WORKING PAPER

Problem Analysis of Integrated Resource Management of Riparian Areas in British Columbia

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Riparian areas, classically considered to be those areas adjacent to lakes and rivers, have exceptional characteristics compared to other parts of the landscape. The demands we humans make of riparian areas are also exceptional. Sensitive management of these areas is a complex task that requires knowledge and communication systems that are only fragmentary in British Columbia at this time. This report is the first essential step toward a holistic approach to resource management in riparian areas.

The need for this project was identified in 1990 independently within the Ministry of Forests and the Ministry of Environment (now the Ministry of Environment, Lands and Parks). Subsequently, the efforts of staff within the two ministries were pooled to provide a more comprehensive and co-ordinated project. A contractor was selected on the basis of a response to a request for proposals from qualified companies. The formidable task set for the contractor, Environmental and Social Systems Analysts (ESSA), was to survey the current state of knowledge about riparian areas in Alaska, British Columbia, Washington, and Oregon, to summarize it, identify needs, and make recommendations for satisfying those needs. Unfortunately, limited resources made it impossible to expand the search beyond these areas. The project was to focus on riparian areas in the classical sense and include reservoirs. Areas classified as wetlands and land adjacent to estuaries or other tidewater areas were not included, nor were mitigation measures related to large dams.

We emphasize that although this problem analysis was not published until 1995, it was completed in April of 1992. No modifications have been made to the contents of the 1992 draft to reflect more recent information or government initiatives for riparian areas in British Columbia. In particular, the Forest Practices Code of British Columbia contains provincial regulations and standards for the designation of riparian management areas bordering streams, lakes, and wetlands in the province. A riparian field guide is being produced to provide guidance in implementing the code and in developing management guidelines for riparian areas. These riparian management guidelines are a significant step towards addressing many of the issues and recommendations put forth in this problem analysis. The reader should refer to these other documents for information on the current provincial approach to riparian management.

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TABLES

FIGURES

1.1 Objectives of Problem Analysis

The two primary objectives of the riparian problem analysis were (1) to review the current situation in the Pacific Northwest including Washington, Oregon, Alaska, and British Columbia; and (2) to make a series of recommendations. Subject areas that were reviewed include:

- classification and inventory systems
- relevant literature
- current research
- current management practices
- existing guidelines for integrated resource management
- existing policy and regulations

The recommendations are concerned with:

- a suitable definition of riparian areas
- classification and inventory systems for British Columbia
- strategies for research
- strategies for pursuing integrated resource management
- extension (courses, lectures, demonstrations, etc.)

1.2 Project Approach

The approach used in this project was to collect information and expert opinion from a variety of sources, and then to synthesize this in a report and database. The first phase consisted of a library search and telephone interviews to collect background information on science, policy, and current management guidelines pertinent to riparian areas. A database was constructed and was submitted to the Ministry of Forests under separate cover (contact Dr. P. Comeau, Ministry of Forests, Research Branch, Victoria, B.C.). The information from these sources was compiled in a review report and subsequently revised to form the body of this report.

The second phase of information collection consisted of a questionnaire, which was mailed to more than 200 respondents who were selected on the basis of their role in riparian area management. They included Ministry of Environment and Ministry of Forests researchers and managers, and representatives from nongovernment organizations and industry. Although 136 returns were received, this did not represent a simple 68% response, because some recipients duplicated and distributed the questionnaire to other concerned individuals. Of the responses received, almost half were Ministry of Forests employees, 80% of whom responded from district offices. Another 25% were Ministry of Environment employees, 70% of whom responded from regional offices. The remainder (just over 25%) were evenly divided between industry and nongovernment organizations such as naturalist and wilderness groups and native organizations, and included three academics. The questionnaire was a method of giving the concerned community an opportunity to contribute ideas. The suggestions and opinions expressed by respondents have been incorporated into this report, primarily in the recommendations section. (A complete summary of the questionnaire results has been submitted to the Forests and Environment ministries under separate cover.)

The third phase of the project consisted of a workshop of 40 people (Appendix 1), held in late February 1991. The purpose of the workshop was to allow participants to discuss issues and recommendations pertinent to classification, inventory, research requirements, land planning and management at both local and provincial levels. This report and Research Report 93003-HQ (Rautio and Bunnell 1994) synthesize all the information gathered from the various sources mentioned above.

2 NATURAL VALUES OF RIPARIAN AREAS

Water is the focus of many demands, including: drinking water for people, livestock, and wildlife; dumping and dilution of waste industrial process water; fish and wildlife habitat; hydroelectric power generation; and recreation. Riparian areas affect and are affected by those who attempt to meet these demands for water. Both the land base and the biota bordering water play a significant role in determining the quality of water and aquatic habitats. In turn, because riparian areas are lent special qualities by their proximity to water, they attract users, particularly wildlife and recreationists. Human users may consume riparian areas (dams), change water regimes that affect riparian areas (water diversion, regulation, or consumption), or change riparian conditions when gaining access to water or water-related values (livestock, recreation). Not only are demands numerous, they are also interrelated and frequently mutually exclusive.

Managing for all of these demands is a complex problem. A reasonable beginning is to examine in more detail the role of riparian areas in meeting user demands.

2.1 Biophysical Description of Riparian Areas

The riparian area is an interface or ecotone between aquatic and terrestrial ecosystems. Physical processes occurring in riparian areas thus stem from interactions between components of the terrestrial and aquatic systems.

Water and the physical conditions associated with its presence can influence the microclimate, soil moisture, and nutrient conditions in the riparian area (Bury 1988; Green and Kauffman 1989; Butt 1990). Riparian areas are often inhabited by plants that can tolerate flooding and occasional anaerobic conditions. Similarly, along wider streams and around lakes where sunlight has access to the understorey, plant species that are tolerant of high light conditions may exist next to a more shade-tolerant mature forest. Biogeochemical cycling is also significantly affected by the higher moisture in riparian areas (Green and Kauffman 1989).

Riparian vegetation, geomorphology, and soils affect the aquatic environment (Meehan et al. 1977; Cummins 1980; Swanson et al. 1982). Vegetation contributes both small and large organic material to streams and lakes. Small material, such as leaves, twigs, and insects, provides food and energy to aquatic organisms. Large organic debris, such as trees, falls into water bodies and contributes structure for habitat and a long-term source of food. Both riparian vegetation and large organic debris help to stabilize stream banks. Riparian areas may also serve as nutrient sinks, extracting compounds of nitrogen, phosphorus, and other elements potentially harmful to the aquatic environment (Green and Kauffman 1989).

Riparian areas differ widely across British Columbia partly because of the influence of water velocity (rapid, slow running, still) and the related landscape position. For example, a tree will function differently depending on whether it falls into a stream or a lake. The importance of the tree in determining stream conditions (bank stability, instream fish habitat, insect substrate, etc.) changes from headwater creeks, to mid-drainage streams, to river floodplains. Just as stream ecosystems are continua that change from headwaters to estuary (Cummins 1980; Minshall et al. 1985), so too are the adjacent riparian areas.

Because of this variability, it is difficult to formulate a biophysical description of riparian areas that will be useful in all situations. The critical values of riparian areas will depend on the position in the landscape and on management goals. The following sections outline in more detail the natural value of riparian areas, including habitat for fish and wildlife and protection of biodiversity.

2.2 Biodiversity

Riparian areas provide numerous opportunities for consumptive and nonconsumptive use by human and nonhuman life. These opportunities include: (1) productive capabilities, such as for high-quality timber; (2) plant and animal species and communities that, besides constituting inherently valuable systems in their own right, provide aesthetic enjoyment, materials for development of foods or medicines, and opportunities for increasing scientific knowledge; (3) genes that can help improve productivity, resistance to disease, and ability to adapt to change; and (4) life support functions, such as water purification. The ability of natural systems, including riparian areas, to produce these opportunities sustainably is frequently said to depend on the maintenance of biological diversity (Samson and Knopf 1982; Wilcove 1988).

Three levels of biodiversity are recognized: genetic, species, and ecosystem (Wilcove 1988). These levels correspond to different scales of resource management. For example: genetic diversity is a function of the number of genes in one tree species in a stand; species diversity is a function of the number of tree species in a local or regional area; and ecosystem diversity is a function of the number of distinct ecological communities in a broader geographical area. Historically, species diversity has received the most attention (Samson and Knopf 1982; Wilcove 1988), although the other two levels are now being increasingly recognized. Bird and small mammal species are often used as diversity indices (Cross 1988; F. Bunnell, pers. comm., 1991).

There is no doubt that riparian areas are diverse in themselves. Frequent disturbance and the numerous habitat edges found in the water-to-land transition are reflected in high biotic diversity. Riparian areas are frequently disturbed by flooding, which can result in sediment deposition and bank cutting, and can trigger debris torrents and landslides (Agee 1988). This promotes a matrix of diverse vegetation communities and, consequently, diverse animal communities. Since water is not normally a limiting factor in riparian areas, vegetative productivity is frequently high, allowing a diversity of species, or many of one species, to inhabit a site. Finally, the extensive edges where riparian areas adjoin upland habitats further promote high wildlife diversity (Thomas et al. 1979).

Riparian areas may serve several functions in landscapes, thereby helping to maintain regional biodiversity. For example, they may link different types of upland wildlife habitats. Streamside habitat appears to function as a travel corridor for many birds and forest-dwelling mammals, supplying forage, adequate cover, and a gentle topography for ease of movement during seasonal migration (Thomas et al. 1979; Simpson 1989). However, the function of riparian areas as dispersal corridors for species and genes has not been empirically documented (West 1988; McComb 1989). It is feasible that, because riparian areas are so productive, they may serve as reservoirs of animal species that can disperse to adjacent habitats to maintain genetic diversity or to repopulate disturbed areas. If upland areas are disturbed by fire or logging, colonizing species of vegetation in adjacent riparian areas can facilitate regeneration of the disturbed area (West 1988). Similarly, intact riparian areas either up- or downstream from a severely disturbed streamside area may serve as a source of seed (Klimas 1988).

The above functions of riparian areas in maintaining landscape-level ecosystems may be more important to protecting biodiversity than the site-level diversity found within riparian areas. In some ways, the current focus on riparian areas as suppliers of diverse habitat for many wildlife and fish species endangers maintenance of regional landscape diversity. While riparian areas provide important and diverse habitat, these areas should not receive emphasis that obscures either their function within the broader system or the non-riparian habitat needs of rare, threatened, or endangered species. Knopf and Samson (1988) stressed the need for a planning approach beginning with a broad-scale perspective, with limited emphasis on site diversity. We recommend that planning and management concentrate on the basic concept that natural system function should be maintained.

Finally, riparian areas appear to play a large role in the function of landscapes, although these functions are often not well documented empirically. Knopf and Samson (1988) outlined several research needs to clarify this role, including: documentation of the extent and composition of native riparian systems; listing of riparian-dependent species; examination of factors limiting riparian-dependent species; and investigation of relationships between riparian and upland vegetation communities, and of the role of riparian corridors as dispersal routes.

2.3 Wildlife and Wildlife Habitat

Riparian areas are recognized as one of the most productive wildlife habitats (Thomas et al. 1979; Oakley et al. 1985; Cross 1988). Most temperate species of birds, mammals, reptiles, and amphibians exhibit varying dependency on riparian areas. For example, these habitats can be used as a source of drinking water and forage for black-tailed deer (*Odocoileus hemionus*). However, they are required feeding, cover, and breeding habitat for beavers (*Castor canadensis*) (Morgan and Wetmore 1986; Bury 1988; Bury and Corn 1988; Knopf and Samson 1988; Raedeke et al. 1988; McComb 1989). Generally, free-flowing water and greater forage and cover availability attract wildlife to riparian areas. Streamside vegetation characteristically has a higher species and structural diversity, which provides a greater variety of forage than surrounding areas.

Higher avian diversity is frequently observed in riparian areas, partly because of the structural diversity of streamside vegetation (Best et al. 1979;

Oakley et al. 1985; Knight 1988). Riparian forests with both coniferous and deciduous components provide the greatest availability of niches within their multilayered canopies and understories. Knopf and Samson (1988) provided a tentative listing of 17 riparian obligate bird species in the Pacific Northwest. These authors concluded that "although less than one percent of the western landscape of the United States contains riparian vegetation, this vegetation provides habitats for more species of breeding birds than any other vegetation type on the continent." Stevens et al. (1977) found up to 10.6 times more migrant passerines per hectare on riparian than on non-riparian plots in the southwest United States. In the southern interior of British Columbia, a total of 49 avian species were identified, with as many as 29 at one riparian site (Morgan and Wetmore 1986). The richness of avian species encountered was attributed to the diversity of shrubs and trees in these arid and semi-arid areas. Morgan and Wetmore (1986) speculated that activities including forestry, livestock grazing, and agriculture would seriously affect up to 25 bird species through elimination or reduction of the deciduous and snag components of the riparian stand. Snags are recognized as necessary in a riparian habitat for various cavity-nesting birds. They also meet perching and feeding requirements (Andrus and Froehlich 1988).

The bald eagle is one of the few avian species that has received significant research and management attention (Knight 1988). These raptors have a strong affinity for riparian areas, where they meet, forage, roost, and nest. Faunal diversity appears to enhance the utility of a riparian corridor as habitat for the bald eagle.

Species richness of small mammals — insectivores and small rodents, such as mice, voles, and chipmunks, the mountain beaver (*Aplodontia rufa*), and small carnivores such as ermine and long-tailed weasels — is reported to be generally higher in riparian areas (Cross 1988). This is true particularly in arid regions where the streamside corridor is distinct from the contiguous upland areas. In southwestern and west-central Oregon, most insectivores are present in both riparian and upland zones (Cross 1985); however, some species of shrews were found to be associated only with riparian areas. Similarly, rodents were reported to be abundant in both zones as well, although 13 species were found to use streamside areas as "primary habitat" and were not detected in upland forests. On the west slope of the Cascade Range in the western hemlock (*Tsuga heterophylla*)/Douglas-fir (*Pseudotsuga menziesii*) zone, Anthony et al. (1987) documented a greater number of rodent species in transects within 1 m of the stream bank than in riparian fringe transects 15–20 m from the stream. Rodents provide a substantial prey base for those raptorial birds, carnivorous mammals, and snakes generally found to have a high association with riparian areas (Cross 1988).

The mountain beaver appears to be particularly dependent on riparian areas. Banfield (1981) mentioned that beaver burrows begin in a stream bank and run 50 yards (46 m) or more up the hillside. He goes on to say that the mountain beaver habitat is primarily a riparian association in forests. With British Columbia having the only population of mountain beaver in Canada, and with the range of mountain beaver being limited to the Pacific Northwest, management actions should consider the effects that activities will have on this species.

Anthony et al. (1987) reported that none of the six insectivore species they captured was dependent solely on riparian habitat; however, these authors stressed the need for additional studies to elucidate habitat associations with more intensive sampling methods. Cross (1988) cautioned that existing reports linking small mammals with various habitats may be biased because of short-term studies that include data collection during mild seasons only. For example, Anthony et al. (1987) completed their study in the spring and summer of 1983. Furthermore, the study area was a moist mesic zone, whereas the results recorded by Cross (1985, 1988) were obtained at drier sites.

In addition to rodents such as beaver, two larger furbearers (river otter and mink) are riparian obligate species. Both species, particularly otter, are largely aquatic, but they also use the riparian zone. Otters feed primarily within larger, lowland streams and rivers, while mink use areas closer to the water's edge. Prey items for both include fish, crayfish, frogs, and small mammals, the last of which are more frequently caught by mink. Both otters and mink also depend on riparian areas for breeding, since they use abandoned beaver lodges, burrows beneath stumps, or muskrat mounds. In general, they inhabit coastal estuaries and the highly productive upstream riparian areas (Raedeke et al. 1988).

Fishers are believed to be associated more with upland old-growth forest and swamps, but can be attracted to the higher prey densities of riparian areas (Raedeke et al. 1988). Currently, however, their numbers are so low that few habitat preference records exist. Marten prefer streamside habitat primarily along headwater streams, which usually do not contain fish. Since the most prevalent forest practices guidelines used in British Columbia — the *Coastal Fisheries/Forestry Guidelines*—concentrate on protecting fish-bearing streams, marten have lost substantial habitat to timber harvest (G. Carlson, pers. comm., 1991).

Other large mammals attracted to the abundance of food in riparian areas include bobcats and grizzly bears. The riparian diet of bobcats comprises lagomorphs (rabbits), larger rodents such as mountain beaver, and carrion. Grizzly bears require moist habitats that are at an early seral stage (Hamilton and Archibald 1985). In some areas, grizzlies consume early seral plants such as cow parsnip, horsetails, grasses, and sedges. Bruce McLellan (pers. comm., 1991) found that bears in the Flathead area of British Columbia use riparian areas significantly more than other habitats in the spring and attributed this to the presence of preferred plant foods. The degree to which non-riparian early seral or hydric sites could meet these food needs is not known.

Ungulates use riparian habitat for water and food, as well as for shade and hiding cover. The high species richness of streamside vegetation in some riparian areas provides abundant forage for moose, elk, caribou, and deer. Furthermore, most riparian corridors offer a combination of gentle topography (allowing for easy travel) and diversity of vegetation for both cover and forage. Ungulates use these corridors as seasonal migration routes and calving or fawning grounds (Oakley et al. 1985; Raedeke et al. 1988; Simpson 1989). To maintain healthy populations of elk, riparian areas are required for supplying moisture and higher nutrient content of forage (Oakley et al. 1985; K. Brunt, pers. comm., 1991; F. Bunnell, pers. comm., 1991).

There is minimal information on the significance of riparian habitat to bats. This is probably because of the lack of general public interest in bats and also the difficulty of unbiased capture and study techniques (Cross 1988). Bat species inhabiting British Columbia and the United States Pacific Northwest are strictly insectivorous, and studies in Oregon and Washington indicate that several forest species feed up to 10 times more frequently above the water surface than within the forest (Cross 1988). Furthermore, insect prey was found to be far more abundant in riparian areas than in forested uplands. Roosting habitat comprises bark crevices and cavities, found in snags or live veteran trees, which Cross (1988) speculated may be prevalent within riparian areas as well. It is possible that the abundance and species diversity of bats is greatest within streamside habitats.

There is also a scarcity of information on the association between herpetofauna and riparian areas; this is probably linked again to the lack of public interest in, and lack of commercial value of, reptiles and amphibians (Bury and Corn 1988).

Bury (1988) acknowledged that several species require an aquatic environment for at least one life stage, or consume aquatic insects or other amphibians. For example, some amphibian species, including the northwest salamander (*Ambystoma gracile*) and rough-skinned newt (*Taricha granulosa*), require slow-moving water for breeding. The tailed frog (*Ascaphus truei*), Olympic salamander (*Rhyacotriton olumicus*), giant salamanders (*Dicamptodon* spp.), and lungless salamanders (*Plethodon* spp.) require wet, cool habitats and are often found in headwaters and small streams (Bury and Corn 1988). This amphibious group requires an aquatic environment for its larval stage, but becomes largely terrestrial as an adult.

The Washington Riparian Habitat Technical Committee (1985) listed 14 reptile and amphibian species thought to require riparian areas for at least some habitat needs, and a further 16 species thought to preferentially inhabit riparian areas over other habitats. Bury (1988) and Bury and Corn (1988) stressed that more research on habitat needs and protection techniques is required for reptile and amphibian species, particularly in headwater streams.

There is no doubt that riparian areas have many values for wildlife: diverse food, thermal and hiding cover, water, breeding and rearing habitat, travel corridors, and late fall or early winter sources of food. However, how these values are best maintained in a managed landscape, and how the riparian ecosystem functions in the broader landscape ecosystem to maintain wildlife and wildlife habitat, are uncertain.

Raedeke et al. (1988:127) summarized the difficulties of determining riparian habitat requirements of wildlife species:

> *Our current review, like most other reviews and compilations of data on wildlife use of riparian communities, has had to rely on information from studies that were generally not designed to measure the affinity of species for riparian habitat characteristics. General ecological requirements of a species were compared with the characteristics of riparian communities, and conclusions were based on the comparisons. This level of information is not fully adequate for the development of effective riparian wildlife management plans and should be used only to indicate which species should be considered for further study.*

2.4 Fish and Fish Habitats

Riparian areas can influence fish populations through at least four pathways:

1. **Physical and biological filtration**: buffering impacts of activities such as logging outside the riparian area by absorbing nutrients and silt produced by those activities;
2. **Amelioration**: reducing variability of physical or chemical characteristics such as water temperatures;
3. **Biological production**: providing the bulk of the aquatic food chain base through terrestrial organic matter and food organisms (insects), especially in small, shaded streams; and
4. **Structural protection and renewal**: stabilizing banks, minimizing erosion and stream sedimentation, and providing sources of logs, gravel, etc. that provide critical structural elements and variation in stream characteristics.

Riparian vegetation, and other structures such as fallen trees, act as a physical barrier to sediment in overland water flow. Vegetation also reduces the erosive potential of flood waters by slowing water velocity and providing support for binding of soils. Sediment in water can: increase turbidity, thereby affecting food searches; clog fish gills; and cover or fill in spawning beds, affecting oxygen availability (Swanson et al. 1982).

Biochemical transformations in riparian areas can decrease the toxicity of some chemicals (Green and Kauffman 1989). Nitrogen and phosphorus reduction seem to be important. These processes are largely a function of water regime; anaerobic conditions are often required. Wildfires in headwaters appear to cause significant changes in ion concentrations, particularly those of nitrate (Gluns and Toews 1989). Gregory (1989a) discussed the effects of streamside vegetation on nutrient dynamics.

Riparian vegetation provides shade that moderates temperature fluctuations in some streams and lakes. Most fish have a limited range of temperature tolerance (Washington Riparian Habitat Technical Committee 1985). Maintenance of cool water appears to be important, particularly to salmonid species. When water temperature increases, primary productivity usually increases (Meehan et al. 1977). To an extent, this can increase food availability, but it can also decrease oxygen availability.

Streamside vegetation and large organic debris (woody material > 10 cm diameter as defined by Froelich and Andrus [1989]) supply food and energy to the aquatic environment. Overhanging trees and shrubs provide fine organic matter as well as insects that fall into the water. Large organic debris may also be the home of insects, and it supplies a long-term source of particulate matter as it is decomposed (Swanson et al. 1982).

Large organic debris helps to stabilize banks through structural support. While logs sticking out into a stream may also redirect water and increase bank erosion on the opposite side, the overall effect of large organic debris seems to be stabilizing (Swanson et al. 1982). Large organic debris also forms hiding cover for fish, and creates pools that serve as resting, breeding, and rearing habitat. For example, during winter, coho salmon use debris jams and off-channel areas (Peterson 1982; Brown and McMahon 1987).

Stream banks are sources of gravel that, upon erosion, are transported downstream to form beds useful for spawning habitat. While excessive erosion is of course undesirable, some erosion is necessary to replace gravel that is transported during normal fluvial processes (Sutek Services Ltd. and Kellerhals Engineering Services Ltd. 1989).

The degree to which any of these factors is important varies by stream size and location in the landscape. In small headwater streams, out-of-stream sources of food and energy are more important than instream sources such as algae (Meehan et al. 1977; Cummins 1980). In larger streams (order of 3 and higher [Swanson et al. 1982]), this dependence shifts and instream sources become dominant.

The role of large organic debris changes as one progresses from headwaters to river floodplain. The characteristics of wood debris loading in streams in undisturbed watersheds is related to bankfull width and stream size (Robinson and Beschta 1989), which hints at the differing roles of large organic debris in streams of different sizes. Lower reaches of rivers are most likely not critical sources of gravel, whereas headwater streams are. Therefore, while all of the factors discussed here are important to fish and fish habitat, their importance varies. There has been a long history of research on these pathways, through approaches varying from studies of detailed behaviour of aquatic organisms to direct experimentation with whole ecosystems. Useful information for management has come from the whole ecosystem or watershed experimental studies, which have been done mainly in Oregon (e.g., Alsea), British Columbia (e.g., Carnation Creek, Keogh River, Salmon River), and Alaska. The main research focus has been on impacts of logging and related watershed disturbances, with less emphasis on other riparian disturbances such as highway construction.

Some other studies are listed here for further reference. Shepherd et al. (1986) described the physical characteristics of Pacific salmon spawning habitat and the biological traits of salmon stocks. Hawkins et al. (1983) examined densities of fish and amphibians and related riparian vegetation and stream attributes. Food and cover requirements of cutthroat trout are investigated by Wilzbach (1985). On a geological and geomorphologic level, Gregory et al. (1990) discussed the relationship between abundance and distribution of salmonids and basin landform characteristics and stream characteristics.

3 THE EFFECTS OF ACTIVITIES ON RIPARIAN AREAS

3.1 Perception of Impacts from Questionnaire Respondents

Although it was not within the mandate of this project to canvas the public for their perception of issues, the questionnaire did provide some insights on several issues. The response numbers given below do not represent a statistical sample; rather, they indicate the degree of concern amongst people who responded to the questionnaire.

The basic underlying issue, mentioned in some form by almost all respondents, was protection of riparian areas. Protection can be addressed from two perspectives: what needs to be protected, and what should it be protected from. In the open-ended question, about half of the respondents focused on the aspects that needed protection; the other half focused on the activities that riparian areas need to be protected from. It should be noted here that there is a real distinction between protecting riparian areas for human use versus protecting them for natural values. (Thus the percentages given below could be doubled to reflect the distribution of concerns within the "protection of" and "protection from" categories. The totals do not add to 100%, as some respondents mentioned more than one category.)

Protection was perceived as needed for fish and wildlife (25%) and biodiversity (25%). Water quality was the next most frequently mentioned concern (15%), with soils, recreation, and visual or aesthetic values mentioned by about 10% of respondents, each. A few respondents mentioned public access to riparian corridors, including access in urbanized areas, and the threat to traditional uses (e.g., harvest of medicinal plants).

The severity of impacts on specified values was perceived to be high for biodiversity, fish, wildlife, water quality, and to a slightly lesser extent, recreation (Figure 1). Perhaps even more notable was the concern for soils and erosion. Soils were not included in the list for evaluation of severity, and almost no one added soil as "other" in the quantitative question. It is not clear whether the expressed concern for protection of soils is based on an understanding of their role in the renewal capability of ecosystems, or is stimulated by the visibility of erosion.

The other perspective on protection, namely protection from human activities, was emphasized by about half of the respondents in the open-ended question on issues. Protection from logging was the concern of about 33% of the respondents, hydro developments 15%, other developments 20%, and grazing, judging by the language used, of a passionately involved group from the southern interior of the province (10%). The tone of these concerns is summarized by a respondent: "The effects of logging or agriculture can never be completely mitigated. Riparian land is fragmented, breaking travel corridors for wildlife, allowing pollution from livestock, and removing the buffer for agricultural runoff."

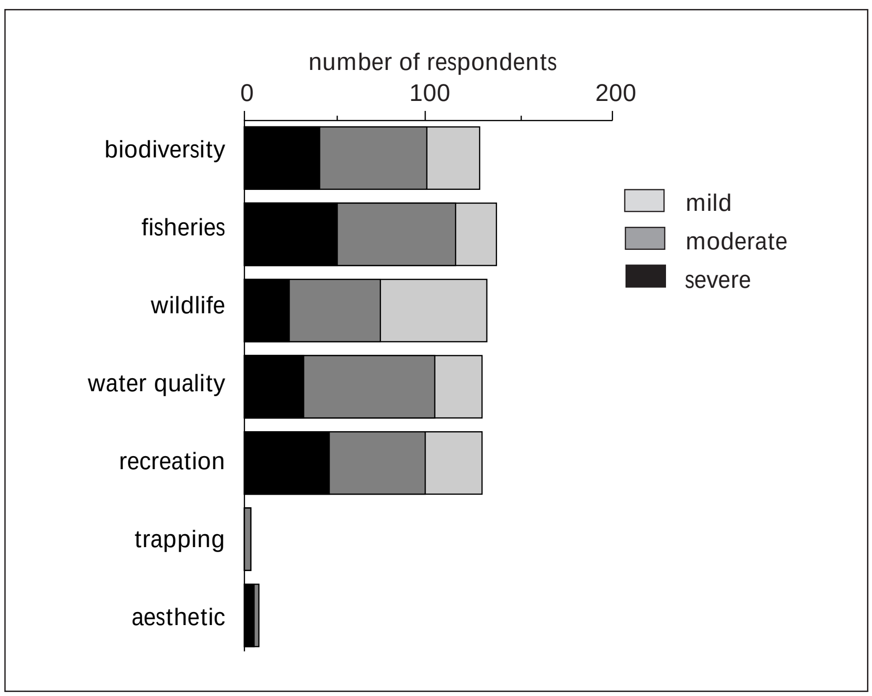

FIGURE 1 *Perceived severity of impacts on values.*

The impact of hydropower and urban development on riparian areas was evaluated as the most severe, with agriculture, forestry, grazing, and transportation following in that order (Figure 2). The wording of the question did not clearly distinguish between local impacts and province-wide impact. Those respondents who worried about the distinction chose the local perspective, describing how much of the riparian area is affected. Assuming that most respondents answered in a provincial context, it is not surprising that the level of concern about forestry is relatively higher in its severity compared to hydro or urban developments: forestry is far more widely distributed than the other two. What is somewhat surprising is that concern about development (urban, recreational, industrial) in riparian areas was expressed by twice as many people as concern for agriculture, grazing, mining, or transportation corridors, although the latter are more widespread. Perhaps developments occur in locations where more conflict is likely to occur.

3.2 Effects of Forestry Activities

Most riparian sites, because of their topographic position, are productive for timber as they are less likely to be short of water and nutrients than other sites further up the slope. One of the factors that make riparian areas particularly attractive for timber harvest is their accessibility. Streamside areas frequently provide a topographically favourable location for road building.

Several researchers focus on various aspects of timber production in riparian areas, both in coastal regions and in the interior. Most papers report on the effects of various factors on stand composition, and in some cases on yield (Smith et al. 1986). The factors investigated were soil composition, terrain characteristics, and climate (Agee 1988), logging and silviculture practices (Andrus and Froehlich 1988), and fire (Agee 1988; Andrus and Froehlich 1988). Beaudry et al. (1990) and McLennan (1990) developed classification schemes for flooding risk and erosion-deposition rates in floodplains. They used these classifications as a basis for silvicultural prescriptions.

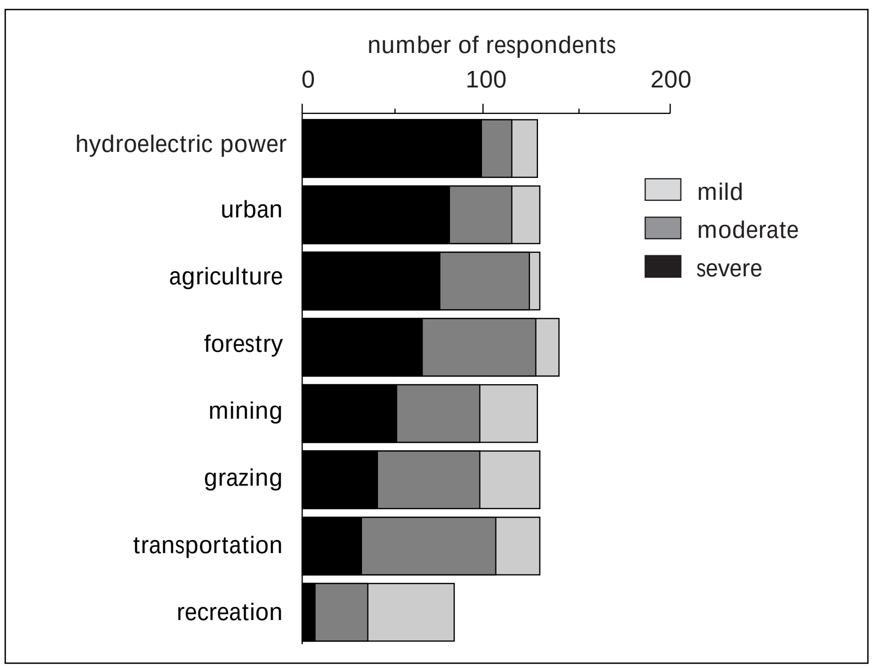

FIGURE 2 *Perceived impact of activities on riparian areas.*

3.2.1 Riparian areas impacts Although forestry practices are perceived as one of the major activities in British Columbia influencing riparian areas, only a few scientific papers address the nature of ecosystem-level impacts. There is a general review of interactions between logging practices and ecosystems attributes (Brown 1974), and a few studies consider the effects of logging activities and silviculture practices on the riparian zone. These studies investigate impacts through changes in soil characteristics and vegetation composition (Bacon and McConnell 1989; Bacon et al. 1989; Debano and Schmidt 1989a; Green and Kauffman 1989; Gregory 1989b), water availability (Bilby 1988; Debano and Schmidt 1989b), and nutrient exchange (Bilby 1988). Research is currently being conducted on the ecosystem impacts of forestry activities (Hibbs et al. 1990a).

3.2.2 Biodiversity impacts As discussed in Section 3.1, riparian areas are considered particularly significant for the maintenance of biodiversity. The term "biodiversity" has captured the consciousness of the public and resource managers relatively recently, and consequently the understanding of it is somewhat vague, and the methodologies for measuring and studying it are in a developmental stage. Some of the distinctions that need to be clarified are the differences between various types of diversity (within a particular site or area, or a pattern over a larger landscape), the variation of diversity over time as a reflection of successional and hydrogeologic changes, and the variation of social values attributed to different aspects of biodiversity.

Some research on the biodiversity of riparian areas has been conducted, particularly with respect to impacts on a diversity of specific taxonomic groups. For example, Cross (1985) reported that timber harvest decreased the diversity of small mammal communities in southwest Oregon. In this situation the use of buffer strips maintained the diversity of small mammals.

3.2.3 Terrestrial wildlife habitat impacts Other than the effectiveness of buffer strips in maintaining particular wildlife species, few studies address the impacts of forest practices on wildlife habitat in riparian areas. Logging was found to have negative impacts, persisting for decades, on amphibian species (Bury and Corn 1988). Buffer strips were strongly recommended for protecting habitat by preventing erosion and sedimentation.

Part of the reason for the paucity of habitat impact studies is that habitat needs for many species are not fully understood. As Best et al. (1979) pointed out, structural features of the vegetation, plant-species composition, availability of food resources, and microclimate conditions may be important in delimiting habitat preferences for various wildlife species. Extensive field sampling would be required first to determine these preferences and their significance to the animals, and second to clarify the impact of various forestry practices on these attributes. Field studies on wildlife habitat needs are further complicated by the enormous variation among seasons, site locations, and species or subspecies.

Riparian habitat requirements may be different for the same or closely related species, depending on coastal or interior location. Generally, riparian areas in the southern interior areas of British Columbia sharply contrast with the surrounding arid or semi-arid upland environment. The presence of water and trees in these regions is a greater attraction to wildlife than on the coast, where there is far less contrast between the riparian zone and the adjacent forest. Consequently, wildlife in the interior regions may be far more dependent on riparian areas and require greater habitat conservation efforts than on the coast (Cross 1985; West 1988). For example, mule deer on the Thompson Plateau in British Columbia require low-elevation riparian areas in seasons other than winter (Simpson 1989), while black-tailed deer, a closely related species, do not show a significant dependence on riparian areas on Vancouver Island (F. Bunnell, pers. comm., 1991).

A different bird species composition was found in each of four different riparian sites within the same biogeoclimatic zone (Morgan and Wetmore 1986). Each site had distinct vegetation creating different bird habitat. One factor that may contribute to this variation is the successional stage of the riparian forest. The authors of the above study advocated site-specific analyses and management to maintain avian diversity.

Another source of variability in habitat requirements is seasonality. Seasonal differences in riparian habitat requirements appear to exist for certain species. For example, riparian areas are more important to bald eagles in winter along salmon-bearing streams because they feed on the salmon carcasses (Knight 1988). Therefore, short-term, seasonal studies will not elucidate full riparian habitat requirements or subsequent effective management.

Even though the relationship between species and habitat is poorly understood, mitigation of impacts may be achieved through some generalized guidelines that lead to use of buffer strips, retention of snags, assurance that a conifer component is left, and preservation of adjacent habitat types.

3.2.4 Fish and fish habitat impacts The long-standing concern for the impacts of logging on fish habitat in the Pacific Northwest has its roots in the existence of a highly visible and publicly recognized resource — the salmonid fishery. Not only are there commercial and sports interests, but there is also a reasonably powerful government agency (Department of Fisheries and Oceans) with substantial funding for research and management. It is not too surprising that more research has been conducted into the effects of logging practices on fish habitat than on the habitats of other species in riparian areas.

A general review of forestry impacts on fish habitat can be found in Hartman (1982). Most studies specify the physical, chemical, or biological pathways of the impact, but a few also describe population-level effects. For example, in the Carnation Creek study, Hartman (1987) reported that logging activities affect coho and chum populations making them fluctuate more than they did before logging. Logging was also found to affect the timing of life history events of juvenile coho in another study done in Carnation Creek by Hartman et al. (1982) and Holtby (1987a). It was predicted that logging would result in 30 years of declining abundance of the adult population, which would only recover after 100 years.

Population-level impacts are also reported for aquatic invertebrates. Hartman (1982) found that logging induced long-term changes in aquatic invertebrate fauna. Falling and skidding were found to have some effect on aquatic invertebrate drift and density (Slaney et al. 1977a). The impacts on invertebrates are not necessarily deleterious. For example, removal of adjacent forest canopy increased primary and secondary stream production (Weber 1981), and streams in clearcut areas had greater densities and biomass of drifting invertebrates (Murphy et al. 1981).

One of the major impacts on fish is through sediment produced by forestry activities. Increased sedimentation has been shown to reduce egg survival in many studies (Slaney et al. 1977b; Tripp and Poulin 1987), and may lead directly to respiratory stress (Langer 1974). Sedimentation also affects the food supply of fish by reducing the density of aquatic invertebrates (Langer 1974) and the distribution of macroinvertebrates (Culp 1987). Finally, increased sedimentation and bedload movement can change fish habitat by choking aquatic vegetation (Langer 1974).

The relationship between sediment movement and forestry practices has been investigated in numerous studies. For example, logging encourages significant bank erosion, accumulation of coarse sediment wedges, and a hundredfold increase in sediment transport in the Queen Charlotte ranges (Roberts and Church 1986). Scrivener (1987) demonstrated that logging induced increases of sand and gravel in the surface layers of the streambed that persist for a few years. Road construction, which is an integral part of many forestry operations, is also responsible for increased sediment levels in water that persist for several years (Reid and Dunne 1984; Brownlee et al. 1988). Furthermore, road construction creates surface runoff, increases streamflow in adjacent tributaries, reduces peak groundwater levels, and causes landslides (Hetherington 1987).

In the Queen Charlotte Islands, studies have indicated that landslides can contribute sudden and often very large pulses of sediment input to streams. Logging has been shown to accelerate the frequency of landslides by a factor of 34 times, vegetation removal by 31 times, and road construction by 87 times (Rood 1984). Yarding and inadequate road drainage particularly increase the frequency of landslides (Krag et al. 1987; Sauder and Wellburn 1987; Sauder et al. 1987), and clearcutting induces landslides with sedimentation rates that far exceed the transport capacity of the stream (Perkins 1989).

As well as changes in stream sediment, forestry practices can significantly affect stream morphology. Logging increases riffle heights, alters pool depths, reduces pool-to-pool spacings and pool areas, reduces the available rearing habitat, shifts organic debris size distribution, reduces the number of cutbanks, and decreases channel stability, habitat diversity, and quality (Hogan 1986). Logging debris tends to move into channels during floods, release sediments, wipe out stable accumulations, and increase channel instability (Toews and Moore 1982; Bryant 1983).

Impacts on fish through physical stream processes are dramatic, but more subtle changes such as temperature, light availability, and water chemistry are also extremely important. Of these, temperature effects have been most thoroughly documented and publicized. In general, logging increases stream temperature and diurnal temperature fluctuations (Narver 1972; Slaney et al. 1977a, 1977b; Brownlee et al. 1988). The increased temperature can be beneficial to fish production in northern and high-elevation environments, but can be detrimental if water temperatures exceed fish tolerance limits. Holtby (1987b) found that the increase in stream temperature was in proportion to the length of stream bank logged. Higher stream temperatures affect salmonids through faster egg development, earlier fry emergence, higher virulence of diseases, lower carbon dioxide concentrations, and changes in juvenile behaviour (Slaney 1974).

Reduced light penetration in the stream due to increased water turbidity can also affect fish populations by reducing algal biomass and primary production (Parkinson et al. 1977). Studies on impacts to water chemistry are few, and the results do not show a pattern. Athman and McCammon (1989) found that logging had no significant impact on water quality and flow responses. Studies by Chatwin (1989) and Kimmins (1974) suggest that the logging method has a significant effect on water chemistry and also has an impact on other stream characteristics.

The role of large organic debris in streams has become well publicized as a result of several recent studies (Bilby 1989; Thomson 1991) and the inclusion of this concern in training programs and various fish and forestry guidelines. Large logs left in streams help retain salmon carcasses, which benefit fish and predators (Cederholm and Peterson 1985), and increase coho overwintering habitat by providing more pools (Tripp 1986). Logging of natural stands and their replacement by plantation forests will dramatically change the future amount and distribution of large organic debris in streams.

While the various studies listed above have emphasized negative effects of deforestation on fish populations, there are a number of hints in the literature that there may be substantial opportunities for co-operation among watershed users to improve aquatic productivity. For instance, coho salmon smolt production has actually increased in Carnation Creek following experimental logging, apparently due to increased fry-to-smolt stage survival associated with increased temperatures (and growth), as well as to changes in aquatic habitat structure. Stream fertilization with chemicals (to simulate logging) is being studied experimentally by the B.C. Ministry of Environment's Fish and Wildlife Branch, with very encouraging results (P. Slaney, pers. comm., 1991). Debris and other structural changes in stream channels associated with logging may actually improve fish habitat (cover, resting areas) if managed with reasonable care. There are enough examples along these lines to indicate that a major focus of integrated riparian management, and of future research to test management options, should not be on protective standards, but rather on means to establish "win-win" policies where habitat disturbances are turned to advantage rather than minimized.

3.2.5 Mitigation measures Numerous studies have been conducted on ways to minimize impacts on streams, and on methods to rehabilitate their physical attributes once impacts have occurred.

There is extensive research in the fisheries literature on the importance of buffer strips in maintaining shading of streams and preventing sedimentation to conserve spawning habitat. Buffer strips help protect channel forms (Powell 1987), but tend to be unstable (Froehlich and Andrus 1989; Hibbs 1989). The use of certain types of trees for increasing bank stability and improving fish habitat complexity is also being tested (Sedell et al. 1990).

Certain logging practices can minimize disturbances to stream channels. These include the appropriate scheduling of operations, using extended rotations, and ensuring that there is an adequate riparian management zone.

Harvesting techniques to minimize damage include hoechucking, helicopter logging, and machine-free buffers. Carr (1985) provided a review of techniques to minimize soil erosion.

Salmon rearing areas can be rehabilitated by placing boulders, log sills, and gabions in them and constructing side channels (Bustard 1984; Klassen 1984). Gabions, log dikes, and log drops can also be used for rehabilitating silt-polluted streams (Brusven et al. 1974), but would only be useful in selected situations (e.g., where flooding would not wash them out).

Where fish populations have been adversely affected, and the habitat has been reconstructed or has recovered, restocking can be considered. Coho and cutthroat trout stocking strategies have been investigated for streams in clearcut and old-growth areas (Tripp and McCart 1983; Bilby and Bisson 1987). Finally, neither habitat restoration nor restocking are effective if the fish resource is overexploited by overfishing. Methods for protection from exploitation are discussed by Stuber (1985).

3.3 Effects of Hydroelectric Activities

There are essentially two kinds of hydroelectric developments: large and small. *Large hydro* refers to projects that generate 20 MW or more of power; *small hydro* refers to projects that generate less than that amount (B.C. Ministry of Energy, Mines and Petroleum Resources 1982).

In the past, research has focused mainly on large hydro developments. Reasons for this focus are environmental and policy oriented. Small hydro, in comparison to large hydro, has localized or small environmental impacts. Often, it does not stop or divert a stream, but pipes portions of the stream through a turbine. The banks of a stream are likely only nominally affected. The second reason for limited research on small hydro is that, until recently, it was not considered as a viable alternative to large hydro development. With growing provincial interest in small hydro development, research into its effects should also be undertaken.

The biological effects of large hydro developments are many and complex, both above and below the dam, and have given rise to much concern in Canada. Much of the concern has focused on the aquatic systems, particularly various fish populations (Baxter and Glaude 1980), but some consideration has also been given to impacts on species in the riparian area. For a general overview of the environmental effects of dams, see Baxter and Glaude (1980).

3.3.1 Impoundment impacts Inundation through the creation of a reservoir does more than simply convert a given area of terrestrial habitat into a lake with a new riparian edge. The new shoreline riparian habitat may take a long time to develop, and it may be limited by the underlying geomorphology at the new water level. Furthermore, water level fluctuations are regulated according to drawdown patterns which generally do not mimic natural seasonal patterns in lakes. The result is that the reservoir may be surrounded by a wide, virtually barren zone. This area is not only ecologically unproductive, but is also an aesthetic problem and may be the source of large amounts of windblown dust.

Many water quality changes may also take place, both in the reservoir and downstream (Kelly 1978). Nutrients from inundated soils and vegetation may be added, which may lead to an increase in phytoplankton and attached algae, as well as a release of toxic substances such as mercury.

3.3.2 Downstream impacts The most obvious downstream impact of a hydro development is a dramatic change in the flow pattern. Generally there is an increase in daily variation, and a decrease in annual variation. Regulation often initiates a gradual reduction in channel size and capacity (Kellerhals 1982). This may lead to large and rapid changes in the water level downstream, which can be very destructive to aquatic and riparian organisms (Fisher and LaVoy 1972; Ward 1976). Further consequences of these changes in flow may include an increase in the downstream flux of dissolved materials, a decrease in the flux of particulate materials, increased biomass, and reduced biodiversity (Stanford and Ward 1992). Ecosystems along streams are largely maintained in their normal state by periodic flooding, and if the flood regime is changed, the ecosystems will be affected.

The magnitude of the impact depends on the flow regulation scheme being used. Rivers regulated by stable surface releases from upstream storage reservoirs (e.g., no short-term flow fluctuations) may manifest conditions that occur naturally in lake outlet streams. Even for such rivers, however, year-to-year operational changes in regulation schemes may introduce so much flow and temperature variability into the regulated river ecosystem that the natural resilience of the riparian ecosystem is exceeded.

Concerns over bank stability and slope morphology also include the effects of ice formation and breakup on northern rivers. There is some evidence that the increased winter flows resulting from flow regulation increase the severity of spring breakup of ice jams. This leads to the flooding of some terrace levels that would otherwise have been well beyond the reach of the river (Kellerhals 1982). A more in-depth study of river ice processes in northern Alberta was done by Kellerhals and Church (1980) and the information found in this report can be used as a reference for carrying out research on British Columbia's rivers.

3.3.3 Mitigation measures BC Hydro has begun addressing the implications of changes in habitat through a program called the "Wildlife Compensation Package." The program was established to compensate for the loss of land and wildlife habitat caused by the creation of reservoirs. It has been applied to the Williston Lake Reservoir and is presently being applied to the lake behind Mica Dam. For Williston Lake Reservoir, the interest from a $10 million trust fund is earmarked for funding habitat recovery programs and research initiatives administered by both BC Hydro and the B.C. Ministry of Environment.

Mitigation of the issues associated with drawdown are reviewed by Gill (1977). BC Hydro is in the process of researching mitigation measures, particularly to reduce the airborne dust problems associated with drawdown around the Arrow Lakes near Revelstoke. Stabilization of the drawdown zone through the planting of species that tolerate alternating drought and flood may also improve the area for some wildlife species.

Mitigation of impacts on salmonids can be achieved through appropriate flow regulation. Low summer flows may be compensated for by releases of water stored for this purpose in headwater lakes. This approach is being researched on the Keogh reservoir on Vancouver Island.

Even though mitigation activities are under way to alleviate the impacts of recent large-scale hydroelectric developments, these by no means address the large environmental impacts that have occurred in riparian areas of past hydroelectric developments such as the W.A.C. Bennett Dam on the Peace River–Athabasca Delta. In this instance, damming has resulted in the loss of up to 25% of the original waterfowl habitat.

Further research should be undertaken to address opportunities to encourage the reconstruction or improvement of riparian areas in past large-scale hydroelectric developments. As well, the cumulative impacts of proposed small hydroelectric developments must also be considered if the provincial long-term plan to encourage independent power producers proceeds.

3.4 Effects of Agriculture

Agriculture has an impact on riparian areas through soil management practices, vegetation clearance for crops, channelization of streams, water removal for irrigation, and fertilizer application (Conine et al. 1979; Hoar and Erwin 1985; Roseboom and Russell 1985; Delong et al. 1989). Agricultural practices can decrease water quality, streamside vegetation, wildlife diversity, and fish populations, and increase erosion from adjacent agricultural lands.

Few studies exist on the specific impacts of agriculture on riparian areas and their component wildlife and fish populations in British Columbia. The existing literature is primarily from the United States (the Midwest and the Southwest) where agriculture has completely changed most riparian areas (Conine et al. 1979; Hoar and Erwin 1985; Kingsley 1985; Nabhan 1985). Agricultural impacts are likely most significant in arid and semi-arid areas, such as the southern interior of British Columbia, where agriculture is a major industry and riparian areas are particularly important to wildlife.

Agriculture has been documented as one of the major land use practices responsible for non-point source pollution (Delong et al. 1989). Runoff from fields transports fertilizer and pesticide residues and nutrients into the stream. Pesticides have obvious deleterious impacts on the aquatic systems they enter. The use of chemical fertilizers and animal manure increases the nutrient loadings of nitrogen and phosphorus in many streams. Nitrogen, which is very mobile, can rapidly reach critical levels for aquatic organisms. Phosphorus, which is less soluble and less mobile than nitrogen, can lead to algal blooms and phytoplankton growth, which in turn can result in oxygen depletion and fish mortality (Bird and Rapport 1986).

The amount of pollution depends on the soil and surficial material conditions and on agricultural practices. Soil conservation efforts to reduce erosion and consequent sediment loading of streams are reported in many studies from a water quality and agriculture perspective. However, few studies document the direct impacts of soil conservation on riparian areas.

Changes to riparian vegetation through agricultural practices significantly reduce wildlife habitat and hence biodiversity (Kingsley 1985). Assemblages of bird communities were reported to be completely altered when a riparian site was converted to agriculture (Conine et al. 1979).

Removal of streamside vegetation and channelization related to agricultural practices also increases sedimentation of stream channels (Nabhan 1985; Roseboom and Russell 1985). As well, these practices affect fish populations through instream habitat degradation. Good management of streamside vegetation can be used to mitigate the impacts of non-point source pollution from agricultural lands. Streamside vegetation filters nutrients entering the stream (Lowrance and Shirmohammadi 1985). These authors have developed a model to manage riparian areas for nutrient and chemical transport from agricultural upland areas. The degree of non-point source pollution control depends on the interaction between the chemical load transported from the uplands and the hydrologic and nutrient cycling processes in the streamside zone.

3.4.1 Livestock ranching Riparian areas attract livestock for some of the same reasons they attract wildlife: free-running water; higher quality, moister, more palatable, and more diverse forage; shade in the summer and thermal cover in winter; and gentle topography for ease of movement (Ames 1977; Goodman et al. 1989; Green and Kauffman 1989).

Grazing by cattle results in several effects on riparian areas (Green and Kauffman 1989):

- direct vegetation damage caused by browsing or trampling;
- changes in plant communities through selective browsing;
- soil compaction and disturbance that increases erosion and decreases water availability to plants;
- changes to fluvial processes, which lower water tables or decrease available sites for invasion of woody species; and
- changes to aquatic ecosystems through sedimentation and fluvial processes, as well as changes to water quality due to fecal inputs.

The impact of cattle on riparian habitat depends on the extent of grazing and the type of vegetation present. Some vegetation communities resist trampling and grazing more than others (Buckhouse and Gifford 1976; Bryant 1985; Minshall and Platts 1989). For example, plant communities characterized by *Carex* spp. are able to resist the negative effects of grazing and maintain a greater stream bank stability (Platts and Nelson 1989).

Alteration of plant communities is a common problem associated with cattle grazing in riparian areas. Grazing affects the species composition so that it becomes less productive and palatable for both livestock and wild herbivores (Behnke and Raleigh 1979). Plant communities are also affected by the soil compaction caused by livestock. Soil compaction, and resultant flooding, can lower the water table so that moisture-dependent plants are replaced by xeric species.

Prolonged heavy grazing in riparian areas can cause erosion and its attendant set of impacts. Bank stability is reduced and erosion is accelerated when the root structure of streamside plants deteriorates and overhanging stream banks bear the weight of cattle (Marlow and Pogacnik 1985; Minshall and Platts 1989). Compaction and erosion also cause soil runoff, creating increased sedimentation of the stream (Minshall and Platts 1989).

Grazing can also have dramatic effects on stream morphology, which decrease its resistance to severe flood disturbance. Minshall and Platts (1989) report that after grazing was allowed, flooding increased stream width and changed the meander pattern and stream depth. These alterations further increased stream velocity, created debris torrents that completely devastated fish habitat, and further accelerated erosion by eliminating existing stream banks.

Water quality is also affected by fecal material introduced into the riparian areas through cattle concentrations in these areas. This results in increased coliform counts, as well as increased nutrient input to streams (Buckhouse and Gifford 1976). Acceptable stocking densities vary from area to area because the manure absorption capacity varies from soil to soil.

Although the effects of grazing on wildlife have not been documented in most of British Columbia, habitat degradation is known to affect wildlife populations and diversity. If the structural complexity of the streamside vegetation is reduced or eliminated, the number of available niches will be similarly affected.

Grazing impacts on wildlife are most likely to occur in arid and semi-arid environments. Not only are riparian areas particularly attractive to both wildlife and cattle in relatively dry climates, but this is also where rangelands in British Columbia typically occur. In most cases riparian zones are grazed more heavily than upland areas (Minshall and Platts 1989). Although riparian areas occupy only 1–2% of the interior northwestern United States they account for 81% of the forage removed by livestock (Green and Kauffman 1989). Riparian areas traversing the extensive rangeland in British Columbia's dry interior will undoubtedly be used disproportionately by cattle unless they are physically excluded.

3.5 Effects of Mining

Impacts of mining have been primarily investigated in terms of water quality, stream hydrology, and effects on the aquatic ecosystem. Impacts on the riparian ecosystem must be interpreted through an understanding of the linkages between physical and chemical changes caused by the mining activity. These pathways of effect have been studied more explicitly in the context of forestry activities.

The traditional view of most mining impacts is that they are largely local in nature (Ripley et al. 1978). In recognition of the variety of mining activities, these authors have prepared tables that compare air, water, and habitat impacts from different activities. The most significant impact was considered to be loss of land due to coal mining. More recent work, however, recognizes a broader range of impacts (Marshall 1982; Halverson and Sidle 1992), which can be summarized as follows:

- The exploration phase of precious metal mining operations can cause considerable disturbance because of the vast network of roads required. Since the exploration phase requires more intensive road networks than the extraction phase, the effects of these temporary roads must be considered in a cumulative effects analysis.
- Surface mining creates the greatest environmental disturbance of all because of the vast land area disturbed, the volume of spoil material generated, and the changes in the properties of the disturbed matrix.
- Two general types of water chemistry changes can be identified. The first case involves chemistry changes directly attributable to current or recent mines. The second situation involves acid drainage from old or abandoned mines. Mine drainage often appears after mining and even reclamation are completed.

Impacts obviously vary with type, extent, location, and duration of mining activities. Hans Schreier (pers. comm., 1991) suggested that in British Columbia the major types of mining that may cause environmental concerns are:

1. *Coal Strip Mining* Most coal mines in British Columbia have relatively low sulphur content, hence the generation of acid drainage is limited. The

large quantities of surface materials disturbed by strip mining affect groundwater regimes and generate sediment. Changes in the extent and frequency of flooding, greater fluctuation in groundwater levels, and sedimentation have all been identified as key problems associated with coal strip mining in British Columbia (Schreier 1977).

2. *Placer Mining* Dredging, extraction, and hydraulic mining are the common practices in placer mining, and the most significant impacts are through decreases in water quality and increases in sediment loadings. Most of the placer mining activity in British Columbia occurs in the Prince George, Quesnel, and Kamloops districts. Some 200 placer mines are currently active in the Barkerville area and sediment containment is critical in these operations (Levson et al. 1990). Major operators are required to hold process water in ponds for settling and clarification. Some placer mining activities do not require fresh water (closed systems), so in effect have little impact on water quality. Parts of the province are zoned for no placer mining activity.

   The historic legacy of using mercury in extracting gold could pose considerable environmental problems at sites where contaminated sediments are buried. Unfortunately there is virtually no information available on the location and possible extent of such a hazard in most of the gold mining areas of British Columbia.

3. *Gravel Extraction* Gravel extraction is the most important mining activity in British Columbia by amount extracted (Hora 1985). In 1985, more than 230 gravel pits were active in British Columbia. The extraction and washing of aggregates can produce considerable sedimentation. Where sand and gravel sources are scarce, direct streambed extraction is often practised. This can seriously alter the stream hydrology and thus affect riparian areas.

4. *Metal Extraction* The major issue related to metal extraction is chemical pollution including acid drainage, metal leaching, cyanide release, and nutrient loading. Of these, acid drainage has been the most extensively studied.

   About 30% of all currently active mines in British Columbia produce acid drainage (Errington and Ferguson 1987). The timing and extent of acid release from active and abandoned tailings is uncertain, but it is believed that release can occur in 1–11 years depending on the pyrite and calcite content of the tailings, the local moisture regime, and the level of *Biobacillus* spp.

   Although the issue of acid drainage has caught the attention of the public and the government, some researchers (Branson and Butch 1971) believe that the most damaging pollutant from a strip mine is not acid drainage, but the high siltation and turbidity originating from erosion of the spoil banks. Collier et al. (1970) showed that a partially strip-mined watershed in Kentucky had an erosion rate of 5.9 tons per acre compared to 0.7 tons per acre for an unmined site.

Mining can also directly affect stream flow through water withdrawals, the complete blocking and redirection of stream flow, or even changing stream direction (Martin and Platts 1981). This is perhaps the most fundamental and irrevocable impact that could occur to a riparian ecosystem.

3.6 Effects of Transportation Corridors

Research on the environmental impacts of transportation corridors has been conducted primarily from an engineering and fisheries perspective; most of the studies investigate the impacts of construction and right-of-way exposure on fish habitat. Very few studies are concerned with the impacts of highways, railways, and powerline corridors on riparian areas or biodiversity. However, a series of studies has been done on the number of roadkills that have occurred as a result of the TransCanada Highway cutting through river valley bottom winter range in Banff and surrounding areas.

Removal of streamside vegetation for road construction or right-of-way exposure is reported to increase erosion and instream sedimentation, which alters stream morphology and degrades fish habitat (Day and Carvell 1979; Patten 1989). Stream bank stability is decreased, thereby accelerating these processes. Furthermore, the elimination of streamside vegetation removes the detrital food source and increases the water temperature for small- and medium-sized streams. During construction, the removal of large organic debris creates further changes in channel morphology and increases channel instability.

A study of bald eagle nesting success shows some of the effects of transportation corridors on wildlife (Knight 1988). In Oregon, nesting success and productivity were found to be reduced for bald eagles with nest sites located near main highways.

3.6.1 Mitigation measures Recently improved engineering practices and habitat rehabilitation techniques have reduced the severity of impacts on fish habitat (M.J. Miles, pers. comm., 1991). Practices to minimize sediment production and conserve the riparian corridor include maintenance of buffer strips, the use of rip-rap, and various slope stabilization methods (Day and Carvell 1979). Although these techniques were used according to environmental impact study recommendations in the completion of the Coquihalla Highway Project in British Columbia, the need for further research was realized during the construction of the highway (M.J. Miles, pers. comm., 1991).

3.7 Effects of Recreational Activities

Water provides a direct substrate for activities such as swimming, fishing, and boating; it has aesthetic appeal; and in more remote areas it can be consumed. People in inland areas use the riparian area for access to water and recreation (Brown 1979; Field et al. 1985; Hoover et al. 1985). Various recreational activities are associated with riparian areas and the adjacent water, including fishing, hunting, hiking, picnicking, bicycling, boating, river rafting, wildlife viewing, canoeing, and camping.

Aesthetics constitute an important aspect of the recreational experience, and the literature lists "pristine wilderness," "beautiful landscapes," "mountains," and "scenery" as descriptors imparting the high recreational value of riparian areas. Additional features that attract people to particular riparian areas include proximity to human population centres, riverbank accessibility, the "power" of the river (presence of rapids within a river), as well as geological, historic, cultural, and archaeological characteristics.

A few studies have examined the impacts of recreational use on riparian areas as a whole. Schmidley and Ditton (1979) reported that damage to vegetation is concentrated in areas of high congregation, such as picnic tables and toilet facilities. These authors reported recreational hunting and trapping to be a greater threat to wildlife than degradation of riparian habitat. Aitchison (1977) found a decrease in bird species richness in an Arizona campground after it was opened for camping, while the control area, where there was no camping, exhibited a concomitant increase in species richness. Knight (1988) reported that bald eagles abandoned areas of human activity because of the disturbance. Activities such as boating, driving, and walking flushed these raptors from perches and interrupt feeding and roosting. Finally, camping may affect water quality by increasing levels of phosphates, nitrates, and sulphates (Rinne 1985).

Outdoor recreationists focus their demands disproportionately on riparian areas (Schmidley and Ditton 1979; Behrens-Tepper et al. 1985; Chilman et al. 1985). Recreational use is expected to increase, with preferences for areas showing few signs of other humans and no grazing livestock (Hoover et al. 1985). Thus, use is likely to spread to previously untrammelled areas. Recreation management must retain the ecological integrity of riparian areas to maintain the recreational, as well as fish and wildlife, value of an area.

The literature linking recreation and riparian areas focuses on the features of riparian areas that are important to recreationists and identifies the recreational demands on rivers, lakes, and streams. Impacts of recreation activities on riparian areas, however, are not well documented.

Nevertheless, a program that partially addresses recreation concerns, including the impact of recreation activities on riparian areas, was started by the British Columbia government more than 5 years ago. The Recreation Corridor Program identifies areas within three degrees of use categories. Once an area has been identified, a lead agency is responsible for a management plan that takes into account heritage, recreational, tourism, scientific, and other resource values. Although well intentioned, this program has no budget for continued operation.

3.8 Effects of Urban Development

Most research on the relationship between urban and riparian areas is concerned with managing riparian zones in large metropolitan regions rather than with determining the impact of urbanization on riparian habitat. Leedy et al. (1981) have categorized the types of disturbances that generally occur in urban areas:

1. *Nutrients* Increased nutrient loading comes from sewage treatment plants, inefficient septic tanks located near water bodies, and fertilizers used on lawns, gardens, and golf courses.
2. *Toxic Materials* Toxic materials include domestic and industrial wastes, salt, de-icing compounds, and pesticides. Not only do they affect aquatic organisms, they also may appear elsewhere in the food chain through bioaccumulation.
3. *Water Flow* Channelization and damming cause a reduction in species diversity because fewer niches are available. Sometimes actual stream length is reduced as stream curves are removed and the stream is straightened out.
4. *Water Temperature* Coolant water from industrial processes and thermal power plants encourages the growth of species adapted to warm water. This frequently displaces native species and sometimes creates nuisance

effects.

5. *Water Clarity* In turbid waters, sunlight penetration, and hence photosynthesis, are reduced, resulting in less primary production, which in turn results in less overall production.
6. *Draining of Wetlands* Draining of wetlands or inland lakeshores and the building of houses on or near the shoreline severely reduce wetland habitat.

An important source of dissolved chemicals and suspended sediments in urban areas is stormwater runoff. Current treatment facilities can rarely cope with storm events. Little systematic monitoring of urban stormwater runoff is done and, according to Ferguson and Hall (1979), Swain (1982), and Lawson et al. (1985), such waters contain pervasive pollutants such as PCBS, pesticides, chlorinated hydrocarbons, and trace metals. Aquatic invertebrates have been adversely affected when sewer overflow occurs during storm events (Hall and Bindra 1979; Hall and Anderson 1988).

Very little research addresses the cumulative effects of urban areas on a watershed. Management planning in a few situations has taken account of cumulative impacts. The State of Washington is trying to address the concern of cumulative effects through the implementation of the *Management Growth Act* (Washington State 1990). Each of the 39 participating counties was required by law to establish a growth management plan for its area by September 1991. The county determines, and then is bound to, the resource activity (agriculture, forestry, or mining) and critical land use option (wetlands, geologically hazardous area, frequently flooded area, fish and wildlife conservation area, and aquifer recharge areas) that it has chosen.

3.8.1 Mitigation measures Various mitigation measures can be undertaken to protect riparian areas from urban development. These range from outright protection of the land through a buffer zone, where no development activity can take place, through to regulating the amount and type of runoff that may enter water bodies. Determination of appropriate actions depends a great deal on the local municipal body. Community watershed management guidelines and land development guidelines (Section 4.1.2) have been established to assist in this process.

4 REGULATION AND MANAGEMENT

4.1 British Columbia

4.1.1 Legislation and policy Unlike the United States, where statutes clearly define jurisdiction and procedures of government agencies (Jung 1989), legislation in British Columbia is generally enabling rather than defining. Several acts, primarily under the jurisdiction of the B.C. Ministry of Environment, apply to all forms of resource development. These include the *Waste Management Act, Environment Management Act, Environment and Land Use Act*, and *Water Act* (Table 1).

Under the *Waste Management Act*, any activity that emits substances that might affect environmental quality and human health must have a waste permit. The act allows for enforcement and for the conviction of companies that exceed their permits. Within each region, a waste manager oversees permit

TABLE 1 *Provincial legislation relevant to riparian areas*

British Columbia legislation/ agreements	Administering body	Applicability of act to riparian areas
Co-ordinated Access Management Plans (CAMP)	Ministry of Forests	Protocol between Environment and Forests to limit public access to sensitive areas (usually at the request of another agency).
Ecological Reserves Act (RS 1979)	Ministry of Lands and Parks	Administered by Ecological Reserves Program. Concerned predominantly with ecosystems and species that are endangered, threatened, or representative of natural ecosystems in the province.
Environment and Land Use Act (RS 1979)	Ministry of Environment	Mainly administrative body determined by the Lieutenant-Governor in Council. The Environment and Land Use Committee (ELUC) participates and makes recommendations on land use and resource development.
Environment Management Act (SBC 1981)	Ministry of Environment	Makes provisions for requiring environmental impact assessments leading to environmental protection and emergency orders, implementation of environmental management plans, and the holding of public enquiries.
Fisheries Act (RS 1979)	Ministry of Environment	Concerned predominantly with the licensing of public and private fisheries, processing of fish, and prosecuting those in contravention of the act. Also refers to fish and protective devices as they relate to dams and other hydraulic projects.
Forest Act (RS1979)	Ministry of Forests	The act oversees all forestry activities including clearing for roads, slash and abatement, and private development. The Ministry of Forests administers almost 85% of Crown land in British Columbia.
Greenbelt Act (RS 1979)	Ministry of Environment	Crown land is acquired as greenbelt land and is ordered as such by the Lieutenant-Governor in Council. The act does not specifically address how Crown land is allocated.
Heritage Conservation Act (RS 1979)	Ministry of Municipal Affairs	The act encourages and facilitates the protection and conservation of heritage property in the province.

TABLE 1 *(Continued)*

British Columbia legislation/ agreements	Administering body	Applicability of act to riparian areas
Highway Act (RS 1979)	Ministry of Transportation and Highways	Under the *Expropriation Act*, the Minister may use any land for the development of roads and highways. Under section 17 (g), the Minister cannot allow the natural flow of water through a drain or culvert on or under a highway to be stopped.
Land Act (RS 1979)	Ministry of Crown Lands	Allows the Ministry to regularly lease, license, or sell Crown land for different activity uses, which are regularly set out in policy objectives. Gives the Crown control of foreshore or land below the upland natural boundary of water for all water bodies.
Mineral Tenure Act (SBC 1988)	Ministry of Energy, Mines and Petroleum Resources	Allows for the determination of mineral rights, claims, and leases. Does not allow for exploration in parks or recreation areas without Lieutenant-Governor in Council's consent.
Mines Act (SBC 1989)	Ministry of Energy, Mines and Petroleum Resources	Oversees coal, mineral, and placer mining activities, including exploration, development, construction, production, closure, reclamation, and abandonment. A security deposit is required for any reclamation work that may be required as a result of the activity.
Municipal Act (RS 1979)	Ministry of Municipal Affairs	Comprehensive act overseeing municipal development including sewers, community plans (areas regularly flooded), and waterways development. Section 976-5(c) states that, where areas have been designated as needing protection, development permits must include a Ministry of Environment request: "that vegetation or trees be planted or retained in order to i) control erosion or protect banks, or ii) protect fisheries or protect banks."
Park (Regional) Act (RS 1979)	Regional Districts	Allows for the designation of park areas (parks and trails) within regional districts.

TABLE 1 *(Concluded)*

British Columbia legislation/ agreements	Administering body	Applicability of act to riparian areas
Parks Act (RS 1979)	Ministry of Environment	The Parks Branch has jurisdiction over, and manages/administers, all matters concerning provincial parks and recreation areas.
Pesticide Control Act	Ministry of Environment	Serves mainly in the administration of licensing pesticides.
Petroleum and Natural Gas Act	Ministry of Energy, Mines and Petroleum Resources	The Mediation and Arbitration Board is a body created under this act to mediate claims made by competing resource users.
Range Act (RS 1979)	Ministry of Forests	The *Range Act* is administered on Crown land and oversees the allocation of grazing leases, hay cutting permits, and cancellation or termination of such permits.
Recreation Corridor Program	Ministry of Parks	The program was established to identify, protect, and provide for recreation use of significant waterway and trail corridors. Corridors can be established under existing acts, such as the *Park Act*, *Heritage Conservation Act*, or *Forest Act*.
Utilities Commissions Act (SBC 1980)	B.C. Utilities Commission	Oversees the development of public utilities, commission enquiries, and enforcement of orders.
Waste Management Act (SBC 1982)	Ministry of Environment	Allows for the provision of waste permits (air contaminants, litter, effluent, refuse, and special wastes) and their enforcement. However, levels of waste disposal are at the discretion of the manager.
Water Act (RS 1979)	Ministry of Environment	Concerned with the determination, issuance, and removal of water licences.
Wildlife Act (SBC 1982)	Ministry of Environment	Concerned specifically with overseeing the administration and enforcement of hunting and fishing licences, registration of traplines, and guide outfitters licences. Also allows for the designation of wildlife management areas, critical wildlife areas, or wildlife sanctuaries.

allocation and enforcement of the act. The main problem with the *Waste Management Act* is that emissions levels determined for companies are arbitrary and vary with the company. The act allows the setting of emissions, but not the determination of legal levels for water quality in a given water body. Therefore, a number of different companies may be permitted to emit wastes at levels that seem reasonable when viewed separately, but that cumulatively may result in poor water quality. Ministry habitat staff claimed that the act is more likely to be enforced when the water quality is a concern to people rather than to fish and wildlife. Under current Crown Lands policy (B.C. Ministry of Crown Lands 1990), riparian rights of landowners include entitlement to clean and high-quality water.

The *Water Act* technically does not provide enforcement powers but may be used as such (mainly through section 7). The act is concerned predominantly with allocating rights and responsibilities through licensing and distribution of water for private and public use. Regional water managers are consulted before licences are issued, and thus have an opportunity to withhold licences.

The *Environment Management Act* provides the Minister of Environment and cabinet with wide and comprehensive powers, including the ability:

1. to require environmental impact assessments;
2. to make environmental protection orders if existing or proposed actions have, or could have, detrimental environmental effects, and to exempt actions from other statutory powers given an approved environmental management plan;
3. to declare environmental emergencies, to allocate government funds for clean-up and control, and to recover costs from negligent parties; and
4. to require public inquiries into environmental issues.

Ranson (1990) noted the following shortcomings in the *Environment Management Act* that have relevance to riparian habitat management:

1. Environmental Impact Assessments: this provision has never been used. This may be because environmental impact assessments are most often requested by other government departments when proponents apply to undertake developments such as large-scale mining or new hydroelectric activities. As well, there is concern over the duplication of effort with the federal government requests for environmental impact assessments. Currently, requests for environmental impact assessments must be made by the Minister. Ranson (1990) suggested that escalating authorization powers be allowed within the Ministry of Environment, ranging from regional directors, through deputy ministers, to the minister, corresponding to escalating scales of environmental impact assessment, from requests for information through to full-scale impact assessments.
2. Environmental Protection Orders: this power has been exercised only once, suggesting that the level of authority to initiate protection orders is too high. Ranson (1990) recommended an escalating scale of environmental protection orders be developed, similar to the powers for requesting environmental impact assessments.

The *Environment and Land Use Act* is more an administrative tool than a legislative one. The act establishes the Environment and Land Use Committee, which is composed of representatives chosen by the Lieutenant-Governor in Council. The *Environment and Land Use Act* supports the

Major Project Review Process, the Mine Development Review Process, and the Guidelines for Linear Development. Riparian concerns may be addressed by the Environment and Land Use Committee in its recommendations.

A final statute under the jurisdiction of the B.C. Ministry of Environment is the *Wildlife Act*. The act gives the Minister the responsibility for wildlife management areas; however, these areas are few and widely separated. The act allows the Lieutenant-Governor in Council to designate wildlife species as threatened or endangered, but does not indicate what will happen after the designation. Two sections of the act provide protection for wildlife habitat: an offence of the *Wildlife Act* occurs when a person disturbs, molests, or destroys a muskrat or beaver house (section 9), or possesses or takes, injures, or destroys a bird or the nest or egg of a bird (section 41). In general, however, the act is concerned with controlling the "harvest" of wildlife through permitting. Wildlife itself is provided some protection; that is, one must have a permit to possess wildlife and cannot kill animals out of season. The act does not in any comprehensive sense protect wildlife habitat.

Only the *Waste Management Act* gives the B.C. Ministry of Environment powers to place substantive limits on resource development activities (e.g., through permits or approved plans), and to prosecute for noncompliance with these limits. Air and water quality concerns are addressed through this act, but two other areas are not addressed in any legislation: wildlife habitat protection and cumulative effects management. In recognition of the first concern, the Ministry has initiated an internal review and draft policy. Although preliminary, the review identifies riparian areas as areas requiring special protection. It is being proposed that a 10 m wide strip be left on both sides of streams and rivers and around lakes, and that all plans for development in riparian areas require Ministry approval. Cumulative effects management would involve a master plan or land use strategy for the province. Although this has been discussed in the past (e.g., the Dunsmuir agreement), it is not anticipated that a planning process to address cumulative effects will be developed in the near future.

The *Environment Management Act* provides means for procedural requirements (impact assessments, inquiries, protection orders) that could be useful for protecting riparian values. However, these mechanisms are limited to high-level government officials. Furthermore, they are very general and offer little guidance to legislators or resource managers as to how and where the means should be used or their results applied. For example, there are no guidelines to determine when an environmental protection order is justified or an impact assessment required. Similarly, there are no formal guidelines on which analytical techniques to use or on how information from impact assessments or public inquiries should be used in decision making.

Timber The *Forest Act* is primarily concerned with allocating timber harvesting rights and responsibilities. These responsibilities are associated mostly with maintaining timber crops, but there are some general stipulations that non-timber values be considered in planning and management. For example, the Chief Forester, in determining the extent of the provincial forest, must assess the potential of land for:

- growing trees continuously;

- providing forest for wilderness-oriented recreation;
- producing forage for livestock and wildlife;
- conserving wilderness; and
- accommodating other forest uses.

Similarly, government objectives for environmental quality, water, fisheries, and wildlife must be considered in the granting of area-based tenures such as Tree Farm Licences and Pulpwood Agreements. Finally, section 4(c) of the *Ministry of Forests Act* requires the Ministry to manage for multiple timber and non-timber values in consultation and co-operation with other government agencies and the private sector. However, neither act is clear about the appropriate order of Ministry priorities: "One of the major factors responsible for the conflicts relating to the use of provincial forest lands is the absence of clearly understood goals and resource use priorities for resource management as intended by government for various regions of the province" (Jung 1989, p. 4).

The *Forest Act* does not regulate forest practices explicitly. For example, the act and its regulations include no requirements for buffer strips or leave trees. Such details are delegated to field staff to determine on site-specific bases. Ministry of Forests staff can suspend or revoke licence rights when licence agreements or pursuant contracts are not followed. Such provisions could be used if environmental damage resulted from noncompliance with licences, but to date no legal actions have been taken in such cases.

Section 118 of the *Forest Act* requires that every standing snag in the area of operation be felled. This provision was likely included to ensure worker safety and compliance with Workers' Compensation Board regulations. However, a forest officer or higher official may exempt an operator from this section. Given the current attention accorded snags as important sources of habitat (although the extent to which riparian snags in particular are crucial is equivocal), this section and comparable Workers' Compensation Board guidelines and regulations may be interpreted more loosely in the future. The Workers' Compensation Board is now in the process of developing a provincially consistent interpretation of its snag policy. Snags that could not reach the opening if they fell, or that lean away from the opening, could likely be left. Creation of future snags, by killing standing live trees after harvest, will also be allowable.

Because the Ministry of Forests controls almost 85% of the provincial land base but does not have clearly defined goals, or goals that specifically address habitat concerns, the following statement by Jung (1989, pp. 22–23) is pertinent: "[T]he Ministry of Forests controls the provincial forest land base and ultimately wildlife habitat. The Ministry of Environment controls wildlife management and yet does not control a land base (except for designated wilderness areas) which is essential for maintenance of wildlife."

Fisheries Two acts oversee the management of fisheries in the province: the federal *Fisheries Act* (Table 2) and the provincial *Fisheries Act*. Only the federal act includes enforceable provisions. The two levels of government have worked out an arrangement whereby the federal government manages waters bearing anadromous fish, and the provincial government manages waters with freshwater fish.

The *Policy for the Management of Fish Habitat* (Department of Fisheries and Oceans 1986) states policy for the review of proposed developments,

TABLE 2 *Canadian federal legislation relevant to riparian areas*

Canadian federal legislation	Administering body	Applicability of act to riparian areas
Canadian Environmental Protection Act	Initiating Department, Federal Environmental Assessment Review Office (FEARO)	Includes proposals affecting an area of federal responsibility, having federal financial commitment, or located on lands administered by the federal government.
Fisheries Act	Fisheries and Oceans Canada, Provincial Ministry of Environment	Covers any activity that will harm fish habitat, or deposit a substance deleterious to fish into water frequented by fish. Enforcement is possible under this act.
International Boundary Waters Treaty Act	International Joint Commission	Covers any activity that will affect water quality and levels in the United States.
Migratory Birds Convention Act (1982)	Environment Canada, Canadian Wildlife Service	Established to ensure migratory bird conservation. Noteworthy is the creation of the North American Waterfowl Management Plan in 1986 between Canada and the United States.
National Parks Act (1970)	Environment Canada, National Parks Service	Sets out provisions for the preservation of areas with nationally significant geological, scenic, and ecological features.
Navigable Waters Protection Act	Transport Canada, Canadian Coast Guard	Applies to work in, on, over, under, through, or across navigable waters.
Pest Control Products Act	Environment Canada, Environmental Protection Service	Approves pesticides to be used by provinces.
Wildlife Act	Environment Canada, Canadian Wildlife Service	Conveys broad powers to the Minister, including the opportunity to enter into agreements with the provinces to provide for wildlife research and conservation and interpretation programs.

protection and compliance monitoring, integrated land use planning, and the "no net loss" principle.

The department states that its long-term objective is net gain of the productive capacity of fish habitat. This policy is being actively pursued in the Fraser River where developers in some areas must compensate for habitat lost due to development, by creating or restoring twice as much habitat elsewhere (North Fraser Harbour Environmental Management Plan).

Sections 34–42 of the federal *Fisheries Act* deal with fish habitat protection. Section 35(1) states that "no person shall carry out any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat."

Section 37(1) gives the Minister comprehensive powers to protect fish and fish habitat from the discharge of deleterious substances; to request plans for developments that may affect fish; to develop regulations; and to modify, restrict, or prohibit certain works or undertakings.

Section 40(1) outlines conviction procedures for people who contravene Section 35(1) and states that individuals in contravention of section 37(1) are guilty of an offence. Department of Fisheries and Oceans staff recognize that the act serves mainly as a means to react to damage already done during development, and hope that the legislation can be rendered more proactive; for example, by instigating an authorization system. Through implementation, development applications for potentially harmful activities are referred to the department, normally through other government agencies and sometimes directly by the developer. The application would allow for some input into ways to make the development less harmful to fish habitat before construction begins.

Although fish habitat does not, in a narrow spatial sense, include upland or riparian areas, courts have decided that riparian vegetation constitutes fish habitat, since alteration to riparian areas can affect the stream environment. It is important to note that the provincial *Fisheries Act* does not provide enforcement powers; when a provincial conservation officer lays charges under federal fisheries legislation, it is the responsibility of the federal government to pursue the charges. Since federal and provincial fisheries management priorities sometimes differ, the enforcement responsibilities of the Department of Fisheries and Oceans means that valuable staff time must be spent pursuing the interests of both government agencies. Clearly, this is not an optimum situation, since the interests of neither agency are likely dealt with adequately.

Mining The *Mines Act* provides the legislation controlling exploration, construction, and operations of mining activities. All mining activity must follow the provisions set out by the *Waste Management Act* and the other associated enforceable environment acts. Regional habitat biologists are contacted for their input into mining activities. Wilderness areas designated under the *Forests Act* are still open to mining activity, but Class A Parks under the *Parks Act* are now closed to all mining activity unless otherwise determined by order of the Lieutenant-Governor in Council.

Under the *Mines Act*, the major kinds of mining projects in the province are reviewed under:

- the Mine Development Review Process and
- the Energy Project Review Process.

With these two processes, all pre-environmental impact analysis is accomplished, with input provided by regional biologists on water, habitat, and waste implications. Habitat biologists say that they feel that this is the most important stage of involvement when plans can still be changed to reflect better environmental concerns. For proposed mines, regional biologists contact Victoria personnel on a project-to-project basis. The B.C. Ministry of Environment has no policy on mine development. The Ministry also does not have the powers to state that mining activity cannot occur in certain areas — it can only provide advice to ensure that mining operations are as environmentally sound as possible.

4.1.2 Guidelines and practices In this section we discuss some planning and management procedures and techniques available to resource managers. The focus is on guidelines that can help in the design of field activities. Before moving to specific guidelines, we will look briefly at two administrative processes that significantly affect resource management in British Columbia: (1) land use planning, and (2) the interagency referral process.

Land Use Planning The uses to which land is allocated affect profoundly how any ecological system will be managed. The overall priorities set among different users largely determine more specific management decisions. For example, the amount of money invested in mills and trees present and the cost of land allocated to forest harvesting are the critical variables in deciding the allowable annual timber harvest. This decision ripples down through the planning and management system in further decisions about building mills, hiring employees, or harvesting a certain riparian area to meet mill demands.

Because 85% of the British Columbia land base is within Ministry of Forests jurisdiction, the outcome of the Ministry's planning process is an important determinant of how riparian lands are allocated. Within this process, allowable annual cuts are determined after Timber Supply Area and Tree Farm Licence planning. Technical aspects of Timber Supply Area planning, such as growth and yield analysis, are performed by the Ministry. However, the process is guided by steering committees chaired by Forest Service district staff and consisting of timber licensees; Ministry of Environment fish and wildlife, and possibly water management, staff; federal Fisheries and Oceans staff; other provincial agencies such as the Ministry of Energy, Mines and Petroleum Resources; and other resource licence holders. There are some moves to include local government (regional, district) as well. Planning for Tree Farm Licences is carried out by timber licensees who consult with government agencies and other interest groups. In both Timber Supply Area and Tree Farm Licence management planning, public comment is sought at some planning stages. However, as it varies from region to region, it may not reach all interested parties.

Steering committee members, or those consulted by licensees during Tree Farm Licence planning, and the public can highlight important non-timber values, such as those in riparian areas. Timber supply analyses then can be run to determine the effects of removing important non-timber areas from the harvestable land base. This information is used in weighing different options for land use within the Timber Supply Area or Tree Farm Licence.

Final decisions on land allocation and the allowable annual cut are made within the Ministry of Forests, with input from the provincial government.

The allowable annual cut decisions are critical to the overall management pattern on provincial forest lands. Contracts for periods of up to 25 years are entered based on the allowable annual cut; the Ministry of Forests has compensation responsibilities if allowable annual cuts are reduced more than 5%. Communities depend on timber harvests for jobs and revenue. Clearly, allowable annual cut determinations have great relevance on the amount of pressure to harvest riparian areas. Although site-specific management prescriptions can assist in increasing the compatibility of timber harvesting with natural ecosystem values, ultimately the degree of tension between competing uses on the ground will be decided largely through land allocation. The land use planning stage of resource management consequently deserves some attention when strategies are being developed to protect riparian values.

While the Ministry of Forests planning process is important on Crown lands, much riparian area is on "private land." British Columbia has no comprehensive land use planning process that encompasses the activities of private landowners. Indeed, placing limits on private activities within a public planning process is in many ways anathema to the idea of private ownership. Nevertheless, protection of riparian areas will depend on the involvement of private landowners — ranchers, homeowners, industries — in riparian management. Furthermore, much riparian land is within the jurisdiction of local government, and forms part of a tax base. Municipalities will be hesitant to set aside riparian areas from development unless there are off-setting benefits. Participation of private landowners and local government, either voluntarily or through protective zoning in community plans, will require incentives and information dissemination. Given that such efforts will tax limited provincial and federal government staff and resources, it makes sense to determine priority areas (e.g., through regional planning exercises that cover both private and public lands).

The Ministry of Forests, private landowners, and local government are certainly not the only stakeholders in land use planning. Other interests include mining, tourism, parks, agriculture, and environment. Long-term protection of riparian-related resources will depend on the involvement of those parties affected by or affecting riparian areas.

Interagency Referrals Several provincial government ministries (e.g., Forests; Environment; Energy, Mines and Petroleum Resources; and Crown Lands) have responsibilities for approving plans and permits for resource development activities. It is the policy of most permitting agencies to refer permit applications to all other agencies with potential interests before giving final approval. For example, the Ministry of Forests passes 5-year development plans and cutting permits to regional Ministry of Environment fish and wildlife staff for comment. Referrals are the most common method for non-permitting agencies, whose interests may be affected by developments, to have input into permitting. Neither incorporation of comments into permits or plans, nor the referrals themselves, are required by legislation. However, referrals are common practice.

Comments on referred applications provide a proactive method for developing resource management prescriptions that protect riparian resources. Additionally, since referrals normally involve staff at local or regional levels, they also allow for inclusion of site-specific information in prescriptions.

There are at least two major shortcomings related to the current referral system. First, referrals address questions of how to, not whether to, undertake resource development. Even if recommendations that development not occur in a certain area are incorporated into a plan or permit, this decision occurs within the context of a broader land allocation pattern that likely limits flexibility in altering resource output based on site-specific decisions. For example, a riparian buffer strip may be deferred from logging, but the productive forest land base of the Timber Supply Area or Tree Farm Licence used in determining the allowable annual cut remains the same. The referral process is a useful mechanism for land management, not for land allocation. Riparian resource conservation requires that resources be allocated appropriately within a comprehensive planning process that provides some direction to more local management decisions.

Secondly, the Ministry of Environment and federal Fisheries and Oceans staff, who are the most frequently called upon to comment on development applications, are inundated with referrals. Since limited time can be spent on each referral, all sites cannot be visited. Limited time may further preclude collection of information required to make sound comments. Therefore, referral comments often may not be as appropriate as would be desired by those wishing to ensure protection of environmental values associated with riparian, or any other, areas. Staff responsible for referrals undoubtedly do their best, but limited time and resources make the job difficult.

The referral process is useful to help ensure that all relevant factors, including environmental values, are considered in resource planning. But referrals cannot deal with all planning and management questions. The question of developing a land use planning process suitable to a dynamic and complex resource management environment is primarily a policy issue. Closer to the ground, one way to circumvent staff shortages that hamper the referral process is to develop guidelines that can assist resource developers and operators, as well as permitting agencies to design activities that maintain environmental quality. The following section describes some guidelines currently in use in British Columbia.

Coastal Fisheries/Forestry Guidelines The *British Columbia Coastal Fisheries/Forestry Guidelines* Technical Committee 1992 were developed cooperatively by the provincial ministries of Forests and Environment, the Department of Fisheries and Oceans, and the Council of Forest Industries. The purpose of the guidelines is to maximize the combined fishery and forestry benefits. The guidelines were formulated to protect fisheries habitat from degradation by forestry activities including road and landing construction, falling and yarding, and silviculture. Besides the guidelines, the manual contains several appendices listing Ministry of Forests road specifications, gravel removal administration procedures, aerial pesticide application guidelines, erosion control procedures for roads and degraded slopes (including grass seeding), and protection methods for aerial applications of fertilizers.

Guidelines pertinent to riparian areas are summarized below:

Roads

- Construct roads a reasonable distance from Fisheries Sensitive Zones (aquatic environments important to fish) to maintain vegetation and prevent instream damage and downstream sedimentation.

Falling and Yarding

- Fall and yard away from streams to maintain, where required, streamside vegetation for bank stability, shading, insect and litter fall, and future large organic debris for the stream.
- Avoid skidding through active floodplains. (What constitutes "active" is a subjective judgement, usually based on signs of annual flooding.)
- Log on one side of a stream only if streamside windthrow is likely, to minimize potential for excessive instream debris.
- Delineate a streamside management zone, defined as the area of major influence on stream processes, to provide bank stability. On class I and II (see Section 5.2) water, the streamside management zone should be one channel width on both sides, with a minimum of 10 m and a maximum of 30 m. Selective tree removal is permitted only beyond 10 m of the stream bank, but a range of tree species and ages should be left.
- Leave mature streamside trees beside class III and IV streams as future large organic debris sources, if this is important to channel stability.
- If compatible with Workers' Compensation Board regulations, retain snags and unmerchantable trees in the streamside management zone as sources of large organic debris or bird habitat.
- Ensure that useful fish habitat is not removed during clean up of stream channel debris.
- Plant or seed stream banks with grasses, brush, or trees, if erosion is occurring.

Silviculture

- Lay out harvest boundaries so that slashburning will not encroach on the streamside management zone.
- During brush control operations, do not destroy streamside deciduous brush or trees that contribute to bank stability, temperature control, and food supply.
- If streamside deciduous trees are to be removed, avoid radically altering the stream environment by phasing harvests over time.
- Leave at least a 10 m wide herbicide-free buffer.
- Leave 10 m fertilizer-free zones in nutrient-nonsensitive watersheds (i.e., where there are no fish productivity and nutrient experiments, or other nutrient [phosphorus] inputs from industrial, municipal, or hatchery sources); and 30 m in nutrient-sensitive watersheds.

A point of discussion about pesticide and fertilizer buffers is whether the important variable is the distance to the water body, or the existence of vegetation in the buffer. Furthermore, how buffer widths might be altered given different terrain (slope, surface materials, bedrock) or climate are not discussed.

The coastal fisheries/forestry guidelines are not legally binding until incorporated as conditions in a cutting permit. They are structured to highlight variables for resource operations planners to consider. In general, quantitative standards are avoided to allow for site-specific considerations (C. Scrivener, pers. comm., 1991).

The Coastal Fisheries/Forestry Guidelines Implementation Committee has the task of training operators and managers in use of the guidelines. This will be a challenging undertaking, especially in cases where small operators are involved. Extension courses and a video lecture are training possibilities, but there are practical and financial constraints. Many small operators will not travel to population centres to attend training sessions. Video development and dissemination are expensive.

An innovative forest management practice currently being experimented with in the Tsitika Valley is the cutting of tree tops along the water's edge. This management technique attempts to limit the amount of blowdown that occurs to those trees left standing after forest cutting has been done in an area.

The coastal fisheries/forestry guidelines undergo periodic monitoring and revision by implementation and technical committees. There are plans to undertake a field application review to evaluate use of the coastal fisheries/forestry guidelines in the forest licensee/government agency referral process, and to determine whether guidelines are applied adequately and whether they meet habitat protection objectives.

Interior Forestry/Fisheries/Wildlife Guidelines Guidelines are presently being prepared for British Columbia's interior that will direct forest management practices in those areas not addressed by the coastal fisheries/forestry guidelines. The process for preparing these guidelines is still being worked out, with different committees struck for different areas of concern. It appears likely that the guidelines will be generated on an ecosection level using the ecoregion classification system (D. Hamilton, pers. comm., 1992). For information about the process, enquiries can made to the Assistant Deputy Minister of Operations, Ministry of Forests, who is the Chairman of the Interior Forestry/Fisheries/Wildlife Guidelines Steering Committee.

Okanagan Timber Supply Area Integrated Resource Management Guidelines for Timber Harvesting The Okanagan Timber Supply Area guidelines are currently used in the Vernon, Penticton, and Salmon Arm forest districts in the Kamloops Forest Region. The guidelines stipulate a 20 m "no machine" buffer strip along both sides of all streams. All unmerchantable vegetation should be left within the buffer. Disturbance of stumps and root systems embedded in stream banks should be avoided. Broadcast (slash) burning or slash removal should not be performed in the buffer.

The guidelines also define a riparian management zone, to be applied on the main stream or primary portion of gazetted streams (streams include lakes, rivers, creeks, springs, swamps, and gulches), including those in community watersheds. An appendix in the guidelines lists all community watersheds and gazetted streams in the relevant forest districts. The riparian management zone incorporates the riparian area (i.e., areas with high water table and wet soils), and an adjacent upland area sufficiently wide to provide stability from blowdown for riparian area trees. The upland area should be no wider than 20 m beyond the riparian area on any side of the stream.

The following guidelines apply to riparian management zones:

- *Shade and Large Organic Debris:* maintain 75% of pre-harvest, mid-day summer shading; leave all unmerchantable vegetation; maintain 50% pre-harvest crown closure.

- *Stream Bank Integrity:* do not disturb understorey vegetation in the riparian area, or stumps, roots, and logs embedded in the bank; leave trees with large root systems in the bank.
- *Logging Practices:* use no equipment within 20 m of the stream; fall and yard away from the stream.
- *Clearcut Openings:* openings along streams listed in the guidelines appendix should not exceed 1000 m in length, and should be separated by reserves of at least 400 m.
- *Cutblock Pattern:* avoid concurrent openings on both sides of the stream until one side has greened up (satisfactory stocking: the greater of 3 m tree height or 1 m above normal maximum snow depth).

Also of relevance to riparian management, the Okanagan Timber Supply Area guidelines discuss special management considerations for lakeshore areas. Three lake categories are recognized based on degree of use, angler effort, productivity, recreational value, aesthetic value, and hydrological importance. Category A lakes have the highest value, and category C lakes the lowest. An appendix lists lakes in the districts by category, but specific delineation criteria and methodology for each category are not provided. Quantitative guidelines are provided for: percentage crown closure to be maintained; maximum percentage of lakeshore to be cut in one pass; timing of the second pass (when stand attains wind firmness, usually 8–15 years); maximum opening widths for clearcuts; distances from haul roads, landings, spur roads, and skidroads to the lakeshore; and visual quality objectives for landscape management (e.g., retention, partial retention, modification). Poulin (1990) summarized the Okanagan Timber Supply Area lakeshore harvesting guidelines, and the draft Kamloops lakeshore guidelines, which apply to similar harvesting variables.

Ministry of Forests District Timber Harvesting Guidelines The Lakes Forest District, in consultation with the Environment Ministry and a local licensee, has developed riparian zone timber harvesting guidelines (Hetherington et al. 1990). These were designed to protect fishery, wildlife, and recreation resources in the Klaytahnkut and Tildesley creek drainages. The Golden Forest District and Environment's Kootenay Region examined both the short- and long-term effects on timber supply of reserving riparian areas from the harvest impacts of an extended rotation (200–250 years). They also recommended that riparian areas be managed at the landscape level (Price and Hamilton 1989).

The Smithers, Williams Lake, and Penticton Environment regions are either in the process formulating, or have recently compiled, their own streamside forest management guidelines to maintain wildlife habitat and biodiversity (G. Wolfe, pers. comm., 1991; A. Heatherington, pers. comm., 1991; G. Ashcroft, pers. comm., 1991; and D. Jones, pers. comm., 1991). For the most part, these guidelines currently exist as requests before logging. They consist of streamside buffer strips with variable amounts of selective conifer cutting allowed. For more sensitive areas in the Williams Lake Region, specific subzone guidelines have been drawn up (e.g., those for the Quesnel Timber Supply Area) where 30 m reserve corridors have been requested (G. Ashcroft, pers. comm., 1991). Within the Penticton Region, the Okanagan Timber Supply Area riparian areas are still dealt with largely on a site-specific basis, although the rest of the region is expected to follow guidelines similar to those set out for Oregon and Washington (D. Jones, pers. comm., 1991). This region has observed various timber harvest prescriptions and has used this information in compiling its guidelines.

The Queen Charlotte Islands Fish and Wildlife office has requested that the forest companies retain buffer strips with the deciduous component intact along class 1 and 2 angling waters to preserve the recreational fishing experience in the area (L. McIntosh, pers. comm., 1991). These requests have usually been met with co-operation.

Water Quality Criteria and Objectives The Water Management Branch of the B.C. Ministry of Environment develops water quality criteria and objectives. Water quality criteria cover various substances or characteristics, such as chlorine, mercury, lead, acidity, colour, particulate matter, and nutrients (Buchanan 1987). They apply generally to all waters in British Columbia. Water quality objectives are developed for specific watersheds or water bodies. Their development is guided by the relevant water quality criteria, depending on the resource uses prevalent in the area. In some areas, the objective is to maintain the current high quality; in others it is to ensure that water quality does not sink below a minimum standard.

The Ministry has published several reports documenting the methods used for determining acceptable water quality criteria for British Columbia. Criteria have been set for particulate matter (Singleton 1985), nutrients and algae (Nordin 1985), phosphorus (B.C. Ministry of Environment and Parks 1985), molybdenum (Swain 1986), nitrogen (Nordin and Pommen 1986), cyanide (Singleton 1986), copper (Singleton 1987), lead (Nagpal 1987), aluminum (Butcher 1988), mercury (B.C. Ministry of Energy, Mines and Petroleum Resources 1990), chlorine (B.C. Ministry of Environment 1989), fluoride (B.C. Ministry of Environment 1990), and microbial indicators (Warrington 1988). The levels suggested are usually considered safe by the provincial government for various users, including fish, wildlife, livestock, and humans.

Environment Canada has also published water quality guidelines (Environment Canada 1987a). These set acceptable levels of chemical and organic compounds for water to be used by aquatic life, and by humans for drinking, recreation, aesthetic endeavours, industry, and agriculture. These guidelines are purely advisory in nature and are established to assist provinces in setting their own criteria and objectives. Water quality standards in Canada should be basin specific because of their specific requirements (Hatfield and Smith 1985). With a classification scheme, these management guidelines could be transferred to other similar areas. This type of procedure is used in national forests in Washington and Oregon (Swank 1990), where quantitative water quality objectives, particularly for fish habitat, guide management prescriptions.

Determining what types of management practices would meet quantitative water quality objectives may entail experimental monitoring. For example, monitoring of different riparian habitat types or classes under different management practices, such as timing between operations, or buffer widths, would help illuminate how variations in management practices affect quantitative quality indices. Development of water quality objectives could therefore assist in development of site-specific guidelines. Blanket guidelines (e.g., on buffer strip width) may be excessive in some riparian areas and ineffective in others, depending on specific uses and characteristics of the area. Whitman (1989) discussed some of the issues relevant in developing management practices to minimize water quality degradation from non-point sources such as forestry.

Approaches used for setting water quality criteria in the United States in terms of sediment loads are discussed by Iwamoto et al. (1978). Karr and Dudley (1981) discussed water quality goals from an ecological perspective. Background production estimates of nutrient exchange rates for wetland streams are also available (Kibby 1979).

Community Watershed Management Guidelines The *Guidelines for Watershed Management of Crown Lands Used as Community Water Supplies* (B.C. Ministry of Environment 1980) apply to watersheds used for domestic water supply where more than 50% of the watershed area is Crown land. All community watersheds are listed in an appendix. A “notation of interest” is placed on all of these areas, meaning that all development applications must be referred to the regional Water Management Branch office.

Community watersheds are divided into three categories. Category I watersheds are less than 970 ha, and receive maximum protection. Very limited development may be permitted. Category II watersheds range from 970 to 5600 ha. Curtailing all activities is impractical in watersheds of this size, but land is alienated only to non-detrimental uses. Sale or lease of land within 20 m of the main channel should be prohibited. Category III watersheds are 5600–32 000 ha in size. It is recognized that guidelines alone cannot protect watersheds this large, but can help to maintain water quality so that water treatment (e.g., chlorination, filtration) will be effective. Most activities are prohibited within 20 m of stream banks.

The following are activity guidelines relevant to riparian zone management.

- *Construction and Roads* Use natural benches away from stream channel. Minimum distances from road embankment to stream are 15–75 m horizontal, depending on slope. Minimize interference at stream crossings. Crossings a minimum of 300 m from water intakes.
- *Agriculture and Grazing* Follow B.C. Ministry of Agriculture Environmental Guidelines (for beef, poultry, dairy, swine). Fence off areas of easy access to streams. Provide water troughs for animals. Maintain natural streamside tree cover to discourage animal use. Do not allow overgrazing.
- *Forestry* Prepare logging plan for entire watershed to ensure that logging sequence and cut sizes do not degrade water quality or yield. Leave a 9 m buffer, and fall trees away from stream courses. No burning within 20 m of the stream unless granted permission.
- *Mining* In general not compatible with high water quality. Legislation controls mining activities (*Mines Regulation Act*, *Coal Mines Regulation Act*, *Pollution Control Act*).
- *Recreation* Ensure that waste and sewage disposal facilities are supplied. Parking areas should be at least 100 m from surface water.

- *Power Transmission Rights-of-Way* No clearing of low-level vegetation less than 50 m from water; 250 m buffer between stream bank and centreline for rights-of-way running parallel to streams.
- *Highways* Keep out of watersheds if possible.

Unfortunately, the community watershed guidelines are not routinely followed. The degree to which watersheds are open to different types of resource development varies; some are closed to most activities, others are virtually open to any development. Day and Affum (1990) suggested that all resource development in community watersheds be halted until priorities for integrated watershed planning can be set, and watersheds with potential water quality problems can be highlighted.

Agriculture No guidelines applying to riparian zone protection were found for British Columbia.

Part of the registration process for agricultural pesticides is development of application guidelines. These guidelines are printed on product labels and are part of legal requirements for pesticide application. Agriculture Canada stipulates the types of tests that must be done for registration.

Some recent studies by Agriculture Canada have shown that even with ostensibly environmentally sound application procedures, toxic levels for fish are being reached near agricultural land (G. Carlson, pers. comm., 1991). This is primarily an issue related to the aquatic, not riparian, environment. The extent to which a vegetated riparian strip could assist in decreasing pesticide flow may be worth investigating.

Agricultural activities that generate wastes, such as livestock production, are required to have permits. However, the *Waste Management Act* is currently being revised to stipulate that activities do not require permits if they follow codes that are attached to regulations. Environmental guidelines published by the B.C. Federation of Agriculture cover activities such as poultry, swine, horse, and beef cattle production, greenhouses, and mushroom composting. An older set of guidelines cover water quality and aquatic environment protection during farm activities more generally (B.C. Federation of Agriculture 1979). These guidelines are being updated to explain how to meet the codes. Current informal guidelines provided by the Agriculture Ministry stress keeping livestock feedlots and fields at least 30 m from watercourses. Storage facilities must be 15 m from water. If cattle are to have access to watercourses, the feedlot must be at least 200 m from the water, unless in natural pasture (D. Sands, pers. comm., 1991).

Additionally, the *B.C. Agricultural Drainage Manual* (Van Der Gulik et al. 1986) has general relevance to riparian management. It explains the types of licences and permits required, and agencies to contact when plans are being made to alter or maintain streams to protect property or reclaim and improve agricultural land. Disputes over environmental impacts of farm activities are adjudicated by committees composed of members of the farm community.

Range The Ministry of Forests employs no formal guidelines for livestock grazing management. In some areas of the province, the effects of grazing around streams and streamsides are minimal, and issues can be dealt with individually (T. Lester, pers. comm., 1991; R. Tucker, pers. comm., 1991). The main goals are to keep cattle away from streams (particularly when the water level is low) and community watersheds, to avoid high coliform counts. Fencing is sometimes used.

However, grazing-related damage is becoming severe enough to cause concern in some areas (e.g., the east Kootenays) (D. Martin, pers. comm., 1991). Here there is pressure to move cattle into mid-elevation drainages where they could destroy good riparian wildlife habitat through grazing and trampling. Potential management practices are fencing and rotation of grazing areas. Until recently, grazing has not been viewed as an important problem. Therefore, guidelines and management alternatives have not been investigated extensively.

Mining Placer operations are perhaps the main mining issue for stream management guidelines. There are placer mining guidelines for British Columbia. Potential placer streams are colour coded—red, yellow, or green—depending on their importance to fish. No work is to be done in streams with high fisheries values. The placer guidelines apply to aquatic fish habitat, not riparian areas. A general prescription by the Ministry of Environment is to keep riparian disturbance to a minimum, and to avoid streamside logging during testing. Recently, post-placer mining reclamation has received more emphasis (D. Martin, pers. comm., 1991).

The *British Columbia Guidelines for Mineral Exploration* (B.C. Ministry of Energy, Mines and Petroleum Resources 1992) apply more generally. These guidelines summarize approval requirements of the Ministry of Energy, Mines and Petroleum Resources, and the *Mines Act*. Requirements and roles of other agencies, including the Ministry of Environment's Fish and Wildlife, Waste Management, and Water Management branches, and the federal Department of Fisheries and Oceans are discussed briefly.

Any exploration that disturbs the earth's surface requires an approval for a reclamation program. Applications are referred to various agencies for comment. Fish and Wildlife and Fisheries and Oceans can recommend standards for reclamation of riparian habitat at this stage.

The guidelines list types of waste disposal and water permits that must be obtained. The operational guidelines of relevance to riparian areas are for road construction and site reclamation. Road guidelines are general, suggesting avoidance of streams, lakes, marshes, and bogs, and maintenance of a 50 m buffer separating roads from these areas. Reclamation guidelines list mixtures of seed (grasses) and fertilizers, application rates, and timing for different biogeoclimatic zones. General procedures for reclamation using shrubs are discussed.

The Ministry of Energy, Mines and Petroleum Resources has previously been a participant in the group formed by the Environment and Forests ministries to deal with development in community watersheds. Recently, however, they have developed their own draft policy on mineral resource development in community watersheds. Community watersheds are defined as watersheds that contain a recognized urban area. At present, it is still a discussion paper, but the Ministry is reviewing comments before adopting it as policy. It outlines 11 policy objectives and 7 implementation strategies. As can be expected, the policy specifically outlines the concern for water quality, but not the effects of development in riparian areas. The seven strategies outlined include no-staking reserve, notification of mineral title owner, road access into watersheds, operations in sensitive areas, reclamation, exploration planning, and exploration on private lands.

The most important strategy proposed is to define areas as "no-staking mineral and placer reserves." The Ministry of Energy, Mines and Petroleum Resources will receive requests from water licensees in category 1 and parts of category 2 community watersheds to have their areas labelled as a reserve. Another important strategy is that mineral claim owners based in environmentally fragile community watersheds will be required to provide water licensees with an annual synopsis of exploration and reclamation programs and will be requested by the Ministry to participate in integrated watershed management planning teams. The draft policy does not state, however, how environmentally sensitive watersheds will be defined.

Placer mining, much like the larger development projects, requires that a reclamation program be identified. Placer miners are requested to submit monies in relation to the size of their activity, which is held in trust until the reclamation work is carried out. Depending on where the land is, a road permit may be required from the Forests or Crown Lands ministries.

Land Development Guidelines Guidelines developed by B.C. Ministry of Environment and the Department of Fisheries and Oceans try to address all land development activities (Chilibeck et al. 1992). Items such as underground detention tanks, deleterious substances, and coffer dams are addressed in the guidelines, with the emphasis on methods for minimizing the negative impacts of urbanization on fish. Most urban or rural land that is likely to be developed for residential or commercial purposes is private. Therefore, government is limited in its ability to enforce guidelines. The best protection of riparian environment occurs if municipalities buy up land to maintain green strips.

Recreation No formal guidelines apply to recreation development for riparian area protection. However, a new Ministry of Forests recreation manual may have some recreation area site selection and development guidelines.

For protection of recreation-related riparian resources, the main avenue is the referral process during development planning. High-value recreation sites can be noted in the inventory (D. Herchmer, pers. comm., 1991).

Wildlife Some wildlife guidelines include:

- Fish and wildlife habitat protection guidelines for the petroleum industry in the South Peace River Deep Basin Area of northeastern British Columbia.
- Region 1 operational procedures for protection and management of raptor and cavity-nesting habitat on Crown land.
- Wildlife handbooks for the Southern Interior ecoprovince (these manuals describe habitat requirements for various wildlife species).
- Logging guidelines for wildlife habitat classes.

No wildlife guidelines appear to be widely used in British Columbia. Most prescriptions are developed on site-specific bases.

4.2 United States Pacific Northwest

4.2.1 Legislation and policy

Federal The major federal pieces of legislation that guide development on state lands include the *Clean Water Act* (1965) and the *Clean Water Act Amendment* (1972), the *Fish and Wildlife Coordination Act*, the *Endangered*

Species Act (1973), and the *National Environmental Policy Act*. The *Clean Water Act* has enforcement powers, but the *Fish and Wildlife Act* is only enforceable on Fish and Wildlife Service lands. Otherwise, the Fish and Wildlife Service has an advisory role. The *National Environmental Policy Act* allows the Fish and Wildlife Service to participate in federal development plans on waterways. The *Endangered Species Act* is much more broad in scope and was set up to ensure that any development does not jeopardize the continued existence of threatened or endangered wildlife.

The Bureau of Land Management is involved in a much more direct way with the management of lands. In 1978, the Bureau managed approximately 20% of the nation's land area with approximately 40% of that occurring in the western states. The department has its own act, in addition to following the administration of the other federal environmental acts. The Bureau has released a policy statement (1989) that addresses riparian areas specifically and emphasizes the multiple values and multi-program responsibilities for riparian management. For example, strategies for sound riparian management are now being included in grazing allotment management plans, timber management plans, mining operation stipulations, and other activity plans. Oakley (1988) stated that the riparian ecosystem is managed as one unit, designated as a Riparian Management Area, and that timber harvesting is generally restricted in those riparian areas with the highest non-timber resource values.

To enhance riparian areas, the Bureau Director has required that each field office develop at least one riparian demonstration area, where the best management practices and instream habitat improvement work have been or will be implemented.

The Bureau is involved in acquiring new and critical riparian areas through land exchanges with state and private owners. In Arizona, more than 63 500 ha of pristine riparian habitat were acquired during the last 2 years (Crouse 1989). The Bureau also encourages local groups to plant trees and enhance streamside areas by matching funding and by allowing groups to carry out monitoring in study areas.

Boyle (1988) suggested, however, that public policy addressing wildlife habitat needs in the United States is not meeting the growing acceptance of fisheries habitats and water quality. He suggested that the answer to meeting habitat needs for wildlife is to develop site-specific plans, as well as to consider the possibility of protecting habitat beyond riparian areas.

Protasel (1988, p. 223) supported this assumption by stating that "as evidence mounts that riparian zones are disproportionately important to wildlife (Thomas et al. 1979)—that is, that wildlife are extremely dependent upon riparian areas—one might anticipate that legislation would move in this direction." He suggested that the water needs of wildlife are of paramount importance and that the best way to meet these needs is to ensure that the *Clean Water Act* is enforced.

He went on to state that forest management has moved away from the legislative arena to the smaller administrative arena of forest boards, narrowing the scope of political conflict, and increasing the bias of the forest policy-making boards.

The concept of adjudication rather than rule making is one which Protasel (1988) endorsed for riparian area management. Already, foresters determine cutblocks on a case-by-case basis and Protasel (1988) suggested that riparian zone management plans be prepared by licensed professional biologists before any forest practice is approved.

Oregon The Oregon Forest Practices Rules are comprehensive. They address not only public forestry operations, but private landowners as well. The state Department of Forestry must be notified at least 15 days in advance of beginning any commercial operation on private forest land. Riparian management areas must be maintained along waters that are identified as important for fish, domestic use, and recreation. There is a table to calculate the amount required for different habitats. Assistance in the procedure is available from the Forest Practices Forester in the Oregon Department of Forestry. The following information summarizes the main points of the regulation.

Oregon Forest Practice Regulations (Oregon Department of Forestry 1987)
Riparian management area required for class I waters:
- an average of three stream widths wide on each side of the stream (average over operating area), except a minimum of 25 feet (7.6 m) wide and a maximum of 100 feet (30 m) wide
- includes the aquatic area (water area of stream, lake or wetland); riparian area (wet soil area next to aquatic area); and riparian area of influence (transition between riparian area and upland vegetation)
- has restrictions on burning
- requires a chemical-free zone of one aerial swath from the water
- falling must be away from the water
- machine use must be limited

Shade and canopy protection for class I and class II (Special Protection waters):
- maintain 75% of original shade over the aquatic area and 50% of the original tree canopy over the riparian area

Large organic debris for class I waters:
- leave all pre-harvest downed timber in the aquatic and riparian areas
- leave all unmerchantable logs in the riparian management area
- leave live trees over 8 inches (20 cm) diameter for future large organic debris. A table is provided for streams from 8 feet (2.4 m) wide (5 trees per 1000 feet [300 m]) to over 33 feet (10 m) wide (21 trees per 1000 feet [300 m]).

Snags for class I waters:
- leave all snags that are not safety hazards

(Note: See Section 5.2.5 of this report for water class definitions.)

Although Oregon has made what appears to be an excellent attempt at protecting riparian areas, Paul Adams (pers. comm., 1991) outlined that state representatives did not properly define how to protect these areas. For example, standards such as “nine conifers per hectare area width need to be left standing” are very difficult to implement.

The Bureau of Land Management has controlling interest over a sizable portion of land in the state including land called the “O&C lands” (old railway lands passed over to the Bureau). The Bureau says it meets or betters the state forestry rules.

The World Forestry Centre (a nonprofit organization) in Oregon has also produced a readable and accessible pamphlet called "Woodland Fish and Wildlife," in which land owners are introduced to the definition of riparian habitat and are made aware of the importance of riparian habitat to wildlife, including the effects of land use, chemicals, recreation, grazing, and agriculture on it.

Washington Forest Practices Regulations Riparian regulations are discussed in the Timber/Fish/Wildlife Agreement (1987). An alternative to the following regulations is a site-specific prescription determined by Department of Natural Resources personnel (Phinney et al. 1989). The five water types relevant to some regulations are described in Section 5.2.5.

Western Washington

Buffer (riparian management zone):

- boundary at change from wet plant to dry plant community
  - minimum 7.6 m
  - maximum 30 m
- 15 m buffer for aerial pesticide application
- reforestation within 3 years
- selective logging only
- no slashburning in riparian management zone

Leave trees:

- 12 conifer or deciduous trees per hectare
- additional minimum requirements on water types 1, 2, and 3:
- Water type 1 and 2 (23 m wide +):
  - 50 trees per 300 m for gravel and cobble reaches
  - 25 trees per 300 m for boulder and bedrock reaches
- Water type 1 and 2 (6–23 m wide):
  - 100 trees per 300 m for gravel and cobble reaches
  - 50 trees per 300 m for boulder and bedrock reaches
- Water type 3 (1.5–6 m wide):
  - 75 trees > 30 cm diameter per 300 m for gravel and cobble reaches
  - 25 trees per 300 m for boulder and bedrock reaches
- Water type 3 (< 1.5 m wide):
  - 25 trees 15 cm diameter or larger per 300 m

Eastern Washington

Buffer widths:

- partial cuts - 9 m
- regeneration cuts (clearcut, seed tree)
- average 15 m, minimum 9 m

Leave trees:

- leave trees < 4.7 cm diameter
- 40 live conifers per hectare
- seven conifers > 7.9 cm diameter; five largest deciduous > 6.3 cm. If deciduous and large snags nonexistent, substitute five conifers > 7.9 cm diameter or twelve largest conifers and seven deciduous 4.7–6.3 cm diameter.

4.2.2 Guidelines and practices Several papers reviewed proposed management guidelines for riparian resources of northwestern states. Several of these stemmed from previous research conducted at the University of Washington and from research programs funded by the Coastal Oregon Productivity Enhancement Program. In addition, much research is now being conducted to develop an integrated management approach for northwest riparian systems as a result of this program. Historical forest practices and regulations have been reviewed (Morman 1989). Long-term management plans are being developed for coastal basins and the specific objectives have been defined (Oregon State University 1989). Distinct riparian management programs are being developed specifically for coastal and interior forests (Bilby and Wasserman 1989). Other management guidelines associated with specific issues have also been addressed. These include the management of woody debris (Swanson et al. 1976), revegetation programs to reduce stream bank degradation (Lines et al. 1979), the management of hydrological regimes for the preservation of riparian systems (Debano and Schmidt 1989b), and the need for maintaining the diversity of plant communities in riparian zones (Hibbs 1989). Inventories of riparian zone types and structure are also being generated for management purposes (Paine et al. 1990)

The United States literature on riparian areas discussed here deals mostly with fish habitat and water quality protection during forestry operations. Vegetated buffer strips varying from 7.6 to 30 m (in one area 45 m) are used to provide shade, food, organic debris, and bank stability, and to filter sediments from runoff (Budd et al. 1987). Directional falling and yarding and suspension of trees yarded through buffers help to minimize both damage to buffer vegetation and disturbance of soil (Timber/Fish/Wildlife Agreement 1987). Wildlife habitat and food needs are also addressed by the vegetation and structures (snags, big trees) in leave strips (Washington Riparian Habitat Technical Committee 1985). Two guidelines of interest are used for specific land use activities. The first is for urban areas and the second is for a national forest.

King County (west-central Washington) These guidelines (Budd et al. 1987) apply to areas undergoing community development.

Buffer width:

- 7.6 m, where topography is gentle, vegetation is dense and healthy
- 15 m, where slopes are moderately steep, potentially polluting land uses (e.g. , dairy farming), vegetation is sparse
- to channel slope break, where channel slope >40%, soils are unstable

Willamette National Forest, Western Oregon (Vanderheyden 1985)

Shade and small debris input:

Fish-bearing streams, maintain:

- 80% overstorey canopy
- 80% understorey canopy
- 60% brush cover
- 10% of stream length may fall below guidelines

Non-fish-bearing streams, within 6 m (horizontal), maintain:

- 75% shade
- 60% cover

Large organic debris:
Criteria:
- length 1.5 times channel width
- diameter in inches equal to channel width in feet (diameter in cm = 0.120 times channel width in m)
- for channels > 30 m wide, diameter of 60 cm or more

Perennial non-fish streams:
- suitable debris every two channel widths along bank

Fish streams:
- average of four channel width spacing

One other guidelines manual from the United States is the American Fisheries Society, Western Division's (1982) *Best Management Practices for the Management and Protection of Western Riparian Stream Ecosystems*. General, primarily qualitative, guidelines are discussed for livestock grazing, mining, water development and irrigation, road construction, agriculture and urbanization, and timber harvest. Little mention of these guidelines was found in the literature, indicating that they probably receive limited use. Nevertheless, they could be useful as a focus for developing broader policy on riparian areas in general.

Finally, there has been some skepticism about how well riparian buffer strips will fare in the long term (Hibbs et al. 1990b). Genetic and reproductive isolation and exposure to wind, sunlight, and overland water flow may result in a fairly rapid demise of some riparian strips. Active management of these areas, including planting, may be required to ensure that buffers accomplish their planned purposes. These issues are being investigated by the Coastal Oregon Productivity Enhancement Program in Oregon.

5 EXISTING TECHNICAL AND SCIENTIFIC SUPPORT

5.1 Existing Definitions

Dictionaries define riparian as pertaining to a bank (from the Latin *ripa* or bank). The common understanding of riparian is land bordering a river, stream, lake, reservoir, pond, or spring. Occasionally, land adjacent to estuaries and tidewater is included as riparian. A *riparian zone* refers to one element in a land classification system, which defines and names *zones* based on an explicit set of characteristics. A *riparian ecosystem* signifies that components defined as *riparian* interrelate more tightly among themselves than with components outside the riparian area. The following section examines a variety of existing definitions, based on biological composition, ecological function, and hydrological regime, for riparian areas, zones, and ecosystems.

The British Columbia Coastal Fisheries/Forestry Guidelines Technical Committee (1992, p. 35) define the riparian zone as being "the streambank and floodplain adjacent to streams or water bodies, with particular reference to the vegetation." The riparian ecosystem consists of the aquatic zone, the riparian zone, and the direct influence zone. The Washington Riparian Habitat Technical Committee (1985) offered the following definitions:

The aquatic zone is "the area below the mean annual high water mark of surface waters."

"The riparian zone borders water bodies and contains a high water-table and possibly plants requiring saturated soils."

"The direct influence zone is adjacent to the riparian zone and includes vegetation that shades or contributes coarse or fine organic material or insects to the water body."

The riparian ecosystem is the combination of these "environmental elements that directly contribute to the structural and functional processes of a body of water."

This riparian ecosystem definition was developed primarily from the perspective of fisheries habitat and food supply (Meehan et al. 1977). The direct influence zone is delimited according to the ability of vegetation to contribute food and structure to the aquatic system. The Timber/Fish/Wildlife Agreement (1987) expands this definition to include the "organic debris, shade, and buffering action" that affect wildlife habitat as well. However, this offers little guidance as to where the direct influence zone, as it affects wildlife, ends. For wildlife species that depend on the aquatic system for food or water, the fisheries-based riparian definition may suffice; for those using riparian areas as late fall or early spring travel corridors or food sources, this definition may not be adequate. Finally, even for fish, the importance of riparian contributions to the aquatic environment changes from headwaters to lower floodplains (Cummins 1980).

This difficulty is magnified by geographic differences in riparian areas. Because of the climatic and geologic differences among regions in North America, and within British Columbia, the processes linking aquatic, riparian, and upland areas vary regionally. While the riparian strip in a moist region may house permanent water for most or all of the year, in a dry region such conditions may exist only infrequently. Nevertheless, these dry riparian areas constitute regionally important habitat (Johnson et al. 1984). Definitions for riparian areas stipulating "permanent water influence," such as those proposed by the U.S. Bureau of Land Management (Swanson et al. 1988), exclude these valuable dry riparian, or xeroriparian, areas.

Johnson et al. (1984) defined riparian areas generally as lands next to rivers, lakes, estuaries, or groundwater seeps (oases), where biotic communities differ from the surrounding uplands because of the periodic submersion, higher soil moisture, or, in the case of rocky substrate, reliance on proximity to water. They further defined four types of organisms that may occur in riparian areas. Obligate riparian organisms require free water (that is, water not held by capillary tension in the soil and therefore free to drain gravitationally); 91–100% of their occurrence is in riparian areas. Preferential riparian species prefer free soil water conditions; 76–90% of occurrences are in riparian zones. Facultative riparian biota do not require, but may inhabit, riparian areas; 26–76% occur near water. Non-riparian species are not well adapted to riparian conditions; 0–26% occur in riparian zones.

Johnson et al. (1984) then distinguished among hydroriparian, mesoriparian, and xeroriparian areas. These different riparian types have different moisture regimes and support different vegetation types. Hydroriparian applies to areas with hydric soils (saturated, anaerobic conditions) or substrates that are never or only temporarily dry. Vegetation is predominantly classified as obligate and preferential riparian. Meso-riparian areas have non-hydric soils that are seasonally dry, with a mixture of obligate, preferential, and facultative riparian plants. Xeroriparian lands are mesic to xeric, with higher soil moisture than surrounding areas, but surface moisture is only occasionally higher than local rainfall. Preferential, facultative, and non-riparian plants may occur. These definitions may facilitate demarcation of riparian areas with some sensitivity to varying regional climatic conditions.

The definitions are, however, qualitative, and open to confusing interpretation. For example, Kovalchik and Chitwood (1990) labelled the aquatic ecosystem as hydroriparian, the stream bank and active floodplain as mesoriparian, and fluvial terraces as xeroriparian. It is unclear whether Johnson et al. (1984) intended that hydroriparian apply to the wet, but predominantly emerging stream bank or lakeshore, or to the predominantly submerged instream or lake wetland community.

Here arises the difficulty in distinguishing riparian from wetland communities. Steen and Roberts (1988) defined wetlands as sufficiently wet or frequently inundated (i.e., they can dry up seasonally) to develop and support vegetation distinct from the surrounding, more well-drained uplands. This is similar to previously mentioned riparian definitions (Thomas 1979; Johnson et al. 1984; Oakley et al. 1985). Wetlands comprise shallow open water, marsh, fen, bog, swamp, shrub-carr, and wet meadow (Steen and Roberts 1988). Water in these types of features generally moves slowly or is stagnant, meaning that soil conditions are anaerobic for greater periods than near more quickly running water. Marshes, however, can occur around lakes or in rivers. Furthermore, marshes, shrub-carr, and wetland meadows can develop on mineral substrate, precluding use of organic soils as a differentiating criterion. There is clearly some difficulty in distinguishing consistently between wetlands and riparian areas. Washington State regulations include swamps, bogs, marshes, and ponds adjacent to water bodies in their riparian management zone definition (Timber/Fish/Wildlife Agreement 1987). If one chooses to distinguish riparian areas from wetlands, a relatively arbitrary standard might be imposed; for instance the presence of surface water of a minimum area, width, or velocity.

Riparian areas clearly are associated with the relative abundant and persistent throughput of water. This makes hydrological or hydrophysical criteria relevant to riparian zone delineation. The most obvious hydrophysical correlate of the riparian zone is the floodplain adjacent to a river system — a zone subject to episodic inundation during high river flows. It may include seasonal or perennial marsh, ponds, or lakes (but exclude lakes through which the entire river flows, which would be recognized as primary aquatic units).

A floodplain can be regarded in distinctly different ways, each corresponding to a concept of the riparian ecosystem. To engineers, a floodplain is part of a valley floor subject to occasional flooding. The floodplain limit and zones within the floodplain are defined by how frequently inundation recurs. For example, in British Columbia the floodplain is delimited by regulation as "the limit of inundation by a flood that recurs on average once in 200 years." Successively lower areas are inundated proportionally more frequently. This concept is related to the classification of Johnson et al. (1984)

in which riparian areas are distinguished on the basis of frequency of occurrence of near-saturated soils. Indeed, riparian plant communities can be correlated with frequency of inundation (Teversham and Slaymaker 1976). Geomorphologists recognize floodplains as a genetic landform, constructed by sedimentation associated with inundation by the river in its present regime. This has implications for the texture and pedological development of floodplain soils. The soils in turn influence the ecosystems that develop on them. The two approaches to floodplain definition are closely related, though not entirely equivalent. The latter, morphological, approach is often advantageous in practice since delineation can be accomplished without the need for substantial hydrological records.

Hydrological and geomorphological information is useful in determining risks of flooding that might have consequences for development activities. A hydrologic definition for riparian areas (e.g., the area within the 50-year floodplain) could be used to prescribe building set-backs and elevations above the normal or average high-water mark. Geomorphic information can be used to delineate floodplain areas subject to differing rates of erosion and deposition, for use in silviculture risk assessments (Beaudry et al. 1990).

Floodplains do not occur everywhere along a river. Where steep, high banks occur there is no floodplain, and riparian areas are accordingly restricted to a very narrow strip adjacent to the shore. Again, not all valley flats constitute floodplains, since river degradation may create terraces — that is, flat land sufficiently high to escape normal inundation. Soil water levels and the water table are accordingly lowered and the ecosystem on the surface takes on upland characteristics. But low terraces might still be inundated occasionally by extreme water levels, particularly those caused by severe ice jams or, in smaller rivers, debris jams. Characteristic water levels in valley flats may be changed occasionally, or may change systematically over time as the river aggrades or degrades, or as the hydrological regime changes. Changes to the hydrological regime may result in corresponding changes to the riparian ecosystem. Human actions to regulate water levels along many rivers in British Columbia have effected such changes in modern times.

One generalization that can be made about riparian areas is that they encompass an area where water influences, and is influenced by, terrestrial processes (Butt 1990). Perhaps this should be the focus of any discussion of riparian areas. In more specific situations, the definition used must be relevant to the specific resource management objectives and values of the user.

5.2 Classification and Inventory of Riparian Areas

There is no widely accepted riparian classification in British Columbia. In this section we examine some aquatic and terrestrial classification and inventory systems that may be useful references in developing a riparian classification. The focus is on biophysical classification and inventory systems, with the view that interpretations relevant to social values can be developed using appropriate biophysical information.

5.2.1 Aquatic classifications used in British Columbia

Stream Information Summary System The "Stream Information Summary System" is a co-operative effort between the B.C. Ministry of Environment's Fish and Wildlife Branch and the federal Department of Fisheries and Oceans. The computerized database includes information on fish (escapements, life history timing, etc.), fish habitat (stream location, gradient, obstructions, flow, etc.), current management activities and land or water uses, and fish population potential and constraints (Department of Fisheries and Oceans 1989). Riparian conditions such as stream bank vegetation, associated stream cover, and bank conditions, may also be surveyed, but are not normally a large component of stream descriptions (S. Hawthorn, pers. comm., 1991). The system concerns salmonid species only, and therefore covers only some of the fish species found in British Columbia. As biological diversity concerns shift some attention to less economically critical species, the inventory may need to expand.

The aquatic inventory system as used in the stream information summary system involves collection of data on stream attributes. Currently, it largely ignores riparian features and processes that may affect or be affected by the stream. This is likely the result of financial constraints, and of the relatively recent recognition of the importance of riparian resources to fish.

The stream information summary system is not a classification system. That is, it does not place streams or reaches into categories, which would allow management practices or research findings to be transferred among similar streams. However, categories could be developed based on information currently entered in the system. A classification proposed by Rosgen (1985) (described in the United States aquatic classification section) could be used as a model. The system does not place streams within a biophysical hierarchy as suggested by Frissell et al. (1986), Lotspeich (1980), and Lotspeich and Platts (1982). A hierarchical classification could be useful for organizing planning at different levels (regional, operational), and placing smaller-level systems in their larger context — for example, to investigate cumulative effects of local actions at watershed or regional scales.

Coastal Fisheries/Forestry Guidelines Stream Reach Classification The *British Columbia Coastal Fisheries/Forestry Guidelines* Technical Committee 1992 are a co-operative, and continuing effort among provincial and federal government agencies and the forest industry. The management guidelines are discussed in Section 4.1.

The coastal fisheries/forestry guidelines stream reach classification was developed using stream classification work from the United States Pacific Northwest and western Canada. The authors recognized that stream characteristics result from a complex interaction of many biophysical variables, and that many criteria could be used for description and classification. They chose, in the interests of developing a clear, understandable, and flexible system that used accessible data, to base the reach classification on fish presence and stream gradient. Fisheries productivity is generally higher in lower-gradient reaches. Higher-gradient reaches, however, have higher capability to transport sediment and debris to downstream reaches where it may affect fish habitat.

The coastal fisheries/forestry guidelines use a four-class system, which recognizes the different management objectives necessary in these reaches to protect fish habitat. The Interior wildlife/fisheries/forestry guidelines now being developed will have a three-class system (D. Hamilton, pers. comm., 1991). The most important areas are those with documented or assumed fish populations where habitat damage must be avoided. Where no fish are present, the objective is to ensure bank stability and minimize sedimentation to protect downstream habitat.

The four stream reach classes are as follows (B.C. Coastal Fisheries/Forestry Guidelines Technical Committee 1992):

- *Class I:* Anadromous salmonids or moderate to high level of resident sport fish are present for at least one life stage, or the reach has been identified for upgrading in an approved fisheries management plan. Gradient is normally less than 8%.
- *Class II:* Low levels of resident sport fish are present. Gradient usually 8–12%.
- *Class III:* Resident non-sport fish are present. Gradient 8–20%.
- *Class IV:* No fish are present. Gradient is normally > 20%.

Stream reach classification may be based on existing stream inventories, or estimated using topographic maps. The Coastal Fisheries/Forestry Guidelines Technical Committee is producing a field guide to assist in stream reach classification. Aside from streams, the *British Columbia Coastal Fisheries/Forestry Guidelines* also apply to estuaries, marine shore areas, and lakes. While gradient is not relevant to these areas, the presence of fish can be used as the classification basis.

The guidelines recognize the importance of streamside or lakeside areas to fish, and therefore the classification has relevance to riparian area management. That is, riparian areas adjacent to different stream reach classes will undergo different management regimes. However, the reach classification itself provides no insight into characteristics of the riparian ecosystem. Furthermore, the coastal fisheries/forestry guidelines classification is concerned with fish habitat and does not indicate potential values for other resources, such as the potential need for a continuous riparian corridor for wildlife travel.

5.2.2 Terrestrial classifications used in British Columbia

Biogeoclimatic Ecosystem Classification The biogeoclimatic classification is used to delineate ecosystems on the basis of climate, vegetation, and soil characteristics (Pojar et al. 1987). The classification comprises climate, vegetation, site (soils, topography, etc.), and successional hierarchies. The climate and site components are most important for field use (Lloyd et al. 1990).

Biogeoclimatic units — zones, subzones, and variants — are delineated based on climate, where possible inferred from climax vegetation, otherwise from regenerating vegetation. Forested zones exhibit characteristic climax tree species and understorey vegetation on the zonal sites; that is, areas where the regional climate is least modified by topography (mid-slope or gentle to moderate slope positions and moderately deep soils). Non-forested zones include Alpine Tundra and Bunchgrass.

Biogeoclimatic units have been mapped for the province. These maps are used mostly to help resource managers determine the biogeoclimatic units into which a certain area falls. Site units are mapped only in special cases. The normal procedure is to use prepared guides (e.g., Lloyd et al. 1990) to assist in identifying site units in the field.

Most site identification guides include "mesoslope" diagrams, or pictorial representations of landscape units and plant associations ranging from crest to depression, for each variant. Meoslope diagrams also provide information on underlying materials (soil parent material) and show the topographic location of stream gullies and organic soils where seepage is occurring or the water table is close to the surface. General information on soil moisture regime, aspect, slope gradient and position, soil texture, parent materials, and important soil features (thin soils, water table close to surface) is presented in an environmental table for each variant. It is therefore possible to infer from mesoslope diagrams and soil features information which plant communities are associated with wet, possibly riparian, areas. However, all wet areas are not riparian, meaning that it cannot be assumed that all plants in wet soils (hydric, subhydric) belong to riparian associations (D. Meidinger, pers. comm., 1991). In most Ministry of Forests forest regions, floodplain site units have been identified. Furthermore, some wet areas are underlain by organic materials, more often associated with bogs or some other wetland condition.

The Ministry of Forests has not determined from the site identification guides which plant associations are exclusively or primarily riparian (D. Meidinger, pers. comm., 1991). This differentiation may not be imperative from a timber management perspective; similar sites will likely respond similarly to management actions regardless of how we label them. However, if the plant associations are to be used to locate riparian habitat on aerial photos during inventory (for example), the distinction may be necessary to accurately locate riparian areas.

During compilation of data for biogeoclimatic classification, many riparian successional types were not sampled unless they were extensive in the area (D. Meidinger, pers. comm., 1991). Therefore, floodplains were normally sampled, but small or narrow riparian areas probably received little attention. It has been proposed that permanent immaturity is an attribute of many riparian areas due to frequent disturbances (Campbell and Franklin 1979). This may mean that immature riparian vegetation types are not represented in site identification guides and poorly represented in the provincial database. Given the complexity of vegetation mosaics in many riparian areas, sampling techniques used for classifying upland areas may also not be appropriate in riparian areas (T. Spies, pers. comm., 1991).

Biophysical Habitat or Ecoregion Classification The Wildlife Branch of the B.C. Ministry of Environment has developed a hierarchical classification to assist in wildlife planning and management (Demarchi and Lea 1989). This work is based in the biophysical land classification approach espoused by the Canada Committee on Ecological Land Classification (Rowe 1979). The biophysical or ecoregion approach uses climate, terrain, soils, vegetation, and wildlife to delineate areas, but focuses more on physiography and landform than does the biogeoclimatic system. This system is believed to be more relevant to the spatial dynamics of wildlife than is climatic zonation, which tends to divide mountainous areas into elevational bands (D. Demarchi, pers. comm., 1991). For riparian classification, which will likely occur at fairly large scales (1:5000 to 1:50 000), these different approaches to regional delineation may not be particularly relevant.

The ecoregion system consists of 33 ecoregions and 83 ecosections, which are useful for regional planning (Demarchi and Lea 1989). Ecoregions are broad units with significant physiographic (e.g., mountains), but minor macroclimatic (general climatic forces, including air movement), variation. Biophysical wildlife habitat classes are based on vegetation species and are further broken down into biophysical habitat units, which are based on soils and landforms. Habitat units at various scales can be characterized within biogeoclimatic units: 1:50 000 units for sub-regional planning, 1:20 000 for watersheds, and 1:5000 for special areas. Site-level units defined within the ecoregion and biogeoclimatic systems are normally very similar, since at this level both classifications use specific topographic and soil information to delineate units.

Currently 91 biophysical wildlife habitat classes have been identified, of which five are found in riparian areas (Harcombe and Lea 1990): black cottonwood, Engelmann spruce, western redcedar–black cottonwood, white spruce–balsam poplar, and white spruce–black cottonwood. Habitat class descriptions include a general discussion of successional pathways, distribution according to Environment Ministry region, biogeoclimatic unit, topography, and tree and understorey species present. These habitat unit descriptions are currently in their "first approximation."

Biophysical wildlife capability mapping, which has been done mostly for ungulates and other large game, is another method of highlighting potentially valuable riparian habitat. Habitat units can be outlined based on vegetative cover, landform, climate, and soil features (Demarchi et al. 1983). Capability ratings for various species can be assigned, and the environmental conditions (soils, landform, climate) noted. In the current capability classification, important riparian habitat may be highlighted with a floodplain designation. A specific notation for riparian soils or landform is not listed in Demarchi et al. (1983).

In summary, the habitat class descriptions provide some indication of the vegetative features of a unit that may provide benefit to wildlife. The habitat capability classification includes evaluation of land unit value to different species, and provides general information about which unit attributes (climate regime, landform, etc.) are important. This may be sufficient for broad-level planning; for example, by ensuring that sufficient high-capability habitat is available for all needs of a wildlife species on a watershed or regional level. Such general information is probably not useful for more specific site management prescriptions.

5.2.3 Soil classification The Canadian System of Soil Classification (Agriculture Canada Expert Committee on Soil Survey 1987) was one of the parameters used in the development of the ecoregion classification scheme (Demarchi and Lea 1989). Many riparian sites experience frequent disturbance, usually due to flooding or periodic overbank deposits of sediment (H. Luttmerding, pers. comm., 1992). The Regosolic and Brunosolic soil orders are commonly found in riparian areas. They are composed of weakly developed soils indicating: (1) frequent disturbance by flooding or overbank deposition; (2) young age of the soils; or (3) slowness of the soil-forming processes such as those found in cold, dry climates. Gleyosolic soils (affected by high water tables) are also a common feature in some riparian areas. Stratification of streamside and lakeside areas according to soil types, in conjunction with other site characteristics, can be useful in showing riparian dynamics, including biogeochemical cycling and disturbance regimes.

5.2.4 Land and water classification in other parts of Canada During the late 1970s, the Canada Committee on Ecological Land Classification published two documents that investigated possibilities for integrating water into terrestrial classifications (Welch 1977, 1978). This work tended to concentrate on reconnaissance-level mapping at small scales. Welch (1978) highlighted some water-related variables, such as runoff response, river regimes in small watersheds, and drainage pattern, that can be inferred from land data. However, particularly for lakes, some factors specific to the aquatic environment cannot be gleaned from terrestrial information.

The National Wetlands Working Group has developed a national wetlands classification scheme that has been applied and tested throughout Canada. The main wetland types include bogs, fens, swamps, marshes, and shallow water (Environment Canada 1987b). Field manuals for British Columbia's Cariboo region (Runka and Lewis 1981; Steen and Roberts 1988) also have a classification scheme for shallow open water, bog, fen, marsh, swamp, shrub-carr, and meadow classification.

Alberta has developed, through the Alberta Water Resources Commission, its own wetland classification scheme that is divided into two types of wetland areas: nonpermanent wetlands and permanent wetlands. The main difference between the National Wetlands Working Group scheme and the Alberta Water Resources Commission study is the greater number of categories recognized by the latter and its inclusion of both lakes and streamcourses (Usher and Scarth 1990). Lakes and streams are considered permanent wetlands along with bogs and fens and permanent sloughs and marshes.

5.2.5 Classifications used in the United States

Stream Type Classifications in the Pacific Northwest The Pacific Northwest Region of the U.S. Forest Service uses four stream classes (Swank 1990):

- *Class I:* perennial or intermittent stream or segment that constitutes (1) a direct source of domestic water use, or (2) spawning, rearing, or migration habitat for a large number of fish, or (3) a major source of water for a class I stream.
- *Class II:* perennial or intermittent streams (1) used by a moderate, but significant number of fish, or (2) constituting a moderate or not clearly identifiable source to a class I stream or a major source to a class II stream.
- *Class III:* all other perennial streams.
- *Class IV:* all other intermittent streams.

The Pacific Northwest Region stream classes apply more generally than does British Columbia's coastal fisheries/forestry guidelines stream reach classification by including domestic water sources. General management goals are associated with each class and are fairly similar to those in the *British Columbia Coastal Fisheries/Forestry Guidelines*. Class I and II water quality must be maintained, while management near or in class III or IV water must ensure that class I and II waters are not degraded. The classes are linked to management goals and current resource uses rather than to detailed biophysical similarities and differences among streams.

The Oregon State forest practice regulations define two water classes, with one subdivided (Oregon Department of Forestry 1987):

- *Class I:* streams, lakes, estuaries, and wetlands important to fishery, domestic, and recreational use.
- *Class II: Special Protection (SP):* waters that cool temperatures of class I water that is at or near limits to fish production.
- *Class III:* any water other than class I that has a definite channel or bed.

Washington State incorporates a system of five water types, described in the forest practices regulations. Water types are defined by flow volume, surface water areas, or upstream drainage area. Associated wetlands are included in water type definitions:

- *Water type 1:* lakes greater than 9.4 ha and associated wetlands
  - west of Cascades: mean annual flow greater than 1000 ft^3/sec (28.32 m^3/sec)
  - tidal and estuarine areas are included
  - east of Cascades: mean annual flow greater than 200 ft^3/sec (5.66 m^3/sec) or where upstream drainage area is 300 square miles (777 km^2)
- *Water type 2:* natural waters with high use or importance for domestic water, public recreation, fish habitat, and water quality protection.
- *Water type 3:* natural waters having moderate to slight use or importance for domestic water, public recreation, fish habitat, and water quality protection.
- *Water type 4:* natural waters that influence water quality in type 1, 2, or 3 streams. Perennial or intermittent.
- *Water type 5:* all other natural waters, including those without a well-defined channel, and perennial or intermittent seepage.

The stream and water typing systems in British Columbia and the Pacific Northwest are all similar; however, the Washington system is more quantitative. Also, while the British Columbia classes are geared to fish habitat, the other classifications, particularly those used in Oregon and by the U.S. Forest Service, recognize domestic water and recreational use.

The above systems classify waters mostly by size and current resource use. None uses geomorphic criteria, and hydrologic criteria, if used, are limited. Furthermore, quantitative bases for determining classes or types are not provided. Classifiers are left to interpret subjectively the meaning of significant, high, or moderate importance, and to determine which waters will have influence on downstream reaches. Some work has been done in the United States on developing more sophisticated stream classifications that might prove useful as hydrologic and geomorphic components in riparian classification. Rosgen (1985) described a stream classification based on gradient, sinuosity (length/width), width to depth ratio, channel bed material size, channel entrenchment and valley confinement, and surrounding landform features, soils, and bank stability. He defined 25 stream types using these, and further proposed sub-type criteria based on channel structures (organic debris, obstructions), riparian vegetation, stream size (bankfull width), flow regimen, bar features, and meander patterns. Gebhardt et al. (1989) incorporated Rosgen's stream types into a riparian classification that also includes riparian vegetation, soil, water regime, and different stream states (entrenchment, lateral erosion) that may occur as a result of stream bank or instream changes.

Frissell et al. (1986) and Parratt et al. (1989) described hierarchical stream classifications. For example, Frissell et al. suggested the following six-level hierarchy:

1. watershed (physiographic, climatic context)
2. stream system (surface waters in watershed)
3. stream segment (uniform bedrock)
4. reach (break in channel slope, valley width, sideslopes, bank material)
5. pool/riffle (uniform water depth, velocity, slope)
6. microhabitat (uniform patch in pool or riffle)

While financial and personnel limitations constrain the ability to survey and classify all streams at all levels, a hierarchical classification could be useful for planning at different levels, and would facilitate one's viewing of smaller areas in a larger context. Broad-scale planning is confounded by too much site-specific information, but local decisions made without a view to their wider consequences may be inappropriate.

Wetland and Deepwater Classification for the United States The Classification of Wetlands and Deepwater Habitats of the United States (Tiner 1984) is a general system with five broad hierarchical levels: system, subsystem, class, subclass, and dominance. The classification is based on a publication written by Cowardin et al. (1979). (The United States wetland classification is included here because it includes riparian and estuary areas.)

The systems included are: marine, estuarine, riverine, lacustrine (lakes), and palustrine. The two systems of interest here are riverine and lacustrine. Riverine is limited to freshwater river and stream channels and is mainly a deepwater habitat system. Lacustrine is a deepwater system, but includes standing water bodies such as lakes, reservoirs, and deep ponds. To more accurately reflect the intent of some system labels, Johnson et al. (1984) suggested changing riverine to fluvial. This makes sense, as Cowardin et al. (1979) clearly intended riverine to mean instream, not bank, habitat.

The United States system further divides systems into subsystems: subtidal (continuously submerged), intertidal, tidal, lower perennial (low gradient and velocity), upper perennial (high gradient and velocity), intermittent, limnetic (deepwater lake), and littoral (lakeshore boundary to 2 m depth). A further division of subsystems brings about classes that denote bed substrate or condition, or general vegetative community type. Subclasses specify material types and textures, and floristic physiognomy (e.g., broad-leaved deciduous, needle-leaved evergreen).

Cowardin et al. (1979) also divided classes into corresponding subclasses, as noted in Table 3. They listed some dominance type (flora and fauna) for each subsystem as well. The types list is not comprehensive, and tends to concentrate on eastern and southwestern United States areas. The vegetation component of this classification does not recognize successional stages. Since fish and wildlife habitat and recreation are affected by vegetation succession, this omission may decrease the management utility of this classification system.

TABLE 3 *Classes and subclasses in the classification of wetlands and deep-water habitats of the United States*

Classes	Subclasses
1. rock bottom	bedrock, rubble
2. unconsolidated bottom	cobble-gravel, sand, mud, organic
3. aquatic bed	algal, aquatic moss, rooted vascular (plants on or below water surface)
4. unconsolidated shore	cobble-gravel, sand, mud, organic, vegetated (non-persistent herbs)
5. moss-lichen wetland	moss, lichen (non-rock substrate)
6. emergent wetland	persistent, non-persistent
7. scrub-shrub	broad-leaved/needle-leaved deciduous/evergreen, dead (woody vegetation < 6 m)
8. forested wetland	same as scrub-shrub (woody vegetation > 6 m)

Terrestrial Riparian Classification in the Western United States Efforts to classify riparian areas in the western United States have occurred mostly in drier areas: Idaho, Montana, Wyoming, Nevada, and central Oregon.

Work in the Intermountain Region of the U.S. Forest Service (e.g., Youngblood et al. 1985, Padgett et al. 1989) has involved primarily vegetation community classification. Because of natural and human-induced (mostly grazing) disturbance, classification of vegetative potential has been difficult (W. Padgett, pers. comm., 1991). Therefore, efforts have concentrated on classifying existing vegetation, with the hope that monitoring over time will illuminate site potential. Similar to experience in British Columbia, classifiers in the United States have found that understorey (mostly herb) species rather than tree species are the best indicators of site differences. This is because tree species tend to be broadly distributed across sites while some understorey species are not.

It is sometimes difficult to predict site potential in areas that have been recently disturbed, because species are not present. The geomorphological substrate of riparian areas is generally more stable than vegetation, and also determines the effects that disturbance will have. Landforms, geomorphological substrate, stream gradient, valley bottom width, elevation, and stream discharge are controlling variables in stream dynamics and riparian development (Winward and Padgett 1988; Kovalchik and Chitwood 1990). Therefore, characterization and classification of riparian areas should incorporate information on geomorphological variables (T. Spies, pers. comm., 1991).

In a riparian association classification for central Oregon, Kovalchik (1987) correlated vegetation with physiographic region, riparian landforms (gradient, soil parent material, elevation), and fluvial surfaces (active floodplain, inactive floodplain, terrace, stream bank). A similar effort has recently been undertaken in coastal Oregon, where streamside area vegetation is being sampled and stratified according to geomorphic unit (T. Spies, pers. comm., 1991). In the coastal Oregon study, transects were run perpendicular to streams to a distance of 50–100 m to investigate vegetation mosaic patterns and help define species groups. No specific definition for "riparian" was used in the study design; one purpose of the study being to help characterize, and develop definitions for, streamside areas.

By linking plant associations and site characteristics, riparian complexes (Winward and Padgett 1988) or fluvial surface/riparian plant association groupings (Kovalchik and Chitwood 1990) can be defined. Areas belong to the same riparian complex if they have potential to support similar groupings of riparian community types. This concept is similar to the site association of the biogeoclimatic classification. If site data specific to riparian areas, such as streamside landforms and fluvial surfaces, are collected for biogeoclimatic ecosystem description, the riparian complex concept could be applied in British Columbia.

Winward and Padgett (1988) hypothesized that, given a relatively stable hydrologic regime, the relative composition of community types within the riparian complex will remain relatively constant over time. Location of community types may change over time due to fluvial processes, such as channel shifting, but the overall composition appears to remain the same.

The concepts being used to classify riparian vegetation in the western United States are not new to British Columbia. However, successional riparian areas have not been surveyed in great detail in this province.

5.3 Current Research Programs

5.3.1 British Columbia

Wildlife and Wildlife Habitat Within British Columbia, little current research is being conducted specifically to investigate the importance of riparian areas as wildlife habitat. Some studies, however, have resulted indirectly in findings of riparian habitat requirements for some wildlife species (e.g., grizzlies in the Flathead Drainage [B. McLellan, pers. comm., 1991]).

Recent wildlife habitat research on omnivores and herbivores documents the importance of riparian areas to wildlife. The Integrated Wildlife-Intensive Forestry Research Program has indirectly elucidated riparian habitat requirements for elk (K. Brunt, pers. comm., 1991; F. Bunnell, pers. comm., 1991). This Vancouver Island study recorded elk and deer habitat interactions and indicated the need for wet habitats. Riparian areas were shown to be important habitat for elk, given the typically high nutrient levels and moisture abundance of the areas.

Similarly, studies in the Selkirk Mountains show that grizzlies select moist habitats of early successional stages. Typically, these habitats are old burns, old clearcuts, avalanche chutes, and, in some instances, riparian areas. Tony Hamilton's work in the Kimsquit and Khutzeymateen areas indicates that riparian habitat is extremely important to grizzly bears for seasonal habitat requirements (Hamilton and Archibald 1985).

A greater understanding of riparian habitat requirements for wildlife is an overall management concern among habitat experts. Wildlife biologists throughout the province mentioned several management issues that they felt deserve policy and research attention. These include conservation of biodiversity, retention of sensitive floodplains, conservation of interior cottonwood habitats, "environmental reconstruction," conservation of furbearer habitat along streams that do not have fish in them, and retention of upper riparian areas as habitat for big game.

Fish and Fish Habitat Several fisheries research projects are currently under way throughout the province of British Columbia primarily under the direction of the federal Department of Fisheries and Oceans, with headquarters in Nanaimo and West Vancouver.

The Carnation Creek study (continuing, but from which Fisheries and Oceans has withdrawn) is the largest and most extensive fisheries-forestry interaction study in North America. The Department has published an annotated bibliography of research done in Carnation Creek between 1970 and 1988 (Poulin and Scrivener 1988). Further updates are available from its office in Nanaimo.

The second largest study was a synopsis recently completed in the Barkley Sound and Clayoquot Sound areas, which revealed important riparian information. Four data reports have already been released and four more papers will be released in future publications.

Just south of Barkley Sound, a small "paired watershed" study is in progress in the Klanawa Creek area. Fish densities, growth, species, and numbers will be recorded for pre- and post-logging conditions. The whole project involves three watersheds: one in Pacific Rim National Park that will not be logged; one that will be logged for 2 or 3 years; and a third that is planned for timber harvest in 10 years.

Continuing research in the Slimtumuch area, east of Prince George, will examine sedimentation and summer and winter logging impacts on trout and chinook fisheries. Work is progressing on the Stuart-Takla project, which is another "paired watershed" study. It will examine instream gravel quality, sedimentation, and temperature effects on sockeye. Finally, two databases have been prepared for the North and South Thompson rivers for interior timber harvest guidelines.

Most of these are purely fisheries projects that incidentally contain riparian information. The Fisheries/Forestry Interaction Program being carried out on the Queen Charlotte Islands is just as relevant, as this program engendered a major interest in large organic debris. Carnation Creek is currently evolving into what may become in part a real riparian zone succession study (S. Chatwin, pers. comm., 1991).

Fisheries and Oceans has also looked at direct water removal from larger river systems by agricultural development and the impacts these practices have on reducing fish habitat and consequently, fish stocks (K. Wilson, pers. comm., 1991).

No research has been done by any provincial government agency specifically on the relationship between riparian conditions and fisheries habitat (D. Hamilton, pers. comm., 1991). However, the Research Section of B.C. Environment's Fisheries Branch at the University of British Columbia (UBC) is currently investigating freshwater pollution control, salmonid enhancement strategies, stream rehabilitation methods, effects of logging practices on fish yields, and methods to mitigate the detrimental effects of large-scale water diversion projects such as dams. There are plans to investigate the effects of stream fertilization on adjacent riparian vegetation.

Water Resources Some research is currently being conducted by the Westwater Research Centre at UBC. The research program is an assessment of water resources, riverine systems, and sustainable development concepts as they apply to large rivers, using the Fraser River as a case study. The program will include a compilation of existing information, and an evaluation of viewpoints on sustainable development. The goal is to determine whether current management practices are consistent with sustainable development in the Fraser River basin.

Agriculture and Range Within British Columbia, no research specifically on riparian areas was found within the provincial Agriculture, Forestry, or Environment ministries (D. Blumenauer, pers. comm., 1991; G. Strachen, pers. comm., 1991; R. Tucker, pers. comm., 1991; B. Wikeem, pers. comm., 1991). Guidelines are developed for the province on a site-specific basis and the only closely related research was in the interior of the province, where a study examined impacts on wetlands and estuaries (B. Wikeem, pers. comm., 1991). According to D. Demarchi (pers. comm., 1991) and D. Blumenauer (pers. comm., 1991) there is no research under way in British Columbia on the impacts of agriculture and range on riparian areas.

5.3.2 United States Pacific Northwest

Wildlife Washington and Oregon have several research projects that look at riparian areas as habitat for wildlife both directly and indirectly. In Washington, Dr. Ken Raedeke has done extensive research through his own consulting firm and the Center for Streamside Studies. In the Olympia area, research projects examining old-growth wildlife habitat, landscape ecology, and forest succession have a significant riparian ecosystem component. For the most part, forestry and wildlife interaction studies address riparian issues indirectly; specific aspects of riparian areas are directly addressed by graduate work through the University of Washington, at the Center for Streamside Management.

Within the Coastal Oregon Productivity Enhancement Program, studies have focused directly on riparian management questions, as well as reforestation questions (A. Hanson, pers. comm., 1991). Bird and small mammal work has been a focus for riparian studies in the past. Currently, the Coastal Oregon Productivity Enhancement Program is looking more at upland habitat, while Bill McComb, an associate wildlife professor at Oregon State University, will remain focused on riparian issues.

Fish Habitat Within the states of Washington, Oregon, and Montana there is a great deal of research investigating forestry impacts on riparian fish habitat (B. Marotz, pers. comm., 1991; T. Quinn, pers. comm., 1991; R. Rhew, pers. comm., 1991; T. Weaver, pers. comm., 1991). Agriculture and range impacts are addressed far less in this part of the United States; they receive greater attention in the Midwest (T. Weaver, pers. comm., 1991).

The Timber/Fish/Wildlife Program in Washington is currently examining several fish habitat parameters for potential impact from timber harvest

(T. Quinn, pers. comm., 1991). These include large organic debris in streams, sediment studies, and temperature studies. Other research involves relationships between fish size and overwinter survival for such species as chinook and coho salmon.

A significant amount of research in the Coastal Oregon Productivity Enhancement Program involves riparian/fisheries interactions (R. Rhew, pers. comm., 1991). Some specific studies include basin-level surveys in co-operation with the U.S. Forest Service to determine differences in fish populations as a result of different forestry practices. The Oregon Department of Fish and Game is investigating winter fish populations and enhancement structure benefits. They are also surveying woody debris piece size in clearcut and mature forested sections of streams to determine any significant differences. Several Master's theses on various fish habitat studies have also come out of Oregon State University. Riparian fisheries habitat enhancement projects are also under way throughout the state.

In Montana, the Fish, Wildlife, and Parks State Office is conducting several riparian fisheries research projects focusing on species such as bull and cutthroat trout. Tom Weaver, fisheries research specialist, has received a contract consisting of eight different study modules for fish and forestry interactions. He will be looking at forestry impacts on water quality, fish spawning and rearing, and embryo survival to emergence. Furthermore, a rehabilitation program is under way in an area where a dam was constructed, and heavy grazing took place. Once the vegetation is brought back, cattle will be fenced out of the area.

Agriculture and Range Oregon has been the most active state in researching agriculture and range impacts on riparian areas, through both the Bureau of Land Management and Oregon State University (D. Blumenauer, pers. comm., 1991; M. Chaney, pers. comm., 1991). Washington appears to participate in such studies on a conservation district basis only, pending a local advisory system (M. Chaney, pers. comm., 1991).

From the University of Oregon, Dr. Bill Krueger reports a great deal of riparian-related range research and, to a lesser extent, similar agriculture research. Primarily, projects have examined nutrient cycling of phosphorus and nitrogen in riparian areas east of the Cascades. Studies have focused on methods to minimize fecal coliform counts. The Oregon results indicate that nutrients within the riparian zone are efficiently filtered during anaerobic reduction processes, the riparian ecosystem thereby acting as an "environmental sewage system."

Wayne Elmore, State Riparian Co-ordinator for the Bureau of Land Management in Oregon, is regarded as the riparian/range interactions expert and has done extensive work in this field (C. Bacon, pers. comm., 1991; D. Blumenauer, pers. comm., 1991; J. Buckhouse, pers. comm., 1991). Elmore maintains that the work is not robust research, but rather comprises monitoring studies of streams under different grazing strategies. He has found success with both early and late winter and spring grazing. Continuous season-long grazing has proven to interfere with normal functions of the stream. These functions are based on the interactions of soil, water, and vegetation and allow natural narrowing of the stream channel, recharging of aquifers, and proper filtering of sediments. Currently, Elmore is involved in an intensive study in the Camp Creek area of Oregon, looking at water tables within a 5-mile (8 km) long livestock exclusion zone. Within the near future, he will also be documenting grazing and juniper relationships in riparian areas.

Elmore has published a workbook on the different grazing systems with John Buckhouse, another leading riparian/range interactions expert in Oregon (C. Bacon, pers. comm., 1991; B. Krueger, pers. comm., 1991). Buckhouse is currently a professor of range at Oregon State University and has been involved in many range impact research projects. Results of one study indicate that if water troughs are provided with hay feed put out in winter, livestock will spend 90% of their time at the water trough rather than in a riparian area with hay feed. This results in lowered stream coliform counts. In another study in the Bear Creek area of Oregon, Buckhouse is looking at summer results of watering troughs and different fencing configurations to keep livestock out of the stream.

Research is beginning to investigate pollution impacts of agriculture. Specifically, Buckhouse will be involved in a project on the Tualatian River, near Portland, looking at phosphate inputs upstream and downstream from farm fields. From these results "best management practices" will be devised.

Washington State is not conducting research to the same extent as Oregon and instead has been more involved in fencing along stream banks and monitoring coliform counts before and after fencing (M. Chaney, pers. comm., 1991). Grazing is reported to be fairly intense in Washington and work has been done to keep livestock out of the streams and prevent trampling, erosion, and a reduction in streamside vegetation. In western Washington, various health departments have also monitored coliform counts upstream and downstream from grazing areas, but no replicative studies have been conducted. Eastern Washington has looked at different types of grazing systems. Research specifically on agriculture impacts was not found; however, some agriculture guidelines were in place.

6 A BASIS FOR RECOMMENDATIONS

6.1 Definition of Riparian

In this section we provide an overview of ideas generated by the questionnaire and workshop described in the Introduction. Input from the workshop was recorded by the reporters from each subgroup. Input from the questionnaires has been compiled into groups of similar responses to give a sense of how prevalent the ideas are in the sampled community. Since a respondent may have mentioned several ideas within one section, the percentage of respondents voicing an idea and the percentage of references to an idea within a section are not identical. Where appropriate, specific contributions are referenced or quoted (sources of quotations are obtainable from the senior author if the respondent permits).

6.1.1 Questionnaire responses This section presents the perspective on an appropriate definition of riparian areas. The question being asked was:

> *Although a riparian strip, adjacent aquatic systems and uplands can be artificially separated, they interact as a riparian ecosystem.*

Due to climatic and geologic differences, the processes linking aquatic, riparian and upland areas vary regionally. This linkage is reflected in a definition of riparian as "Land that influences or is influenced by an adjacent body of water." Although this definition provides flexibility for a logical site and situation-specific interpretation of riparian, it becomes cumbersome for legal and regulatory concerns.

Do we need an unambiguous (arbitrary) definition of riparian, or should we work with a basic (functional) definition such as the one specified above?

Sixteen percent of respondents said that the definition was adequate as given. Over half (58%) indicated a preference between a functional and arbitrary definition; 86% of those favoured the functional definition. Most of these (73%) noted that ecosystems are not arbitrary, but instead are dynamic and complex, and thus felt that management must be flexible and take place with site-specific considerations. One interesting comment was that an arbitrary definition would lead to attempts to discover loopholes and evade the intent of legislation and policy.

The offered alternative definitions included:

- Land bordering a river, stream, lake, reservoir, pond, bog, or spring that can vary considerably in size and can be identified by the presence of vegetation that requires free or unbound water sources and physical characteristics including soil, elevation, topography, gradient, and soil.
- The land, together with the vegetation it supports, immediately in contact with the stream and sufficiently close to have a major influence on the total ecological character and functional processes of the stream.
- The wet soil areas next to streams, lakes, and wetlands. These areas have high water tables and soils which exhibit characteristics of wetness. Water-loving plants are often associated with these areas.

6.1.2 Recommendation for definition A suggested definition for riparian areas in British Columbia is as follows:

The land adjacent to the normal high water line in a stream, river, lake, or pond and extending to the portion of land that is influenced by the presence of the adjacent ponded or channeled water.

Determining the level of influence means that an understanding is first needed of the soil, plant, and vertebrate communities typically found in riparian areas. A riparian "species and soil table" indicating traditional riparian communities or indicator species would assist in field identification. A sample of this table should be developed initially, using current information on British Columbia species and updated as further research is undertaken. Some areas that should be defined as riparian in the province are described here.

Forested Riparian Areas *Alluvial Ecosystems* are forested ecosystems that lie adjacent to rivers (and sometimes lakes) and are periodically inundated. For most of the year, however, soils are not saturated. Alluvial ecosystems are very common along the lower- and medium-gradient reaches of rivers throughout British Columbia, and provide a very important component of wildlife habitat in the watersheds they drain. In coastal British Columbia, alluvial ecosystems have been divided into low, middle, and high bench site associations (see Banner et al. 1990; McLennan 1991) according to the timing and duration of flooding. These units may have to be expanded or amended as more detailed work is carried out. Flooding classifications have also been developed by Beaudry et al. (1990). All regional ecological guides in British Columbia delineate alluvial floodplains as separate site units. These units are familiar to most field personnel.

Forested Wetlands (Swamps and Bogs) are forested (or sometimes semi-forested) ecosystems that are often (but not necessarily) associated with rivers and lakes. They are characterized by wet and very wet soil moisture regimes for the entire year. Swamps generally have higher nutrient status than bogs because of mineral nutrient inputs. They may develop on mineral (Gleysols) or Organic soils, and provide growing conditions for important browse species such as skunk cabbage and other nutritious herbs and shrubs. Bogs also occur where drainage is impeded, but nutrient levels are much lower because of a lack of subsurface mineral inputs (in true bogs, nutrient input is entirely atmospheric). Swamps and bogs are often associated with alluvial floodplains in backwater areas where levees of meandering rivers impede drainage and create inter-levee basins. In such situations, these ecosystems would be included under the "riparian" definition above. Swamps and bogs may also occur in landscape depressions not associated with rivers and lakes and are common under both conditions in most areas of British Columbia. Regional Ministry of Forests field guides have keys for identification of swamps (nutrient medium to very rich, wet to very wet edatopes) and bogs (nutrient very poor to poor, wet to very wet edatopes).

Other Forested Ecosystems are those areas affected by water levels in lakes and streams. Ecosystems on alluvial-colluvial fans are periodically inundated by high-energy flooding and sedimentation. Such ecosystems are abundant in valley systems in all areas of the province. Because they support vegetation communities similar to those on alluvial floodplains, they have many of the same values as wildlife habitat. Also, areas of low relief along lakeshores may have water tables that fluctuate with those in the lake and give these sites a moist to very wet soil moisture regime. Such situations are relatively uncommon in British Columbia, although they form an important wildlife habitat component where they do occur.

Non-forested Riparian Areas This group of ecosystems includes a range of different plant communities that vary with climate, nature of flooding, and other abiotic factors. They are distinguished primarily on the basis of vegetation physiognomy and have been summarized in the Canadian System of Wetland Classification (Zoltai et al. 1979). Non-forested wetlands are abundant throughout British Columbia, especially on the shores of ponds, lakes, and streams, and in depressions within floodplains or non-riparian landscape depressions. They form an extremely important component of habitat diversity in any region, and have been the focus of considerable management and research. Non-forested communities are not dealt with in Ministry of Forests regional guides, but have been classified and described to some extent by other agencies.

Within the strict definition of riparian, there are areas that will be excluded even though they lie adjacent to streams or lakes. It is therefore recommended that a riparian management zone be applied to all areas adjacent to streams and lakes. Thus, in a recommended riparian management zone, the following areas will be included when management actions are considered: (1) those areas where, instead of the water influencing the land, the land influences the water body; and (2) those riparian areas that are small because the amount of area actually influenced by the water is nominal, or where the land-water interface is a steep bank or cliff. Riparian management zones would be wider than the defined riparian areas and, in areas where there is no defined riparian area, would include land adjacent to streams and lakes. Determination of the width of the riparian management zone should be done on a site-specific basis with minimum standards set for the whole province. If necessary, a buffer should also be established in site-specific areas to protect the riparian management zone.

The recommended definition is functional and easy to remember, which was the main concern of the questionnaire respondents. It does not, however, respond to the need for a legal definition, which would require further work by professionals versed in this area. The main consideration in the development of any definition is that it clearly makes the distinction that the riparian area is separate and lies between the other two ecosystems: uplands and water surface.

6.2 Strategy for Integrated Resource Management of Riparian Areas

6.2.1 Questionnaire responses The following sections summarize respondents' ideas about what is lacking in the current approach to integrated resource management and how these shortcomings could be overcome.

Barriers and Resolution Questionnaire respondents were asked to identify the issues they perceived related to integrated management of riparian areas (described in Section 3.1).

Lack of Information The greatest single barrier against achieving integrated management of riparian areas, as perceived by the respondents (the majority of whom are actively engaged in management), is a lack of information.

A similar distribution in the perceived information needs emerged from a question on the preferred expenditure of a hypothetical very large donation of funds. Namely, 58% of the total responses specified allocation of the funds to basic research, either on the natural system (36%) or on the impacts of human activities on the system (22%). Inventory systems would have garnered 23% of this windfall were it real, and the remainder would have been allocated to research on management methods, planning, and values (in that order). Further detail on perceived research needs is presented in Section 6.4.

Lack of Support Lack of support for integrated management of riparian areas was mentioned in some form by more than half the people discussing barriers to management. Among the perceived reasons for lack of support were:

- economic barriers;
- inadequate understanding and inappropriate attitudes in the society as a whole; and

- inadequate government or agency commitment.

These three sets of reasons were mentioned with equal frequency.

Most respondents who mentioned economic barriers were concerned with the economic pressures on the forest industry, forest tenures, overcommitment of resources, and the industry's unwillingness to forego economic opportunities. A few mentioned similar concerns with power production (hydro and petroleum) and a few recognized the impact of population growth on resource demands, and hence resource economics.

Respondents felt that if the general public understood the values inherent in riparian areas, and the importance of these areas to acknowledged values, there would be far more support for integrated management. Part of the difficulty was seen to be the relative invisibility of riparian issues, and part was seen to be our general inability to measure, and hence recognize, noneconomic values. Finally, a need to change was identified, although a lack of trust was seen as an impediment to change.

A practical solution to changing social goals (other than education) offered by several respondents was to broaden perception of resource values through the development of more secondary industry, so that there would be less reliance on primary forest industries.

Suggested approaches to remedy the lack of commitment included Cabinet involvement in determining objectives, responsibilities, and accountability. Many recommended that the power of the Environment and Forests ministries be strengthened, and that various appropriations of funds be made to support integrated management. One respondent felt that continuity achieved through a guaranteed 3-year minimum tenure of ministers would ensure more commitment, and many felt that increased public pressure was required to precipitate political action.

Lack of Adequate Management Of all the barriers mentioned, about a quarter could be categorized as inadequacies in management, deficiencies in objectives and long-term planning, lack of adequate methodologies for integrated management, poor procedures; and lack of guidelines for practical management decisions.

Inadequacies in long-term planning were referred to by about a third of all respondents. A third of these felt that we simply lack an adequate comprehensive integrated resource management or land use plan. Another third specified that the allowable annual cut is inappropriately formulated to support or even permit the consideration of non-timber values, and that both yield analyses and Timber Supply Area plans do not adequately account for these values. Most of the rest referred to a lack of objectives suitable for long-term planning.

The basic recommendation called for overcoming the inadequacy in long-term planning. Respondents clearly felt that long-term planning is not an issue of riparian management alone, and specified that it should be part of a general landscape-level land use strategy.

Suggested approaches included holistic ecosystem planning, coupled with economic analysis and an adaptive management process by which forestry activities are planned at the landscape level. The plan should be flexible enough to incorporate new information as it becomes available, and should explicitly include a monitoring component.

Requests for better methods to use in integrated management included methods for determining priorities (ones that adequately accommodate nonmonetary values) and better harvesting or silviculture procedures that would preserve essential attributes of riparian areas. Several people recommended these be developed through a workshop and committee process, as well as through an experimental approach.

The basic recommendation for guidelines was direct: develop guidelines and ensure immediate release of revised guidelines. The details requested included requiring colour aerial photographs, specifying acceptable levels of disturbance on a regional basis, specifying guidelines according to classes of lakes and waterways, addressing the unique character of each riparian area, and encouraging local level interactions with other users and the public.

Lack of Legislation and Regulation Lack of legislation and regulation was mentioned as a barrier to integrated resource management by 10% of the respondents, but three times as many offered legislation and regulation as a solution to their concerns in another part of the questionnaire. Economically based controls (such as tax breaks for good management, financial penalties for infractions, and a reduction in the allowable annual cut) accounted for half the recommendations. The rest of the recommendations specified improved legislation, regulation of use through zoning or access, protective measures such as moratoria or reserves, and better standards for construction and resource use.

Lack of Education Only 10% of respondents specified lack of education as a barrier to integrated resource management. But elsewhere in the questionnaire, 28% of respondents stated that education would overcome barriers to integrated management. Seventy percent of these respondents specified public or community education; the rest were concerned with the education and training of managers and field staff. The recommendations for education are presented in Section 6.5.

6.2.2 Management on local and provincial levels Many of the concerns associated with integrated resource management were expressed by both questionnaire respondents and the workshop participants. Two subgroups within the workshop addressed management from local and provincial perspectives. The provincial subgroup discussed a strategy for integrated resource management, whereas the local management subgroup discussed barriers that occur in individual management areas.

6.2.3 Provincial management Common themes that emerged from this subgroup were:

1. *Clarity of Goals and Objectives:* Management goals and objectives should be clear from the outset. Without clear goals and objectives, further actions will likely be undirected and inconsistent. Goals and objectives are (or should be) products of social discussion, and should guide resource managers in their activities. The public should therefore be encouraged to discuss and decide on appropriate goals and objectives for riparian resources.

2. *Education:* Education and awareness-raising is required at all levels of decision making and planning. This applies to both the private and public sectors. At the local level, operators, developers, and landowners should be apprised of the importance of riparian resources, and the availability of guidelines to assist in protecting these resources. At higher decision-making levels, those with power should be made aware of the need to protect riparian areas through policy and legislation.
3. *Land Use Planning:* Land use planning is required to form a framework for local planning, and to provide some certainty that local initiatives within the plan will receive support from higher levels.
4. *Guidelines:* Management practice guidelines should provide flexibility to local conditions, and should be clear and consistent. Guidelines for riparian areas should be integrated into existing manuals. Such guidelines should merge requirements to protect all riparian values. What should be avoided is developing a manual for each resource value separately.
5. *Local Involvement:* Involvement of local government is crucial if riparian resources are to be adequately protected. If local governments are to participate in land acquisition and restrictive zoning, they must receive financial support, and be shown how such activities will be in their interests.
6. *Local Discretion:* Discretion at the local level of resource management is required if decisions (including how to delineate riparian management zones) and development prescriptions are to reflect site-specific factors.
7. *Legislation:* Legislative change is required to ensure that riparian resource protection is undertaken consistently by all interests involved. Furthermore, additional legal protection should be accorded riparian values such as wildlife habitat (game and non-game), recreation, aesthetics, non-commercial fish habitat, and associated water quality.
8. *Increased Staffing:* Resource agency staffing should increase. Current staffing levels are too low to deal adequately with development proposal referrals and monitoring tasks.

Two other points made during the workshop deserve mention. First, it is important to distinguish between standards, which effectively encourage damage up to a point, and guidelines, which provide insight into overall management goals and incentives for good management. Second, management for the most important values (biodiversity, wildlife, fish, water) should ideally work within a landscape perspective. One must not lose this perspective by focusing too heavily on the riparian issue.

Elements Required for Provincial Strategy The following requirements provide a starting point for developing a framework for co-ordination between participants. The workshop allowed time only for a preliminary view of the elements that would be required in developing a provincial strategy for integrated resource management. Implicit in the discussion was that this strategy would be applicable to other areas even though the workshop focused on riparian areas. The provincial processes subgroup identified three major subjects that require particular attention: values, methods, and implementation. Interwoven through these considerations was the recognition that approaches other than confrontation and trade-offs are possible — namely, approaches ("win-win") where all parties may benefit. However, the development of these more favourable approaches requires imagination and thought. The point was made that we cannot afford to proceed without thoroughly thinking through options and processes.

Values Underlying all the issues related to integrated resource management are the noneconomic values that determine goals, objectives, and practice. Where an agency is charged with the management of a single resource (e.g., mining), the underlying values are relatively simple. To effectively manage when considering many different resources (e.g., mining, forestry, and water quality), as one must do in integrated resource management, we must articulate and work with the various underlying values. This requires the development of a vocabulary, a framework for considering a variety of values on equal footing, methods and process for value assessment, and a means for implementing management such that the values are accepted and understood at a local level.

The process for value assessment cannot be completed in isolation by the groups who hold the different values. The definition, assessment, and setting of value standards require the involvement of all participants, including managers, users, and the public. This process can be helped if an independent body is used to do an unbiased job of resource valuation, which assures the consideration of local uses and encourages local incentives. We must also overcome the problem of the provincial Cabinet having an ability to override land use decisions once the will of the people has been determined. Whatever process is implemented, it should have a built-in mechanism for value assessment review and revision in response to changing priorities.

Analysis to Support Decision Making To determine strategic options for integrated resource management, one must be able to consider alternatives. This generally means trade-offs and costs of actions. Analytic techniques are needed to clarify trade-offs between resource management objectives and to evaluate the per capita public cost of protective measures in response to environmental values and ethics.

To accomplish provincial or regional integrated resource management, we must consider the larger or cumulative impact of various actions. This requires the capacity to measure and predict larger-scale implications of local aggregate choices. Applicable methodologies include cross-system or cross-use impact assessments and cumulative assessment models.

Suggestions for Implementation of Integrated Resource Management Several points about the implementation of an integrated resource management framework were discussed:

- There are currently insufficient staff to police management and apprise the public of development ramifications.
- Incentive systems (e.g., economic) are needed to ensure compliance.
- Appropriate tenure arrangements are important for encouraging local people to undertake incentives for integration and valuation.
- Imagination is required to develop more effective approaches because we do not have enough human resources to accomplish locally based planning and management at the required level of expertise and detail throughout the province.

- Regional and provincial standards and limits are necessary for sustainable development. These attributes should be determined by the provincial government and revised to suit local needs.
- Legislation is required to provide for, or encourage development of, positive economic incentives for compliance. This should include incentives to local private and community interests and a more effective land tenure (Tree Farm Licence status) involving more users.
- Biophysical monitoring is a necessity for the evolution of management methods and approaches, and for the re-evaluation of values and goals.

6.2.4 Local management The workshop subgroup concerned with management on a regional or site-specific basis identified gaps where the present system does not incorporate riparian concerns. They suggested solutions or alternative management techniques to resolve the problems listed in other parts of this document. Some can be incorporated immediately into the present system, while others will need to be enacted over a longer period of time.

Listed below are those suggestions:

1. *Training of Personnel Involved in the Mining Industry* Solutions to the lack of reclamation carried out after exploration involve communication and training rather than police efforts on all levels (field management and policy). For example, policy makers should be apprised of the importance of riparian resource values and the need to design mining to maintain these. This is crucial because people at higher levels set standards for field-level work. However, policy-setting does not preclude the need for field training of operators or government staff.

2. *Biodiversity* There is a need to expand the present management process to include noncommercial ecosystem components. This applies to research, guidelines development, and legislation. Some ways to improve local management include:
   - conducting inventories before development that include a broader, technically quantifiable range of flora and fauna;
   - amending the provincial *Wildlife Act* and provincial *Fisheries Act* to include protection of habitat for nongame species such as provincially recognized threatened and endangered species or Wildlife Habitats of Major Concern (B.C. Ministry of Environment 1991);
   - dovetailing protection needs for non-fish resources with the *Coastal Fisheries/Forestry Guidelines* to minimize the number of documents operators and resource managers must consult when designing activities; and
   - enacting private land management legislation, land purchase, municipal zoning, and agreements with landowners to undertake habitat protection measures. Proposals for legislation included something similar to the Ministry of Forests' private land forestry amendment, or a land practices act to protect endangered species habitat on private land.
3. *Agriculture and Range* One solution has been to spend available government funds on fencing to limit cattle access to riparian areas. This has been done in the Fraser Valley by the Department of Fisheries and

Oceans. Currently, those wishing to protect water quality and the riparian zone from grazing must take the initiative and fund projects (e.g., Naramata watershed near Penticton).

Research is required to determine the carrying capacity of soils to absorb animal wastes, and thereby facilitate planning to limit grazing densities.

A recommended legislative solution was to encourage local governments to pass bylaws that limit access to waterways.

4. *Post-logging Site Treatment* Post-logging treatments such as scarification and slashburning that occur adjacent to riparian areas can affect water quality, and the availability of dead and down material for wildlife habitat and soil regeneration. Slashburns often escape into standing timber and may damage riparian vegetation. A related problem is that post-harvest treatment is not accorded as much attention as the harvesting stage by Ministry of Forests staff.

   While a simple solution would be to not perform these actions in riparian areas, timber licensees are required to restock harvested blocks, and disallowing these activities would make regeneration of conifer species very difficult in some areas.

   Potential solutions might include:
   - providing licensees with reforestation exemptions in sites near riparian areas, meaning that the Ministry of Forests would have to accept less of its timber production objectives in these areas.
   - Pre-harvest Silvicultural Prescriptions are a good way of ensuring that site information is incorporated into decision making related to harvesting. The process for choosing Pre-harvest Silvicultural Prescriptions should be modified to become an interdisciplinary effort to ensure that all interests sanction the decision.

5. *Workers' Compensation Board* Workers' Compensation Board rules for timber harvesting currently conflict with proposed harvesting alternatives that call for more partial cutting and leaving of snags. This includes all snags within cut boundaries, and within two tree heights of the work area. Inability to implement alternative harvests could result in loss of wildlife habitat. The Workers' Compensation Board's interpretation of this policy has not been consistent. Historically it was interpreted conservatively, so that snag loss was maximized. The current trend seems to be that snags outside cut boundaries can be left if they cannot reach the opening, or if they lean away from it. There is some movement in the Workers' Compensation Board to ensure that interpretation of its snag policy is consistent throughout the province.

   Nothing in the Workers' Compensation Board policy precludes creation of future snags by leaving standing trees, and (if desired) accelerating snag development by killing the trees.

   Therefore, clarification of Workers' Compensation Board policy should assist in implementing alternative harvesting methods. This interpretation should be communicated to harvest planners and operators.

6. *Logging Road Construction: Access for Cattle to Traditionally Ungrazed Areas* This is slightly different from the issue discussed under point 3 above, which focused somewhat more on grazing in already developed areas. The main issue here is that appropriate protection (fences, cattle guards etc.) may not be present, and damage may be done to riparian resources before any action is taken.

   The solution consists of identifying potential problems during review of 5-year development plans, and communicating with cattle owners the need to protect riparian areas from livestock. The infrastructure required is not significant, and there is an appraisal allowance during stumpage calculations for timber licensees, so costs need not be borne by the forest industry.

7. *Community Watershed Guidelines Not Being Followed* Discussion on this point was brief. The main points were that the guidelines are not followed, that the degree to which watersheds are open to development and access varies widely, and that the provincial *Water Act* deals primarily with water quantity, not quality.

   Solutions to the problems lie in more attention to the need to protect water quality by using the community watershed management guidelines (although this seems unlikely, given the tone of the discussion), more consistent treatment of watershed access issues, and legislative change to increase protection for water quality.

8. *Water Diversion or Extraction and Small Hydro* This discussion focused on the effects on riparian areas of small hydro projects, and extraction or diversion of water for agricultural or domestic use, or to "reclaim" land to allow for development.

   Solutions include establishing minimum flow requirements to maintain downstream habitat, and avoiding over-licensing of water amounts. Also helpful would be to work on legislation, such as the *Water Act*, to ensure that fish and wildlife habitat is not degraded, and that instream recreation activities are protected. (Note: The federal *Fisheries Act* currently protects fish habitat, but it is normally used reactively to prosecute for damage done by introduction of deleterious substances, not by flow requirements.)

9. *Urban Development* One potential solution to habitat loss and water degradation is for local governments (municipal, regional district) to establish "development permit areas" under the *Municipal Act*. Such designation stipulates that no clearing can be done until the local council grants a permit. This arrangement allows Fisheries and Oceans and the Ministry of Environment to comment on proposals. While developers should refer proposals to these agencies anyway, the development permit area creates a more rigorous process. In the lower Fraser Valley, Fisheries and Oceans has suggested establishment of permit areas in official community plans.

   However, convincing local governments that development permit areas are a good idea can be a battle. For local governments to be involved in riparian (or other land type) protection, they must be shown the advantages. The advantages include the ability to plan for linear municipal parks or water access on a broad scale, rather than in piecemeal negotiations with many landowners. Both easier management and administration, and potential political "points" (designation of water-access parks), may be attractive to local government officials.

10. *Floodplain Management* To control floods and erosion, local governments frequently build dikes or line riverbanks with boulder-sized rock (rip-rap), which in turn affects water quality, quantity, and downstream flow.

    Several potential solutions exist. Diking that is set back can retain riparian habitat while protecting structures from flood damage. Municipalities could acquire riparian land that may otherwise be developed. Local governments should draft floodplain bylaws restricting activities (many municipalities already have these). Floodplains on provincial Crown land should not be zoned for development. Finally, both developers and potential purchasers should understand the various definitions for floodplains, that is, the different flood frequencies and related areas of innundation. This will require education, probably headed by the Ministry of Environment, which has floodplain expertise, and possibly the Ministry of Crown Lands.

6.3 Classification and Inventory System

There are a number of different levels by which riparian areas can be classified. It is important to differentiate between those that are based on theory and those that can be used to direct management actions. One theoretical classification scheme refers to the definition of riparian areas (Figure 3). Using the definition recommended in Section 6.1.2, "riparian" would refer only to those areas influenced by the presence of water. In this instance, land situated next to water may not be defined as "riparian" if it is not influenced by water. The next type of scheme would refer to actual classification units such as Douglas-fir–fescue or ponderosa pine–wheatgrass. Thus, in one area theoretically defined as "riparian," two or more types of plant associations may occur. The third level of classification would be the mapping unit or a combination of many plant associations such as Douglas-fir–fescue and ponderosa pine–wheatgrass. The last classification scheme would refer to how land next to streams and lakes should be managed. The riparian

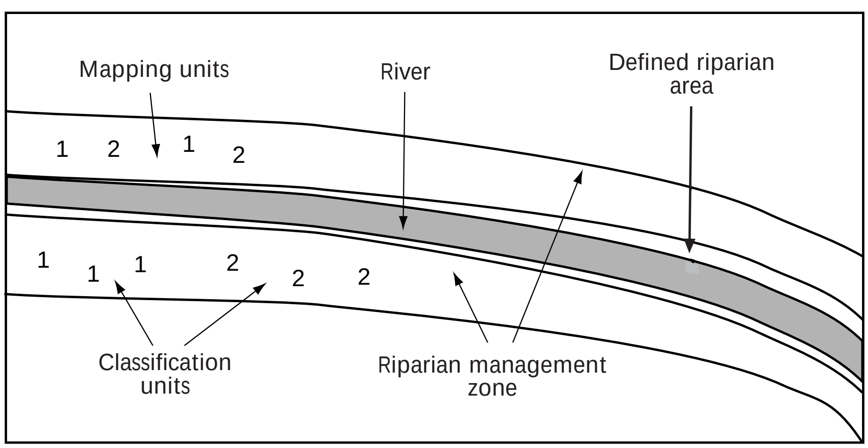

FIGURE 3 *Location of different classification schemes.*

management zone would include all the schemes mentioned above and would direct management actions in all areas next to lakes and rivers.

6.3.1 Workshop deliberations The following is a list of attributes that may be appropriate for characterizing a riparian zone:

- longitudinal gradient of valley
- valley shape
- bedrock geology
- surficial geology
- watershed aspect
- elevation
- hydrologic regime
- temperature regime
- precipitation regime
- soils
- species checklists, for example, presence and abundance (fish, wildlife, plants)
- water quality indicators
- vegetation effects on water body

Not all of these attributes may be required, and in some situations certain attributes found in other classification schemes may be necessary, depending on the inventory scheme chosen. The level of resolution or detail for any particular attribute will also depend on how that attribute fits in the inventory scheme.

Inventory Scheme An inventory scheme should be developed to accommodate and integrate a number of levels of detail, to accommodate planning at levels ranging from regional to site specific. Inventories suitable for regional concerns would require less detail than those that are site specific. Site-specific inventories would be useful for referrals, guidelines, and incentive programs, although additional on-site data may be required. Strategic planning can be accomplished at a slightly broader scale (e.g., 1:50 000), which provides a landscape context.

Co-ordination of information is required among all levels in the classification system. Therefore, the design of the classification system must ensure consistency at the detailed level, as well as in broad regional classifications. It must be possible to aggregate detailed surveys and local information from various sources into larger units that are both consistent and ecologically meaningful. On the other hand, regional information from any source should provide a meaningful context for detailed local information. Table 4 lists examples of parameters relevant to different levels of resolution.

It should be possible to classify riparian areas with existing data sets at the broad regional level. Polygonal maps of biophysical habitat units could be integrated with lake and stream surveys. The existing site series classification of the Biogeoclimatic Ecosystem Classification could be expanded to better characterize the riparian areas. Classification at the detailed level will need additional data collection. Several other information gaps were identified at the workshop:

- Terrain mapping is missing from north-central and northeastern parts of British Columbia.

- Although descriptive classifications exist, little has been done to produce interpretive classifications.
- Economically unimportant wildlife has not been inventoried.
- Much of the available information has not been publicized.

TABLE 4 *Examples of parameters relevant to different levels of resolution*

Attribute/ level	Levels of resolution 1:1 000 000	1:250 000	1:50 000	1:20 000 and more detailed
Climate	Regional climate	Snowpack, Degree-days		
Vegetation	Ecoregions Biogeoclimatic zones	Biogeoclimatic subzones	Habitat unit	Plant communities
Water	Hydrography	Stream/lake/ marsh	Hydrologic regime	Hydrologic regime
Topography	Valley/upland	Geology Elevation Terrestrial processes	Slope Gradient Aspect Elevation	Soils Slope Gradient Aspect Elevation
Species	Wildlife capability	Species richness		Species diversity
Current data available	Most available, requires compilation	Noneconomic species would have to be added to existing data sets	Appropriate data may be available with effort, except for noneconomic species	Appropriate data generally not available

Note: This table is incomplete due to lack of time in the workshop; blank spaces in matrix do not imply that no data is necessary.

Recommendations

1. An interagency committee should be convened to:
   - identify the attributes needed to describe each resource in the riparian zone;
   - standardize definitions for collecting and recording data;
   - standardize methods for collecting and recording data;
   - collate and publish existing information; and
   - direct efforts to fill gaps in existing data and gather new data.
2. Rather than developing a new classification, inventory, and mapping system, existing systems should be modified and integrated to accommodate riparian concerns. The linkage of linear elements from stream reach surveys to area elements and from ecological mapping will provide required information at a range of scales suitable for strategic planning and

site-specific referrals. The design of a riparian inventory should not proceed in isolation. Data from adjacent sites such as upland areas should be co-ordinated with the riparian data.
3. A set of guidelines for managing riparian areas at the site-specific level should be developed and integrated with other management guidelines.

6.4 Research Strategy

A research strategy should address the main impacts on riparian areas identified in Section 3 (e.g., forestry, hydroelectric, agriculture, mining, urban use, and transportation corridors) and include those recommendations made by questionnaire respondents and workshop participants. Section 6.4.3 suggests one process that could be used to develop this research strategy.

6.4.1 Community perspective When questionnaire respondents specified research as a means of overcoming barriers to integrated resource management, about half specified a need to know "how much and where," and the other half specified a need to know "how it works."

The question asked was as follows:

> *If the good fairy were to donate a large sum of money specifically for filling gaps in our knowledge about riparian systems, what do you think would be the wisest application of those funds?*

Half of all respondents specified basic research on ecosystem structure and function, a third specified impact assessment, and a fifth specified research on management or planning methodologies.

Ecosystem Structure and Function Most of the recommendations in this category were simply "baseline research" on the interactions and dependencies. A few areas were specified by at least five people each, namely: hydrologic research, wildlife habitat, biodiversity, and aquatic system interactions. Other recommendations made by individuals were species or location specific, or pertained to a specific process such as blowdown.

Impact Assessment Respondents requested more research on the impact of forest management regimes, including the comparative benefits of different silvicultural approaches on riparian areas. The need for information on the rates of change and recovery from various developments or disturbances, as well as long-term pre- and post-impact assessments, was also mentioned by 10% of respondents.

Planning Methodology Applied research programs and experimental management programs were requested in equal proportion. Applied research should be designed to explore how an array of riparian values could be maintained over the long term, particularly how alternative harvesting methods could be used to preserve these values. Experimental management was recommended as a specific approach to applied research — an approach that would rely on field trials and extensive monitoring and follow-up.

The need for research in planning methodologies or value assessment was also mentioned by 18% of all respondents.

6.4.2 Known research needs The following points were determined at a brainstorming session held at the end of the riparian workshop. They should be reviewed at the recommended follow-up workshop on riparian research.

1. Riparian needs must be defined, identified, and classified. Part of this will involve research.
2. Researchers must identify riparian-dependent species, including plants, nongame species, invertebrates, and amphibians, and quantify the degree of dependency.
3. The response of riparian-dependent species (or suitable indices of them) to changes in habitat because of natural and anthropogenic factors must be quantified.
4. The size and management of buffers and special management zones required to protect riparian areas and species dependent on them must be determined.
5. The links between riparian areas and others in a landscape must be studied.
6. Research is required in a provincial and regional context.
7. Research is required on different classes of streams (I to IV) and on how their function changes.
8. The effect of riparian ecosystem vegetation on the structure of stream channels should be studied.
9. Social research is needed to determine the extent of concern about riparian areas.

6.4.3 Suggested process for defining research needs Defining research needs is cyclic: information gaps are defined, research is carried out, guidelines are formulated, monitoring is accomplished, and the gaps are re-evaluated. There is no endpoint to this cycle, although the focus will shift as gaps are filled and new priorities emerge.

A general approach has been developed to assist groups in proceeding through the research planning cycle. It is based on a framework of "impact hypotheses" that clarifies what is currently known and what the gaps are. Impact hypotheses describe the connection between various management actions and their effects on the system. The hypotheses are developed by the researchers involved so that they each contribute their knowledge and so that all of them have a common understanding of the whole system. They are particularly useful in circumstances where complex ecological systems interact with human activities. The research subgroup of the riparian problem analysis workshop attempted a minimal version of the approach. The impact hypothesis approach, along with some preliminary development from the workshop, is described below.

The core of the impact hypothesis approach is the development and evaluation of a conceptual model of the environmental system. In some cases, it may be advantageous to translate part or all of the conceptual model into a computer simulation model. A computer simulation model is appropriate when there is a requirement for quantitative analysis or more rigorous assessment of uncertainties.

The model is structured to trace the effects of management activities on the environment. It may seem inappropriate to develop a model of a problem or system that is poorly understood, and about which much uncertainty exists. However, the model and the process of building it are very powerful devices for:

- integrating current understanding of the problem from a diverse set of perspectives;
- introducing rigour into discussions about the problem;
- identifying important uncertainties and information gaps in our current understanding;
- providing a vehicle for communication among interest groups participating in the project;
- reflecting the combined knowledge of all interest groups and thus being superior to the mental model of any individual; and
- representing a consensus about system structure and behaviour.

The development and evaluation of a model consisting of a set of impact hypotheses is most effectively accomplished in a set of workshops. This ensures that all interested parties contribute their knowledge and that the model is acceptable and comprehensible to all. The steps in building a set of impact hypotheses are:

1. Identifying the indicators or "valued ecosystem components" to be included in the models. These are measures to be used by the interest groups in evaluating the impact of the management activities. (A preliminary set of valued ecosystem components for riparian systems is presented in Table 5.)
2. Identifying the management activities to be considered. (A preliminary set of activities occurring in riparian systems is presented in Table 6.)
3. Defining the area and time that the impact hypotheses represent—that is, the domain in which management activities influence environmental indicators.
4. Grouping the system of concern into logical components and defining the interactions among these components or "submodels."
5. Developing impact hypotheses that represent a chain of connections within a submodel. (Although a few draft impact hypotheses were constructed during the workshop, these are very superficial at this time.)

Impact hypotheses are evaluated using existing evidence. The evidence may consist of data, experience, or results from computer simulations. Qualitative as well as quantitative evidence may be used, and often the experience of nontechnical interest groups is particularly important. The evidence for each link in the hypothesis is first evaluated independently, and then the significance of the entire hypothesis for the planning process is evaluated. For example, management activities or monitoring plans may be recommended, or research may be required to obtain further evidence for specific links in the hypothesis. An example decision tree that may be used for this evaluation is presented in Figure 4.

The first question (1) is to determine whether there is any evidence that the proposed effect or link exists. If quantitative (2) or qualitative (3) evidence already exists, it can be used directly for management (4). If qualitative information can be quantified (5), then research (6) may be appropriate. If it cannot be quantified, then monitoring may be recommended (7) or management will have to take place under uncertainty. If there is no evidence for the effect, the next question is whether this is an important link (8). If it is not important, no action is required (9). If it is important, and measurable (5), then research is recommended (6).

TABLE 5 *Valued ecosystem components*

Valued ecosystem component	Examples
mammals	mink beaver navigator shrew grizzly bear moose white-tailed deer river otter
birds	eagle osprey pileated woodpecker kingfisher warbler dipper shore-nesting birds (e.g., sandpiper) wood duck bufflehead
salmonids (members of aquatic, not riparian, ecosystem)	pink (minimum time in stream) resident cutthroat (maximum time in stream) kokanee coho char
amphibians	Pacific giant salamander tailed frog
invertebrates	mayflies (as for fish, above)
plants	cedar spruce (especially old Sitka and black) cottonwood rare and endangered plants
water quality (influenced by riparian ecosystem)	
biodiversity	
human use	visual camping sites fishing sites archaeological cattle access

TABLE 6 *Activities that affect riparian areas*

Activities	Examples
forestry	harvesting silviculture mechanical site preparation planting herbicides brushing thinning fertilization
developments	building urban expansion booming grounds hydro dams access roads seismic lines industrial effluent
placer mining	
range use	grazing trampling seeding watering (stock)
water regulation	irrigation water withdrawal diking/drainage water return (effluents)
agriculture	nutrient runoff fertilization species change
public use	camping trails

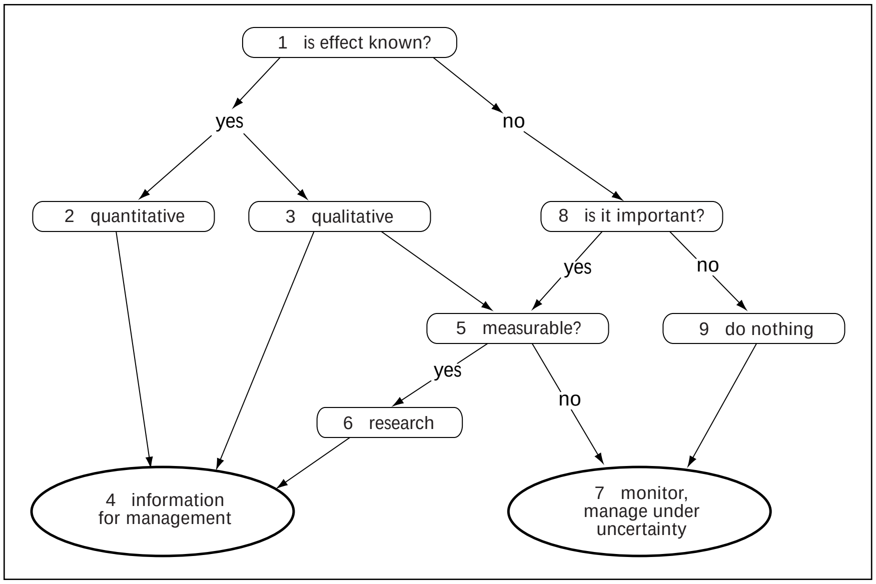

FIGURE 4 *Decision tree for impact hypotheses.*

There are several important advantages of hypothesis evaluation conducted in this fashion:

- The conceptual model (set of hypotheses) is evaluated in a workshop environment by all the concerned groups, and the conclusions therefore represent the combined expertise and perspectives of all participants.
- The conclusions reached by the participants are defensible because of the rigorous approach taken in evaluating the model.
- Any monitoring, research, or experimental management activities that may be recommended involve the testing of hypotheses, so that these efforts acknowledge uncertainty.
- The evaluations are biased towards management activities and indicators of concern to interest groups.

Alternative approaches to defining research needs for a complex environmental concern include expert judgement, selection by committee, or exhaustive listing of all possible needs. In the case of an exhaustive listing of all unknowns, two problems arise. First, it is difficult to know how exhaustive the list really is. Second, the list is inevitably longer than any research program could investigate, so priorities must be ranked. In practice, this is usually done by a committee.

The problems associated with expert or committee processes are several. First, the interest of the committee members greatly influences their perception of what is important. Second, the process is easily influenced by reputation or persuasiveness rather than by shared understanding. Third, it is very difficult to document the rationale of the decision made, and hence difficult to maintain credibility with those not party to the decision. A defensible ranking of research priorities requires a framework for the decisions made. This framework would provide linkages with the scientific method (hypothesis testing) and promote the development of a robust research program.

The impact hypothesis approach to research planning is specifically designed to be integrated with adaptive or experimental management. The hypotheses are constructed to suggest specific management experiments, and the results of these experiments provide further evidence to clarify the hypotheses.

6.4.4 Participation in a research program Research programs should be co-operative among university researchers, government managers, industry, and other stakeholders. Participants in the program should include representatives from:

- Ministry of Forests
- Ministry of Environment
- Ministry of Crown Lands
- Ministry of Agriculture and Fisheries
- Ministry of Energy, Mines and Petroleum Resources
- Department of Fisheries and Oceans
- nongovernment organizations
- forest industry
- BC Hydro
- farmers, ranchers, etc.

Examples of existing programs for organizing, guiding, or conducting riparian research and extension in British Columbia were provided by Fred Nuszdorfer, and are listed in Table 7.

6.5 Extension and Education

Extension and education is an acknowledged need for integrated resource management in riparian areas. The effort given this aspect of the riparian problem analysis does not adequately reflect the significance of this component. The only significant source of input about extension and education is the ideas offered by questionnaire respondents.

When questionnaire respondents offered mechanisms to overcome barriers to integrated resource management, 75% of them mentioned public education and 25% recommended education or training of management and field staff. Those who specified that the hypothetical funding be applied to education gave equal weight to public programs and field training.

Few questionnaire respondents offered suggestions, although training packages, videos, and field demonstrations were all mentioned. Several individuals commented on the need to collect, collate, and disseminate existing information on riparian ecology and management.

Many opinions were expressed about the educational process at local and community levels. The purpose of public education, implicit in most recommendations, was the encouragement of local or community participants in multi-interest resource management processes.

To generate increased awareness of resource values and management concerns, interesting problem descriptions and success stories were recommended. The topic must be made more interesting to the public. We need to make better use of the media.

Problem descriptions should not only deal with the ecological system, but also with the institutional and social aspect. For example, policies, expenditures, and the potential economic and social benefits should be explained.

TABLE 7 *Planned or existing programs that may help organize, guide, or conduct riparian research and extension*

Research guidance	
	• B.C. Forest Research Advisory Committee: sets priorities, establishes funding • regional programs: implement and monitor research • workshops, meetings, technical advisory committees: priority concerns identified and relayed upward in the hierarchy; provide links to other programs
Programs/committees	
	• Fish/Forestry Interactions Program (S. Chatwin, Chairman, Ministry of Forests) • Carnation Creek Steering Committee • Integrated Wildlife–Intensive Forestry Research Program (B. Nyberg, Chairman, Ministry of Forests) • Flathead Bear Study (B. McLellan, Ministry of Forests)
Operational emphasis	
	• Fish/Forestry/Wildlife Steering Committee (W. Cheston, Chairman, Ministry of Forests) • Fish/Forestry/Wildlife Implementation Committee: makes recommendations to above, receives input from below (K. Ingram, Chairman, Ministry of Forests; Department of Fisheries and Oceans, Ministry of Forests are members) • Interior Fish/Forestry/Wildlife Guidelines Committee: develops guidelines, submits to above • Coastal Fish/Forestry Logging Guidelines Committee: develops guidelines, submits to implementation committee (C. Wilson, Chairman, Ministry of Forests; Ministry of Environment, Department of Fisheries and Oceans are members)
Extension programs	
	• Ministry of Forests regional ecological training • FRDA II extension program • university and college programs and extension courses • the school system
Institutes	
	• Centre for Applied Conservation Biology (UBC) • Sustainable Development Institute (UBC)

An example of a success story to demonstrate the complexity of the issues and the process of resolution was recommended by several respondents. The story might be based on a small resource use plan in an area with several conflicting resource uses. The process of resolving these issues would serve as a model of co-operative planning and environmentally sensitive management. One participant cautioned that unless such a demonstration were expanded to other areas, it would appear as a "decoy demonstration" and erode public trust.

The mechanisms of delivering a public education program were mentioned only superficially. Delivery could take place through the educational system, primary to university levels, and should certainly make good use of the media.

6.6 Summary of Recommendations

The following recommendations represent a synthesis of ideas from the literature research, interviews, questionnaire returns, and workshop discussions carried out in fulfilling the terms of reference for a problem analysis on riparian areas. The domain of some of the recommendations is broader than riparian management per se, but as these general resource management recommendations support effective integrated management of riparian areas, they are presented in this summary.

Definition

1. A riparian area is defined as "the land adjacent to the normal high water line in a stream, river, lake, or pond and extending to the portion of land that is influenced by the presence of the adjacent ponded or channeled water."

Policy and Guidelines

2. A framework for considering values in management must be developed. This requires:
    - the development of a vocabulary;
    - a value-based — rather than a purely physical — inventory and mapping system;
    - methods and process for value assessment, including nonmonetary values;
    - social research to determine the extent of concern about riparian areas; and
    - a means for implementing management such that the values are accepted and understood at a local level.
3. Methods must be refined for dealing with tactical and strategic options based on our heterogeneous value system. This requires the development of analytic techniques to clarify trade-offs between resource management objectives, and to evaluate the public cost of protective measures in response to environmental values and ethics.
4. Methods must be developed and applied for measuring and predicting the cumulative effects that may occur from local developments in a watershed. Applicable methodologies include "cross-system" or "cross-use" impact assessments and cumulative assessment models.
5. An overall set of guidelines for managing riparian areas at the site-specific level should be developed and integrated with other management guidelines (e.g., Coastal Fisheries/Forestry Guidelines), and published as soon as possible. These guidelines should be flexible enough for application to local conditions, and should be clear and consistent. Guidelines for riparian areas should be integrated into appropriate existing manuals. The guidelines should merge requirements to protect all riparian values, rather than each resource value separately.

Classification and Inventory

6. An interagency committee composed of representatives from the ministries of Environment; Forests; Agriculture and Fisheries; Energy, Mines and Petroleum Resources; and Municipal Affairs should be convened to:
   - identify the attributes needed to describe each resource in the riparian zone;
   - standardize definitions for collecting and recording data;
   - standardize methods for collecting and recording data;
   - collate and publish existing information; and
   - direct efforts to fill gaps in existing data and gather new data.
7. Rather than a new classification, inventory, and mapping system being developed, existing systems should be modified and integrated to accommodate riparian concerns. Elements to be considered include:
   - linkage of linear elements from stream reach surveys to area elements;
   - development of a range of scales suitable for strategic planning and site-specific referrals;
   - incorporation of data from adjacent sites such as upland areas; and
   - riparian areas in the context of a more extensive inventory.

Research

8. The process to define research needs should be based on a framework that represents the biophysical and socioeconomic interactions of riparian areas. Clarification and prioritization of the research needs identified in the past workshop (Section 6.4.3) should form the basis for discussion at another workshop.
9. Existing programs (e.g., Carnation Creek) and mechanisms to define, guide, and implement riparian research should be used as much as possible. Riparian research should be developed in a regional and provincial context.
10. Research programs should be co-operative among university researchers, government and industry managers, and other stakeholders. Participants in the program could include representatives from:
    - Ministry of Forests
    - Ministry of Environment
    - Ministry of Crown Lands
    - Ministry of Agriculture and Fisheries
    - Ministry of Energy, Mines and Petroleum Resources
    - Department of Fisheries and Oceans
    - universities and technical colleges
    - nongovernment organizations
    - forest industry
    - BC Hydro
    - resource users (farmers, ranchers, etc.)
11. Baseline research should be conducted on the interactions and dependencies in British Columbia riparian areas. This should include, but not necessarily be limited to, studies of:
    - hydrology, including the effect of riparian areas on the stream morphology;
    - wildlife habitat;

- biodiversity;
- riparian-dependent species, including plants and nongame species (invertebrates and amphibians), and quantifying the degree of dependency;
- changes in riparian function as defined by classes of streams (I to IV) and how their function changes; and
- links between riparian and other ecosystems.

12. Research should be conducted on the impact of forest management regimes, including the comparative benefits of different silvicultural approaches on riparian areas. This includes collecting information on:
    - rates of change and recovery from various developments or disturbances;
    - quantitative response of riparian-dependent species (or suitable indices of them) to changes in habitat due to natural and anthropogenic factors; and
    - size of buffers or special management zones required to protect riparian areas.
13. Research should be undertaken to understand the effects of small and large hydroelectric activities (past, present, and future) on riparian areas in British Columbia Elements to research include determining and measuring the impacts of development on biophysical components and determining potential mitigation techniques.

Integrated Ecosystem Management

14. Management goals and objectives should be clarified. These should be the products of social and technical discussion, and should be developed to guide resource managers in their activities. Management guidelines should be applied to an area referred to as the riparian management zone, which would include an area wider than the defined riparian area. Determination of the width of the riparian management zone would be done on a site-specific basis with minimum standards set for the province. If necessary, a buffer should also be established in site-specific areas to protect the riparian management zone.
15. Riparian management should be viewed as one element of a comprehensive land use strategy. Efforts to develop a land use planning system should therefore be supported.
16. An adaptive management approach should be used as a context for riparian research and management. This would include:
    - holistic ecosystem planning at the landscape level;
    - economic analysis;
    - biophysical monitoring;
    - research guidance; and
    - cumulation of practical and theoretical knowledge.
17. A multi-interest process is recommended for integrated resource management, particularly at the local level. A neutral group should be convened by government to develop the ground rules for this process.
18. Financial support should be provided to local governments, and their participation in the multi-interest process actively sought. Adequate information should be provided so that local governments understand that the activities will be in their interests.

19. The mapping of values developed as a result of the value assessment process should be channelled into existing local and regional planning processes to provide a rational basis for public involvement in decisions.
20. Significant discretion at the local level of resource management is required if decisions (including delineation of riparian management zones) and development prescriptions are to reflect site-specific factors. Local people should receive guidance as to what factors they should consider, not be told what decisions to make.

Extension and Education

21. The development of a riparian extension program should be continued and co-ordinated with other extension programs within the Ministry of Forests.
22. Field training on riparian management concerns should be continued and expanded to all forest regions.
23. A public education program should be developed in conjunction with a multi-interest integrated management process. At the local level, operators, developers, and landowners should be apprised of the importance of riparian resources and the guidelines, regulations, and protective measures to assist in protecting these resources. At higher decision-making levels, there should be an awareness of the need to protect riparian resources through policy and legislation.

Legislation

24. Legislative change is required to ensure that riparian resource protection is undertaken consistently by all interests involved. Furthermore, legal protection should be accorded to riparian values such as wildlife habitat, recreation, aesthetics, noncommercial fish habitat, and associated water quality.
25. Legislation is required to provide for or encourage development of positive economic incentives for compliance. This should include incentives to local private and community interests, and a more effective land tenure (Tree Farm Licence status) involving more users.
26. Regional and provincial standards and limits for sustainable development should be formulated.
27. Land tenure arrangements should be reviewed in an effort to create local incentives for the valuation and protection of riparian areas.

Support

28. An individual or a working group should be identified and funded to act as "secretariat" to oversee and co-ordinate the implementation of the recommendations from this report that are accepted by the ministries of Environment and Forests. This group should direct and support interagency co-operation, synthesize and distribute information, and assist in the selection and actualization of research, extension, and education initiatives.
29. Staff in resource agencies who deal directly with riparian areas should be increased so that they can deal adequately with development proposal referrals, monitoring tasks, and multi-interest process and educational initiatives.

Classification and Inventory Subgroup

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COMB Database

The database constructed for the riparian project is a modification of the already existing COMB database. This database was created for the Ministry of Forests to house a computerized bibliography on the ecology and management of several trees, shrubs, and herbs. The species found in the original forestry database were kept, and two additional databases were created for this project, RIPBIB and RIPPER. The RIPBIB database includes riparian-related bibliographic entries, such as technical reports, conference papers, and government information. The RIPPER database houses personal contact information gathered through discussions with academics, government personnel, and representatives from industry and special interest organizations.

Gathering the Information

Four people were involved in gathering the information entered in the databases. These people were chosen for their expertise in fish and water quality, classification and guidelines, policy analysis, wildlife and habitat. At the first meeting, other subject areas relevant to the topic of riparian areas were allocated to the project team members. The additional research areas researched included mining, agriculture, range, transportation corridors, urban areas, floodplains, and recreation.

The first phase of information gathering included an on-line search of the Dialog Information Services system at the University of British Columbia. The two databases searched were Enviroline and Environmental Bibliography. As well, a search was conducted of the NTIS (National Technical Information Service) ROM system, a database that includes all United States government-sponsored research, development, and engineering reports. The results of these searches were distributed to the project team, who attempted to get copies of applicable papers and reports.

Data gathering continued, with members of the team contacting key people, and conducting research at the University of British Columbia, Simon Fraser University, the Vancouver Public Library, and private libraries. As information on riparian-related topics was sparse, most of the relevant information was obtained by talking to key people in government and academia.

The mandate of the project included analysis of the current situation not only in British Columbia but also in the northwestern Unites States. The project team found that most of the information generated had come from two research bodies found in Washington (Center for Streamside Studies) and Oregon (Coastal Oregon Productivity Enhancement Program). Each body has a mandate to study riparian areas and has, for the past 5 years, sponsored a number of symposia dealing with this subject. Alaska was also included in the study area, but the team was unsuccessful in reaching anyone from the Copper River Delta Institute.

The majority of the British Columbia information came from conversations with government personnel and academia. Industry people and special interest groups were contacted, but were able to offer little new information.

Because of the limited amount of written information available, these discussions proved to be a very important method of data gathering. Information received from the United States was easier to gather as it usually required just one phone call to the institutions mentioned. The British Columbia research, on the other hand, required contacts with many individuals before one person was found with the information on riparian management and areas.

How to Use the Database

The COMB database has a user's manual that describes how to enter information into the system, search the database, and print results. For this project, the fields for entering the information in the RIPPER (personal contacts) database were changed to reflect the type of information to be gathered. The following is a list of the changes made to the field titles:

- "Species" field was changed to "Topic Area." Each team member entered the discipline relevant to area of responsibility (e.g., mining, agriculture, or fisheries).
- "Author" field was changed to "Contact Name, Position and Organization."
- "Publication Year" was changed to "Date of Call."
- "Source" was changed to "Who Recommended the Contact."
- Keywords remained the same and referred to words determined by project team members to represent the discussion they had with the contact (e.g., "water turbidity," "wildlife habitat," or "acid mine drainage").

The RIPBIB (bibliography) database was slightly modified by removing the Species field altogether.

When using the program, the first menu offers a choice for either entering information (either of the two databases) or searching and printing (COMB). The search command allows the user to look under a number of fields: years to search, author, title, and keyword display. The print command offers three options for printing: the citations alone; citations and keywords; or citations, keywords, and abstracts.

Each team member received a copy of the database for entering information. At the end of the research phase, all databases were integrated into one system. This system now has 85 entries in the RIPPER database and 285 entries in the RIPBIB database.

For a complete description of how to use the database, contact the Ministry of Forests, Research Branch, in Victoria for a copy of the user's guide.

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