have been adversely impacted by past forest harvesting practices. Included in the WRP program are the goals to provide community-based training, employment, and stewardship opportunities, as well as to encourage working partnerships among local stakeholders. Reports under other initiatives, i.e. provincial, federal, international, and non-governmental also contribute to this body of knowledge.

The Horsefly River Watershed is in the heart of Northern Shushwap nations territories. It is an important salmon spawning watershed highly important to their culture and spiritual values. Over the past decades, the Cariboo Tribal Council (CTC), representing the Williams Lake, Soda Creek, Canim Lake, and Canoe Creek Bands, has grown in its involvement and expertise regarding watershed/fisheries issues. They are currently building a data base and have their own GIS mapping and capabilities. In the process of pursuing knowledge concerning the state and stewardship of natural resources in their territories, the Tribal Council has initiated this project. Utilizing funds from Fisheries Renewal BC, a contract to review and synthesize reports related to stewardship in the watershed was awarded to R.L. Case and Associates from Big Lake, BC. The intent of the project is to provide summaries and suggestions related to the stewardship of the Horsefly River Watershed. This includes identifying information gaps, project needs, and/or potential partnership opportunities for native peoples and community groups wishing to participate in the stewardship of their home watershed.

2.0 GLOBAL AND HISTORICAL CONTEXT

In many areas of North America and Europe aquatic ecosystems and salmonid stocks are in serious decline (Nehlsen et. al. 1991, Frissell 1993, Parrish et.al. 1998, Slaney et.al. 1996). Problems are often complex and cumulative; related to habitat degradation, declines in food organisms, water quality problems, ocean survival, and predation.

Due to the rapid expansion of human populations during the past century (increasing demand for products) and the rapid development of machine technology, our power as a species to quickly alter ecosystems and the environment (forests, watersheds, and even climate) has reached awesome proportions. Unfortunately, the Science and processes necessary to guide decision makers is still incomplete and evolving. Scientists barely understand the complexities of how forests and watersheds function (Kohn and Franklin 1997), let alone the multiple watershed scale consequences of these alterations. The careful research based approaches implemented by the Ministry of Forests, Ministry of Environment, Department of Fisheries and Oceans, Major Licensees, and the Horsefly River Watershed Monitoring Committee needs to be commended.

We are lucky here in Western North America (Interior B.C). We are still fortunate to have some relatively intact unaltered watersheds that support an intact fishery, as a frame of reference for understanding natural systems. We are also fortunate to be able to draw upon the science and evolving research-based knowledge generated by universities, governments, and watershed groups throughout the Pacific Northwest (British Columbia, Washington, Oregon, and Idaho). We also know that many earlier cultures had evolved understandings and economies that did not cause serious resource decline.

A great deal of credit goes to the Watershed Restoration Program, which focuses on the watershed as a unit for analyses and restoration. The program provides step by step procedures (still evolving) for assessing aquatic ecosystems and upslope processes, at the whole forest or watershed level. Many of these studies and assessments have been conducted in the Horsefly watershed over the past decade. The intent of this report is to review and summarize the many reports that contribute to this body of knowledge (see Literature Summary List – Appendix VII).

3.0 OBJECTIVES

A decade or more of watershed reports (and older studies) have attempted to quantify and qualify potential and existing watershed impacts due to logging, mining, agriculture, and recreation on hydrologic functioning, sediment delivery, stream temperature, stream channel integrity, and fish habitat. Overall objectives of this report are to:

- List and summarize the major reports, i.e. their key findings and recommendations

- Briefly describe the recent history of stewardship processes, i.e. formation of the Horsefly River Watershed Monitoring Committee (HWMC), its initiatives and recommendations

- Briefly summarize stakeholder initiatives (in addition to major reports) in the watershed in response to report findings (i.e. those activities that are completed, current, and/or planned).

- Briefly summarize issues and questions (especially long term) that have been raised by the progression of reports

- Make general suggestions regarding information gaps and project needs in order to improve knowledge and stewardship in the Horsefly Watershed

4.0 WATERSHED CHARACTERISTICS

The Horsefly River Watershed, for the purposes of this study, is defined as the area upriver from the confluence of the Little Horsefly River. It is located on the eastern edge of the Interior Fraser River Plateau, south of Quesnel Lake, and east of Williams Lake. Elevations range from 730m at Quesnel Lake to 2,300m at the mountain summits.

The watershed was subdivided by MOF into 21 sub-basins, although they do not all follow a strict sub-watershed definition (i.e. some are portions of watersheds and some cross watershed boundaries). Some reports refer to the sub-basins as polygons because of this inconsistency. This report uses the term sub-basin and Table 1 describes their areas as discussed in the major reports.

Table 1 Sub-Basin Areas

Sub-Basin	Area (sq.km)	Sub-Basin	Area (sq.km)
Upper Horsefly River #1	141	Molybdenite Creek #12	80
Horsefly above the falls #2	169	Lower McKinley Creek #13	77
McKusky Creek #3	184	Doreen Creek #14	20
MacKay River #4	144	Horsefly Below Falls #15	238
Upper McKusky Creek #5, #6, #7	123	Tisdall Creek #16	71
McKinley Creek above Bosk #8, #9, #10	107	Moffat Creek #17, #21	557
McKinley Creek above McKinley L. #11	180	Woodjam Creek #18, #19, #20	64

Within the watershed are contained four major biogeoclimatic zones the ICH, SBS, ESSF, and AT, with precipitation ranging between 400mm and 2200mm in the 3 forested zones. The climate is continental with cold winters and warm summers, with maximum precipitation occurring in late spring early summer. The melting of snowpacks is the primary source of runoff, with high flows often having two peaks and lasting up to six weeks during May and June.

The soils supporting lower and mid elevation forests are derived from glaciation and modified by geomorphic processes. Soils are gravelly sandy tills and colluvium in most locations, with some glacio lacustrine sediments also present. Upper slope and alpine elevations are largely bedrock supporting treeless alpine tundra vegetation.

5.0 WATERSHED ISSUES AND CONCERNS

5.1 Peak Flows

Forest harvesting by conventional clearcutting can increase peak flows and sediment generation in the watershed (intensities, frequency, duration). Flowing water is the scouring and transport mechanism, which can cause surface erosion, slides and slumps, streambank cutting, and stream sedimentation. These energies if significantly elevated beyond a norm, when coupled with exposure of soils, have the potential to trigger sediment transport and deposition beyond the assimilative capacity of stream ecosystems (Cairns 1977). In simple terms the following outlines the processes that elevate peak flows.

In the BC interior, peak flows occur as snowpack melts in the spring. Harvesting by conventional clearcut can increase peak flows in three different ways. The most important is through the removal of forest canopy, which increases both winter snowpack accumulations and spring melt rates. The second way is through transpiration losses (water not taken up by trees) which can also add to runoff levels, frequencies, and duration. The third way overland flows can be increased is through the interception of the subsurface flow of water by roads. Road ditches intercept and efficiently convert groundwater (seepage water) to overland flow. . Soil compaction due to roads, spurs, and trails reduces water infiltration, also increasing overland flows. High road densities, steep slopes, and harvesting at higher elevations have the greatest effect.

5.2 Sedimentation

Natural erosion is present almost everywhere across the landscape and both movement and deposition of sediment is a natural characteristic of rivers and streams. Sediment plays important roles in stream and floodplain ecology including, floodplain formation, nutrient supply, and bank building processes (Gregory et.al. 1991). Most natural sediment inputs are small and can be incorporated by stream processes. Ecosystems are adapted to and dependent endemic levels of sediment. It is excessive sediment (beyond a norm), generated by frequent upstream/upslope disturbance that often overwhelms the "assimilative capacity" of a stream, altering its biological components and function. Of greatest concern in stream and river sediment problems are the fine inorganic particles that either flow with the current (turbidity) or that are deposited on the streambed. Sediment can cause losses in biotic stream communities (aquatic plants, insects, food webs, and fish habitat) (Tschaplinsky 1992). Most sedimentation in stream systems is the result of human activity, in particular that generated by machines (Waters 1995).

Consequences to streams Sediments are transported in streams (but also in ditches) as either suspended particles or as bedload. Suspended sediment (particles of silt and clay) effects upon stream communities include coating the active surfaces of both plants and animals (Waters 1995). Sediments can abrade and suffocate small aquatic plant organisms (periphyton and macrophytes), decrease rates of photosynthesis because of reduced light, and reduce respiration and behavior of aquatic insects. In fishes the respiratory capacity of gill surfaces can be lost and vision and feeding efficiency diminished. Eggs and emerging fry in the gravels can be suffocated due to the reduction in water flow and oxygen in plugged interstitial pore spaces (Cooper 1965). Migrating and spawning fish will avoid streams with high suspended sediment concentrations.

Bedload transport of larger particles can degrade streams through the scouring (pummeling) of streambanks, filling in of pools, reductions in channel roughness effecting velocity dissipation and hiding/foraging territories), and reductions in channel depth and cover (for adults and juveniles). These effects amount to reductions of critical rearing habitat for juvenile salmonids (Waters 1995).

5.3 Roads

Ninety per cent of stream sedimentation generated by roads occurs during construction and is transported during the early part of the following decade (Beschta 1978). Sediment generation is also related to vehicle traffic (including maintenance machinery) and amounts/frequency of precipitation (Reid and Dune 1984).

Erosion of exposed soils in ditches and on road surfaces is a function of particle size and velocity of flow. Sand size particles begin to move on road surfaces and in unvegetated ditches at gradients around 2.5% (Bilby et.al. 1989). As unvegetated road and ditch gradients increase, the potential for movement of larger particle sizes also increases. Woody debris in natural channels or stable logging slash will buffer and slow the erosive forces, as well as, trap and filter out sediments and debris. When soil coarse fragment content is low, erosion and sediment transport potential increases. Fine textured soils (i.e., lacustrine), soils with round particle shapes (fluvial, glacial-fluvial), highly saturated soils, exposed soils on steeper slopes are of greatest concern.

Management - Roads tend to revegetate and armor with time as root matrices establish and the fine sediments are washed out. Erosion pavements form on road surfaces and in ditches while woody and herbaceous species root and bind soil particles.

Road ditches on slopes tend to intercept subsurface water converting it to overland flow. Water management (i.e. crossdrains, waterbars, outsloping, etc.) that redisperses this intercepted water onto the forest floor promotes filtering of the sediments and returns the flow to its subsurface regime. Sediment flowing onto hillslope litter (nonchannelized flow) from crossdrains/culverts can be deposited/filtered out of the water column in short distances (depends on slope and the type and depth of litter/duff). If flows exiting a cross drain continue as a defined channel (can be a manmade erosion channel or a natural drainage depression with defined bed and banks) it is essentially apart of the stream network system (100% delivery).

Re-dispersing intercepted subsurface water back onto the forest floor:

- Reduces stream size, erosion hazard, and bank cutting
- Enhances cold water storage for slow release during base flow periods
- Provides sediment filtration for the protection of water quality
- Recovers lost soil moisture for forest ecosystem productivity/ maintenance below the road

Road maintenance is also a source of sediment as machine scouring of ditches and the blading of road surfaces disrupts stabilizing processes, exposes soils, and disrupts armoring (Bilby et.al. 1989). Road maintenance processes, which scour ditches and scrape road surfaces, should be minimized where practical to encourage armoring and revegetation.

5.4 Temperature

High water temperatures effect salmonids in the following ways. Temperatures influence rate of growth, swimming ability, levels of dissolved oxygen, ability to capture and process food, and resistance to disease. The effects are most pronounced in summer when juveniles are rearing, and late summer during spawning. Royal (1966) and Williams et.al. (1977) identified a threshhold temperature of $14^{o}C$ for the Horsefly River sockeye race above which columnaris disease and pre-spawning mortality can develop. Land clearing and forest fires were blamed for high water temperatures at the time of the studies in 1966. Total mortality of salmon can occur if temperatures exceed $25^{o}C$ (Bjornn and Reiser 1991). Maximum summer water temperatures of $23^{o}C$ are not uncommon in some areas of the Horsefly. While temperatures at the time of spawning at the upper Black Creek spawning grounds is generally under the $14^{o}C$ threshold, temperature at the McKinley spawning grounds and the middle and lower Horsefly River sites are commonly above this threshold.

Water temperature increase is known to be directly related to the heat generated at the water surface by the sun. Other factors that influence water temperature are air temperature, cold water seepage from streambanks, depth and width of stream, type and size of stream substrates, density and type of streamside forest, as well as aspect, elevation, and slope.

The Forest Practices Code does not require a reserve zone along S4, S5, and S6 streams (Appendix II). However it says that where riparian harvesting is allowed, management should retain sufficient vegetation to provide shade, reduce bank microclimate changes, maintain natural channel and bank stability and, where specified, maintain important attributes for wildlife. It also states that adjacent to small wetlands and lakes where a reserve is not required, key wildlife habitat attributes characteristic of natural riparian ecosystems should be retained.

6.0 HISTORY OF THE HORSEFLY WATERSHED MONITORING COMMITTEE

In 1992 during decisions regarding building a new road into the sensitive headwater areas of the watershed, Jackobson Brothers (now Riverside) and Ministry of Forests (MOF) initiated a watershed advisory committee (Gord Chipman personal communication). By 1994 the committee had evolved to an official status with representation from all major stakeholders, i.e. Major Licensees, Department of Fisheries and Oceans (DFO), Ministry of Environment, Lands and Parks (MELP), Ministry of Forests (MOF), Ministry of Energy and Mines (MEM), Horsefly Cattlemans Association, First Nations, and the Regional Hydrologist. Terms of Reference (TOR) at that time as designated by the Horsefly MOF District Manager included:

- Devise and implement an environmental monitoring program namely: complete a watershed assessment, maintain a suspended sediment monitoring program, complete a sediment source map, maintain water temperature records at key stations, implement a gravel quality monitoring program, maintain hydrographic records and assess hydrologic trends
- Provide technical information and make recommendations for forest resource management in the context of maintaining the integrity of Horsefly River aquatic ecosystems

The first major study initiated by the committee was the Interior Watershed Assessment Procedure (IWAP) which assessed current conditions but also projected information to the year 2002, based on 5 year Forest Development Plans (FDP's). This study, a first step in the Provincial Watershed Restoration Program WRP, was contracted to Dobson Engineering in (1996). The results of this effort after two years of analysis, discussion, and corrections (Teti 1997), produced draft recommendations for the following sub-basins of the Horsefly River Watershed:

- Upper Horsefly River
- MacKay Creek
- McKusky Creek
- Horsefly River above the falls
- McKinley Creek above McKinley Lake
- McKinley Creek above Bosk Lake

Due to a lack of consensus on some issues, some uncertainty about the terms of reference for the HWMC, and some encouragement from DFO and MELP, the District Manager, in January of 1998, invoked the formal watershed assessment process outlined in OPR 32 (1)(b) of the Forest Practices Code. This process spelled out specific responsibilities and procedures involving the Major Licensees. Under this direction the Horsefly Watershed Monitoring Committee became the IWAP Roundtable with similar representation.

Terms of Reference for the roundtable included making recommendations to address the four hazard indices generated by the IWAP, namely, peak flows, soil erosion, riparian buffers, and mass wasting. Recommendations were to focus on short term time frames (5 years) in order to give guidance to the District Manager (DM) approving FDP's. Draft recommendations produced earlier by the HWMC easily rolled into the roundtable task.

Other studies including and besides WRP, commissioned by HWMC and the IWAP Roundtable included: suspended sediment monitoring, stream temperature monitoring, hydrologic trend analysis, channel assessments, gravel quality sampling, sediment source surveys, terrain stability mapping, and fish habitat inventories. Results from these reports were all utilized (depending upon degree of completeness) in formulating Interim Forest Development Recommendations for the watershed for the District Manager. General recommendations pertaining to the whole watershed are included in **Table II - Summary of Reports - Key Findings and Recommendations**. Recommendations specific to individual sub-basins are included in section **Summary of Recommendations for each Sub-Basin.**

In April 1998 in addition to the IWAP Roundtable, DFO MELP and MOF jointly created the Horsefly River Watershed Interagency Team, consisting of two committees, which would deal with technical issues in particular a more long term perspective. The executive committee was comprised of officials from DFO, MELP, and MOF. Members included the Area Chief of Upper Fraser River Department of Fisheries and Oceans, the Regional Fish, Wildlife, and Habitat Manager - Cariboo Region Ministry of Environment, Lands and Parks, and the District Manager - Horsefly Forest District Ministry of Forests. This committee was to give guidance to the sub-regional process including issues in the Horsefly River Watershed. By consensus this committee would give interim direction the DM and Licensees for operational planning.

The Technical Committee would receive direction from the executive committee and would address strategic planning recommendations and interim measures to be applied to operational planning for the maintenance of the Horsefly River's aquatic ecosystem, hydrological stability, and the conservation of it's fisheries resource. Terms of reference for the Technical Committee include:

1) make recommendations on the continuance of the gravel and water monitoring programs (stream temperature and suspended sediment) initiated by the HWMC
2) review, evaluate, and collate all studies and work required under and IWAP and beyond in terms of data gaps
3) identify and map temperature sensitive sub-drainages and recommend riparian protection measures
4) develop monitoring programs to identify sources of sediment and standards for control, including enhanced road construction, maintenance, and deactivation practices
5) review terrain stability maps and develop constraints and measures if needed
6) review the IWAP in order to address short and long term harvest levels if needed
7) collect and organize information related to fish and fish habitat inventories
8) identify communication and information gaps including needed studies
9) develop a restoration activities accounting system by sub-basin including private land
10) develop requirements for a comprehensive road inventory linked to restoration activities
11) make recommendations to the sub-regional planning team and for long term FDP's
12) provide suggestions for educational activities from a technical perspective

Technical Committee recommendations by Sub-Basin are included in sections that follow.

SUMMARY OF MAJOR REPORTS

TABLE II - CHRONOLOGY OF MAJOR HORSEFLY RIVER WATERSHED STUDIES (1956 – 2000)

#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
1	1956	A study of the Horsefly River and the Effect of Placer Mining Operations on Sockeye Spawning Grounds ——— A.C. Cooper –for International Pacific Salmon Fisheries Commission	1) construction of a fishway over the falls is feasible as is the feasibility of passing fry over the falls and rapids, thereby extending the habitat for the early Horsefly sockeye run - the late run is judged to have been destroyed by the Hells Gate 2) Horsefly River above McKusky 8^{o} F cooler –above McKinley 9^{o} F cooler at same time of day in late August, than the two respective tributaries 3) No turbidity could be measured at any of 16 Horsefly River sampling stations using the Jackson Turbidimeter (minimum measurable 25 ppm) 4) Based on records, water temperature was average for the time of year and above optimum for spawning below the town and too cold above McKusky 5) suspended sed. 2-11 ppm (ave. 6) at time of survey (late Aug.), very clean 6) bed materials coarse between McKay and McKusky (8-24 inches) 7) suitable spawning gravels McKusky to Prairie Ck progress finer to Club 8) bed particle size slowly declines below the falls, finest at Woodjam 9) 46 acres of spawning gravel below falls, 145 acres near and below town, 55 acres close to mouth 10) maximum size particle transported as suspended sediment through spawning reaches at time of survey (spawning season) is 0.3 mm , particle sizes of 0.15 mm dia. could be expected to accumulate in the spawning beds 11) fine sediment at risk of being deposited in the spawning gravels is that which is generated and transported during the declining freshet 12) turbidity is not a problem during migration but salmon depend upon clean water and clean gravels for spawning 13) turbidities during spawning most be less than 25 ppm (mg/l) 14) reductions in egg survival are directly related to reduced oxygen and flow of water through the gravel (permeability)	1) no placer mining be permitted within the confines of the Horrsefly River streambed and any of its tributaries 2) No placer mining be permitted adjacent to Horsefly River or any of its tributaries without provision of one or more settling basins where its effluent contains particles less than 0.1 mm diameter during the period of July 1 to April 1, the turbidity of the effluent should be less than 25 ppm 3) Materials from settling pond cleanout should deposited where they cannot be washed into the river	1) ? 2) ? 3) ?
2	1966	Problems in Rehabilitating the Quesnel Sockeye Run and Their Possible Solution ——— Royal L.A. for: International Pacific Salmon Fisheries Commission	1) pre-spawning mortality of Horsefly sockeye ranged between 30% and 62% between 1953 and 1965 2) mortality is due to columnaris disease, which is associated with high water temperatures 3) infection generally begins at temps above 60^{o} F in spawning reaches 4) colummaris disease seldom occurs at temps below 57 ^{o}F 5) current sockeye migrations are typically 5 days earlier than the historic runs (1901-1913) when the waters are warmer 6) migration time from the mouth of the Fraser to the Horsefly is typically 19 days 7) it is speculated that separate races of sockeye existed prior to the Hells Gate obstruction (1913) and all but the early run are extinct. The extinct race would have arrived at and utilized the lower spawning grounds 3 weeks later during cooler temperatures	1) recommend a project to draw cold water for stream flow (78" pipe) from the depths of McKinley Lake to add to McKinley Ck and the Horsefly River 2) construct a fishway around the Horsefly falls to add 170,000 sq yds of new spawning area 3) if Mckinley cold water additions work construct another cold water source at Crooked Lake including a 9m high dam	1) yes 2) no 3) no

SUMMARY OF MAJOR REPORTS

TABLE II - CHRONOLOGY OF MAJOR HORSEFLY RIVER WATERSHED STUDIES (1956 – 2000)

#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
3	1977	Investigations of Prespawning Mortality of 1973 Horsefly River Sockeye Salmon ——— Williams et.al.1977 – for International Pacific Salmon Fisheries Commission	1) The 1973 Horsefly sockeye run had a low 27.1% prespawning mortlity compared to years since 1957. 2) Early studies suggest that high water temperatures at Hells Gate and an early timing of the run typically produces high mortality 3) Cool water temperatures at the spawning grounds and a late migration timing combined to offset the high water temperatures at Hells Gate and reduced prespawning mortality 4) River temperatures were below 14°c (57° F) 5) A 6.7% mortality was observed on the upper McKinley 6) Prespawning mortality was also correspondingly low for the Mckinley Creek and Mitchel runs i.e. 25.6% and 19.1% respectively 7) A high mortality of 62, 65, and 60% occurred in 1961 for the 3 streams		
4	1981	The Horsefly River Sockeye Salmon Story ——— International Pacific Salmon Fisheries Commission	1) In 1913 the Horsefly River produced approximately 8 million sockeye establishing it as one of the major sockeye producers in the Fraser system 2) As a result of the Hells Gate obstruction in 1913, by 1941 the run had declined to 990 spawners 3) A fishways constructed by the Commission in 1945 reversed the nearly extinct run starting a regrowth to over 357,000 spawners in a 6 mile stretch downstream of the falls by 1977 4) A seventeen mile stretch of river from the town of Horsefly to Quesnel Lake could accommodate 2 million more spawners 5) Cold water siphoned from McKinley Lake to Mckinley creek reduced stream temperatures but half the spawners died anyway from a gill infection 6) Spawners transported to cooler water above the falls suffered even greater prespawning mortality 7) In 1957 to test the feasibility of a fishway over the falls transported sockeye went back down over the falls 8) In 1973 a gravel cleaning project to increase fry survival produced a minor increase 9) In 1979 a project fertilizing and planting 6 million eggs from moribund females produced 20,000 fry. 10) A 30 ft wide spawning bed 1200 ft long with graded gravel was constructed immediately downstream from McKinley Lake. The bed could accommodate 5400 spawners, but the largest number to use the area so far has been 1400 in 1973 and these had to be confined		
5	1994	Reconnaissance Level Sediment Source Mapping ——— David Proudfoot DFO	1) terrain stability polygons were identified, classified, and mapped - sediment sources were classifiied, and a sediment throughput (transfer and delivery) rating developed for each creek – from air photos 2) a wide low gradient meander floodplain, above the falls (4 km), probably blocks the transport of gravels and cobbles, except during infrequent high discharges - sand is probably flushed from storage during seasonal high	1) road construction should be minimized on Class IV and V terrain utilizing full bench cuts, no sidecast, and only when on unfrozen and unsaturated ground - should avoid steep walled creeks and gullies and deactivate roads before snowmelt or high rainfall season 2) consider sky line logging systems on Class V terrain to minimize ground disturbance- leave feathered buffer of trees to protect gully walls from	1) ? 2) ?

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#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
			flows - fine sand, silt and clay are probably transported through the reach all year 3) serious road erosion exists on heavily roaded and logged Club Creek sub-basin 4) sidecasting was observed on many older roads with slopes > 60% 5) MacKay, Doreen, Sawley, Black, Woodjam, Deerhorn, Moffat, Vedder, and numerous unnamed creeks were rated as high & very high hazard to deliver sand, silt and clay 6) Prairie, Wilmot, Tisdall, Sucker and Patenaude creeks rated as moderate hazard to deliver sand, silt, and clay 7) McKusky and McKinley creeks rated as low hazard	blowdown 3) consider no clearcut logging in Club Creek until field studied by a terrain specialist 4) conduct terrain stability assessment on Horsefly River north valley wall 5) conduct a sediment delivery, (throughput, transfer) hazard study to determine delivery patterns and potentials from various source terrain	3) ? 4) yes 5) no
6	1996	Revised Horsefly River IWAP ______ Dobson Engineering MELP	1) low potential peak flow hazards in the watershed and all sub-basins in 1996 2) high surface erosion hazard for McKay River and Horsefly River above the falls, the remaining sub-basins are a moderate hazard 3) moderate riparian buffer hazards for Molybdenite and McKinley creeks, the remaining sub-basins are low 4) High potential landslide hazard ratings in Horsefly River above the falls and the McKusky Creek sub-basins, moderate in the McKinley Creek above Bosk Lake and MacKay River, low ratings in the remaining 3) secondary rds built on fine soils and w/ no cap are of greatest concern 4) numerous roads in poly #2 need de-activation 5) some surface erosion problems in poly #11 6) fish assessments needed where riparian logging in polys #2 and #11 7) several development related slope failures in poly #2 8) numerous mass failures in poly #3 (roads and logging close to creek) deactivation plan needed	1) use a careful review when developing plans for poly's #1, #8, and #9 2) implement channel, fish, and riparian assessments on agricultural land 3) IWAP results are indicators of potential for problems, any decisions should be based upon real assessments 4) - numerous rds do not have adequate # of drainage structures to maintain natural drainage patterns, the road drainage network through-out the watershed should be assessed and upgraded 5) terrain stability mapping needed for poly # 1, 2, 3, 4, 5, 6, 7, 8, 9	1) yes 2) yes 3) yes 4) ? 5) yes
7	1996	Sediment Source Inventory and Mapping (air-photo analysis) ______ Carr W.W., J.A. Beer, and I.C. Wright for MELP	1) 596 manmade sediment sources were identified 2) 243 were main and branch roads, 223 were block roads, 70 were rated to cutblocks, 43 were agriculture, 10 recreation, and 7 mining 3) of the 596, 160 fell into the high to critically high category 4) highest priority polygons with more than 0.20 sites/km were #'s 2 ,4, 10, 11, 12, 13, 14, and 16 - the second priority group includes: #1, 3, 8, 15, 18, & 20 5) the cumulative impact from the more numerous low risk sites may be more significant and should not be avoided	1) comprehensive watershed access strategy needed to facilitate deact planning 2) use terrain stability analysis for decisions in steep watersheds 3) focus on restoring natural drainage and road de-activation 4) do not dismiss sediment sources with a low risk rating 5) use road grading techniques which minimize road wash, sediment generation and sediment delivery 6) revegetate nenuded cut/fill slopes and ditchlines in order to stabilize and trap sediment 7) develop Integrated Hillslope Maintenance plans for complex road and block networks 8) integrated hillslope maintenance plans should include: road deactivation, landing rehabilitation, gully clean-out, landslide rehabilitation, seeding of exposed soils, biogeotechnical slope stabilization	1) yes? 2) yes 3) yes 4) ? 5) ? 6) yes 7) yes 8) ?
8	1995	Hydrometric Trend Analysis	1) ECA's for the gauged sub-basins analyzed was 12-15% at time of		

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#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
		Hetherington and Dobson MELP	analysis 2) trends in mean annual, peak, and low flows in the four Horsefly River sub-watersheds are probably caused by variations in climate 3) the lack of predisturbance streamflow measurements weakens detectability 4) low ECA levels may not influence flows enough to be detectable from natural variation		
9	1996	Watershed Monitoring Program Review — Hetherington and Dobson MELP		1) sample suspended sediment (manually) twice weekly during runoff at 17 sites, i.e. 4 along Horesefly, 4 along Moffat, 1 below McKinley Lake, at mouths of McKusky, McKay, and Molybdenite, and 2 each on Sutter, Woodjam, and Back Creek 2) install water temperature monitoring instruments at 12 sites, i.e. 4 along Horsefly, at mouths of Moffat, Woodjam, Tisdall, McKinley, and McKusky and one each along McKay and Moybdenite 3) install automatic pump samplers at 7 sites 4) enlist local residents and workers to report on sediment fluxuations 5) contract out parts of program, use video from helicopter, and conduct summer flow stream surveys 6) develop a procedure to track unusual suspended sediment pulses 7) operate the network for at least 5 years 8) produce an annual report to summarize results for resource managers	1) 11 sites 2) 7 sites 3) no 4) ? 5) ? 6) ? 7) yes 8) no
10	1996	Results of Channel Assessment Procedure - (analysis of channel changes along the Horsefly River) — Dobson Engineering for MELP	1) due to large differences in discharge (200m^3/s vs. 14 m^3/s) between the airphoto sets (1958 and 1992) being compared in the analysis, changes in channel morphology, sediment storage patterns, and large wood jams were difficult to discern, however changes in sediment delivery patterns and channel pattern were readily visible 2) 1450 m of channel along the Horsefly showed change - 3% = low impact 3) 80 m of channel along McKinley showed change - 3% = low impact 4) changes included change in location, back channel infilling, channel straightening, and meander cutoffs 5) lower reaches of Moffat Creek showed channel widening, straightening, and bank erosion	1) field verification of changes in channel morphology should be undertaken 2) 7 km along the mainstem were not assessed due to absense of air-photos this section should be completed when photos are available 3) a channel assessment should be done on the mainstem of Moffat Ck. as channel straightening was noted near its confluence	1) yes 2) ? 3) no
11	1996	Applying CCLUP Salmon Fisheries Targets and Strategies -–Black Creek Assessment (Draft Landscape) Unit — Northwest Hydraulic	1) greatest likelihood of landslides that would affect spawning gravels are in the Doreen and MacKay watersheds 2) spawning occurs throughout 5 reaches of the Black Creek Assessment unit 3) the Horsefly River is rated as an enhanced watershed by DFO 4) eroding banks (% of length) Woodjam to Black Ck 16%, 31%, 26%, 44% 5) banks w/ inadequate riparian veg (% of reach length) Moffat Ck. to Falls	1) no more than 20% ECA for main watershed and major tributaries connected to spawning reaches 2) analyze distribution of cutblocks and hydrologic recovery by year 2000 for upper Horsefly northside, Doreen, MacKay, and McKinley Creeks 3) reduce rate of cut in Woodjam and Black Creek watersheds and analyse 4) rehab critical manmade sediment sources in Doreen and MacKay basins 5) develop plan for all sediment sources identified by Dobson and Carr 1995 6) increase reserve zones to 20m along steep S4 to S6 tributaries	1) yes, but McKinley no, Tisdall no, Deerhorn no, Sucker no, Doreen no, 2) ? 3) yes

SUMMARY OF MAJOR REPORTS

TABLE II - CHRONOLOGY OF MAJOR HORSEFLY RIVER WATERSHED STUDIES (1956 – 2000)

#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
		Consultants and Coast River Environmental Services for Dept of Fisheries and Oceans	27%, 34%, 0%, 0%, 60%, 89%, 57%, 67%, 0%, 4% 7) Black Creek delivers large amounts of sediment, its fan is highly unstable 8) main sources of fine sediment come from upper river tributaries	7) riparian reserves should be extended to the edge of the river floodplain at reaches 2 thru 6 and to Mckinley Lake to protect off channel habitat and sediment generation from scars on valley walls from access structures 8) replant riparian zones w/ endigenous woody species along reaches 2, 4-6 of the mainstem 9)..establish extended reserves on alluvial fans 10) work with landowners to revegetate denuded fans on private land 11) restrict further harvesting in Doreen Creek because of high sediment risk 12) manage for hydrologic recovery in Tisdall and Deerhorn 13) upgrade inventories of salmon (i.e. coho) use of tributary streams 14) exclude harvesting on tributary alluvial fans on Crown land 15) educate landowners i.e. riparian/stream stewardship, restrict livestock access along denuded riparian stream banks and plant woody species	4) yes ? 5) in part ? 6) no 7) ? 8) yes, in part 9) ? 10) yes, in part 11) ? 12) ? 13) ? 14) ? 15) yes, in part
12	1996	Applying CCLUP Salmon Fisheries Targets and Strategies - McKinley Assessment (Draft Landscape) Unit ________ Northwest Hydraulic Consultants and Coast River Environmental Services for Dept of Fisheries and Oceans	1) sockeye, coho, and chinook spawn in reaches 1, 3, and 4 of McKinley Creek, i.e. to the Elbow Creek confluence 2) McNeil, Gotchen, and Bosk Lakes trap all coarse sediment from the upper watershed as well as most fine or suspended sediment w/ little risk to salmon 3) Molybdenite Creek and small east bank tributaries in polygon #11 (below Elbow) are potential surface sediment sources 4) spawning reaches downstream of McKinley Lake are coarse sediment supply limited and sensitive to increased peak flows which could reduce gravels and coarsen the substrate 5) reach 3 above McKinley Lake is a moderately unstable depositional reach with banks sensitive to increased peak flows 6) reach 4 is laterally stable but sensitive to increased supply of sand and fine gravel arriving from small right bank tribs and channel banks	1)limit ECA to 20% except for the lower McKinley basin (#13) and analyse distribution of cutblocks for hydrologic recovery after 2000 2) no further harvesting in Elbow and Bassett Creek drainages (polygon #11) w/o a detailed hydrologic assessment 3) remediate active sed sources in Moly basin #12 Dobson and Carr (1995) 4) establish 10-20m riparian reserves along steep potentially unstable S4, S5, and S6 streams – i.e. protects valuable spawning and rearing reach 5) exclude harvesting in riparian management zones of reaches #1 and #4 to protect off-channel habitat 6) extend riparian reserve to 100m in reach #3 and minimize harvest in RMZ to edge of floodplain –protect old channels and depressions (backwaters) 7) assess agricultural practices and runoff control in reach #1 8) determine status of spawning populations upstream of Elbow Creek	1) partly ? 2) no 3) yes? 4) no 5) ? 6) ? 7) ? 8) no
13	1996	Gravel Sample Analysis for 1995/1996 Horsefly River ________ Kara Pylypiuk, Jim Roberts, Bruce MacDonald and Jason Hwang for DFO	1) 25-80mm is excellent spawning gravel for sockeye salmon with a Fredle Index of 6-10 2) three sites with 5 transects each and 10 samples per transect resulted in high standard deviations (variability) 3) gravel quality at the 3 locations is considered excellent for spawning although the lower site is slightly less	1) to obtain more definitive results it may be beneficial to increase # of sites	1) ?
14	1997	An Inventory of Watershed Conditions Affecting Risks to Fish Habitat - Horsefly Watershed ________	1) the lower 20 km of Moffat Creek is heavily disturbed (channel widening, bank erosion, mid-channel bars, are common.) 2) Black Creek on its alluvial fan has avulsed and is highly unstable 3) forest development bank failures have occurred along MacKay creek	1) complete a total development plan to manage for low peak flow hazard 2) maintain a 5 m no-machine buffer along all S4, S5, and S6 streams and protect all immature and non-merchantable species in the RMA 3) de-activate unrequired roads to standards appropriate to terrain sensitivity	1) no 2) yes 3) yes

SUMMARY OF MAJOR REPORTS

TABLE II - CHRONOLOGY OF MAJOR HORSEFLY RIVER WATERSHED STUDIES (1956 – 2000)

#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
		Chapman Geosciences and Dobson Engineering for Cariboo Region Interagency Management Committee	4) road generated landslides have occurred at Pegasus Creek in MacKay basin and at unnamed tributary below Crooked Lake in McKusky basin 5) old roads were generally stable although cross drain frequencies were low with long uninterrupted ditchlines 6) old open-pit mine at Molybdenite Creek contributing large amounts of fine sediment 7) channel conditions for the Horsefly Watershed are generally good	4) increase cross-drain frequency (eliminate long ditchlines) and construct sumps in ditchlines at all stream crossings 5) implement sediment control measures during road construction (i.e. sumps, silt fences, waterbars, geotextiles etc.) 6) complete terrain mapping for all sensitive slopes and drainages 7) use terrain maps to assist in forest development planning 8) develop a riparian zone awareness program for landowners along Moffat Creek 9) establish riparian buffer zones along Moffat Creek and plant with shrubs and trees	4) yes 5) yes 6) yes 7) yes 8) yes 9) part
15	1998	Channel Assessment Procedure of Parts of the upper Horsefly River, McKusky Creek, and MacKay River, Cariboo Forest Region Luanne Chew M.Sc. Carmanah Research Ltd. for Riverside Forest Products	1) large differences in discharge (147 m^3/s, 5 m^3/s, and 16.9 m^3/s) between the 3 sets of photos (1958, 1970, and 1996) obscured a majority of channel characteristics compared 2) Horsefly R between falls and MacKay - shifting log jams and channel caused by large floods in the late 80's - local increase in sediment at confluence with MacKay R- some instability between Doreen Creek and falls- 2.3 km of altered channel possibly part due to forestry - 0.5 CIV indicates moderate impact 3) McKusky Ck below Crooked L - some aggradation in upper reach - sediment accum for 500m below mouth of unnamed trib w/ slides - 0.53 km of altered channel - 0.4 CIV indicates low impact 4) McKinley Ck between Bosk and Gotchen L. - no instability or channel change found - Gotchen Lake buffers against forestry impacts 5) MacKay R below Pegasus Ck - several slides and large bank failures along lower reaches, half are natural - historically MacKay receives much sediment - stream power transports most to the Horsefly R - only 400m of forestry related slide altered channel indicates CIV of 0.4 or low impact		
16	April 1998	McKinley Creek Watershed - Overview Fish Habitat Assessment	1) sockeye, chinook, and coho spawn in McKinley Ck reaches up to Elbow L - coho may extend to Bosk L and utilize off channel and littoral lake areas for rearing - rainbow throughout the basin 2) reaches 3, 4, and 5 below McKinley Lake contain several tributaries with failed culverts blocking fish access to off channel habitat – sediment input from road drainages was observed 3) McKinley Ck reach 8 may receive sediment from adjacent logging, otherwise, stable low impacted channel observed reaches 8 thru 10 (to Elbow L) 4) reaches between Bosk L and Gothchen L w/ varying degrees of related impacts (no riparian buffer 350m, may be private land) 5) Basset Ck - possible cumulative impacts from moderate to high levels of harvest including some riparian logging and impassable culverts 6) Molybdenite Ck - juvenile coho in lower reaches - mine site observed to contribute fine sediment - upslope logging a potential sediment source,	1) portions of McKinley Ck below the Lake and much of Molybdenite Ck and Divan Ck were given moderate to high priorities for Level 1 FHAP's 2) McKinley above Bosk L and portions of Basset Ck and Divan Ck recommended for Riparian Assessments 3) fish passage culvert inspections recommended for portions of Bassett Ck, Divan Ck, Offset Ck and two unnamed tribs 4) sediment control and monitoring suggested for much of McKinley Ck, some of Basset Ck, much of Molybdenite Ck, some of Offset Lake Ck. and two unnamed tributaries (SEE APPENDIX for G3 summary Tables)	1) ? 2) no 3) no 4) part

SUMMARY OF MAJOR REPORTS

TABLE II - CHRONOLOGY OF MAJOR HORSEFLY RIVER WATERSHED STUDIES (1956 – 2000)

#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
			although large wetland restricts transport to high flow seasons - some bank instability associated with streambank logging 7) Divan Ck - kokanee, rainbow, and possibly coho present – culverts in reaches 2 to 5 may be barriers to fish - logging to streambank along same reaches 8) unnamed tributary flowing into Gotchen L logged both banks with some instability and an aggrading channel observed - rainbow trout stream		
17	May 1998	Horsefly River Watershed - Sediment Source Survey G3 Consulting Ltd. for Riverside Forest Products	1) 78 low to very high risk sediment source sites were selected for viewing from the 596 sites identified by Dobson and Carr (1996) - only high and above Carr sites were visited, most were in the drainages with steep terrain 2) most sediment sources described were related to cut and fill slopes, roads, drainage, and culvert problems, around 15% were related to slides and potential slides (tension cracks), 5 were bridge abutments and armoring 3) see G3 summary tables in Appendix IX 4) ditchlines, a major source of fine sediment, were apparently not assessed 5) consequence was apparently based on coarse sediment delivery potential only	1) recommendations were very general and often related to entire road networks, with cut and fill slopes the main mention (Appendix IX) 2) 161 recommendations fell into the following main categories: level 2 assessment (64), deactivate road (26), maintenance (20), make repairs (17), vegetate (7), bio-engineer (6), hydraulic review (6) 3) use terrain hazard maps and geoscientist in sensitive areas 4) develop an on-going audit program to assess existing and new sediment sites 5) develop effectiveness monitoring plan along with level 2 assessments	1) yes 2) yes 3) yes 4) ? 5) ?
18	May 1998	Horsefly River Watershed Effectiveness Monitoring System G3 Consulting Ltd. for Riverside Forest Products	1) without Level II prescriptions a monitoring system is difficult to prescribe 2) suggested <u>implementation monitoring variables</u> to measure included: length of road fully contoured (23 sites), # of cross drains per km (2 sites), 3) suggested <u>effectiveness monitoring variables</u> to measure included: per cent survival of planted trees (24 sites), net areas revegetated (23 sites), amount of slumping and raveling (6 sites), # and size of tension cracks (1 site) 4) <u>validation monitoring variables</u> to measure included: stream siltation (45 sites),	1) suggested monitoring methods include: supervise repairs at 54 sites, supervise revegetation at 32 sites, supervise recontouring at 7 sites, supervise bioengineering at 9 sites, (I don't think this is monitoring) 2) suggested implementation monitoring is: measure stocking densities at 36 sites 3) suggested validation monitoring is: employ sediment traps and turbidimeters at 8 sites	1) yes 2) ? 3) ?
19	2000	Horsefly River Black Creek Restoration Project – Riparian Assessments and Prescriptions R.L. Case & Associates – Watershed Consulting For Riverside Forest Products	1) two general ecologies characterize the valley bottom soil types, moisture regimes, surface topography, and vegetation for 8 km along the Horsefly R. 2) early seral mixed pine aspen spruce forests historically occupied well drained coarse textured alluvial fans built by numerous lg and sm tributaries 3) shrub sedge meadows would have dominated wet low-lying fine grained floodplain areas, where numerous remnant old channels, depressions, and oxbow lake cutoffs mix with the fans to diversify the surface topography, moisture regimes, and plant species mosaics 4) clearing, farming, and grazing from the early part of the 20th century converted much of this area to domesticated grasses, although remnant shrubs and wild grasses are still evident 5) treeless and shrubless riverbanks give way more readily to erosive river processes which generate sediment and lateral river movement of up to 1 meter or more per year at some corners	1) a breaking plow should be used to peel back the sod and suppress the grasses before planting 12 shrub and 4 tree species 2) coarse woody debris should be placed on sites to be forested (alluvial fans above high water). Species should be planted in mixed clusters to reestablish early seral mixed communites according to a natural template 3) meadow communities should be planted with mixed species having a high flooding tolerance using the plowed strip site prep treatments (mainly willows) 4) riverbanks, oxbow lakes, old remnant channels, and depressions should be lined with plantings in groups and clusters using the flooding tolerant species in the low lying areas, adding cottonwood and spruce on higher ground. 5) migrating riverbanks should be densely staked with willows up to 2 meters back on the highly active outside meander corners	1) ongoing 2) ongoing 3) ongoing 4) ongoing 5) ongoing

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TABLE II - CHRONOLOGY OF MAJOR HORSEFLY RIVER WATERSHED STUDIES (1956 – 2000)

#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
20	2000	Prescriptions to Protect, Enhance, and/or Restore Eleven Small Tributaries and Backwaters Along the Lower Horsefly River R.L. Case & Associates – Watershed Consulting For Riverside Forest Products	1) small S4 tributaries to the Horsefly River near spawning grounds are sought out and utilized by rearing coho and rainbow trout 2) old river meander cutoffs once isolated as ponds or lakes can trap rearing juveniles when peak flows recede 3) off channel habitat and small tributaries on private ranchland and in hay fields can be protected and rehabilitated with minimum impact to ranching operations yet great benefit to the salmonid species 4) creative cooperative prescriptions can serve both interests	1) reconnect biologically suitable isolated old river sections (ponds, oxbows), to insure fresh river water and fish access during low flow 2) enhance and/or restore potential off-channel habitats and small creeks, and ditches with woody debris and plantings. Use cuttings and seedlings of trees and shrubs modeled after successional processes, potential natural communites, and biodiversity 3) protect small streams and plantings from trampling and browsing by using tree carcasses as a barrier when feasible 4) use riparian fencing and alternate watering systems in selected locations 5) breach the dike at four locations to reconnect the river to its floodplain 6) reestablish hillslope natural drainage by breaching the diversion ditches on The Land Conservancy property 7) replace metal culverts with fish friendly culverts (open bottom or log) 8) transplant willow clumps and create high microsites while excavating connector ditches and breaching the dike	1) NA ?
21	1994 to 2000	Stream Temperature Monitoring Rob Dolighan and Moshi Charnell MELP Cariboo	1) air and water temperatures are being monitored at 8 key stations in the Horsefly Watershed using temperature reading data loggers 2) readings are collected every 8 seconds and averaged every 30 minutes beween ice off and freezeup. 3) a Masters Candidate student (Moshi Charnel) will be analyzing the data and expanding the study in cooperation with Riverside to assess correlation's with level of retained trees (shade). 4) McKinley Creek is above threshold temperatures during most years, so is the river below the townsite 5) cool water comes from the upper Horsefly and MacKay sub-basins but probably also from streambank seepage (groundwater) and small tributaries		
22	1994 to 2000	Suspended Sediment Monitoring Pat Teti – MOF Research Hydrologist Cariboo	1) suspended sediment is being monitored at 8 locations 2) suspended sediment is below threshold levels (25 mg/l continuous) during non-peak flow seasons at the 4 locations along the Horsefly River 3) sediment levels range between 5 and 15 mg/l (approx.) depending upon wetness of the year 4) Moffat Creek suspended sediment levels ranged between 150 and 20 mg/l in a wet year (1999) with values doubling between the highest and lowest sampling points due to agriculture as well as some naturally unstable banks		
23	2000	Detailed and Reconnaissance Terrain Stability Mapping for Nine Watersheds Horsefly River Area Terra Engineering Ltd. For Riverside Forest Products	1) the majority of the operable forest within the Horsefly River Watershed is considered stable (Classes I, II, and III) 2) Class IV and V (unstable terrain) is most common in the sub-alpine regions of the high relief Quesnel Highlands and Upper Quesnel Highlands, i.e. middle to upper valley slopes, also some steep glaciofluvial deposits along the Horsefly River 3) considerable Class IV and V terrain occurs in the Upper Horsefly,	1) a qualified Registered Professional is required to conduct a terrain stability field assessment on Class V terrain prior to development 2) a qualified Registered Professional may be required on Class IV terrain (location and harvesting method dependent) 3) management options on IV and V include: avoidance, prevention, stabilization and protection including: 4) use of excavators and full bench end haul techniques, compact fill	1) yes 2) yes 3) yes 4) yes

SUMMARY OF MAJOR REPORTS

TABLE II - CHRONOLOGY OF MAJOR HORSEFLY RIVER WATERSHED STUDIES (1956 – 2000)

#	Date	Title of Study / Consultant and Proponent	Principle Findings	Recommendations	Follow-up
			MacKay, and McKusky, sub-basins 4) some Class IV and V terrain occurs on upper slopes along the Horsefly River above the falls and in the Doreen sub-basin 5) little unstable and potentially unstable terrain occurs in the McKinley sub-basin	5) avoid cross-gully yarding and heavy rainfall months 6) use rock fill buttressing and catch-walls when appropriate	5) yes 6) yes
24	April 1998	Interim Forest Development Recommendations for the Horsefly River Watershed ——— Horsefly River Watershed Monitoring Committee HWMC		1) Develop access management plans and strategies in order to facilitate road construction, maintenance, and deactivation activities 2) Provide erosion control plans for enhanced road construction, maintenance, deactivation, and monitoring (see Erosion Control Plan – Appendix I) 3) Establish a communication process, to inform users and agencies of study results, restoration efforts, road deactivation, road inventories, monitoring 4) Continue the terrain stability mapping including beyond class IV and V terrain 5) Continue watershed restoration activities 6) Enforce MX recommendations for mining access temporary road construction (Appendix)	

8.0 SUMMARY RECOMMENDATIONS FOR EACH SUB-BASIN

8.1 Horsefly River above MacKay Ck- Sub-basin #1

The upper Horsefly River sub-basin has a drainage area of 141 sq. Km and is dominated by steep slopes that are directly coupled to the mainstem channel. Potential delivery of sediments to the main channel from landslides is high. Suspended sediment coming from the basin above forestry activities during spring runoff was observed to be low (Chapman and Dobson 1997). Lower reaches are sediment transport zones. The upper channel is alluvial and sensitive to increases in peak flow and sediment supply. A table of IWAP hazard indices (Teti 1997) and other useful parameters and a summary of principle findings and recommendations by specific report (and HWMC) follows. Indices <0.5 are low hazard, between 0.5 and 0.7 are medium hazard, and those above 0.7 are high hazard.

Polygon #1		Hazard Indices by year 2002				Other Useful Parameters @2002					
Watershed	Area sq. km.	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2001	Road Lngth (km)	Stream crossings	Land-slides (man-made)	Roads 100m to creek (km)	Road Dens km/km^2
Horsefly River above MacKay Ck	141	0.11	0.44	0.13	0.39	6.4%	55	61	11	20	0.25

Proudfoot (1994)
- Minimize road construction on class IV and V terrain
- Deactivate roads before snowmelt
- Consider skyline logging on class V terrain
- Numerous unnamed creeks with steep valley walls above Mackay Creek have a very high hazard to delivery sands, gravels, cobbles to the mainstem Horsefly
- Conduct sediment delivery (throughput/transfer) study to determine delivery patterns and risk

Carr et. al. 1996
- Fifteen sediment sources, five are high risk or greater
- Low and moderate risk sites should not be ignored
- Inherent soils and terrain instability in basin (74 natural slides found)
- Focus on drainage restoration and deactivation

Northwest Hydraulics and Coast Environmental (1996)
- Very high transport hazard (gullies and tributaries)
- Extend reserves on steep tributaries and gullies
- Main source of sediment is upper river tributaries

Chapman and Dobson (1997)
- High potential sediment delivery from steep valley slopes
- Roads on lower slopes are contributing sediment to the main channel

- Sumps at crossdrains are infrequent and where present require maintenance
- Unstable terrain may exist on middle and upper slopes
- Moderate potential surface erosion hazard index
- Moderate potential landslide hazard index
- Input of sand to main channel at some cross-drain locations

G3 Consulting (1998)

- Majority of soils are erodible, i.e. sand and gravel with minor silt
- 9 sediment sources identified - 2 high, 2 moderate, 4 low to moderate, and 1 low
- Sources were related to culverts, crossings, 1 bridge abutment, and roads
- Several undersized culverts (some damaged or poorly armored) along main road
- Inadequate culvert frequency, erosion channels, and tension cracks along main road

HWMC recommendations to the District Manager (April 1998)

- Implement an enhanced road monitoring, maintenance, and deactivation program to minimize surface erosion (see Upper Horsefly Current Operational Standards – Appendix III)
- Develop mitigation plans for potential erosion sites to be included in road plans
- Continue seasonal operation inspections of main line road
- Complete Sediment Source Survey field assessment of all priority hot spots and roads
- Schedule road activities and communicate actions taken on problem areas
- Develop road condition assessment and prescriptions for main line roads and hot-spots
- Continue a one cut-block per year harvesting guide above second crossing until completion of the detailed Sediment Source Survey field inspection report
- Apply more water temperature monitoring to better understand the sources of cold water input
- Apply Best Management Practices to S4, S5, and S6 streams (Appendix II)

8.2 Horsefly River above the falls - Sub-basins #1, 2, 3, 4, 5, 6, 7, 14

The watershed above the falls covers a total area of 785 sq. km. Hazard indices were calculated for the composite area. Specific recommendations for the tributaries are also contained under the appropriate sub-basin. Recommendations from reports apply to Sub-basin #2 called Horsefly River above the falls, while the hazard indices apply to the whole watershed above the falls. In general the area is mountainous with steep valley walls and a high potential for sediment delivery. Hazard indices as a result of forest harvesting and road development by the year 2002 are high for surface erosion and landslides, 0.68 and 0.71 respectively (Teti 1997). The IWAP table of hazard indices and other parameters for the year 2002 and recommendations by specific report follows. Indices <0.5 are low hazard, between 0.5 and 0.7 are medium hazard, and those above 0.7 are high hazard.

Polygon #1, 2, 3, 4, 5, 6, 7, 14		Hazard Indices by year 2002				Other Useful Parameters @2002					
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2001	Road Lngth (km)	Stream crossings	Landslides manmade	Rd lngth 100m to ck (km)	Road Dens km/km2)
Horsefly River above the falls	785	0.41	0.68	0.35	0.71	21.3%	615	394	177	179	0.66

Proudfoot (1994)

- Club Creek roads (older roads, steep terrain) were constructed using extensive sidecasting and are a hazard. Serious road erosion is carrying sediment to the creek. Permanent and semi-permanent road deactivation and a terrain specialist is needed here before future logging
- Sawley Creek (high hazard) has a steep gradient flowing through a steep-sided gully for most of its length. It has a high potential to transport coarse and fine sediment to the Horsefly.
- Doreen Creek (high hazard) has large volumes of sediment temporarily stored in unvegetated bars at is mouth. It can probably be transported during most of the year. Field studies are required.
- Prairie Creek (moderate hazard) flows through a low gradient floodplain before reaching the river. There are no features indicative of moderate to high transport (unvegetated bars)
- A sediment transfer hazard study is recommended for the Horsefly River Watershed. Source areas, temporary storage areas, and throughput potential would be analyzed using field data.
- Recommend field measurement of sediment transport in the meander reaches above the falls. This would determine how much sediment passes through this section to the spawning gravels and when.

Carr et.al. (1996)

- In sub-basin #2, along the Horsefly between McKinley Creek and MacKay Creek, 105 forestry related sediment sources were found, while only 35 were rated as having a high or above risk.
- Low and medium risk sites are sometimes block roads and clearcut complexes, which could have a high cumulative impact. They should not be ignored.
- A road deactivation program, a review of maintenance, and an integrated hillslope rehabilitation plan are the three main recommendations

Northwest Hydraulics and Coast Environmental (1996)

- Club and Sawley Creeks have a high sediment transport potential to the spawning gravels in the Horsefly
- Additional riparian buffers are needed on steep tributaries and gullies on the northside of the Horsefly River
- A detailed review of ECA is needed on northside of Horsefly River

G3 Consulting (1998)

- 32 sediment source sites were identified, 5 were rated high risk, 3 were rated low risk and the rest were in between
- Older pre-code logging on steep slopes has numerous areas with cut and fillslope slumping, decayed log culverts, tension cracks, diverted drainage, and slides. Some have the potential for direct sediment delivery
- Recommendations include: improve deactivation, deactivate, recontour slopes, improve road surface/bed, improve drainage, make necessary repairs

HWMC recommendations to the District Manager (April 1998)

- Complete Sediment Source Survey field assessment including priority hot spots, roads, and especially stream crossings and roads within 100m of streams
- Review non-status roads – those naturally deactivated to ensure they are not a sediment source
- Apply Best Management Practices to S4, S5, and S6 streams (Appendix II)

8.3 McKusky Creek - Sub-basin #3

The McKusky creek flows on a low gradient meander plain for more that 11`km from Crooked Lake to its confluence with the Horsefly River. The lake acts as a trap for sediments derived upstream such that sediment delivered to the Horsefly River only comes from valley slopes and tributaries below the lake.

Topographic relief is high on the north side of Crooked Lake and in the upper sub-basin. A large wildfire covered much of the northeast portion of the sub-basin above the lake and in the lower tributary basins. Numerous landslides both natural and manmade have occurred in two of these tributary sub-basins causing some stability concerns. The actively moving coarse bedload is slowly moving toward McKusky Creek where it should stop. A table of IWAP hazard indices (Teti 1997) and other useful parameters and a summary of principle findings and recommendations by specific report (and HWMC) follows. Indices <0.5 are low hazard, between 0.5 and 0.7 are medium hazard, and those above 0.7 are high hazard.

		Hazard Indices by year 2002				Other Useful Parameters @2002						
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2001	Road Lngth (km)	Strm xings	Strm logged (km)	Slides man-made	Rd lngth 100m to ck (km)	Road Dens km/km^2)
McKusky Creek	311	0.41	0.44	0.26	0.83	30	177	118	43	92	50	0.41

Proudfoot (1994)

- Low hazard due to gentle gradient and Crooked Lake trapping sediment
- Transported gravel probably requires years (or decades) to reach the Horsefly River
- Sand is probably transported during moderate discharges.
- Silt and clay may move to the main river during all but lowest discharges

Carr et.al. (1996)

- Sixty-one sediment sources identified, 35 manmade
- Sixteen related to haul roads, 17 related to logging and block roads, 8 are high risk
- Of the 8, 4 are related to drainage problems, one associated with numerous slope failures
- An integrated hillslope rehabilitation plan is recommended for 5 sites, maintenance and deactivation for the others
- Sediment loading by natural origins should be considered in the context of the plan
- One sediment source (high) related to recreation and one related to agriculture (low)

Northwest Hydraulics and Coast Environmental (1996)

- Low to moderate landslide and surface erosion risk with potential for fine sediment to reach spawning gravels
- Review riparian reserves below lake, establish 20m reserve along S4, S5, and S6's

Chapman and Dobson (1997)

- Unstable terrain may exist on middle and upper slopes, based on frequency of slides
- New road construction is a sediment concern on lower slopes close to the mainstem
- Maintain a 5m no-machine buffer along all S4, S5, and S6 streams
- Protect all immature and non-merchantable species in the RMZ
- Increase cross drain frequency on long uninterrupted ditch lines and construct sumps at all stream crossings
- Implement sediment control measures during road construction
- Deactivate all roads not needed

G3 Consulting (1998)

- Failing fillslopes, erosion channels, and drainage problems on gentle over steep terrain (2nd drainage below Crooked Lake eastside). Deactivation and Level II Assessments are required
- Several debris slides, fillslope, erosion channel, and gully problems (high hazard) in tributary basins on west side. Deactivation and Level II Assessments required.
- Three low hazard sites on eastside of Crooked Lake, maintenance and/or deactivation required

HWMC recommendations to the District Manager (April 1998) McKusky River:

- Complete detailed site assessments on potentially unstable slopes
- Complete sediment source survey field assessments of all priority hot spots and roads
- Evaluate landslides in lower McKusky. No further harvesting in this area except for beetle salvage until assessment is complete
- Identify necessary road deactivation work

- Monitor and report road deactivation work on high risk sites
- Complete channel assessment including field inspections
- Apply Best Management Practices to S4, S5, and S6 streams (Appendix II)

8.4 MacKay River – Sub-basin #4

The Mackay is a broad U-shaped glacial valley with numerous hanging tributary valleys. The lowest reach about 1 km long is low gradient with large volumes of sediment temporarily stored in unvegetated bars (sand and gravel). Lower and middle hillslopes are partially connected to the mainstem channel. Alluvial fans are present at the toe of tributary streams. Topographic relief and sediment delivery potential is high in tributary valleys and in the upper main basin. The Eureka Gold Mine on Eureka Creek is a concern due to cyanide, copper sulfate, and sediment. There are moderate potential surface erosion and landslide hazard ratings. Pre-FPC road construction and logging on unstable terrain has some slides and debris transport that did not reach the MacKay. Unstable kame terrace deposits may exist along middle and lower slopes of the main valley and in tributary valleys. A table of IWAP hazard indices (Teti 1997) and other useful parameters and a summary of principle findings and recommendations by specific report (and HWMC) follows. Indices <0.5 are low hazard, between 0.5 and 0.7 are medium hazard, and those above 0.7 are high hazard.

Polygon # 4		Hazard Indices by year 2002				Other Useful Parameters @2002						
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2001	Road Lngth (km)	Strm xings	Strm logged (km)	Slides man-made	Rd lngth 100m to ck (km)	Road Dens (km/km²)
MacKay River	144	0.32	0.78	0.28	0.54	15.3	152	115	25	18	40	0.92

<u>Proudfoot (1994)</u>

- Large volumes of sediment (sand and gravel) are temporarily stored in bars along the low gradient 1st reach.
- High sediment delivery potential due to capacity to transport silts, sands, and clay to the Horsefly during all but the driest part of the year.
- Gravel can probably be mobilized by near peak discharges
- When harvesting on Class IV and V terrain minimize disturbance of soil surface. Fine rubbly coluvium, gullies, and steep creek valley walls incised into unconsolidated sediment are most sensitive.
- Full suspension logging systems should be considered for yarding on Class IV and V terrain
- Active slide initiation zones and tracks and steep sided gullies should not be logged
- A feathered buffer of trees should be left to protect gully walls from blowdown
- Use full bench cuts and no sidecast on slopes >60%. Avoid gully headwalls.

Carr et.al. (1996)

- 89 sediment sources identified, 13 associated with logging, 21 are associated with roads, and 1 associated with mining
- 54 are natural sediment source sites associated with gullies and steep unstable terrain
- 21 H+ forestry related sediment source sites should be a focus for initial remedial work, most are associated with road fill failures and drainage concerns
- The 13 source sites rated low should not be ignored due to cumulative impact
- 20 sites were recommended for the Integrated Hillslope Rehabilitation Plan (IHRP), 6 of these were to be ASAP
- The IHRP incorporates road deactivation, landing rehabilitation, gully clean-out, and landslide rehabilitation. Revegetation of denuded soils through seeding of grasses and legumes for surface erosion control or biogeotechnical slope stabilization using native shrubs is viewed as a key component of the plan.
- Rehabilitation should focus on road de-activation and restoring natural drainage
- The high risk source at the mine development should be looked at by the appropriate agency

Northwest Hydraulics and Coast Environmental (1996)

- Rehabilitate man-made sediment sources (high priority) before further harvesting in this high sediment risk drainage
- Review ECA and maintain 20% or less, analyze distribution of cutblocks and manage for hydrologic recovery
- Define stream classes and review S4, S5, and S6 riparian reserves, establish 20 meter reserves

Chapman and Dobson (1997)

- Water quality risk from cyanide, copper sulfate, and sediment at Eureka Brook
- Increased bedload, debris, channel avulsions, and bank erosion along fan of Pegasus Creek above the river, due to road generated slides in unstable terrain. Considerable road deactivation completed. Some tension cracks in deactivated roads observed.
- Terrain instability along lower and middle slopes of main valley and on middle slopes of tributary valleys
- Proposed road construction on valley lower slopes is a sedimentation concern
- Complete a road assessment in Pegasus basin to restore natural drainage
- Complete road assessment on lower MacKay mainline to check drainage structure frequency to maintain natural hillslope drainage.

HWMC recommendations to the District Manager (April 1998)

- Complete Sediment Source Survey field assessments of priority hot spots and existing roads
- Investigate causes of mass wasting and initiate rehabilitation and road deactivation
- Conduct detailed terrain assessments in the field on all sites before development
- Provide a detailed road deactivation plan, which includes monitoring
- Monitor and report road deactivation work on high risk sites

- Address sediment source survey concerns before road development after 1999
- Road development in 1999 should only proceed after terrain stability field assessment that addresses surface erosion
- Apply Best Management Practices to S4, S5, and S6 streams (Appendix II)

8.5 McKinley Creek - Sub-basins, #13 (lower), #11 (above McKinley Lake) #8, #9, #10 (above Bosk Lake),

For analysis McKinley has been broken into 3 sections (below McKinley Lake, above McKinley Lake, and above Bosk Lake. The terrain is rolling in the lower and middle sections and mountainous in the head waters. The lower (#13) and middle (#11) basins are considered high value watersheds due to the salmon spawning gravels in those reaches. Impacts to the spawning reaches are buffered by Bosk Lake, which traps all sediment. McKinley Creek supports three species of salmon in addition to kokanee, and rainbow trout. The estimated number of sockeye spawners utilizing McKinley Creek were estimated at 175,000 in 1993. DFO classifies McKinley as an "enhanced" watershed requiring greater levels of planning and management, because of its sensitivity to development impacts. A table of IWAP hazard indices (Teti 1997) and other useful parameters and a summary of principle findings and recommendations by specific report (and HWMC) follows. Indices <0.5 are low hazard, between 0.5 and 0.7 are medium hazard, and those above 0.7 are high hazard.

Polygon #11		Hazard Indices by year 2002				Other Useful Parameters @2002						
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2000	Road Lngth (km)	Strm xings	Strm logged (km)	Slides man-made	Rd lngth 100m to ck (km)	Road Dens km/km^2)
McKinley Creek at mouth	76.8					26.0						0.43
McKinley Creek above McKinley L.	368	0.41	0.51	0.55	0.37	19.3	345	159	73	27	71	0..84
McKinley Creek above Bosk L.	107	0.13	0.30	0.56	0.69	4.7	44	27	10	23	12	0.41

<u>Proudfoot (1994)</u>

- The sediment throughput rating (to the Horsefly River spawning gravels) for McKinley Creek is low due to the lake 8 km upstream and the low gradient meander plain in the lowest reach.
- Silt and clay are transported during all but low discharge periods.
- Sand is probably moved from temporary storage by moderate discharge and is likely flushed through to the river during peak discharge. Gravel transport is uncertain
- A sediment transfer hazard study is recommended for the Horsefly River Watershed. Source areas, temporary storage areas, and throughput potential would be analyzed using field data.

<u>Carr et.al. (1996)</u>

- 28 forestry related sediment sources were identified (ll mainroad, 17 logging). 10 were rated high or above risk
- 6 high risk sites were recommended for integrated hillslope rehabilitation plan (1 ASAP), the rest required a review of maintenance practices

<u>Northwest Hydraulics and Coast Environmental (1996b)</u>

- Maintain less than 20% ECA for the main spawning stream and for sub-basins up to one stream order less than spawning streams
- Molybdenite Creek and Elbow/Basset Creek watersheds are at 25% ECA by 2000 creating a potential increase in snowmelt floods and risk to the spawning gravels
- Recommend further analysis of the distribution of cut blocks and their hydrologic recovery (point of interest head of McKinley Lake) prior to approval of any harvest after 2000
- Because of a lower elevation melt period, the basin below McKinley Lake is considered a low priority in terms of peak flow hazard, over 20% ECA is acceptable
- Reach 1 receives sediment from small tributaries (west bank), main road along east bank, and agricultural fields
- Review runoff and sediment production from agricultural fields along reach 1
- Study is needed to determine status of spawning populations upstream of Elbow Ck
- Exclude harvesting in riparian management zones in reach #1 and #4 (below and above McKinley Lake to insure protection for spawners
- Moderate to high potential for landslides above Bosk Lake and low in the lower reaches
- McNeil, Gotchen, and Bosk Lakes trap all coarse and most fine sediment generated in the upper watershed. and a low risk to the spawning reaches
- Recommend remediation of high priority sediment sources leading to reach 4 spawning gravels (Molybdenite Creek, small tributaries, Elbow Creek, and Basset Creek) as identified by Carr et.al. (1996)
- Reach 1 is gravel supply limited and at risk of losing spawning gravels (coarsening) if peak flows increase in magnitude and frequency
- Reach 3 is unconfined (shifting meanders) and a producer of valuable off channel habitat as well as sediment. Increased peak flows could accelerate bed and bank scour (sediment) in this reach.
- Medium and coarse sand from Molybdenite (road construction and harvesting) could potentially degrade spawning gravels in reach 3.
- The riparian management zone (RMZ) should extend to the edge of the floodplain, which is about 50m in reach 1, 310m in reach 3, and 40m in reach 4.
- Harvesting would be excluded in the RMZ of reaches 1 and 4.
- The riparian reserve should be extended to 100m, with limited harvesting in RMZ, along reach 3. This will protect wetlands and off-channel habitat.

- If harvesting proceeds in RMZ several precautions should be taken. Maintaining a 20 ECA is probably OK

Chapman and Dobson (1997)

- Stream temperatures in the lower McKinley approach salmon mortality concerns
- There is moderate concern for riparian buffer and landslide hazard above Bosk Lake
- Above Molybdenite Creek gravel/cobble beds were found to be moderately compacted with fine sediment.
- Large sediment plume in Elbow Lake from Bassett Creek coming off roads and ditchlines
- Some long uninterrupted ditchlines and infrequent crossdrains and sumps, where running surfaces are fine grained. In Basset Creek drainage some deactivation needs repair.
- Surface erosion concerns related to new road construction
- Complete a road assessment in Basset Creek drainage

G3 Consulting SSS (1998)

- 3 low and 1 moderate sediment source site were identified
- One site noted drainage problems and unstable cut/fill slopes
- Level 2 assessments, road maintenance, and one deactivation was recommended

G3 Consulting FHAP (1998)

- McKinley Creek below McKinley Lake contained several tributaries with failed culverts blocking fish access to off-channel habitats
- Basset Creek - possible cumulative impacts from moderate to high levels of harvest including some riparian logging and impassable culverts
- Recommend high priority for Level I Fish Habitat Assessment - McKinley Creek below the lake, Divan Creek, and Molybdenite Creek
- Fish passage culvert inspection recommended for portions of Basset Creek, Divan Creek, Offset Creek, and 2 unnamed tributaries
- McKinley above Bosk Lake, and portions of Basset Creek and Divan Creek are recommended for riparian assessments
- Sediment control and monitoring recommended for much of McKinley Creek, some of Basset Creek, much of Molybdenite Creek, some of Offset Creek, and two unnamed tributaries.
- Divan Creek - kokanee, rainbow and possibly coho present - culverts in reaches 2-5 may be barriers to fish
- Unnamed tributary into Gotchen Lake logged both banks - some instability and an aggrading channel - rainbow trout stream

HWMC recommendations specific to McKinley Creek:

- Complete sediment source survey field assessments of priority hot spots and roads
- Complete channel assessment procedure
- Complete riparian overview assessment to identify and prioritize riparian rehabilitation needs

- Apply interim terms and conditions for stream crossings and Best Management Practices from riparian management guidebook (Appendix II)

8.6 Molybdenite Creek - Sub-basin #12

Molybdenite Creek, a tributary to McKinley Creek, is an important habitat for salmon spawning and rearing. Fisheries agencies are concerned about activities that lead to increases in sediment, peak flows, and stream temperatures. It is a long linear sub-basin with a broad low gradient floodplain. Wetland complexes are distributed throughout. IWAP calculates a moderate hazard for riparian buffer due to length of stream logged. Basin contains erodible fine grained soils.

Polygon #12		Hazard Indices by year 2002				Other Useful Parameters @2002						
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2000	Road Lngth (km)	Strm xings	Strm logged (km)	Slides man-made	Rd lngth 100m to ck (km)	Road Dens km/km^2)
Molybdenite Creek	79	L	L	M	na	25.6	93	34	15	na	14	0.91

Carr et.al. (1996)

- Forty-three sediment sources were identified - all but one were man-made - 2 were associated with mining - most were associated with block roads and drainage problems.
- 32 were rated as low to moderate risk, they should not be ignored due to cumulative impacts
- Two critically high risks associated with mining should be investigated for compliance and cooperation to reduce impacts
- Five sites require the development of an integrated hillslope rehabilitation plan, 3 require the implementation of road deactivation

Northwest Hydraulics and Coast Environmental (1996b)

- Molybdenite Creek and small tributaries on east bank of McKinley Creek are the main potential source of sediment to the McKinley Creek reach 4 spawning gravels
- Molybdenite creek delivers only fine sediment (silt, sand), due to a highly sinuous low gradient bog in its lower reaches
- Recommend 10 - 20m windfirm reserve zones along S4, S5, and S6 streams
- Recommend remediation of high priority sediment sources identified by Carr et.al. (1996) as they are a potential risk to spawning gravels in McKinley Creek

Dobson and Chapman (1997)

- Basin contains highly erodible fine grained soils - high sediment loads during runoff
- Old open pit mine in upper basin is a major cause of high suspended sediment levels - recommend development of an erosion control plan

- Harvesting in riparian zone of lower basin has caused bank erosion, channel widening, and aggradation
- Lower mainstem channel sensitive to direct riparian disturbance, increases in peak flow, and bedload
- Rutting and surface erosion on post-FPC roads - due to the fine textured materials
- Infrequent cross-drains and ditch line erosion needs armoring
- Cut and fill slopes need grass seeding
- Roads need restrictions on use during wet weather
- Recommend reduced rate of cut due to surface erosion problems and amount of proposed road

G3 Consulting FHAP (1998)

- Juvenile coho in lower reaches of Molybdenite Creek
- Sediment control and monitoring suggested for much of Molybdenite Creek
- Recommend high priority for Level I Fish Habitat Assessment
- Mine site observed to contribute fine sediment to Molybdenite Creek

G3 Consulting SSS (1998)

- Potential bank instability due to logging to stream bank in some locations
- Several landings were observed close to the creek
- Little potential for delivery of coarse sediments to McKinley Creek due to low gradient wetland complex in reach 1 and 2- risk rating given is low

Interagency Technical Committee Recommendations (Sept 1998)

- Molybdenite Creek – Harvesting levels should not be more than 85 ha/yr with 3 km of new road per year until the Erosion Control Plan (ECP – Appendix IV) are proven effective.

8.7 Doreen Creek – Sub-basin #14

Doreen creek is a 20 sq km watershed in the north central part of the Horsefly Watershed. It is directly connected and a source of sediment to the Horsefly above a low gradient section. Unstable steep terrain surrounds the lake and along lower sections of the creek. Natural slides have occurred in several locations. The creek flows at a low gradient for about a kilometer above the Horsefly River.

Polygon #14		Hazard Indices by year 2002				Other Useful Parameters @2002						
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2000	Road Lngth (km)	Strm xings	Strm logged (km)	Slides man-made	Rd lngth 100m to ck (km)	Road Dens (km/km^2)
Doreen Creek	20	H			H	30	27	12	7	Na	5	1.35

Proudfoot (1994)

- Creek is low gradient for the first kilometer

- Large volumes of sediment (probably sand and gravel) are temporarily stored in unvegetated gravel bars and floodplains in this lowest reach
- Doreen Creek is given a high sediment transport rating due to the capability to transport sand, silt, and clay into the Horsefly River during all but driest parts of the year.
- Field studies are required to verify gravel transport

Carr et.al. (1996)

- Eleven manmade sediment sources, two natural sources
- Five H+ risk sites should be a high priority for remedial works
- Block roads with edge and slope related failures need integrated hillslope rehabilitation plan

Northwest Hydraulics and Coast Environmental (1996)

- Creek leads directly to the Horsefly River
- Creek has high peak flow and transport hazard
- High priority for work due to potential for sedimentation in downstream spawning reaches
- Establish 20m reserve along S4, S5, and S6 streams
- Review distribution of cutblocks and hydrologic recovery
- Restrict harvesting in watershed due to high hazard to transport sediment to the Horsefly River

G3 Consulting (1998)

- Steep unstable terrain (old slide tracks) and old logging needs field assessment on cutblocks along northside and southwestern end of Doreen Lake
- Six sites of concern were identified, 4 rated as high or above with deactivation, bio-engineering, improved drainage, road repair, and Level II assessments recommended

HWMC recommendations to the District Manager (April 1998)

- Identify sediment sources in the field – especially stream crossings and roads within 100m of streams
- Complete SSS field assessments of all H+ (priority hot spots) and roads
- Review non-status roads to see if they need attention or are naturally deactivated
- Apply Forest Practices Code Best Management Practices at all S4, S5, and S6 streams (see Appendix II)
- Interagency Committee may wish to address stream temperature issues at their table

8.8 Woodjam Creek – Subbasin #18

The Woodjam watershed covers 86 sq. km. in an area of low topographic relief. The terrain is rolling and gentle with some wetland areas in upper drainage. Ninety-six percent is Crown land with 4% in private ownership, mostly along a 4 km alluvial channel at the mouth of the watershed. Fine textured erodible soils in the watershed are a concern regarding increased road development and harvesting which are planned over the next few years. Farming and grazing along streambanks of the agricultural reaches is also a concern. Twenty per cent of the basin is proposed for development in the next few years increasing ECA's from 3.5% to 22.1%. A table of IWAP hazard indices (Teti 1997) and other useful parameters and a summary of principle findings and recommendations by specific report (and HWMC) follows. Indices <0.5 are low hazard, between 0.5 and 0.7 are medium hazard, and those above 0.7 are high hazard.

Polygon #18		Hazard Indices by year 2002				Other Useful Parameters @2002						
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2001	Road Lngth (km)	Strm xings	Strm logged (km)	Slides man-made	Rd lngth 100m to ck (km)	Road Dens (km/km^2)
Woodjam Creek	86	0.50	0.66	0.54	na	22.1	69	60	23	na	18	0.80

Proudfoot (1994)
- High capability to carry large volumes of fine sediment (clay, silt, and sand) into the Horsefly River

Carr et.al. (1996)
- Eleven sediment source sites were identified. Four were related to roads, four were related to logging, and 3 were related to agriculture. The two high risk sites were along roads.
- Road deactivation is recommended for the road related sources and the agriculture sites were undetermined.

Northwest Hydraulics and Coast Environmental (1996)
- Proposed harvest will lead to increased peak flows, increased surface erosion, and increased sediment delivery to the Horsefly River
- Woodjam actively delivers sediment to the Horsefly and is sensitive to changes in the flood regime
- Reduce the rate of cut in the Woodjam.
- Analyze the distribution of cutblocks and hydrologic recovery
- Address high sediment sources identified by Carr et.al.
- Work with landowners to restore riparian vegetation along denuded reaches on private land
- Review need for riparian reserves along S4, S5, and S6 streams

Chapman and Dobson (1997)
- Lower mainstem riparian areas have been cleared for farming and destabilized banks are a potential source of sediment
- Channels in upper basin are stable, however sediment input from roads was noted
- Running surfaces of new roads are fine textured, not stable, and delivering sediment
- Reduce the 3.7%/year rate of cut in order to reduce new road construction, surface erosion, change in peak flows

G3 Consulting (1998)

- Sediment Source Sites identified by Carr et.al. (1996) were reviewed by air photo and given a low rating. None were considered a risk.
- Forestry related sites were expected to be limited to exposed soil on road surfaces and undersized or poorly installed culverts.

HWMC Recommendations to the District Manager (April 1998)

- Potential impact from hardrock mining in next 5 years (i.e. roads, trenching, drilling)
- Moderately erodible soils in the drainage
- Significant short term increase in hazard indices (i.e. peak flows, surface erosion)
- No suspended sediment monitoring in Woodjam
- Use winter road construction whenever possible for on block roads
- Evaluate effectiveness of Erosion Control Plan (Appendix IV)
- Develop enhanced stream crossing construction practices (see Appendix V)
- Re-evaluate riparian hazard index in two years to check operational planning and implementation

Interagency Technical Committee (Oct 1998)

- Limit harvesting to 86 ha/year
- Limit road building to 4 km per year until Erosion Control Plan is proven effective.

8.9 Horsefly Below the Falls – Sub-basin #15

Sub-basin #15 is comprised of the portion of the Horsefly River valley between its confluence with McKinley Creek and the townsite of Horsefly. Veder Creek, Deerhorn Creek, and Sucker Creek are major tributaries to the Horsefly in this northwestern portion of the polygon. The terrain is generally rolling with a low gradient channels in the lower reaches. Black Creek, Wilmot Creek, and Patenaude Creek are also major tributaries in moderately steep terrain in the northeastern part of the polygon. These channels are of a higher gradient and have steep valley walls. The Horsefly River in this polygon flows through low gradient agricultural land for most of its length. A table of IWAP hazard indices (Teti 1997) and other useful parameters and a summary of principle findings and recommendations by specific report (and HWMC) follows. Indices <0.5 are low hazard, between 0.5 and 0.7 are medium hazard, and those above 0.7 are high hazard.

Polygon #18		Hazard Indices by year 2002				Other Useful Parameters @2002						
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2001	Road Lngth (km)	Strm xings	Strm logged (km)	Slides man-made	Rd lngth 100m to ck (km)	Road Dens km/km^2)
Sucker Creek	27.6	H				36.8						
Deerhorn Creek	30.8	H				63.5						
Patenaude Creek	11.1	L				16.6						
Wilmot Creek	11.6	L				10.2						
Black Creek	21.6	H				26.8						

<u>Proudfoot (1994)</u>

Black Creek

- Valley walls are moderately steep and composed of silty to sandy silty morainal and colluvial sediment, sometimes gullied – headwaters are in terrain stability class V
- One area is naturally ravelling and sloughing between 1.5 and 2.5 km upstream from the Horsefly River
- Sands silt and gravel are transported to the river during all but lowest flows
- Placer mine excavations and road is a high sediment source
- Logging on gullied headwaters has a high potential to cause erosion and slope instability

Wilmot and Patenaude Creek

- Moderate to high gradient and moderately steep valley walls
- Both have potential to transport sediment but it appears low

Deerhorn and Veder Creek

- Low gradient for 2 km upstream from the Horsefly River
- High capability to carry large volumes of sediment to the Horsefly River
- Sand and silt stored in unvegetated bars

Sucker Creek

- Low gradient and lacks a sediment supply

<u>Carr et.al. (1996)</u>

- 59 sediment sources were identified in polygon #15
- 16 associated with agriculture, 27 roads, 2 mining, and 15 logging
- 33 out of 42 forestry related sources are rated moderate or low
- 8 high rated sites are associated with roads requiring better maintenance or deactivation

<u>Northwest Hydraulics and Coast Environmental (1996)</u>

- Deerhorn, Sucker, Wilmot, and Patenaude Creeks are presently stable.
- Deerhorn, Sucker, and Patenaude watersheds have lakes which protect the main Horsefly channel from sedimentation
- A detailed review of ECA and blocks before further cutting approvals in Sucker, Deerhorn, and Black Creek due to the high ECA by the year 2000
- High rates of cut in these basins is expected to cause erosion in their lower channels, destabilize some tributaries, supply coarse and fine sediment to the Horsefly River
- Review need for riparian reserves along S4, S5, and S6 streams in Patenaude, Wilmot, and Black Creek basins

<u>G3 Consulting (1998)</u>

- Seven sites were assessed from air photos. All were related to the road along the river. Four were assessed as high the other three were low or moderate and were non-conclusive.

Interagency Technical Committee (Oct 1998)

- ECA and terrain stability assessments and a road inventory should be conducted for the Black Creek drainage

8.10 Moffat Creek - Sub-basin #21

The Moffat Creek sub-basin is situated in the southwestern portion of the Horsefly Watershed. The terrain is generally low rolling except for approximately 5% of moderate relief in the headwaters. The mainstem channel is generally low gradient and alluvial with fine textured gravel banks and bed. Approximately 20 km in the lower reaches flows through private land, with about 6% of the basin in private ownership. The mainstem channel, flowing through these agricultural reaches, shows evidence of channel aggradation, bank erosion, channel widening, and lateral shifting. The channel is stable upstream of private land. Sockeye spawn in reaches below the falls (6 km). A table of IWAP hazard indices (Teti 1997) and other useful parameters and a summary of principle findings and recommendations by specific report (and HWMC) follows. Indices <0.5 are low hazard, between 0.5 and 0.7 are medium hazard, and those above 0.7 are high hazard.

Polygon #21		Hazard Indices by year 2002				Other Useful Parameters @2002						
Watershed	Area (sq. km.)	Peak Flow	Surface Erosion	Riparian Buffer	Land-slide	%ECA to 2001	Road Lngth (km)	Strm xings	Strm logged (km)	Slides man-made	Rd lngth 100m to ck (km)	Road Dens km/km^2)
Moffat Creek Sub-basin	527	0.52	0.51	0.38	0.03	22.1	625	224	77	3	104	1.2

Carr et.al. (1996)

- 127 sediment sources were identified from airphotos. Thirty one were related to roads, 62 were related to logging, 22 agriculture, and 12 natural streambank erosion.
- 88 out of 93 forestry related sources were rated moderate and low. Because of cumulative impacts they should not be ignored.
- 5 high risk forestry related sediment sources should be the focus of initial remedial works
- 2 old cutblock road complexes are rated very high and should be addressed with the integrated hillslope rehabilitation plan, the other three high rated road related sites require deactivation to restore natural drainage including pullback fill and/or review of maintenance practices
- restoration program should review works in the context of natural streambank erosion occurring at 12 sites

Chapman and Dobson (1997)

- The lower mainstem channel below the falls (6 km) contains glacio-fluvial gravels and is naturally eroding in numerous locations.
- The removal of riparian vegetation on private land has contributed to streambank instability
- Moffat Creek is stable above the private land
- A natural organic load from the upper basin contributes to dark colored water.
- Channel widening up to 200% has occurred in some areas in the first 20 km.
- Increased areas of deposition apparent from comparing 1958 and 1992 airphotos may have been caused by the 1990 flood
- ECA is projected to increase by 11.6% over 5 years to a total of 22.1%.
- Sediment generation in the Moffat is mainly produced on agricultural land. Forestry impacts are low.

<u>HWMC recommendations to the District Manager (April 1998)</u>

- Temporary roads should be fully deactivated within 2 years
- Effectiveness of deactivation should be monitored
- Establish a Forest Ecosystem Network (FEN- Appendix VI) along the upper Moffat mainstem
- Management within the FEN should be consistent with Fen objectives
- Reevaluate the potential effects of logging on peak flows and erosion in 2000
- Continue suspended sediment monitoring and install new monitoring stations upstream
- Encourage bank planting along the lower Moffat

<u>Interagency Technical Committee (Oct 1998)</u>

- Limit harvesting levels to 316 hectares/year above 1080 m elevation (H 60 line) and 210 ha/year below with 19 kilometers of new road per year.
- This limits ECA increase to 1% per year or about a 84 ha/year reduction from what was proposed

9.0 LIST OF SOME STAKEHOLDER STEWARDSHIP INITIATIVES

Riverside

Terrain stability mapping has been completed in the MacKay Creek, Doreen Creek, and McKusky Creek sub-watersheds. Some of the steeper terrain is in terrain class IV and V.

Ongoing road deactivation is designed to address sediment source sites identified by G3 Consulting and Riverside and it includes (see map Appendix VII):

- Upper Horsefly River Four block road complexes and 2 individual sites have been deactivated between 1996 and 1998. Future deactivation is planned for the Teapot Road area on the northside of river near the MacKay confluence.
- Mackay River Five block road complexes and 3 individual sites were deactivated between 1997 and 1998. Ongoing and future work is planned for the unstable Pegasus Creek area. Two other sites on the southwest side of the river are planned for future deactivation.
- Lower McKusky and Offset Lake area   Five large block complexes were deactivated between 1995 and 1998 including the unstable terrain in the Sky Fire area. Ongoing road deactivation and slope stabilization is planned for 2 locations in the lower sky fire area.
- Horsefly Above the Falls Block road deactivation has been completed on two sites on high elevation west facing slopes near Prairie Creek (97) and at one site on upper terrain near Big Slide Mtn. above Harvie Creek (97). One site is on the southside of the river near Doreen Creek and near the D Road Junction just up river from Prairie Creek.
- Doreen Creek Several km of road were deactivated in the headwaters of a main tributary to Doreen Creek (1998).

Enhanced road construction, maintenance, deactivation, and monitoring is being utilized in the Upper Horsefly River Basin (see Appendix III). This includes:

- sediment ponds and ditch blocks at all culvert intakes
- outlets have flumes or riprap to protect erodible fill
- 600 mm diameter culverts are used for all cross drains
- all disturbed soils are seeded with grass/legume mixture
- road inspections are conducted in the spring and fall and regularly during operations and after storm events
- all branch and spur roads are reclaimed (ripped and seeded) following harvest

Riverside is interested in Total Resource Plans. A Total Resource Plan was developed for McKusky basin, this included an analysis of wildlife habitats and travel corridors, as well as protection for fisheries and visual concerns

Blocks visible from the Crooked Lake resort were harvested using retention prescriptions. On an experimental basis windfirm hemlock were retained at 20 and 30% to meet visual quality objectives.

Experimental road construction techniques have been employed in several trial locations to explore ways to reduce amount of sidecut and groundwater interception.

Riverside is interested in methods that will speed hydrologic recovery and is contemplating a long term Hydrologic Recovery assessment.

A demonstration area was setup in the McKusky sub-basin to explore thinning techniques in mature stands that would enhance old growth attributes, i.e. creation of open spacing, snags, snags with broken tops, initiation of cavities, etc.
Riverside is interested in techniques that will maintain and improve cold water storage (groundwater).

Research by Moshi Charnel will investigate riparian influence (levels of retention) on stream temperatures. This work is supported by Riverside (Charnel 2000).

Lignum Ltd.

Lignums has cooperated with Weldwood, Riverside, Ainsworth, and Small Business to develop a detailed Erosion Control Plan (ECP) to be used in the erosion sensitive Moffat Creek, Molybdenite Creek, and Woodjam Creek sub-watersheds (see Appendix IV). The plan has been developed to minimize surface erosion from roads and related harvesting activity. Key ingredients of the plan include:

- minimizing the amount of annual road constructed with a limit on total active road allowed in the watershed as determined by the District Manager with recommendations from the Horsefly River Watershed Technical Committee
- using erosion control measures during road construction, deactivating roads promptly after operations are completed, and restricting access to new (highly erodible) new roads
- road inspections will take place throughout the year focusing on wetter periods and following heavy rainfall events. As a minimum, licensees will inspect active road sections at least twice annually (spring break-up and prior to freezeup).
- risk rating roads in order to assign inspection priorities - conditions that increase risk will include proximity to watercourses, type of construction, whether the road has been deactivated, soil type, age of road, and whether any ongoing problems have been documented
- using physical barriers to block access on main access roads less than 4 years old that are not being used (to reduce sediment generation)
- field trips with the Horsefly River Watershed Interagency Technical Committee in order to recommend additional site-specific measures and to determine compliance with the plan
- completing and annual ECP ledger summarizing total active road length, length of road less than 4 years old, length older than 4 years, length deactivated, proposed road construction, and proposed deactivation for the year. See complete Erosion Control

Plan details listing construction, maintenance, deactivation, shutdown guidelines, and ledgers for 2000 in Appendix IV). Ledgers have been completed for 1999 and 2000.

Lignums has 156.5 km of active road in the Horsefly Watershed, 54.5 km of road have been deactivated, and 9 km planned for deactivation in 2000.

Following operations Lignums rehabilitates all block roads, spur roads, and landings, i.e. roads and landings are ripped, prepped, and planted.

Lignums has contributed funds, personnel, and equipment to implement streambank protection measures on unstable portions of Moffat Creek in cooperation with community groups and ranchers.

Weldwood

Weldwood is a key player in the Erosion Control Plan being implemented in the Woodjam, Molybdenite, and Moffat Creek sub-basins. Main ingredients of the plan are listed under Lignums initiatives and the full plan with ledgers by each sub-basin is included in Appendix IV.

Currently Weldwood has 298.9 km of active road in the three sub-basins, with 84.5 km deactivated and 114.7 km planned for deactivation in 2000.

Road deactivation is the principle treatment for addressing identified sediment sources.

Prescriptions to address an actively sliding area in the McKinley drainage included: diverting subsurface flow away from the unstable areas using drainpipes, basting the overhanging headscarp to create a terrace, and then bio-engineering with wattle fences, modified brush layers, and heavy planting of willow cuttings on the unstable soils after the water had been redirected.

Fish passage culvert inspections have taken place in most of the operating area in the upper Moffat drainage with numerous culverts replaced by bridges or by culverts that are fish friendly. The culvert inspections were done by EBA Engineering in 1999.

Fish passage culvert inspections were also completed in the Molybdenite drainage, by Westroad Resources (1999). Two culvert were replaced.

Weldwood is currently inventorying all roads in their operating area using satellite imagery combined with airphoto analysis. The updated maps from this exercise are then used for public review and access management planning leading to deactivation planning. The project is near completion.

Landings, which were built after the Forest Practices Code are ripped, fertilized, seeded and planted. Pre-code landings are left to natural processes.

Fish Habitat Overview Assessments and Riparian Assessments are planned for the Molybdenite drainage during the year 2000.

Fish Habitat Assessments and Inventories have been completed for the Woodjam sub-basin including planting of cottonwood whips along one denuded riparian area. Westroad Resources completed the Level 1 Fish Habitat Assessment in this drainage.

Road deactivation along the 8100 road and in the Bassett Creek drainage are near completion. Roads within the Moe Fire (Moffat) were deactivated last year.

A rare, threatened, and endangered species inventory was conducted in the Moffat Creek operating area.

A Forest Ecosystem Network has been proposed by Weldwood for portions of their operating area from Moffat Lakes west along the creek, and connecting to wetlands in the main northern tributary (Appendix VI). The intent is to protect and connect important wildlife (particularly moose) movement corridors between and around wetlands.

Weldwood is proposing a demonstration site in the McKinley area to explore management techniques that will enhance succession toward old growth attributes. Mature stands would be lightly thinned combined with creating snags, snags with broken tops, coarse woody debris, cavities for woodpeckers, and denning sites.

Simon Fraser University

In 1993 shallow water bathimetry was conducted using remote sensing techniques. Water depths were modeled including areas in pool and riffle habitat.

In 1997 and 1998 a remote sensing project was initiated to explore using imagery as a method of estimating spawning salmon populations

Between 1969 and 1999 remote sensing was explored as a method to measure stream turbidity. All of these studies were designed and conducted by Dr. Roberts in the Geography Department. All were on the Horsefly River.

Ainsworth Lumber Company

Ainsworth is conducting a 5 year browsing experiment in the Sucker Lake area. Livestock exclosures are placed in areas where moose, deer, and cattle are feeding on regenerating aspen stands. Results show that there is enough browse for all without hurting the young stand.

Ainsworth is in the process of designing aspen cutblocks to meet visual quality objectives along the Black Creek Road. Blocks will be harvested in 5 years.

Ministry of Environment Lands and Parks (MELP)

In addition to the MELP projects listed under Dolighan in Appendix VIII a four year project is planned to assess the status of kokanee and rainbow trout in the Quesnel Lake and Horsefly River watershed. It is thought that declining kokanee populations may be in part caused by the increases in sockeye which compete for the same food base as juveniles. Because kokanee juveniles are a main food source for Quesnel Lake rainbows the rainbows are also effected. To better understand these relationships, population status, and potentials and consequences for enhancement activity baseline data is needed.

In conjunction with the ongoing temperature monitoring studies (since 1994) mentioned in the body of this report an expanded temperature research project is scheduled for the Horsefly Watershed. A graduate student Moshi Charnell has added 15 additional sites and will monitor, in addition to air and water temperature, the variables humidity, solar radiation, precipitation, wind, and discharge. One goal of a project initiated by Riverside, is to better understand the influence of riparian shade on water temperature at different levels of harvest and in different environmental circumstances.

Quesnel River Watershed Alliance (QRWA)

The following table lists past and current activities, which this Horsefly group have contributed toward restoration and stewardship in the Horsefly Watershed.

Restoration and Stewardship Projects Carried out by the QRWA 1998-2000			
Date	**Location**	**Funder**	**Description/comments**
June1998-March 1999	Horsefly Area	HRSEP	Streamkeepers program carried out with students and scouts in Horsefly, first community willow cuttings carried out, first landowners meetings to discuss bank stabilization and stewardship ideas
Summer 1998	Moffat Creek at Starlite Lake Bridge	Lignum with technical support from Pat Teti MOF	Tree revetments were done upstream from the bridge. Design was Pat's and Lignums paid for it. QRWA's part was to put the landowner together with Lignum and to do the planting later in the fall. Pat wrote a

Restoration and Stewardship Projects Carried out by the QRWA 1998-2000			
Date	**Location**	**Funder**	**Description/comments**
			report describing this work.
October 1998	Purchase of Black Creek Ranch on the Horsefly River by The Land Conservancy	HCTF and DFO BC Conservation Society and a number of other funders	QRWA helped to promote this purchase. They have a seat on the management committee. Their Environmental Youth Team helps with the restoration work on site
November 98-June 99	Moffat Creek on Bruce Rolphs ranch Lot 9576 Total cost (not including planting) $3580	CCFES/FsRBC	Bruce placed rocks at key spots that he identified to stop erosion. He also moved willow clumps in at some spots. He then fenced (5m setback) and the Eteam planted in summer 1999. Site was assessed by Gary Tacogna (DFO) and the DFO engineer before and after work was done. Further assessment of success and planting will take place June 2000
November 98-June99	Quesnel River Watershed	CCFES/FsRBC	Eyes of the River video produced and presented to the public spring 2000
Spring 1999	Black Creek Ranch and Quesnel River Watershed	HCTF	Qrwa erected watershed map signs in Likely and Horsefly They are carrying out a plant and bird survey at the ranch They will develop a display about the watershed.
Summer 1999	Horsefly Watershed	CCFES/FsRBC and MOELP Environmental Youth Team	A native (small) plant nursery focused on riparian shrubs was started on Hemphill/Hornburg land on Moffat Creek. The Eteam collected and planted seed, dug root cuttings and potted them, and transplanted shrubs from under power lines to the nursery. The alder stock was planted at the Black Creek Ranch in 1999 and the other stock was used at the Walters and Devillier's sites in June 2000
November 98-June 99	Horsefly River Ron Williams ranch Lot 11879 Total Cost (not including planting) $20 700	CCFES/FsRBC	Approximately 150m of bank was riprapped with rock hauled from a nearby field. The area was fenced (10m setback) and planted. Gary Tacogna and DFO engineer assessed before and after. Further assessment and

Restoration and Stewardship Projects Carried out by the QRWA 1998-2000			
Date	**Location**	**Funder**	**Description/comments**
			planting will take place June 2000
November 99-June 2000	Moffat Creek above and below the Starlite Lake Bridge on Gilbert Walters ranch lot 718 Total cost not known yet	CCFES/FsRBC	The tree revetments done in 1998 were added to. Another layer was placed on top and another set was placed at the upriver end. This was to satisfy the owner's request. He wasn't sure the revetments would hold as is even though they made it safely through the high water of 1999. Another area downstream of 120 meters was stabilized also using tree revetments. Both areas were fenced (10-15m setback) and other areas protected from cows. Standing trees were cabled to keep them at the bank edge if they do fall. Planting of areas was carried out this spring.
April-June 2000	Horsefly River Elizabeth Devillier's property Lot 2569 Total Cost not known yet	CCFES/FsRBC	Ploughing, LWD anchoring and planting of two areas that the landowner had fenced the previous year. Goal is to slow down the erosion and restore riparian habitat
June 2000	Mutschele property on the Horsefly River Lot? Next to Squaw flats	CCFES/FsRBC	Brush mats to stabilize bank, planting, possibly anchoring of LWD at base of eroding bank to deflect current Fencing will be done (30 m setback) Works in progress.

10.0 SUMMARY AND CONCLUSION

Numerous integrated watershed level studies have occurred in the Horsefly River Watershed. Substantial baseline data, as well as better understandings of the watershed and its processes has been generated. The majority of reports (since 1995) have focused on forestry effects (mainly road building and logging) on aquatic ecosystems. The preceding sections attempted to summarize the principle findings and recommendations from each of the studies chronologically and by sub-basin. The following paragraphs attempt to synthesize the important issues and stewardship processes that have emerged during the reports.

A key report which served to initiate the process, numerous questions, and follow-up studies was the Interior Watershed Assessment Procedure (IWAP) initiated in 1995 by the Horsefly River Watershed Monitoring Committee. This procedure is the first step in the Provincial Watershed Restoration Program (WRP). Questions raised by the report were then put to the advisory committees (HWMC and HIATC) through Terms of Reference (TOR) directed by the District Manager (Section 6.0). To answer some of the questions the WRP provides guidance and tools in the form of additional studies. Separate reports commissioned by the DFO and the IAMC-Cariboo provided additional interpretation and guidance to the committees. Studies and recommendations were generally geared toward the protection of salmonids. Principle issues which emerged with respect to fish in the Horsefly River Watershed are: 1) high stream temperatures, 2) potential sedimentation due to road building, logging, agriculture, and mining, 3) development activities on steep potentially unstable slopes, and 4) riparian retention (how much is needed) to protect riparian functions and shade along key small S4, S5, and S6 streams.

1) The Interior Watershed Assessment Procedure (IWAP) is designed to be the first step in a WRP. It is designed to assess potential forestry impacts on peak flows, surface erosion, riparian function, and landslide potential. Indices from 0.0 to 1.0 are used to rate each hazard. Studies by Dobson (1996) and Teti (1997), initiated in 1995 by the HWMC, established low hazard indices (<0.50) for most sub-basins (only 3 out of 32 indices were rated moderate, no highs), with the exception of landslide indices, which were moderate or high in 4 sub-basins. However, by 2002 projected indices based on Forest Development Plans would rise on average 15% (3 greater than 38%) in one five year development period. Four indices moved to moderate range and 2 into high. This procedure suggests that the current rate of logging is not sustainable or the procedure is flawed (i.e. progressively higher indices suggests higher and higher impacts).

   The procedure raised numerous questions regarding the risks and consequences of increasing peak flows, increasing surface erosion potentials, losses in riparian function, and potential problems on unstable slopes. The studies, recommendations, and activities that have followed focus on addressing these questions.

2) To address the elevated peak flow question, a hydrometric trend analysis was commissioned to Hetherington and Dobson (1995). They analyzed climate and flow records going back several decades. Although a useful exercise, the question of whether clear cutting was causing higher spring flows could not be answered. It was felt that detection could not be separated from natural variability when only 13% of watershed had been logged. Twenty per cent is considered a threshold for detectability. No changes in peak flows were detected in 1995.

3) Following the WRP procedures two separate channel assessments were commissioned, one by Dobson (1996) and one by Chew (1998). Assessments using

1958 and 1996 air photos, evaluated possible changes in channel widths, exposed bank, sediment deposition, and channel wood. Due to significantly different discharge levels between the two years (flood stage vs. low flow) analysis was limited. Some channel change (aggradation) was observed in reaches below landslides in McKusky and MacKay basins, but in general significant channel damage due to increased peak flows and forestry impacts was not observed. However, Moffat Creek showed significant channel straightening and widening in the lower agricultural reaches.

4) To check for significant sedimentation of Horsefly River spawning gravels, a gravel quality assessment was commissioned to Pylypiuk (1996). At that time and level of watershed logging, the results of the tests showed good quality spawning gravel with little to no sedimentation. This is due in part to the unique distribution of lakes and wetlands, which trap most sediments upriver from the key spawning areas. Gravel quality in the lower river was slightly lower probably due to sediment input from Moffat Creek.

5) To monitor suspended sediment levels, MOF has established 8 monitoring locations along the Horsefly River and Moffat Creek beginning in 1994, i.e. see review and suggestions by Dobson and Hetherington (1995b). Levels of suspended sediment along the Horsefly River in general range between 10 and 18 mg/l (Pat Teti personal communication) during non-peak flow months, depending upon the wetness of the year. This is well under the 25 mg/l level considered a threshold for impacts on egg incubation and fry emergence (Waters 1995, Cooper 1956). The earlier studies by Cooper (1965) measured an average of 6.2 mg/l along the Horsefly at the time of spawning, during a period of heavy rain and high discharge. However, sediment concentrations of Moffat Creek were often over 50 mg/l in the agricultural reaches during the wet 1999 non-peak flow season. Some of this is probably generated by natural bank erosion (Pat Teti personnel communication). See suspended sediment charts courtesy of Pat Teti (Appendix X).

6) Three sediment source surveys have been conducted, e.g. Proudfoot (1994), Carr et. al. (1996), and G3 Consulting (1998). Building upon each others work, airphoto analysis has identified 596 manmade sources of sediment (low, medium, high), of which only 78 high rated sources were field or air reconnaissance checked by G3 Consulting (see summary tables Appendix IX). Probably others have been field checked by area supervisors and ministry staff. This survey needs to be completed.

7) Most high rated sediment sources identified by G3 Consulting have been addressed or are being addressed by licensees mainly through road deactivation (Appendix III and IV), with special attention at stream crossings (Appendix V) and on roads within 100m of streams. Some roads are put to bed (i.e. rehabilitated and planted), some deactivation involves pullback of fill, and some deactivation includes blocking and or

closing roads to vehicle traffic, including public input solicited during access management planning. One complex slide on gentle over steep terrain in McKinley basin has been addressed using bio-technical slope stabilization techniques (Weldwood). Many culverts have been removed or replaced to restore natural drainage patterns. Exposed soil is seeded. Culvert inspections for fish passage have occurred in Molybdenite, Moffat, and Woodjam sub-basins.or are planned for most areas of the watershed. Several culverts impassable by fish have been replaced with bridges or fish friendly culverts that maintain a natural stream bottom (no jump).

8) To address landslide issues, Terrain Stability Mapping was commissioned to Terra Engineering (2000). Potentially unstable Class IV and V terrain has been identified and mapped on middle and upper slope locations in the Upper Horsefly, MacKay, McKusky, Doreen, and Horsefly above the falls sub-basins. Technical experts (Geo-Scientists and Engineers) guide development on this terrain, with special considerations as per the Forest Practices Code (FPC).

9) To address high surface erosion potential in three highly erodible basins (Woodjam, Moffat, and Molybdenite), the cut rate was reduced (HWIATC recommendations) to a sustainable level for that sub-basin (1% per year). To further address erosion and sediment concerns, Licensees have initiated and developed a comprehensive Erosion Control Plan (ECP) which is being used in these 3 drainages (Appendix IV). In the upper Horsefly Watershed, Riverside is using enhanced road construction and maintenance strategies (Appendix III), with special attention at stream crossings (Appendix V).

10) Water temperatures, at several locations in the watershed (spawning and rearing habitats), is at or above threshold conditions (14^{o}C) in most years. Temperature related pre-spawning mortality has long been a problem in the watershed (Royale 1966, Williams et.al. 1977). MELP has been monitoring temperature at 8 locations along the river since 1994 and IPSFC data at the townsite goes back to 1946. The temperature issue is summarized and complicated by the following factors: 1) sun on water causes a temperature increase, 2) lakes dominate the temperature regime in numerous locations, 3) small S4, S5, and S6 streams are not well protected by the FPC, 4) small streams are quite numerous on the landscape 5) blanket prescriptions would be highly restrictive to timber availability and may not always be needed, 6) many small streams do not flow during the warm season, 7) shrubs, small trees, and intermediate size trees provide some shade and riparian function along small S4-S6 streams, 8) large woody debris in the bed of small streams creates many small check dams, which act to trap sediment, 9) a step pool stream channel created by wood is much better for fish, 10) an S5 stream can be quite large, 11) small S4 streams in some locations are important coho and chinook rearing habitat, 12) temperature influences downstream are variable, cumulative, maybe diminishing depending upon changes in canopy, aspect, slope, stream size, substrates, air temperature, proximity to

lakes, and groundwater influences 13) the upper Horsefly and MacKay Rivers are major sources of cold water, 14) streambank seepage (groundwater) and hundreds of small tributaries that don't flow into lakes are also cool water sources.

This ongoing complicated issue is the subject of ongoing research and discussion at both an operational level (Charnel 2000) and a Provincial level (Teti 2000). Shade retention and temperature monitoring are a key focus for a cooperative project between Riverside and MELP (Charnell 2000). Temperature data since 1994 is being correlated with air temperature and statistically analyzed to detect increasing trends. Logging trials are being explored to determine how much retention is needed to minimize temperature increases in (and to) sensitive reaches.

To address riparian concerns, in the interim, licensees are using FPC Best Management Practices for S4, S5, and S6 streams (Appendix II) in some locations (above the falls and in McKinley Creek sub-basin).

11) McKinley Creek watershed is considered a high value fisheries watershed because of substantial salmon spawning and rearing habitat. To mitigate against the high water temperatures below the lake and as a cold water source for the Horsefly River a siphon drawing cold deep water from McKinley Lake was constructed (Royale 1966, IPSFC 1981). The siphon is used during dominant sockeye years. Enhanced management has been recommended by DFO for McKinley Creek to minimize sedimentation, temperature increases, and losses of off-channel habitat. Recommended measures (Northwest Hydraulics and Coast Environmental 1996) include extending some riparian management zones, extending some reserve zones, and more fish distribution inventories (see section 8.0).

12) The Black Creek Ranch area (Horsefly River Riparian Conservation Area), of the Horsefly mainstem, contains prime sockeye spawning gravels and off channel habitat for coho, chinook, and rainbow. To protect and restore this area of the river for fish and wildlife, the 8 km section of the river was purchased by The Land Conservancy, DFO, and MELP. Projects to restore native riparian plant communities, stream to hillslope connectivity, and numerous riparian functions are now underway (Case 2000a, Case 2000b) (also see QRWA in Section 9.0).

13) Tributary stream basins with a potential to deliver sediment to the upper Horsefly spawning gravels are those without lakes or low gradient wetlands in their lower reaches and they include: MacKay, Club, Sawley, Doreen, Harvie, Black Creek, unnamed tributaries along the Horsefly and unnamed tributaries along the lower McKinley. Streams with a high potential for fine sediment delivery to spawning gravels along McKinley Creek include: the Molybdenite Creek basin and all middle and lower McKinley feeder tributaries below Elbow Lake. Tributary basins with high

potential for fine sediment impact to the lower Horsefly River spawning gravels include: Woodjam, Deerhorn, and Moffat Creek.

11.0 SUGGESTIONS AND RECOMMENDATIONS

The suggestions and recommendations that follow are final products of a watershed stewardship study. While some recommendations are meant to address data gaps, others are more long term big picture perspectives. All suggestions are meant to build upon and be complimentary to the ongoing good work of the Horsefly Advisory Committees. As background, appropriate paragraphs are referenced to the Terms of Reference (TOR) guidelines given to the committees by the District Manager (Section 6.0, page 13).

1) Explore Provincial mechanisms/processes that would enable designating the Horsefly River Watershed a <u>Provincial Applied Research Watershed</u> (Model Watershed) for short and long term educational purposes. This would be beneficial to Industry, the Province, and the Cariboo. The long history of data gathering by IPSFC and the step by step investigative WRP procedures make it an ideal candidate for such a designation. The well established watershed advisory committees (HWMC and HIATC) are already in place to review and propose potential projects. A research designation would also help attract funding and expertise, as well as be a compliment to the Landscape Ecology Center initiative by UNBC, at the Likely Hatchery. Research should be expanded to encourage operational trials based on adaptive management, monitoring, and simple reports. Forest Practices Code Regulations (i.e. free to grow, stocking requirements, road standards, and others) may need to be relaxed (when appropriate) in order to encourage trials by major stakeholders. Stumpage incentives could also be considered.

2) Complete a field-based <u>road condition inventory</u> (TOR #10), including an evaluation of the effectiveness of different levels of road deactivation (TOR #4). A focus should be on assessing road and trail modified drainage pathways, i.e. especially the fate of erosion from ditchlines, wheel tracks, and crossdrain outlets. Is crossdrain frequency adequate, do crossdrains end as channelized flow, are ditches vegetated and/or armored, have stable pavements formed? Bilby et.al. (1989) suggests that sand size particles begin moving on road surfaces (and probably unvegetated ditches) at 2.5% gradient.

   <u>Suggestion</u> - Develop a <u>hierarchical numbering system</u> for labeling roads. A simple signage system could be implemented (see sample map from Oregon - Appendix IX), with road number signs placed at every junction as has been done in parts of Oregon. This would facilitate monitoring, mapping, planning, access strategies, inventories,

reporting, navigating, and long term tracking. An Official Use Only - Oregon Road Map (scale: 1 inch to 1 mile) is available upon request.

3) Field check all 596 manmade sediment source sites as suggested by Carr et.al (1996) (TOR #4), including those that are low and medium. Determine actual risk in terms of proximity to channelized flow (could be an outlet of a cross drain). Incorporate with the road inventory (recommendation #2).

4) Redo and expand the gravel quality monitoring program, as suggested by Pylypiuk (1996). Include all major salmon spawning gravels (TOR #1), including McKinley and Moffat Creeks. It has not been done since 1994. We should be diligent about this; it is our principle precautionary monitoring tool.

5) Identify and map key cool water tributaries (areas of sub-basins), with the greatest potential temperature effect on high value fish streams (TOR #3). Develop procedures for evaluating the temperature importance of S4, S5, and S6 streams, as recommended by Teti (2000). Evaluate variable retention harvesting effects on the temperature outputs of small streams. Consider the importance of other long term riparian functions such as the trapping of sediment by embedded large woody debris. We need to think about recruitment, losses, and consequences over a rotation.

6) Continue with small stream fish inventories. Identify S4 streams potentially used by coho and chinook for rearing (TOR #7), i.e. the upper McKinley as suggested by G3 Consulting (1998c) and other areas suggested by DFO. Coho may be limited by rearing habitat (Meehan and Bjornn 1991). Several small S4 tributary streams were being used by coho near the Horsefly River Riparian Conservation Area spawning grounds (Case 2000).

7) Expand the suspended sediment-monitoring program (TOR #1) to include sampling in the drainages with no manmade disturbance (background information) and in drainages with elevated activity. Road deactivation and the Erosion Control Plan (ECP) are the principle methods being used to address sediment generated by roads. Is it effective? The sediment-monitoring program should sample to provide feedback to planners experimenting with the erosion control measures. Two useful sites to add would be at the lower bridge crossing Woodjam Creek and above the private land. This would separate logging from agriculture and help us understand these differences. How about Molybdenite Creek, upper Moffat, and other locations. Perhaps use alternative methodologies (turbidimeters, pump samplers) for less accessible sites.

8) Conduct a sediment delivery analysis (transport/throughput) for the watershed (TOR #2) as suggested by Proudfoot (1994). An analysis using field data would enable the mapping of sediment transfer potential in relation to seasons of concern and high

value fish streams. Knowing which streams had the greatest potential to deliver sediment during the spawning and incubation seasons would allow better risk rating in areas of potential sediment generation. Where are the areas of instability, erodability, and risk, in terms of transport processes (bedload, suspended sediment, peak flows)? Map these areas.

9) Conduct a trial watershed risk analysis in one (or a group) of the high priority sub-watersheds. Map areas with high potential risk using information from the sediment transport analysis (recommendation #8). Using terrain stability mapping, soils information, road condition assessments (recommendation #2), the expanded sediment source survey (recommendation #3), fish distribution inventories, and the sediment transfer analysis (recommendation #8), risk rate hazard and consequence for water quality and fish in that sub-watershed.

10) Commission another IWAP to insure that a trend toward higher indices is not maintained, as suggested by Chapman and Dobson (1997). Part of this should be to review the rate of cut (TOR #6). Five year development plans in 1997 called for harvesting 8% of the watershed in 5 years. This amounts to overcutting by 60% based on 100 year rotations. Is this true? Committees should discuss the benefits/consequences of setting harvesting rates at a sustainable level (good forest management). For example: 1) provides a framework for planning, 2) minimizes impacts upon fish, wildlife, and ecosystems, 3) it insures long term stability in the rural economy. The important Horsefly River Watershed should be managed to the same standards as area-based tenures (Woodlots, Community Forest Licenses, TFL's, etc.).

11) Contract a hydrologist, engineer, or stakeholder to develop a simple field/office based method for determining when a road/ditch complex is producing zero sediment (TOR #4). This would be to eliminate road lengths from IWAP calculations (or a portion of, based on level of recovery). Stabilization would be related to natural armoring, forming of erosion pavements, and revegetation processes, as well as level of deactivation, slope, soil type, time, and level of use. In this way an updated IWAP could reflect recovery toward a pre-road (no sediment) condition.

12) Explore techniques to accelerate hydrologic recovery, i.e. techniques to mitigate against snowpack accumulation and progressively higher ECA's (TOR #11). For example, by retaining non-merchantable stems, intermediate stems, seedlings, and perhaps some windfirm groups of trees recovery time could be reduced perhaps by 30 years, depending upon how much live structure was retained. This would require exploring alternative harvesting approaches and equipment such as small skidders, forwarders, and skyline systems in order to retain and protect residual trees. Hydrologic recovery will become a major issue in the decades ahead.

13) Find funds and expertise to continue to explore new road building (and logging) techniques that minimize excavation, ditching, and the need for roads (G. Chipman personal communication). Explore the use of minimum practical design standards, with respect to minimizing road widths, radius, and gradient. Explore the research which is being tried by the Scientific Panel in Clayoquot Sound (1995) and in the states. Explore techniques that allow uninterrupted downhill passage of groundwater, thereby reducing the need for ditchlines (i.e. outsloping where feasible, pervious subgrade materials, drainpipes in subgrade, fewer roads).

14) On steeper slide-prone terrain explore ways to retain more live roots for slope and soil reinforcement. Consider retaining non-merchantable stems, advanced regen, seedlings, large windfirm trees, and/or groups of trees. As roots from harvested trees decay soil reinforcement and slope stability diminishes, but then recovers in a few decades (Swanson et.al. 1987). The tubes and chambers that form below ground as the roots decompose can channel water to slide initiation zones. Leaving live roots to quickly reoccupy deep soil profiles would add to soil shear strengths (as harvested tree roots decay) during this vulnerable period.

15) Subsurface moisture in the form of seeps and groundwater, are probably a substantial source of cooling water to important tributaries and the Horsefly mainstem. During summer precipitation, the amount of water that is retained in the soil (detention storage), serves to recharge (and be) groundwater for dry season release. What role do decaying logs (soil wood) play in terms of soil moisture storage and release to summer baseflow? Research in Oregon suggests that decaying logs act as moisture reservoirs (sponge-like) during the dry season and continuing as they are incorporated into the soil (Amaranthus et.al. 1989). Clearcutting without retention can reduce soil wood up to 75% by the end of the first rotation, declining further during the second rotation (Maser et.al. 1988). Soil textures, relative amounts of micro and macro pores, as well as level of organic matter influence detention storage (Childs et.al. 1989). Although transpiration losses (increased groundwater) following harvest complicate this discussion, it may be small during the dry season when leaf stomata may be closed. Recovery of transpiration losses (normal groundwater) would also be shorter, perhaps 20 years (Beschta – class notes). In simple terms rotting wood in soils influences soil moisture and groundwater. Maybe we should think about managing for dead wood (especially over time, especially input processes), in order to retain this component and function. This is a data gap with potential long term consequences (TOR #2 and #8).

16) Perhaps management in the Research Watershed should explore Total Resource Planning (upfront) as opposed to the current management by referral (TOR#2). Licensees developing plans should use interdisciplinary approaches that would include wildlife as well as fish and forest perspectives. Initiatives like those by Weldwood and Riverside (i.e. the Moffat FEN and the Total Resource Plan for the

McKusky) should be encouraged so that planning is total and complete at the outset. Perhaps cut blocks could be a little larger in order to allow within block retention, thereby increasing connectivity and reducing fragmentation. Planning should more closely mimic natural disturbances in particular the incorporation of a range of post-disturbance biological legacies, which are the base for continued (carryover) ecosystem functioning. Perhaps management in the new Research Watershed should be guided by a "Scientific Panel" (made in the Cariboo) similar to the model at Clayoquot Sound (Scientific Panel in Clayoquot 1995).

17) Broaden committee representation (Naimen et. al. 1997). For educational, public outreach, and technical reasons invite a representative from the Horsefly environmental community (QRWA) to sit at the HWMC table (TOR #12). Their interest and involvement in stewardship is proven to be committed and ongoing. In addition, add expertise to the Interagency Technical Committee by including an Ecologist, especially one that understands the role and range of post-disturbance legacies in maintaining ecosystem functions and speeding recovery (TOR #8).

18) Set up a sub-committee to explore long term broadscale planning issues (TOR #11, #2, and #8), such as level of cut and sustainability, ceilings for hazard indices, hydrologic recovery, long term site productivity (Perry 1989), possible changes in soil moisture and groundwater, long term pest management (Perry 1988, Schowalter et.al 1997), sediment control at the level of small streams, and Forest Ecosystem Networks (FENS).

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APPENDIX I MAP OF THE HORSEFLY RIVER WATERSHED

APPENDIX II - STREAM RIPARIAN MANAGEMENT AREA BOUNDARIES FROM FOREST PRACTICES CODE AND BEST MANAGEMENT PRACTICE FOR S4, S5, S6 STREAMS

APPENDIX III - UPPER HORSEFLY CURRENT OPERATIONAL STANDARDS

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APPENDIX VII - WATERSHED LITERATURE SUMMARY
BY: SUE HEMPHILL

APPENDIX VIII - OFFICIAL USE ONLY – COUNTY ROAD MAP (SAMPLE) LA GRANDE W ½ RANGER DISTRICT – WALLOWA WHITMAN NATIONAL FOREST

APPENDIX IX - G3 CONSULTING LTD. – 1998 SEDIMENT SOURCE SURVEY SUMMARY TABLES

APPENDIX X - SUSPENDED SEDIMENT CONCENTRATIONS OF THE HORSEFLY RIVER AND TRIBUTARIES
(Courtesy of Pat Teti)