ASSESSING THE IMPACT OF HYDRO DEVELOPMENT:

A Case Study of the Columbia River Basin in British Columbia[1]

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HYDRO DEVELOPMENT along the Columbia River has brought major benefits to British Columbia, most notably electric power production and improved flood control. Accompanying these positive effects, however, have been significant local costs associated with the flooding of land for reservoir creation and the continuing disruption of resource use associated with changing reservoir levels. This article re-examines the controversial impact of hydro development on the Columbia using, as an analytical aid, several indicators of sustainable development. While the concept of sustainability suggests that resource use decision-making should attempt to balance demands on environmental, social, and economic systems, the application of this concept is particularly challenging when the greatest benefits of hydro development — those related to increased power generation — are decided in and received by communities hundreds of kilometres away in the Lower Mainland of BC and the US Pacific Northwest.

The profound imbalance in the locus of costs and benefits associated with hydro development on the Columbia River is a variant of what has been termed the "ecological footprint" (Wackernagel and Rees 1996) of the modern urban economy. The resource demands of urban centres extend far beyond their physical confines and may have major detrimental effects on their hinterlands. Such impacts are frequently invisible to the urban dweller and, where visible, are usually justified on the grounds that they have facilitated economic

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growth. This view is not always shared, however, by rural people, who frequently bear a disproportionate amount of the economic, social, and ecological costs associated with such development. A great deal of passionate discussion has been generated over Columbia River development and the population displacement, flooding of farm and recreation land, and loss of riverine and other habitat associated with it. This article revisits these issues using an analytical frame-work that may improve the understanding of past and ongoing resource-related issues and, ultimately, facilitate the integration of regional sustainability into long-term resource use planning for the Columbia River Basin.

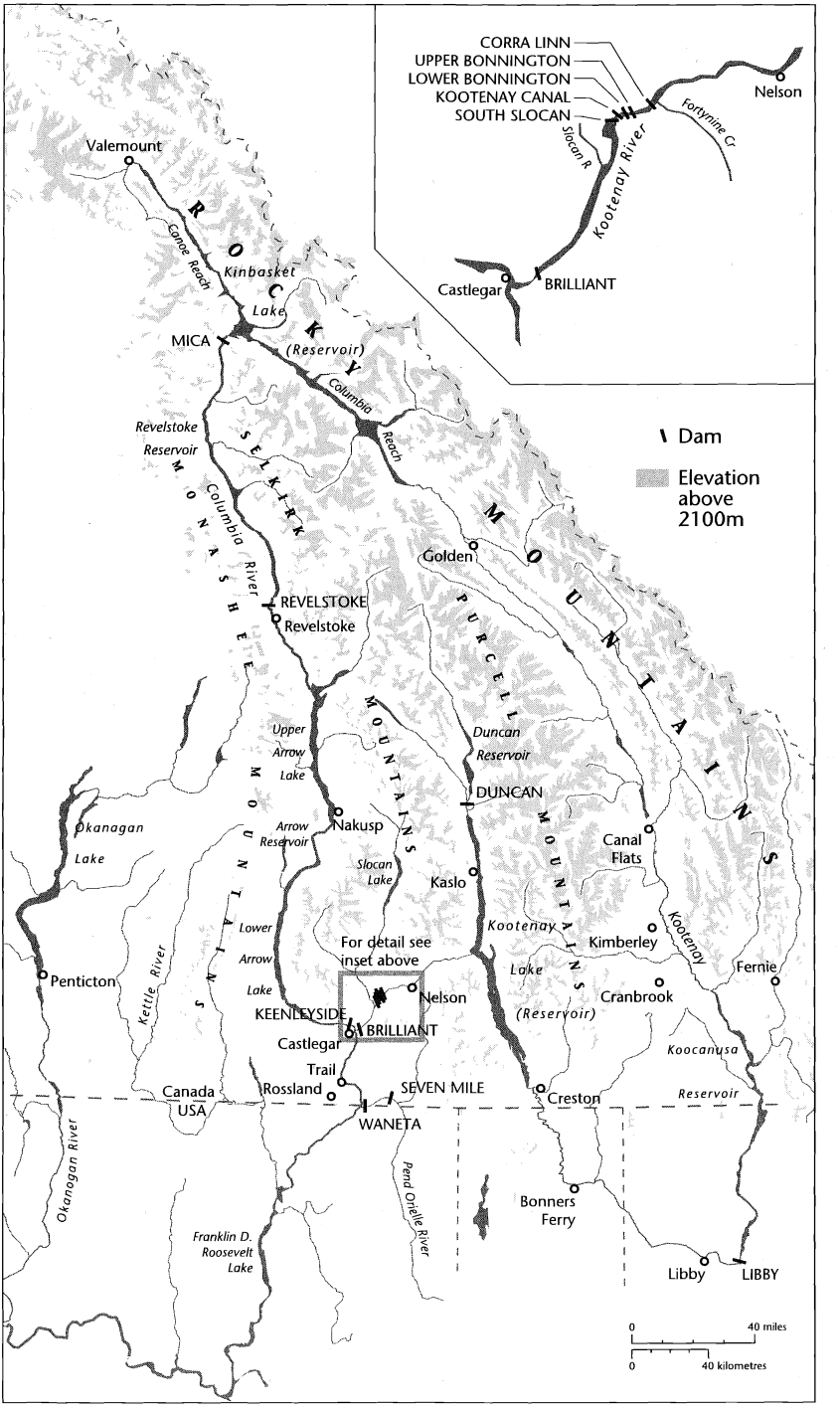
HYDRO DEVELOPMENT AND RESOURCE USE PROBLEMS

With approximately 500 dams on the Columbia and its tributaries (Mallette 1991, 14), the Columbia River contains one of the largest hydro-electric systems in the world, generating an average of 184,000 GWh of electricity annually from 21,000 MW of installed capacity. Of this amount, Canadian production represents 22,000 GWh (Newton 1995). Canadian dams play a key role in storing water due to their strategic position on the upper reaches of the Columbia River system.

Residents of the Kootenay region in southeastern British Columbia (Figure 1) have maintained that they bear an unfair amount of the costs of supplying energy to the rest of the province and the Pacific Northwest (Fraser 1993). Canadian dams on the Columbia River hydroelectric system have a total capacity of approximately 5,000 MW, representing 50 per cent of total provincial generation, while local consumption accounts for only 12 per cent of provincial electricity demand (BC Hydro 1993a; Newton 1996). Residents believe they lacked decision-making power over the initial development of the water resources within their region, a problem common to many outlying areas where water is managed for urban demand (Kindquist 1996).

While dams in the Canadian portion of the Columbia River Basin were first built on the Kootenay River shortly after the turn of the century, the largest hydro projects in the region were developed as a result of the Columbia River Treaty, which was signed in 1961 by the governments of Canada and the United States in a co-operative effort to regulate the Columbia for power generation and flood control. The Columbia River Treaty was ratified in 1964, at which time Canada's role in moderating the flow of the Columbia was

FIGURE 1
Hydro Development in the Kootenay Region



acknowledged through payments for power and flood control benefits received downstream. The downstream power sale negotiated in 1964 ends between 1998 and 2003, thirty years after the completion of each of the three treaty dams.

At the time of the Columbia River Treaty, the selection of water development sites and the determination of water rights and compensation were the subject of considerable controversy. Although the reservoir sites were ranked and constructed in order of their benefit-cost ratios, many of the political and economic aspects of these sites and their alternatives have been questioned (Krutilla 1967; Waterfield 1970; Wilson 1973; Swainson 1979). Since the establishment of reservoirs in the Columbia River Basin, hydro development has displaced other competing uses of valley bottoms (such as timber production, wildlife habitat, farming, recreation, tourism, and human settlement) in a region where land use is largely constrained by steep mountain ranges. One can only speculate about how different such cost-benefit calculations would be today, given the increased value of forest and recreation land alone. Social decision-making in the face of dynamic changes in the streams of costs and benefits is not easy, although methodologies have been developed that attempt to capture the value of rising benefits of natural resource preservation alternatives (Krutilla and Fisher 1985). Such an analysis is beyond the scope of this article, however. The research reported here portrays some of the more important ways in which local regions and communities are affected by major development decisions that are crafted in a political, economic, social, and geographic environment far removed from them.

Many of these issues have received new attention during the last five to six years, as British Columbia and Canada have faced the necessity of developing a policy for allocating the Canadian Entitlement from the Columbia River Treaty's second thirty-year period. The Columbia River Treaty Committee (CRTC), formed by local community leaders in 1991, has viewed the process of treaty renegotiation as an opportunity to address sustainability issues related to hydro project decision-making. The CRTC successfully lobbied the provincial government to address the impacts of hydro development on the Kootenay region. Many of the CRTC's concerns were stimulated by particularly low water levels in the Kinbasket, Koocanusa, Arrow, and Duncan Reservoirs during the summers of 1992 and 1993 — levels that reduced access to water for recreation, fishing, tourism, and logging and that inhibited fish spawning. The CRTC has since been formally established as an independent institution under the Columbia

Basin Trust Act, 1995, and will manage substantial funds and assets (arising from the US payment of downstream benefits) for the economic, environmental, and social benefit of the region.

BC Hydro, the Crown corporation in charge of hydro development in British Columbia, has recognized the significance of the impact of its dams on the inhabitants of the Columbia River Basin and has embarked on new initiatives to address past problems. BC Hydro now favours energy demand management over supply based alternatives, as new power generation is expensive and detrimental to the environment. Numerous mitigation and compensation projects have been undertaken in co-operation with the region.

DEFINING SUSTAINABILITY

The regulation of the Columbia and Kootenay Rivers has led to land use change and resource use conflicts. The concept of sustainability offers a useful framework within which to unravel some of the complex facets of resource management conflicts. We define sustainability as: *a long-term goal to maintain and enhance quality of life through the balance of ecological, social, and economic systems. Total system sustainability cannot be achieved if one or two of these component systems is being sacrificed to sustain another.* Progress towards sustainability can be "measured," albeit imperfectly, by establishing indicators representative of ecological, social, and economic issues and by evaluating associated trends.

INDICATOR DEVELOPMENT

In this article nine indicators are used to examine nine corresponding issues related to hydro development and its implications for regional sustainability within the Columbia River Basin (Table 1) (Toller 1994). The use of such indicators provides a means of distinguishing the perceived from the actual impacts of dams. The selection of indicators is based on several critical criteria: first, they have to bear directly on regional issues of sustainability; second, time series data must be available over a reasonable period in order to detect important shifts or trends in values; and third, they have to address the concerns of those local residents most directly affected by the impairment of sustainability. Table 1 summarizes the development of indicators from initial problem statements, hypotheses, and issues. The results of this analysis are discussed in the following sections under three interrelated topics: ecological sustainability, economic sustainability, and social sustainability.

TABLE 1
Problem Statements and Indicators Chosen

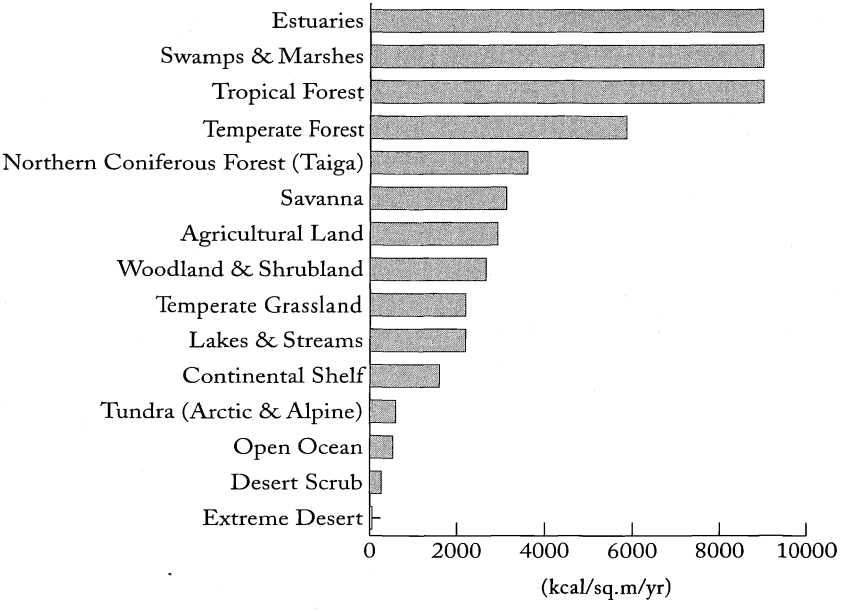
Problem	Hypothesis	Issue	Indicator
1. Ecological productivity has been disturbed	hydro development has reduced ecological productivity	(a) reduced fish productivity (b) reduced wildlife habitat (c) ecosystem integrity has been distrubed	(a) kokanee fish populations (b) ungulate habitat capability (c) net primary productivity
2. Social living conditions have been degraded	hydro development has limited community participation in decision-making and caused undesirable living conditions	(a) boom and bust effects (b) reduced recreational opportunities (c) little community participation in decision-making	(a) population of Revelstoke (b) angler hours (c) opportunities for public participation
3. Economic development opportunities have been restricted	hydro development has limited community participation in decision-making and caused undesirable living conditions	(a) restricted econonomic development opportunities (b) high unemployment (c) reduced resource base and increased forestry costs	(a) tourism room revenues (b) unemployment rates (c) accessibility to timber supply

ECOLOGICAL SUSTAINABILITY

Net Primary Productivity

Many residents of the Kootenays believe that hydro development has adversely affected the ecological integrity of the Columbia River Basin. Approximately 50,000 hectares of some of the most productive forests in Canada have been inundated (Canada 1970). Net primary productivity rates are an indicator of the rate of production of usable energy available for consumption by other organisms, and they serve as an indicator of ecological integrity. Although comparable data on primary productivity before and after reservoir establishment are unavailable, in general the flooding of temperate forests to create hydroelectric reservoirs can reduce net primary productivity by two-thirds because it renders aquatic ecosystems such as lakes and streams less productive (Figure 2). In reservoirs with fluctuating water levels, processes such as erosion, resuspension, entrainment, and redistribution of sediments may greatly reduce or eliminate primary productivity, as has occurred in the drawdown zone of the Arrow Lakes (Triton 1990).

FIGURE 2
Estimated Average Net Primary Productivity by Plants in Major Types of Environments



Source: Miller 1982, 72.

In addition to decreasing productivity, hydroelectric regulation results in perpetual unseasonal variation in reservoir levels and may cause stress on what would otherwise be natural ecosystems. Terrestrial and aquatic organisms may expend large amounts of energy trying to survive within the drawdown zones of reservoirs, with large fluctuations where wetlands have not re-established themselves (e.g., the Kinbasket, Koocanusa, Duncan, and Arrow Reservoirs), thus diverting energy away from growth and production.

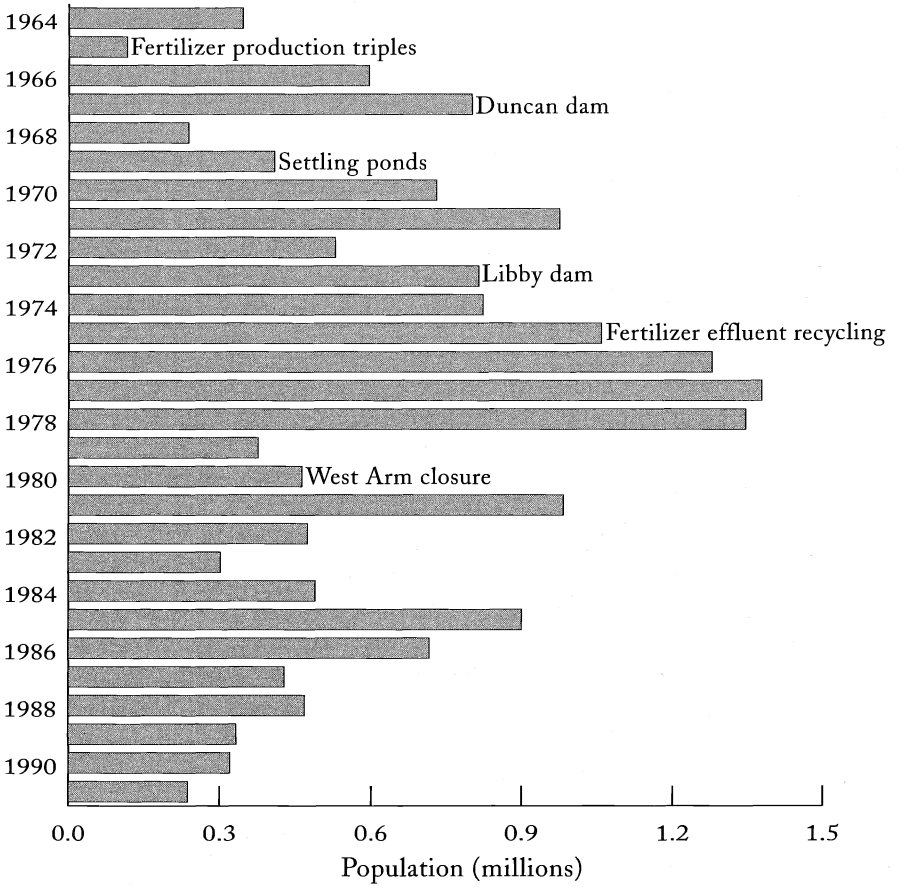
Fish: Kokanee Salmon Populations

Fish species are often used as indicators of the state of aquatic ecosystems. Kokanee salmon comprise an important sport fishery in Kootenay Lake and have attracted anglers from all over North America (Pearse and Laub 1969). Kokanee also serve as food for Gerrard trout, renowned in Kootenay Lake for their trophy size. Kokanee populations in Meadow Creek, the north arm of Kootenay Lake, provide a means of evaluating the effects of dams on fish, since they have been affected by both the Duncan and Libby Dams.

Figure 3 shows a general increase in kokanee populations from 1964 until 1977, followed by a decline through the 1980s and early 1990s. These trends can be largely attributed to increased human intervention in an ecological system that was once self-regulating. In 1949, a small shrimp-like organism, *mysis relicta*, was introduced into Kootenay Lake to improve the supply of food for the aquatic food chain (Hirst 1991), but, in fact, it competed for the same zooplankton that fed the kokanee. From 1953 until 1975, a fertilizer plant near Kimberley discharged phosphates into the St. Mary River, a tributary of the Kootenay River, supplying substantial amounts of nutrients to both the *mysis* and the kokanee (Whateley 1972).

The significance of the impacts of dams on kokanee in Kootenay Lake is well understood. The immediate consequence of the construction of the Duncan Dam in 1967 was the prevention of fish access to previous spawning grounds. Of over 4 million kokanee spawners in the Duncan-Lardeau system, it was estimated that 2.8 million would not reach their normal spawning grounds behind the dam (Bull 1965). This loss was somewhat mitigated by the Meadow Creek spawning channel built in 1967, the year the dam was completed. Subsequently, nutrient retention behind the Libby Dam has caused significant reductions (45 to 50 per cent) of phosphorus downstream (Daley et al. 1981). While the 1973 operation of the Libby Dam on

FIGURE 3
Kokanee Population in Kootenay Lake - Meadow Creek



Source: Adapted from British Columbia and Environmental Canada 1993, 81.

the Kootenay River, combined with the complete recycling of fertilizer effluent, reduced nutrient supplies to the river, the effect on Meadow Creek populations may have been delayed and partially mitigated by enhanced spawning conditions.

Increased numbers of kokanee accompanied by high fishing success rates attracted large numbers of anglers throughout the 1970s, until fish populations crashed dramatically in 1979 due to overfishing and nutrient retention (Hirst 1991). The collapse of the fishery resulted in the closure of the west arm kokanee fishery in 1980 (Andrusak 1981) and a reduction in kokanee populations in the north and south arms.

During the early 1990s, kokanee productivity has been limited by reduced phosphorus availability due to the elimination of phosphate in effluents, nutrient retention behind the Libby Dam, and the competition for nutrients from *mysis*. Because there is no known method for removing *mysis*, and because the Libby Dam continues to impede nutrient flow, in 1992 fisheries managers implemented a phosphorus addition program to ensure sufficient food supply (British Columbia and Environment Canada 1993). Future fisheries management programs will have to address the ongoing problems related to dam operations. However, this may require the modelling of dam-related consequences with other variables, such as availability of nutrients, quality and quantity of spawning grounds, predator efficiency, and fishing pressure. In essence, human activity has disturbed a delicate ecological balance that was once self-regulating, replacing it with a less ecologically robust alternative requiring continual intervention and management.

Wildlife: Land Capability for Ungulates

The Rocky Mountain Trench, the valley on the western side of the Rocky Mountains that forms the eastern boundary of the Kootenays, offers particularly good habitat for moose, deer, caribou, and elk. Steep mountain ranges to the east and west provide much more limited support for ungulates. However, wide valleys at both ends of the reservoir (near Valemount and Golden) offer relatively large sections of high capability habitat that is particularly important for winter range. The flooding of these and other valleys within the Kootenays for the purpose of hydro development has reduced the regional capability to support ungulates.

It is difficult to ascertain the significance of habitat loss beneath reservoirs along the Columbia due to the lack of accurate information on previous wildlife populations. The inundation of land for the Mica Dam was estimated to have resulted in a loss of 105,000 acres (42,500 ha) of wildlife habitat, including wetlands, riparian zones, and natural meadows. It was predicted that this habitat loss would cause reductions in populations of moose (70 per cent), deer (50 per cent), elk (40 per cent), and caribou (10 per cent) as well as the displacement of most aquatic animals and waterfowl (British Columbia ELUC 1974).

Moose, elk, and deer lost a substantial portion of their high capability habitat to impounded water behind the Mica Dam. Since the critical factor affecting the distribution and abundance of

ungulates in the reservoir area is the availability of winter ranges, it is probable that wildlife losses within the Kinbasket Reservoir region have been severe. Of the approximately 340,000 acres (137,600 ha) of winter range below the elevation of 3,500 feet (1,067 m) (British Columbia ELUC 1974), the inundation of 105,000 acres (42,500 ha) of relatively high capability habitat represents a withdrawal of approximately one-third of the original winter range and a substantial reduction in the variety of habitats. Ungulates that previously relied on narrow strips of habitat along the valley bottom may have tried to move elsewhere, increasing the competition for limited food and shelter in adjacent areas, or they may have accepted less favourable conditions along the steep slopes of the reservoir. In either case, it is likely that the ungulate population has decreased, although conclusive empirical data are unavailable.

In addition, the reservoir is an accident hazard and acts as a barrier to migration. Floating debris is a hazard to moose and caribou attempting to cross the reservoir. Winter reservoir drawdown can cause accidents for moose, elk, deer, and caribou due to ice breakage. The additional area covered by water acts as a barrier to migrating species such as caribou (British Columbia ELUC 1974).

The decline of big game as a result of the creation of the Kinbasket Reservoir affects local hunting, as hunters and guides in the area have noted decreased numbers of ungulates (Schuck 1992; Arlt, Gutzman, and Sim 1992). The total capital value of all wildlife resources (excluding waterfowl) in the Mica basin was evaluated as $10.9 million (discounted at 8 per cent) before flooding and at $5.6 million after reservoir creation, representing a loss of 50 per cent of the original value of wildlife resources (British Columbia ELUC 1974). Wildlife observers as well as local hunters and guides may suffer from reduced wildlife numbers, incurring greater travelling costs and/or having to change occupations. Due to the region's harsh climate and topography, there is little opportunity to replace lost habitat.

COMMUNITY STABILITY

Population of Revelstoke

Many resource-dependent communities have experienced periods of growth and decline with the fluctuations of external resource markets. As rapid change in population affects the availability of services and the attraction of living in a community, it also affects sustainability.

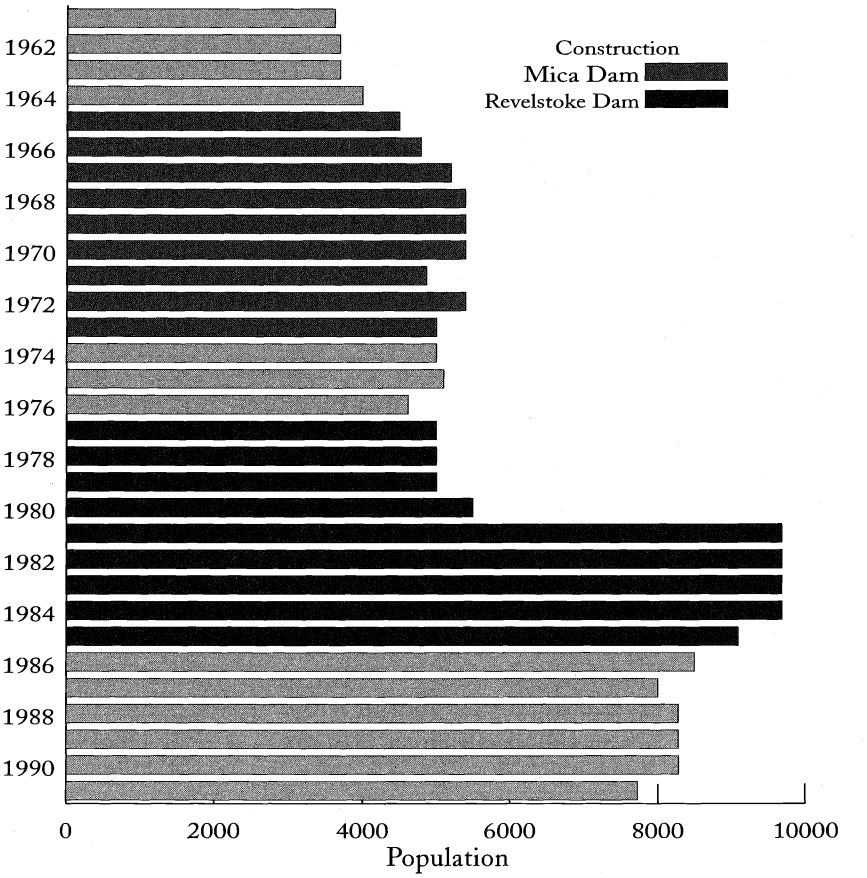
Revelstoke has been influenced by two periods of dam construction. Figure 4 illustrates the city's population between 1961 and 1991. Two periods of growth are evident. The first period shows a 49 per cent increase in population from 1961 until 1968. This growth was initiated by the construction of the Trans-Canada Highway and the expansion of the Canadian Pacific Railway (CPR). It was sustained by the construction of the Mica Dam, 136 kilometres north of Revelstoke, between 1965 and 1973. The second period of growth was due to the construction of the Revelstoke Dam between 1977 and 1985, and it included a period of very rapid growth (76 per cent) between 1980 and 1981. Although Revelstoke maintained its larger size for several years, its population has since decreased (though it is still higher than it was before 1981).

Although a community was established at the Mica Dam site to accommodate workers and to relieve pressure on Revelstoke, rapid population growth in and around the latter affected its residents. Dam-related employment increased local income levels, which exceeded the 1971 average in the Kootenay region by 17 per cent. However, social, health, educational, and recreational services were all strained by the additional demands placed on this community and were deemed to be inadequate to future population expansion (British Columbia 1976).

Employment provided by the construction of the Revelstoke Dam insulated Revelstoke from the economic recession of the early 1980s. Hydro-related jobs paid high hourly wages to a largely male workforce for periods of several months. While the short-term nature of hydro employment did not result in large annual wages, these jobs drew tradespeople and skilled workers as well as displaced workers from the forestry and railway sectors. Labour shortages required the recruitment of less skilled workers from outside the region (DPA 1986). While many unemployed residents of Revelstoke gained jobs related to dam construction, the number of people who required social assistance during the same period increased by 43 per cent due to the inflation of food and housing costs. This rate was higher than the 37 per cent average provincial increase during the dam construction period of 1979 to 1984 (DPA 1986). Housing prices almost doubled from 1975 to 1980, then declined during the peak period of construction when workers preferred to rent rather than to own.

High incomes created disparities between highly paid dam workers and those on fixed incomes, such as the elderly and the unemployed. A socio-economic assessment of the Revelstoke Dam concluded that

FIGURE 4
Population of Revelstoke, BC



Source: Compiled from British Columbia, Municipal Statistics 1961-1991.

local residents generally perceived the project to have resulted in a net gain, while noting the following concerns: they received an unfair (small) share of dam-related jobs; local businesses did not profit as much as had been anticipated; and residents in nearby Sicamous believed that their community had not been compensated as fairly as had Revelstoke in terms of municipal infrastructure, and they were generally dissatisfied with BC Hydro's community relations (DPA 1986).

With a smaller population and its corresponding tax base, current residents of Revelstoke continue to pay maintenance costs for expanded infrastructure that was established during the dam-building

years. Although BC Hydro contributed to improving the water supply and sewage system, funded fire trucks, and paid annual grants and taxes to the municipality of approximately $1 million (BC Hydro 1993b; Newton 1996), the local population believes that it finances an unfair share of what is now unnecessary infrastructure (Battersby 1992).

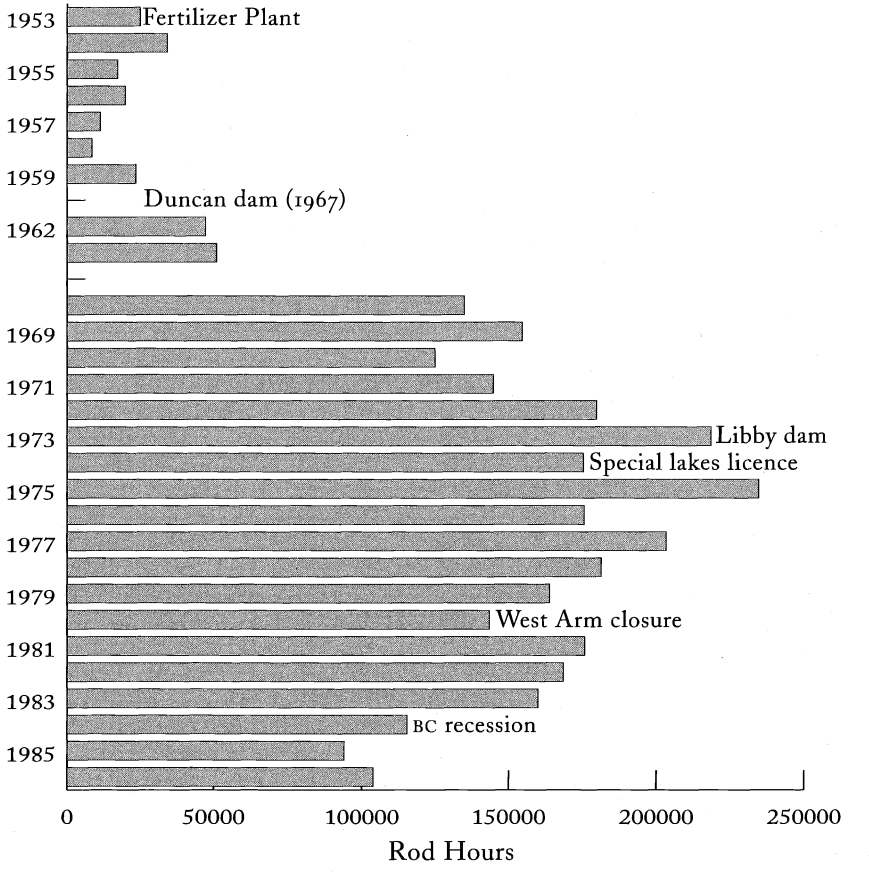
Recreational Fishing: Rod Hours

Kootenay Lake is renowned for having one of the most productive sport fisheries in British Columbia. Anglers from all over North America have been drawn by its wide variety of sport fish, principally rainbow trout, Dolly Varden, kokanee, mountain whitefish, and burbot. Local residents value the Kootenay Lake sport fishery for recreation rather than income, and the lake has never had a commercial fishery (Pearse and Laub 1969). Reduced lake productivity due to nutrient retention behind the Duncan and Libby Dams has decreased fishing.

Changes in angling on Kootenay Lake between 1953 and 1986 are shown in Figure 5. Generally, angling in Kootenay Lake increased substantially after 1953, reached a peak in 1975, and declined thereafter. Recreational fishing is clearly linked to factors affecting fish populations. Increased angling activity in the late 1950s may have been triggered by improved fishing, which resulted from larger fish stocks (Cartwright 1961). Increased fish productivity may have occurred due to the greater availability of nutrients arising from phosphorous emissions from a fertilizer plant that opened on the Kootenay River in 1953. Growing settlement in the Kootenays increased the number of local anglers.

Fishing increased through the early 1970s until 1975 in response to the rising numbers and size of fish. The 1974 requirement for anglers to obtain a Special Lakes licence in order to ensure high-quality fishing for large Gerrard trout (Andrusak 1987) may have reduced angling that year (Andrusak 1981). However, angling appears to have declined in the late 1970s as a result of decreased catches and the 1980 closure of the West Arm kokanee fishery. Fish stocks have been affected by nutrient retention behind the Libby Dam, completed in 1975, as well as by lack of access to major spawning and rearing grounds behind the Duncan Dam (Andrusak 1981). In addition to being weakened by reduced lake productivity and the complete closure of the West Arm kokanee fishery, angling was also adversely affected by the economic recession experienced throughout British Columbia during the mid-1980s.

FIGURE 5
Annual Fishing Rod Hours on Kootenay Lake



Sources: Compiled from Cartwright 1961, 28; BC Fish and Game Branch 1965, 24; Andrusak 1987.

Oportunities for Public Participation

Residents of the Kootenays have been frustrated by their limited participation in hydro-related decision-making in the Columbia River Basin. They believe that being involved in regional resource use decisions is critical to achieving regional sustainability (Fraser 1993). Certainly the extent of such involvement is an indicator of the quality of communication and decision-making mechanisms at a social systems level.

Initial opportunities for participation in decision-making related to Columbia River Treaty dams consisted mainly of public hearings

convened *after* significant decisions had already been made. The International Joint Commission held public hearings in Cranbrook in March 1951 regarding construction of the Libby Dam on the Kootenay River in Montana. Discussion of the consequences of the flooding of Canadian land occurred after the US Congress had authorized the construction of the dam in 1950 (Swainson 1979).

Public hearings concerning Canadian dams were not held until after the signing of the Columbia River Treaty on 17 January 1961. Several days of water comptroller hearings were then arranged in the communities of Revelstoke, Nakusp, Castlegar, and Kaslo during September, October, and November 1961 to discuss the water licences for the Duncan, Keenleyside and Mica Dams. Local residents called these hearings "a farce." The mandate of these hearings precluded the substantive discussion of the various projects and, instead, addressed licensing conditions and compensation, thus indicating that the fate of Kootenays' residents had already been decided (Waterfield 1970; Wilson 1973).

Although the relocation of Arrow Lakes residents from Burton, Edgewood, and Fauquier in advance of reservoir flooding was achieved with the involvement of community groups, BC Hydro's overall performance led to the impression that project management decisions were being directed from Vancouver. In a follow-up survey conducted in 1970, respondents indicated that the question of compensation overshadowed the entire resettlement program. With its authority to expropriate, the government largely controlled compensation decisions (Wilson 1973).

The 1984 Non-Treaty Storage Agreement was signed without any public consultation and was similarly extended in a subsequent agreement in 1990. Since the additional storage provided through these agreements was already authorized by the original water storage licence for Mica, no hearings were deemed to be necessary (Kendall 1993).

More recently, local groups have been asked to assist in the resolution of hydro development issues. BC Hydro established the Columbia River Advisory Committee in 1989 so that representatives of the Kootenays could discuss unresolved issues and provide recommendations concerning the provincial utility's operations in the region. The Columbia Basin Compensation Program and its predecessor (which focused solely on Mica) have attempted to incorporate public views into the development of fish and wildlife enhancement programs.

BC Hydro has recognized that its dams have disrupted the lives of Kootenay residents, and it has made a commitment to seek greater involvement with local governments and community organizations in its future hydroelectric planning (BC Hydro 1993c). BC Hydro included Columbia River Basin communities in its Electrical Systems Operating Review (1994). Working groups were established in seven communities to assist in the identification of issues relevant to the operation of dams in the region.

The establishment of the CRTC in 1991 represented a significant community-based effort to participate in hydro-related decisions. The CRTC consisted of representatives of the five regional districts and tribal councils in the Columbia River Basin, and it sought to monitor provincial commitments to address the social, economic, and environmental impacts of hydro development and to insist that a portion of the downstream benefits resulting from hydro operations be returned to the Kootenays. The province agreed to provide the CRTC's successor organization, the Columbia Basin Trust, with several payments: sixteen annual amounts of $2 million, initiated in 1994 for administration and study; a one-time payment of $45 million on 1 April 1996 for investment; and $25 million per year for 10 years, with matching funds for investment in regional power projects (along with provision for additional amounts, if necessary) (Newton 1996).

ECONOMIC DIVERSITY

Tourism Room Revenues

Most resource-dependent communities in the Kootenays seek to encourage tourism as a means of economic diversification. Residents view the scenic beauty of the Kootenays as an attraction that could stimulate economic activity (Fraser 1993). The development of an economic sector that strengthens local business without exploiting the region's resources would assist regional sustainability. Although dams and reservoirs were initially viewed as tourist assets, the flooding of forested land, loss of recreational fishing on inundated rapids and falls, and large reservoir drawdowns have all adversely affected tourism. A portion of these negative impacts — those pertaining to reservoir drawdowns — can be assessed by using data on seasonal room revenues and local anecdotal evidence.

Studies of the Central Kootenay area along the Arrow Reservoir have recognized the detrimental consequences of dam operations for

tourism. Recreation opportunities have diminished during periods of large drawdown due to reduced boating access to the lake and debris accumulation in the water and along the shoreline. The exposure of debris and stumps remaining in the reservoir affects boating safety and the appearance of the water (Marshall Macklin Monaghan 1982; DPA 1990).

A decrease in room revenues in 1992 coincided with particularly low reservoir levels on the Arrow Reservoir. Statistics related to highway traffic, visitor centre records, national and provincial park attendance, and local weather all indicated favourable conditions for regional tourism (Toller 1994). However, room revenue expenditures of approximately $837,900 ($1986) in July 1992 represented an 8 per cent decline from the previous year's expenditures of $908,700 ($1986), while similar spending in other regional districts increased 1 to 5 per cent, excluding the 19 per cent increase in Fraser-Fort George. Campground operators have received complaints from campers, and have had fewer visitors and smaller revenues during periods of drawdown.

Employment Stability

Unemployment rates are often used to measure socio-economic welfare, as they are widely understood and serve as an early warning of economic and social problems. Employment stability is a major concern in the Kootenays because of the region's dependence on cyclical resource-based industries. Although the construction of hydro dams stimulated short-term employment, residents of the Kootenays have expressed dissatisfaction with the small number of resultant long-term jobs. Some residents believe that resource use problems resulting from dam operations constrain economic activity and increase unemployment rates.

The Central Kootenay and Columbia-Shuswap Regional Districts have experienced the highest levels of unemployment in the Kootenays. Unemployment rates in this area were on a par with the provincial average during the late 1970s but increased dramatically through the early 1980s. They have since declined but still remain higher than the provincial average. This area depends largely on forestry and has, therefore, been susceptible to labour reductions due to increased mechanization, diminishing timber supply, increased international competition (Barnes et al. 1992), and high union wages.

The development of four large dams in the Kootenays in the 1970s and 1980s provided some short-term insulation from increasing unemployment rates. Many workers employed near Revelstoke on the Mica project (1973) were able to use similar skills on the later Revelstoke Dam construction (1985), thus reducing unemployment for this community. Although the number of unemployed employable applicants decreased significantly as a result of dam-related jobs at Revelstoke, non-resident workers also brought dependants who required social assistance (DPA 1986). Workers in Nelson and Castlegar found employment on the Kootenay Canal project (1976), which was followed by the Seven Mile Dam project (1980).

While the large hydroelectric development project at Revelstoke partially alleviated unemployment in the Revelstoke and Sicamous-Malakwa area, dam activity may have only delayed the problem of growing regional unemployment (DPA 1986). Some of the high unemployment in 1985 (11.3 per cent as against 9.9 per cent in 1981) is a direct result of the completion of work on the Revelstoke Dam and represents those who had not yet relocated as well as those affected by the closure of the Goldstream Mine in 1984. Railway jobs associated with CPR tunnelling and double-tracking of Rogers Pass offset some unemployment from 1984 until 1988. Unemployment rates have declined as workers previously employed on the Revelstoke project have resettled within or without the region.

BC Hydro continues to play a role in alleviating unemployment in the Kootenays, although far fewer people are employed near working hydro dams than was the case during their construction. While the Columbia Basin provides half of the power generated in the province, few residents are employed by local dam operations. Of the 6,038 regular and temporary employees of BC Hydro as of 31 March 1996, approximately 3 per cent are residents of the Kootenays (Newton 1996).

While large hydro development projects have alleviated unemployment in the Kootenays for short periods, they do not contribute substantially to the long-term economic sustainability of local communities. Dams in the Kootenays provide employment largely for engineers and planners in Vancouver, where most of BC Hydro's central decision-making is conducted.

Accessibility to Timber

While the economies of most Kootenay communities are highly

dependent on forestry, the latter is most important to the town of Golden. Forestry jobs are viewed favourably for their relatively high weekly earnings and their ability to generate additional local employment (Horne and Robson 1993). The creation of reservoirs throughout the Columbia River Basin has reduced timber supply through a permanent loss of the most accessible timber, reduced access to remaining forests, and generated additional logging costs related to reservoir operation (Szaraz 1981; Triton 1990; Thibodeau 1991; Bennett 1993). Forestry operations in the Golden Timber Supply Area (TSA) have been affected more than have operations in any other TSA within the Kootenays.

At the time of the construction of the Mica Dam, Golden's main supply of timber was the Golden TSA, formerly the Kinbasket Public Sustained Yield Unit (PSYU). The creation of the Kinbasket Reservoir resulted in the inundation of the Big Bend Highway, the central transport route for forestry operations within the Golden TSA, and a direct annual loss of 75,393 m^3 or 9 per cent of the annual allowable cut (AAC). This loss was caused by (1) the initial inundation of productive forest land and (2) the reallocation of forest land from the northern portion of the PSYU (previously accessible to Golden forestry operators by the Big Bend Highway) to Revelstoke in the late 1970s after the flooding of the highway limited accessibility to Yellow and Potlatch Creeks.

The 117 kilometre Big Bend Highway has been replaced with a total of 200 kilometres of roads, which comprise the East Bend side system to Sullivan River and the West Columbia Road to Wayne Creek. Although most of this network was financed by forest service funding or BC Hydro, Evans Forest Products (formerly the major forestry operator in the TSA and now no longer in operation) had to extend the Sullivan River Forest Road from Boulder Creek to the top of Sullivan Arm at a capital investment of $1,076,000 (Thibodeau 1991).

Reduced access to local timber increased forestry costs in a number of ways. The replacement of the public Big Bend Highway with logging roads resulted in increased East Bend road maintenance costs ($1.37/$m^3$) for wood harvested by Evans Forest Products. Hauling costs along the reservoir's "East Side Road Cycle" of $11.63/$m^3$ included an extra cost of $3.45/$m^3$ due to the additional 40 kilometres of road required to travel around flooded drainages. Logging costs increased by $1.14/$m^3$ because of the need to use cables on steep terrain following

the innundation of more gradual slopes. Development costs, including mapping, road layout, cruising, and pre-harvest silviculture preparation, added $0.25/m³ (Thibodeau 1991).

An additional cost of $1.50/m³ followed from the increased requirements for water transport of logs. These operations required additional infrastructure (such as log dumps with ramps at various levels and dewatering and reloading facilities to accommodate reservoir level fluctuations) as well as additional supervision and administrative costs. On occasion, even the use of boat ramps at low elevations has not alleviated the difficulties of water transport, as protruding stumps prevent passage in some areas (Triton 1990). Wave and ice action as well as accumulation of debris require ongoing ramp maintenance (Ricard 1992). The necessity for water transport has reduced the logging season to an average of five months per year, generally mid-June or early July to mid-October, because of water-level fluctuations and weather hazards during October and November.

While lost forest resources and increased operating costs on Crown land are essentially a provincial loss, they also represent lost income and taxes for local communities. One analysis has concluded that changes to access and transportation patterns were more significant than was the withdrawal of timber supply, even around the Kinbasket Reservoir, as the volume cut was always below the maximum net AAC. Increased operating costs have resulted in a greater sensitivity to market conditions and have reduced the volume of economically recoverable timber (Szaraz 1981).

CONCLUSIONS

The empirical data assembled in this research support the views of Kootenay residents concerning the detrimental impacts of hydro developments in the Columbia River Basin. The ecological indicators show a general decrease in ecological productivity and ecological integrity. Kokanee populations, land capability to support wildlife, and net primary productivity have all declined. The regulation of the flows of the Columbia and Kootenay Rivers has replaced naturally varying ecosystems with aquatic and terrestrial systems managed for human purposes. In so doing, some of the region's most productive and critical habitat has been modified so that it can no longer support the populations that previously flourished there.

Mitigation and compensation programs implemented by BC Hydro and the provincial government have redressed some ecological im-

balances. The success of these initiatives is more easily evaluated for fisheries than for wildlife, as there is little quantitative information on wildlife prior to dam construction. The impacts on broad ecological processes such as nutrient cycling, energy fluxes, and global warming are complex and difficult to determine or address. Certainly, ecological integrity has declined and may reach a new equilibrium with lower productivity if left undisturbed. Higher levels of ecological productivity may be desirable but may not be feasible due to the limitations imposed by the harsh physiographic constraints of the region. The enhancement of fish and wildlife populations will require continuous management.

While from an ecological perspective one type of ecosystem is not necessarily better or worse than another, from a human perspective this is not the case. Changes in primary productivity may have social and economic implications for local communities. People who rely on the presence of forests, fish, and wildlife for economic and recreational pursuits may be affected by the diminished supply of available resources. The intensification of silviculture, the maintenance of fish-spawning channels, and increased wildlife habitat management may enable greater levels of productivity in those ecosystems affected by hydro development. However, there are trade-offs; for example, the preservation of wildlife habitat may require reduced forestry in certain areas, and the regulation of water levels to provide appropriate spawning conditions may mean decreased power generation. Not least, mitigation efforts will require continuing management and external subsidies to compensate for resource loss and to replace a naturally self-regulating ecological system.

The social indicators used in this study reveal communities that have undergone significant change in response to the economic cycles of resource development. While fluctuations may continue as a result of economic activity in other industrial sectors, it is unlikely that future hydro development will trigger such large impacts on communities in the Columbia River Basin. Generally, hydro-related population changes have stabilized. In response to the impact of hydro development on the Kootenays, however, some of the previous limitations to local participation in decision-making have been removed through the establishment of the CRTC (an independent regional institution with a substantial trust fund), thereby creating the potential for local input into the management of resources.

Increased community participation in the planning of hydroelectric operations appears to be critical to addressing many of the social

issues concerning Kootenay residents. Access to greater information and decision-making, and improved opportunities for local involvement arising from community and regional initiatives as well as from BC Hydro, should increase awareness of the impacts of dams on community services, recreation, and other critical social variables. Community participation in resource management decisions may lead to more effective management, enabling the identification of issues and goals relevant to regional and not just to provincial needs.

The economic indicators examined highlight the implications of hydro development for economic development in the Kootenays. While unemployment rates rose throughout the province during the period under study, they have consistently remained highest in the Kootenays. Although dam construction has employed large numbers of workers during the relatively short period of construction, ongoing operation has created relatively few regional jobs. Opportunities to enhance forestry have been constrained by the harsh physiographic conditions of the region, the loss of timberland through innundation, and additional operating expenses resulting from the creation of reservoirs and fluctuating reservoir levels. Although tourism has been viewed as a means of achieving some regional economic diversification, low water levels have discouraged summer visitors from participating in recreation along certain reservoirs, and the loss of naturally flowing rivers has prevented many river-based recreational activities.

As most communities in the Kootenays are highly dependent on resource development, the local economic benefits associated with land use in productive valley bottoms are greater than is any remaining resource use associated with fluctuating reservoirs. Any type of economic development relying on forests, fish, or wildlife will be restricted by the diminished size and/or quality of these resources. Maintenance of municipal infrastructure, expanded as a result of population increases during dam construction, incurs ongoing costs. Economic development initiatives will require new, creative approaches that consider both the opportunities and the limitations of a reduced resource base.

In conclusion, hydro dams have adversely affected the ecology, economy, and social fabric of the Kootenays. While the province of British Columbia and the American Pacific Northwest have benefited from Canadian dams on the Columbia River, dam-related modifications to this river system have caused substantial regional

land and resource use changes. Taken together as interacting variables of sustainability, these modifications are significant for resource-based communities with a restricted range of natural assets. Future development of water resources (or other regional assets) should consider the ecological, social, and economic implications of any resulting land use change in order to ensure the capability of the Columbia River Basin to support communities within, as well as without, the Kootenays.

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