PROCEEDINGS OF A WORKSHOP TO DEVELOP A STRATEGIC PLAN FOR A WATERSHED ASSESSMENT MODEL (WAM)

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Forest Technology School
Hinton, Alberta

Prepared for

FOOTHILLS MODEL FOREST
Hinton, Alberta

by

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EXECUTIVE SUMMARY

The Foothills Forest is located in the foothills of west-central Alberta, near Hinton, It encompasses an area of approximately 1.2 million hectares and has supported an active forest management program for over 37 years. This operation is presently one of ten large-scale working Model Forests across Canada designed to demonstrate how forest ecosystems can be managed according to a sustainable development philosophy. The initiative is sponsored by Weldwood of Canada, The Alberta Forestry Technology School, and Alberta Environmental Protection; funding is provided by Forestry Canada under the Partners in Sustainable Development of Forests Program.

In 1988, Weldwood and I.R.M.S.C. initiated a major research program to catalogue wildlife species and define their habitat needs and relationships. Habitat suitability index models for key species have been developed and are now integrated into the overall forest management Decisions Support System (DSS) for the Foothills Model Forest. Because of the importance of watershed values in the overall context of forest management, Foothills Forest is investigating the need for, and possibility of, developing a watershed assessment model. It would characterize and predict responses of critical hydrological and aquatic resource parameters to a range of forest management scenarios and would integrate with the existing Foothills Model Forest DSS. A three day workshop was held on January 10-12, 1994 to produce a strategic plan for developing a Watershed Assessment Model (WAM) and identify key project events for the first three years of the program. Twelve individuals, representing various provincial government agencies, Foothills Forest personnel, University of Alberta, and a private environmental consulting firm, participated in the workshop.

Initially, the workshop focussed on a review and discussion of forest management impacts on watershed values. Forest management can, potentially, affect existing hydrological conditions by altering water yield, modifying flow regimen, and changing water quality. Typical watershed responses to a timber harvesting operation could include: higher seasonal stream flows during the open water period, increased annual peak flows and storm flows, and possibly reduced water quality (e.g., increased sediment contribution). These changes would be most pronounced on small 2nd and 3rd order streams and during the initial years following logging (i.e., up to five years post management).

The Foothills Forest area supports an estimated 3300 km of streams and rivers. Much of this supports populations of the four key fish species which includes: rainbow trout (native Athabasca River strain), bull trout, Arctic grayling, and mountain whitefish. The status of many of these populations has been generally reduced due to previous landuse (timber harvesting, oil/gas development, roads, etc.) and overfishing. The negative influences of forest management on aquatic habitat and fish populations are generally stem from increased sediment input and deposition in the stream channel (i.e., due to loss or degradation of high quality feeding/holding habitats, reduced spawning/incubation success, decreased invertebrate production, etc.). In most cases these problems arise at and within the zone of influence of stream crossings.

Another major concern is increased access, which in the absence of strict regulations and enforcement, and adequate baseline inventory data, can seriously harm (in some cases irreparably) sport fish populations. Other concerns include: possible changes in nutrients, water temperature, flow regime, and culvert fish passage problems.

Over the three day workshop, which included a number of break-away (hydrology vs. fisheries) and plenary sessions, the workshop group discussed the structure and functioning of the proposed Watershed Assessment Model (WAM). The primary goal of WAM will be to assist managers in maintaining the integrity of aquatic ecosystems and associated hydrologic values. By simulating the outcome of different land management alternatives in time and space, both negative and positive impacts of land disturbances can be identified and incorporated into management decisions. Initially, the development and use of WAM will be based, largely on existing information. This information will be incorporated into a database, using a GIS format to characterize existing and forecast future conditions. The WAM will be designed as a sub-component of the existing forest management DSS (i.e., can be incorporated into the DSS at the same level as the terrestrial assessment model). As such, it will be possible to assess, using a common environment, the affects of forest management on terrestrial, aquatic and hydrologic resources.

The initial step in forming the watershed model is to develop aquatic habitat suitability index models for the four key species and to characterize local and regional hydrologic regimens. The Workshop recommended that existing and readily available information be used (at least initially) to get the WAM "up and running". Following this, more detailed and precise information could be incorporated into the system to improve its predictive capabilities. It was clearly established that additional watershed-related studies are needed. Under the hydrological umbrella, it will be necessary to assess, flow regimen, climatic extremes and norms, evapotranspiration, sediment and bedload movement, substrate changes, buffer strip management in relation to sediment control, effects on groundwater and winter flows, and nutrient export and loadings. Some of the data gaps from an aquatic resource point-of-view are: information on specific habitat requirements (e.g., spawning, rearing) for key fish species, relationships between bedload movement and habitat suitability (for spawning, invertebrate production, etc.), impacts of sport fishing, distribution and availability of important/critical fish habitats.

The Workshop produced an action plan and schedule for the initial three years of the program. Overall, the objective was to get a WAM "up and running" as soon as possible. Hopefully, once the system is running it will stimulate further development and refinement. The first action during Year-1 (1994-95) should be to hire a Watershed Coordinator. This individual would not only provide focus and momentum in the planning and implementation phase, but would organize external funding and support efforts. The proposed budget for Year-1 is $252 000, of which $52 000 is for the coordinator position and the remainder is for other action items. The proposed budgets for Year-2 and Year-3 are $177 000 and $162 000, respectively. The total for the initial three year period is $591 000. It should be pointed out that at some point (preferably early in the model implementation phase) it will be necessary to complete the stream fisheries inventory program; the approximate cost of achieving will likely be in the order of $300 000. Human resources to implement the

WAM will be available from a wide range of groups and organizations (Model Forest, government agencies, university, private consultants). The Model Forest GIS personnel will play a pivotal role in the development of WAM; the identification of human resources will be one of the primary tasks of the Watershed Coordinators.

It was agreed that the development of a worthwhile and effective WAM requires a long-term commitment, requiring a substantial investment of human and financial resources. Furthermore all agreed that such an undertaking is worthwhile and feasible. The existence of WAM as a component of the forest management DSS will provide balance, insuring that watershed values are fully considered in land management planning.

1.0 INTRODUCTION

1.1 Background

The Foothills Forest is located in the foothills of west-central Alberta, to the east of and adjoining Jasper National Park. Lying within the boreal, subalpine, and montane forest regions, the Foothills Forest Area encompasses an area of 1 218 014 ha. This area has been the focus of an active forest management program for over 37 years. The Foothills Forest is one of ten large-scale working models across Canada. Together, these represent the five major forest ecoregions. "The Model Forest Network will demonstrate how forest ecosystems can be managed in the real world to achieve sustainable development" (Foothills Forest, 1993). The Foothills Model Forest program is sponsored by Weldwood of Canada, the Alberta Forestry Technology School, and the Department of Environmental Protection, Alberta Forest Service. Forestry Canada (Green Plan) provides funding for this initiative under the Partners in Sustainable Development of Forests program.

In 1988, Weldwood and the IRMSC committee initiated a major research program to catalogue wildlife species and to define their habitat needs and relationships. This has resulted in the development of habitat suitability index models that are now integrated into the wildlife habitat supply analysis for the overall forest management Decision Support System (DSS) for the Foothills Model Forest. The Foothills Forest is currently investigating the possibility of developing and incorporating a Watershed Assessment Model (WAM) into the DSS. The intent of the model will be to address the spatial and temporal effects of forest management and other land use disturbances on hydrological and aquatic resources. To achieve this goal, Foothills Forest felt it was advantageous to hold a strategy development workshop attended by a small, select group of scientists with a background in either hydrology or aquatic biology and a familiarity with the study area. The workshop objective was to produce a strategic plan for three years to start development and incorporation of a WAM into the forest management DSS. We were approached by Foothills Forest to organize and implement the workshop, summarize the proceedings of the workshop, and develop a strategic plan.

1.2 Objectives of Workshop

The overall objective of the WAM was identified in the Terms of Reference (14 October 1993) as:

> "to have a system capable of evaluating a harvest plan for the resulting cumulative effects of forest management activities on the quantity and quality of water yield from a given watershed or complex watersheds, and in turn be able to evaluate the impact of the harvest plan on the quantity and quality of aquatic habitat (e.g., fish)."

The three major components of the task were as follows:

1) Organize a workshop, attended by a select group of experts in hydrology and biology to produce a strategic plan that address the detailed plans and projects required for the development of a complete Watershed Assessment Model. This involved the following:

- establishment of goals and topics for workshop sessions;
- cooperation between the hydrology and aquatic biology facilitators;
- establishment of the workshop format in consultation with the coordinator; and
- development of a pre-workshop package for distribution to participants.

2) Facilitate a workshop, to be held at the Forest Technology School in Hinton. This involved the following:

- chairing of plenary and working group sessions;
- developing and supplying of required workshop materials;
- chronicling workshop progress and achievements for incorporation into a strategic work plan;
- developing and guiding of a summary session for priority ranking of projects; and
- ensuring that the working group sessions meet the overall goals of the WAM development process.

3) Produce a strategic plan that addressed the overall goals of the WAM and accounted for the following:

- the overall and tier-specific goals and objectives;
- the overall and tier-specific projects required to develop the WAM;
- the priority ranking developed at the workshop;
- the project feasibility, timeliness, milestones, cost estimates, options of potential people or organizations; and
- to undertake the work identified and potential funding sources.

The complete Terms of Reference transmitted by Foothills Forest (14 October 1993) are provided in Appendix A.

1.3 Hydrology Impacts

The hydrological impacts of forest management are well documented in the literature. The hydrology of an area can be described in a number of ways. One of the simplest is the water balance equation, which can be expressed in two forms.

[1] $P + Q + ET + I + \Delta S = 0$

[2] $Q = P - (ET + I) + \Delta S$

Where P=precipitation, Q=discharge or streamflow, ET=evapotranspiration, I=interception, and ΔS=change in storage

The second equation [2] has more utility, because it deals primarily with streamflow and the volume of water flowing from a watershed. Forest management and other disturbances that affect the vegetation and soil properties of a watershed can affect one or more of the water balance components. The hydrological effects of forest management or other land uses are more frequently expressed in terms of streamflow than the other water balance components.

The effects of forest management on streamflow are usually expressed in terms of water yield, water regimen, and water quality. Water yield is the volume of flow from a given land area in a specified time period. Water regimen is the pattern or delivery of water in time at a given point of measurement. Water quality is the value or utility of water for a specific end purpose. Forest management or other land disturbances can affect all three of these watershed characteristics.

1.3.1 Water Yield

Increases in water yield occur following the removal of forest vegetation from a watershed (Bosch and Hewlett 1982). The increases result from reduced evapotranspiration and interception losses, and the redistribution of snow within the watershed. The magnitude of water yield increases will be a function of the amount of vegetation removed, species, climate, and watershed size. Most of the research documenting the effects of forest removal on water yield have been done on small 2nd and 3rd order watersheds, where the effects are strongly expressed and experimental control in terms of treatment application in time and space are possible.

Through experimental studies, researchers have established a number of relationships between timber harvesting and changes in watershed hydrology (Bosch and Hewlett 1982).

1) Water yield increases vary with extent of vegetation removed.

2) Magnitude of increases in water yield is largely a function of climate, in particular the coincidence of available water and energy. The largest increases in water yield occur in warm, humid climates where evapotranspiration and precipitation are abundant; changes are less dramatic in cooler and drier climates.

3) Increases from 0-60% in annual water yield are reported in the literature (Anderson et al. 1976)

4) Increases in water yield are usually most evident in the first 1 to 5 years after vegetation removal. Also, they will vary with annual precipitation (i.e., high in high precipitation years and low in low precipitation years).

5) Increases in water yield diminish over time with the regrowth of vegetation in the watershed (i.e., increased evaporative losses). In warm humid zones, increased water yields can decrease rapidly (i.e., not detectable after 5-7 years). In contrast, increased water yields in cooler drier climates, where growth rates of vegetation are slower, may last for many years (20-30 years or more). In Colorado, at the Fool Creek Experimental Watershed (Goodell 1958; Leaf 1975), no significant decrease in water yield was determined during the 17 years after cutting.

6) Redistribution of snow in climatic zones like Colorado and Alberta, where snow is low in density and easily redistributed by wind, can also contribute significantly to increased water yield. Significant losses in water and a reduction in water yield may be caused by evaporation or sublimation of snow packs in large exposed areas (i.e., cut blocks/agricultural fields).

7) The increases in water yield on small 2nd and 3rd order basins diminish, in relative terms, at downstream locations when they flow into larger streams and rivers (i.e., a dilution effect). The cumulative effects of increased water yields in time and space are difficult to assess.

Research results for Alberta are similar to those reported in the literature. For example, Swanson and Hillman (1977) reported seasonal streamflow increases of 27% and flow increases of 52% during the spring snow melt period (Swanson and Hillman 1977).

1.3.2 Water Regimen

The delivery of water to a certain point in a stream channel is largely a function of watershed characteristics, such as slope, size, vegetation, soils, intensity, frequency, and duration of precipitation. In snow dominated areas such as Alberta, water regimen will also be influenced by the area and depth of snow packs and the rate of melting in the spring. Water regimen is determined by a composite of these different interacting processes that affect the condition of a watershed to delay and temporarily store incoming precipitation (i.e., storage). The effects of land disturbances, such as forest harvesting, on water regimen are perhaps best expressed by how they affect watershed storage.

Storage is a dynamic process that increases and decreases seasonally in response to precipitation, drainage, and evapotranspiration. Storage is primarily a function of soil area and depth, soil properties, slope, and evapotranspiration. Watershed area, soil depth, and soil porosity basically determine the total storage volume for a watershed. Evapotranspiration and slope act together to reduce or draw down the amount of water held in storage. Forest management primarily affects storage by reduction of evapotranspiration. Storage on cut watersheds will generally be higher than on uncut watersheds during the growing season when evapotranspiration demand is high and precipitation levels low and infrequent.

Changes in water regimen following vegetation removal (forest harvesting) are usually expressed in terms of the magnitude and frequency of flow, in particular peak flows. Results from the literature, from a wide range of locations in North America, indicate the following effects of vegetation removal on the magnitude and timing of flows.

1) Peak flows and storm flows following vegetation removal generally are increased (Anderson et al. 1976).

2) The magnitude of increases in flow are highly variable because storage is dynamic. On average, storm peaks and storm flows associated with rainfall are 15 to 25% and 10 to 15% greater, respectively, after vegetation removal. Extreme differences for individual storm peaks can range from 0 to >100%, depending on storage conditions (Hetherington 1987).

3) The largest differences in peak flows and storm flows between vegetated and nonvegetated areas (uncut vs. cut) occur during or following periods of high evaporation and low rainfall. At this time, differences in storage between the two areas are greatest (Rothacher 1973).

4) Differences in flow will be very small (or nil) when conditions of high precipitation and low evapotranspiration prevail. At this point soils are wet with little or no differences between cut and uncut watersheds.

5) The frequency of given flood-size events (i.e., return periods) can also be expected to increase although supporting data are limited. A storm formerly described as a 5-year event could occur more frequently. For example, after logging it could become the 3-year event.

6) The effects of forest management on peak flows will be most pronounced on the low to medium size events, largely because these will fall within the range of watershed storage. The effects on extreme events usually are so large that the effects of land use and watershed storage are overwhelmed and are not evident.

Snow melt peaks following vegetation removal can also be affected. The magnitude of change will be largely determined by the extent of vegetation and the size and shape of cut areas. Although supporting evidence is limited, the following interactions are likely to occur.

1) Higher flows and larger volumes will occur following logging. Usually, peaks will be higher and an increased percentage of the flow will be concentrated on the rising-limb of the hydrograph (Anderson et al. 1976).

2) Snow melt peaks from areas characterized by large cuts can be very high because vegetation removal fully exposes the snow pack to solar radiation, thereby rapidly increasing the rate of snow melt.

3) Snow melt peaks on areas characterized by small cut areas, such as patch clear cuts, can be smaller and longer in duration because residual vegetation will protect snow packs and slow the rate of snow melt. These kind of effects are largely determined by the ratio of cut-block edge to cut-block area associated with the different cutting patterns. Low edge to area ratio probably will yield greater peak flow responses than high ratios of edge to area.

4) Low flows appear to be changed little following vegetation removal.

Most of the above observations appear to apply to the Alberta foothills setting. Peak flows from cut basins in the Hinton area had higher peaks and greater storm flows than similar uncut basins (Swanson and Hillman 1987). Differences for summer storms were greatest in late August, when storage differences are greatest between cut and uncut basins. Snow melt peaks were 1.5-times greater than similar uncut basins.

1.3.3 Water Quality

Forest management, and land disturbances in general, can affect the quality of water flowing from forests. Changes in water quality from disturbed "wildlands" is generally referred to as nonpoint pollution because of the diffuse nature of the disturbances. Major impacts associated with forest management include changes in stream temperature and concentrations of dissolved oxygen, nitrate-N, and suspended sediments. A recent review of forest practices as nonpoint sources of pollution in North America (Binkley and Brown 1993) made the following points.

1) Retention of buffer strips in most areas prevents unacceptable increases in stream temperatures.

2) Current practices do not typically involve addition of large quantities of fine organic material to streams or the depletion of dissolved oxygen.

3) Sedimentation of gravel streambeds, however, may reduce oxygen diffusion into spawning beds.

4) Concentrations of nitrate-N typically increase after forest harvesting, but only a few cases have exceeded or approached drinking water standards of 10 mg/L.

5) Road construction and harvesting increased suspended sediment concentrations in stream waters. The magnitude of changes are highly variable among regions of North America, probably a function of soils, topography, climate, and forest practices.

6) The use of **best management practices** (BMP) usually prevents unacceptable increases in sediment concentrations, but large responses from extreme storms can still occur.

Most of the above observations apply equally well in Alberta. The interaction of increased peaks and flows after logging with suspended sediment concentrations and bedload movement have been noted as possible areas of concern with regard to maintaining aquatic habitats of foothill streams. However, little information is available to support these concerns.

1.4 Aquatic Impacts

The effects of timber harvesting and associated trail and road networks on aquatic resources have been well documented in the literature (Meehan 1991, Krygier and Hall 1971, Schultz and Company 1973, Johnson et al. 1971). Aquatic habitats and the fish populations that they support can be influenced in a variety of ways, ranging from infilling with sediment to altered water temperature regime (due to removal of overstorey vegetation in bankside areas). Persistence of effects also varies from acute (short-term) to chronic (long-term). Some of the early concerns may be less serious today because forest companies and resource agencies have a greater awareness and of aquatic resource issues. Although the knowledge base exists to circumvent most serious adverse impacts, this implies a need for strict application of regulations (e.g., ground rules). Concerns have been raised by fisheries personnel (including those present at this workshop) that this is not always occurring; resulting in what are considered avoidable aquatic habitat disturbances. Although there is a considerable amount of data available from outside the province, much remains to be learned about the primary effects of timber harvesting on hydrological regimes and channel conditions in the foothills and boreal forests of Alberta. Furthermore, there is a need to make the link between these changes and the fish populations, particularly those residing in small 2nd and 3rd order basins. These streams are the preferred habitats (for all or part of their life cycles) for important populations of rainbow trout (native Athabasca River strain), bull trout, Arctic grayling, and mountain whitefish. Unfortunately, because of various land uses (timber harvesting, oil/gas extraction, pipelines, roads, etc.) overfishing, many of these populations have been eliminated from portions of their former range or reduced to remnant populations. Aggravating the situation is the fact that fish populations in the Foothills Forest are present in low densities and exhibit slow growth (and delayed onset of maturity in the case of bull trout). For this reason they have a relatively low capability to withstand habitat perturbation and fishing pressure. Although "hard" data is limited, it is very likely that many populations do not produce a harvestable surplus of fish on an annual basis. It is important, then, that we proceed carefully with future forest management developments with full recognition of potential impacts.

Following is a description of some of the major aquatic resource concerns with respect to present and future forest management operations.

1.4.1 Sedimentation

Sediment addition to flowing waters, and subsequent deposition in aquatic habitats, is a major concern from a fisheries protection and management perspective. Accumulations of sediment in streams as a result of land use practices can have serious detrimental effects on the stream biota (Brusven and Prather 1974). Net accumulation occurs if sediment supplied to the system exceeds material removed by available river energy. Addition of sediment to the stream can cause (1) reduced light penetration, which inhibits photosynthesis (causing a decline in production of periphyton, invertebrates, and consequently a reduced carrying capacity for fish), (2) reduced dissolved oxygen levels (due to decomposition of organic matter frequently deposited with sediment), (3) dramatic reduction in the egg-to-fry survival of sportfish (due to reduced percolation through substrate, which reduces oxygen supply to eggs and restricted emergence of fry from spawning redds), and (4) reduced depth (due to infilling of important feeding/holding and overwintering areas) (Ritchie 1972).

Excessive sediment content in the streambed also decreases productivity by smothering or crowding macroinvertebrates (Burns 1970). Sediment accumulation in rock interstices creates a seal, restricting invertebrate access to the undersurface region that is preferred (Brusven and Prather 1974). Unstable sand substrate is particularly unsuited to benthic invertebrate production (Alexander and Hansen 1988). Sediment addition causes an immediate avoidance reaction by surface dwelling macrobenthos species. Rosenberg and Wiens (1978) investigated the effects of sediment addition on the macrobenthic invertebrate community on the Harris River, Northwest Territories. They found that species that are particularly sensitive to exposure of sediments begin leaving immediately (Simuliidae, Plecoptera, Ephemeroptera). As more sediment accumulated, the more tolerant species, or those located deeper in the substrate, began to leave as well (Oligochaeta). Larger sediment becomes part of bedload movement, which causes scouring of the streambed and damage (possibly dislodging) to attached macrophytes and periphyton. Scouring and dislodging of invertebrates will increase invertebrate drift rates. Although greater drift can temporarily increase growth rates and biomass of fish, over time the lost invertebrate habitat will result in reduced fish production.

High sustained levels of suspended sediment (i.e., turbidity) from an outside source (e.g., unstable road crossing) can reduce primary production in streams. Decreased conversion of solar radiation into usable forms of energy will influence all trophic levels (i.e., effects entire food chain). Because most fish are sight-feeders, a reduction in the clarity of water will reduce feeding efficiency and perhaps prevent feeding altogether. Reduced feeding success or activity can also cause a drop in angling success (Langer 1974). Sediment accumulation in the channel and entrainment increases cause scouring and smothering of periphyton; in large quantities it will produce a highly mobile substrate.

The link between sedimentation of spawning grounds and increased egg-to-fry mortality has been well documented. As the percentage of sediments in the substrate increases, gravel permeability and egg survival decrease at an alarming rate. Excessive amounts of fine sand kills embryos, alevins, and fry occupying the channel substrate. By decreasing gravel permeability oxygen availability to the embryos is decreased, metabolic wastes are increased, and emergence is prevented or delayed (Platts and Megahan 1975). Sedimentation can destroy interstitial habitats (i.e., spaces of gravel and between boulders) for fry. Elimination of these critical habitats will expose the fry to stream currents and predation and reduce overall invertebrate production.

Low-gradient stream channels may take a long time to adjust to an input of sand-bed material (Alexander and Hansen 1988). Riffles in streams with stable flow regimes tend to accumulate sediment more readily than those with very high peak flows (Burns 1970). If sediment deposition is severe, it will fill pools that provide living space, feeding areas, and protection for larger salmonids. Changes in channel morphometry, bed composition, and cover have been shown to increase vulnerability of trout to predation (Alexander and Hansen 1988). Addition of fine sediments to streams decreases fish biomass, depending on the amount and degree of deposition (Bjornn et al. 1980). Deposition of sediment on the streambed reduces streambed complexity and pool volume and may lower winter carrying capacity (Shepard et al. 1984).

Sediment particles can abrade the body surface and the gill tissue of fish, although the greatest effect on gill tissue which is highly sensitive. Sediment particles tend to adhere to mucus secreted by gill tissue for protection. Therefore, in extreme conditions the gills will no longer serve as an effective respiratory surface, and the fish will suffocate.

1.4.2. Stream Crossings

Fisheries related problems resulting from improperly located, designed, stabilized, and maintained stream crossings are well documented. The problems are generally due to either erosion-sedimentation at or within the drainage area of the crossing site or fish movement blockage (or delay) at culvert installations. Although the technology is available to prevent these occurrences (e.g., ground rules covering site selection, reclamation methods/standards, and culvert/fish passage guidelines) fisheries personnel are concerned that the operating rules will not be strictly and uniformly applied or that adequate monitoring and maintenance cannot be assured. With respect to fish passage at road crossings, there is considerable potential for problems to develop. Each of the key fish species targeted for inclusion into the WAM (rainbow trout, Arctic grayling, bull trout, mountain whitefish) are migratory in nature. For example, many streams are utilized on a seasonal basis for spawning, whereas overwintering occurs downstream in larger streams or rivers. This implies migrations on an annual basis and the need for extreme diligence when locating, designing, and constructing culvert installations (i.e., follow-up monitoring and maintenance required).

1.4.3 Increased Access

Expanding forest management operations will result in a influx of access roads (temporary and permanent). In addition to the concerns associated with erosion-sedimentation at and adjacent to stream crossings, there is a problem of increased access to the fishery resources. Although this could be viewed as a positive step by many anglers, fisheries managers and researchers are concerned that these access roads could seriously impact fish populations. As stated previously, sportfish populations in the Foothills Forest (and in the boreal forest region as well) are very susceptible to overfishing (i.e., low population densities, slow growth rates). Therefore, in the absence of very protective angling regulations (e.g., total catch-and-release), which at this time appear to be favoured by many (but may not be in place soon enough, if at all), many of these populations may be irreparably harmed. Unfortunately, the level of fisheries baseline data that currently exists does not allow precise delineation of important stream reaches or sites. Therefore, management and enforcement becomes very difficult. Essentially, there is a concern that populations could be negatively impacted (i.e., through land use and/or overfishing) without our knowing it.

1.4.4 Nutrients and Water Temperature

Concentration of inorganic nutrients (N, P, K, Ca) in streams may increase after logging. However, the type and degree of response can vary considerably according to watershed and timber removal patterns. Streams in which algal production is limited may experience major algal blooms in response to minor increases in inorganic nutrients (i.e., if temperature and flow conditions permit) (Meehan 1991). These blooms were found to be harmful to salmonid production because the algal bloom settled into the interstitial gravel space. Hartman and Holtby (1982) found that moderate nutrient increases (along with temperature increases) were beneficial to the production of algae, invertebrates, and juvenile salmon in Carnation Creek, British Columbia. Korchinski and Sneddon (1987) documented noticeable increases in total phosphate following logging in the Tri-Creeks Experimental Watershed. Increases in mean monthly temperatures were also recorded in this watershed (Andres et al. 1987). Sterling (1990) recorded marked increases in the production of periphyton in response to these changes. Although he also recorded increased growth rates of rainbow trout, he was unable to relate this change to the nutrient enrichment or elevated water temperatures.

Timber harvesting practices can produce large changes in the temperature of small streams (Brown 1971). Smaller streams may heat up relatively fast when a buffer zone is harvested because a large proportion of their surface area will be exposed to the sun (Meehan 1991). Cold water streams that are relatively unproductive (relative to other systems in the area) may benefit from moderate increases in water temperature (i.e., increased production). Alternatively, streams that are relatively warm could be harmed (e.g., temperature may already be at or near preferred temperature for particular species).

2.0 WORKSHOP STRUCTURE (METHODS)

Table 1 Individuals attending the Foothills Model Forest workshop (January 10 - 12, 1994).

Name	Affiliation/Address	Phone	Fax
AQUATIC BIOLOGY GROUP			
Hunt, Carl Fisheries Biologist	Alberta Environmental Protection, Fish and Wildlife Services, Provincial Building Edson, AB	(403) 723-8244	(403) 723-8502
O'Neil, Jim Fisheries Biologist	R.L. & L. Environmental Services Ltd. 17312 - 106 Avenue Edmonton, AB T5S 1H9	(403) 483-3499	(403) 483-1574
Rodseth, Norm Forester	Foothills Forest (home) Edson, AB Box 6330 Hinton, AB T7V 1X6	865-8193 (o) 723-6058 (h)	865-8164 (Hinton) 723-3879 (Edson AFS)
Sterling, George Fisheries Biologist	Alberta Environmental Protection, Fish and Wildlife Services, Provincial Building Lac La Biche, Alberta	(403) 623-5247	(403) 623-5360
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HYDROLOGY GROUP			
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FOOTHILLS MODEL FOREST GROUP			
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Rick Bonar Wildlife/Recreation Coordinator	Weldwood of Canada Ltd., Hinton Division 760 Switzer Drive Hinton, AB T7V 1V7	865-8193	865-8164
Hugh Lougheed	Weldwood of Canada Ltd., 760 Switzer Drive Hinton ,AB T7V 1V7		
Sean Curry	Weldwood of Canada Ltd., 760 Switzer Drive Hinton, AB T7V 1V7		

3.0 WORKSHOP RESULTS

3.1 Watershed Assessment Model - Goals

The WAM will be a planning tool designed to assist managers in the formulation and evaluation of different land management alternatives. The primary goal of the WAM is to assist managers in maintaining the integrity of aquatic ecosystems and associated hydrologic values. By simulating the outcome of different land management alternatives in time and space, both negative and positive impacts of land disturbances can be identified and incorporated into management decisions. Such an approach is valuable as many of the impacts of land use on aquatic and hydrologic values are subtle, occurring in an accumulating or incremental fashion, which makes their detection and evaluation difficult. WAM is a planning tool only, it is not a mechanism to define polices or to make decisions.

Hydrology

The hydrological goals of the WAM are to maintain the integrity of aquatic ecosystems and the associated hydrological regime affected by land disturbances. Both a deterministic and stochastic approach will be used to develop models and to predict impacts of harvesting practices.

Fisheries

The main goal of the WAM, from a fisheries perspective, is to maintain the integrity and quality of aquatic habitats, as a prerequisite for the support of viable, stable fish populations. It should allow managers and researchers to assess the implications (positive and negative) of various forest management alternatives on the current baseline (i.e., preharvest habitat quality and fish populations).

3.2 Watershed Assessment Model - Objectives

Hydrology

The WAM will also assess the effects of land disturbances on associated hydrologic values of water yield, water regimen, and water quality because changes in these values control and determine the existence and quality of aquatic habitats. The WAM should also be adaptable to other land disturbances, such as the effects of wildland fires, insect and disease infestations, flooding, and infrastructure and access development.

Fisheries

The primary focus of the WAM will be to assess the impacts of forest management on aquatic habitats utilized by key fish species, namely rainbow trout, bull trout, Arctic grayling, and mountain whitefish. Because the approach adopted to ensure protection and conservation of fisheries value is habitat-based, the objective will be to develop habitat suitability models for the four key species. These models must be both sensitive to changes (proposed or real) in land use in the watershed and relevant to the survival and well-being of fish populations. The process of selection of habitat model descriptors will be of utmost importance.

3.3 Structure of the Watershed Assessment Model

The development and use of WAM will be based, as much as possible, on existing and available information. This information will be incorporated into a database, which will manipulate GIS methods to characterize existing and future conditions resulting from various land-use scenarios. The effects of land use on hydrologic and aquatic resources, and the relations between these resources and others, will be assessed by a range of environmental and socio-economic models. The design of land-use scenarios for testing will be based on the outcome of these models and management objectives and constraints. The WAM will perform interactively allowing a user to assess and to view the outcome of a range of different land-use scenarios in time and space. A possible structure for WAM is illustrated in Figure 1. This structure is similar to that of the forest management DSS, which should allow WAM to be incorporated into the DSS at the same level as terrestrial assessment model (i.e., wildlife habitat supply).

Assessment and data gathering will be done on a watershed basis, possibly focusing on 2nd and 3rd order (15-100 km^2) basins. Aquatic resource databases should be structured and ranked in terms of physical habitat (primary), fish species (secondary), and fish populations (tertiary). Initially the WAM will focus on aquatic habitats. Given time and development, the system may be upgraded to include and manipulate fish species and/or population data as new methodologies and resources become available. Hydro-meteorological databases and available soil and geological information should be collated and incorporated into the WAM (e.g., GIS). These data will be important input variables used to develop hydrological and biological estimates. Additional data collection, however, will be necessary as a basis for evaluating and testing of existing methods and development of new methods.

WAM will be designed as a subcomponent that will link with the existing forest management DSS to provide a common environment for the assessment of the effects of forest management on both terrestrial, aquatic and hydrologic resources. Existing components of the forest management DSS, such as the Blocking Model and Growth Models, will complement the needs of WAM. The Blocking Model will identify and describes the level and extent of different forest management activities and other land uses (i.e., size of cut areas and their spatial and temporal distributions, topographic locations etc.). These are basic prerequisites for the assessment of impacts on aquatic and hydrologic values. The Growth Models will also be valuable to define the recovery of evapotranspiration (i.e., decrease in water yields and peak flows following cutting) on harvested watersheds. Further development and refinements to the existing GIS may be necessary to provide more specific hydrologic and aquatic information. Data such as stream lengths, stream reaches, watershed areas, characterizing of channel substrates and development of algorithms to link terrestrial disturbances to aquatic systems will be necessary. Methods and techniques utilized for

Insert Figure 1

assessment will be modular in nature. This will allow upgrading and substitution of new methods as they become available and avoid the need for rebuilding the system Both deterministic and stochastic models and methods will be used. Deterministic models will simulate habitat and hydrologic responses to proposed management activities. Stochastic methods will provide estimates of hydrologic events based on assessments of historic records. It is recognized that many of these methods are simplistic and may not provide the full degree of precision desired. They should, however, provide a basis for the recognition and development of new methods (i.e., research needs).

3.4 Hydrological and Biological Watershed Assessment Model Outputs

Hydrological outputs, or end products, from the WAM will include the following.

- Impacts of land disturbances on water yield
- Water volumes distributed in time and space (flow duration curves, persistence of increased flows following cutting)
- Impacts of land disturbances on the magnitude and frequency of maximum and minimum flow events
- Impacts of land disturbances on suspended sediment and bedload movements
- Impacts of land disturbance on site factors such as infiltration, soil drainage, erosion, erodibility, and sediment delivery

Biological outputs, or end products, from the WAM are closely linked with the hydrologic outputs and include the following.

- Impacts on aquatic habitats expressed in terms of a habitat suitability index models specific to the four key target species (rainbow trout, bull trout, Arctic grayling, mountain whitefish) and their major life-requisite functions (i.e., spawning, incubation, rearing, adult feeding, overwintering).
- Habitat descriptors that need to be assessed/predicted include the following:
    - bedload movement
    - sediment deposition and entrainment into substrates
    - substrate type and quality (texture, embeddedness, compaction, etc.)
    - spawning areas (availability, distribution, quality)
    - suspended sediment concentrations (short term, long term)
    - stream temperature (mean, maximum)
    - dissolved oxygen (mean, minimum)
    - nutrient levels (nitrate-N) (external vs. internal sources)
    - streambed and bank scour (extent, severity)
    - large organic debris and cover (allocthonous vs. on-site)
    - flow variability (seasonal, year-to-year)

- timing of max. and min. flow (particularly in relation to critical spawning, rearing events)
- winter flows (distribution and availability of holding water of overwintering of fish)
- access and infrastructure development to/or near streams (as relates to increased angling pressure)
- high quality adult feeding/holding habitat (availability/distribution during summer/winter critical low flow periods)

3.5 Linkages between Watershed, Hydrology, and Biology

A matrix was developed to assist us in identifying and assessing the relative influence of various forest management activities on a wide range of watershed parameters (Table 2). The relationships were ranked according to a four-point Classification Scheme. A Class 1 rating implies a direct relationship, which is highly sensitive and easily detected (Appendix C). This relationship would be of primary concern to the Working Group. In contrast, a Class 4 rating indicates a relationship that is not sensitive to changes, and as such is of minor concern at this level of planning. It is apparent that timber harvesting (summer and winter) and road construction and maintenance have the greatest potential to alter key hydrological and water quality parameters. Harvesting and road construction were considered important because they can affect numerous parameters. These affects usually occur in the immediate vicinity of harvesting or construction, but they can also cause widespread disturbances downstream. In addition, these effects can influence the aquatic ecosystems in the long term as well as the short term. The potential effects of grazing, coal mining, and gas or oil exploration also were significant but were judged to be slightly less important because of their more "limited" spatial and temporal distribution. Generally, these landuse activities influence water quality (primarily turbidity) sediment deposition, and bedload.

A second matrix (Table 3) analyzed the sensitivity of aquatic resource values to hydrologic factors. The results indicated that water yield, peak flow events, snow melt runoff, soil disturbance or erosion, and associated sediment and bedload movement have the greatest potential to alter aquatic habitats. These hydrologic factors influence aquatic habitat and fish populations even in the absence of forest management. Management activities can increase the magnitude and frequency of these hydrologic processes. The effects of forestry developments on water quality and aquatic habitats are relatively well known but are not well defined in quantitative terms. Therefore, it is difficult to predict or describe reliable fishery management strategies. Better linkages need to be developed between the hydrological effects of forest management activities and their impacts on aquatic habitats.

Summer aquatic habitats were judged more susceptible to the hydrological impacts of land use than winter habitats because of open stream conditions and greater potential for soil disturbance, erosion , and sedimentation. Water quality parameters during the summer season were also more susceptible to impacts from management activities than during winter conditions. Winter habitats, however, remain very important, especially in terms of holding water for over-wintering fish. Small streams in the region tend to freeze to the bottom over lengthy reaches; this results in isolation of fish in discrete, and often sporadically distributed pools. Winter habitat was considered very sensitive to low flows, snowpack depth, and channel conditions affecting icing and winter holding pools. Very little is known about these winter habitats despite the fact that most streams are ice bound for at least six months of the year.

The role of large organic debris and its dynamics in stream channels and buffer or leave strips, were considered of importance. The occurrence of organic debris, primarily dead trees or logs, are important in the creation of resting and escape cover for fish. However, excessive accumulations of organic debris in the channel (due to logging of timber on immediate stream banks) can be detrimental (i.e., channel changes, blockage of fish movements). Little information is available in the Foothills or Boreal forest setting on the importance of large organic debris and how streams should be managed to ensure its presence in the preferred amounts..

3.6 Rankings of Projects and Data Needs

Based on the matrix analyses, studies and data needs were identified according to their importance in developing a WAM. An assessment of the major interactions between forest harvesting and hydrologic values in the matrix analysis indicated that impacts on flow volumes and timing of flows, and on water quality in terms of sediment and bedload, resulting from erosion principally at road-stream crossings were most important (i.e. most frequent by the scoring system). A similar analysis was done for the interaction between hydrologic factors and aquatic habitats. This assessment indicated that the hydrologic parameters of yield, peak flows, low flows, sediment and bedload can have significant impacts on aquatic habitats.

3.6.1 Infrastructure

The hiring of a watershed coordinator was considered an essential step, and the initial one, in the development of a WAM. This person would coordinate the program, arrange and seek external funding, organize and make contacts for research, and participate in the design and development of WAM based on existing databases and technologies available.

Development or modification of the Model Forest GIS and Landscape model is needed to provide basic landscape data, such as watershed areas (2nd-3rd order basins 5-12 km^2 in size), watershed slope, stream gradients, description of vegetation in terms of buffers, and areas cut in time and space, delineation of existing and future road systems, and soil descriptions and properties. Incorporation of climatic data, such as precipitation, storm events, and snow depths, into a database is also essential in developing a WAM. Availability of these basic data into the Model Forest will allow for some basic hydrological and aquatic assessments.

Table 2 Matrix showing sensitivity of watershed, hydrology, and water quality parameters to management activities.

	FOREST MANAGEMENT ACTIVITIES						OTHER MANAGEMENT ACTIVITIES			
WATERSHED, HYDROLOGY AND WATER QUALITY PARAMETERS	HARVESTING		ROAD BUILDING AND MAINTENANCE	APPLICATIONS			GRAZING	RECREATION	COAL MINING	OIL AND GAS EXPLORATION
	Summer	Winter		Fertilizers	Herbicides	Pesticides				
YIELD	1	1	3	3	2-3	4	3	4	2-3	4
PEAK FLOWS	1	4	1	4	3	4	2	4	1-2	2-3
LOW FLOWS	2	2-3	3	3	3-4	3-4	3	4	1-2	2-3
GROUNDWATER	2-3	3	3	2-3	2-3	2-3	3	2-3	2-3	2-3
SPRING/SNOW MELT RUNOFF	1	1	3	4	2-3	4	3	4	2-3	3
RIPARIAN BUFFERS										
Canopy Openings	1-3	1-3	4	4	3	4	2	4	3	3
Vegetation	1-3	1-3	4	4	3	4	1	4	3	3
CHANNEL CHARACTERISTICS										
Width/Depth Ratio	2-3	3	1	4	3	4	1	4	3	3
Pool-Riffle Ratio	2-3	3	1	4	3	4	1	4	3	3
Bed Material Size	2-3	3	1	4	3	4	2	4	2-3	2-3
Embeddedness	2-3	3	1	4	3	4	3	4	2-3	2-3
Large Woody Debris	1-2	1-2	4	4	3	3	3	4	3	3
Bank Stability	2-3	2	1	3	2	4	1	4	3	1-2
AQUATIC ORGANISMS										
Bacteria	4	4	4	4	4	4	1	4	4	4
Algae	3	1	4	2	2	4	1	4	3	4
Invertebrates	1	1	1	3	3	2	1	4	2	1
Fish	2	2	1	3	3	3	2	4	1	1
SPORT ANGLING	2-3	2-3	1	4	4	4	2-3	1-2	1-2	1-2
EROSION/SOIL DISTURBANCE	1	1	1	4	2-3	4	1-2	2-3	1-2	1-2
TURBIDITY	1	1-3	1	4	4	4	1-2	3	1-2	1
SEDIMENT	1	1-3	1	4	4	4	1-2	3	1-2	1
BEDLOAD	2	1-3	1	4	4	4	1	4	1-2	1-2
WATER QUALITY										
Temperature	1-2	1-2	3	4	3	4	2	4	2	3
pH	3	3	3	3	3	4	3	4	3	3
Conductivity	3	3	3	3	3	4	3	4	1-2	3
Dissolved Oxygen	3	2	1-2	2	3	4	1	4	2	1-2
Intergravel DO	2	2	4	3	3	4	2	3	2	3
Nitrogen	2	2	3	1	3	4	1	3	2-3	3
Phosphorous	2	2	3	1	3	4	1	3	2-3	3
Herbicides and Pesticides	4	4	3	4	3	4	4	3	2-3	3

Notes: 1 = directly affected, highly sensitive with easily detected effects; 2 = moderately affected, sensitive but not easily detected; 3 = indirectly affected, not very sensitive, difficult to detect; 4 = not sensitive, not affected.

Table 3 Matrix showing sensitivity of aquatic habitat parameters to watershed, hydrology, and water quality parameters.

WATERSHED, HYDROLOGY, AND WATER QUALITY PARAMETERS	HABITAT		SPAWNING		CHANNEL CHARACTERISTICS					BANK STABILITY	RIPARIAN/BUFFERS		AQUATIC ORGANISM				ICE
							BED MATERIAL										
	Summer	Winter	Spring	Fall	Width-Depth Ratio	Pool-Riffle Ratio	Size	Sediment Embedded	Large Woody Debris		Canopy Openings	Vegetation	Bacteria	Algae	Invertebrate	Fish	
YIELD	1	2-3	1	1	2-3	1-2	1	1	1	1	4	4	4	1	1	1	1
PEAK FLOWS	1	2-3	1	2-3	1-2	1-2	1	1	1	1	4	4	4	4	1	1	3
LOW FLOWS	2	1-2	2-3	1	3-4	3	2	1	3	3-4	4	2-3	3	2	1	1	1
GROUNDWATER	2-3	1-2	3	2	3-4	4	3	3	4	3-4	4	2	3	2	2	2-3	1
SPRING/SNOW MELT RUNOFF	1	2-3	1	4	1	1-2	1	1	1	1	4	3	4	4	1	1	3
SPORT ANGLING	1	3	2	1	4	4	4	4	4	2-3	4	4	2-4	4	2-3	1	4
EROSION/SOIL DISTURBANCE	1	3	1-2	2-3	2-3	1-2	2-3	1	1-2	1-2	4	1-2	4	4	1	1	3
TURBIDITY	1	3	2	2	4	3	1	1	4	1	4	1	4	4	1	2	3
SEDIMENT	1	3	1	1	2	2	1	1	3	1	4	1	4	4	1	2	3
BEDLOAD	2	3	2	2	1	1	1	2	2	1	4	1	4	4	1	2	3
WATER QUALITY																	
Temperature	1	1	1	2	2-3	4	4	4	4	4	1	1-2	1-2	1-2	?	1	1
pH	2-3	3	3	3	4	4	4	4	4	4	4	4	2-3	2-3	?	2-3	4
Conductivity	2-3	3	3	3	4	4	3	4	4	4	4	4	2-3	2-3	?	2-3	4
Dissolved Oxygen	1-2	1-2	2	2	2-3	4	1	4	4	4	2-3	2-3	1-2	1-2	?	1-2	4
Intergravel DO	1-2	2-3	1	1	2-3	4	1	4	4	4	3	3-4	2-3	2-3	?	1-2	4
Nitrogen	2-3	3	3	3	4	4	4	4	4	4	4	4	1-2	1	?	2-3	4
Phosphorous	2-3	3	3	3	4	4	4	4	4	4	4	4	1-2	1	?	2-3	4
Herbicides	2-3	3	3	3	4	4	4	4	4	4	4	4	4	1	?	3	4
Pesticides	2-3	3	3	3	4	4	4	4	4	4	4	4	4	3	?	1-2	4
Fertilizers	2-3	3	3	3	4	4	4	4	4	4	4	4	4	1	?	3	4

Note: 1 = directly affected, highly sensitive with easily detected effects; 2 = moderately affected, sensitive but not easily detected; 3 = indirectly affected, not very sensitive, difficult to detect; 4 = not sensitive, not affected.

3.6.2 Hydrology and Aquatic Studies

An important first step to support development of a WAM is to adopt or develop aquatic habitat suitability index models and to characterize regional and local hydrologic regimens. Both of these items will provide databases for inclusion into the GIS and Landscape Models. Subsequent work should centre on testing and/or development of environmental assessment models that will link land disturbances to the hydrologic and aquatic systems. In parallel with these studies will be the testing and validating of habitat suitability index model. The general approach recommended by the Workshop was to first utilize and test techniques and methods readily available to get the WAM "up and running." Following this, more detailed and precise methods can be incorporated into the system.

Hydrological and biological studies were considered important to the development of the WAM. These studies will not only assist in the development of a DSS but will also provide useful information for both forest management and fish management activities. In addition, analysis of current databases and the development of new databases would have to be established.

Hydrological Studies Required

1) Describe regional and local hydrology of the Foothills Model Forest management area.

2) Describe climatic extremes and norms for the Foothills Model Forest management area. (This would be primarily based on historical records and development of a series of stochastic estimates for extreme events.)

3) Investigate the spatial and temporal recovery of evapotranspiration (ET) following vegetation removal. (This study and previous study are similar in intent, but approach is different. This would be by direct measurement of ET, whereas the other would be a modelling approach.)

4) Investigate the initiation of sediment and bedload movement as a function of spring runoff, summer storms, and flow velocity.

5) Develop a predictive model for summer peak flows for disturbed and undisturbed foothill and boreal landscapes.

6) Investigate sediment or bedload dynamics and budgets downstream of point-sources (i.e., road-stream crossings or contacts).

7) Evaluate sediment embeddedness and response to peak flow events in small foothill and boreal streams. (Attempt to evaluate recovery of favourable substrate conditions following sedimentation.)

8) Review riparian or buffer strip management for control of sediment on ephemeral and perennial streams.

9) Evaluate impact of vegetation removal on groundwater levels and winter flows in small foothills and boreal watersheds. Attempt to identify linkages between logging impacts and winter salmonid habitat.

10) Evaluate effects of land clearing on nutrient export from watersheds and the assimilative capacity of buffers to mediate nutrient exports. This study probably is important in boreal forest setting (i.e., low gradient, low flow streams) where small changes in nutrient loading could affect primary producers. Little work of this nature has been done on boreal streams. Furthermore, most water quality assessments are based more on drinking water standards than on the requirements of aquatic organisms.

Aquatic Studies Required

1) Adopt and test habitat suitability index (HSI) models for key fish species to serve as a basis for evaluating environmental impacts (i.e., management activities plus hydrologic interactions) and for comparisons with other resources used in the DSS. Consideration should be given to applying the models developed by the U.S. Fish and Wildlife Service (H.E.P.). These models will need to be "fine-tuned" to the Alberta setting. It is likely that sufficient data is currently available in Alberta to develop preliminary working models for key species (in particular the Athabasca strain of rainbow trout and Arctic grayling).

2) Characterize spawning criteria and habitats (depth, velocity, substrate etc) for key fish species and relate the seasonal timing of their use to relevant hydrological factors (e.g., peak flows).

3) Characterize dynamics of substrate movement and define effects on physical fish habitat and food availability (i.e., invertebrate production).

4) Define dynamics and sources of large organic debris in small foothill/boreal streams with objective of defining management strategies and methods of identifying resources on the ground.

5) Assess the impacts of sport fishing on fish populations. It is essential to determine the role of the angler in regulating (and in the worst case depleting) the density and stability of sportfish populations and to separate effects of land disturbances from those that result in direct human utilization of the resource.

6) Determine the physiological and reproductive responses of key aquatic species to hydrological and water quality changes induced by land disturbances.

Baseline Data to be Obtained/Integrated

! Stream inventories to characterize aquatic resources and to provide base for developing and testing aquatic HSI, to input into GIS-Landscape Models.

! Inventory of critical habitats (major spawning, rearing, overwintering areas) and stream reaches. (should be part of the overall inventory process)

! Collection and assimilation of existing climatic and hydrometric databases that can be input into GIS and Landscape Model. At this point it would be useful to schedule another workshop to further identify and refine data requirements and formats needed for the WAM.

- Analyses and assessments of the quality of small basin data from the Tri-Creeks Watershed Study and other studies done in early 1970's (Canadian Forest Service Study). These studies will provide useful baseline data for any testing and/or development of hydrologic-aquatic models.

- Collection of baseline data and response data for flows and fish populations from a small number of "test" or "index" basins. These data and basins would provide a testing area for different models, methods, and technologies adopted or developed.

- Obtain and integrate into the database information from forest management plans relating to species and scheduling of cutting in time and space; it should be assessed on a watershed basis.

- Description of soils and surficial and bedrock geology for the management area, and their input into GIS-Landscape models.

- Integration of existing Alberta Fish and Wildlife stream survey data (fish species presence/absence, CPUE, physical habitat data, important/critical sites and reaches) into the database.

3.7 Feasibility of Developing a Watershed Assessment Model

Development of a WAM is a long-term commitment, requiring a substantial investment of human and financial resources. Workshop participants were in full agreement that such an undertaking is worthwhile and feasible. The existence of WAM as a component of the forest management DSS will provide balance insuring that aquatic and hydrologic resources and values are fully considered in land management planning. The existing forest management DSS is an excellent foundation upon which WAM can be developed. Furthermore, advances in GIS and other technology will further support the development of WAM. The workshop participants also agreed that it would be a significant contribution to sustainable forest management of the Foothills Model Forest. We have outlined a three-year plan encompassing the start up phase of a Watershed Assessment Model. Also included is a proposed budget and a list of potential financial and human resources.

3.7.1 Action Plan and Study Schedule

Outlined is a schedule of activities for the next three years to facilitate development of a WAM for the Foothills Model Forest. The focus should be on the development of an associated research program to improve the knowledge base and understanding of interactions between land disturbances and hydrologic-aquatic resources. The overall objective is to get a model "up and running" as soon as possible. Although the initial outputs will be very rudimentary, they will be of considerable value to resources managers. Once the system is running successfully it will stimulate further development and refinement.

1994-95 (Year 1)

- Hire Watershed Coordinator for Foothills Model Forest.

! Incorporate existing climatic and landscape data into the Model Forest GIS-Landscape Models; these will serve as a basis for initial hydrologic and aquatic assessments.

! Describe regional and local hydrological regimes in as much detail as possible using readily available data, and prepare format for input into GIS-Landscape Models.

! Organize and conduct a workshop to assist in adopting and developing a Habitat Suitability Index Model for key fish species (rainbow trout, Arctic grayling, bull trout, and mountain whitefish).

! Identify 3-4 small "test basins" ("index basins") to provide a database for testing of environmental assessment models and other technologies. These basins would provide a foundation for future work. Infrastructure and investments in these basins will be limited. Anticipate minimum instrumentation: flow and precipitation only on a regular basis. Other parameters would be collected by individual projects or researchers (e.g., fisheries baseline inventory data).

! Initiate study of sediment and bedload movement in relation to storm events.

1995-96 (Year 2)

! Hold workshop to review and refine data needs and format requirements for GIS-Landscape Models. Needs and plans for specific WAM outputs would be considered.

! Initiate testing of aquatic HSI model on test basins and other independent data sets. May be able to use existing database for study area (i.e., Alberta Fish and Wildlife inventory data) to develop "made in Alberta" habitat model descriptors.

! Develop a predictive model for summer peak flows for disturbed and undisturbed foothill and boreal landscapes. This model should support work on sediment and bedload movement.

! Continue study in sediment and bedload movement with regard to storm events.

1996-97 (Year 3)

! Perform a spatial and temporal assessment of water yield increases following vegetation removal and input into WAM to allow assessment of different harvesting and cutting schedules. This can probably be accomplished using the WRENSS methodology.

! Continue study and peak flow prediction model.

! Continue study in sediment and bedload movement.

! Incorporate preliminary HSI Model output data into GIS-Landscape models.

The goal is to have the WAM operating at the end of the three-year period. At this time it should provide (1) basic landscape information for hydrologic and aquatic resources evaluations, (2) basic information for describing regional and local hydrologic regimens and responses to forest harvesting in terms of annual yields and peak flow events, and (3) a HSI Model for key fish species operating at a preliminary level.

3.7.2 Proposed WAM Budget For the First Three Years - (1994-1996)

The working group recommended five projects for year-1 (Table 4). These projects were considered both practical and essential to getting the WAM operating in the first 6-12 months, at least at a rudimentary level. Hiring of a Watershed Coordinator was considered very important to the success of the program. This individual would provide focus and momentum in the planning and implementation phase and would organize external funding and support efforts. Although the first year budget may appear to be disproportionately large, this is primarily because of the high costs of initiating the program. In comparison, budgets for years 2 and 3 (Table 5) are lower because in many cases they are a continuation of work initiated in year-1.

It was recognized that full funding from the Model Forest will not be likely. Hopefully, however, money to secure the watershed coordinator and some "seed" money to support (i.e., kick start) some of the other initiatives will be made available. The existence of partial support for an initiative is often very effective in securing additional funding. Workshop participants were in agreement that a large share of the cost to develop WAM will need to be derived externally.

Table 4 Proposed budget for Year-1, WAM Development.

WAM Component	Budget (estimate)
1. Watershed Coordinator and Leader	$52 000
2. Establish protocols with Model Forest GIS and Landscape model; get WAM at operating level within first 6-12 months; provide focus for hydrological and aquatic needs. Hydrological description at regional and local levels; provide initial data base for testing and development of impact models	$80 000 (in kind)
3. Habitat model development (literature search, workshop, limited sampling for test data)	$60 000
4. Model/methods to assess substrate, channel dynamics and habitat links (MSc or PhD candidates)	$30 000
5. Model/methods to link land-use impacts to aquatic habitats (erosion-sediment-bedload) (MSc or PhD)	$30 000
TOTAL	$252 000

Background Notes from Workshop

Habitat Model

1. Literature Review to scope and narrow choices for development of an Aquatic Habitat Model.
   Look at things like riparian areas, woody debris, spawning criteria for key species $50,000
2. Workshop to develop proposed Habitat Model. $10,000
3. Model Testing, based on use of existing data base on species composition, and some limited sampling for species composition on additional streams
   Anticipated time frame 2-3 years. $?????
   Eventually will need to sample and characterize remaining streams in Model Forest...minimum cost.....$300,000

Regional Hydrological Description

1. Regional Analysis - 6-7 months full time
2. Harvesting Impacts on existing conditions using WRENSS analysis..maximum impacts 4-5 months
3. Hydrologic Recover of Watersheds - simple to very complex...simplest maybe 1-2 months using WRENSS
4. Channel Dynamics - by assessment of flow duration relations...4-5 months
   Assessment of Channel Dynamics-Habitats-Storm Responses, more demanding in time and resources. Propose as a graduate student project..PhD...annual cost $30,000/year for 3 years
   Assessment of Landuse Impacts and linking to Habitats. Graduate Student
5. Protocols for GIS would be done by consultation with Model Forest personnel

Table 5 Proposed budgets for Year-2 and Year-3, WAM Development.

WAM Component	Budget
Year 2	
1. Watershed Coordinator	$52 000
2. Workshop to review and refine data needs for GIS-Landscape Models	$15 000
3. Testing of HSI Model	$20 000
4. Model/methods to assess substrate, channel dynamics and habitat links etc.	$30 000
5. Model/methods to link landuse impacts to aquatic habitats	$30 000
6. Peak flow model to assess flow peaks and velocities relative to substrate movement, graduate student	$30 000
TOTAL	$177 000
Year 3	
1. Watershed Coordinator	$52 000
2. Spatial and temporal assessment of water yield increases following vegetation removal, graduate student or consultant	$20 000
3. Model/methods to assess substrate, channel dynamics and habitat links etc.	$30 000
4. Model/methods to link landuse impacts to aquatic habitat	$30 000
5. Peak flow model to assess flow peaks and velocities relative to substrate movement	$30 000
TOTAL	$162 000

3.7.3 Human Resources for WAM Development

Human resources to implement the WAM will be available from a wide range groups and organizations (Table 6). It is expected that the initial work (i.e., adapting existing GIS-Landscape Models for hydrologic and aquatic values) will involve the watershed coordinator from the Model Forest, government management agencies, and private consultants. The Model Forest GIS personnel will play a pivotal role in development of the WAM. As such, they will have to interact with all of the groups involved in the WAM project. Description of regional and local hydrology of the Model Forest can be achieved through collaboration between government and universities (using graduate students) or by employment of private consultants. Adoption and development of aquatic HSI Models could be implemented through a facilitated workshop involving Model Forest, government, and university personnel. Development of sediment-bedload relationships and a peak flow response model could be achieved through university graduate student research, by government researchers, or private consultants. The identification of human resources for the WAM will be one of the primary tasks that the Watershed Coordinator.

Table 6 Human Resources for WAM Development

University	**Government Research Agencies**
Graduate Student Research	Collaborative Research
Contract Research	Contract Research
Government Management Agencies	**Private Consultants**
Collaborative Research	Contract Research
Monitoring	Monitoring
Inventory - Databases	Inventory - Databases
Forest Industry	**Other Model Forests**
Collaborative Funding of Research Projects	Joint Funding of Research
Monitoring	Joint Monitoring
Inventory - Databases	Joint Inventory - Databases
Conservation Groups	**Communication Responsibilities**
Collaborative Research	Model Forest
Funding	Individuals
Direct Involvement by Volunteers	Partners

3.7.4 Potential Sources of Funding WAM

The budgets outlined for the WAM exceed funding available from the Model Forest. Therefore, external funds must be secured if the WAM is to be successful. Hopefully funding from the Model Forest will be available to serve as seed money to stimulate project start-up. Financial support for the Watershed Coordinator, by the Foothills Model Forest, will be a very important first step in getting the WAM project underway. A list of possible funding sources is provided in Table 7. Initially, opportunities for joint funding with other forest companies in the province and with provincial agencies should be explored. A number of forest companies are currently assessing the need to integrate hydrology/watershed research in their forest management plans. Some government research institutions are currently planning research/management projects in the areas of ecosystem and watershed management. Also, collaboration with other Model Forests may provide good opportunities because many of them are just starting to plan and initiate their research programs. Conservation groups such as Trout Unlimited Canada and Alberta Fish and Game Association also are potential supporters of the WAM project. These groups may be able to provide volunteer help and in some cases direct funding, although these amounts contributed are anticipated to be small. Securing funding for the WAM project will be an important and probably on-going task for the Watershed Coordinator.

Table 7 Potential Sources of Funding for WAM

Federal Government	**Private**
Canadian Forest Service	Forest Industry
Department of Fisheries and Oceans	Model Forests
MacKenzie Basin River Study	**Conservation Groups**
Northern Rivers Basin Study (joint federal/provincial group)	Trout Unlimited Canada
Water Management Services, Environment Canada	Alberta Fish and Game Assoc.
Green Plan	Alberta Ecological Trust
Partnership Agreements in Forests (PAIF)	Shell Environment Fund
Natural Sciences and Engineering Research Council (NSERC)	World Wildlife Federation
Provincial Government	
Alberta Forest Development Research Trust (AFDRT)	
Fisheries Management Enhancement Program (FMEP)	
Alberta Recreation and Parks	
Alberta Environmental Protection	
Surface Water Assessment	
Lands and Forests	
Fish and Wildlife	
Alberta Environmental Research Trust	

4.0 CONCLUSIONS AND RECOMMENDATIONS

Recommendations developed during the workshop included the following:

1) The employment of a Watershed Coordinator-Leader was deemed necessary to ensure that the WAM receives strong representation during the planning and implementation phase of the project. The Watershed Coordinator would also coordinate funding and support efforts. In fact, hiring of a Watershed Coordinator was considered the number one priority by the Workshop participants.

2) The priority two activity is to incorporate the hydrologic protocols and enable the GIS to provide simple and rudimentary data for basic hydrologic and aquatic resources evaluations. Priority 3 was development of the Habitat Suitability Models Index for the four key sportfish species. Priority 4 was undertaking the Regional Hydrologic Description. Subsequent items for assessment will include such things as channel dynamics, buffer strips, and links between land use and habitat changes.

3) In general, a strategy that identifies actions that will result in the operation of the WAM as proposed by the Working Group is recommended.

4) Set goals with a short time frame to increase the ease of securing support and funding; this should enable the WAM program to develop and to be successful over the long term.

5) Adopt a three-year plan proposed by the Working Group, with the intent of getting the WAM "up and running" as soon as possible.

6) Follow a step-wise program of development; success at the early, formative levels should facilitate early use of the WAM and assist in its future development.

7) A first year budget of $247 000 is proposed; this level of funding is considered realistic and necessary to get the WAM started. It was recognized that full funding from the Model Forest would not be possible. However, it is hoped that partial funding could be obtained from the Model Forest, with the rest coming from other sources. An expected annual budget for the next 3-5 years would be $100-200K per year.

8) Concurrent with the above, the Watershed Coordinator, once in place, should begin to enlist human resources to commence work on the different components of the WAM and explore possibilities for collaborative efforts and joint funding to support these activities.

9) Establish an ad hoc committee interested in supporting and participating in the development of a WAM. Participants at the current workshop could represent a "core group." Furthermore, the "Watershed Research Group" could act as a coordinating or steering committee for watershed concerns.

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APPENDIX A

TERMS OF REFERENCE

FOOTHILLS FOREST WATERSHED WORKSHOP

DRAFT
Terms of Reference
Workshop Facilitators

The Foothills Forest is preparing a Watershed Decision Support System (DSS) for incorporation into the overall forest management DSS currently being developed for the Foothills Model Forest.

We required a strategy development workshop to produce a detailed strategic plan on which to base the next 3 years of project activities within the watershed component of the DSS.

Watershed DSS Objective:

"To have a system capable of evaluating a harvest plan for the resulting cumulative effects of forest management activities on the quantity and quality of water yield from a given watershed or complex of watersheds, and in turn be able to evaluate the impact of the harvest plan on the quantity and quality of aquatic habitat (e.g., fish)."

A preliminary watershed workshop in April of 1993 produced a 3-tiered approach to the development of a watershed DSS. These 3 tiers or areas of priority are: 1) watershed - water quantiy and qualtiy at the watershed level; 2) hydrology - stream and channel morphology; and 3) habitat/ biology - aquatic and fisheries habitat and biology.

Workshop Goals:

The primary goal of this planned workshop is to bring together a number of domain experts in hydrology and biology, under the direction of 2 domain facilitators (a hydrologist and an aquatic biologist) to produce a strategic plan which will address the detailed plans and projects required for the development of a complete watershed DSS.

A secondary goal involves the priority ranking of projects and work both within each tier of the watershed DSS and between tiers.

Terms of Reference:

The consultants retained to facilitate this workshop will be required to:

1) Organize the workshop.

Tasks identified:

- establish goals/topics for workshop sessions, covering the fulfilment of the overall goals of the workshop as identified above e.g., establishment of parameters, levels of precision, scope, scale, etc.
- cooperation with other consultant
- establish workshop format in consultation with workshop coordinator e.g., plenary sessions alternating with domain specific working group sessions
- develop a pre-workshop package for distribution to participants to allow participants to prepare

2) Facilitate the workshop.

Tasks identified:

- chair plenary and working group sessions
- develop and supply and required workshop materials
- chronicle workshop progress and achievements for incorporation into strategic work plan
- development and guidance of a summary session for priority ranking of projects and work within and between the tiers of the watershed DSS

ensure the working group sessions meet the overall goals of the watershed DSS

3) Production of Watershed DSS strategic plan.

Tasks identified: develop a strategic plan which addresses the overall goals of the watershed DSS and accounts for the following:
- overall and tier-specific goals and objectives
- overall and tier-specific projects required to develop the watershed DSS
- priority ranking developed at workshop
- project feasibility, timelines, milestones, cost estimates, options of potential people/organizations to undertake the work identified, potential funding sources

Workshop Milestones: Workshop completed by 31 December 1993
Strategic Plan Draft Submission by 31 January 1994

Workshop Participants: to be selected and contacted by the Foothills Forest
participant meals and accommodation provided by Foothills Forest
participants will cover their own travel expenses

Workshop Location: Forest Technology School, Hinton, Alberta

Workshop Coordinator: Norm Rodseth, Foothills Forest Partners Advisory Committee
P.O. Box 8055, Edson, Alberta T7E 1W2
(403) 723-6058

Contact: Melissa Todd, Foothills Forest Biologist
P.O. Box 6330, Hinton, Alberta T7V 1X6
(403) 865-8180

Prepared: 14 October 1993

APPENDIX B

WORKSHOP SUMMARY (14 January 1994)

APPENDIX C

RANKINGS OF HYDROLOGICAL AND BIOLOGICAL PARAMETERS

Ranking based on only those items scored as highly sensitive (1) in the matrix analysis

Harvesting impacts - summer

- Yield
- Peak flows
- Spring runoff
- Riparian buffers
- Erosion soil disturbance
- Large wood debris
- Invertebrates
- Water temperature

Harvesting impacts - winter

- Yield
- Spring snowmelt
- Riparian buffers
- Erosion and soil disturbance
- Water temperature

Road building and maintenance

- Peak flows
- Channel characteristics
- Fish
- Sport angling
- Erosion soil disturbance
- Turbidity
- Sediment
- Bedload
- Dissolved oxygen

Fertilizers

- Nitrogen
- Phosphorus

Identification and ranking of hydrologic x aquatic parameters

Habitat - summer

- Yield
- Peak flows
- Spring runoff
- Sport angling
- Erosion/soil disturbance
- Turbidity
- Sediment
- Temperature

Habitat - winter

- Temperature

Spawning - spring

- Yield
- Peak flows
- Temperature
- Intergravel dissolved oxygen

Spawning - fall

- Yield
- Sport angling
- Sediment
- Intergravel dissolved oxygen

Channel characteristics

- **Width\depth ratio**
  - Spring runoff
  - Bedload
- **Pool\riffle ratio**
  - Bedload
- **Bed material**
  - Size
    - Yield
    - Peak flows
    - Spring runoff
    - Bedload
    - Dissolved oxygen
    - Intergravel dissolved oxygen
  - Sediment embedded
    - Yield
    - Peak flows
    - Low flows
    - Groundwater
    - Spring snowmelt
    - Erosion disturbance
    - Turbidity
    - Sediment
- **Large wood debris**
    - Yield
    - Peak flows
    - Spring runoff
    - Erosion soil disturbance

Bank stability

- Yield
- Peak flows
- Spring snowmelt
- Erosion soil disturbance
- Turbidity
- Sediment
- Bedload