THE BIOLOGY AND STATUS OF RIPARIAN POPLARS IN SOUTHERN ALBERTA

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THE BIOLOGY AND STATUS OF RIPARIAN POPLARS IN SOUTHERN ALBERTA

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EXECUTIVE SUMMARY

World Wildlife Fund and Alberta Fish and Wildlife Division commissioned this study to summarize existing information relevant to the conservation biology of riparian poplars and to determine the distribution and status of riparian poplars in southern Alberta.

Poplar forests along rivers in the grasslands of southern Alberta are very important for wildlife and recreation as well as being of considerable cultural significance to indigenous peoples. They also provide agricultural and water quality benefits. Three poplar species - balsam poplar, plains cottonwood and narrowleaf cottonwood - converge and hybridize in southern Alberta, each with differing physiological and ecological characteristics. All, however, are adapted to regenerate and survive under the naturally dynamic river regimes of southern Alberta rivers.

Successful replenishment occurs infrequently and appears to be correlated with high spring flood events during the time of seed dispersal followed by gradually receding water levels and moist conditions in late summer. Two forms of replenishment are recognized - 'general replenishment' across much of the floodplain attributed to very large, infrequent floods; and 'fringe replenishment' along existing channels attributed to smaller, more frequent floods. Prolonged drought causes increased mortality.

Numerous studies have documented a decline in poplar forests along rivers in the plains of western North America and have attributed it to man's activities. Altered river regimes downstream of dams is implicated as the major factor responsible. Other factors are livestock grazing, harvesting and floodplain developments. In Alberta two studies have documented decline in riparian poplars, one on the St. Mary and Waterton rivers, where decline is attributed to dams, and the other on the Milk River, where decline is attributed to fire. Concerns have been raised about the impacts of the Oldman Dam on extensive stands of riparian poplars immediately downstream on the Oldman River.

As part of this study, the distribution and density of riparian poplars along major rivers in southern Alberta were mapped using 1980s aerial photography. Of about 2000 km of river investigated, 1500 km support riparian poplars and of this, about 1000 km support stands considered moderate, dense or very dense. The total aereal extent of riparian poplar forests is less that 500 km2. Six reaches were determined as particularly significant for riparian poplars: Bow River (Carseland - Cluny), Oldman River (Brocket - Lethbridge), Belly River (Glenwood - Waterton River), Red Deer River (Finnegan - Empress), Milk River (through Milk River Canyon) and Sheep River (near Okotoks).

Comparison of 1980s distribution of riparian poplars with 1880s mapping by Dawson and 1950s air photo analysis suggests no general decline of riparian poplars in southern Alberta in the last century. In fact, there are apparent increases along some reaches of the Red Deer, Bow, and South Saskatchewan Rivers. However, declines are apparent along the St. Mary and Waterton Rivers below dams and along two reaches of the Oldman River where clearing for cultivation is a probable factor. Before a reliable assessment of the status of riparian poplars in Southern Alberta can be made, verification that mortality does not exceed replenishment, through age-class analysis of representative stands, is required. As well further investigations into those aspects of riparian poplar ecology and physiology which will assist in management planning are recommended as are socio-economic assessments of the value of riparian poplar forests.

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THE BIOLOGY AND STATUS OF RIPARIAN POPLARS IN SOUTHERN ALBERTA

1.0 INTRODUCTION

Over the past few decades there has been growing recognition of the importance of poplar stands along rivers in southern Alberta for wildlife, and increased concerns for their health and survival. In response to these concerns, World Wildlife Fund Canada and Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division have identified the need:

- to determine the present distribution and density of riparian poplars along rivers in southern Alberta;
- to assess changes in distribution and density using historical maps and aerial photography; and
- to summarize existing information relevant to the conservation biology of riparian poplars.

Western Environmental and Social Trends (W.E.S.T.) was contracted to do this work.

This report represents the first step in setting management objectives for riparian poplars in southern Alberta. It provides an information base to assist decision making about appropriate management actions and what additional research may be required to assist in future management of riparian poplars. World Wildlife Fund and the Fish and Wildlife Division recognize that decisions about the management of riparian poplars will involve a broad spectrum of stakeholders, including provincial government agencies, municipal government agencies, native organizations, environmental groups, grazing leaseholders, private landowners and other interested individuals. It is hoped that this report will be a useful information base for all these interests.

Furthermore, World Wildlife Fund and the Fish and Wildlife Division recognize that many of the management decisions regarding riparian poplars will have implications for other riparian habitats such as wetlands and shrub communities. It is assumed that a conservation strategy for riparian poplars will not negatively affect, and in fact will hopefully benefit, a whole suite of riparian habitats and the wildlife dependent on them.

2.0 METHODOLOGY

Present distribution and density of riparian poplars in southern Alberta was determined through analysis of recent air photos. A preliminary assessment of status was accomplished by comparing this information with that from analysis of 1950s photos and with Dominion Survey maps by Dawson from the 1880s. Results are presented in Section 8.0 of this report.

A review of the extensive literature relevant to conservation biology of riparian poplars was completed and key points are summarized in Sections 3.0 to 7.0. To ensure accuracy and completeness of the summary, the first draft of these sections was circulated to several individuals knowledgeable in the field. Thoughtful comments and suggestions were provided by Ron Bjorge and Steve Brechtel (Alberta Fish and Wildlife Division), Ian Dyson (Alberta Regional Co-ordination Services), Lorne Fitch (Alberta Fish and Wildlife Division), Joyce Gould (World Wildlife Fund), Maureen Hills-Urbat (University of Calgary), Sandra Marken (University of Calgary), Ron Middleton (Alberta Public Works, Supply and Services), David Reid (Hardy BBT), Dr. Stewart Rood (University of Lethbridge), Eric Vuori (Alberta Fish and Wildlife Division), Greg Wagner and Gordon Walder (Alberta Environment), and Cliff Wallis (Cottonwood Consultants).

3.0 SIGNIFICANCE OF RIPARIAN POPLAR FORESTS

On the western prairies of North America, the ribbons of floodplain forests that border rivers provide welcome relief from the wind and sun in a generally treeless grassland. However, the benefits derived from these productive riparian areas extend beyond the shelter they provide.

For centuries, indigenous peoples on the prairies have lived and hunted in riparian poplar forests. The importance of these environments to indigenous cultures is reflected in the fact that three major Indian Reserves in Southern Alberta - the Blackfoot, Blood and Peigan - are located along river valleys which contain extensive stands of riparian poplars.

Today, many southern Albertans preferentially choose riparian poplar stands as outdoor recreation environments. It is noteworthy that four provincial parks - Dinosaur, Woolford, Writing-on-Stone and Dry Island - as well as major urban parks in Calgary, Lethbridge and Medicine Hat and several parks in smaller centres are located in riparian poplar forests. It also is not surprising that local parks or picnic areas have been developed at several locations where riparian poplar forests occur near river crossings.

More importantly, the riparian ecosystem is probably the single most productive type of wildlife habitat in the semi-arid Great Plains (Bottorff, 1974; Hubbard, 1977; Rhodes, 1991). Similarly riparian habitats in the semi-arid regions of southeastern Oregon are used more than any other type of habitat by 82% of the terrestrial species (Thomas et all, 1979).

Many bird species in the prairies are dependent on riparian poplar forests. In Alberta, Savoy (1991) reported that 72% of the bird species found in the riparian poplar forests of Dinosaur Provincial Park on the Red Deer River use that habitat exclusively. Breeding bird densities range from 550-706 pairs per 40 ha., among the highest densities in Canada. Savoy concluded that disappearance of riparian poplar forests would result in a dramatic reduction of bird species and numbers in prairie regions. For example, studies in Fish Creek Provincial Park found that American kestrels nest almost exclusively in riparian poplars (Greg Wagner, pers. comm.). Furthermore, great blue heron rookeries are restricted to riparian poplar woodlands in the prairies and eagles use poplar groves in valleys for night roosting. Other highly visible bird species using riparian poplar habitats in the prairies include Swainsons and red-tailed hawks, tree-nesting common mergansers and Canada geese, and ring-necked pheasants, who concentrate in the understories.

Virtually all of the forests found in the river valleys of southern Alberta constitute critical habitat for deer (Fitch, pers. comm.). Critical habitat refers to winter range and breeding areas, because these are the habitat components in shortest supply . Both mule deer and whitetail deer use riparian forests. During Spring, 1988 and 1989 researchers of plains cottonwood forests along the lower Red Deer River observed four to eight mule and white-tailed deer fawns along each 700 to 1200 m transect (Sandra Marken, pers. comm.). A survey by the Fish and Wildlife Division along the Oldman River has shown that areas of healthy, continuous poplar forest support about four times more deer (11.2/km^2) than areas with discontinuous forest (3.1/km^2) (Fitch, pers. comm.).

Aerial surveys for deer in southern Alberta are flown almost exclusively over riparian habitats as deer are virtually absent elsewhere. In January 1982, an aerial survey which included the Belly River, St. Mary River, Waterton River and the Oldman River from Pincher Creek to Lethbridge found 725 mule deer, 1565 whitetail deer, 94 coyotes, seven foxes, 123 pheasants, 268 sharptail grouse, 60 grey partridge, seven prairie falcons, 11 bald eagles, ten golden eagles and 500 waterfowl (Fitch, pers. comm.).

The same characteristics that make riparian poplar stands attractive to wildlife make them attractive for livestock production. Livestock use these forests for shelter, water and bedding or resting. It is interesting to note that forage species for cattle in riparian habitats are generally not as high in nutrient content as upland forage species. However because density of forage is usually higher in the riparian zone the overall nutrients available to livestock generally is comparable to upland habitats (Roath and Krueger, 1982; Kauffmann and Krueger, 1984).

As importantly, riparian vegetation benefits fluvial systems. By stabilizing river banks and providing protection from ice scouring, flooding and erosion, sediment loads are reduced and water quality is improved (Schlosser and Kerr, 1981). Vegetation cover also slows runoff from the prairie upland and by so doing may help reduce pollution of rivers from agricultural chemicals (Lowrance, 1985). Shade provided by overhanging trees and embankments stabilized by root systems reduce water temperatures and help to increase the oxygen levels of smaller rivers (Meehan et al., 1977). These overhangs also provide important cover for fish populations (Marcusson, 1977, Rhodes, 1991). In addition, debris entering the fluvial system from the riparian zone accounts for most of the organic material necessary to support aquatic communities (Kennedy, 1977).

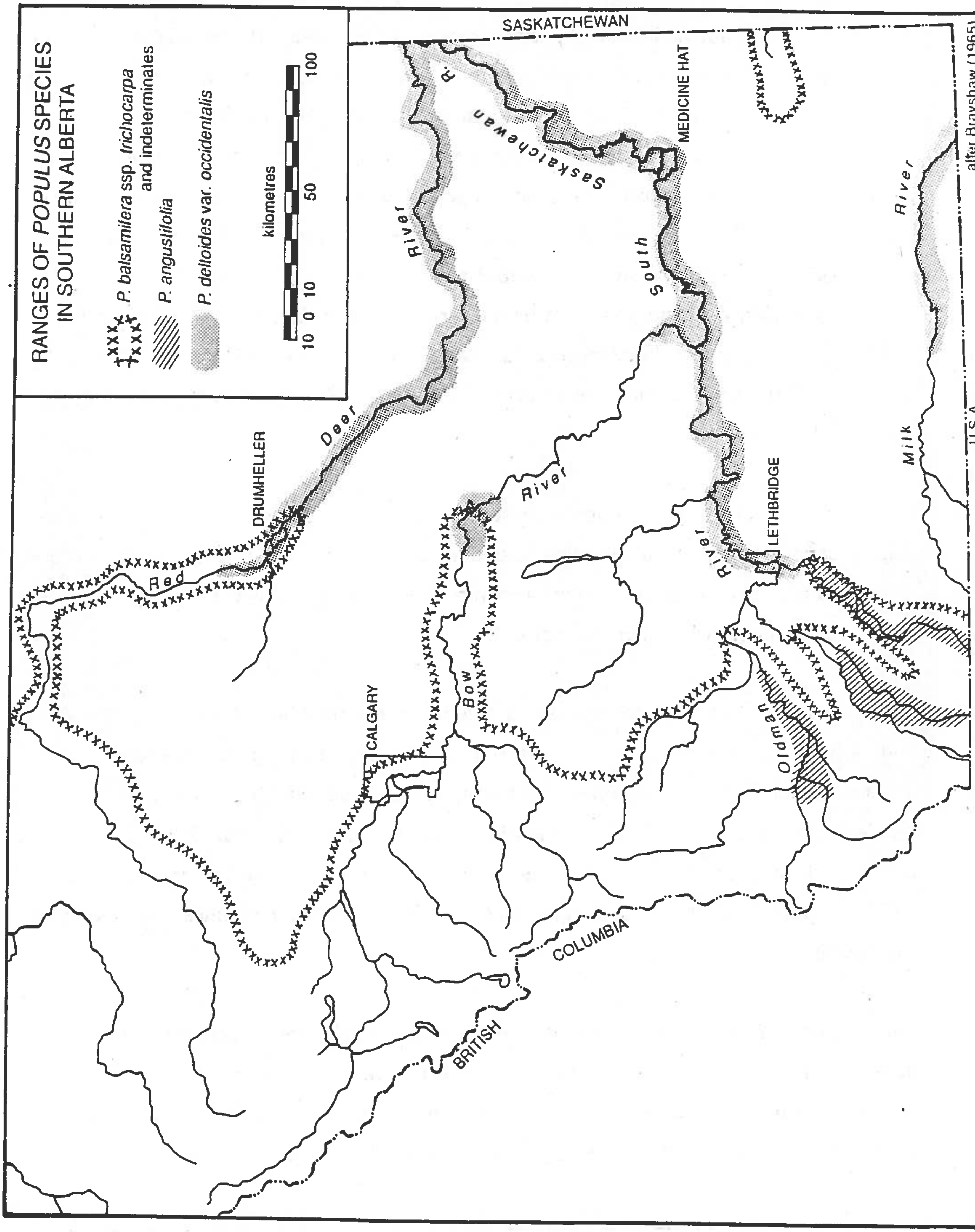
Riparian forests of the western prairies (specifically along a corridor east of the Rocky Mountains ranging from Alberta south through Montana, Wyoming, Colorado, Utah, New Mexico and Arizona) differ fundamentally from those of eastern prairie regions. Along rivers in the eastern prairies, poplars are a pioneer species, being replaced by other tree species as the forest matures. On the other hand, along western rivers poplars are generally the dominant or sole tree species. Thus, riparian stands in the western prairies are often considered to be in a perpetual seral condition and dependent on the predictable instability of the fluvial system for renewal (Brayshaw, 1965; Rood and Mahoney, 1990). Loss of flooding and channel shifting can lead to overwhelming loss of riparian forests. This in turn leads to loss of understory communities. As well, loss of productive riparian wetland and shrub communities can be expected. As the riparian habitats decline, so does the wildlife that depends on them and likewise the other irreplaceable benefits they provide.

4.0 POPLARS OF SOUTHERN ALBERTA

A survey of the poplars of southern Alberta by Brayshaw (1965) found that three poplar species - balsam poplar (*Populus balsamifera* subs. *balsamifera* and *P. balsamifera* subs. *trichocarpa*), plains cottonwood, (*P. deltoides*), and narrowleaf cottonwood (*P. angustifolia*) - are at the limits of their ranges in this area (Figure 1). Trembling aspen (*P. tremuloides*) is also found in the upland areas of southwestern Alberta, but is not a riparian species and is therefore omitted from this discussion. Balsam poplar approaches from the north and west, plains cottonwood from the east and southeast, and the narrowleaf cottonwood from the south along the foothills into Alberta via the St. Mary, Belly and Waterton rivers.

Plains cottonwood in southern Alberta is found east of a line running approximately between Lethbridge and Drumheller. The Red Deer River represents the most northerly extension of plains cottonwood in North America. Populations also are found east of Alberta, in Saskatchewan, Manitoba and Ontario. Narrowleaf cottonwoods are limited to the southwest corner of Alberta extending only as far northeast as Lethbridge (Brayshaw, 1965). Like plains cottonwood the Alberta population of narrowleaf cottonwood represents the most northerly extension of this species. Noteworthy is that Alberta is the only province in Canada in which narrowleaf cottonwood occurs. With respect to balsam poplar, its distribution in Southern Alberta is limited to the foothills but extending eastward and southward to Drumheller along the Red Deer River.

Figure 1: Ranges of Riparian Poplar Species in Southern Alberta



Brayshaw (1965) noted that interspecific crosses are possible between the three parent poplar species. Hybrid forms occur readily where the ranges overlap. Balsam poplar (*Populus balsamifera*) and narrowleaf cottonwood (*P. angustifolia*) are both in the Tacamahaca Section and hence, very close; they freely interbreed in many locations. Plains cottonwood (*Populus deltoides*) is in the Aigeros Section. The Tacamahaca x Aigeros hybrids are a little more unusual and these receive the names *P. x jackii* (*P.deltoides x balsamifera*), and *P. x acuminata* (*P. deltoides x P. angustifolia*). Rood et al. (1986) found a continuous hybrid swarm generated by the three parent species with a unique trispecific population found in the Lethbridge area. Biochemical analysis (Greenway et al., 1990; Vanende, 1991) supports the conclusions of Rood et al. (1986) in differentiating between the hybrid crosses.

It is noteworthy that in the vicinity of Drumheller, older poplar trees (120-140 years) are *P. x jackii* crosses whereas younger trees (less than 80 years old) are pure plains cottonwood (*P. deltoides)*. This suggests a recent westward extension of plains cottonwood along the Red Deer River (Marken, pers. comm.).

The reasons for the differing ranges of the three riparian poplar species is not well understood. It may be an artifact of the rate of species range expansion following deglaciation or it may be a function of differing environmental tolerances, such as climate. As well, there are a number of notable differences in the general characteristics of rivers that flow through the foothills compared to those that flow through the prairies; and the different species may be preferentially adapted for the different regimes and floodplain characteristics.

Balsam poplar is found along foothill rivers, which generally have steep gradients, coarse beds, low suspended sediment loads and braided or straight channels. Plains cottonwood occurs along prairie rivers which generally have low gradients, sand beds, high suspended sediment loads and freely meandering (unless confined by bedrock) or braided channels.

Narrowleaf cottonwood and the natural hybrids are found in the transition zone between the foothills and prairies (Brayshaw, 1965; Eckenwalder, 1984b; Rood et al. 1986).

The remainder of this report will discuss poplars in general, noting differences in the species when known. Most studies on poplar biology have dealt with a single species, usually of silvicultural significance. Few studies examine the differences in species physiology or ecology. Although there is little evidence to suggest that poplars cannot be discussed together, reason dictates that differences in species physiology and ecology may be adequate to necessitate different management approaches. Caution should be used before applying the general conclusions to a specific situation.

5.0 THE POPLAR LIFECYCLE

5.1 Sexual Reproduction

A single mature poplar produces tens of millions of small, light seeds annually (Bessey, 1904). The seeds are attached to cottony enclosures (hence the common name of "cottonwood") that aid in wind dispersal. Generally, release of seeds occurs every spring to early summer when normal river flows are high (Everitt, 1968; Ware and Penfound, 1949). The synchronization of seed release and high flows ensures that new, moist sand and silt beds are available for successful seed imbibition and establishment. Lack of seed production can occur in some years, such as when severe frosts occurring in late spring cause damage to catkin buds (Marken, pers. comm.).

Seed viability usually lasts only two to four weeks (Fenner et al., 1984; McComb and Lovestead, 1954; Moss, 1938; Ware and Penfound, 1949). Viability varies with humidity, temperature and photoperiod (Hellum, 1948; Hosner, 1957; Farmer and Bonner, 1967;

Fenner et al., 1984) but germination must occur during this time if seeds are to establish in any given year.

Poplar seedlings require barren sites for successful establishment since they are poor competitors (Read, 1958). Ideal sites are clear of other vegetation to allow abundant sunlight, and remain constantly moist for the first few weeks. Even under these conditions, many more seedlings germinate than survive the first year. A common reason for losses of seed viability and small seedlings in the first season is drying of seed beds (Engstrom, 1948; Moss, 1938; Read, 1958; Farmer and Bonner, 1967).

The uncertain timing of annual peak flows means the hydrologic conditions essential for successful seed germination and establishment occur irregularly (Barnes, 1985). Bradley and Smith (1986) suggest that about a two to ten year interval, with an average interval of five years, may be expected between successful regeneration events along the meandering reaches of the Milk River. Analysis of age-class distribution of plains cottonwoods along the lower Red Deer River shows much less frequent regeneration events (Sandra Marken, pers. comm.). A significant proportion of the present woodlands were established between 40 and 80 years ago. Trees aged 75-85 years old are found over large expanses of floodplain, their establishment coinciding with record high spring flood events occurring in generally very wet years. This age group is found mainly along braided sections, which comprise 70% of the river length. Trees at both ends of the age spectrum cover relatively small areas, although there is a surge in representation of 135 to 140 year old trees. Marken (pers. comm.) suggests that trees in the 0 to 10 year old age class are extremely limited due to decreased flow resulting from decreased precipitation and the Dixon Dam, and from local water removal.

As well as point bars, abandoned channels are important sites for plains cottonwood establishment along the Milk and Lower Red Deer Rivers (Dave Reid, pers. comm.; Maureen Hills-Urbat, pers. comm.; Sandra Marken, pers. comm.). Other observations specifically along the Red Deer River in Dinosaur Provincial Park suggest that in some instances plains cottonwood seedings establish under stands of young willows that have been recently flooded (Maureen Hills-Urbat, pers. comm.).

5.2 Asexual Reproduction

All three species of riparian poplar are known to propagate asexually through suckering (sprouting from roots), coppicing (sprouting from stems) or cladoptosis (sprouting from branch tips). In nature some forms of asexual reproduction are more common in some poplar species than in others (Dickmann and Stuart, 1983).

Field observations in southern Alberta suggest that suckering seldom occurs in plains cottonwood. Bradley (1982) and Dave Reid (pers. comm.) observed no suckering of plains cottonwood along the Milk River. Sandra Marken (pers. comm.) observed suckering of plains cottonwood only twice along the Red Deer River; both times this occurred in young saplings (3 years), in backwater areas characterised by high clay content and standing water. Narrowleaf cottonwood and its hybrids produce suckers very infrequently, according to observations by Dave Reid (pers. comm.) along the St. Mary, Belly and Waterton Rivers. However, further investigation of this is required. On the other hand, middle-aged trees of balsam poplar commonly produce new individuals by suckering from lateral roots.

Suckering is promoted when flooding or ice scouring removes bank materials and shears poplar roots (Williams and Wolman, 1984). The severed roots then form dense new growth. These events are probably important components of natural riparian forest cycling where balsam poplar dominates (Ashton, 1979; McBride and Strahan, 1984). However, the relative contribution of suckering as opposed to reproduction from seeds to natural forest regeneration in southern Alberta is difficult to assess. Preliminary work using root excavation has been attempted along southwest Alberta rivers, but is inconclusive since root grafting may link neighbouring trees (Rood and Mahoney, 1991a). Isoenzyme or flavonoid analysis may permit more confident analyses of the extent of suckering in riparian poplars in the future (Vanende, 1991).

Coppice growth, the production of shoots from stems of young to middle aged trees occurs in all three species of riparian poplars in southern Alberta. Coppicing generally occurs following damage to trunks by fire, beavers, flooding or ice scouring. The large established root system supports regrowth that is often much more rapid than the rates seen in seedlings (Dickmann and Stuart, 1983). This form of propagation declines in older trees (Read, 1958). For example, sprouting from old plains cottonwood trunks damaged by a recent fire were noted in 1982 (Bradley, 1982), but by 1989 these new sprouts had died (Reid, pers. comm.).

As well, coppicing can occur through flood training (Everitt, 1968). In this process pliable saplings are bent over and covered by sediment. New shoots may then emerge from the buried stems creating a clonal group progressing downstream from the original sapling. This form of asexual reproduction has been observed on the Belly River and Bow River (Reid, pers. comm.) and at two sites on the Red Deer River related to ice scour events (Sandra Marken, pers. comm.). At one site on the Red Deer River, an entire large stand was affected, and stand density was estimated to have increased four to six times because of it.

Cladoptosis, the rooting of branch tips that are broken off and land on suitable sites has been observed occasionally in riparian poplars in southern Alberta (Shaw, 1976; Bradley, 1982). However, this form of asexual reproduction is much more significant for balsam poplar in the wetter Pacific Northwest (Galloway and Worrall, 1979).

Silvicultural techniques have been developed to exploit the tendency for asexual reproduction in poplars (Fege, 1983; Strong, 1989). The most common technique used in establishing poplar plantations is through sprouting from shoot tissues, (cladoptosis) (Phipps et al., 1977). Coppicing also is used in short rotation poplar silviculture to maintain high productivity (Dickmann and Stuart, 1983).

5.3 Growth and Longevity

Poplars obtain water primarily from groundwater sources, which is characteristic of most deep-rooted trees and results in them being termed phreatophytes. Thus, the depth of the water table determines the availability of water and the severity of drought stress during the growing season. Precipitation may provide a small amount of moisture for poplars through their extensive shallow root system, but does not appear to contribute to the long term growth success (Reily and Johnson, 1982). Since root growth must be rapid enough to maintain contact with the riparian water table as it recedes following spring flooding, the limits of root growth may determine the initial success of the seedlings. If water supply recedes more rapidly than the ability of the roots to grow to maintain contact, seedlings will dry out and die.

Plains cottonwood (*P. deltoides*) seedlings can grow 50 cm in their first year in Oklahoma and roots may extend a similar distance (Ware and Penfound, 1949). Along the Milk River, first year growth of shoots and roots seldom measured more then 30 cm (Bradley, 1982). In the greenhouse, the seedling roots of a closely related species, Fremont cottonwood (*P. fremontii*), have been reported to grow about 6 mm per day although higher rates were observed in some soils (Fenner et al., 1984). Fenner et al. (1984) also found that Fremont cottonwood seedling roots reached 72 cm by the end of the first summer in the field. Again, final depth varied with genotype and substrate composition (Fenner et al., 1984).

The small size and correspondingly small root systems of seedlings keep them vulnerable to drought-induced mortality in the year following establishment. Through the second year, growth is more rapid than that of the first year and at the end of two years, roots may extend almost three meters in length (Ware and Penfound, 1949). The longer roots help plants exploit more stable, deeper water sources (Pezeshki and Hinckley, 1988).

In contrast to their intolerance of drought, poplar seedlings are quite tolerant of flooding. Hosner (1957) found that nearly half the seedlings tested survived 30 days of inundation. This characteristic is useful in helping seedlings survive flooding in subsequent years. However, high flows can scour seedlings away or bury them with sediment. For example, along the Red Deer River seedlings established in June, 1989 which were in densities of up to $500/m^2$ and 2 to 6 cm tall were scoured away by high August flows (Sandra Marken, pers. comm.).

Poplar saplings become more tolerant of flooding and drought stress after the first two years as the root system develops (Pezeshki and Hinckley, 1988). This permits accelerated growth so that three to five year-old trees can grow more than a meter in height annually (Dickmann and Stuart, 1983). Growth rates slow down after the first five years and remain relatively constant for the next few decades. Flowering first occurs after approximately seven years depending on the genotype (Rood, unpublished).

Changes in the rate of poplar growth are readily evaluated by measuring tree ring increments from stem cores or discs. Albertson and Weaver (1945) found that annual growth increments were reduced in poplars of the western prairies during the drought of the 1930s. Growth increments were also reduced in riparian species following damming of the Missouri River in North Dakota (Reily and Johnson, 1982). These researchers concluded the reduced growth was probably related to reduced early-season downstream flows.

Poplar longevity is influenced by a number of environmental factors, especially drought stress (Reily and Johnson, 1984). During the extensive drought of the 1930s on the western prairies, older poplars were observed to be especially vulnerable (Albertson and Weaver, 1945). Riparian poplars that have survived a number of dry periods often appear very ragged due to the death of some upper branches. When the volume of water transpired cannot be replaced through the xylem, a break in the water column occurs. This effectively shuts off the water supply to the branch, thereby reducing the shoot mass and leaf area to a level that can be supported by the root system with the water available.

Although poplars can live for over 200 years, most trees in Alberta die before the end of their first century (Shaw, 1976; Cordes, 1991; Marken, 1991). On the Milk River in southeastern Alberta, few plains cottonwood were found over 100 years of age (Bradley and Smith, 1986; Hardy, 1990). However, Marken (pers. comm.) has found several trees aged at 135 to 140 years along the Red Deer River. It should be noted that precise aging of poplars is difficult due to burial of the lower portions of stems by floodplain sedimentation and heartwood rot in older trees.

6.0 NATURAL FACTORS AFFECTING REPLENISHMENT AND SURVIVAL OF RIPARIAN POPLAR FORESTS

6.1 Replenishment vs Mortality

The status of a poplar forest is determined by the relative rates of replenishment and mortality. The rate of replenishment will depend on the frequency at which events suitable for seed germination and seedling establishment, or suckering (in balsam poplar), occur. The rate of mortality will depend on species longevity as well as several factors including severe drought, flood, winds, beaver, fire and disease. Generally, replenishment of the younger age classes must exceed mortality of the middle to older age classes if the forest is to increase or even maintain equilibrium. If mortality exceeds replenishment the stand will decline. An analysis of the age-class composition of a forest helps to determine if a forest is increasing, in equilibrium or declining. Since the reasons for increased or decreased replenishment are somewhat different from those causing increased or decreased mortality, an age-class analysis is essential in determining the factors underlying general forest trends. Factors affecting replenishment and mortality are discussed in detail in the following sections.

6.2 River Regime

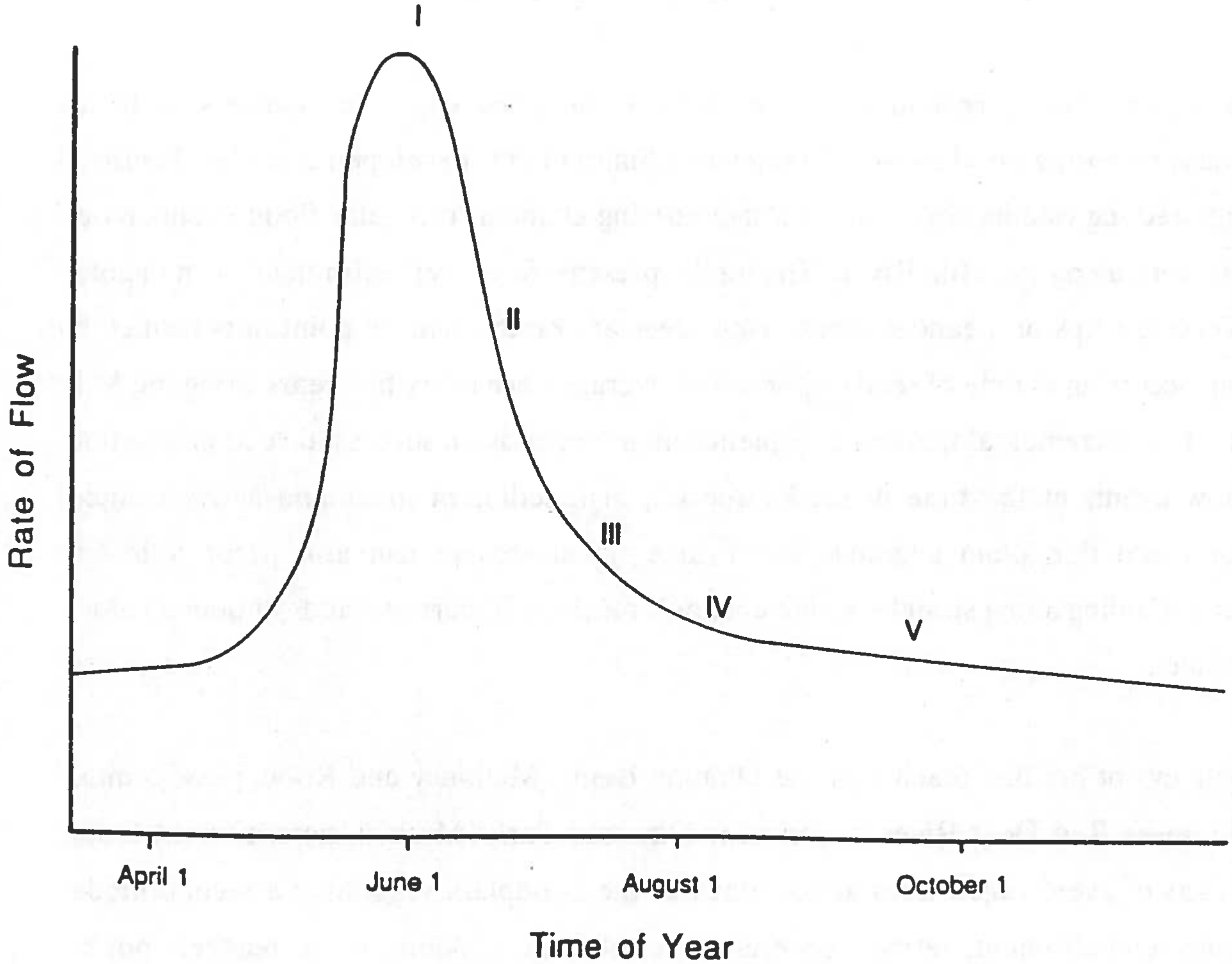
Riparian ecosystems in southern Alberta are adapted to, and may even depend on, the dynamic flow regimes which are characteristic of rivers in the region. However, the unpredictable variation in the range and timing of parameters such as flooding and seed dispersal also means establishment is successful only at irregular intervals.

Figure 2 presents a river flow pattern typical of an unmodified river in southern Alberta. A discussion of the contribution of five characteristics of river flows that influence poplar forest survival and replenishment noted on Figure 2 follows.

6.2.1 Spring Flooding/Fringe and General Replenishment

Most major southern Alberta rivers fluctuate annually with peak flows in late spring following snow melt in the Rocky Mountains. Overbank flooding may occur when heavy spring rains augment the rapid melting of deep snow packs (Johnston, 1987; Gildart, 1984). The highest flows normally last for just a few days in early to mid-June although annual peaks range between April 25 and June 30 for some rivers (Environment Canada, 1985). These floods shift the course of river channels and carry large sediment loads which they deposit adjacent to the channel or in low-lying areas of the floodplain (Williams, 1989). As well, existing streambanks and bars are scoured and new sand and gravel bars are deposited (Colby, 1964; Everitt, 1968; Wolman and Leopold, 1957). These barren sites of fresh sediment, sand and gravel are favourable locations for poplar seedling establishment (Behan, 1981; Johnson et al., 1976; Noble, 1979).

Figure 2: **Typical Discharge Hydrograph Showing Elements Important in Riparian Poplar Survival**



I	SPRING FLOOD LEVELS
II	FALLING RIVER FLOWS DURING POPLAR SEED RELEASE
III	GRADUAL TAPERING OF RIVER FLOWS
IV	MINIMUM SUMMER FLOWS
V	AUTUMN FLOW LEVELS

The newly formed seed beds are saturated by the floods so that poplar seeds released immediately after the flood and landing on those barren, moist sites are likely to survive. The surface moisture is necessary to support the seedlings until the roots penetrate to the water table. Once seedling roots contact the water table, root growth must be adequate to follow the water table as it declines over the growing season.

Fringe replenishment, replenishment of poplars along the edges of channels, is highly dependent on spring flood events. Bradley and Smith (1986) developed a model (Figure 3) relating seedling establishment along a meandering channel to regular flood events based on their work along the Milk River. The model presents forest replenishment as an ongoing process on the tips of meander lobes. New trees are established on point bars formed by flooding occurring at time of seed dispersal (on average once every five years along the Milk River). This incremental method of replenishment depends on successful seed production, high flow events at the time of seed dispersal, high sediment loads and active channel migration and floodplain aggradation. Fringe replenishment can also occur following overbank flooding along straight, stable channels resulting in narrow bands of poplars along the channel.

Field surveys of braided reaches of the Oldman Basin (Mahoney and Rood, pers. comm.) and the lower Red Deer River in and near Dinosaur Park (Marken, pers. comm.) found large tracts of evenly aged trees across much of the floodplain suggesting a second model of poplar replenishment, termed general replenishment. Along these reaches, poplar replenishment may be linked with major overbank flood events rather than incremental point bar aggradation. These major flood events may occur about every 30-50 years instead of every five, and encourage replenishment of large areas across the full width of the floodplain rather than only on the tips of point bars. Marken (pers. comm.) observed that a significant proportion of the poplar woodlands, occurring on large expanses of the lower Red Deer River floodplain, were established 75 to 85 years ago. Establishment of these woodlands coincided with record high spring flood events occurring in generally wet years.

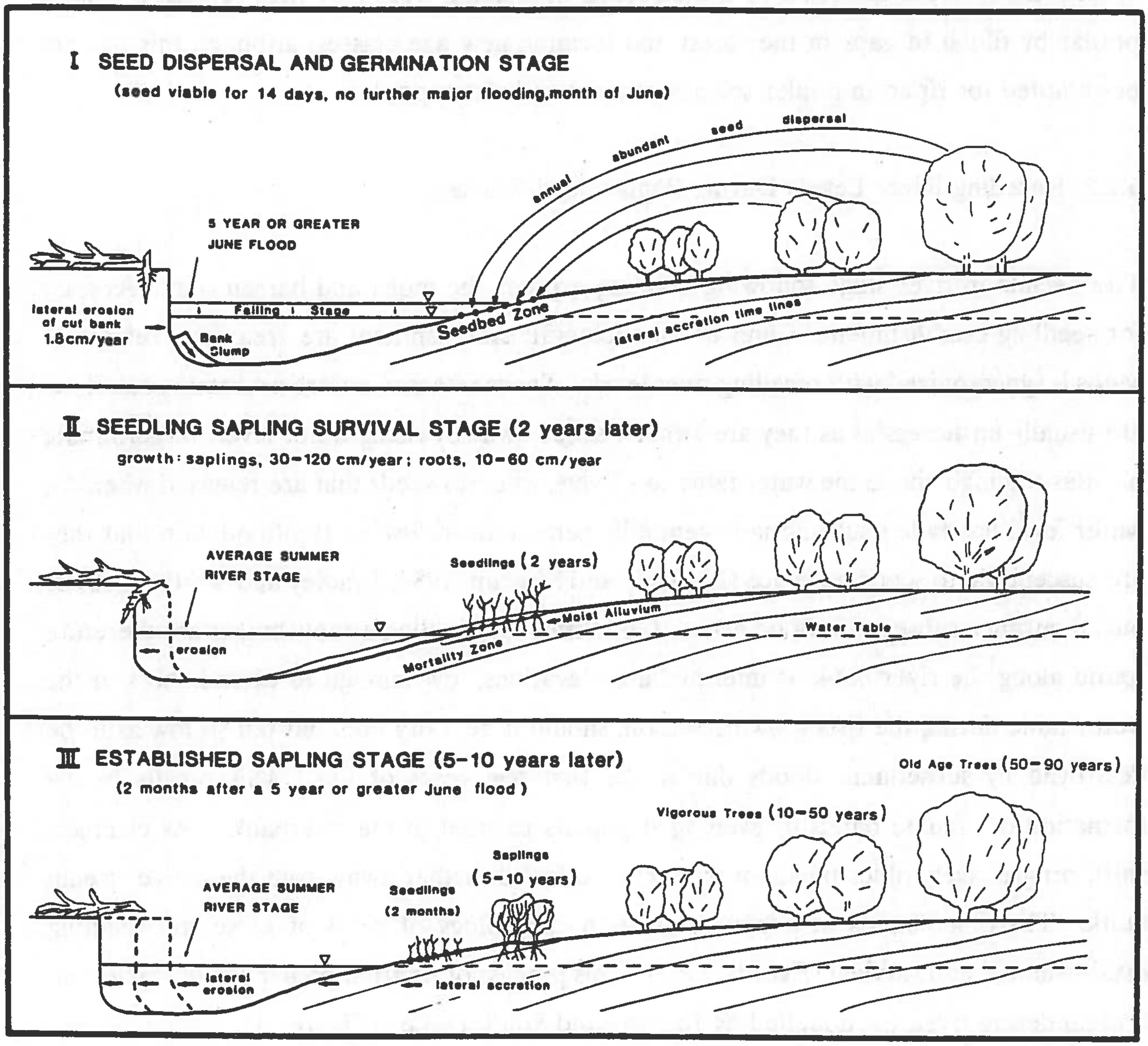
In summary, for both fringe and general replenishment, spring flooding serves two essential functions. Firstly flooding prepares sites suitable for successful poplar seedling establishment through scouring and deposition. Secondly it recharges the riparian water table and inundates the floodplain including new barren sites. In addition, the emergence of new shoots from the roots or buried stems of existing trees may help replenish balsam poplar by filling in gaps in the forest and forming new age classes, although this has not been noted for riparian poplar species other than balsam poplar.

6.2.2 Receding River Levels During Poplar Seed Release

The decline in river stage following flooding exposes the moist and barren sites necessary for seedling establishment. Chances for successful establishment are greatest if release of seeds is synchronized with receding river levels. Seeds released before or during peak flows are usually unsuccessful as they are either washed away by rising water levels or germinate on sites too high above the water table to survive, whereas seeds that are released when the water level has fallen substantially generally germinate so low on the floodplain that they are susceptible to scouring by ice (McBride and Strahan, 1984; Bradley and Smith, 1986) or burial during a subsequent flood event. Good sites for seedling establishment are therefore found along the river bank at intermediate elevations, low enough to extend roots to the water table during the first growing season, should it be a dry one, but not so low as to be destroyed by subsequent floods during the first few years of life. This results in the formation of arcuate bands of even aged poplars parallel to the riverbank. As channels shift, progressively older bands of trees can be found further away from the active stream bank. The older bands of poplars provide a chronology of years of successful seedling establishment and survival (Everitt, 1968). This process of riparian poplar establishment on a meandering river, as modelled by Bradley and Smith (1986) (Figure 3).

Figure 3: A Proposed Conceptual Model Showing an Association Between Cottonwood Establishment and River Flooding and Sedimentation

BRADLEY AND SMITH



6.2.3 Tapering River Flows After Seed Germination

Since poplars exploit ground water reserves as their main source of moisture, seedling root growth must be rapid enough to maintain contact with the riparian water table as it drops in concert with declining river flows. The natural decline of the water table following peak flows is usually relatively gradual, and poplar seedlings are able to maintain the root link with the water supply. Abrupt drops in water table, such as those associated with artificial reductions in river flows due to reduced releases from dams or increased diversion, can be lethal to poplars. Research has shown that rates of water table decline exceeding 4 cm/day has serious effects on poplar seedling growth and survival (Mahoney and Rood, 1991a).

As well as seedlings and saplings, mature trees also are susceptible to drought stress induced by rapidly falling water tables especially if this is preceded by a prolonged period of inundation. When inundated for periods of 8 days or longer root absorption declines and within 32 days roots die (Hosner, 1958; 1962). The zone of active absorption is limited to the roots above the level of inundation. As the water table declines, the non-functioning portion of the root must be reactivated to maintain effective water absorption. If the water table declines at a rate faster than the roots can be reactivated, drought stress and mortality may occur (Mahoney and Rood, 1991a). Very old trees are expected to be especially susceptible to this stress.

6.2.4 Minimum Summer Flows

The lowest river flows during the growing season normally occur in the late summer months. This is also the time when hot, dry weather causes high water demand for plant survival. Low flows and a related deep water table during July and August when water demand is high may cause drought stress in seedlings and saplings, especially for those established high on the floodplain or far back from the channel. This is substantiated by observations along the Red Deer River which suggest that a wet August followed by several wet years are required to insure seedling survival on sites far back from the river after a general replenishment event (Sandra Marken, pers. comm.). However, Bradley (1982) found that summer flows were not the most critical factor governing successful replenishment along the Milk River. Even though there were high summer flows both upstream and downstream of the Fresno Dam, seedlings below the dam did not survive.

Mature trees usually have deep root systems and will probably be noticeably impacted only when extremely low summer flows occur over a period of several years, such as occurs during prolonged drought or on rivers where substantial withdrawals are made annually for irrigation purposes.

6.2.5 Autumn Flows

River flows remain low in the fall, however cooler temperatures and shorter days lower the water requirements of the trees so that overall drought stress is decreased.

Overwintering survival of riparian poplars in southern Alberta is probably dependent on a healthy water status in the autumn. Stored moisture helps poplars survive winter freezing and the drying effects of Chinook winds. Both processes remove moisture from shoot tissues. Since water cannot be transported by the roots through the zone of frozen soil, a water deficit results leaving the trees in a weakened condition in the spring. Thus, trees entering the winter with a healthy moisture balance have greater moisture reserves and improved tolerance to winter stresses.

6.3 Drought

The weather of the Great Plains, including southern Alberta, is extremely variable with dramatic seasonal and annual fluctuations in precipitation and temperature. Longer term fluctuations, such as the extended drought of the 1930s are also apparent. Ellison and

Woolfolk (1937), Weaver and Albertson (1936) and Albertson and Weaver (1945) documented widespread drought-induced mortality of poplars in many regions of the North American prairies during the 1930s and 1940s. They related the extensive mortality of riparian poplars to the general lowering of the riparian water table due to deficient precipitation and a resultant reduced stream flow. The shallowness of root systems of seedlings and saplings were identified as the probable reason for the high drought-induced mortality of this age class. Older trees (greater than 30 years) were also more susceptible to drought.

At sites where the water table declined rapidly, Albertson and Weaver (1945) observed the death of riparian trees within a few months. This mortality was apparently the result of a specific drought event. At other sites, mortality progressed over the period of continued drought. Albertson and Weaver (1945) proposed that the effects of loss of tree vigour and viability were cumulative at these sites. Growth rates of leaf area, branches, and radial increments of the trunks were all reduced and extensive leaf senescence, leaf abscission, and death of branches was often observed prior to whole tree mortality (Albertson and Weaver, 1945). Reid (pers. comm.) has observed widespread evidence of drought stress during 1984-87, a series of dry years, along rivers throughout southern Alberta. He speculates that cottonwoods along the Milk River are an exception to this due to the fact that summer flows are enhanced by a diversion into the headwaters.

6.4 Cumulative Hydrological Factors

The replenishment and survival of riparian poplar forests is probably most dependent on a combination of flow regime and climate factors. The patterns of precipitation and temperature, locally or upstream in the headwaters, may compound the effects of altered river regime. An indication of the hydrological component responsible for a decline can be determined by noting the age of the trees that are affected. A forest with few seedlings might indicate changes in the volume or the timing of peak flows. These changes would be expected to limit seedling replenishment while older trees would probably be less influenced. Rapidly declining flows following flooding and low minimum summer or autumn flows, would probably increase drought stress on both young seedlings and older trees which have reduced vigour. The loss of these age groups may indicate drought-induced mortality. In general, seedlings and young saplings are expected to be the most vulnerable age groups to environmental stresses followed by the older trees. Middle aged poplars are expected to be least affected.

In summary riparian poplars are highly sensitive to drought stress in their first few years of growth, become fairly resistant once their roots have reached water table, and then become sensitized again as they approach old age. Mature poplars appear to be able to survive single stress events, but it is reasonable to assume that they are less likely to survive through sequential and cumulative stresses. Natural hydrological stresses, compounded by other stresses including those imposed by man's activities can lead to a major decline of all age classes. This decline may occur dramatically over a few years or it may not be readily apparent for a period of several years.

7.0 MAN'S IMPACT ON REPLENISHMENT AND SURVIVAL OF RIPARIAN POPLAR FORESTS

Numerous researchers have documented a decline in poplar forests along rivers in the western prairies of North America (Figure 4, Table 1) and have attributed it to man. The majority of these studies have focused on the downstream impacts of dams and diversions as the principle factor affecting replenishment and survival (Table 2). Livestock grazing is also cited as a major factor contributing to poplar decline. Other factors include harvest by man and beavers and localised floodplain developments. The following section is a review of these studies and following that are sections analyzing the key factors attributed to man which contribute to riparian poplar decline.

Figure 4: Locations of Studies Documenting Decline of Riparian Poplars in Western North America

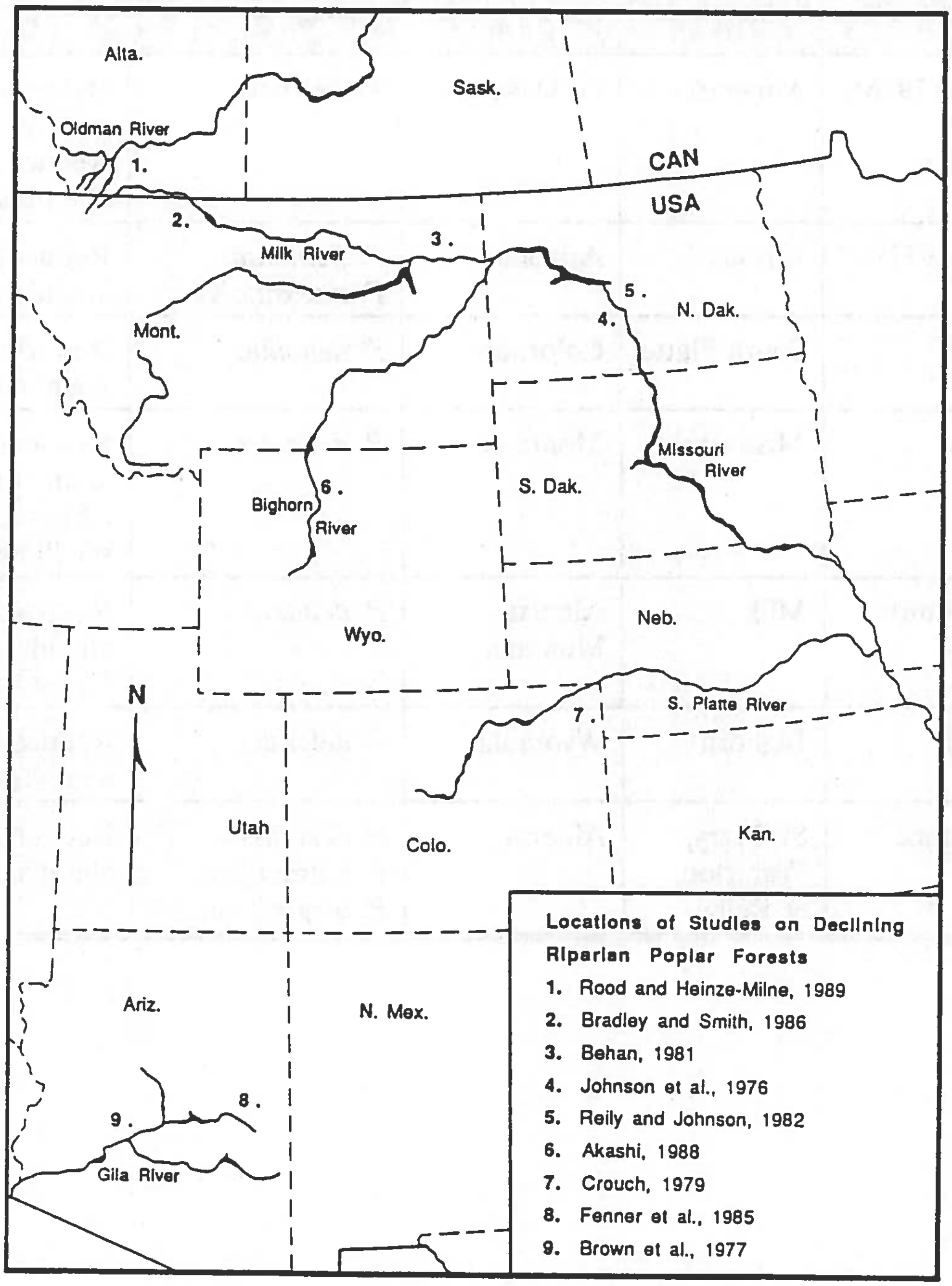


Table 1: Summary of Principal Studies Documenting Decline of Riparian Poplars

Author (Date)	River	Region	*Populus*	Impacts
Johnson et al (1976), and Reily and Johnson (1982)	Missouri	N. Dakota	*P. deltoides*	Reduced tree growth Reduced seedling abundance
Brown et al (1977)	various	Arizona	*P. fremontii*, *P. angustifolia*	Reduced forest abundance
Crouch (1979)	South Platte	Colorado	*P. deltoides*	Reduced forest abundance
Behan (1981)	Missouri	Montana	*P. deltoides*	Reduced forest abundance Absence of seedlings
Bradley and Smith (1986)	Milk	Alberta/ Montana	*P. deltoides*	Reduced forest abundance Fewer saplings
Akashi (1988)	Bighorn	Wyoming	*P. deltoides*	Reduced forest abundance
Rood and Heinze-Milne (1989)	St. Mary, Waterton, & Belly	Alberta	*P. deltoides*, *P. balsamifera*, *P. angustifolia*	Reduced forest abundance

Table 2: Altered River Regime Factors Contributing to Decline of Riparian Poplar

Proposed Cause	Comments	References
I. Hydrological changes:		
A. Reduced flooding	Spring flooding is essential to create moist seed beds for seedling establishment	Johnson et al. (1979) Brown et al. (1977) Fenner et al. (1985)
B. Reduced downstream flows	Diversion of water offstream creates a water deficit downstream, resulting in drought stress and enhanced mortality	Brown et al. (1977) Rood et al. (1989)
II. Geomorphological changes resulting from hydrological alterations:		
A. Reduced meandering	With reduced flooding, channel migration is reduced and suitable seed beds are reduced	Johnson et al. (1979) Bradley and Smith (1986)
B. Sediment depletion	The water impoundments lead to settling of suspended silt loads and downstream reaches are impoverished of the sediment	Bradley and Smith (1986)

FROM ROOD AND MAHONEY (1990A)

7.1 Review of Relevant Studies

Johnson et al. (1976) were the first to report reduced plains cottonwood (*Populus deltoides*) abundance, downstream from the Garrison Dam on the Missouri River in North Dakota. The population structure observed by Johnson et al. (1976) suggested that either a recent increase in seedling mortality or a decrease in seed production was causing a decline in the contribution of cottonwoods to the riparian forest. They concluded that the operation of the dam for downstream flood protection was causing a number of vegetation changes in the riparian zone. Although Johnson et al (1976) noted that cottonwood abundance was highly variable, they did not compare poplar abundance upstream and downstream from the dam to determine the dam's causative effect. However in 1982, Reily and Johnson, by comparing downstream riparian sites with an upland site and a site on an undammed river, concluded that flow control by the Garrison Dam caused reduced river meandering resulting in reduced production of satisfactory seed beds. This led to lower seedling establishment.

Brown et al. (1977) studied riparian communities of Fremont cottonwood (*P. fremontii*) and narrowleaf cottonwood (*P. angustifolia*) in western Arizona. They compared the present forest abundance to historical reports and found a significant decrease. The losses were attributed primarily to reduced stream flow following damming. Grazing pressure from livestock was cited as another factor causing decline. Problems of increased water salinity and ground water pumping were also noted to have contributed to the decline of riparian poplars in this area. Brown et al. (1977) recognized the vital role of spring flooding for creating seedling establishment sites. Their results showed that decadent stands were found along reaches with stabilized flows. They also noted that unregulated rivers with high spring run-off still generated considerable seedling replenishment.

Crouch (1979a) reported variations in poplar forest abundance along the South Platte River in Colorado over the past century. He found that in the late 1800s, during the first explorations of the region, few trees were present however they increased in numbers until the mid-1900s. The reasons for this are unknown. However, following the mid-1900s riparian poplars declined. Sites along grazed and ungrazed reaches of the South Platte River were assessed in 1961 and 1978 to measure changes in poplar abundance and health (Crouch, 1979b). This analysis permitted comparisons both between sites and within sites over 17 years. Declines in abundance and vitality were noted on both types of sites with greater losses on the grazed sites due to grazing of seedlings. However, Crouch (1979b) also suggested that grazing improved some sites for poplar by clearing the understory of competition. Harvesting by beavers was another factor cited as contributing to the poplar decline on this reach. Additionally, flow alterations due to upstream damming were cited as the cause for a failure of seedling replenishment at both types of sites in 1978.

The Missouri River in central Montana has twenty-seven dams that moderate spring flooding along the reach described in a study by Behan (1981). He found that young plains cottonwood (*P.deltoides)* are often absent along this portion of the Missouri River and that most of the trees are mature or over-mature. He suggested the upstream dams reduce spring flooding and slow the rate of river meandering to limit the formation of sites suitable for seedling establishment. Behan (1981) also noted that cattle grazing contributed to poplar decline by removing small seedlings. He recommended fencing cattle from poplar stands.

The hydrology of the Salt River in Arizona is altered by the Stewart Mountain Dam (Fenner et al., 1985). Typically, the spring flood is trapped and high, steady summer flows are released. These authors compared pre-dam stream flows and poplar abundance with post-dam stream flows and present abundance. They concluded, based on their knowledge of the relationship between river flow and poplar establishment requirements, that the change in flow regime (which included loss of peak spring flows and augmented summer flows) is unsuitable for Fremont cottonwood (*P. fremontii*) replenishment.

The operation of the Fresno Dam on the Milk River in Montana has led to reduced flood magnitude and frequency, reduced sedimentation and reduced rates of meander migration downstream (Bradley and Smith, 1984). Although this does not appear to affect the recruitment of plains cottonwood seedlings, based on upstream and downstream comparisons of seedling densities, it has resulted in decreased survival of seedlings past two years of age and a decrease in the overall abundance of poplars (Bradley, 1982; Bradley and Smith, 1986). By comparing forest age structure from transects upstream and downstream of the Fresno Dam, Bradley and Smith (1986) were able to attribute changes in the downstream forest to the influence of the dam. The data collected from the upstream reach is an important control in the study since both the upstream and downstream reaches are exposed to similar environmental conditions, including constant mid-summer flows, winter grazing and local harvest by beavers.

Another study along the Milk River in southeastern Alberta, reported a 16% decline in the area of plains cottonwood (*P. deltoides*) forest between 1951 and 1989 (Hardy BBT, 1990). This loss was attributed primarily to the effects of a fire that removed over 100 hectares of riparian forest. Although alterations to flows since 1917, winter grazing by livestock, harvesting by beaver, and browsing by deer have all occurred continually along this reach, there is no evidence that they have affected the long term establishment and survival patterns of the cottonwoods (Bradley and Smith, 1986; Hardy BBT, 1990).

A historical distribution of poplars along the Bighorn River downstream from the Boysen Dam in Wyoming was compiled by Akashi (1988). The loss of poplars over the past 50 years in this area was attributed to land clearing, increased occurrence of fires, and changes in the rates of channel migration and sedimentation (Akashi, 1988). Akashi (1988) also reported that poplar seedling replenishment was reduced following river damming due to the alteration of flow regime. This reduced replenishment contributed to the observed downstream forest decline.

Rood and Heinze-Milne (1989) studied the downstream impacts of river damming on riparian poplars in southwestern Alberta. Three parallel rivers were analyzed with air photos to ascertain the decline of poplars along the rivers. The unique arrangement of dammed rivers, the St. Mary and Waterton, flowing on either side of a relatively uncontrolled river, the Belly, through generally undeveloped regions permitted a controlled, replicated study of the downstream forest declines. The analysis showed declines in forest abundance of 48% and 23% between 1961 and 1981 downstream from the St. Mary and Waterton River Dams, respectively. Forest declines upstream from the dams were only 5% and 6% respectively. Little change (0-5% decline) in forest abundance was observed along the middle, undammed Belly River. These results support a causal relationship between river damming and downstream forest decline.
Further to this, Reid (pers. comm.) has compared present distribution of cottonwoods along the St. Mary, Waterton and Belly Rivers with maps developed by Dawson and McConnel in the 1880s and has concluded that poplar distribution today is very similar as 100 years ago except for obvious declines below dams on the St. Mary and Waterton Rivers.

Plains cottonwood (*P. deltoides*) has been found to suffer localized, drought-induced mortality along the South Saskatchewan River (Reid, 1991). At Police Point Park in Medicine Hat, cottonwoods died in the immediate vicinity of three high capacity water wells shortly after they were drilled. In these areas, mature poplars were unable to extend the root system rapidly enough to maintain contact with the altered water table. These trees consequently succumbed to drought stress.

7.2 Ongoing Studies in Alberta

Studies on riparian poplars presently being conducted in Alberta as of Fall, 1990 are listed in Table 3.

Table 3: Current (Fall 1990) Studies on Riparian Poplars in Southern Alberta

Researcher	Affiliation	Rivers	Purpose
Larry Cordes	University of Calgary	Lower Bow	On-going investigation of the biogeography and distribution of poplars in the area
Maureen Hills-Urbat	University of Calgary	Red Deer	Master's thesis to investigate regeneration and survival of cottonwoods in Dinosaur Provincial Park
Sandra Marken	University of Calgary	Red Deer	Master's thesis to relate riparian vegetation and cottonwood age-class distribution to hydrologic regime and land use
David Reid	Hardy BBT	Oldman, Waterton, St. Mary, Belly, Milk	Inventory of riparian vegetation to develop instream flow needs for these streams
Stewart Rood John Mahoney	University of Lethbridge	Oldman, Waterton, St. Mary, Belly	Inventory of riparian poplars to assess the operation of the Oldman Dam and determine instream flow and other mitigation requirements
Tony Yarranton	Concord Scientific	Highwood	Inventory of riparian vegetation to assess impacts of Highwood water diversion project and establish instream flow requirements
Tony Yarranton	Concord Scientific	Willow Creek	Inventory of riparian vegetation to assess impacts of a proposed offstream storage reservoir and to establish instream flow requirements

7.3 Reduced Seedling Establishment due to Dams

As discussed above, spring flooding is essential to the riparian ecosystem and must persist for forest replenishment. The operation of flow control structures to trap spring floods has a serious ecological impact on the riparian ecosystem downstream. The prevention of downstream flooding, or storage of water for municipal, industrial, or hydroelectric needs (Harris et al., 1987) may be desirable, but it also eliminates one, or all, of the conditions necessary for seedling establishment. Although many impoundments in southern Alberta do not have the capacity to significantly alter peak flows, some reservoirs may. Moreover, as more dams are constructed, the cumulative effect within a basin may become significant.

The river systems of southern Alberta are naturally very dynamic. Periodic overbank flooding shifts channels and drives the meandering process. The movement of the river channel within the river valley constantly exposes or builds new sites suitable for poplar establishment. Trapping spring floods or releasing a constant flow downstream from impoundment structures alters the hydrological pattern and creates a more stable regime. Stabilized flows contribute to degradation of the streambed, less floodplain deposition, and less lateral movement of the channel (Williams and Wolman, 1984). Downgrading eliminates broad sand and gravel bars and forms steeper embankments that are less suitable for poplar establishment (Everitt, 1968; Johnson et al., 1976; and Bradley and Smith, 1986).

The model of poplar establishment presented by Bradley and Smith (1986) (Figure 3) depends on a constant supply of sediment for deposition and formation of new point bars. The loss of this material will inhibit the formation of the bars essential for poplar regeneration. The placement of large reservoirs on rivers causes the formation of a silt shadow where river sediment is depleted for some distance downstream (Williams and Wolman, 1984). The loss of the sediment load downstream from dams is a critical element contributing to the decline of riparian poplar forests downstream from dams (Johnson et al., 1977; Crouch, 1979b; Behan, 1981; Bradley and Smith, 1986; Akashi, 1988).

The characteristics of the river and normal sediment load determines the extent of the silt shadow (Williams and Wolman, 1984). Clean, steep-gradient rivers with coarse textured beds recover silt loads quickly while shallow-gradient rivers with sand and silt beds recover much more slowly. Up to 300 km may be required for meandering prairie rivers to recover the pre-dam sediment load (Williams and Wolman, 1984). The sediment-depleted river below a dam scours the river bend and bank to replenish the sediment load. This action removes sediment from the riparian system so that the formation of sites suitable for poplar seedling establishment is reduced.

If poplar forest decline is closely related to sediment depletion, the forest decline should be limited to the zone of depletion. The poplar forest should recover as the river regains its sediment load and deposition of sediments forming suitable establishment sites reoccurs. No studies have been completed in southern Alberta on the actual extent of sediment load changes downstream from dams. However, preliminary work (Mahoney and Rood, pers. comm.) below the St. Mary and Waterton dams suggests that pre-dam sediment loads may be regained within 15 km of the dams. Since no forest recovery is found within 40 km of these dams (Rood and Heinze-Milne, 1989), it is postulated there are other factors besides the silt shadow contributing to the downstream forest decline along these rivers.

With respect to other dams on southern Alberta Rivers, the silt shadow created by the Dixon Dam on the upper Red Deer River probably is not affecting cottonwood replenishment along the lower Red Deer River since there are major sources of sediment, including tributary streams and badlands, downstream of the dam (Marken, pers. comm.). The silt shadow below the Bearspaw Dam on the Bow River may not to be affecting riparian poplar replenishment in the Blackfoot Indian Reserve due to an influx of sediment from the Highwood River, which is not dammed. However these predictions need verification.

As a general conclusion, however, the silt shadow appears to be an important factor in riparian poplar decline on high sediment rivers where there are few new sediment sources for considerable distances downstream of dams.

7.4 Drought Stress due to Dams and Diversions

Seedling survival is a limiting factor of the poplar forest cycle in southern Alberta. An increase in drought stress would likely decrease seedling survival and further exaggerate this limitation to forest replenishment. Changes in the flow regime that reduce flow during the hot, dry summer probably increase the rate of substrate drying and the level of drought stress.

Under natural conditions, slow flow reduction provides poplars with an interval for hardening. During this period plant tolerance to drought stress gradually increases. An abrupt reduction in downstream flow eliminates this hardening interval and is likely to be particularly stressful (Crouch, 1979b; Rood and Heinze-Milne, 1989). Preliminary work (Mahoney and Rood, pers. comm.) indicates that riparian water table levels closely match river stage. Rapid stage decline is therefore indicative of rapid water table decline. If root growth is inadequate to maintain contact with the falling water table, drought stress and, possibly, mortality will result. This is most likely to occur in sites with a gravel on the surface or with a gravel substrate below fluvially deposited sands and silts. Seedlings have limited root systems to cope with a sudden change in water availability throughout their first year. If the water table declines abruptly during the first year, desiccation and mortality is very likely. Marken (pers. comm.) noted that plains cottonwoods in the 30 to 40 year age class have significantly smaller diameters where they grow on sites which have gravel substrates compared to those that do not. Albertson and Weaver (1945) noted that older, less vigorous trees are less drought resistant than middle-aged trees so that an abrupt water cut-off could be fatal to these trees as well. In Alberta, this was observed in Police Point

Park on the South Saskatchewan River in the vicinity of high capacity water wells (Reid, 1991).

The ability of poplars to resist drought stress varies with the species (Pallardy and Kozlowski, 1981). For example, plains cottonwood was found to respond more slowly to drought stress than balsam poplar hybrids by taking longer to close leaf stomata and longer to reopen them as well. These researchers did not investigate narrowleaf cottonwood. However, a decline of all species may occur over large areas if severe drought conditions occur.

7.5 Livestock Production

River valleys are used extensively for livestock production. The forest provides protection from poor weather, the river provides ready access to water, and the generally abundant vegetation provides forage. It is noteworthy that the nutrient value of forage species in riparian poplar stands is generally low compared to that of the adjacent grasslands. However, this is often compensated for by increased biomass production.

Light grazing is probably not detrimental to riparian poplar forests. It can clear the understory and add nutrients to the riparian zone. Unfortunately, livestock overuse is often the case and this can seriously degrade the riparian ecosystem and contribute to riparian poplar decline (Behan, 1981; Crouch, 1979a; Kauffmann and Krueger, 1984; Kellogg and Swan, 1986; Shaw, 1976). Cattle prefer the young poplar seedlings and saplings as a food source (Behan, 1981). In addition, they often congregate on point bars near the river's edge to obtain access to water which can lead to trampling of young seedlings. These losses limit poplar replenishment in grazed areas. Marlow and Pogacnik (1985) report that in late summer when water is scarce, up to 80% of the forage may be derived from the 4% of pasture acreage that is in the riparian zone in Colorado. Marken (pers. comm.) suggests that one of the major causes of lack of poplar replenishment along the Red Deer River is grazing by cattle. As well, overgrazing can alter the quantities of dead and live stems (Knopff and Connor, 1982) and reduce shrub cover by 92% and canopy cover by 55% (Marcusson, 1977).

The effects of cattle grazing are illustrated by the recovery or survival of forests along river reaches that have been protected by fencing (Behan, 1981; Crouch 1979b). Protection from grazing promotes rapid recovery of poplars and understories (Davis, 1977; Elmore, 1989; Kauffman and Krueger, 1984; Hansen, 1985; Reichard, 1989; Smith, 1989). Protection during the hot summer months appears to be especially important (Marcusson, 1977; Platts et al., 1987), although studies on the effectiveness of various grazing systems to reduce negative effects on poplars have so far been inconsistent and inconclusive (Hansen, 1985).

7.6 Harvest by Man and Beavers

Historically, the river forests were important sources of wood since the uplands of the western plains support few trees. Although poplar has poor construction characteristics, it was often pressed into service as the only material available. River poplars were used to build homes, forts and other structures both in the river valley and on the prairie (Shaw, 1976).

Poplar was also used extensively as fuel for cooking and heating. Gildart (1984) reports that harvesting of poplar to power steamboats also had a considerable impact. The removal of 250,000 cords of poplar between the Yellowstone River and Fort Benton on the Missouri River over a period of 20 years must have seriously reduced the riparian forest along that reach (Gildart, 1984). Marken (pers. comm.) suspects that a lack of trees in the 80 to 120 year age class along the Red Deer River may be due to a large influx of settlers to the region just before and at the turn of the century.

Riparian poplar forests have been cleared to open areas for crop cultivation and urban expansion. The alignment of transportation routes and the development of recreation areas has also resulted in the clearing of poplar forests. Removal of these forests has led to a concentration of wildlife in the remaining stands. This may cause species such as beaver, which preferentially select young poplars over willow, to increase harvesting in limited areas in an attempt to survive in the smaller forest (Barnes, 1985; Crouch, 1979b). If the balance of beavers and poplars is further distorted due to a reduction in beaver predators around developed areas, an increased loss of riparian poplars can result.

Removal of trees by beaver has been suggested as a threat to limited stands of riparian poplars along the lower Bow River (Cordes, 1991) and the Red Deer River in Dinosaur Provincial Park (Maureen Hills-Urbat, pers. comm.).

7.7 Developments on Floodplains

Several developments on floodplains affect riparian poplar replenishment and survival in relatively localized areas, but the cumulative effect may have a significant impact in southern Alberta, especially when they lead to demands for flood control. These developments include:

Rural Acreage Development - This is a relatively new and incremental encroachment which can result in permanent removal of riparian vegetation, intensive grazing pressure and pumping of groundwater. More importantly it can lead to demands for flood control. Municipal zoning to prevent building in floodplains can be used to address this problem.

Agriculture - Besides the cultivation of flood plains, these areas are attractive for feedlot operations and as farm building locations. As well, it is suspected that competition from introduced agricultural species such as sweet clover (*Melilotus* sp.), may hinder poplar replenishment on newly formed bars. Irrigation activities and application of fertilizers, which can lead to salinization of soils in river valleys, are another threat. Herbicide drift from aerial spraying of agricultural lands has been postulated as another agricultural factor which may affect survival of riparian poplars (Middleton, pers. comm.).

Golf Courses - These and other recreational developments result in removal of riparian vegetation and negative impacts on riparian forests with pumping from groundwater sources, herbicide drift and, possibly, fertilizer use.

Gravel Mining - This activity can result in temporary, sometimes permanent removal of forests and impacts on ground water.

Industrial Activities - Primarily including oil and gas exploration, development and transportation, this can result in clearing of forests.

Onstream Reservoirs - While much of this report discusses downstream effects of reservoirs, direct loss of riparian poplars can occur behind dams when river valleys are flooded out.

8.0 RIPARIAN POPLAR DISTRIBUTION AND DENSITY IN SOUTHERN ALBERTA

As part of this overall assessment of the biology and status of riparian poplars in southern Alberta, a project was undertaken to determine the present distribution and density of riparian poplars along rivers in southern Alberta through interpretation of recent air photos. Comparisons were made of distribution and density of riparian poplars interpreted from air photos from the early 1950s to determine if any changes were apparent over a 30-year period along the Bow, Oldman, Red Deer and South Saskatchewan Rivers. The present distribution of riparian poplars also was compared to the mapped distribution of wooded river valleys in the early 1880s to identify reaches that have changed since that time.

8.1 Methods

Poplars were mapped using air photo interpretation along major river valleys and their major tributaries within the grasslands of southern Alberta (Map 2). More specifically, mapping of the major rivers was completed upstream to a point where balsam poplar, aspens and conifers were found in large numbers in the coulees and the main valley. This generally included those portions of the rivers occurring in the Mixed Grassland, Fescue Grassland and outer fringe of the Aspen Parkland Natural Regions. Mapping of major tributaries to these rivers was completed up to a point where riparian poplars no longer occurred.

Rivers and their major tributaries investigated were:

- Red Deer River - Threehills Creek, Kneehills Creek, Rosebud River
- Bow River
- Oldman River - Pincher Creek, Willow Creek (to Hwy 2), Little Bow River
- Belly River
- St. Mary River - Lee Creek
- Waterton River - Drywood Creek, Foothills Creek
- South Saskatchewan River - Bullshead Creek
- Milk River

Poplars could be detected on photos at scale of 1:40,000 or greater using a mirror stereoscope at three times magnification. Mapping was first done from photos dating to the early 1980s to determine present distribution and then from photos dating to the early 1950s, the earliest available photography, to determine if any changes in distribution or density could be detected. Air photography flown by the federal government in the 1920s also was examined but did not cover areas pertinent to this study. In total over 1300 photos were interpreted. Table 4 provides a summary of photos used for the 1980s mapping. A more complete listing of photos used for both the 80s and 50s is filed with Alberta Forestry, Lands and Wildlife - Fish & Wildlife Division in Lethbridge. Only four rivers were considered in the 1950s mapping - Bow, Red Deer, South Saskatchewan and Oldman - as changes in distribution and abundance along the Milk River (Hardy BBT, 1990) and the Belly, Waterton, and St. Mary Rivers (Rood and Heinze-Milne, 1989) have been completed by other researchers.

The location and density of riparian poplars was mapped onto 1:50,000 NTS map sheets. A colour-coded system representing four density categories was used; stands were mapped as greater or less than 50 m wide, and as sparse or dense. Areas undergoing cultivation were also delineated. The original colour-coded maps are on file with the Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division in Lethbridge, Alberta.

Table 4: 1980s Air Photography Used to Determine Riparian Poplar Distribution and Density

River	Year	Scale	Type
Red Deer	1986	1:40,000	b/w
Bow	1981 1983 1985	1:30,000 1:30,000 1:30,000	b/w b/w b/w
Highwood	1983	1:40,000	b/w
Oldman	1985	1:30,000	b/w
Belly	1985	1:30,000	b/w
St. Mary	1985	1:30,000	b/w
Waterton	1985	1:30,000	b/w
South Saskatchewan	1980 1985 1985 1986	1:30,000 1:30,000 1:30,000 1:40,000	b/w b/w false colour infrared b/w
Milk	1984	1:30,000	false colour infrared

Data from the 1:50,000 scale maps was summarized for presentation on a 1:1 000 000 map by dividing each river into fairly homogeneous reaches based on riparian poplar distribution and density, and geomorphology. The divisions are somewhat subjective since in nature changes in riparian poplar density are often gradual rather than abrupt. Map 2 shows reaches identified by a river letter and reach number (e.g. R1, BL3).

For each reach an overall assessment was made of poplar density - none/negligible, sparse, moderate, dense and very dense. The river length in each density category was measured using a computer coordinating planimeter. Although it might have been more desirable to planimeter areas of stands in each density category, this would have required working again from the original air photos, which time and resources did not permit. For each reach notes were also made of channel character (freely meandering, confined meandering, straight and braided), floodplain width, disturbance and special features.

Although there is a great deal of confidence in the results, mention should be made of certain limitations inherent in air photo interpretation. One very important limitation is that young age classes of poplars (under 2m) could not be differentiated from shrubs, therefore they are not mapped. And, photos taken very early in the season before leaves appear or very late after leaf senescence may result in underestimation of density. As well, some photos are over- or under-exposed resulting in loss of contrast and thus detail. These difficulties are accentuated with older photography. Furthermore, changes in the cultural landscape (ie roads) and in the physical landscape (ie river course) can inhibit accurate transfer of air photo information onto map sheets. And of course less detail is evident with smaller scale photography. One final point is that groundtruthing, which allows for verification of the interpretation, was not undertaken as part of this project.

The distribution of wooded areas in river valleys for most of the present study area was mapped in the 1880s as part of the Dominion Survey (Dawson, 1885). In this survey, Dawson identified river valleys that were treeless, valleys with small isolated groves, or wooded river valleys. By relating these three categories to those used in the present study, it is possible to qualitatively compare the historic distribution with the present distribution. Dawson (1885) did not use the same categories as those used in the present study, nor did he use density as a weighting factor. For comparison between the two data sets, it was assumed that the density of forest along reaches left unmarked by Dawson were equivalent to the density of forest along reaches rated none/negligible in the present study. Reaches noted to have only isolated groves in Dawson's report were assumed to be equivalent to reaches with sparse forests in the present study. The wooded river valleys identified by Dawson were estimated to be equivalent to those rated as moderate, dense or very dense in the present study. Reach boundaries used for airphoto analysis were easily located on the 1885 map for the purposes of comparison.

Statistical analysis of the data was not undertaken as much of the interpretation is qualitative rather than quantitative.

8.2 Present Distribution and Density

Distribution and density of riparian poplars in southern Alberta as determined from 1980s air photos is presented in Map 1. Table 5 provides information on the length of each river in each density category, in kilometres and by percent.

Of the 2075 km of river length investigated, 30 percent (625 km) has sparse density of poplars; 23 percent (470 km) has no or negligible density; 22 percent (465 km) has moderate density, 15 percent (320 km) is considered dense and nine percent (195 km) very dense (Figure 5).

Figure 5: 1980's Riparian Poplar Density Distribution in Southern Alberta (percent river length per density class)

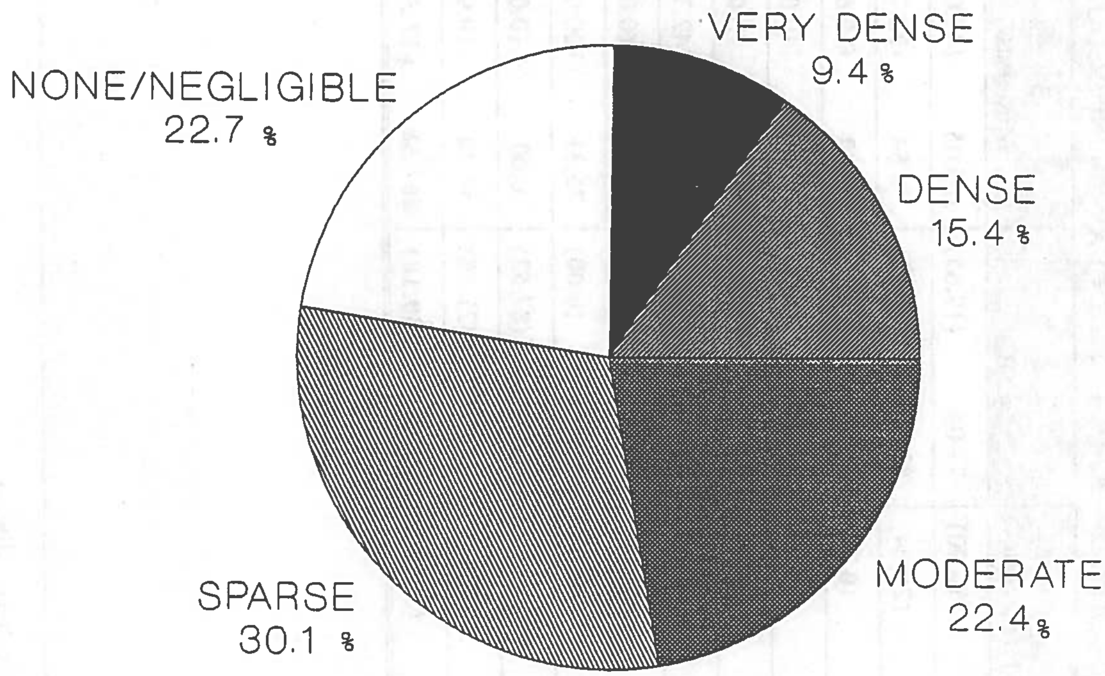


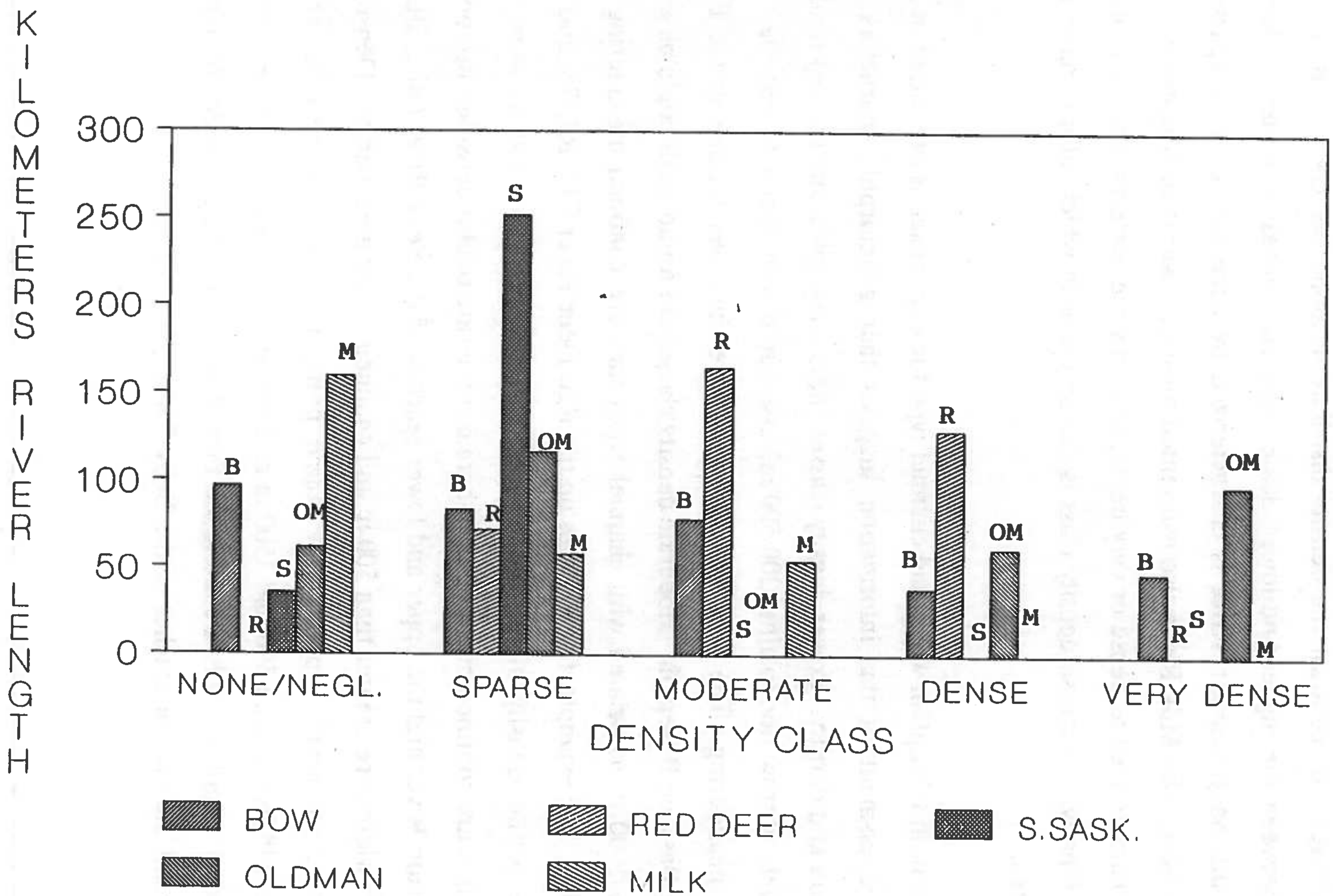
Table 5: 1980s Density Distribution Along Rivers in Southern Alberta

River	Length (Km)		KM/DENSITY CLASS (% INDIVIDUAL RIVER LENGTH)									
			1 None/Negligible		2 Sparse		3 Moderate		4 Dense		5 Very Dense	
Red Deer	366.65		0.00	(0.00)	72.04	(19.65)	165.05	(45.02)	129.56	(35.34)	0.00	(0.00)
Bow	346.62		97.18	(28.04)	83.60	(24.12)	78.84	(22.75)	38.86	(11.21)	48.14	(13.89)
Highwood	69.18		0.00	(0.00)	41.76	(60.36)	27.42	(39.64)	0.00	(0.00)	0.00	(0.00)
Sheep	25.93		0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	25.93	(100.00)	0.00	(0.00)
Oldman	340.01		62.08	(18.26)	117.18	(34.46)	0.00	(0.00)	61.93	(18.21)	98.82	(29.06)
Belly	149.96		0.00	(0.00)	0.00	(0.00)	63.56	(42.38)	37.59	(25.07)	48.81	(32.55)
St. Mary	140.91		115.51	(81.97)	0.00	(0.00)	0.00	(0.00)	25.40	(18.03)	0.00	(0.00)
Waterton	75.31		0.00	(0.00)	0.00	(0.00)	75.31	(100.00)	0.00	(0.00)	0.00	(0.00)
South Saskatchewan	288.04		35.95	(12.48)	252.09	(87.52)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Milk	272.32		159.96	(58.74)	57.96	(21.28)	54.40	(19.98)	0.00	(0.00)	0.00	(0.00)
Total (% Total)	2,074.93	(100)	470.68	(22.68)	624.63	(30.10)	464.58	(22.39)	319.27	(15.39)	195.77	(9.44)

Some general aspects of riparian poplar distribution along the major rivers are worth noting (Figure 6). The Bow River is the only river which has reaches in all density classes. Density of riparian poplars along the Red Deer River is clustered within the three middle density categories (sparse, moderate, dense); no reaches were at either extreme (none/negligible or very dense). By contrast the density distribution along the Oldman River is equally divided between the higher and lower classes with no reaches of moderate density. The entire South Saskatchewan River is characterized by none/negligible or sparse riparian poplar density. The Milk River also is oriented towards lower density distribution, with no reaches characterized as dense or very dense, and only the easternmost reach of moderate density. Finally, the sparse density class is the only one in which all the major rivers are represented.

Information on floodplain width and channel type for each reach is presented in Appendix A. An assessment of this information suggests that geomorphic characters influence distribution and density. Lower density classes (none/negligible and sparse) tend to occur on relatively narrow floodplains (200-500 m) associated with channels that are straight or confined meandering. The best examples of this are the lower reaches of the Bow River below the Bassano Reservoir. Moderate density classes are found on floodplains with widths of 300 to 1000 m associated with channel types that are confined meandering or freely meandering. For example, four reaches on the Red Deer River (R1, R3, R5, and R9) have moderate poplar density along floodplains which are less than 500 m wide and have channels that are confined meandering; whereas moderate poplar densities also occur along the Waterton River and the upper and lower reaches of the Belly River (BL1, BL4) where floodplain widths are greater than 500 m and channels freely meandering. Dense and very dense classes of riparian poplars are found predominantly along reaches which have floodplain widths between 500 and 1500 m and channel types which are freely meandering or braided. Examples of this are along the Bow River within the Blackfoot Indian Reserve (B2, B3) and the middle reaches of the Belly River (BL2, BL3).

Figure 6: **1980's Riparian Poplar Density Distribution Along Five Major Rivers in Southern Alberta (river length per density class) (Reference to Table 5.)**



8.3 Comparison with 1950s Distribution

Table 6 and Figure 7 present riparian poplar distribution and density on the Red Deer, Bow, Oldman and South Saskatchewan Rivers during 1950-52 compared to that of the 1980s. Overall there appears that little or no change in distribution and density of riparian poplars along these four rivers in the last thirty to thirty-five years. In fact, the data suggests a slight increase in density along some reaches. Analysis of Table 6 reveals that one reach on the Red Deer (R8) shifted from moderate in the 1950s to dense in the 1980s and one reach on the Bow River (B3) shifted from dense (1950s) to very dense (1980s). No major changes in density along the Oldman River were determined. The easternmost reach of the South Saskatchewan River (S3) shifted from none/negligible (1950s) to sparse (1980s).

Caution must be exercised when interpreting these results due to the arbitrary nature of the reach divisions and the necessity of generalizing density within each reach. As a result, localized changes in density may be masked.

8.3.1 Cultivation

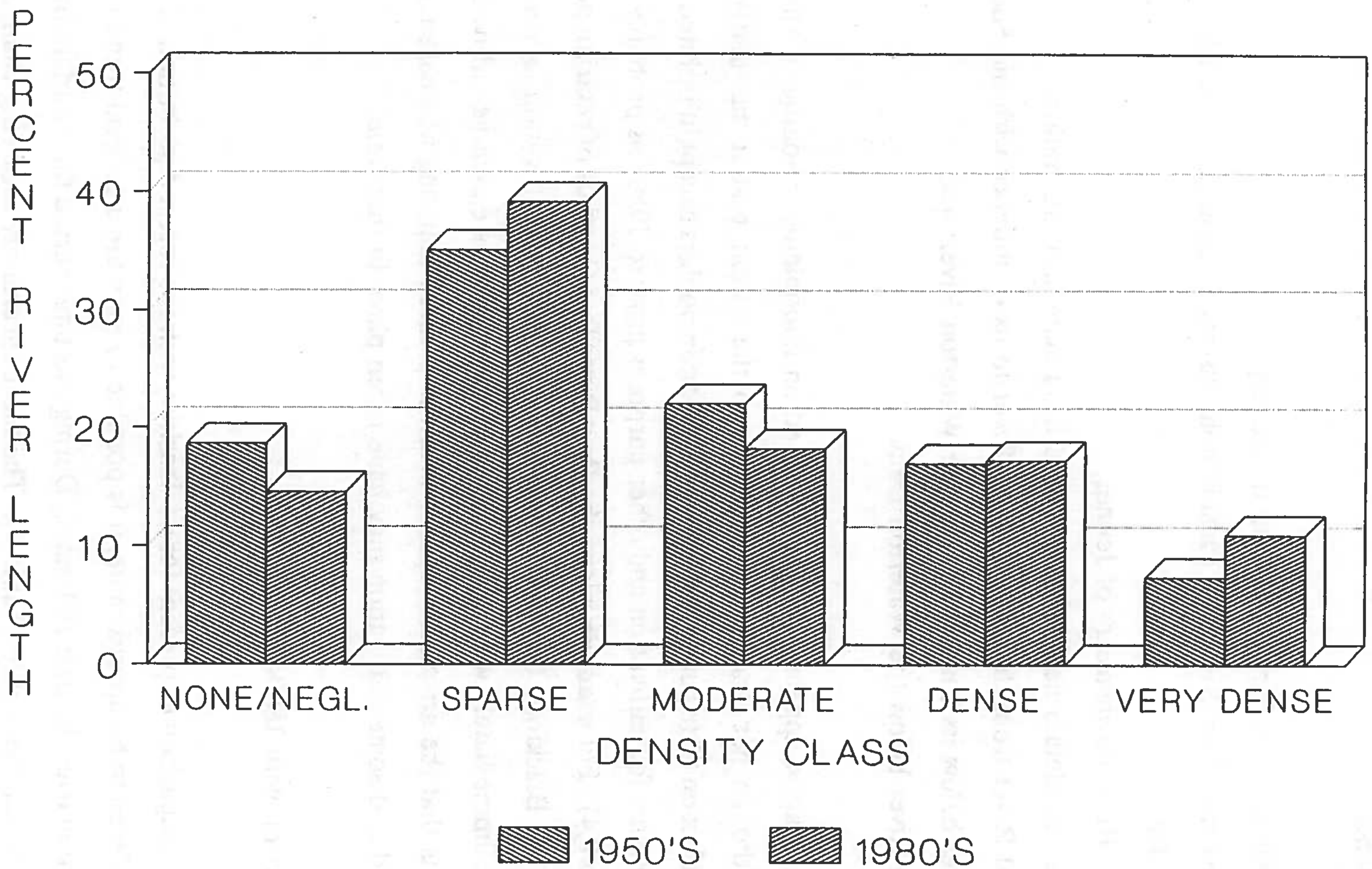
According to interpretation of the 1980s air photos, cultivation is present in 31 of the 44 river reaches (Appendix A). Areas of cultivation are outlined on the 1:50,000 maps which are on file with Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division in Lethbridge, Alberta.

Table 6: 1950s and 1980s Riparian Poplar Density Distribution Along Four Major Rivers in Southern Alberta

River	Length (Km)		KM/DENSITY CLASS (% INDIVIDUAL RIVER LENGTH)									
			1 None/Negligible		2 Sparse		3 Moderate		4 Dense		5 Very Dense	
Red Deer	366.65	1950s	*0.00	(0.00)	72.04	(19.65)	216.38	(59.02)	78.23	(21.34)	0.00	(0.00)
		1980s	**0.00	(0.00)	72.04	(19.65)	165.05	(45.02)	129.56	(35.34)	0.00	(0.00)
Bow	346.62		97.18	(28.04)	83.60	(24.12)	78.84	(22.75)	87.00	(25.10)	0.00	(0.00)
			97.18	(28.04)	83.60	(24.12)	78.84	(22.75)	38.86	(11.21)	48.14	(13.89)
Oldman	340.01		62.08	(18.26)	117.18	(34.46)	0.00	(0.00)	61.93	(18.21)	98.82	(29.06)
			62.08	(18.26)	117.18	(34.46)	0.00	(0.00)	61.93	(18.21)	98.82	(29.06)
South Saskatchewan	288.04		90.84	(31.54)	197.20	(68.46)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
			35.95	(12.48)	252.09	(87.52)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Total (% Total)	1,341.32		250.10	(18.65)	470.02	(35.04)	295.22	(22.01)	227.16	(16.94)	98.82	(7.37)
			195.21	(14.55)	524.91	(39.13)	243.89	(18.18)	230.35	(17.17)	146.96	(10.96)

* 1950s Density
** 1980s Density

Figure 7: **1950s and 1980s Riparian Poplar Density Distribution Along Four Major Rivers in Southern Alberta (percent river length per density class) (Refer to Table 6)**



According to the 1980s air photo analysis, cultivation of floodplains is prevalent along the following reaches:

- Oldman River from Fort McLeod to its mouth;
- South Saskatchewan River for considerable distances upstream and downstream of Medicine Hat;
- Red Deer River downstream of Jenner;
- Bow River floodplain near Carseland and from Scandia to its mouth;
- Highwood River from the town of High River to its confluence with the Sheep River;
- Belly River below its confluence with the Waterton River; and
- Waterton River below the Waterton Dam.

Generally, cultivation appears to have increased on floodplains in southern Alberta since the 1950s, although not dramatically and not to the extent that it has had an overall measurable effect on distribution and density of riparian poplars except in isolated locations. Clearing of poplars for cultivation and other purposes prior to 1950 has probably had some effect (section 8.4). For example, along the Bow River larger stands of riparian poplars are found within the Blackfoot Indian Reserve where there is no cultivation as compared to smaller stands immediately west of the Reserve where there is extensive cultivation. One further point is that the air photos upon which the present mapping was based are now 5 to 10 years old and some cultivation may have taken place in that time.

8.4 Comparison with 1880s Distribution

Although the comparison of present forest densities with the forest distribution of the 1880s must be considered to be approximate, it is possible to estimate a general trend in riparian forest distribution over the past 100 years. During this time period the riparian forest along most reaches has changed little (Table 7). The most uncertainty regarding changes in river valley forests since the 1880s is with those which were mapped as wooded by Dawson compared to those mapped as moderate, dense or very dense in the 1980s. For the purposes of this study they have been considered equivalent since the generality of Dawson's "wooded" category does not allow for a more refined assessment.

Reaches of the Red Deer River show the most consistent change over 100 years. From the 1880s to the 1980s, four reaches show increases in riparian poplars from negligible/none or sparse to moderate or dense. None of the reaches investigated along the Red Deer River showed a decline in this period. A tributary of the Red Deer, the Rosebud River, did show a decline from moderate-very dense to sparse over this interval.

There is no discernable change along the Bow River between the time of these two surveys with the exception of an increase from none-negligible to sparse along the reach from Bassano to Bow City (B5). The lower portion of the Highwood River is unchanged, but riparian forests above High River (H1) appear to show an increase from sparse to moderate. However, this may be due to an overlap between the boundaries of the limit of wooded river valley noted by Dawson and the upstream boundary of the H1 reach. The Sheep River near Okotoks has increased from a few isolated groves to a more densely wooded stream along the reach surveyed.

Two reaches of the Oldman River show a change since the 1880s. Reach OM3, immediately upstream of the Belly River confluence, shows a decrease in the riparian forest from dense to sparse between the 1880s and the 1980s, the largest apparent decline of any major river in the study area. Reach OM6, just upstream of the mouth of the Oldman River, shows a decline from sparse to negligible. The reasons for these declines are unclear, although cultivation may be a factor.

Table 7: Changes in Riparian Forest Distribution 1880s to 1980s

Reach		Dawson *	1980s	Change
Red Deer:	R3	Negligible	Moderate	increase
	R4	Sparse	Sparse	no change
	R5	Sparse	Moderate	increase
	R6	Moderate - Very Dense	Dense	no change
	R7	Negligible	Moderate	increase
	R8	Sparse	Dense	increase
Rosebud River		Moderate - Very Dense	Sparse	decrease
Bow:	B1	Moderate - Very Dense	Moderate	no change
	B2	Moderate - Very Dense	Dense	no change
	B3	Moderate - Very Dense	Very Dense	no change
	B4	Moderate - Very Dense	Moderate	no change
	B5	Negligible	Sparse	increase
	B6	Negligible	Negligible	no change
	B7	Negligible	Negligible	no change
	B8	Sparse	Sparse	no change
Highwood:	H1	Sparse	Moderate	increase
	H2/3	Sparse	Sparse	no change
Sheep:	SH1	Sparse	Dense	increase
Oldman:	OM1	Moderate - Very Dense	Moderate	no change
	OM2	Moderate - Very Dense	Very Dense	no change
	OM3	Moderate - Very Dense	Sparse	decrease
	OM4	Moderate - Very Dense	Dense	no change
	OM5	Sparse	Sparse	no change
	OM6	Sparse	Negligible	decrease
Belly:	BL1	Moderate - Very Dense	Moderate	no change
	BL2	Sparse	Very Dense	increase
	BL3	Moderate - Very Dense	Dense	no change
	BL4	Moderate - Very Dense	Moderate	no change
St Mary:	SM1	Moderate - Very Dense	Dense	no change
	SM2	Sparse	Negligible	decrease
Waterton:	W1	Moderate - Very Dense	Moderate	no change
South Saskatchewan:	S1	Sparse	Sparse	no change
Milk:	M1	Negligible	Negligible	no change
	M2	Negligible	Negligible	no change
	M3	Negligible	Negligible	no change
	M4	Sparse	Sparse	no change
	M5	Negligible	Negligible	no change
	M6	Sparse	Sparse	no change
	M7	Moderate - Very Dense	Moderate	no change

* Distribution categories used by Dawson (1880s) have been translated for the purpose of comparison with the present study as:

Present 1980s:	**Dawson 1880s:**
None/Negligible	treeless
Sparse	small isolated groves
Moderate	-
Dense	wooded river valleys
Very Dense	-

Along the Belly River all but one reach have remain unchanged since the 1880s. Reach BL2, immediately upstream of the confluence with the Waterton River shows an increase in forest density from sparse to very dense over the past 100 years. This is a dramatic change considering the lack of change along the other rivers studied. Again, the reasons for this are unclear. On the other hand, the St. Mary River below the St. Mary Reservoir (SM2) shows a decrease in riparian forest distribution from sparse to none/negligible. The Waterton River shows no apparent change.

The South Saskatchewan River to Medicine Hat (S1) shows no change during the past 100 years, riparian poplars being rated as sparse both in Dawson's 1880s maps and in the 1980s air photo interpretation. Dawson's maps do not extend beyond Medicine Hat so comparison of the lower reaches is not possible.

All reaches of the Milk River show no change. However it is noteworthy that Dawson mapped Reach M4 above Verdigris Coulee as treeless and below Verdigris Coulee as a wooded river valley. The 1980s maps show the whole reach as sparse, with an annotation that riparian poplar distribution is generally patchy and sparse except for two dense concentrations.

8.5 Significant Reaches

Based on the results of this study, six river reaches stand out as particularly significant for riparian poplars in southern Alberta. Criteria used to assess significance are 1) density, 2) species diversity and position in range of species and 3) amount of disturbance. The river reaches assessed as significant are:

- Bow River, Carseland - Cluny (B2-3) (87 km)
  - poplar stands broad and dense to very dense
  - composed of balsam poplar, plains cottonwood and hybrids; at limit of ranges of both balsam poplar and plains cottonwood
  - relatively undisturbed, particularly in Blackfoot Indian Reserve; cultivation west of the Blackfoot Indian Reserve and eastern portion of reach influenced by Bassano Reservoir
  - floodplain broad (up to 2500m wide) with freely meandering and braided channel

- Oldman River, Brocket - below Lethbridge (OM2-4) (182 km)
  - poplar stands broad and dense to very dense
  - composed of narrowleaf cottonwood and balsam poplar and their hybrids including trispecific hybrids with plains cottonwood; part of very restricted range of narrowleaf cottonwood in Canada
  - relatively undisturbed, particularly in Peigan Indian Reserve; cultivation along lower portion of reach
  - floodplain broad (up to 2000m wide) with freely meandering and braided channel; channel has changed course in several places over 30 years; 20 km reach (OM3) has narrow, straight valley with confined channel and sparse poplar density

- Belly River, Glenwood - below Waterton confluence (BL2-3) (86 km)
  - poplar stands narrow and dense to very dense
  - composed of narrowleaf cottonwood, balsam poplar and their hybrids; part of restricted range of narrowleaf cottonwood in Canada
  - relatively undisturbed particularly through Blood Indian Reserve
  - 500 to 1500 m wide floodplain with freely meandering and braided channel

- Red Deer River, Finnegan - Empress (R5-10) (240 km)
  - poplar stands generally elongated in form but with a particularly diverse mosaic of stand sizes upstream of and extending into Dinosaur Provincial Park and moderate to dense
  - composed of plains cottonwood; at northern and western limit of range of plains cottonwood in North America
  - relatively undisturbed; some cultivation on floodplain below Jenner
  - floodplain consistently 500 m wide with confined meandering, freely meandering and braided channel

- Milk River, through Milk River Canyon (M7) (54 km)
  - poplar stands medium-sized and sparse with localised dense patches
  - composed of plains cottonwood; at western limit and near northern limit of range of plains cottonwood in North America
  - isolated and undisturbed except for a fire that killed trees in a 10 km reach in 1973
  - floodplain 500-750 m wide with confined and freely meandering channel

- Sheep River near Okotoks (SH1) (26km)
  - poplar stands medium-sized and very dense
  - composed of balsam poplar and hybrids with narrowleaf cottonwood
  - disturbance includes residential development in and near Okotoks and cultivation at confluence with Highwood River
  - 500 m wide floodplain with freely meandering channel

8.6 Status of Riparian Poplars in Southern Alberta

Over 50% of total river length in southern Alberta is characterized by none or sparse riparian poplar density. The 980 km of river valleys that do contain relatively continuous stands of poplars therefore represent a very restricted habitat, less that 500 km2 in total area. Because these habitats have such disproportionately large importance to wildlife relative to the total area they occupy on the prairies, loss of even a small portion of the riparian poplar forests, and in particular of those reaches assessed as significant in the previous section, could have major implications for prairie wildlife.

It is encouraging that there appears to have been no general decrease in riparian poplars along rivers in southern Alberta since the 1880s. In fact comparison of the 1980s mapping with that for the 1950s and 1880s suggests slight increases in distribution and density along some reaches of the Red Deer, Bow and South Saskatchewan Rivers. As well, the Belly River above its confluence with the Waterton River and the lower Sheep River show notable increases in riparian poplars since the 1880s.

However some reaches have experienced notable declines. A study by Rood and Heinze-Milne (1989) documented a decline of riparian poplars along the St. Mary and Waterton Rivers below dams since the 1950s. A decline on the St. Mary River also is apparent when 1980s mapping is compared with 1880s mapping. As well, two reaches on the Oldman River, one immediately upstream of the confluence with the Belly and the other downstream of Taber, and the lower Rosebud River show declines since the 1880s. Clearing for cultivation is a probable factor in these declines.

Concerns have been expressed about the impacts of the nearly-completed Oldman Dam on significant tracts of riparian forest in the Oldman River valley below that dam (Cliff Wallis, pers. comm.). The legitimacy of these concerns is substantiated not only by the results of this study and that of Rood and Heinze-Milne (1989) in Alberta, but also by the results of several studies of riparian poplar forests below dams in the United States (Johnson et al., 1976; Brown et al., 1977; Crouch, 1979; Behan, 1981; Reily and Johnson, 1982; Bradley and Smith, 1986; Akashi, 1988).

Furthermore, determination of age structures of riparian poplar stands through field surveys will be required before any conclusion about the status of riparian poplars in southern Alberta can be clearly ascertained. If such studies find that, in general, replenishment is not keeping up with mortality, then there will be cause for even greater concern about the long-term survival of riparian poplar forests in southern Alberta.

9.0 RESEARCH AND MANAGEMENT NEEDS

The understanding of the extent and reasons for the decline of riparian poplar forests along several rivers in the western prairies has increased rapidly through the 1980s. However, there is further information required on the status of riparian poplars, the ecology of these forests, and the physiology of the species involved to assist in developing effective management plans.

9.1 Determining Status and Trends

Several studies have reported decline of riparian poplars in the Great Plains of North America including two from Alberta. Significant decline was noted on the St.Mary and Waterton Rivers below dams and on the Milk River over a 30-year period (Hardy BBT, 1990). However, only a very slight decline was noted on the Belly River and on the St. Mary and Waterton Rivers above dams over a 20-year interval 1961-1981. Furthermore, as part of this study, air photo analysis at a 1:40,000 scale of the Red Deer, Bow, Oldman and South Saskatchewan Rivers suggests no significant decline of riparian poplars along these rivers over a 30-year period, 1950s-1980s.

These general observations need to be verified through more detailed inventories, particularly focused on significant reaches identified in this report. These inventories need to include air photo interpretation and mapping at a scale of 1:20,000 or larger to serve as a baseline for monitoring trends over the long term, field checks to confirm mapping units, and age-class analysis to determine if regeneration is occurring at a rate which matches or exceeds mortality of older trees.

Preliminary work on determination of age structures has been conducted along the Milk River (Bradley, 1982; Hardy BBT, 1990) and the lower Red Deer River (Sandra Marken, pers. comm.; Maureen Hills-Urbat, pers. comm.), but an assessment of long-term survival of these stands has not been undertaken.

In order to more accurately determine the effects of dams on riparian poplars downstream, measurements need to be made of altered river regime. These measurements would include changes in peak flows, mid-summer flows, sediment load, channel movement, and floodplain building.

While the effect of damming on downstream poplar forests is most prominent in the literature as causing poplar decline, other causative agents have been identified as well. These factors, such as livestock grazing, increased beaver activity and floodplain developments, may not have the widespread impact of reduced river flows, but can have significant local impacts. Thus, surveys to locate sites where these other factors are working will help managers target areas where specific intensive management programs can be quickly implemented. This data will also help researchers determine the relative contribution of these factors in riparian forest decline. In particular, specific studies are needed to determine the impacts of livestock production and beaver on replenishment and survival of riparian poplars in southern Alberta. The results of such research will help determine where controlling livestock access to riparian zones through fencing is appropriate and if beaver control programs are needed.

9.2 Riparian Poplar Forest Ecology

The riparian poplar forests of southern Alberta occur along two distinct types of rivers. Reports in the literature refer almost exclusively to the prairie type situation dominated by plains cottonwood. Since some 30% to 50% of the riparian poplars in Alberta are found along foothills type rivers where narrowleaf cottonwood, balsam poplar and hybrids dominate, it is necessary to clarify the differences between these two types of forests and their relationships with the river. Management plans may need to be developed that address the differences found in each zone.

Related to the two river types found in Alberta, is the mechanism of forest regeneration that occurs in each. The general replenishment model proposed for foothill rivers is only in the preliminary stages of development and requires more work. A population survey and construction of an age class profile is needed before this model can be completed. Some researchers have suggested that survival of poplars along foothills rivers may be more tenuous than along prairie rivers due to fewer sites being available for establishment, greater potential for drought stress due to coarser substrates, and dependence on higher, less frequent floods for major regeneration events.

Much of the ecology of poplar forests is based on an understanding of their age class profile. These profiles are normally generated by analysis of increment cores. Such analyses often make basic assumptions on the number of years required to grow to the sampled height. Recent field observations indicate that it may be unreasonable to make some of these assumptions. A study to validate the procedure currently used to age riparian poplars, or develop a modified procedure is necessary to strengthen age class profiles for further analysis.

In addition, little is known about other floodplain species, their interrelationships and requirements for successful establishment. For example, given that the extensive shallow root system of riparian poplars greatly deplete soil moisture (McQueen and Miller, 1966), how is the composition of understories in riparian poplar stands and the vigour of component species affected during times of drought stress? What is the synergistic effect of reduced flooding and drought stress on poplar stands and other riparian habitats, such as wetlands? There is a suggestion that requirements for replenishment of riparian shrubs such as water birch (*Betula occidentalis*) and buffalo berry (*Shepherdia canadensis*) are even more stringent than for riparian poplars (Marken, pers. comm.). Answers to these and other questions could contribute to instream flow needs assessments for riparian habitats and development of models of flow rates and channel dynamics (including sedimentation) required to optimize or maintain these habitats.

9.3 Poplar Physiology

Although the discussion in this report has dealt with poplars in general, the three species found in the riparian areas of southern Alberta are known to react to various stimuli differently. The ability to tolerate flooding, resist drought, and grow roots, shoots, or leaves all vary between species under different pressures. Studies to determine whether these differences are significant is important for management purposes. If the differences are not significant, general management guidelines can be formed; whereas if the differences are significant, specific plans would need to be developed for each species.

In particular, studies on the factors limiting seedling establishment and survival and encouraging asexual reproduction need to be investigated. Seedling establishment and survival is known to limit poplar forest cycling. Availability of seedbeds and water supply have been identified as an important factor contributing to seedling establishment and survival. Other environmental parameters are almost certainly contributing as well and need to be identified. The effects of over-wintering and growth in the second year warrant special attention at this time.

To date, seedling establishment has been assumed to be the overriding mechanism in riparian poplar forest regeneration. However, asexual reproduction may also contribute to the maintenance of the poplar forest through coppicing and suckering. The relative importance of each form of reproduction needs to be clarified as do the conditions that encourage each of these.

Finally, much of the information on poplar physiology presently available is based on laboratory or greenhouse experimentation under controlled conditions. Experimentation in the field or nursery setting will help determine the rate of growth or recovery of riparian poplar forests that might be expected following the implementation of management plans.

9.4 Socio-economic Assessments

As the status of riparian poplars becomes better understood, it will be possible to estimate the significance of any change on related resources. The loss of riparian forests is expected to cause a reduction or loss in wildlife populations, water quality, recreational use and agricultural value. Studies are required to determine how great a loss each of these resources may suffer depending on future trends in the status of riparian forests. This information will help put more accurate values on the costs and benefits of development proposals which affect riparian poplars. It will also help identify the stakeholders most affected by further forest declines, and indicate the resources in greatest need of mitigation measures or protection.

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APPENDIX A

SUMMARY OF REACH CHARACTERISTICS, AND DESCRIPTION OF REACHES:

Belly, St. Mary, Waterton
Bow
Highwood and Sheep
Milk
Oldman
Red Deer
South Saskatchewan

SUMMARY OF REACH CHARACTERISTICS

RIVER: BELLY
ST. MARY
WATERTON

Reach (#)	Length (Km)	Flood Plain Width (m)	Channel Type	Density Category		Cultivation	
				1980's	1950's	1980's	1950's
BL1	28.82	300 - 500	FM	3		P	
BL2	48.81	500 - 1200	FM	5		P	
BL3	37.59	1000 - 1500	FM BR	4		P	
BL4	34.74	700 - 1500	FM	3		P	
TOTAL	**149.96**						
SM1	25.40	300 - 700	FM	4		P	
SM2	115.51	200 (-1000)	CM	1		P	
TOTAL	**140.91**						
W1	75.31	500 - 700	FM	3		P	

KEY TO REACH CHARACTERISTICS

(See Map 2 for location of reach divisions)

Channel Type:

FM — **Freely Meandering:** a channel exhibiting a regular pattern of broad, semicircular curves that develop as the channel erodes the outer band of a curve and deposits sediment against the inner bank.

CM — **Confined Meandering:** resembles a freely meandering channel but is confined by the valley walls so that curves become irregular as they abruptly change course.

ST — **Straight:** a channel which is severely confined by surrounding bedrock such that little to no lateral migration of the channel is possible.

BR — **Braided:** made up of numerous shifting shallow intertwining stream channels separated by sand and gravel deposits.

Density Category:

1 = None/Negligible
2 = Sparse
3 = Moderate
4 = Dense
5 = Extremely Dense

Cultivation:

P = Present
A = Absent

DESCRIPTION OF REACHES

RIVER: BELLY RIVER

Reach (#)	1980's	1950's
BL1	The distribution of cottonwoods in this reach consists of moderate sized dense and sparse alternating with narrow sparse and dense bands which bracket the channel. The downstream portion of this reach seem to be influenced by the irrigation canal from the Waterton Reservoir.	not applicable
BL2	Occupied area of the floodplain is quite narrow, but there are continuous moderate sized dense stands of cottonwoods. Some sparse extensive sections also occur. Cottonwoods do not occupy the whole floodplain in the upper portion of the reach.	not applicable
BL3	This reach has well-developed meanders, with cottonwoods occupying the majority of the floodplain. Active channel migration is occurring. Cottonwood distribution is in large sparse and dense stands on a wide floodplain.	not applicable
BL4	Most of the floodplain in this reach is under cultivation. Distribution is moderate and quite discontinuous. There are sparse and dense narrow bands occurring along the channel. Also, some portions of this reach have large dense stands, especially at the confluence with the Oldman River.	not applicable

RIVER: ST. MARY RIVER

Reach (#)	1980's	1950's
SM1	This reach consists of fairly large, continuous stands of cottonwoods, both sparse and dense. The floodplain is quite narrow, with active lateral migration of the channel. **Lee Creek:** patchy distribution with dense and sparse pockets interspersed.	not applicable
SM2	This reach contains the St. Mary Reservoir. The channel is disturbed and entrenched, containing isolated sparse pockets of cottonwoods. At the confluence with the Oldman River, large dense and sparse stands of cottonwoods occur.	not applicable

RIVER: WATERTON RIVER

Reach (#)	1980's	1950's
W1	This reach consists of a fairly continuous diverse mixture in size and density of cottonwoods. Although some stands are dense, they are quite limited in areal extent. Some disturbance occurs downstream from the Waterton Reservoir. Towards the confluence with the Belly River, stands become considerably larger and more cultivation is present where the floodplain widens. Cultivated areas adjoin narrower bands of cottonwoods. **Drywood Creek:** cottonwoods present for approximately 5 kilometres within the grassland ecoregion. **Foothills Creek:** cottonwoods present for approximately 2 kilometres within the grassland ecoregion.	not applicable

SUMMARY OF REACH CHARACTERISTICS

RIVER: BOW

Reach (#)	Length (Km)	Flood Plain Width (m)	Channel Type	Density Category		Cultivation	
				1980's	1950's	1980's	1950's
B1	42.58	300 - 1500	FM CM	3	3	P	P
B2	38.86	500 - 1500	FM BR	4	4	P	P
B3	48.14	500 - 2500	FM BR	5	4	A	A
B4	36.26	500 - 1000	FM	3	3	A	A
B5	60.38	200 - 500	ST	2	2	P	P
B6	55.79	200 - 500	ST	1	1	P	P
B7	41.39	200 - 500	ST	1	1	A	P
B8	23.22	200 - 500	ST	2	2	A	P
TOTAL	346.62						

KEY TO REACH CHARACTERISTICS

(See Map 2 for location of reach divisions)

Channel Type:

FM **Freely Meandering:** a channel exhibiting a regular pattern of broad, semicircular curves that develop as the channel erodes the outer band of a curve and deposits sediment against the inner bank.

CM **Confined Meandering:** resembles a freely meandering channel but is confined by the valley walls so that curves become irregular as they abruptly change course.

ST **Straight:** a channel which is severely confined by surrounding bedrock such that little to no lateral migration of the channel is possible.

BR **Braided:** made up of numerous shifting shallow intertwining stream channels separated by sand and gravel deposits.

Density Category:

1 = None/Negligible
2 = Sparse
3 = Moderate
4 = Dense
5 = Extremely Dense

Cultivation:

P = Present
A = Absent

DESCRIPTION OF REACHES

RIVER: BOW

Reach (#)	1980's	1950's
B1	A diverse mixture of sizes and densities of stands. Distribution is generally discontinuous. Many moderate sized sparse stands. Density and size of stands increases at the confluence of the Highwood River.	Similar. Stands seem to increase in density downstream.
B2	Quite large stands, both sparse and dense. Channel bars quite well occupied. Extensive cultivation outside the Blackfoot Reserve. Size of stands decreases at the end of this reach.	Similar
B3	Virtually continuous large and dense stands. Relatively few sparse stands. Stands occupy old channel scars and use the full extent of the floodplain.	Basically similar but stands are less continuous.
B4	Discontinuous stands of cottonwoods. Larger stands are dense. Some narrow sparse bands also present. This reach is partially disturbed by flooding from the Bassano Reservoir.	Similar with fewer cottonwoods approaching the Bassano Reservoir.
B5	Very small sparse pockets of cottonwoods occurring infrequently on an extremely narrow floodplain. The lower portion of this reach has predominantly no cottonwoods.	Similar
B6	Very sparse distribution with most cottonwoods on Grassy Island. Very small sparse pockets occurring very infrequently.	Similar
B7	Virtually no cottonwoods in an entrenched river valley.	Similar with minor cultivation present.
B8	Narrow, fairly continuous bands of cottonwoods bracketing the channel, both sparse and dense.	Similar with some cultivation at the beginning of this reach.

SUMMARY OF REACH CHARACTERISTICS

RIVER: HIGHWOOD AND SHEEP

Reach (#)	Length (Km)	Flood Plain Width (m)	Channel Type	Density Category		Cultivation	
				1980's	1950's	1980's	1950's
H1	9.92	100 - 500	ST	3		A	
H2	17.50	500 - 1000	FM BR	3		P	
H3	41.76	100 - 500	FM	2		P	
TOTAL	69.18						
SH 1	25.93	200 - 700	FM	4		P	

KEY TO REACH CHARACTERISTICS

(See Map 2 for location of reach divisions)

Channel Type:

FM **Freely Meandering:** a channel exhibiting a regular pattern of broad, semicircular curves that develop as the channel erodes the outer band of a curve and deposits sediment against the inner bank.

CM **Confined Meandering:** resembles a freely meandering channel but is confined by the valley walls so that curves become irregular as they abruptly change course.

ST **Straight:** a channel which is severely confined by surrounding bedrock such that little to no lateral migration of the channel is possible.

BR **Braided:** made up of numerous shifting shallow intertwining stream channels separated by sand and gravel deposits.

Density Category:

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4 = Dense
5 = Extremely Dense

Cultivation:

P = Present
A = Absent

DESCRIPTION OF REACHES

RIVER: HIGHWOOD AND SHEEP

Reach (#)	1980's	1950's
H1	Distribution of cottonwoods is primarily in narrow sparse bands paralleling the channel.	not applicable
H2	Large stands of cottonwoods, both sparse and dense occupying the whole floodplain. Stand size decreases by the town of High River.	not applicable
H3	Very discontinuous distribution of cottonwoods, mostly sparse. There is an increase in stand size at the confluence with the Bow River. Much agricultural activity extending to the confluence with the Sheep River.	not applicable
SH1	Predominantly dense stands, especially by Okotoks. At the confluence with the Highwood River, the channel straightens and distribution becomes banded. Cultivation is present near the confluence with the Highwood River.	not applicable

SUMMARY OF REACH CHARACTERISTICS

RIVER: MILK

Reach (#)	Length (Km)	Flood Plain Width (m)	Channel Type	Density Category		Cultivation	
				1980's	1950's	1980's	1950's
M1	58.93	400	FM CM	1		A	
M2	23.10	UNDEFINED	FM	1		P	
M3	39.74	50 - 500	CM	1		A	
M4	26.96	200 - 400	CM	2		P	
M5	38.19	UP TO 1000	FM	1		P	
M6	31.00	500 - 750	CM FM	2		A	
M7	54.40	500 - 750	CM FM	3		A	
TOTAL	272.32						

KEY TO REACH CHARACTERISTICS

(See Map 2 for location of reach divisions)

Channel Type:

FM **Freely Meandering:** a channel exhibiting a regular pattern of broad, semicircular curves that develop as the channel erodes the outer band of a curve and deposits sediment against the inner bank.

CM **Confined Meandering:** resembles a freely meandering channel but is confined by the valley walls so that curves become irregular as they abruptly change course.

ST **Straight:** a channel which is severely confined by surrounding bedrock such that little to no lateral migration of the channel is possible.

BR **Braided:** made up of numerous shifting shallow intertwining stream channels separated by sand and gravel deposits.

Density Category:

1 = None/Negligible
2 = Sparse
3 = Moderate
4 = Dense
5 = Extremely Dense

Cultivation:

P = Present
A = Absent

DESCRIPTION OF REACHES

RIVER: MILK

Reach (#)	1980's	1950's
M1	Weakly confined meandering channel. Channel scars present.	not applicable
M2	Floodplain undefined. Cultivation around the city of Milk River.	not applicable
M3	Confined meandering channel.	not applicable
M4	Very discontinuous patchy distribution of cottonwoods. Most pockets are sparse. Two dense concentrations occur within this sinuous reach.	not applicable
M5	Other than two small, sparse localized occurrances, this reach is devoid of cottonwoods. The floodplain is poorly defined.	not applicable
M6	Small and sparse discontinuous patches of cottonwoods.	not applicable
M7	Moderate size sparse stands with localized dense patches. The central third of this reach has a sparse and discontinuous distribution (as a result of fire).	not applicable

SUMMARY OF REACH CHARACTERISTICS

RIVER: OLDMAN

Reach (#)	Length (Km)	Flood Plain Width (m)	Channel Type	Density Category		Cultivation	
				1980's	1950's	1980's	1950's
OM1	17.26	200 - 500	FM	2	2	P	A
OM2	98.82	1500 - 1700	BR FM	5	5	P	P
OM3	21.28	200 - 1000	ST	2	2	P	P
OM4	61.93	500 - 2000	FM CM	4	4	P	P
OM5	78.64	300 - 2000	CM FM	2	2	P	P
OM6	62.08	300 - 700	ST CM	1	1	P	P
TOTAL	340.01						

KEY TO REACH CHARACTERISTICS

(See Map 2 for location of reach divisions)

Channel Type:

FM **Freely Meandering:** a channel exhibiting a regular pattern of broad, semicircular curves that develop as the channel erodes the outer band of a curve and deposits sediment against the inner bank.

CM **Confined Meandering:** resembles a freely meandering channel but is confined by the valley walls so that curves become irregular as they abruptly change course.

ST **Straight:** a channel which is severely confined by surrounding bedrock such that little to no lateral migration of the channel is possible.

BR **Braided:** made up of numerous shifting shallow intertwining stream channels separated by sand and gravel deposits.

Density Category:

1 = None/Negligible
2 = Sparse
3 = Moderate
4 = Dense
5 = Extremely Dense

Cultivation:

P = Present
A = Absent

DESCRIPTION OF REACHES

RIVER: OLDMAN

Reach (#)	1980's	1950's
OM1	The distribution of cottonwoods consists of mostly sparse, some dense, narrow bands bracketing the channel. **Pincher Creek:** sparse, discontinuous isolated pockets on a small floodplain.	Similar
OM2	Large stands, more dense than sparse, occupying a broad floodplain with well-developed meanders. There is active lateral migration of the channel. Distribution becomes slightly more discontinuous and stands decrease in size downstream. **Willow Creek:** moderate density distribution along a freely meandering channel.	Basically similar. Stands appear more discontinuous. Possibly some stands near Fort Macleod more dense. Some changes in the position of the channel.
OM3	This reach consists of mostly sparse narrow bands bracketing the channel. The channel is very entrenched upstream. As the floodplain widens, cultivation increases, and the size of stands increases slightly.	Similar
OM4	Cottonwood distribution consists of mostly large stands which are more dense than sparse. Cottonwoods occupy the full extent of the floodplain, with distribution being somewhat discontinuous. In a few sections there seems to be a correlation between the presence of cultivation and smaller sparse stands of cottonwoods.	A few more stands. Mostly large stands, more sparse than dense. Some change in the position of the channel.
OM5	Very discontinuous distribution of sparse, narrow bands of cottonwoods along the channel. There is one exception to this at the confluence of the Little Bow River where approximately a six kilometre reach contains large sparse and dense stands of cottonwoods in a widened floodplain.	At the confluence of the Little Bow River, the path of the channel has changed and stands appear more sparse than dense.
OM6	Virtually no cottonwoods along this reach. More cultivation exists down river where the floodplain widens.	Similar

SUMMARY OF REACH CHARACTERISTICS

RIVER: RED DEER

Reach (#)	Length (Km)	Flood Plain Width (m)	Channel Type	Density Category		Cultivation	
				1980's	1950's	1980's	1950's
R1	22.86	200 - 300	CM	3	3	A	A
R2	32.06	300 - 400	CM	2	2	A	P
R3	32.13	200 - 400	CM ST	3	3	P	P
R4	39.98	100	CM ST	2	2	P	P
R5	16.48	300 - 500	CM	3	3	P	A
R6	78.23	500	CM	4	4	P	P
R7	37.14	200 - 300	CM ST	3	3	P	A
R8	51.33	500 - 1300	CM FM	4	3	P	P
R9	18.45	300 - 500	ST CM	3	3	A	P
R10	37.99	1000 - 1500	FM BR	3	3	P	P
TOTAL	366.65						

KEY TO REACH CHARACTERISTICS

(See Map 2 for location of reach divisions)

Channel Type:

FM **Freely Meandering:** a channel exhibiting a regular pattern of broad, semicircular curves that develop as the channel erodes the outer band of a curve and deposits sediment against the inner bank.

CM **Confined Meandering:** resembles a freely meandering channel but is confined by the valley walls so that curves become irregular as they abruptly change course.

ST **Straight:** a channel which is severely confined by surrounding bedrock such that little to no lateral migration of the channel is possible.

BR **Braided:** made up of numerous shifting shallow intertwining stream channels separated by sand and gravel deposits.

Density Category:

1 = None/Negligible
2 = Sparse
3 = Moderate
4 = Dense
5 = Extremely Dense

Cultivation:

P = Present
A = Absent

DESCRIPTION OF REACHES

RIVER: RED DEER

Reach (#)	1980's	1950's
R1	Cottonwoods appear in narrow sparse and dense bands on a restricted floodplain.	Similar
R2	Narrow sparse bands of cottonwoods bracketing the channel. **Threehills Creek:** presence of a few cottonwoods at the confluence with the Red Deer River.	Similar
R3	Some large but sparse stands increasing in density at the confluence of the Rosebud River. Urban development from the City of Drumheller in the river valley. **Kneehills Creek:** confined, tight meanders with sparse and isolated pockets of cottonwoods. Increasing density at the confluence with the Red Deer River. **Rosebud River:** confined meanders with numerous sparse pockets and isolated dense pockets extending to the town of Rosebud. Larger and more continuous stands at the confluence with the Red Deer River.	Similar with less cultivation at the confluence of Kneehills Creek.
R4	This reach begins with an extremely confined floodplain containing sparse narrow bands of cottonwoods. Where the floodplain widens, some cultivation exists and cottonwood density increases somewhat, with bands bracketing the channel.	Similar with cultivation mostly absent.
R5	Some large sparse stands, smaller dense bands interspersed.	Similar with no cultivation.
R6	Extensive variation in the density and distribution of cottonwoods. The floodplain is of a consistent width of 500m. Cultivation exists only at the beginning of the reach. The western portion of Dinosaur Provincial Park is at the end of this reach.	Similar
R7	Cottonwood distribution consists of narrow and wider elongated bands which are primarily sparse, as well as some small dense sections. The eastern section of Dinosaur Provincial Park is at the beginning of this reach.	Similar
R8	Overall, a broad band of cottonwoods on an extensive floodplain. They are primarily sparse, large stands with denser sections present throughout. Parts of this reach are extensively cultivated.	Fewer cottonwoods along the lower portion of this reach.
R9	Fairly discontinuous distribution of cottonwoods, primarily sparse stands with a few isolated dense pockets.	Similar although cottonwoods appear to be less continuous.
R10	Stands are generally very large but sparse. There are a few isolated dense pockets.	Similar with a few large dense stands at the end of this reach.

SUMMARY OF REACH CHARACTERISTICS

RIVER: SOUTH SASKATCHEWAN

Reach (#)	Length (Km)	Flood Plain Width (m)	Channel Type	Density Category		Cultivation	
				1980's	1950's	1980's	1950's
S1	197.20	200 - 3000	ST CM FM	2	2	P	P
S2	35.95	200	ST	1	1	A	A
S3	54.89	200 - 750	ST CM	2	1	P	A
TOTAL	**288.04**						

KEY TO REACH CHARACTERISTICS
(See Map 2 for location of reach divisions)

Channel Type:

FM — **Freely Meandering:** a channel exhibiting a regular pattern of broad, semicircular curves that develop as the channel erodes the outer band of a curve and deposits sediment against the inner bank.

CM — **Confined Meandering:** resembles a freely meandering channel but is confined by the valley walls so that curves become irregular as they abruptly change course.

ST — **Straight:** a channel which is severely confined by surrounding bedrock such that little to no lateral migration of the channel is possible.

BR — **Braided:** made up of numerous shifting shallow intertwining stream channels separated by sand and gravel deposits.

Density Category:

1 = None/Negligible
2 = Sparse
3 = Moderate
4 = Dense
5 = Extremely Dense

Cultivation:

P = Present
A = Absent

Table 3.6: Assessments of riparian forest abundances along the South Raskatchewan River in the 1880's, 1950's, 1980's, and late 1990's using historic surveys and aerial photographs.

Current Study Reach Code	Reach:	-----------1980's----------- Length (km)	Floodplain Width (m)	Channel Type	Riparian Poplar Density: 1880's	1950's	1980's	1997-99	General Change 1880-1999
SS1&SS2	S1	197.20	200-3000	ST-FM-CM	2	2	2	2	
SS1	S2	35.95	200	ST		1	1	1	
SS1	S3	54.89	200-750	ST-CM		1	2	1 to 2	+

(1880-1980 content adapted from Bradley et al. 1991)

Channel Type categories:
FM = freely meandering; ST = straight
CM = confined meandering; BR = braided

Density categories:
1 = none / negligable
2 = sparse; 4 = dense
3 = moderate; 5 = very dense

Although Brayshaw (1965) reports the occurrence of poplar hybrids, the most common riparian poplar found along the ~~entire~~ South Saskatchewan River in Alberta is the plains cottonwood, *P. deltoides*. In general cottonwoods are sparse along the entire S. Sask R with ~~only~~ a few notable exceptions (Bradley et al, 1991). Dense cottonwood forests can be found at the western most end of reach SS2 at the confluence of the Bow and Oldman rivers. ~~At th~~ Despite ~~[illegible]~~ negligible forests in [illegible] – on both the Oldman and Bow Rivers, a dense cottonwood forest can be found at the confluence of these rivers that marks the start of the S Sask. The

DESCRIPTION OF REACHES

RIVER: SOUTH SASKATCHEWAN

Reach (#)	1980's	1950's
S1	This reach extends approximately two-thirds of the river's length. At the confluence of the Bow and Oldman Rivers, Bow Island's cottonwoods are large and predominantly dense. Cottonwood distribution for the rest of this reach, however, consists of mostly sparse, discontinuous pockets. This is particularly the case in the first portion of this reach where the channel is entrenched and the floodplain is extremely narrow. The area of the floodplain used for cultivation increases approaching and past Medicine Hat, where the channel becomes freely meandering. Here, cottonwoods become more continuous and appear as bands along the channel. The occasional larger but sparse pocket also occurs. Police Point Park in Medicine Hat has a localized occurrence of larger cottonwood stands, both sparse and dense. At the end of this reach, cottonwood distribution becomes sparse and discontinuous as the floodplain becomes confined once again. **Bullshead Creek:** contains a few discontinuous pockets of cottonwoods.	Similar with less cultivation around Medicine Hat. There is a larger dense stand within Police Point Park.
S2	A reach with consistently narrow floodplain and very few sparse, narrow occurrences of cottonwoods.	Similar
S3	Very sparse, narrow discontinuous distribution of cottonwoods along an entrenched channel.	More discontinuous, fewer, sparse narrow occurrences of cottonwoods.