The Biology and Management of Southern Alberta's Cottonwoods

Edited by: Stewart B. Rood and John M. Mahoney

Balsam Poplars along the Oldman River near Fort Macleod (S. Rood).

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Preface

1. The Concern for the Riparian Cottonwoods of Southern Alberta

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Cottonwoods, various species of poplar (*Populus*), are the principal and often exclusive trees in the riparian regions of the western prairies of North America. In southern Alberta, the riparian forests have special importance for both humans and wildlife as they offer welcome relief from the treeless prairies.

Although cottonwoods have been thought of as undesirable weeds, they are the foundation of the riparian forest ecosystem in southern Alberta. No other trees can survive the dry summers and cold winters of the western prairies. Unlike areas to the east (Wilson, 1970) and west (Szaro, 1990), a loss of cottonwoods in southern Alberta is not compensated through enrichment from other tree species. If the cottonwoods die, so goes the entire forest ecosystem.

George Dawson (1885) first described the extent of southern Alberta's riparian forests following his visits to the region from 1882 to 1884. Various casual reports and photographs have been collected by the Galt Museum, Lethbridge, since that time (A. Johnston, Lethbridge historian, personal communication). In the 1930's, the famous Albertan botanist, Moss, studied Alberta's poplars and aspens and recognized the existence of interspecific poplar hybrids in southern Alberta (Moss, 1944). Brayshaw (1965) surveyed the southern Alberta poplars and discussed the taxonomic status of the riparian trees concluding that the regional cottonwood species interbreed to produce a complex hybrid swarm.

In the late 1970's, disturbing reports began to emerge on the decline of riparian cottonwoods downstream from large river dams in the Missouri River Basin. Bradley and Smith (1986) concluded that the Fresno Dam on the Milk River, just downstream from the Alberta-Montana border had caused a similar decline of riparian cottonwoods. Other reports from across the American western prairies have since confirmed the vulnerability of the riparian cottonwood forests.

Our interest was prompted by an abrupt decline in cottonwoods downstream from the St. Mary Dam in southern Alberta (Rood and Heinze-Milne, 1989) and the possibility of a similar impact downstream from the Oldman River Dam, now nearing completion. The Oldman River Dam, near Pincher Creek, is immediately upstream of one of the largest riparian cottonwood forests in Canada. This unique hybrid swarm of balsam poplar (*P. balsamifera*) and narrowleaf cottonwood (*P. angustifolia*) extends downstream from the new dam for over 150 km. Alberta Public Works Supply and Service has recognized the cultural, environmental and recreational importance of this forest and supported research to prevent a decline of the forest.

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Table 1-1. Published reports describing the riparian cottonwoods of southern Alberta.

Author	Year	River	Species	Contents
Bradley	1982	Milk	*Populus deltoides*	biogeography of cottonwoods and the effects of river damming
Bradley and Smith	1986	Milk	*P. deltoides*	cottonwood decline downstream from the Fresno Dam, Montana
Brayshaw	1965	S. Sask. Basin	*P. angustifolia, P. balsamifera, P. deltoides*	survey of hybridization and distribution in southern Alberta
Elliott	1987	Oldman	*P. balsamifera* (*P. trichocarpa*)	distribution and ecology on Peigan Reserve
Greenaway et al.	1991	Oldman Basin	*P. angustifolia, P. balsamifera, P. deltoides*	chemotaxonomy of native hybrids
Hardy Assoc.	1986	Oldman	*P. balsamifera, P. angustifolia*	distribution and ecology at the Oldman River Dam site
Hardy BBT	1988	South Sask.	*P. deltoides*	analysis of cottonwood mortality near water wells in Medicine Hat
Hardy BBT	1990	Milk	*P. deltoides*	distribution and ecology
Mahoney and Rood	1991	St. Mary	*P. balsamifera*	seedling drought tolerance
Moss	1938	Central Alberta	*P. balsamifera*	seed germination and seedling establishment
Rood et al.	1986	Oldman Basin	*P. angustifolia, P. balsamifera, P. deltoides*	distribution and interspecific hybridization
Rood and Heinze-Milne	1989	St. Mary, Waterton, Belly	*P. angustifolia, P. balsamifera,*	cottonwood forest decline downstream from dams.
Shaw	1974	St. Mary, Belly and Lee Ck.	*P. balsamifera P. angustifolia*	distribution and ecology of cottonwoods
Vanende	1990	Oldman Basin	*P. balsamifera,* (*P. trichocarpa*), *P. angustifolia*	chemotaxonomy of balsam poplars

Our understanding of the effect of river damming on downstream cottonwood decline or survival is growing rapidly. Insight has been gained by studying reports describing characteristics of southern Alberta's riparian cottonwoods (Table 1.1). The amount of work already completed by researchers in Alberta indicated the value of sharing current information and discussing deficiencies in the present data base. This prompted the organization of this workshop from May 4 to 6, 1990. About 100 people attended the conference which included 16 technical presentations, discussion groups, and a field trip to the river valleys of the Oldman River Basin.

These are the proceedings of the workshop. A map of the region showing the location of the rivers and dams discussed in the accompanying chapters is presented in Figure 1.1.

Thanks are extended to all who attended and particularly, the authors who took the time to make presentations and review their transcripts. The support from Ron Middleton and Alberta Public Works, Supply and Services with the field trip was appreciated. Thanks are also extended to Trevor Potter, Karen Zanewich, Chris Lastuka, and Sue Smienk for assistance with workshop organization and the production of these proceedings.

Research performed by the University of Lethbridge group was funded by Alberta Environment and Alberta Public Works Supply and Services contracts addressing the mitigation of impacts of the Oldman River Dam on downstream vegetation.

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Dawson, G.M. 1885. Map showing Wooded and Prairie Districts, etc., in the Region of the Vicinity of the Bow and Belly Rivers. In. Maps, etc. to accompany Report of Progress for 1882-83-84. Geological and Natural History Survey and Museum of Canada. Dawson Bros., Montreal.

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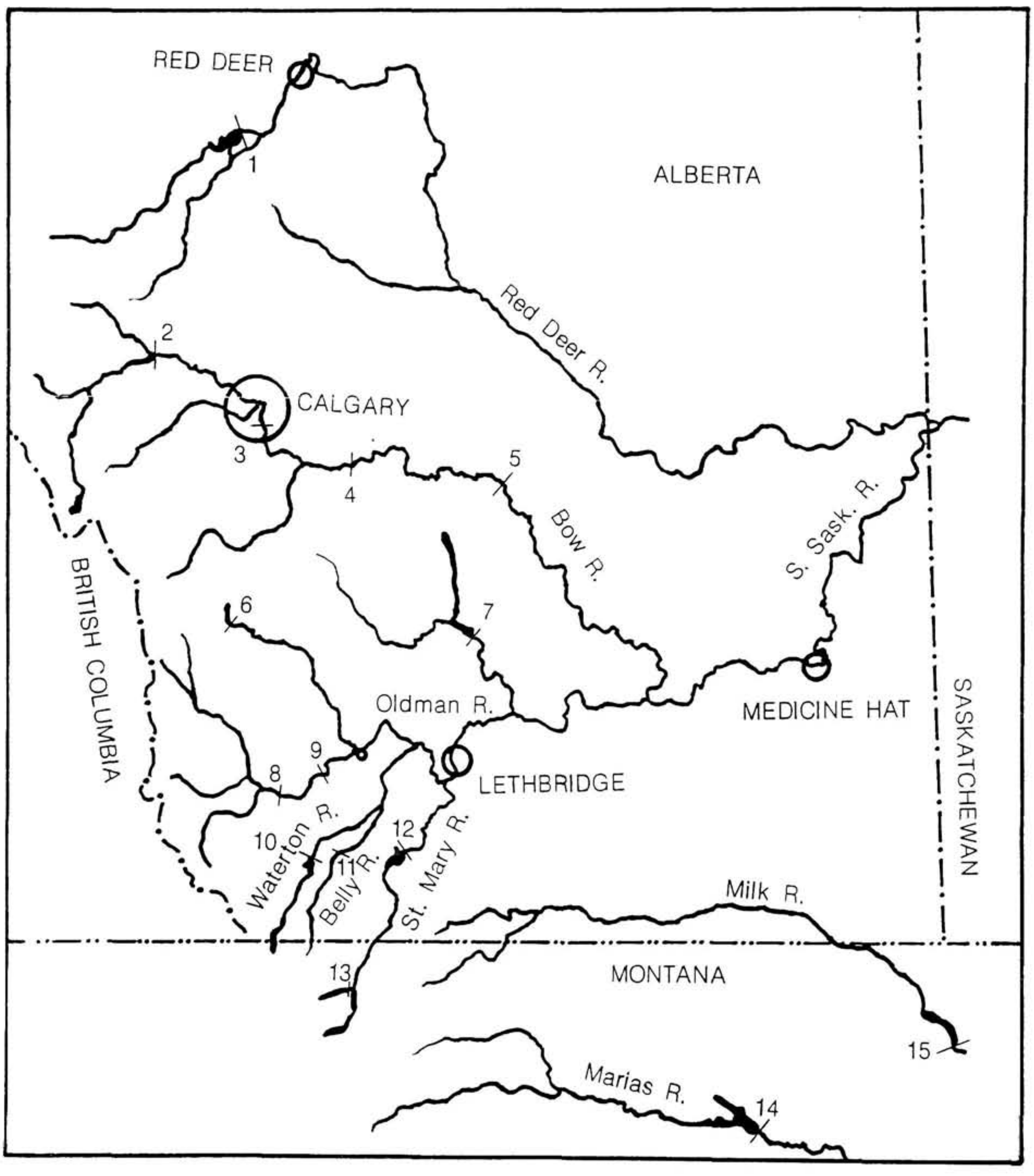
Figure 1-1. Map of southern Alberta and northern Montana showing rivers, dams and reservoirs discussed in the following chapters. The Red Deer, Bow, Oldman and South Saskatchewan Rivers flow northeasterly into Hudson's Bay. The Milk and Marias Rivers flow southeasterly into the Missouri River which joins the Mississippi River and empties into the Gulf of Mexico.

1. Dickson Dam (Glennifer Lake), 2. Ghost Dam, 3. Western Irrigation DistrictWeir, 4. Carseland Weir, 5. Bassano Dam and Reservoir, 6. Chain Lakes Reservoir, 7. Travers Reservoir and McGregoLake, 8. Oldman Dam, 9. Lethbridge Northern Irrigation District Weir, 10. Waterton Dam and Reservoir, 11. Belly River Weir, 12. St. Mary Dam and Reservoir, 13. Lake Sherburne, 14. Tiber Dam (Lake Elwell), and 15. Fresno Dam.



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2. The Importance and Extent of Cottonwood Forest Decline Downstream from Dams

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In the field of plant physiology there is a keen interest in determining how and why plants grow fast. Perhaps the fastest growing woody plants in the temperate regions of north America are interspecific poplar hybrids. Artificial hybrids such as the cross of the prairie cottonwood, *Populus deltoides*, with the French black poplar, *Populus nigra* (referred to as DN hybrids or *Populus x euramericana*) are extremely productive. Similarly, interspecific hybrids of *Populus deltoides* x *Populus balsamifera* subspecies *trichocarpa* are also very productive and are currently in commercial use for pulp and paper production in the Pacific northwest of the United States. Hybrid poplars may therefore be the plant of choice if the target is to rapidly produce low grade fiber for use in pulp and paper or wood. Although the potential economic usefulness of artificial interspecific poplar hybrids is recognized, many naturally occurring interspecific hybrids have not received attention in the search for productive poplar hybrids.

For more than two decades it has been recognized that a distinctive and possibly unique trispecific hybrid swarm exists in southern Alberta (Brayshaw, 1965; Rood et al. 1986). The three species of poplars involved in the swarm include the prairie cottonwood, *P. deltoides*, the balsam poplar, *P. balsamifera*, with its two subspecies, and the narrowleaf cottonwood, *P. angustifolia*. This is one of the few regions worldwide that the three species overlap in their range and apparently hybridize freely. This diverse collection of natural poplar hybrids likely includes specimens which may be regionally useful for farmstead, shelterbelt, or reclamation plantings. These trees are uniquely adapted to survive the harsh climate of southern Alberta with its distinctive but stressful winter Chinook winds. The trees are also adapted to combat a broad range of local herbivores and diseases such as the poplar gall.

The Indian name for the St. Mary River means 'green banks' which recognized the naturally lush riparian forest with its abundance of trees and wildlife that existed along that river (Shaw, 1975). However, while studying various reaches of the St. Mary River, we quickly recognized that some of the riparian forests were quite unhealthy. In contrast to the valley forests presently thriving along the St. Mary River near the Alberta/Montana border, the forests downstream from the St. Mary Dam are largely dying or dead. We know that in the relatively recent past there were some cottonwood living forests along the lower reaches because remnant skeletons of trees remain standing or fallen on the floodplain.

An indication of the historical distribution of riparian forests can be gained through the surveys prior to extensive settlement of southern Alberta. Dawson (1885) noted variations in riparian forest abundance in southern Alberta. Indeed, he found that the lower reaches of the St. Mary River were

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naturally more sparsely populated by poplars than some of the upstream reaches. This may be partly because the lower St. Mary River is largely confined in a narrow, sandstone canyon and in places the river has a steep gradient. The natural scarcity of poplars of the lower St. Mary may indicate that those forests were particularly vulnerable to any increase in environmental stress.

To investigate the possibility of a correlation between river damming and the forest decline downstream of the St. Mary Dam, we analysed air photos taken prior to river damming and air photos taken after damming. We found that the abundance of poplars declined by 48% in the relatively brief two decade interval from 1961 to 1981, along the reach of the St. Mary River downstream from the dam. This is a very abrupt decline over a relatively short time interval.

A recent review of the scientific literature reveals that at least 11 studies completed on a range of rivers that indicated that river damming had apparently led to a downstream forest decline (Table 2-1). The reports began in the 1970's, with a study of the Missouri River in North Dakota indicating that prairie cottonwood forests had declined downstream from certain river dams (Johnson et al., 1976; Reily and Johnsøn, 1982). Brown et al. (1977) reported reduced Fremont cottonwood (*P. fremontii*) abundance, downstream from dams on the Salt and Gila Rivers and their tributaries in Arizona. Crouch (1979) reported reduced forest abundance along the South Platte River near Denver. Behan (1981) has a rather casual but consistent report on reduced forest abundance along the Missouri River downstream from Great Falls, Montana. Bradley and Smith (1986) reported a decline of the prairie cottonwood downstream from the Fresno Dam on the Milk River near the Alberta/Montana border. The commonality from these and other reports (Rood and Mahoney, 1990) suggests that if dams are installed along rivers in the Rocky Mountain foothills or western prairies, problems with the health of downstream cottonwood forests can follow.

To more fully understand the cause and extent of cottonwood decline downstream from dams, research needs to be extended to other areas such as the upper Colorado River near the Green River junction, or the Green River downstream from the Flaming Gorge Reservoir (W.L. Baker, personal communication). The comparison of dammed river systems that have caused riparian forest declines with those that have not, will also help extend our understanding of the mechanisms causing forest mortality downstream from dams.

To date, two major factors have been implicated in the decline of these cottonwoods downstream from dams: (i) reduced downstream flooding and (ii) the direct or indirect effects of altered or reduced downstream river flows (Table 2-2).

Many dams are intended to reduce damage to river valley developments by moderating spring flooding. However, a number of researchers have proposed that flood moderation could result in reduced poplar seedling replenishment. It is agreed that spring flooding is essential to create moist seed beds suitable for poplar replenishment. Attenuated flooding may therefore reduce the number of sites available for poplar seeding establishment. This would, in turn, limit the introduction of new individuals to replace dying trees in the poplar forest.

An analysis of hydrographs downstream from dams in southwestern Alberta, such as the St. Mary

Dam, shows that regional dams do not substantially moderate spring flooding most years (Rood and Heinze-Milne, 1989). However, forests downstream of these structures have declined. These dams do significantly reduce downstream flows during the growing season, particularly in dry years. We believe the diversion of water offstream creates a water deficit in the riparian forest resulting in drought stress. As the drought stress accumulates over the years, a measurable decline in forest abundance can follow. The importance of water availability for poplars in semi-arid regions such as southern Alberta is noted in a number of reports of the present conference.

Table 2-1. Reports of negative impacts of river damming on downstream cottonwood forests in the western prairies or California. Expanded from Rood and Mahoney (1990).

Author (date)	River	Region	*Populus*	Comments
Johnson et al. (1976)	Missouri	N. Dakota	*P. deltoides*	Reduced tree growth and Reduced seedling abundance
Brown et al. (1977)	various	Arizona	*P. fremontii, P. angustifolia*	Reduced forest abundance
Ohmart et al. (1977)	Colorado	California	*P. fremontii*	Reduced forest abundance Absence of seedlings
Crouch (1979)	South Platte	Colorado	*P. deltoides*	Reduced forest abundance
Behan (1981)	Missouri	Montana	*P. deltoides*	Reduced forest abundance Absence of seedlings
Brothers (1984)	Owens	California	*P. fremontii*	Reduced forest abundance
Stine et al. (1984)	Rush Ck.	California	*P. balsamifera*	Reduced tree abundance
Strahan (1984)	Sacramento	California	*P. fremontii*	Fewer seedlings
Fenner et al. (1985)	Salt	Arizona	*P. fremontii*	Conditions unsuitable for seedling establishment
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
Smith et al. (1989)	Bishop Ck.	California	*P. fremontii, P. balsamifera*	Smaller leaves, drought stress

Table 2-2. Factors proposed to contribute to the decline of western riparian cottonwood forests following river damming or water pumping from wells. Expanded from Rood and Mahoney (1990).

Proposed Cause	Comments	References
I. Hydrological changes:		
A. Reduced water availability	Diversion of water offstream or well pumping creates a water deficit, resulting in drought stress and enhanced mortality	Brown et al. (1977), Brothers (1984), Stine et al. (1984), Hardy BBT Ltd. (1988), Rood et al. (1989), Smith et al. (1989), Williams (1989)
B. Reduced flooding	Spring flooding is essential to create moist seedbeds for seedling establishment.	Brown et al. (1977), Ohmart et al. (1977), Johnson et al. (1976)
C. Stabilized Flows	Declining flows are essential for seedling establishment.	Strahan (1984), Fenner et al. (1985)
II. Geomorphological changes resulting from hydrological alterations:		
A. Reduced meandering	With reduced flooding, channel migration is reduced and suitable seedbeds are reduced	Ohmart et al. (1977), Johnson et al. (1976), Bradley and Smith (1986)

The potential for drought-induced poplar mortality downstream from dams was vividly shown by Stine et al. (1984) for Rush Creek, the principal stream flowing into Mono Lake, California. Rush Creek was dammed and entirely diverted by 1970 to provide municipal water for Los Angeles. As well as leading to a drawdown and increased salinity of Mono Lake, the riparian forests of Rush Creek were almost entirely eliminated due to drought stress.

Interestingly, a recovery in the flow of Rush Creek in the early 1980's due to the imposition of minimum flow standards coupled with a sequence of wet years resulted in some recovery of the balsam poplars (*P. balsamifera* subsp. *trichocarpa*) (Stromberg and Patten, 1989). This confirms that the cause of the decline was drought stress and also indicates that balsam poplar forests are more robust than previously thought. The recovery was through suckering, the growth of new shoots from remaining roots, a process common in balsam poplars. Although the shoots of the trees appeared entirely dead, the roots retained some life. This observed partial recovery through suckering provides additional hope for the riparian poplar forests of southwestern Alberta, which are predominantly balsam poplars and their hybrids and have undergone some decline, probably due to drought stress (Rood and Heinze-Milne, 1989).

Bradley and Smith (1984) and others have focussed on geofluvial changes, particularly in the river bed itself, as an important factor in riparian cottonwood decline. Reduced flooding not only prevents the creation of the moist seedbeds but it also reduces channel migration and causes channel entrenchment. Dynamic channel migration is probably essential for riparian poplar forest replenishment along some rivers.

Finally, reservoirs create a condition that we have named the 'silt shadow', a zone of sediment depletion downstream from a dam. The impoundment of water in a reservoir permits the suspended silt to settle out. Consequently, the water released downstream is free of silt. Some distance is required for the river to reacquire the normal silt load and begin leaving deposits necessary to form beds suitable for seedling replenishment.

Thus, there is a range of possible causes contributing to the decline of cottonwood forests downstream from dams. It is possible that these factors may interact to enable or prohibit poplar growth and survival. We should also remember that the factors underlying riparian forest decline may vary from one case to another. An analysis of the cause of observed forest declines and recommendations for mitigation must therefore be site specific.

In some situations, river damming can lead to enhanced vegetation downstream. Perhaps the most widely studied river in the world is the Colorado River downstream from the Glen Canyon Dam through the Grand Canyon. Downstream from that dam, the riparian vegetation community is probably enhanced as a result of the attenuation of flood flows that previously scoured out this restricted river valley. However, the situation on this river and many of others in the southwestern U.S. has become confused because many of the riparian plants are introduced, particularly the salt cedar (*Tamarix chinesis*) which was imported Asia (Ohmart, 1977).

The ecology of the riparian zone is naturally very dynamic. There are numerous natural events that influence the riparian forests. One such event occurred along the Oldman River in 1986. A unique combination of rain and warm weather in the early spring caused an explosive ice breakup in March. The ice sheared willows and poplars and scoured the river bed. This is the type of natural event that poplars have evolved to adapt to. Consequently, three years later the new channel banks are occupied by thriving populations of willows and poplars.

A range of reproductive strategies are used by native southern Alberta poplars to revegetate the newly scoured areas. Some of the new growth of balsam poplars and narrowleaf cottonwoods results from asexual suckering from roots. The occurrence of suckering in the prairie cottonwood is uncertain but probably rare. All three poplars demonstrate coppice regrowth, the production of additional shoots from stumps after decapitation. Many of the trees originate from seeds released and establishing on the new barren sites in the early summer. The specific role of these various reproductive modes varies with poplar species and probably also varies across sites and seasons.

The dynamic ecology and life strategy ensures a constantly changing pattern of riparian forest distribution and abundance. If we compare poplar distributions today with historical distributions either upstream or downstream from dams, we must consider the possibility of substantial natural variation. For example, as a result of the drought of the 1930's, the poplar forest declined throughout the western region of North America (Albertson and Weaver, 1945). This observation indicates that the availability of water is crucial to poplar distribution and also provides some insight into a possible factor leading to the decay of poplar forests downstream from dams.

However, in contrast to the natural variation that riparian forests are able to survive, a number of artificial conditions create stresses that can be lethal (Table 2-3). Forest clearing for urban settlement or agricultural cultivation reduces forest abundance instantly. Cattle grazing can prevent replenishment of new trees through grazing and trampling of seedlings which will prevent forest replenishment. The artificial negative impacts probably interact, possibly in a synergistic fashion. Individual impacts may be survivable but a combination of impacts may be lethal. Further, impacts can be latent, requiring years or even decades to be detected.

The riparian forests have also faced unexpected pressures from well-meaning land use managers. It is well established that riparian poplar uptake and then transpire large quantities of water. A number of river valley managers in the western prairie regions, particularly between 10 and 15 years ago, harvested poplar forests adjacent to creeks in an effort to enhance stream flows. Unfortunately, the removal of the trees lead to increased erosion and a collapse of the riparian ecosystem with a net degradation to the basin environment. In retrospect, we may judge such actions to be unreasonable, but at the time they seemed quite sensible. Present managers may make similar errors in judgement due to a lack of understanding of the complex riparian ecosystem. Actions designed to enhance fisheries, wildlife or vegetation may lead to generally undesirable consequences.

While the value of often ragged riparian cottonwoods may be disputed, riparian wildlife are considered by most Albertans to be desirable. Throughout the year, the riparian woodlands provide essential habitat for both terrestrial and avian wildlife. If the riparian cottonwoods are permitted to die so will the entire riparian forest ecosystem.

Some observers have proposed that a decline in natural poplar forests due to damming or other factors is unimportant because the poplars can be easily replanted. However, if we establish a monoculture of propagated poplars, we will lose the genetic diversity of the riparian poplar swarm of southern Alberta. This genetic diversity is probably important to long-term forest survival and also offers potential applications of poplar hybrids for other uses. The vast range of natural hybrids in southern Alberta may enable poplar tree breeders to develop superior disease or stress resistent cultivars. For example, poplars distributed for shelterbelts and farmstead plantings are often hybrids originating from other regions such as North Dakota. It is not surprising that trees that evolved elsewhere are not well adapted to the harsh conditions of southern Alberta and therefore thrive for only a few decades before succumbing to galls or drought stress. In contrast, some local poplars are thriving after two centuries of life in the difficult southern Alberta environment.

Table 2-3. Factors with negative impacts on the riparian poplar forests of southern Alberta. The list reflects the general order of importance in the South Saskatchewan River Basin, however quantitative comparisons have not been completed. The ranking will likely vary for different rivers in the basin.

Factor	Comment
1. Agricultural Clearing	Clearing for pasture or crop production. The proximity of rivers permit inexpensive irrigation. Flood plain soils are often fertile.
3. Domestic Settlement	Clearing for homes, towns, cities, roads, bridges and other uses. Pressure is generally proportional to human population density.
2. Livestock Grazing	Cattle graze and trample seedlings. Overgrazed regions are characterized by a deficiency of seedlings and saplings. Forests decline as older trees die. The impact of livestock grazing is progressive and may require years to detect by remote sensing techniques.
3. Direct Harvesting	Historically, poplars provided material for buildings and fuel wood. Poplar wood is generally undesirable for construction use and coal provided an alternate fuel in southern Alberta. Consequently, this factor has been less important than along many American rivers.
4. Onstream Reservoirs	Riparian forests are cleared prior to filling of onstream reservoirs such as those on the Oldman or St. Mary Rivers.
5. Gravel Mining	The river floodplains are prime areas for sand and gravel extraction. Forests are cleared to open pits and service the operations. Gravel pits may alter stream dynamics although they may also provide additional sites for poplar establishment.
6. Channelization	Alberta rivers have not yet been challenged with extensive programs to straighten and control meandering. Such actions inhibit the meandering of prairie rivers essential for some types of poplar replenishment.
7. Herbicide Spraying	Herbicide programs to control the imported noxious weeds, leafy spurge (*Euphorbia esula*) and knapweed (*Centaurea repens* or *C. maculosa*), were conducted in southern Alberta river valleys. Many of the herbicides used could kill poplar seedlings and saplings and some could kill larger trees.
8. Beavers	Forest decline alters the natural balance of beavers and trees placing additional stress on the forest and increasing the effects of other factors.

There are considerable economic as well as environmental reasons for preserving southern Alberta's cottonwood forests. We have observed a disturbing, rather abrupt decline of cottonwoods downstream from the St. Mary Dam. Other researchers have reported similar declines elsewhere.

We have a basic understanding of the ecology and physiology of riparian cottonwoods but require considerably more information before we can confidently identify the specific causes of riparian forest decline downstream from river dams. Such an understanding is essential to prevent a future decline of forests downstream from dams that are proposed, such as the Milk River, Willow Creek or Little Bow Dams, or dams already under construction, such as the Oldman River Dam, in southern Alberta.

Only small remnants of once abundant riparian poplar forests survive in most regions of the southwestern United States. Estimates of the extent of riparian vegetation decline range from 70% to 95% for the overall southwest (Johnson and Haight, 1984). Even more severe declines have been experienced in the heavily developed areas of California such as the Sacramento Valley, which has lost about 98.5% of the riparian forests that existed in 1850 (Sands and Howe, 1977).

We are fortunate to retain the majority of the riparian poplar forests in southern Alberta that Dawson reported in 1885. However, our forests are presently under pressure from a range of artificial impacts. River damming and water diversion probably have the most widespread potential impact on poplar forests in the Oldman River Basin. The realized impacts of river damming are principally due to the schedule of release of water downstream. If the forests fail to receive water, they will die from drought stress. If water is provided, maintenance of the riparian forests may be an achievable goal as long as other artificial impacts are also contained.

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3. Plains Cottonwoods and Riparian Vegetation Along the Lower Red Deer River

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Four reaches on the lower Red Deer River were sampled in order to develop a system for classifying and mapping floodplain vegetation. This system is based on the association and structure of dominant species and on the age classes and density of plains cottonwood. It was then used to compare the extent and distribution of vegetation types and of plains cottonwood age classes between four different channel types: entrenched, confined meander, unconfined meander and braided. This data, in conjunction with historical flow data from the Red Deer river will be used to elucidate what prerequisites (hydrological, soil, landform and biotic) are most conducive to the successful establishment of plains cottonwood. In addition, the status of other floodplain species and vegetation types on the Red Deer River was assessed. Four sites were carefully selected, each site representing one of the four fluvial channel types. Each site was sampled along ten to thirteen surveyed transects. using 10x10 meter quadrats at each change in vegetation composition and/or structure. Data collection included tree cores, tree and shrub density, soil samples from two depths, and percent cover of all species present. Preliminary analysis indicate that each of the four channel types create a distinct floodplain in terms of the size and distribution of fluvial landforms which, in turn, highly influence the recruitment and survival of plains cottonwood and the distribution of floodplain vegetation types. It appears that the braided regime, that was most represented on the lower Red Deer River, is most adversely affected by reduced flow resulting from decreased precipitation, the Dixon Dam and from local water removal. The data also indicates that plains cottonwood trees are most abundant in the 40 to year old bracket and are far less represented in the younger and older age groups. Data analysis is still in progress and other relationships are being investigated.

In: Rood, S.B., and J.M. Mahoney (eds.), 1991. The Biology and Management of Southern Alberta's Cottonwoods. University of Lethbridge, Alberta.

4. The Distribution and Age Structure of Cottonwood Stands Along the Lower Bow River

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An extensive riparian woodland exists along the Bow River from the mountains, to the Bassano Dam. The lower Bow River, immediately upstream from the junction of the Oldman, has a very limited riparian woodland. The reduction in riparian woodland along this reach is probably primarily due to changes in channel geomorphology and other factors.

Ideal conditions for riparian woodlands are found along the pointbars of river meanders. The pointbars migrate with every flooding, cutting into the old embankment and terraces and forming new pointbar surfaces for colonization by riparian woodlands. Figure 4.1 shows a river meander and pointbar along the Red Deer River. Older vegetation and newly exposed, usually sandy substrates ideal for the establishment of a number of riparian species, can be seen. Figure 4.2 shows the profile of a sandy pointbar with young cottonwood seedlings establishing on the surface. We know from our work and others that these riparian poplars need moist substrates. Sandy material seems to be better than clays or silts although a little bit of clay tends to hold the moisture in if there is sand underneath. Establishment has to be high enough on the embankment so that the sites are not washed away by movement of the channel during subsequent high water events.

Cottonwood is not a very competitive species. It will seldom move into a dense stand of shrubby or grassy vegetation. It needs a site where there is little other vegetation. We know that cottonwoods, once established, go through the different successional sequences quite quickly. New trees continue to grow until the flood plain surface becomes too high either by being built up through sedimentation or the river channel downcutting as it does on a number of our prairie rivers. The older trees gradually die out and are replaced by grass or shrublands.

Therefore, on a healthy river that is actively migrating, zones of different successional stages tend to form. These stages range from the mature cottonwood forest to cottonwoods establishing on sand flats that are just the initial stages of colonization.

The species studied was the plains cottonwood, *Populus deltoides*, or what some have called *Populus sargentia*. These are often fairly large, nice looking trees. We studied three sites on the lower Bow River. The first was right at the confluence of the Oldman and Bow rivers, a site at Bow Island and two sites upstream from there (Figure 4.3).

The flow of the Bow River is highly regulated, probably the most regulated in Alberta, and is comparable to the regulation of a lot of rivers in the United States. Figure 4.4 shows the dams and diversions on the main stem of the Bow River. There are also a number of controls on tributaries, not

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Figure 4.1. The Red Deer River in eastern Alberta showing actively migrating point bars providing ideal conditions for riparian woodlands. Note the successional sequence from recently formed sand flats to mature cottonwood forests.

Figure 4.2. Two year old plains cottonwood seedlings on an aggrading point bar along the Milk River, Alberta.

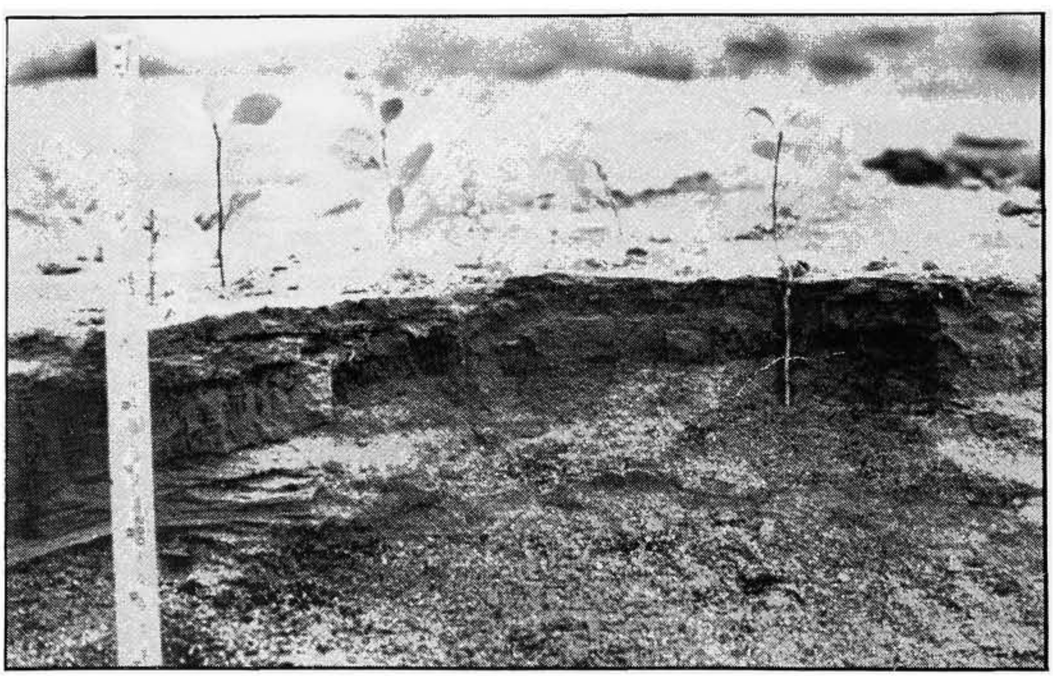
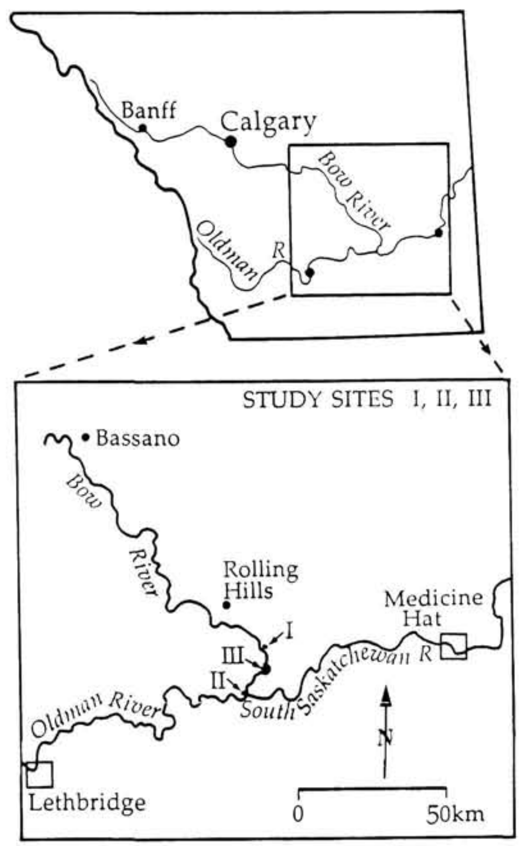


Figure 4-3. Location of riparian woodland study sites.



shown in Figure 4-4 like Midlake, Minawanka, the Kananaskis Lakes, and the Glenmore Reservoir in Calgary. Some of the weirs and dams have been in place since the early part of the 1900s.

The lower Bow is a single channel river in most places, with a very small or no riparian zone along the channel. It is fairly well entrenched into an old meltwater channel so meandering is limited. The riparian woodlands are usually a very narrow band along the channel. Most of the woodlands were old, but we did find some young woodlands. Since woodlands were scarce, we sampled all the areas available. The total area sampled was not great in size. Samples were taken by running transects from the river through the wooded zones and placing quadrats at every change in landform or vegetation.

The transects were surveyed with a dumping level to determine the elevation above the river level of the different stands of vegetation that were sampled.

A classification system was developed based on landforms and plant associations or communities. The system starts with a landform such as pointbars, abandoned channels, or fluvial plains which are then subdivided to smaller landform units, and again to the smallest unit which is basically a

Figure 4.4. Location and dates of installation of dams and weirs on the Bow River, Alberta.

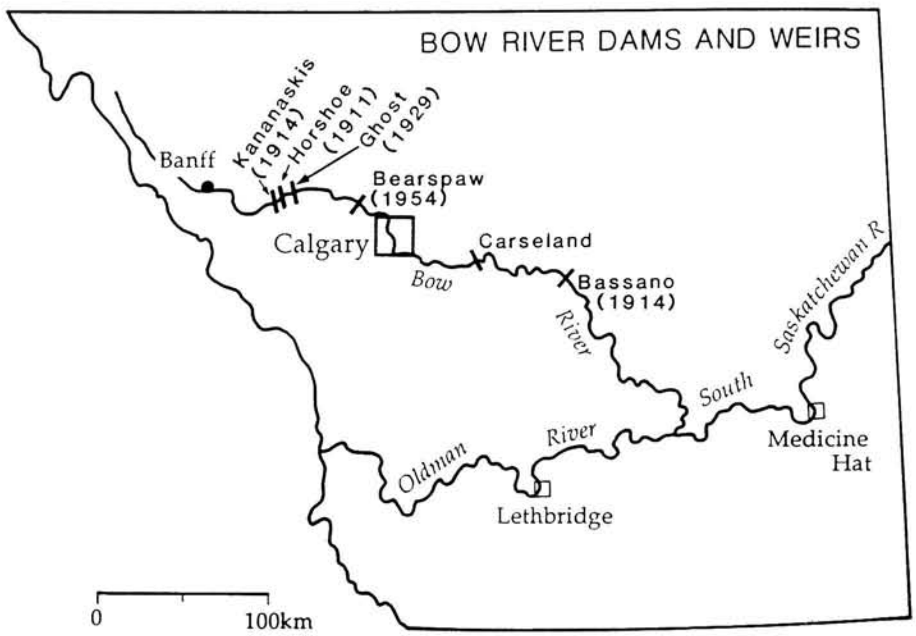
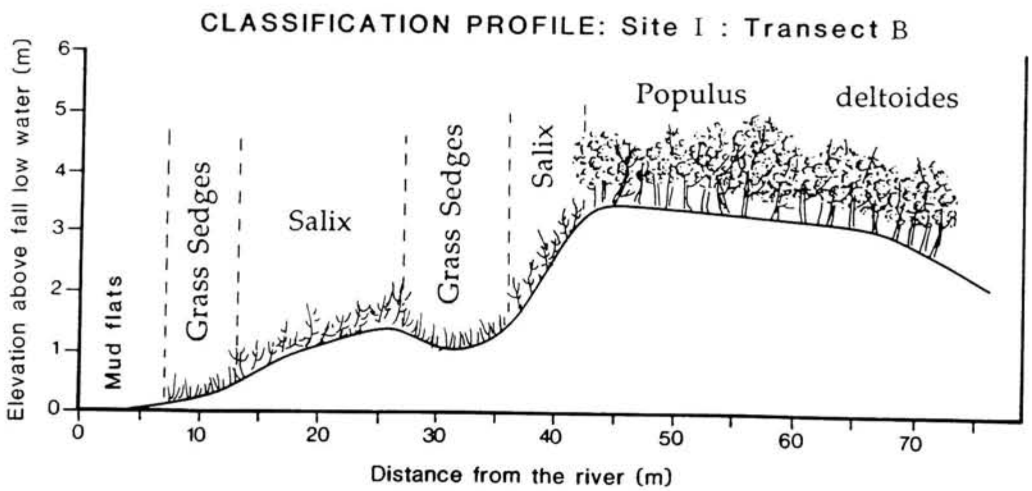


Figure 4.5. Typical profile of study site 1 showing the relationship between floodplain topography and plant associations.



plant community. Figure 4.5 shows several classifications with sedges, *S. interior*, and finally mature *P. deltoides*.

The hydrologic data available for most of these sites is in cubic metres per second (cms). This is of limited use for a particular site along the river if you want to determine the exact area that is flooded during a flood event. The relationship between river elevation or stage and the discharge must be developed. This is done by surveying the transect and establishing a standard such as low fall water level. The elevation above the low fall water level is then measured for a known discharge and a stage - discharge curve is developed. This curve, along with the hydrologic data, then enables you to determine the flooding history of a particular plant community or landform with some accuracy.

Since this is an open water system the stage - discharge relationship does not help in the event of an ice jam flood. If ice is associated with a flood, flow levels are likely to increase. The extent of the increase is very difficult to determine unless you are in study the area at the time of the flood.

The different land forms and plant communities were plotted along each transect. In some cases there were simple systems in place and fairly complex systems in others. The ages of the cottonwoods along each transect were estimated. Ages could only be estimated because of a number of problems. If the tree was browsed off by deer when it was young, or if the young tree was cut down by beaver, then the tree is actually older than the estimated age of the existing stem. Being able to count the annual rings properly is another problem.

Most areas of *P. deltoides* had very low regeneration. Each of the areas that we studied was mapped to calculate the area of all the different cottonwood stands. Figure 4.6 shows one of the two islands now found at the Bow Island area. This island is the younger of the two and was the only site where we found any real significant young cottonwood establishment in our surveys.

A lot of the Bow River area has a very narrow riparian zone that tends to be dominated by a reed grass, *Juncus* community with some bands of *S. interior*. There are few places with significant cottonwood development. Figure 4.7 shows riparian woodlands in study site I. In most cases older cottonwood stands along this reach were usually associated with an alluvial island. These alluvial islands develop in the middle of the river and as time passes, one of the channels tends to close off and the water flows through the other channel. The alluvial island is thus incorporated into the mainland. It is along the edges of these abandoned channels that older stands of cottonwood are found.

Channels along one side of alluvial islands may also be dammed by beavers. At some point the channel is cut off high enough so that it does not flood anymore. The channel then begins to infill creating regeneration areas for poplars. However, many reaches of the Lower Bow River have virtually no riparian woodlands at all. In the few locations where there is young cottonwood, beaver come in and chew them over quite badly.

Figure 4.6. A stand of young plains cottonwood in the Bow Island area (study site 2). This was the only area found along the lower Bow River to have significant young cottonwood establishment.

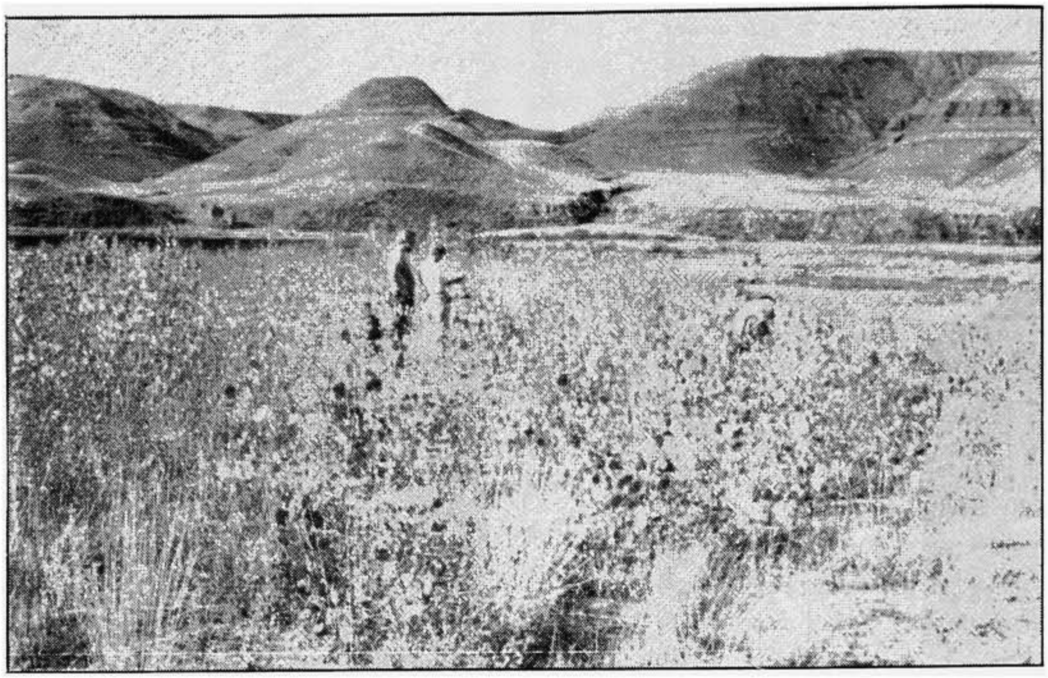
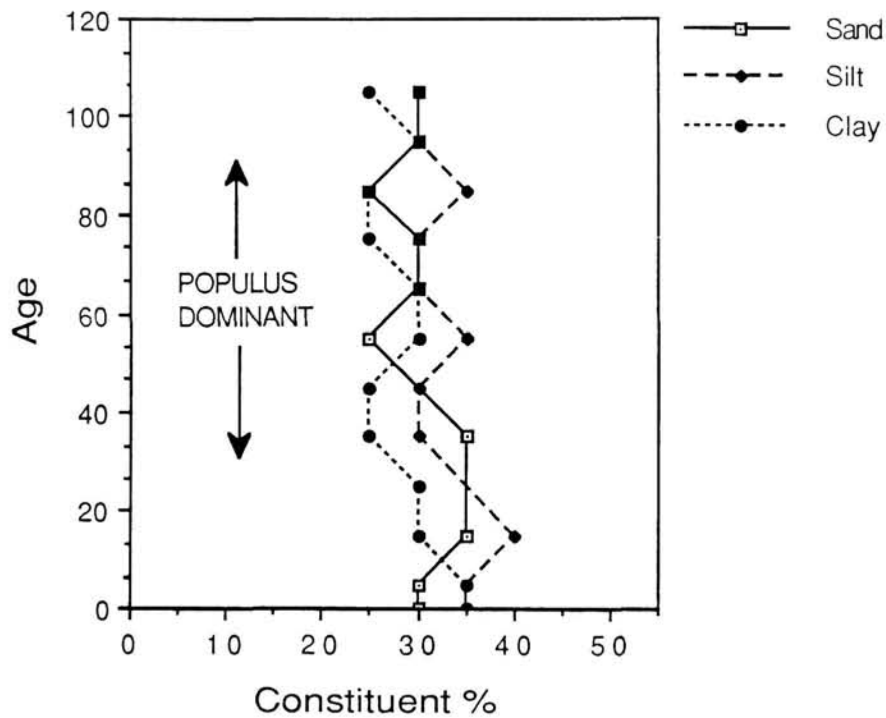


Figure 4.7. Riparian woodland on an alluvial island and an associated abandoned channel in study site 3.

The older cottonwood stands tend to be 3-5 meters above water level and some distance back from the river edge. This means that it now takes a very significant flood to get water up to these levels (Figure 4-5). In the lower levels, *Salix*, grass, and sedge predominate. In most cases little *Populus* establishment occurs along the lower Bow River.

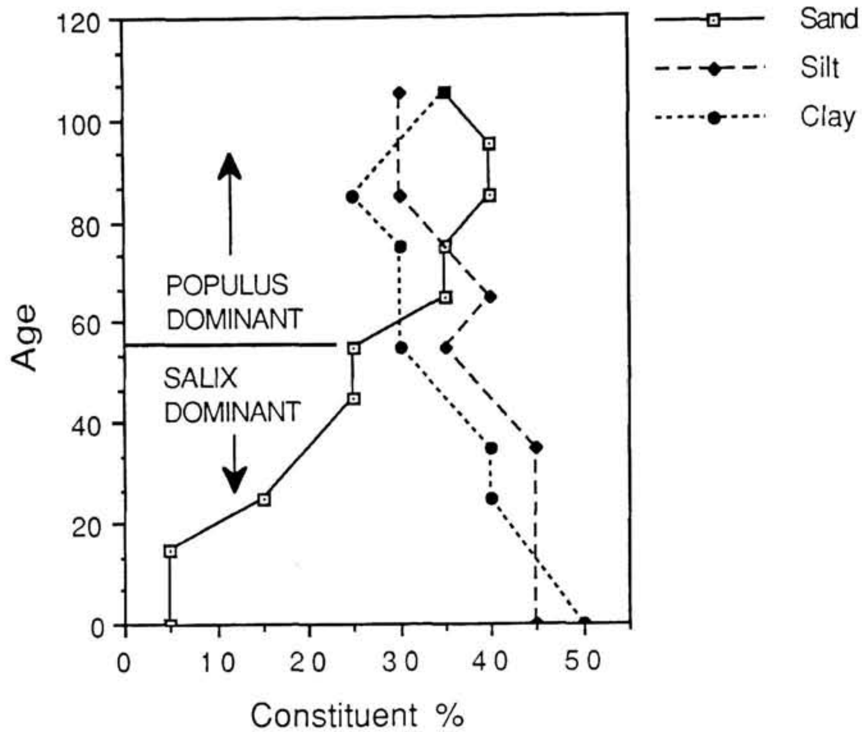
Following a good flood along the Red Deer, sediment is deposited underneath the *Salix*, and a lot of cottonwoods establish there (Figure 4-8). Establishment is best in sandy material. The sediment covers the grass on the ground underneath the *Salix* so the only competition is between *Salix* and the cottonwood. In situations where little sediment is deposited, even with large floods, there is virtually no cottonwood establishment at all.

Figure 4-8. Soil texture along a plains cottonwood dominated transect at a Red Deer River floodplain site.



On most Bow River sites, soil texture varied along the transects (Figure 4-9). Moving away from the river, clay and silt content was reduced, whereas the sand component increased. *Salix* dominated areas with a dense grass understory had high clay and silt components. In the *Populus* dominated areas there is a significant sand constituent indicating a probable change in the river regime under which that material was deposited. Larger floods usually tend to mix a major sand component in with the silts and clay. With minor floods, or along rivers that do not carry sand because there simply is not any sand in the system, the sediment is predominantly silt and clay.

Figure 4.9. Comparison of soil texture between *Populus* (cottonwood) and *Salix* (willow) dominant sites at Bow River study site 1.



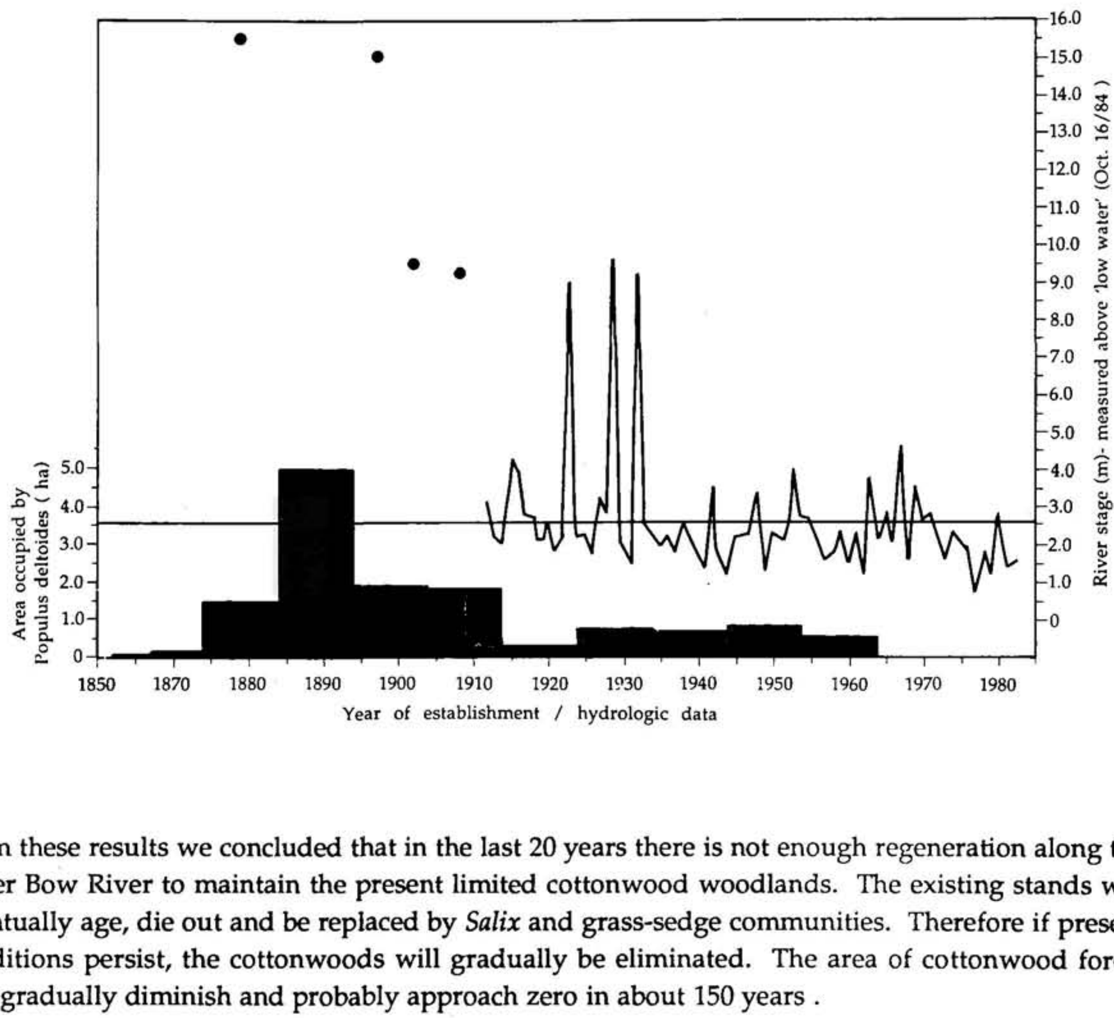
In areas where cottonwood regeneration did occur, usually about 3-4 metres above fall low water level, sediment does not vary much between the areas where young cottonwood are establishing and the older cottonwood grow. This indicates that the substrate, and presumably the fluvial regime under which that substrate was deposited, is probably quite important to the establishment of young cottonwoods. Along rivers that have a gravel bottom, such as the lower Bow River, there is very little sediment in the system. If cottonwoods were present, they would try to establish on gravel substrates too.

Seedlings established near low summer water level will be flooded quite a bit of the time. Ice moving down the channel also tends to scour these young tress during spring breakup. So although cottonwoods try to establish at low bank elevations, their chances of survival for any period of time is minimal. Poplars are not trees that are able to withstand long periods of flooding. They are unlike *Salix* species that can withstand flooding for two to three months with minimal ill effect. They must therefore establish high enough that they are above the river water level most of the time. Trees that do survive in this area fare poorly. Some small trees in this zone were found to be 20 to 40 years old. The trees are damaged every year by the ice moving out in the spring, and therefore have a hard time growing beyond this stage.

To summarize what we found, we combined the transect data from all the study sites. Figure 4.10 shows the area of established cottonwoods for 10 year intervals for the two sites on the Bow River.

Although some trees date back to about 1850, it is difficult to be sure of their age because they often have rotten cores by that time. Few stands were found that formed before about 1870. A fairly significant period of establishment was found from 1875 to about 1895. Establishment declines somewhat until about 1915, at which time there is quite a significant drop until about 1930. There is some establishment of cottonwood between 1930 and 1965 but not very much, and then virtually nothing until we finished the study in 1984.

Figure 4-10. A comparison of the area of plains cottonwood (*P. deltoides*) establishment and yearly maximum mean daily water levels on the lower Bow River. Dots (o) represent major flood maximum flows prior to 1910 (Sites I and III).



From these results we concluded that in the last 20 years there is not enough regeneration along the lower Bow River to maintain the present limited cottonwood woodlands. The existing stands will eventually age, die out and be replaced by *Salix* and grass-sedge communities. Therefore if present conditions persist, the cottonwoods will gradually be eliminated. The area of cottonwood forest will gradually diminish and probably approach zero in about 150 years .

We tried to relate the decline in cottonwood establishment to several factors. One was the hydrologic regime of the river. Good hydrologic records going back to about 1910 are available for Calgary. This was related to each study area using stage discharge curves (Figure 4-10). Before 1910 there was some data on peak floods on the Bow River, so peak flows were used for this period. Major floods occurred in the 1870s, and another one just around the turn of the century. Two high flows were recorded in the early 1900s, followed by a period with few major flows until the 1920s and early 1930s. There have not been any significant floods on the Bow River since 1932.

There seems to be a relationship between major floods and cottonwood establishment, at least in the late 1800s, early 1900s. These major floods most likely eroded banks, moved and deposited sediment fairly high up along the banks of the river and the old flood plain surface giving ideal conditions for cottonwood establishment. In contrast, the floods of the 1920s and 1930s do not cause any significant increase in cottonwoods. In fact, a decline in cottonwoods is noted at this time. These three large floods occurred after most of the dams were constructed on the Bow River. The damming may therefore have had an effect. The damming does not seem to have significantly decreased these flood events. However, these dams could have reduced sedimentation in the lower Bow River, despite the fairly high water levels. This would have limited the formation of new sites for cottonwood establishment.

The small number of flood events since 1932 in the Bow River drainage can be attributed, for the most part, to a shift in weather patterns. High flows in the Oldman drainage during this period have occurred when major low systems drag warm, moist tropical air up from the Gulf of Mexico. This air is pushed up along the mountains giving an orgraphic effect. If this happens when there is still a large snow pack in the mountains, a major flood in the river systems along the east slope of the Rocky Mountains occurs. It has been the lack of these weather events, not the presence of dams that have limited flood events in the lower Bow River.

Another important factor is fire. The good establishment of cottonwoods noted in the last half of the 19th century corresponds to a period of major devastation in the mountains and foothills along the east slope. The journals of people that went through the country starting about 1850, report large areas being devastated by forest fire. Most of the Bow River valley and its tributaries, were burned over by fire at that time. The construction of the Canadian Pacific Railway in the 1880s brought a lot of people to the area as well. These people also caused a number of fires.

Logging in the Bow Valley around the time that the railway went through and cultivation of marginal lands by settlers removed the natural vegetation cover. These human activities probably had a major impact on cottonwood establishment at this time too. This means that even 100 years ago natural conditions were not necessarily in effect at the time of cottonwood establishment. The periods of good regeneration may be as much caused by the acts of man, as the later periods of poor replenishment. To check regeneration under more natural conditions, pre 1850, few cottonwoods survive on the lower Bow River so the sample size is very small. The lack of stands from that date suggests it is not likely that there were large areas of cottonwoods established at that time.

Some large trees still remain the lower Bow River that could be listed in *Alberta Trees*. The record for *Populus deltoides* is not extremely large. Some trees almost six feet in diameter still exist in the areas we studied. Unfortunately, because there are few young cottonwoods, beaver appear to feed on the old ones and occasionally remove some of the very large, old trees. Predation by beaver is a problem on the Red Deer River, which has a very high beaver population at the present time.

The Bow Island site is the nicest area we found in the lower Bow River and probably most of the South Saskatchewan River. The Bow Island area is where the Oldman joins the Bow River. The channels around the island were altered about 120 years ago, probably during a major ice jam. The island has been enlarged quite a bit and active meandering downstream creates good sites for young cottonwood. There is also a very nice stand about 120 years old on the island that is quite large and healthy. Standing in the middle of this grove is almost like being in an eastern deciduous forest. You cannot see the prairies anymore.

5. The Accuracy of Tree Ring Analysis for Estimating the Age of Riparian Poplars

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One characteristic essential to understanding any population is the age distribution of individuals in the population and changes in that distribution over time. For riparian poplar forests, it is important to know whether there are adequate young trees to replace the aging and dying trees or not. If younger trees are lacking, the decline of the forest will be quite rapid. Without regular replenishment, 150 years is a reasonable estimate of how quickly a forest will decline in southern Alberta.

A number of techniques have been used to determine the ages of individual trees. The crudest and oldest method results from the observation that as trees get older, they tend to grow larger. This technique is poor since individual growth rates vary widely between genotypes and depend on environmental conditions.

A more refined procedure is to count annual growth rings. Annual rings are formed in a circular pattern in the stem of most trees. Trees normally form one ring per year, although under certain conditions they may lay form two or none. The lack of a ring in a particular year is referred to as a missing ring, a phenomenon discussed in the literature. Although double and missing rings complicate the analysis, a simple count of the growth rings in a stem is generally a good estimation of the age of the tree.

Growth rings are easily counted on a cross section of a stem (disc). This method allows the selection of the radius with the clearest view of the rings. If a zone of unclear rings is encountered during a count, a ring can be traced around to a clearer area, and the count continued. Consequently, the researcher can be confident of finding all of the growth rings after a careful search. Counting growth rings on a prepared disc is therefore the most accurate technique for estimating the age of riparian poplars and will yield the best estimate of true age.

Unfortunately, analysing discs is impractical as it requires cutting down the tree to remove a disc. Ring counts may be made occasionally from the stumps of trees harvested by beavers. This method is only satisfactory if the time of felling is known and if the remnant stumps have not weathered excessively. This alternative is limited since beaver harvesting is irregular.

The most common technique for aging trees was developed about 75 years ago. This procedure requires the removal of cores from the stem with an increment borer, a hollow tube with a screw tip and a crosspiece driver. The borer is screwed into the tree trunk and an extractor is used to pull out a core with annual growth rings. The core is analysed under magnification to count the growth rings and estimate the age of the tree. A number of sources of error are know to influence the accuracy of

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age estimates base on increment cores. Reports suggest that these errors may be especially significant for trees sampled from the riparian zone. It is important therefore, to determine the accuracy of age estimates using increment core analyses before these estimates can be used in other work.

The construction of the Oldman River Dam provided the research opportunity for this study. The river valley to be inundated with the closing of the dam was to be cleared of poplars to prevent problems with the operation of the dam. This made it possible to visit the area, take increment cores from a tree, and then fell the tree and remove a disc. The age of the tree was estimated by counting the annual rings on both the prepared disc and the increment core. The increment core count was compared to the true age of the tree as estimated from ring counts of the disc. This comparison gave an indication of the accuracy of the increment core method.

In September, 1989, fifty trees were selected from four sites with diameters ranging from 10 to 30 cm at breast height (dbh). A few larger trees of up to 55 cm dbh were also included. These trees were typical riparian poplars of the foothills region of southwestern Alberta being predominantly balsam poplar (*Populus balsamifera*: Rood et al, 1986; site 8), some narrowleaf poplar (*P. angustifolia*), and numerous balsam and narrowleaf hybrids (Rood et al, 1986).

Figure 5.1 shows the relationship between stem diameter and age of the riparian cottonwoods. Variability in the relationship was high even between trees from close proximity. Samples of trees of the same age were found to have stem diameters that varied by over 35 cm. Other samples of trees with similar stem diameters were found to differ in age by up to 100 years. These results indicate that estimating the age of riparian poplars in southern Alberta by measuring stem diameters is extremely uncertain.

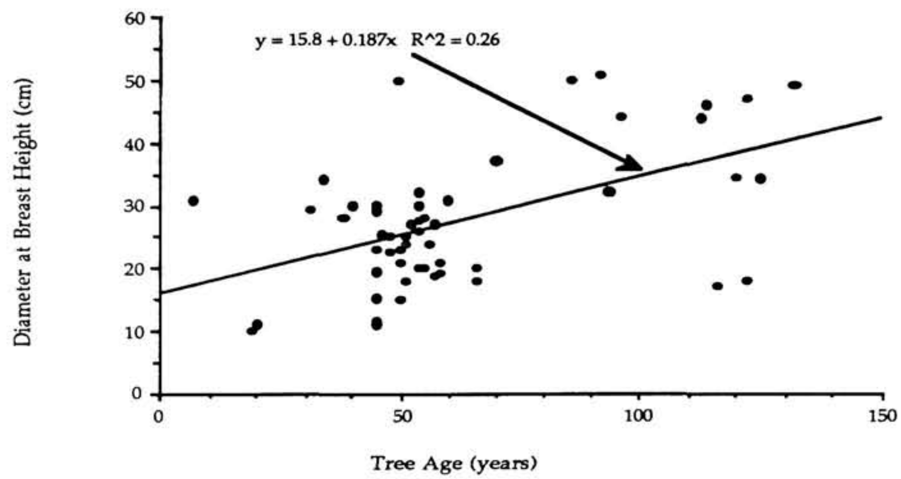
Increment core analysis estimates riparian poplar age much better than measuring stem diameters. When the age of trees based on core counts (estimated age) is compared to the age of trees based on disc counts (true age), the values are expected to be the same. Initial analysis in this study found a significant ($P<0.0001$) correlation between the slope of the linear regression between the estimated age and the true age of trees (Fig. 5.2). Further analysis showed that the slope of the linear regression between the estimated age and the true age was 0.909 ± 0.019. The calculated slope varies significantly from the value of 1.000 that would be expected if counting annual rings on increment cores was as accurate at estimating tree age as counting rings on prepared discs. The divergence from unity in the plot can be seen at about 25 years of age (Fig. 5.2). After this time the slope less than unity indicates that increment core analysis consistently underestimates the true age of the trees. For trees 100 years old, there is an underestimation of about 7 years.

The consistency of the underestimation of Oldman River poplar ages when using increment core analysis suggests that the estimate can be improved by applying a correction factor. By correcting the counted age through the regression of Figure 5.2:

$$\text{true age} = \text{increment core age estimate} \times 0.909 + 2.254,$$

it is possible to generate a more confident estimate of the age of the tree. The coefficient of determination of 0.982 indicates that this regression accounts for over 98% of the variation in the data. Correcting core ring counts through the regression equation will bring corrected estimates to within 2% of the true age of the tree. This is a substantial improvement over simple core ring counts that would typically underestimate tree age by about 7 years in 100.

Figure 5.1. Relationship between the age and diameter at breast height of poplars from sites on the Oldman River.

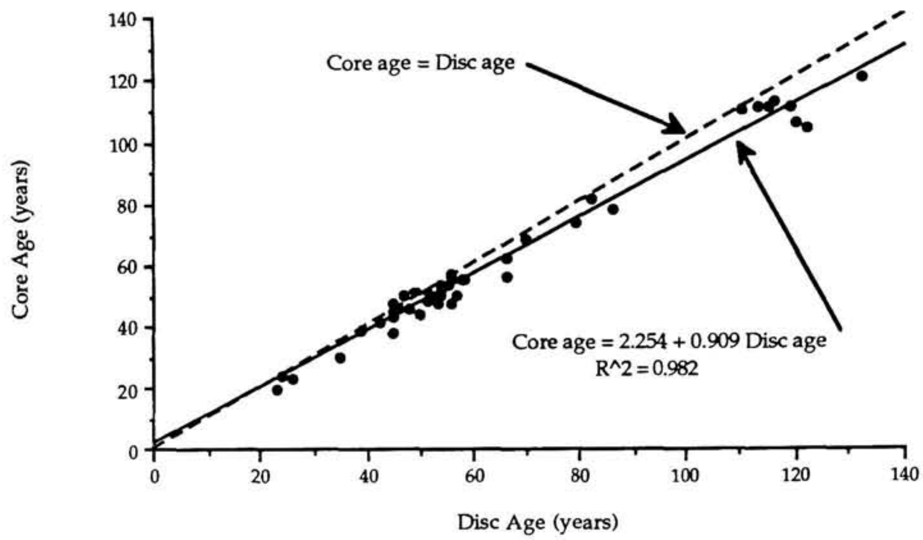


The underestimation of age by the increment core analysis is significant in attempts to relate the establishment of poplar seedlings to specific environmental conditions. Studies to determine the environmental conditions necessary for poplar regeneration depend on being able to identify specific years of successful seedling establishment. Knowing these years, the researcher can check the environmental data for that period and gain insight into the required conditions. The present work, coupled with other known sources of error in aging trees, precludes aging trees with greater than about 5% accuracy. The year of establishment for trees that are 100 years old can only be estimated therefore, to within 5 or 10 years.

The close relationship between the estimated and true ages of Oldman River poplars seems to hold for the entire sample (Figure 5.2). Variation from the regression line does not increase with the age of the poplars. This indicates that accurate age estimates can be obtained for both older and middle-aged trees and that core ring counts can be used confidently for the whole range of ages in a poplar population. In general however, the age of the older trees can only be estimated to within a decade.

The observed underestimation of tree age is caused by missing annual rings during increment core analysis. The major reason for missing rings is ring complacency, a series of evenly spaced rings. Because the rings are evenly spaced, indicator rings or identifiable sequences of rings do not appear. Indicator rings are formed during particularly favorable or unfavorable growth periods that cause

Figure 5.2. Relationship between tree ages as estimated from core and disc analysis for poplars from Oldman River sites.



unusual rates of growth and widths of annual rings. Trees from the same region tend to experience the same growth conditions and form the same patterns of favorable or unfavorable growth rings. By identifying unique sequences of rings, it is possible to cross reference a tree with another from the same region and generate a more accurate estimate of tree age. Ring counts only need to be completed from the last year identified positively by the ring pattern thereby shortening the length of core in which a ring could be missed.

Another characteristic that contributes to missing annual rings during analysis is that the rings are often very diffuse and difficult to identify, even under magnification. If a single large ring appears in the middle of a complacent series an interpretation has to be made as to whether the large ring is a single ring, or actually two poorly distinguished rings. These interpretations are less of a problem with disc analysis because the rings can be traced to other sections where the rings are clearer.

Various stains have been recommended to improve the distinction between rings and the accuracy of core counts. The stain highlights the lignin contained in the annual rings to give better definition between rings. This method is satisfactory for a number of tree species, however the composition of poplar wood is such that everything stains equally with little enhancement of contrast between the annual rings.

Observation of full stem discs shows many poplar trunks to be radially asymmetrical. This makes coring to the pith difficult. Experienced corers can usually account for this asymmetry and still core through the pith. If the pith is missed however, the distance to the pith must be estimated by looking at the curvature of the central rings and estimating the number of annual rings that were missed. This process introduces another source of error.

A last factor complicating ring analysis is that tree growth is often very rapid early in the life cycle. This causes the formation of large rings. Ring width then decreases as the tree ages. This makes it difficult to compare ring patterns from different trees or group data for statistical analysis.

Several variables affect the accuracy of estimates of tree ages outside of the analysis of the increment core itself. These variables will combine with those described above to further underestimate the true age of the tree. Increment cores are usually extracted at a height of about 1.5 m on the trunk. It might be estimated that poplars take 3 years to grow to that height, so 3 years are added to the age estimated by core analysis. A fixed addition of 3 years is probably inappropriate due to variation in individual growth pattern and environmental differences.

Another variable is the amount of sedimentation that occurs after seedling establishment. If a tree has been buried by a meter of sediment over the years, the increment core is actually being taken at 2.5 m rather than the 1.5 m level. The tree may have taken 5 years to reach this level and not the 3 years estimated. This will cause a further underestimation of the age.

In the dynamic riparian ecosystem, the zone of poplar regeneration is also the area of greatest fluvial activity. In this zone, saplings may be sprout from under the sedimentation of one flood event only to suffer subsequent burial. This process can occur repeatedly. It is almost certain that trees that survive repeated burial will not achieve the same height as a tree growing in less traumatic conditions. Trees on good sites may well attain heights of 2.5 meters in 5 years, whereas trees regularly covered over may require several more years to attain the same height.

Underestimation of tree age may also be caused by scouring. A sapling that is scoured off by ice or harvested by beaver will usually regenerate. In these cases, the root system that developed from a seed could actually be many years older than an analysis of increment rings indicates. At present we cannot determine which trees yield erroneous results through coppice growth.

The final complicating factor is that balsam poplars characteristic of southwestern Alberta sucker profusely. In this process new shoots emerge from existing roots forming apparently distinct individuals. If the shoots are aged, that age will not represent the age of establishment of the original seedling, but some later time when the sucker arose.

Through this study we have been able to estimate the error in using increment core analysis to age riparian poplars in southwestern Alberta. The results indicate that increment core analysis is a good tool for studying the general population ages and trends, but imprecise in aging individual specimens. Potential sources of error occur within the technique itself, in estimating the real height of the tree at the time of sampling, and in estimating the time required for a seedling to grow to the height of sampling. These potential sources of error produce a consistent underestimation of tree age. Surveys of poplars into decade age classes appears to be a reasonable objective, however researchers should be cautious about assigning specific ages or years of establishment to individual trees. Attempting to link the establishment of cottonwood seedlings to specific environmental conditions through increment core analysis is tenuous at best.

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6. The Importance of Riparian Cottonwoods to Wildlife

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I was asked to discuss the importance of cottonwoods to wildlife. However, rather than providing a treatise on the importance of habitat to wildlife, I will summarize the Fish and Wildlife Division's perspective on this issue, and indicate how cottonwood habitat has been ranked with respect to importance for wildlife. I will also provide an overview of current threats to cottonwood habitat and causes of cottonwood decline in southern Alberta. Lastly, I will discuss Fish and Wildlife Division programs and initiatives aimed at reversing the decline.

What is wildlife habitat? My first year university textbook defines wildlife habitat as a unique combination of space, food, water and shelter upon which all wildlife depend.

I do not think anyone will argue against the fact that wildlife and habitat are inseparable. The prime determinant of wildlife welfare is habitat. The diversity and abundance of wildlife populations can be directly linked to the quantity, quality and diversity of associated habitat.

The river valleys in southern Alberta, particularly west of Lethbridge, including the Belly, Waterton, St. Mary's and Oldman Rivers, offer a unique combination of vegetation and physical topography. The structural diversity and high productivity of the river valley cottonwood forests creates a variety of niches providing an oasis of rich habitat in an otherwise predominantly agricultural landscape.

Over 40 mammal, six amphibian and four reptile species are known to inhabit or frequent the riparian cottonwood forests in the Southern Region. This habitat is also of crucial importance for nesting and migrating birds and will be discussed elsewhere. Many of these wildlife species can often be found out of the valleys during different times of the year, however one or more stages of their life cycle is usually dependent in some way on the riparian areas and in many cases the cottonwood forests specifically.

The Fish and Wildlife Division has identified riparian habitat (including riparian cottonwood forests) as critical or key habitat for both game and non game species of wildlife.

Riparian cottonwood habitat has been recognized as being particularly critical for mule deer and white-tail deer as winter and spring fawning range. Optimum fawning habitat for deer consists of wooded areas with greater than 50 percent canopy cover, a dense low shrub layer, a minimum size of 0.5 to 2.0 ha and within 200 m of potable water. In southern Alberta, riparian cottonwood forests are often the only areas satisfying these habitat requirements.

Interestingly, this past winter the Wildlife Branch conducted an aerial winter survey of deer

In: Rood, S.B., and J.M. Mahoney (eds.), 1991. The Biology and Management of Southern Alberta's Cottonwoods. University of Lethbridge, Alberta.

populations in the southwestern prairie region including the Oldman, Belly, St. Mary and Waterton River Valleys. Eighty to 90 percent of observed deer were within the river valley and over three quarters of those deer were directly associated with cottonwood forest habitat. Comparison between this survey and the last time it was conducted in 1982, indicates that the St. Mary River survey block showed the only decrease in overall deer numbers (-7%) whereas the Belly and Waterton that had increases of 56% and 32% respectively. These results are interesting in light recent reports that cottonwood forests below the St. Mary Dam show the greatest decline and those along the Belly River the least decline.

Obviously, all is not well with cottonwood forest habitat in southern Alberta. Currently there are a number of land use activities that are threatening riparian cottonwood habitat in southern Alberta. The Fish and Wildlife Division has identified the following factors as the most significant affecting riparian cottonwood habitat:

1. Water Management eg. dams, weirs, diversions
2. Cattle Grazing and Cattle Wintering
3. Cultivation (the alluvial soils in valleys are prized for irrigation farming)
4. Development eg. urban settlement, industry, recreation
5. Transportation Routes (the easiest path is often through river valleys)
6. Gravel Extraction (clearing and water table effects)
7. Landfills
8. Logging of firewood and timber.

Beaver activity could also be added to this list. Beaver activity is starting to have a significant impact on cottonwood forests due to the extreme reduction in forest size. This impact is likely to increase as forests are reduced further.

The data already presented at this conference indicates that one main factor leading to cottonwood decline in southern Alberta has been water management practices. The Fish and Wildlife Division would like to stress however, that water management is not the only negative activity. Water management may be a significant negative factor itself, but is also likely compounding the effects of a number of other negative activities, making those impacts that much worse.

Cattle grazing has been identified as one of the major problems in riparian areas, affecting cottonwood regeneration. Possibly equal in magnitude to grazing, is the wintering of cattle in the shelter of cottonwoods. Significant trampling and clipping of seedlings and vegetation occurs through a winter of feeding in high density confinement.

Recreation demands such as areas for golf courses are increasing at an incredible rate right across Canada and southern Alberta is not exempt. The most desired locations for new golf courses in southern Alberta is amongst the cottonwoods in the river valleys. Urban sprawl, new transportation routes and gravel extraction have also had impacts on cottonwood forests and are still threatening these habitats.

The Habitat Branch of the Fish and Wildlife Division has a number of programs and initiatives designed to protect, maintain, restore and/or manage wildlife habitat.

The Buck for Wildlife program is probably the best known. This program, initiated in 1973, receives funding from a levy on fishing and hunting licenses and tax deductible contributions. The goal of the program is to isolate critical habitat from other land uses through cooperative agreements with private landowners that promote the protection or maintenance of habitat.

In the Southern Region approximately 4-5 percent of the Buck for Wildlife budget goes to stream enhancement projects. Half of this would consist of streambank fencing. To date most of the cooperative agreements have been for 25 year periods and located east of Lethbridge in the Eastern Irrigation District or the Bow River Irrigation District. Most of the streambank fencing projects have been along small tributaries. This program reacts primarily to requests from landowners,although projects in some critical areas are pursued.

The Landowner Habitat Program is also funded through the Buck for Wildlife Trust Fund. It is an incentive program where the Fish and Wildlife Division reaches agreement through the provision of incentives with private landowners to protect, or maintain specific areas. The program usually involves restrictive grazing agreements where a limited number of head are allowed into a certain area. This prevents overuse and promotes the restoration and maintenance of valuable wildlife habitat. One major grazing restriction agreement that was negotiated last year encompasses approximately 350 acres of riparian cottonwood habitat.

Another major initiative is the Habitat Protection Program. Through this program critical areas on Crown land are retained or acquired. The Fish and Wildlife Division becomes involved whenever an application is made for a stream crossing or any type of exploitation or sale of Crown land. The Fish and Wildlife Division reviews these applications and can place restrictions or conditions on these activities to ensure the protection of wildlife and fisheries resources. A grazing lease that included 100 acres of cottonwood became available north of Lethbridge a few years ago. A golf course development group applied to purchase the land including the cottonwood stand. The Fish and Wildlife Division reviewed the proposal and recommended that the land not be sold, but be retained by the Crown as protected wildlife habitat.

A fourth program, initiated in 1988, with the funding from the Buck for Wildlife Trust Fund, the federal Department of Fisheries and Oceans, and Wildlife Habitat Canada, is the Riparian Habitat Project. This is a three year pilot project on the Battle River, similar to the Landowner Habitat program which targets riparian habitat specifically.

In the Southern Region a Riparian Inventory Program was initiated two years ago. The objective of this program is to identify and inventory riparian habitat on Crown land along the Oldman, Belly, Waterton and St. Mary Rivers. Unfortunately, this program has been discontinued due to lack of funding. There is hope that the program may be revived with future funding.

Last but not least, the Fish and Wildlife Division can have an impact through interaction and close consultation with other agencies such as Alberta Public Works, Supply and Services. The Fish and Wildlife Division has been involved from the beginning of the Oldman Dam Project. Alberta Forestry, Lands and Wildlife has been involved in planning and implementation studies providing expertise and scientific advice to Alberta Public Works, Supply and Services on a regular basis.

The effect of the Oldman River Dam and its operation on downstream cottonwoods has yet to be quantified. Thus no one really knows what is going to happen with the cottonwoods downstream. I want to emphasize the importance of the work that is currently being done at the University of Lethbridge and by other investigators on this issue. The Fish and Wildlife Division relies on this information to a great extent and the importance of this work cannot be understated. We need to understand the ecology of cottonwoods and the reason for their decline in order to facilitate changes in Government Policy and water management practices in the province. Workshops like this are a first step and the development of the monitoring program that will be discussed later in the workshop is a necessary second step.

The Fish and Wildlife Division will continue to target riparian cottonwoods for protection and expand, hopefully, our programs to a larger geographic area. Finally, it will require a combined commitment from the private sector, universities, interest groups and all levels of government, to conserve these riparian cottonwood habitats that are crucial to wildlife and are vital component of southern Alberta's heritage.

7. Cottonwoods of the Milk River

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The purpose of my talk is to provide the results of a study in which I have documented the extent of cottonwood communities along the Milk River valley. In addition, I established permanent transects for long term monitoring along the cottonwood stands and also looked at an assessment and confirmation of the relationships between cottonwoods and the river regime.

The study was designed taking into account the considerable amount of work already done on the Milk River. Work began in 1917 when the U.S. and Canada made an agreement to use the Milk River channel to convey irrigation water from Montana and Glacier National Park through Alberta to eastern Montana. As a result of that agreement, numerous hydrological surveys were undertaken complete with cross-sections and river flows. In 1982, Cheryl Bradley did a thesis on the relationships of the cottonwoods and the river regime in 1980.

The Milk River drainage basin originates in Glacier National Park in Montana, flows north to meet the North Milk River branch, through the town of Milk River, past Writing-on-Stone Park and on to Montana again at Eastern Crossing (Figure 7.1). The Americans collect water during the spring snow melt from the Rocky Mountains at Glacier. The water is stored until the irrigation season is in full tilt, and then released in June, July or August. It flows through Canada and into the Fresno reservoir where it is diverted to irrigation.

The effect of this practice on stream flow is shown in Figure 7.2. The average monthly flow conditions recorded prior to 1917 have a peak in April and decline in May. There are records some years of when there was no water in the river in August, September and October.

With the transfer of irrigation water the peak flood is delayed until May or June. The peak flow is also higher. The flow then drops off during July and August to normal levels by the end of the year. The effect of the irrigation diversion on daily maximum flows has been negligible. The daily maximums are as high as they ever were.

Another interesting feature of the Milk River is the sedimentation regime measured at the town of Milk River. The amount of average seasonal suspended sediment is about 50,000 tons. By the time the river reaches Eastern Crossing, the sediment load is between 300,000 and 500,000 tons. The major contribution of sediment in the Milk River is the badlands topography in the last 100 km before Eastern Crossing, since the bed of the river is predominantly gravel upstream of Writing-on-Stone Park.

The distribution of cottonwoods along the Milk River is influenced by these characteristics. The main features found from Writing-on-Stone Park to Eastern Crossing, are two channel types; the

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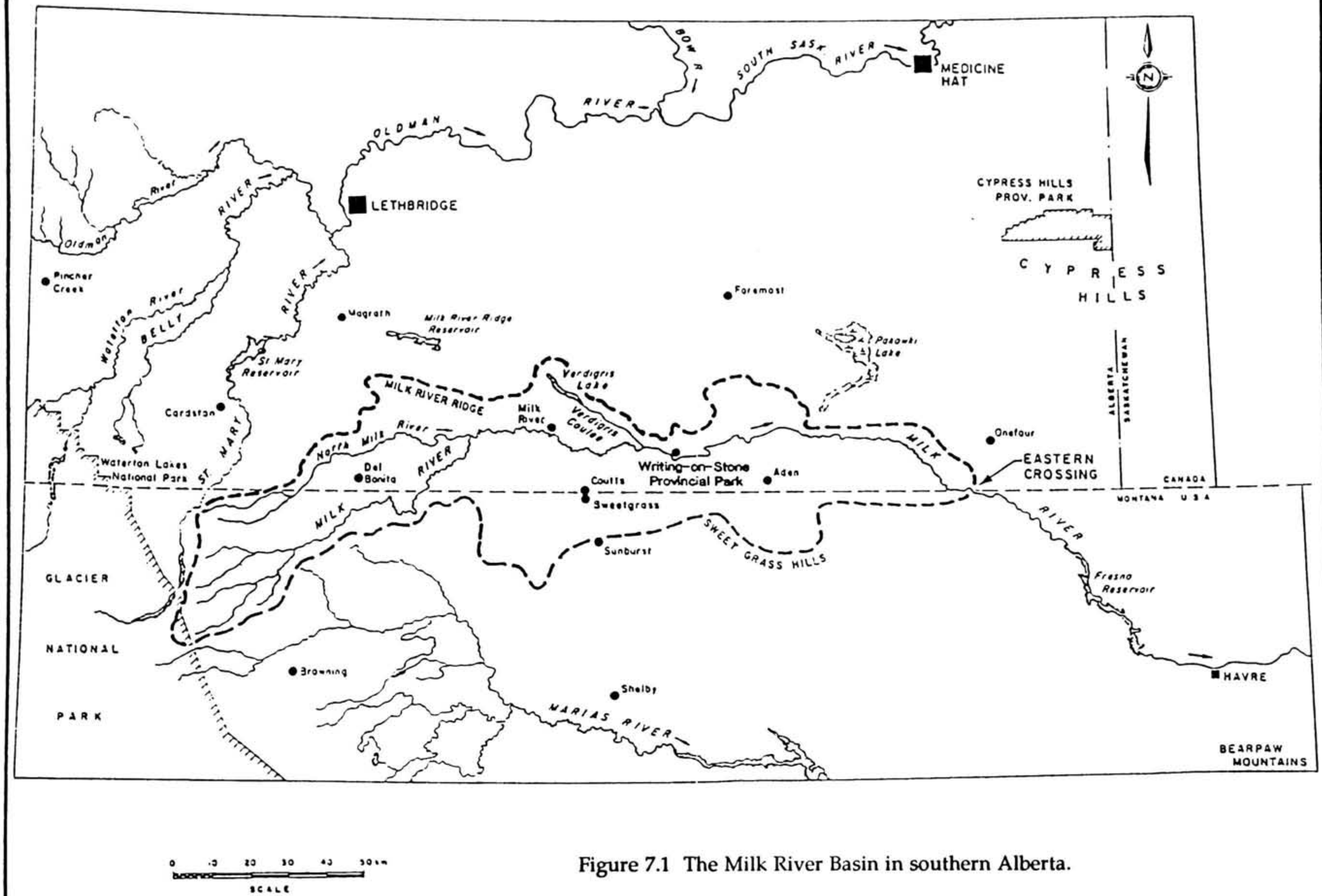
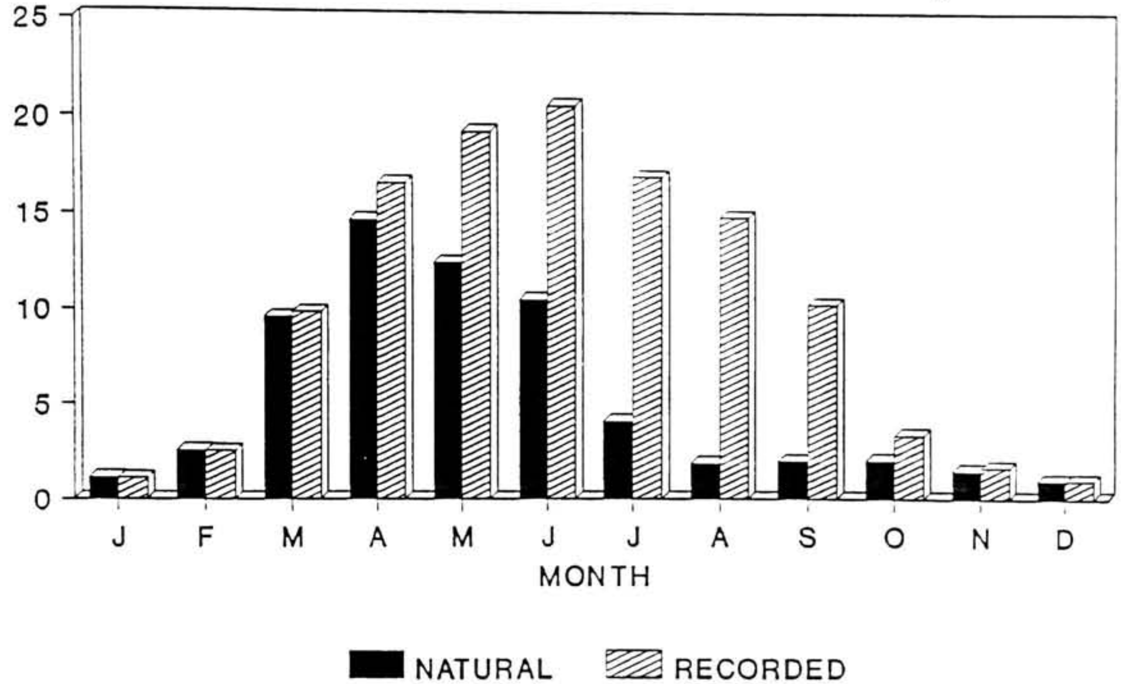


Figure 7.1 The Milk River Basin in southern Alberta.

Figure 7.2. Monthly mean flows for the Milk River, Alberta at the eastern crossing from 1912-1986.



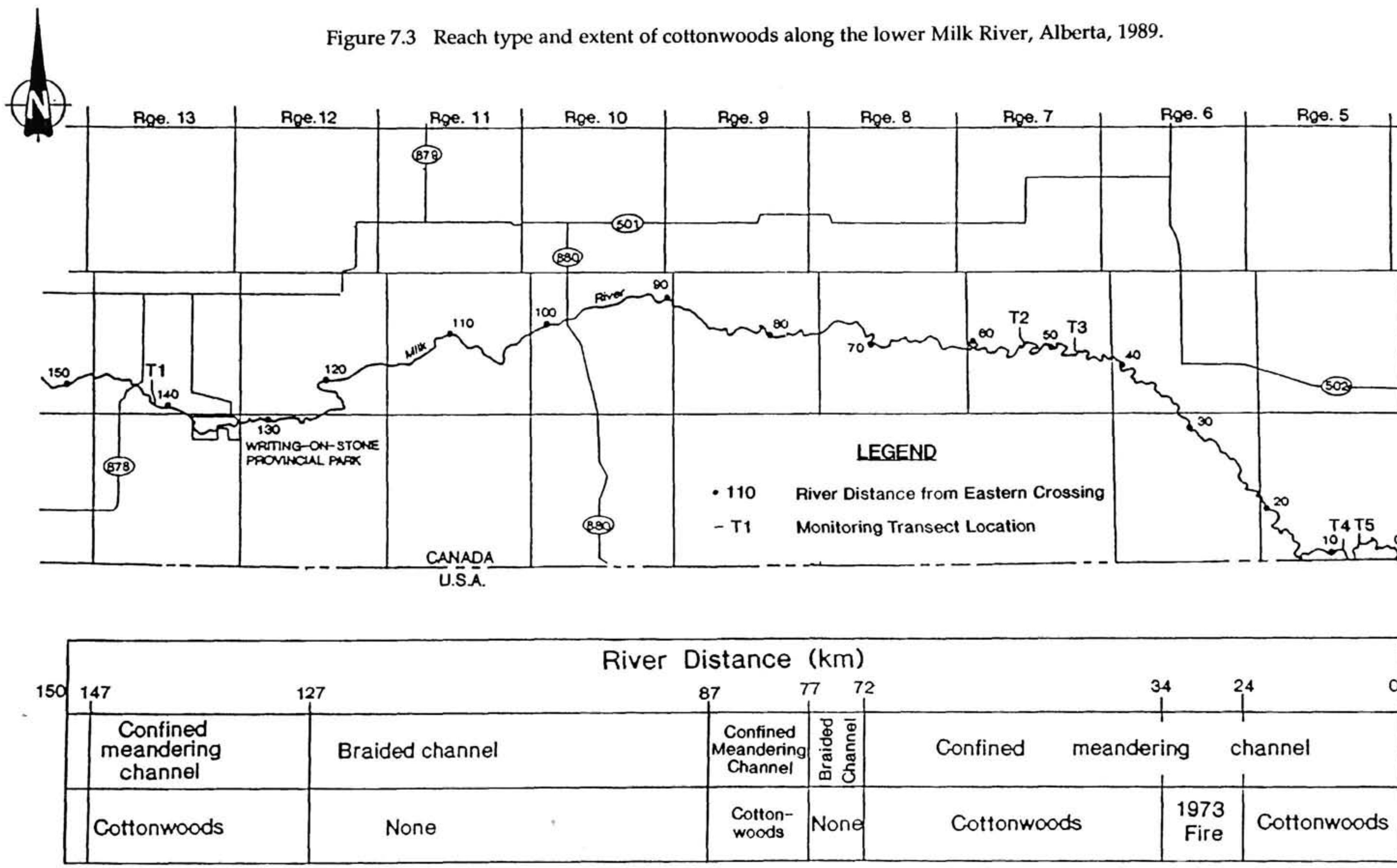
meandering channel and braided channel. The meandering channel supports cottonwoods, the braided channel does not. Starting at Writing-on-Stone Park, there is a small area of cottonwoods, followed by a large gap without cottonwoods, followed by about a 10 km stretch of cottonwoods, a zone without any, and then the last 72 km with an abundant population of cottonwoods (Figure 7.3).

The lower stretch of the Milk River through the Pinhorn Grazing Reserve is very meandering with extensive point bars and cottonwood stands. The valley is 300 to 400 m deep with badlands and unvegetated formations along the bank that, when eroded, provide much of the sediment in the river. In contrast, a braided stretch has very little point bar development. There are no trees, and a fairly confined channel. Point bars have typical arcuate bands of cottonwood trees with the oldest ones being back near the coulees and the youngest ones along the edge of the river. Extensive sagebrush flats occur beyond the edge of the forest.

In order to document the extent of cottonwoods along the valley I used the oldest, complete set of air photos of the river valley. These turned out to have been taken in 1951. Since 1951, very high flood flows in 1953 realigned much of a meandering stretch near Writing-on-Stone Park. The river has been straightened and cut off a number of meander loops. The cottonwood trees that grew along the old channel are no longer present, but they have been replaced by regrowth along the new channels.

More recent airphoto coverage is incomplete so I used a variety of photos from 1979 to 1986 including color photos and false color infrared photos that really make the job a lot easier. I was able to compare photos from 1979 to the same site in 1989 and found very little change in that 10 year interval. The cottonwood stands are very open and scattered with a few denser areas.

Figure 7.3 Reach type and extent of cottonwoods along the lower Milk River, Alberta, 1989.



At the Lost River Ranch area there are also a number of meander lobes about to be cut off in the next flood. There is evidence that when a loop is cut off the area is regenerated with young willows and some cottonwoods. In 1973 a severe fire destroyed extensive stands of cottonwoods that are now overgrown with chokecherries, grass and some willows.

The change in area of cottonwoods along the Milk River between 1951 and the field survey in 1989 amounted to a loss of some 75 hectares or 15% of the total area. For the most part that was accounted for by the fire of 1973. When Bradley (1982) studied the area, she mentioned that there was a lot of sprouting from the trees in the area. Our observations in the same area last summer found only the old skeletons. Some trees had probably lived for a while and eventually died.

Another aspect of cottonwood adaptation to the flood plain is the ability to send out new root systems as the old ones are buried. Trees established on the flood plain are often buried by silt up to 2.5 m deep. These specimens can have up to three or perhaps four buried root systems. Trees that were aged at 30 cm above the current ground surface were found to be 80 years old. However, samples near the second root system were about 60 years old.

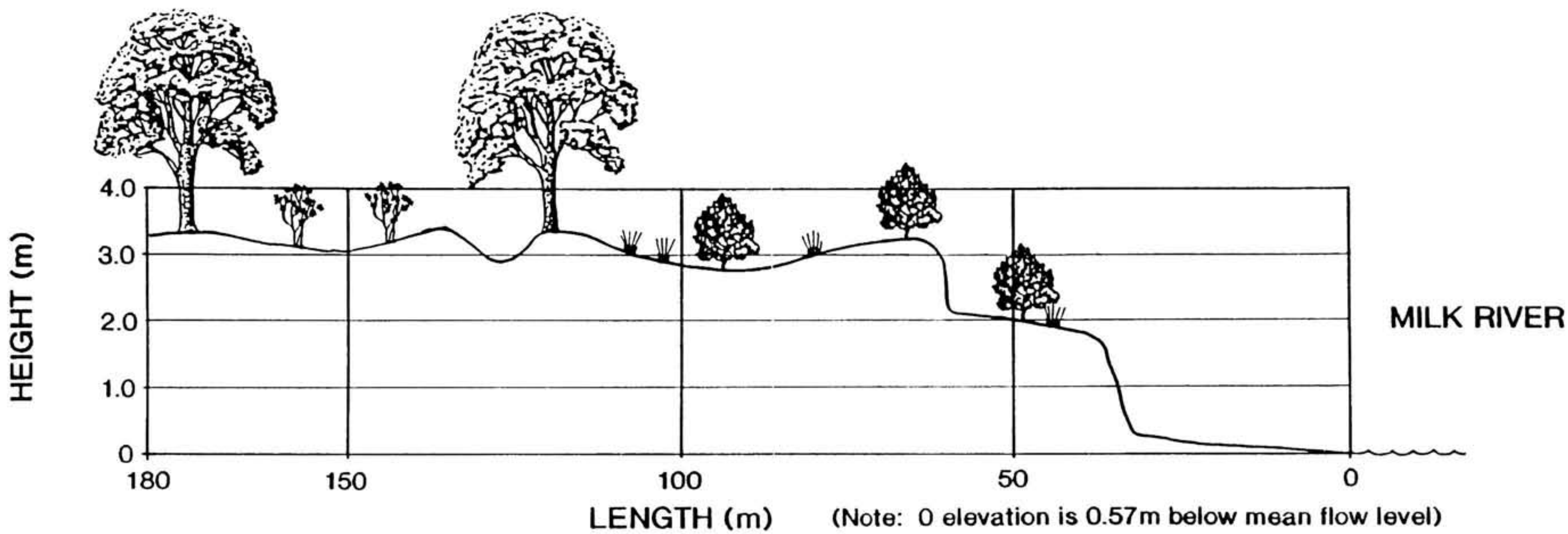
Young cottonwoods are quite able to withstand being cut down by beaver through coppice sprouting. Older, larger ones do not have the same regeneration potential. Deer also browse regularly on cottonwood. While local declines or losses of trees have occurred on individual meander lobes, there is no evidence that animal activities have affected the long-term survival of riparian poplars.

The cottonwood stands along the Milk River have been used for winter grazing from the late 1890's to the present. The result is obvious trampling and browsing of young saplings and seedlings and maintenance of open stands of trees. While losses of trees have occurred in local areas, cottonwoods extent has not changed over the past 100 years despite constant cattle grazing pressure.

A typical cross section of a meander lobe has seedlings near the river followed by younger trees, willows, grass, then the first cottonwoods, starting at 60 years old (Figure 7.4). There is not a continuous sequence in cottonwood ages, but rather two or three age classes. The elevation above the mean river level is 3 m or so for mature trees. The seedlings were very abundant in 1989 with up to 240 m^{-2}. They established about 0.4 m above mean river level in areas where sediment was 0.3 cm to 1 cm deep. Drought conditions were not severe, as the river level dropped fairly gradually throughout the summer. Given the known rate of seedling root growth, they have been able to keep up with the water table decline and survive the summer.

Cottonwood establishment tends to be related to flooding and flood peaks. Trees seem to establish best in years with flood peaks above 60 m^3sec^{-1} (Figure 7.5). The relationship is not perfect. The 1989 flood peak of 64 m^3sec^{-1} was reasonably high and was followed by a good stocking of trees. However we have not seen a large flood (over 100 m^3sec^{-1}) since 1974. So, while many trees have been established in the 1980's, it is uncertain as to how many might survive a severe flood.

Figure 7.4. Profile of Transect T2 along the Milk River, Alberta.



Vegetation Type

Cotton-wood	Thorny buffalo-berry and willow	Cotton-wood	Willow and Grass	Sandbar and cottonwood seedlings	Water

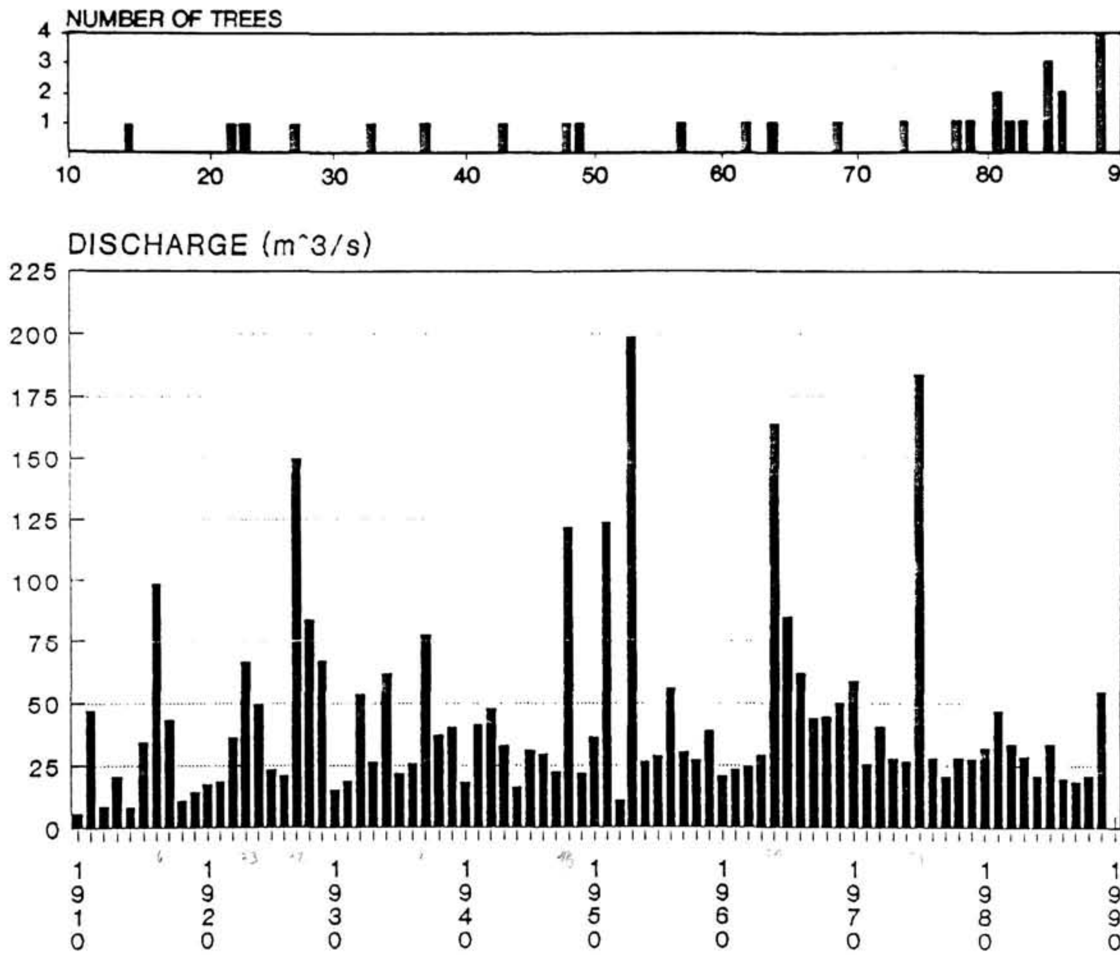
Density of Cottonwoods (stems/m^2)

0.05		0.15		1.93

Age (yr)

82		60		1–4

Figure 7.5. Frequency distribution of cottonwood ages compared with June 1 to July 10 macimum daily discharges (1910-1986), Milk River, Alberta at eastern crossing.



Knowing that seed beds are formed and seedlings survive following summer flows of around 60 m^3sec^{-1}, we can determine that these daily maximums occur every 5 years from flood frequency curves. Based on these values, we find that flows with return periods of 0 2 years (low level floods) failed to promote cottonwoods establishment (Table 7.1). However, 15 trees established in years with return periods of 2-5 years, in years with floods of 60 to 100 m^3sec^{-1}, and 8 trees in years with flows greater than 100 m^3sec^{-1}. The significant feature of this is that 7 and 8 trees, or 50% of the trees aged in this study, occurred at flood levels above 60 m^3sec^{-1}.

During an earlier study of the Milk river, Bradley (1986) found that 92% of the living trees had established following flood flows greater than 60 m^3sec^{-1}. This indicates a trend towards the importance of these major flood events in cottonwood establishment.

Table 7.1. Relationship between June and early July maximum daily discharges, Milk River at the Eastern Crossing (1910-1989) and cottonwood ages.

Recurrence Interval (Discharge Class)[1]	Observed Cottonwood Frequency[2]	Discharge Frequency		Expected Cottonwood Frequency[4]
		# of Years	(%)[3]	
0-2 yr (0-30 m^3sec^{-1})	0	4	(5.2)	1.6
2-5 yr (30-60 m^3sec^{-1})	15	32	(42.2)	12.7
5-10 yr (60-90 m^3sec^{-1})	7	19	(25.0)	7.5
>10 yr (>100 m^3sec^{-1})	8	21	(27.6)	8.2

Notes:

1. Recurrence intervals (discharge) class of maximum June and early July daily discharge.
2. Observed frequency distribution of the number of cottonwoods attributed per discharge class (maximum in preceding 4 year period).
3. Frequency distribution (%) of maximum discharge for all 4 year periods.
4. Expected frequency distribution of the number of cottonwoods (based on discharge distribution).

The relationship of cottonwood establishment and sedimentation is clearly demonstrated along the Milk River. From 0 10 years, there is a high rate of sedimentation and much seedling establishment. Sediment accumulates at a rate of about 14 cm per year. After 10 years there is a long period until 80 years where not much sedimentation occurs, perhaps 2 cm a year. Beyond 80 years the flood plain is essentially beyond the flooding regime of the river.

In summary, cottonwoods are quite well adapted to the meandering river regimes and are dependant upon flood events and sedimentation in order to have seed beds for seedling establishment.

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8. Cottonwood Mortality Assessment, Police Point Park on the South Saskatchewan River

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The City of Medicine Hat is concerned about large numbers of cottonwoods that are dead and dying in Police Point Park on the South Saskatchewan River. The purpose of the study is to assess the most likely cause of mortality and recommend measures to replace the dead trees and to maintain existing trees.

Police Point Park probably has the largest single stand of cottonwoods in south eastern Alberta. It is quite a unique area. The park is currently managed as a natural site in that there are not groomed lawns or irrigated flowerbeds, etc. The park is situated on a meander loop that is now quite high above the river. As result, natural succession is occurring and the trees are slowly dying off with shrubs and grasses replacing them.

The park has a few areas of dead cottonwood trees with extensive tracts of chokecherry bushes and grassy areas (Figure 8.1). There are many normal, healthy, living trees as well. In fact, there are some rather large, very old trees in the Park. I think one of them is in the book of Trees of Renown in Alberta, but it is as big as the one mentioned by Dr. Cordes (1991). In the center of the park, about 5 m above river level, there are some very old trees with thick stems and the top branches broken off. Some of these trees have fallen down. On a nearby cutbank I was able to find trees rooted on the surface and follow the root systems down a distance of 3 m to the bed of the river. The riverbed is gravel covered with silt and sand. We were able to find a lot of roots going down to the water table in the gravel layer and winding their way through it.

Looking at Police Point Park from the air, the light colored dead trunks of the trees can be seen easily. Two large patches are obvious near the river bank. An old gravel mining operation can also be found on the meander lobe, but this has not been in operation since the park was established. Quite healthy trees are still growing along the outer bend of the park area.

Coincident with the dead areas are man-made structures. Two of three ground water wells are surrounded by areas of dead trees. The wells have a very large capacity, something like 1 million gallons a day. There is evidence of climatic drought stress in the trees. Prematurely dying leaves and branches that no longer hold leaves, indicate the tree has shut down these upper parts to maintain an adequate water balance for the rest of the plant. These same symptoms of drought stress also occur in cottonwood stands in other parks along the river.

Right beside the Interpretive Centre in Police Point Park are several cottonwood saplings. They are quite tall and have become established in an area that was relatively bare ground. There was little or no competition from the native grasses or shrubs. The area was perhaps cleared during

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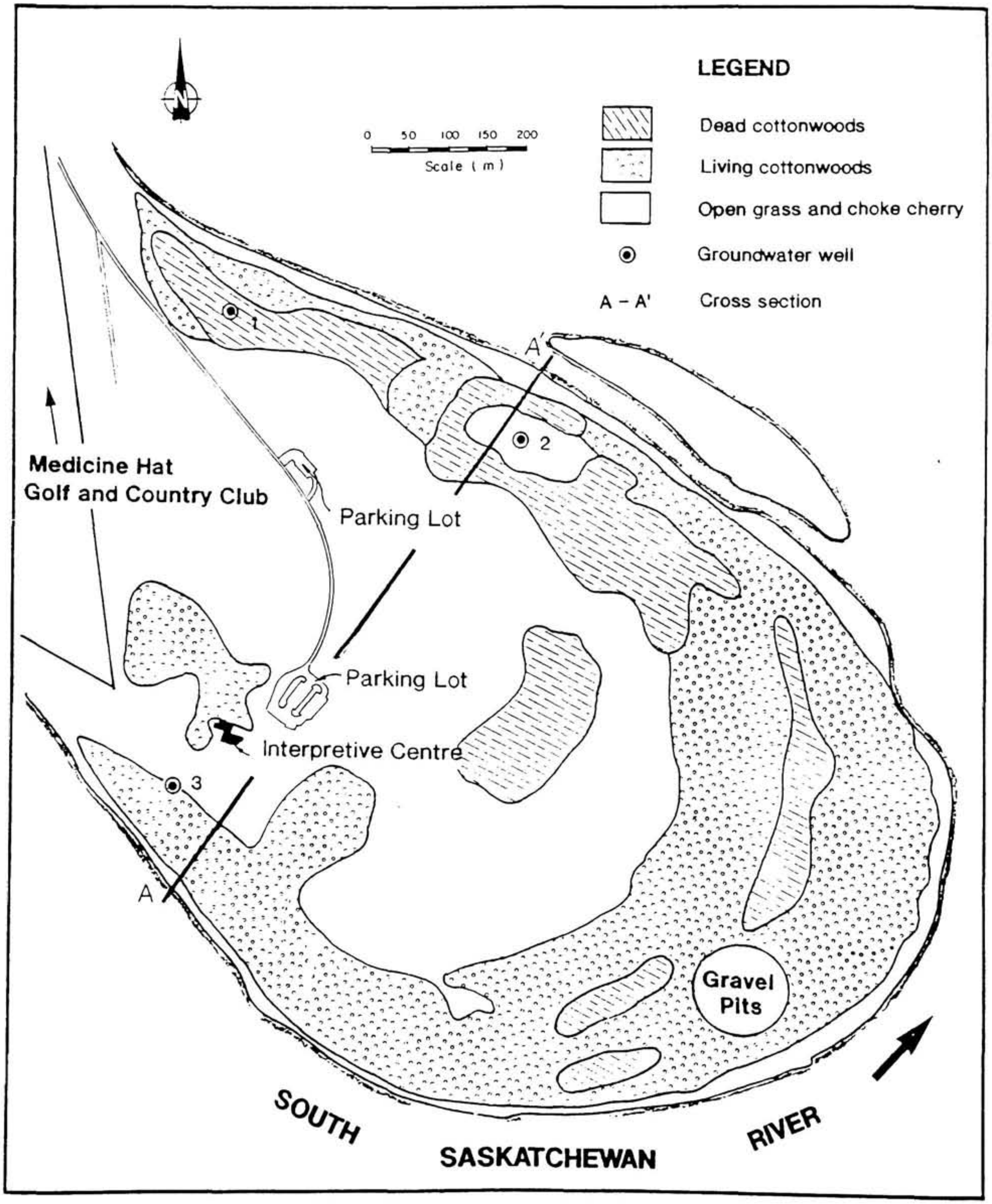
Figure 8.1. Extent of dead and living cottonwoods on Police Point Park, Medicine Hat, Alberta.



construction and may have been seeded lightly with wheatgrass which did not take very well.

Figure 8.2 shows a cross section from the middle of the park. The mean water level from 1913 to 1979 is marked. Our study found that the mean monthly water level in the most recent period was 0.5 m lower. This lower level was considered to be a drought situation. When we analysed the influence of the Bassano Dam on the mean water level during the summer we found that it may have caused the ground water level to drop by 20 cm. However, since this decline occurred many years ago, we felt it was unlikely to have had an influence on the survival of mature trees.

Not having found really large differences elsewhere, we looked at the wells and tried to estimate the effect of removing a million gallons a day on the groundwater table. That rate of removal is going to cause a cone of depression in the water table in the immediate vicinity of the well even though most of the water flows in from the river. The problem arises where the gravel layer begins. That is about where the tree roots would have normally extended because that is just into the water table. The operation of the well will cause a sudden drop in the water table. Even though roots can grow 20 cm a year, it is inadequate to meet the artificial draw down that occurred here. We estimate that the immediate draw-down of the water table would be approximately 1 meter which would affect an area about 2 to 3 hectares around each well site. This draw-down was too rapid for the tree roots to respond, hence the cottonwoods died.

The evidence suggests that in the immediate vicinity of the well, the operation of the wells did kill the trees. However, in the other areas of the park climatic drought has also contributed to the decline of the cottonwoods.

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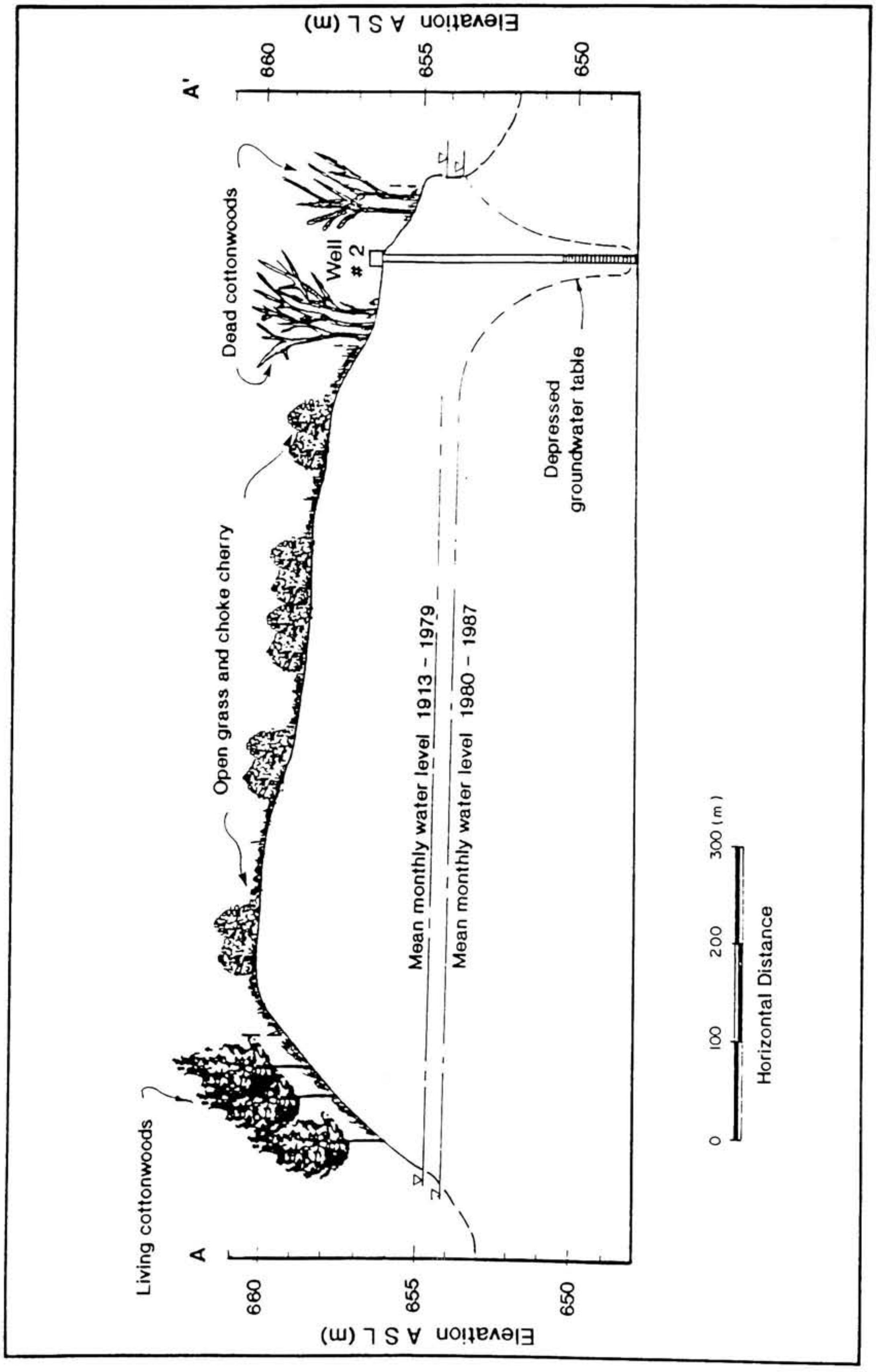
Figure 8.2. Elevation profile, mean monthly water levels and effect of groundwater well during the growing season (April-August). Adapted from Alberta Environment, 1986.



9. Influence of Rate of Water Table Decline on Establishment and Survival of Hybrid Poplar Seedlings

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Many studies have found a marked decline in poplar forests downstream from dams in the western prairies. One hypothesis made in our lab was that this decline is caused by abrupt declines in water table levels. The rhizopod, `rhizo´ meaning root, `pod´ a cylindrical chamber, is a simple and effective model system for determining the effects of various rates of water table decline on poplar seedlings (Figure 9.1). In effect, the wells at Police Point, Medicine Hat, already discussed (Reid, 1991) are a large-scale form of the rhizopod.

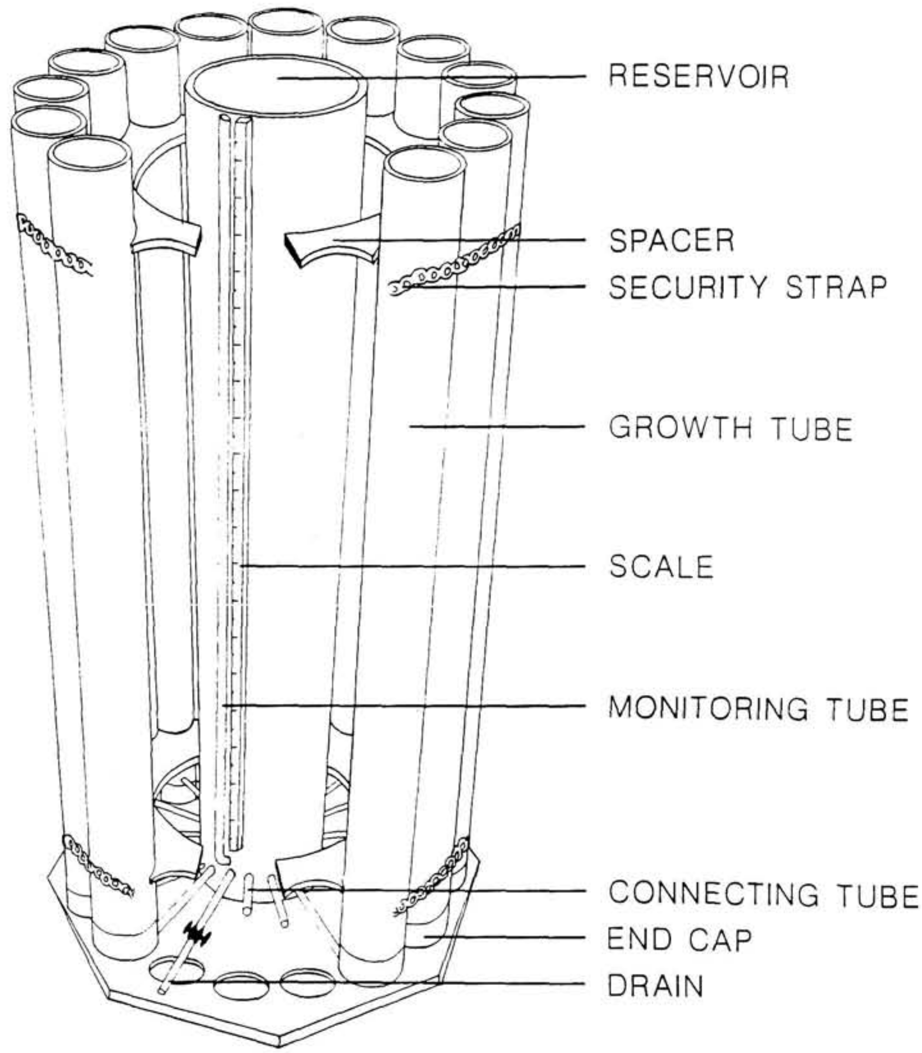
Our model device consists of 15 tubes, 1.2 meter tall, that contain a growth substrate. In our experiment, the substrate was a mixture of 1 part sand to 2 parts gravel (by volume). These tubes are connected at the base to a large central water reservoir. By regulating the water level in the central reservoir, we are able to expose seedlings in each growth tube to the same varying water table level. Figure 9-1 shows the vertical nature of the growth tubes of a rhizopod. A meter stick and a clear length of plastic tubing is affixed to the side of the reservoir, as a water table gauge. At the bottom of the central reservoir is a drain tap that is used for drainage as required.

Seeds were collected on June 24, 1989, from a natural *Populus deltoides* x *P. balsamifera* hybrid along the St. Mary River at Kimball Alberta, near the Montana border. The trees in the area produced copious seed. About 100,000 seeds were collected from a few branches of one tree in about one-half hour. The seeds were checked for viability by imbibing them with water in petri dishes. The viability of fresh seeds was found to be 92%. The seeds were maintained with their cotton enclosures in the dark with a silica gel desiccant at -20° C. On January 15, 1990, 30 seeds were removed from the cottony enclosures and scattered on the substrate surface of each growth tube in 5 rhizopods (30 seeds x 15 tubes x 5 rhizopods = 2,250 seeds). The seeds were misted with water to promote imbibition. Germination success for the experiment was about 56%. Germination success in this experiment and other studies suggests that initial seedling establishment should not be limited by seed viability. If an adequate seed supply and establishment sites exist, good poplar forest regeneration should be seen.

The water table was established initially 5 cm below the surface of the substrate. The surface was wet, but not flooded. After 3 days, the water table was adjusted 3 times daily to establish rates of water table decline at 0, 1, 2, 4 or 8 cm per day. On day 14, seedlings were thinned to 10 uniform plants per tube. Plant heights were recorded daily for the first three weeks and semi-weekly thereafter.

Figure 9.2 shows the increase in shoot height after thinning. The plants exposed to the 8 cm per day rate of decline, showed virtually no growth during the course of the experiment. However, the plants under the control treatment and 2 cm per day rate of decline showed relatively constant rates of growth up to about day 32. Beyond this point, the control plants grew much faster.

Figure 9.1. The rhizopod system.



Leaf areas were measured for all seedlings with a Licor LI 3000 area meter. Seedling leaf areas were found to be reduced as the rate of water table decline increased (Figure 9.3). The values above the bars in Figure 9.3 indicate the sample size for each treatment. The few plants that survived the 8 cm per day treatment had leaf areas only about 1/6 of those of the control plants.

Root growth was also reduced in plants grown with faster rates of water table decline. Plants treated with slower rates of water table decline of 1 or 2 cm per day, had roots nearly double the length of those under other treatments (Fig. 9.4). The roots of the control plants were very short and dense. This was expected as the constant water supply eliminated the necessity for the plant to expend energy on root elongation. A gradual water table decline appears to promote root elongation whereas faster rates of water table decline inhibits root elongation. Under conditions of rapid water table decline, root growth fails to keep pace with the water decline resulting in drought stress and a general failure of seedling growth. This growth failure is expressed in reduced leaf and stem growth as well as reduced root growth.

Figure 9.2. Change in the height of poplar seedlings grown under different rates of water table decline.

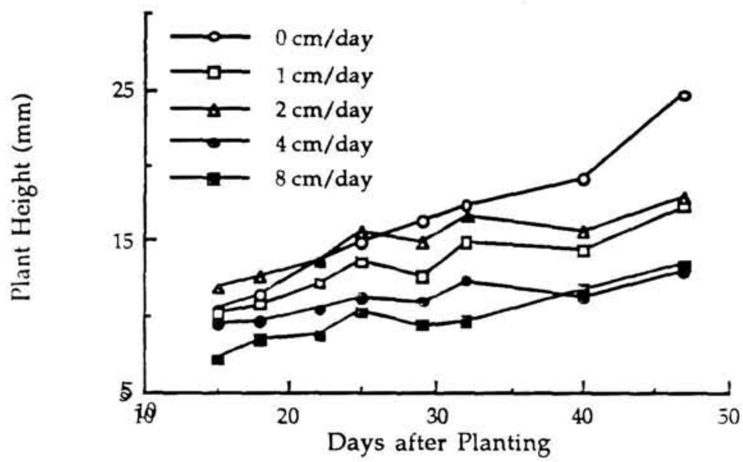
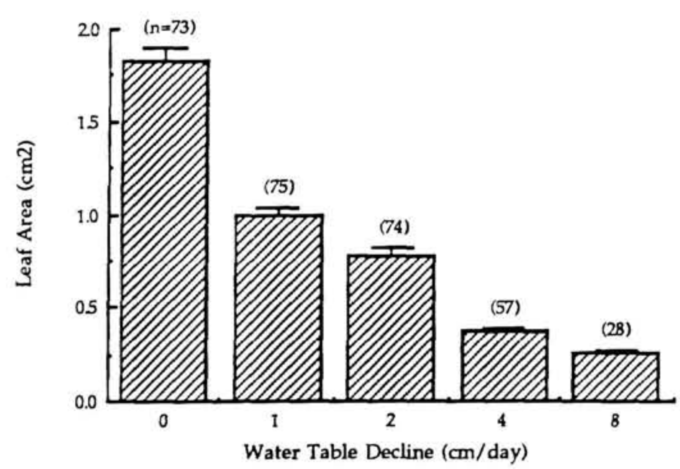


Figure 9.3. Leaf areas of poplar seedlings at time of harvest grown under different rates of water table decline. The numbers in parenthesis are the number of plants measured.



Seedling survival also varied significantly across treatments (Figure 9.5). Plants under the control and 2 cm per day conditions, had consistent rates of survival about 90% following thinning.

Seedlings in the 4 and 8 cm per day rhizopods had already suffered marked mortality by day 14 when they were thinned. When the plants were harvested on day 46, only about 40% of the 4 cm per day plants and about 25% of the plants in the 8 cm per day rhizopod had survived. The principal impact of rapid water table decline may be on seedling mortality, becoming more severe with increasing rates of water table decline.

Figure 9.4. Poplar seedling root lengths after treatment with different rates of water table decline for 47 days. The numbers in parenthesis are the number of plants measured.

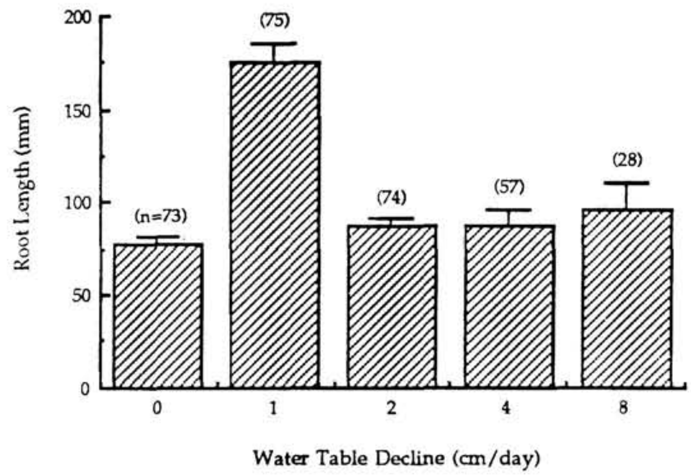
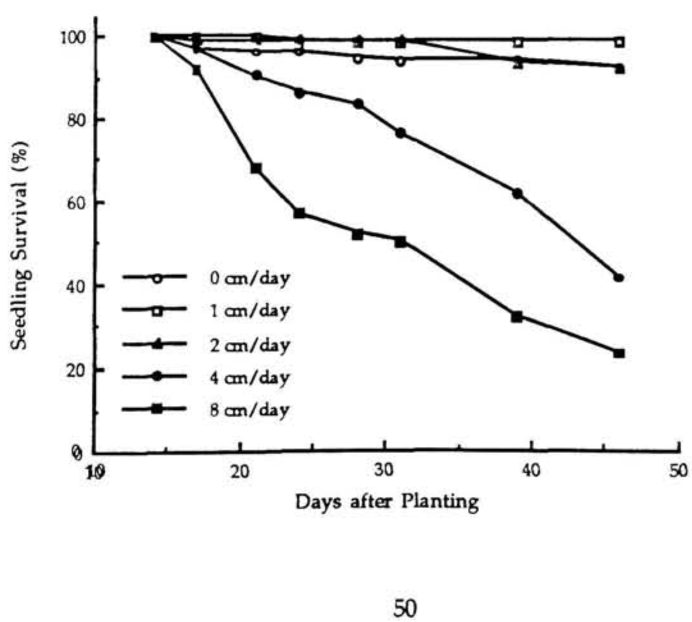
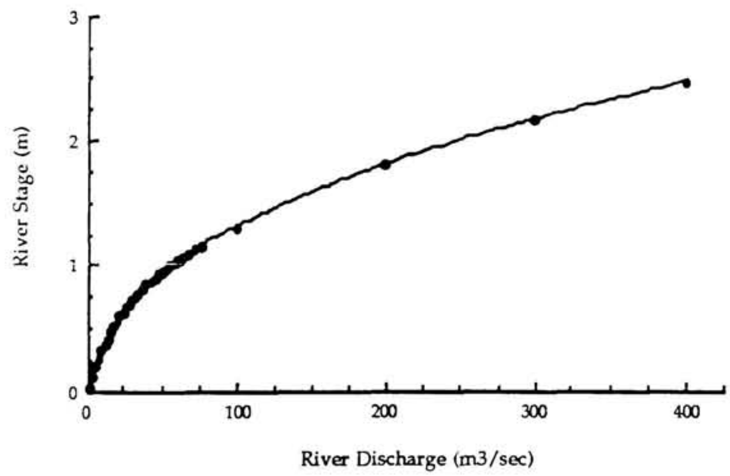


Figure 9.5. Survival of poplar seedlings treated with different rates of water table decline.



Results from any model system must be validated with respect to the natural situation. Figure 9.6 shows the river stage-discharge relationship for the Oldman River near Brocket. This function relates the river bank elevation of the river surface (stage) to river flow (discharge). The data points, compiled over a 15 year period, indicates that peak stage levels rose to only about 2 or 2.5 m. The lower part of the curve show a that the river stage is about 1 to 1.25 m at low flows in typical years. The river stage naturally varies about 1 m annually, the same elevation that was investigated in the rhizopod experiments. The rhizopod model is similar to the natural flow regime of rivers in southern Alberta.

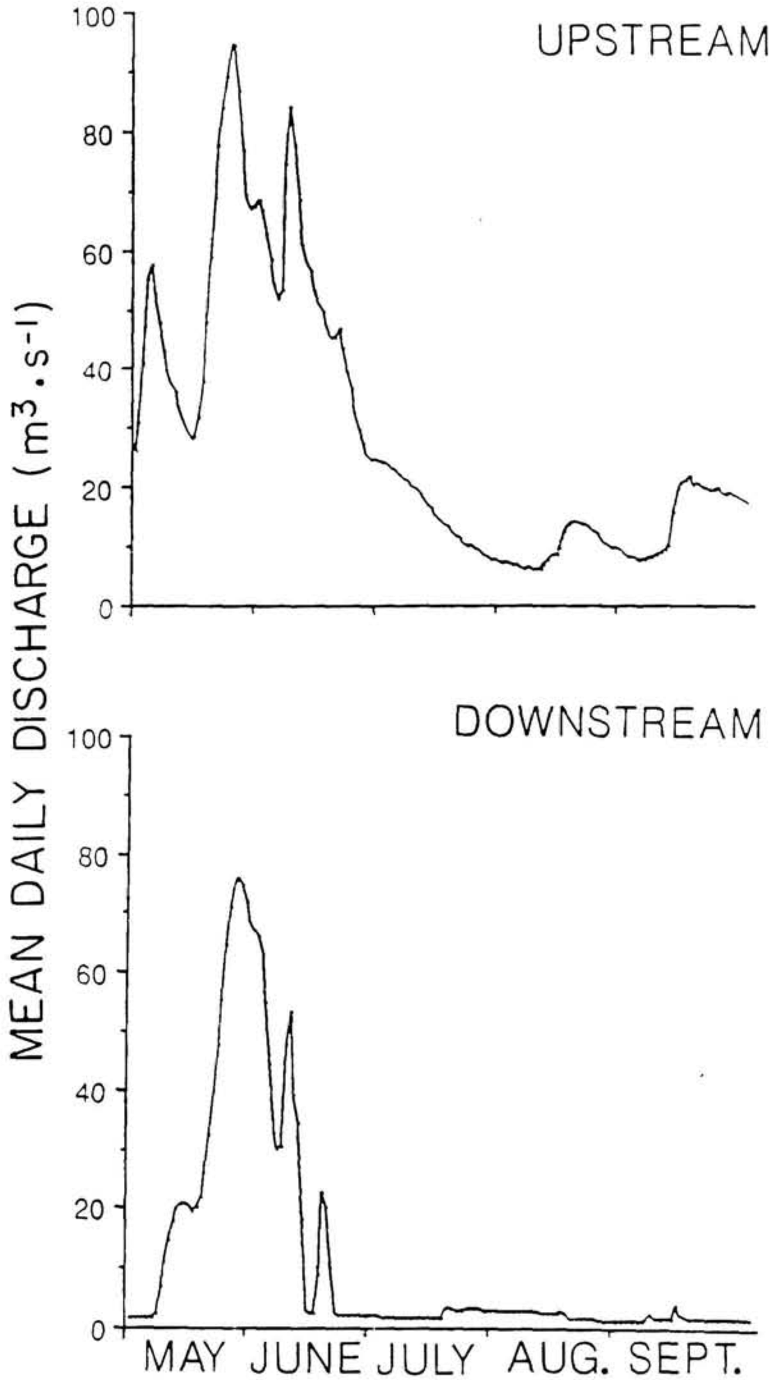
Figure 9.6. The relationship between river stage (elevation) and discharge for the Oldman River near Summerview, Alberta.



Daily hydrographs for the reaches upstream and downstream of the Waterton Dam are shown in Figure 9.7. The upstream pattern is typical of flow regimes in this area. An abrupt shutoff of flows can occur downstream of the dam in mid summer. Typically, the discharge of 80 to 100 m^3 sec^{-1}, which is roughly equivalent to a river stage of 1 m, drops in a matter of days to a flow of less than 10 m^3 sec^{-1} and a river stage of a few centimeters. The water table declines would be equivalent to about 14 cm per day at typical sites, a rate nearly double those studied and found to be lethal in the rhizopods. Upstream of the dam the flow rate is tapered, dropping relatively slowly over a period of several weeks. The operation of dams in southern Alberta can alter the rates of riparian water table decline making them lethal to poplar seedlings. This may be an underlying cause of the lack of seedlings found downstream from some dams.

Further experimentation with rhizopods should reveal the rates of water table decline that are survivable or lethal for poplars and other riparian plants. With this information, operating

Figure 9-7. Differences in flow regimes during the growing season upstream and downstream of the Waterton River Dam in southern Alberta.



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10. Establishment and Survival of Poplar Seedlings Along the Oldman River, Southern Alberta

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A number of reports have described the decline of riparian poplar forests downstream from dams in the western prairies including southern Alberta (Rood and Mahoney, 1990; Rood and Heinze-Milne, 1989). The Oldman River Dam is similar to some of those previously studied as is the downstream riparian poplar forest (Rood et al. 1986). It is therefore likely that if the Oldman River Dam is operated similar to these other dams, the downstream forest will also suffer.

We have been working with Alberta Environment and Alberta Public Works, Supply and Services in an attempt to prevent a riparian forest decline downstream from the Oldman River Dam. The project has involved a range of studies attempting to identify the causes of the forest decline and potential mitigation processes. The present study investigated the early life cycle of poplars in the river valleys of southern Alberta to determine the present extent and ecology of the riparian poplar forests along the Oldman River, downstream from the new dam.

This study focussed on the maintenance of poplar forests through the recruitment and survival of poplar seedlings. The role of the river in this process was also investigated. Seedling replenishment, was determined by monitoring poplar seeds and seedlings through the 1989 growing season. During this period we determined (i) the extent of seed dispersal on suitable substrates, (ii) the germination rate of fresh seed, (iii) the success of initial seedling establishment, and (iv) the degree of seedling survival. By studying these characteristics, we hoped to identify vulnerabilities in the early phases of the riparian poplar life cycle. This understanding was expected to provide insight into the phase of the life cycle that limits poplar replenishment.

Sites were monitored along the Oldman River in southern Alberta. The sites were at (i) the Summerview bridge, upstream from the Lethbridge Northern Irrigation District (LNID) headworks, (ii) Fort Macleod, downstream from the LNID headworks, and (iii) Lethbridge. The Lethbridge site was selected to give an indication of the general health of the riparian forests in the Oldman River Basin. Since all the major tributaries upstream of Lethbridge have flow control structures and there are no significant contributions to the flow below Lethbridge until the confluence with the Bow River, the flow of the Oldman River at Lethbridge will reflect the water management plan of the entire Oldman River Basin. The vitality of the riparian forest in this area will be the result of the ability of popla's to adapt to the overall water management program. The specific study sites were selected based on requirements for poplar germination success as described in the literature. Sample plots were established on barren, sandy and gravelly substrates near the river edge

The Lethbridge site was flooded in the late spring of 1989 during seed release so the site was not

In: Rood, S.B., and J.M. Mahoney (eds.), 1991. The Biology and Management of Southern Alberta's Cottonwoods. University of Lethbridge, Alberta.

exposed until after seed release was complete. Consequently, no seedlings were monitored at that site in 1989. It appears that the site will flooded again in 1990. This suggests that the timing of seed release relative to flooding is critical for successful seedling establishment. If sites are inundated during seed release, poplar seedlings will not succeed in regenerating at that site in that year.

At both the Summerview and Fort MacLeod sites, two transects were established perpendicular to the river bank. Each transect was surveyed to determine the terrain profile of the site, the existing vegetation cover, and the surface substrate materials. Quadrats (1m x 1m) were staked out in the first area free of competing vegetation below the high water line to monitor seed germination and growth. In 1989, peak flow on the Oldman River occurred between June 6 and June 12. The quadrat sites were selected at that time so that each quadrat was near the high water level of that year.

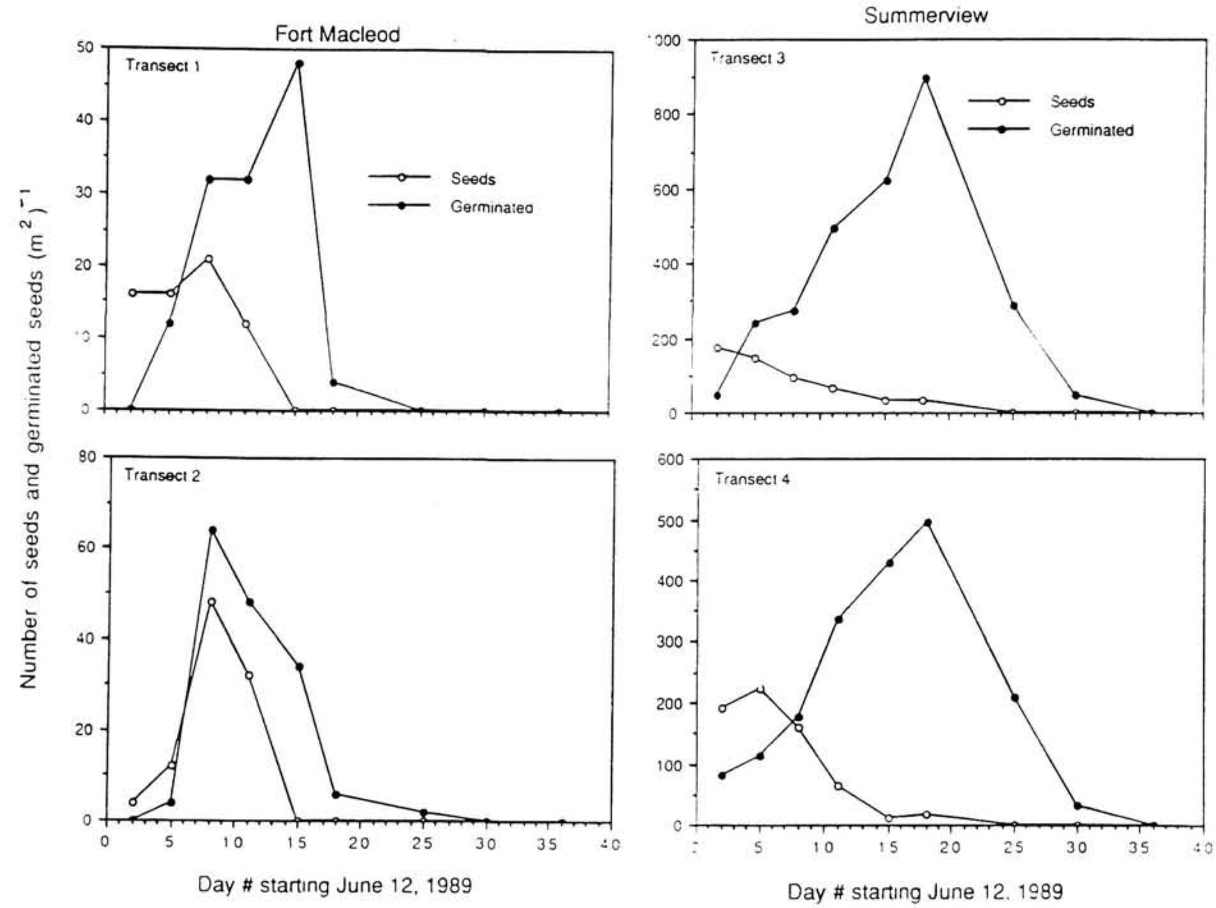
The Fort MacLeod site had large barren areas near the river that appeared suitable for poplar seed germination. In these areas, vegetation was sparse and the substrate consisted of gravel and cobble covered with sand. Many of the poplars near the river showed signs of ice scouring, but a healthy forest extended onto the floodplain a short distance from the river edge. There were few willows at the site. The Summerview site was similar although vegetation cover was slightly more dense. Numerous barren areas that appeared suitable for seed germination were present.

Poplar seed production is quite high with estimates in the order of thirty million seeds produced annually by a mature riparian cottonwood (Bessey, 1904). Substantial seed production was observed in 1989 at all sites providing no reason to change this estimate. During each site visit, seeds were collected and brought into the laboratory to test viability. Germination rates were found to be in excess of 90% for all samples throughout the period of seed release. It therefore appears that neither (i) the availability of seeds nor (ii) seed germinability are limiting the maintenance of the poplar forests at these sites.

The germinability tests showed that poplar seeds germinate within about 24 hours of imbibition. Although this rate could be altered by environmental conditions in the field, it is likely that the seeds counted in the quadrats at each site visit mainly represented a sample of the of seeds released in the preceding 24 hours. Figure 10.1 shows the density of seeds and seedlings that were observed at each quadrat. Seed densities at Fort MacLeod peaked between 20 and 50 per m^2 about June 20, 1989. Seed densities were substantially higher at Summerview peaking at about 200 per m^2 around June 17. Seed release was complete at both sites by about the end of June in 1989. Seedlings were observed shortly after the onset of seed release and seedling densities increased to a peak that coincided with the end of seed production. The seedling densities are much higher than seed densities because the seedling values are cumulative while seed values are nearly instantaneous. As seeds germinate, seedling density increases until seedling mortality exceeds seed germination.

At Fort Macleod, seedling densities peaked between 50 and 60 per m^2. Seedling densities were higher at Summerview, reaching between 500 and 1000 per m^2. This is consistent with the higher seed densities found at the site. These observations support other reports that seed production is substantial, seed viability is high, and subsequent seedling establishment is enormous. Figure 10-1 also shows however, that seedling survival declined rapidly in early July, so that almost no seedlings survived through the summer.

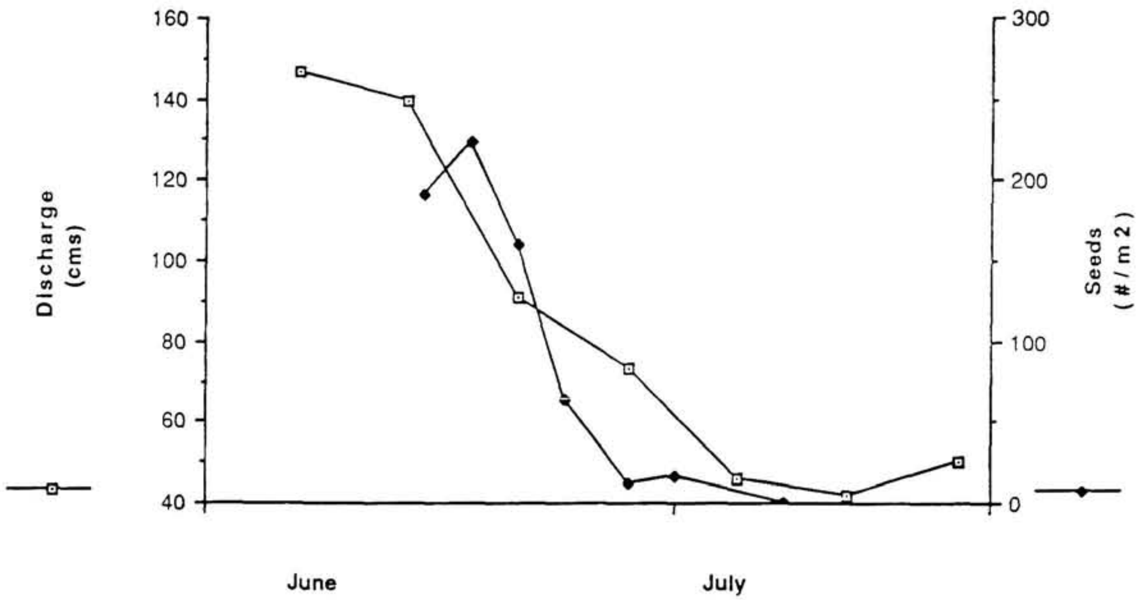
Figure 10.1. The density of seeds and seedlings recorded on transects along the Oldman River at Fort MacLeod and Summerview Alberta in 1989.



Poplar establishment and growth is largely dependent on the pattern of river flow. Figure 10.2 compares seed dispersal rates and river flows in 1989 for the Oldman River at the Summerview Bridge. A fairly rapid decline in flow volumes from 147 to 91 m^3 sec^{-1} occurred during seed dispersal. That decline represented a 28 cm drop in river stage over just three days for an average of about 9 cm decline per day. The further drop from 91 to 73 m^3 sec^{-1} over the next few weeks result in a further decline in river stage of 44 cm.

Seedlings that survived to the end of the summer were excavated and the root lengths measured. An analysis of this data showed that the rate of root growth for these poplars was about 3.2 mm per day. This rate is inadequate to follow the total seasonal drop in river stage of 44 cm. The inability of seedling roots to grow rapidly enough to maintain contact with the declining water supply suggests that drought stress probably caused or at least contributed to the observed seedling mortality over the first growing season. It would appear that seedling survival may be improved if seeds were released well after the peak flows had occurred when the rates of river stage decline had slowed. Unfortunately, although seedling survival through the first growing season may be improved by germinating at lower bank elevations, those seedlings may be vulnerable to subsequent flooding or ice scouring at these elevations. Poplar seedling survival may be rare in southern Alberta because of the unique hydrological pattern that is necessary to encourage poplar establishment in the first year and permit continued development in succeeding years.

Figure 10.2. Poplar seed release and related river flows on the Oldman River at Summerview, Alberta in 1989.



Transect data from both the Summerview and Fort MacLeod sites showed the same trends. Numerous seeds were dispersed and landed on favorable germination beds. Germination was rapid resulting in high densities of seedlings. Seedling survival declined rapidly following the initial germination success. The considerable distance between the sites at Fort Macleod and Summerview indicates that the cause of the common seedling decline was probably not due to differences in microsite, but rather a wide ranging factor. Changes in river flow and stage fit this description. This lends further support to the proposal that drought-induced seedling mortality following river decline is a limiting factor for poplar forest replenishment.

The quadrats for this study were established immediately after peak flows at elevations just below the high water level. Seedling survival might be expected to improve at sites closer to the river. Poplar seedlings were found at Fort Macleod about 10 m from the river bank during site visits on September 22, 1989. These seedlings were closer to the river during minimum summer flows and were probably exposed to more slowly declining water levels and a shallower final water level. These results are in keeping with the general theory that poplar seedlings can survive a slowly declining water supply. The poplar seedlings at Fort Macleod that survived through 1989 were at a low elevation and were scoured away by early season flows in 1990.

No seedlings survived the summer of 1989 at any elevation at the Summerview site. Seedling mortality at this site may have been due to competition from other plants and shading from a dense shrub and grass cover near the river.

These observations indicate that there is a specific elevation along the river bank where germinating seedlings will survive both initial declining of the water suppiy and subsequent flood or ice scouring events.

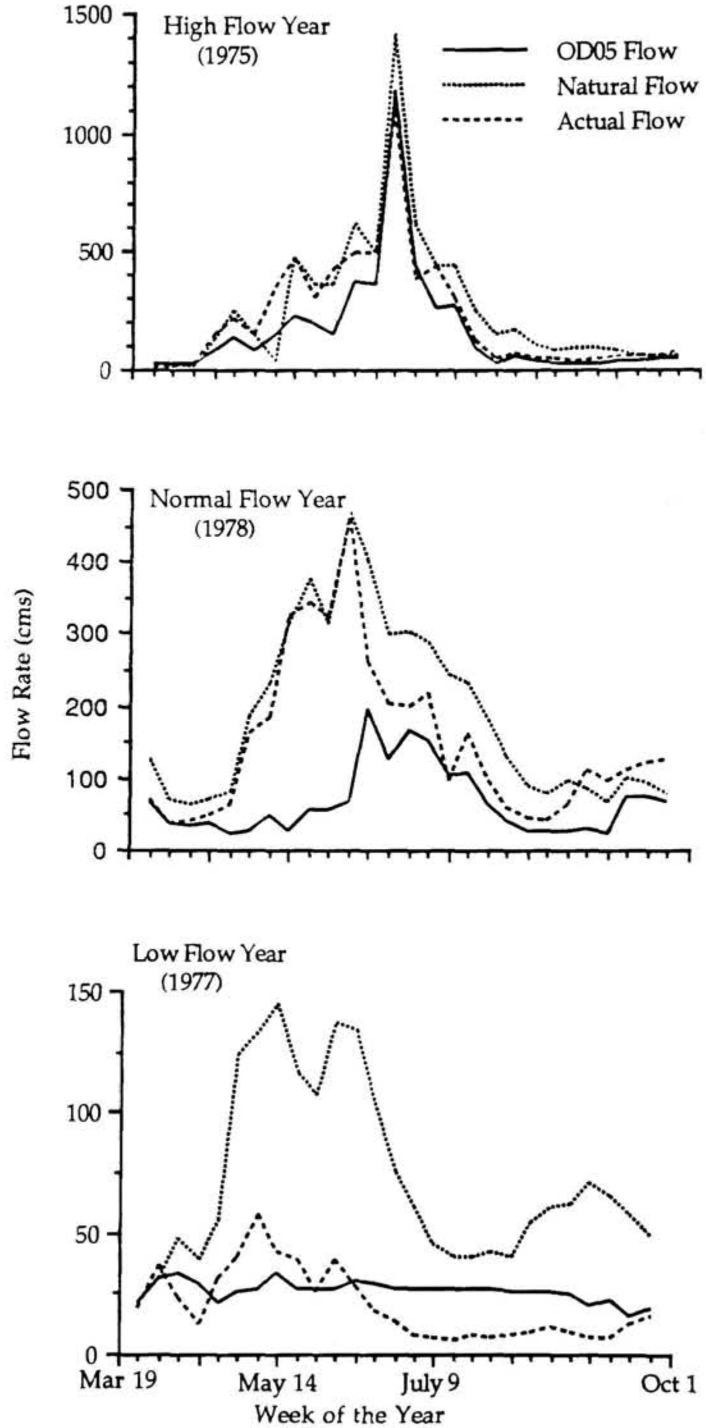
Although the present riparian forest in Lethbridge appears to be quite healthy, surveys along the Oldman River in the city indicate many mature trees and a lack of seedlings in this area. Studies in Lethbridge found good seed sources and many sites that appear suitable for germination. The observed lack of seedlings and saplings in this area may also be related to river flows.

In most years, peak spring flows through Lethbridge are essentially the same as those that would be expected if no dams or diversions existed upstream (Fig. 10.3, Natural Flow). Poplar seedlings therefore tend to establish at bank elevations similar to those at Fort MacLeod and Summerview. Subsequently, the operation of the St. Mary and Waterton dams can be substantially diminish the summer flow of the Oldman River through Lethbridge, especially in years of lower flow (Fig. 10.3, Actual Flow). This probably places additional drought stress on the poplar seedlings during the hot summer months and may already be limiting successful poplar seedling establishment. Increased water stress also likely increases mortality of old trees. In dry years (Fig. 10.3 Low Flow), the flow rates are very low by the beginning of July. In this example, less than 10 m^3 sec^{-1} or about 5 percent of the natural flow actually passed Lethbridge. The older trees are known to be more vulnerable to environmental stress than more vigorous middle-aged trees. Consequently, it is probable that middle aged poplars are over-represented along the Oldman River near Lethbridge.

These results suggest that the riparian poplar forest from Fort Macleod through Lethbridge is presently under stress due to water management programs in the basin. The addition of the Oldman River Dam has the potential to increase the drought stress on downstream riparian poplars or to compensate for present damming and diversion practices. Hydrological models of Oldman River Dam operation plans (Fig 10.3, OD05 Flow) indicate that mid summer flows through Lethbridge will be increased in dry years making the flow regime more favorable for poplar survival. In years of high flow, the Oldman Dam will have little effect, whereas in normal flow years, the dam may affect seedling establishment by reducing peak spring flows and impeding site preparation.

This study indicates that riparian poplar forest replenishment is probably not normally limited by seed availability, seed germinability, or initial seedling establishment. If moist and barren sites are available, poplar seedlings are likely to establish in high densities. The limiting factor appears to be subsequent seedling survival. Drought stress is likely the major factor responsible for seedling mortality in the first growing season. Poplar seedlings that establish at bank elevations low enough to access the declining water level are often removed by ice scouring or flooding in subsequent years. For these reasons, the enormous reproductive potential of riparian poplars is seldom realized. Only a few seedlings survive to contribute to the mature forest.

Figure 10.3. Hydrographs for the Oldman River near Lethbridge during years of high, normal or low flow. Natural Flows are the estimated flows that would have passed Lethbridge had no water control structures been in place upstream. Actual Flows are the recorded flows through Lethbridge for the years indicated. OD05 Flows are the modelled flows to pass Lethbridge had the Oldman River Dam been operating during the years represented.



Successful seedling establishment growth requires a specific pattern of river flow. The variability of river flow patterns in the foothills of Alberta make poplar seedling establishment an uncommon and irregular event in this area. It may be possible therefore to enhance poplar seedling replenishment through water management programs that include river damming and/or diversion.

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11. Effects of Substrate Texture and Rate of Water Table Decline on Transpiration and Survival of Poplar Species

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A natural disectional tri-specific hybrid swarm of *Populus balsamifera* (balsam poplar), *P. angustifolia* (narrowleaf cottonwood) from section Tacamahaca and *P. deltoides* (prairie cottonwood) from section Ageiros occurs in southern Alberta. These species are the major trees of the riparian forests of southern Alberta. Recent research suggests that flow regulation structures on rivers in southern Alberta have caused a decrease in the downstream populations of these riparian poplars.

Riparian poplars grow on different substrates. At one extreme poplars can grow on coarse rocky, gravel characteristic of the fast flowing streams of the Rocky Mountain foothills. At the other extreme, poplars may also grow on silty or sandy substrates. The finer substrates are characteristic of areas where water flow is slow and the rates of sediment deposition are higher.

This discussion will focus on an experiment designed to determine whether similar rates of water table decline have different effects on poplar growth and survival depending on the texture of the growth substrate. This study used the rhizopods that were described previously (Stobbs et al, 1991) and by Mahoney and Rood (1991). For this study cuttings from a single, naturally occurring *P. balsamifera* x *P. deltoides* hybrid were used. Cuttings 5 cm long were rooted in root trainers and then transplanted to rhizopods and allowed to take root before being exposed to rates of water level decline at 0, 1, 2, 5 or 10 cm/day.

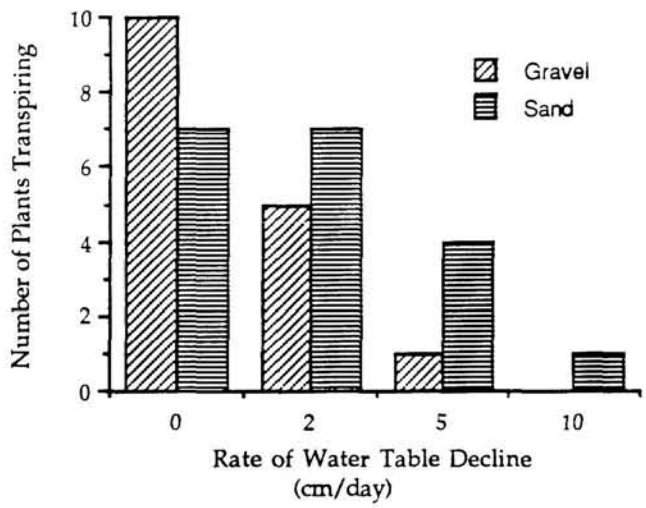
The rhizopod growth tubes were filled with gravel (typical diameter 1 cm, range 0.6 to 1.5 cm), sand (typical diameter 0.6 mm, range 0.03 to 1 mm) or a mixed (1:1, sand:gravel, v:v) substrate. Growth tubes were alternated in each rhizopod so that each rhizopod had five replicates of the three substrates. Plant height and transpiration were recorded regularly during the experiment. Transpiration was determined using a LiCor steady state diffusion porometer from the lower leaf surfaces. Root length, plant survival and the ratio of shoot dry weight to root dry weight were recorded at harvest.

Transpiration is the evaporation of water from a plant occurring primarily through the leaves. Water is absorbed passively through the root system, transported through the non-living xylem of the plant, and then removed as water vapor from the leaves through stomata. When plants suffer drought stress (water intake is less than water loss), the guard cells of the stomata become flaccid and the stomata close. This limits water loss and helps plants conserve water. Under favorable water conditions, the stomata guard cells become turgid causing the stomata aperture to open allowing water to once again evolve from the leaves as water vapor.

In: Rood, S.B., and J.M. Mahoney (eds.), 1991. The Biology and Management of Southern Alberta's Cottonwoods. University of Lethbridge, Alberta.

Transpiration rates were measured once a week between 12:00 and 15:00. Figure 11.1 shows the number of plants transpiring for each rate of water table decline. For this study, the actual rates of transpiration are probably less important than whether the plant is transpiring or not. For the 0 cm per day rate of water level decline, 10 plants growing in gravel were transpiring whereas only 7 of the 10 plants growing in sand were transpiring. As the rate of water level decline increased, more poplars growing in sand were found to be transpiring than those growing in gravel. For plants grown on the mixed substrate, the number of plants transpiring was intermediate in all cases. This difference can be attributed to the particle size of the substrate. The smaller particle size permits sand to hold more water than gravel. Secondly, water can actually rise through sand, by capillary action to meet the roots.

Figure 11.1. Number of plants grown on different substrates and treated to different rates of water table decline that were transpiring measurably. Maximum number measured was 10.



When the water table is constantly high, the coarser gravel substrate allows some drainage so that air can get to the roots of the plants. Plants grown under these conditions in the sand substrate would have the roots flooded and under partially anaerobic conditions. The plants growing in sand are therefore expected to grow more slowly.

The relationship between leaf surface area and the rate of water table decline is shown in Figure 11.2. The trend is the same as that seen for rates of transpiration. The faster rates of water table decline cause a reduction in leaf area. Leaf area production is greatest in poplars grown on gravel substrate with no decline in water table. As the water table begins to decline, greater leaf area production is seen in plants grown on finer substrates.

Shoot-root dry weight ratios were also calculated after harvest. When plotted against rates of water table decline, shoot to root ratios declined with increasing rates of water tables decline (Figure 11.3). This was expected since plants need to allocate more resources to root elongation to try and maintain contact with the receding moisture.

Figure 11.2. Relationship of leaf surface area of cuttings at time of harvest to gowth substrate and the rate of water table decline.

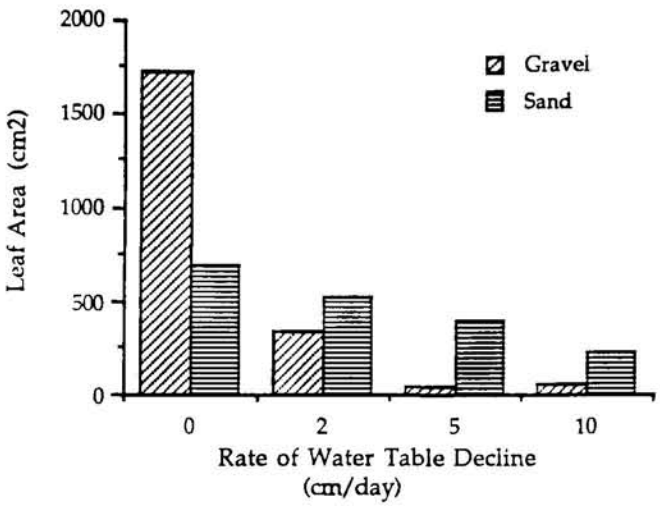


Figure 11.3. Relationship of the ratio of shoot and root component weights of cuttings to growth substrate and the rate of water table decline.

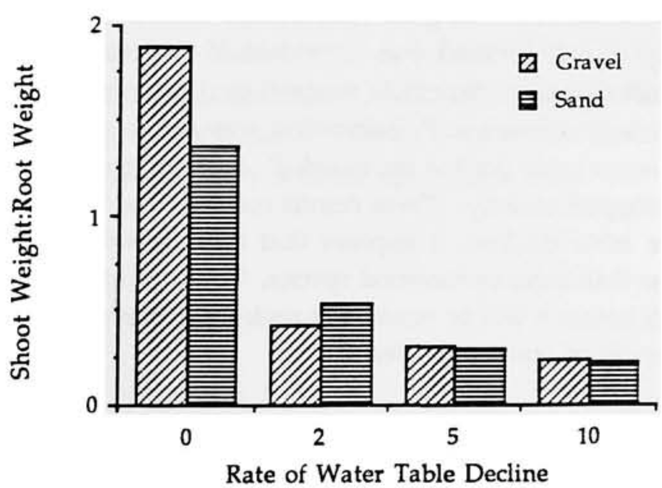
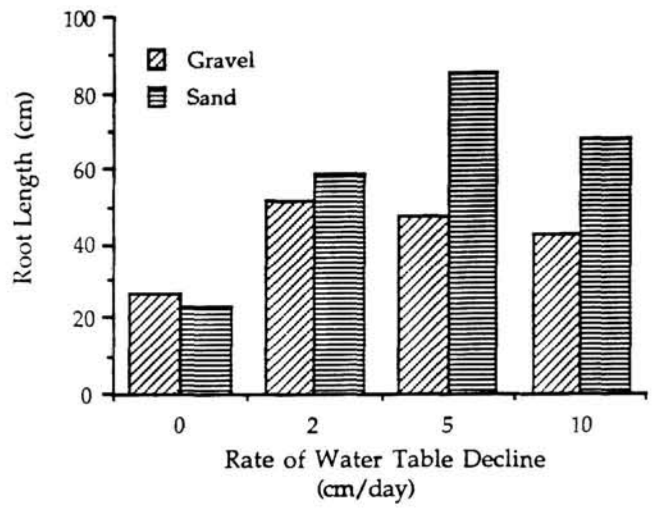


Figure 11.4 shows a pattern opposite to the trends of previous graphs. Root length increased as the rate of water table decline increased until the rate of water table decline became greater than 5 cm per day. At treatments of 10 cm per day the roots are shorter because even maximal root growth was inadequate to maintain contact with the declining water table.

Figure 11.4. Root length of poplars at time of harvest for cuttings grown on different substrates with different rates of water table decline.

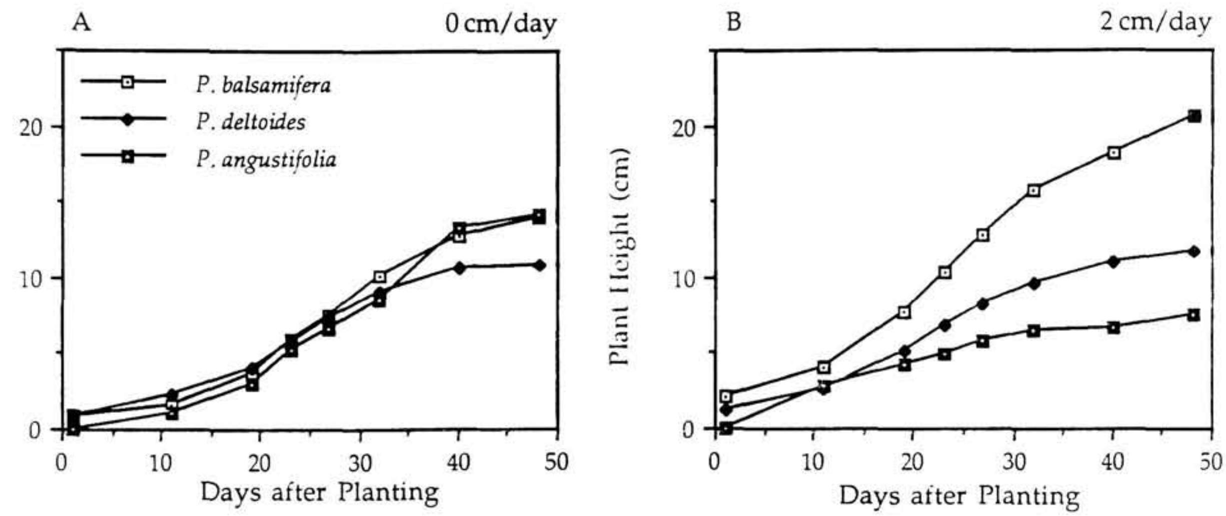


This study indicates that substrate texture affects poplar growth for a particular rate of water table decline. Poplars growing on coarse substrates grow better when the water table is high and constant, conditions of partial flooding stress. Poplars growing in sand grow poorly under this treatment, but show better growth with increased rates of water table decline.

The difference in the growth of cuttings from three poplar species treated with different rates of declining water table is shown in Figure 11.5. All genotypes treated with a constant water table had similar growth rates although the *P. deltoides* was the slowest. Differences in the rate of plant growth became apparent under different water table treatments. Under intermediate rates of water table decline, growth of *P. angustifolia* and *P. balsamifera* was reduced while *P. deltoides* was less affected. As the rate of water table decline increased, *P. deltoides* growth was inhibited and the growth of *P. angustifolia* stopped entirely. These results confirm that there are genotypic differences in tolerance to water table decline. It appears that *P. balsamifera* might be more tolerant to rapid water table decline than other cottonwood species. These preliminary results need further work with additional clones before it will be possible to rank the different species according to their ability to tolerate various rates of water table decline.

The present study showed that plant transpiration is a good measure of poplar seedling drought stress and that it may be used as an indication of plant growth. The rate of transpiration is easily measured in the field with a steady state diffusion porometer. Measurements can be made on plants as they are being affected, long before the stress reaches a lethal level. The experiment also showed that both substrate texture and plant genotype influence plant growth for specific rate of water table decline. These characteristics need to be taken into consideration when developing a water management program for a particular situation. An evaluation of the impact of a water management plan will therefore need to consider the genotype of the trees in the area, the type of substrate on which they are growing and the rate of water decline during the growing season.

Figure 11.5. The effect of declining water tables on the seedling growth of three poplar hybrids.



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12. Native Poplar Hybrids of Alberta - Analysis of balsam poplar species using flavonoid markers

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My graduate project began nine years ago with a project to differentiate between the varieties of poplar cultivated in France. The objective was to find a method to distinguish them using morphological characters. However, I soon realized that morphological characters would not be sufficient. Indeed, most species of poplars exhibit leaf plasticity, foliar dimorphism or heterophylly, which introduces high levels of individual variability. Under these conditions the use of morphological characters is difficult and quite unreliable. It was necessary to find another approach, independent of individual variability to complement the use of morphology. I chose to study a family of phenolic compounds, the flavonoids.

Flavonoids were extracted from winter buds and analyzed by high performance liquid chromatography. By this technique it was possible to produce a fingerprint of each variety studied and to determine the identity of the cultivated varieties under investigation.

The project I am working on now in Alberta is very similar to the French project except that instead of studying cultivated varieties natural varieties are involved. The objectives are the same, however, to use new approaches along with morphology to study the very closely related balsam poplars of southwestern Alberta.

Two balsam poplar species are native to North America, *Populus angustifolia* James and *Populus balsamifera* L. which includes two subspecies, *balsamifera* and *trichocarpa*. Typically pioneer species, balsam poplars are trees of riparian habitats in boreal and montane regions. *Populus angustifolia*, named narrowleaf cottonwood, is the smallest of the three taxa, usually 5 to 10 m tall with a slender trunk, and long and narrow leaves with short petioles. *P. angustifolia* is distributed in the Rocky Mountains and plains from southern Alberta to the Mexican border in flood plains and along stream banks.

P. balsamifera is a taller tree, 20 to 30 m high. The leaves are ovate or cordate with longer petioles. Subspecies *balsamifera*, or balsam poplar, is distributed throughout the boreal forest from Newfoundland to Alaska and subsp. *trichocarpa* extends along the Pacific Coast from Alaska to Baja California.

The three taxa meet in southwest Alberta and in this area they have been reported to hybridize. The poplar populations in this area were studied by Brayshaw in 1965 who also designated the hybridization zone and established the ranges of the three taxa.

In: Rood, S.B., and J.M. Mahoney (eds.), 1991. The Biology and Management of Southern Alberta's Cottonwoods. University of Lethbridge, Alberta.

Brayshaw (1965) reported the occurrence of hybrid individuals with morphological characters with all degrees of intermediary between the two species. Because of the complexity of this continuous variation several authors suggested that the individuals should be under a single name *Populus brayshawii.*

In fact, there are three distinct taxonomic problems of balsam poplars in this area. Firstly, there is the problem of the status of *Populus balsamifera*. Prior to Brayshaw (1965), the two subspecies were considered as two distinct species. Brayshaw changed the status because of the apparent lack of effective sterility barriers between the two taxa.

The second problem is the very difficult distinction between the two subspecies of *P. balsamifera.* Most characters used to distinguish them are subjective and foliar dimensions overlap completely.

Floral and fruit characters are the only ones which are reliable. Unfortunately, variable flowering rates and the short life of the male flowers make their collection impractical.

The third problem is the *P. angustifolia* x *P. balsamifera* putative hybrids. Morphologically, it is possible to presume their identity. But it is difficult to determine the degree to which each variety contributes its characteristics.

Brayshaw studied the balsam poplars of southwestern Alberta using only morphological characters. The objective of my study was to investigate other technologies to find new characters which would help to clarify these three problems.

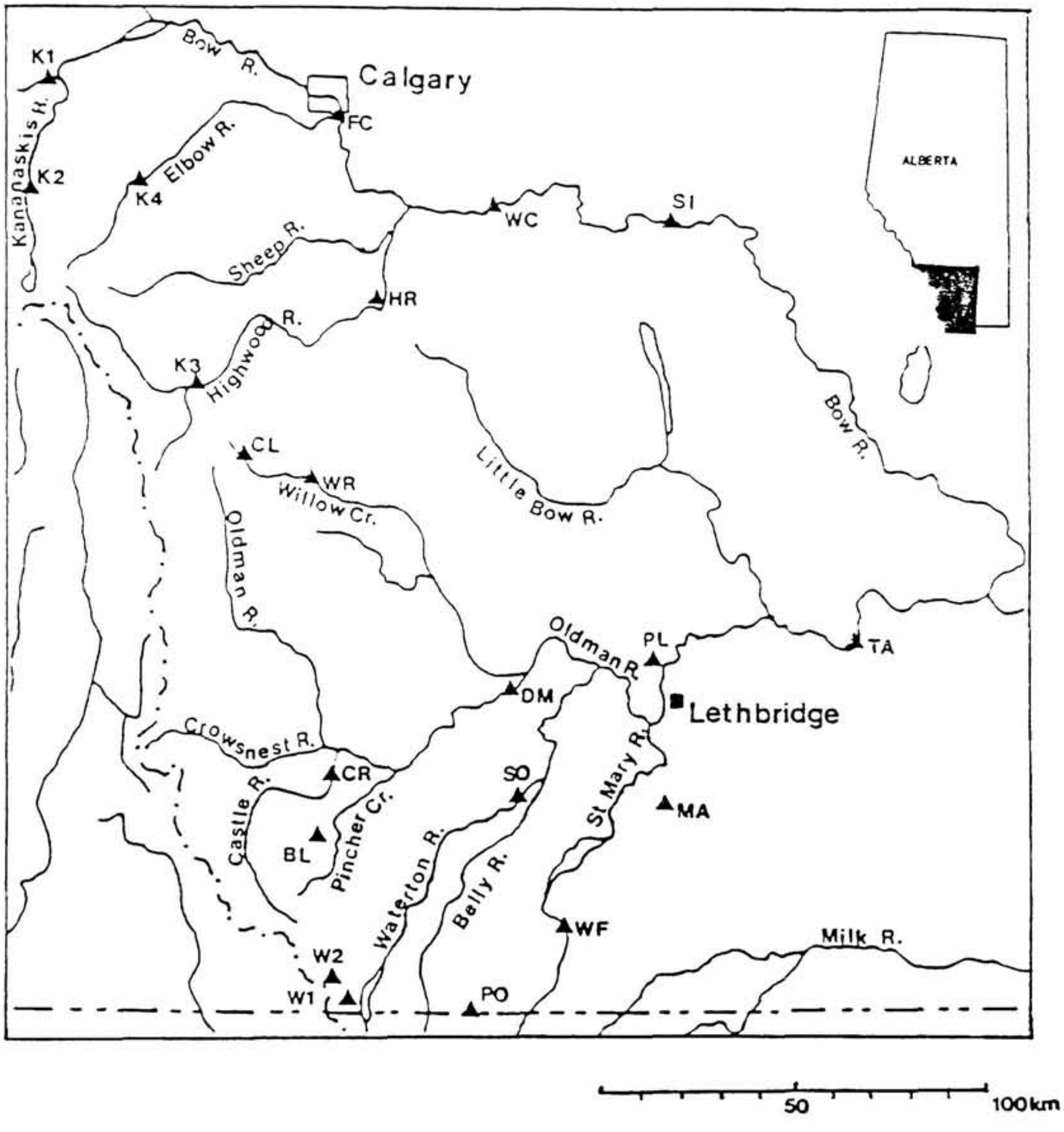
Firstly, I attempted to find new data to confirm the two subspecies status of *P. balsamifera,* as introduced by Brayshaw. The second goal was to find a method to efficiently distinguish the two subspecies. The third objective was to clarify the degree of intermediacy existing among the *P. angustifolia* x *P. balsamifera* putative hybrids.

The study area of the present study followed Brayshaw's study area plus an extension in the foothills to determine if poplar populations there are also affected by hybridization. A total of twenty-one locations were selected in this area in order to represent most river systems of southwestern Alberta (Figure 12.1; Table 12.1). In each location, twenty trees or fewer were selected to best represent the total variation of that location and assess the morphological variation found in the location. A total of 366 trees were selected. Each tree was tagged to allow several samplings.

Today, I will present only one of the technologies I studied, the flavonoid chemistry which had already been used in the earlier French project.

Flavonoids have been extensively used in the late 1950's to solve many taxonomical problems. Procedures are quick with a relatively simple extraction, and their main advantage is their structural diversity. From these common 15 carbon units we can distinguish 10 different flavonoid families and from these families thousands of structures have been isolated differing by the addition of sugars or other radicals.

Figure 12.1. Study area and 21 selected *Populus angustifolia* and *P. balsamifera* locations (^) in southwestern Alberta.



The technique used in the study is that of two dimensional paper chromatography after flavonoids were extracted in aqueous methanol from leaves. A number of florescent zones resulted in the paper chromatograms with each corresponding to a different flavonoid compound. From a paper chromatogram it is possible to cut out different zones and to isolate and identify each flavonoid compound present.

Before studying the 366 trees which were sampled I first analyzed the flavonoids present in each of the three taxa. Flavonoid profiles of the three taxa were constructed from samples collected outside the hybridization zone. *P. angustifolia* was collected in Colorado. *P. balsamifera* subsp.

balsamifera was collected in northern Alberta and subsp. *trichocarpa* was collected in western British Columbia.

Table 12.1. Altitude, latitude, longitude of the 21 *Populus* locations selected for the study of balsam poplars in southwestern Alberta.

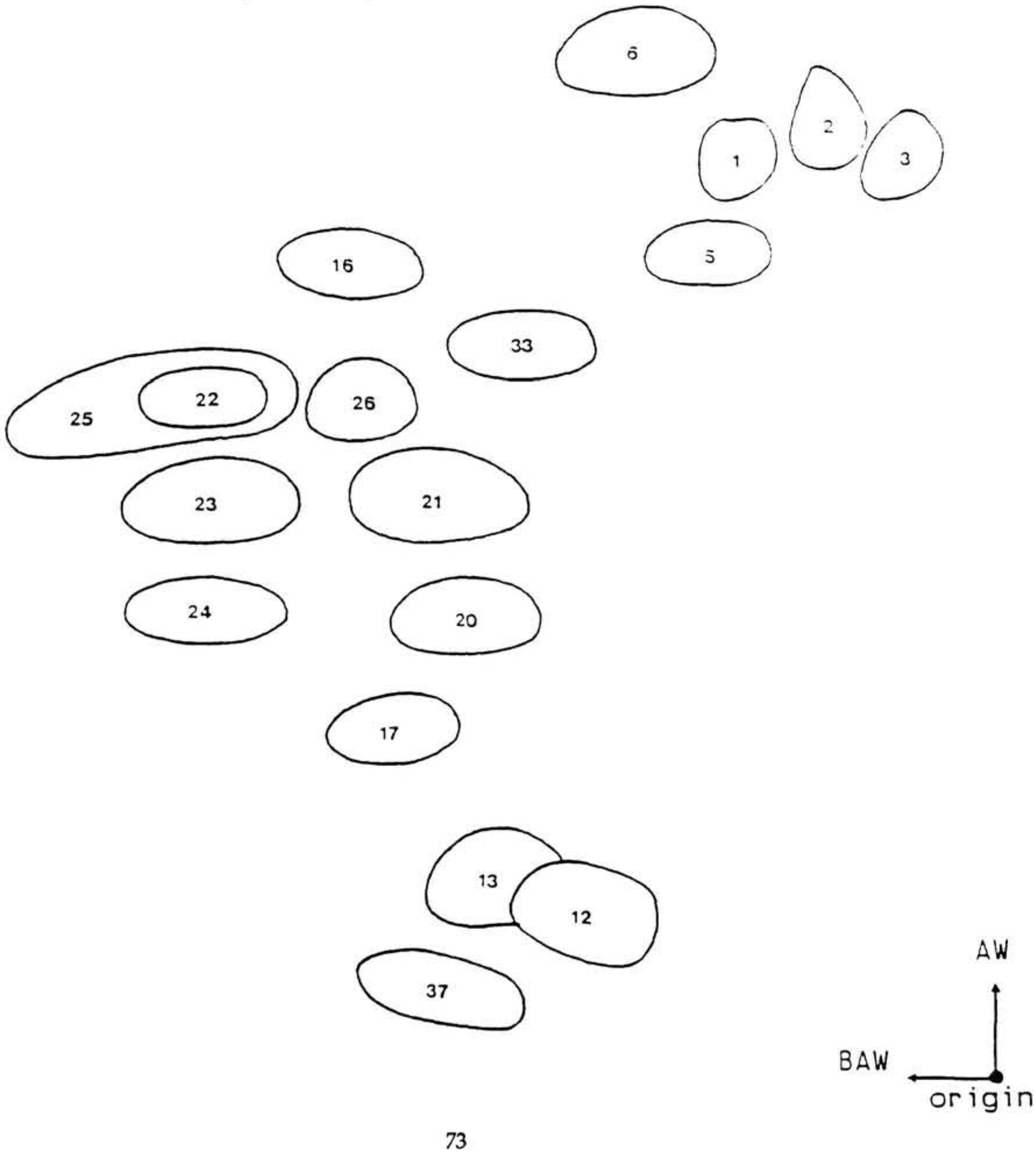
Location	Altitude (m)	Latitude (°,' N)	Longitude (°,' W)
BL(B)	1350	49,25	114,05
CL(C)	1350	50,13	114,12
CR(R)	1200	49,32	114,02
DM(D)	930	49,43	113,24
FC(F)	1000	50,55	114,01
HR(H)	1020	50,35	113, 50
K1(I)	1290	51,05	115, 05
K2(J)	1440	50, 56	115,09
K3(K)	1500	50,25	114,35
K4(L)	1500	50,53	114,42
MA(M)	960	49,24	112,57
PL(P)	900	49,48	112,55
PO(O)	1350	49,00	113,27
SI(S)	810	50,46	112,51
SO(U)	960	49,30	113,20
TA(T)	750	49,49	112,10
W1(A)	1500	49,06	113,58
W2(W)	1500	49,04	113,58
WC(X)	900	50,50	113,25
WF(Y)	1100	49,11	113,11
WR(Z)	1020	50,05	113,45

The letter between brackets after the location initials is the code used on correspondence analysis plots in Figures 12.1 and 12.4.

The flavonoids present in these taxa's profiles belonged to two different classes of flavonoids, the flavonols and the flavones (Figure 12.2). The main difference between *P. balsamifera* and *P. angustifolia* is the absence of flavones in the *P. angustifolia* (Figure 12.3). Flavonoids number 12, 13 and 37 are entirely absent from *P. angustifolia*. Conversely, *P. angustifolia* is characterized by flavonoid number 16 and 22; those two are absent from *P. balsamifera*.

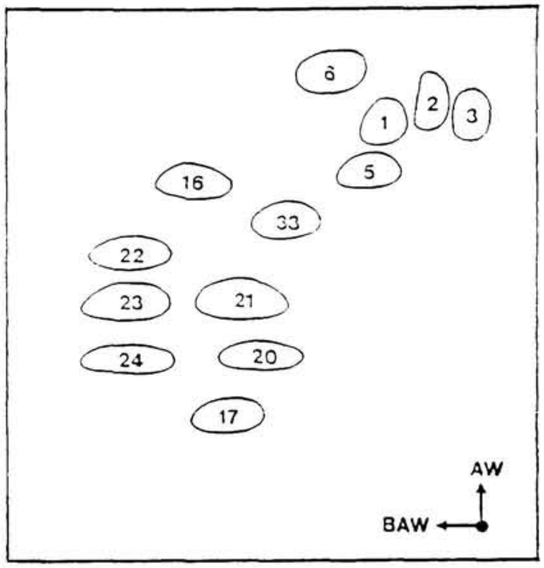
P. balsamifera is characterized by flavonoid number 25 and between the two subspecies of *P. balsamifera*, the distinction is more subtle. The subspecies differentiation does not affect the family of flavonoid but instead the pattern of the sugar attached to the flavonoid themselves. The sugar pattern in subsp. *balsamifera* is more simple than the sugar pattern of subsp. *trichocarpa*. For example, flavonoid 33 which is present in subsp. *trichocarpa* is absent from subsp. *balsamifera* and replaced by number 25 which has one less sugar. Also, flavonoid number 6 is absent from subsp. *balsamifera* and represents the highest level of sugar substitution. And finally, flavonoid number 37 is absent from subsp. *balsamifera*.

Figure 12.2. Synthetic flavonoid profile of the *Populus* taxa studied; each flavonoid zone is delimited and numbered. First dimension: BAW (Butanol, 60 - Acetic Acid, 10 - Water, 20). Second Dimension: AW (Acetic Acid, 15 - Water, 85).

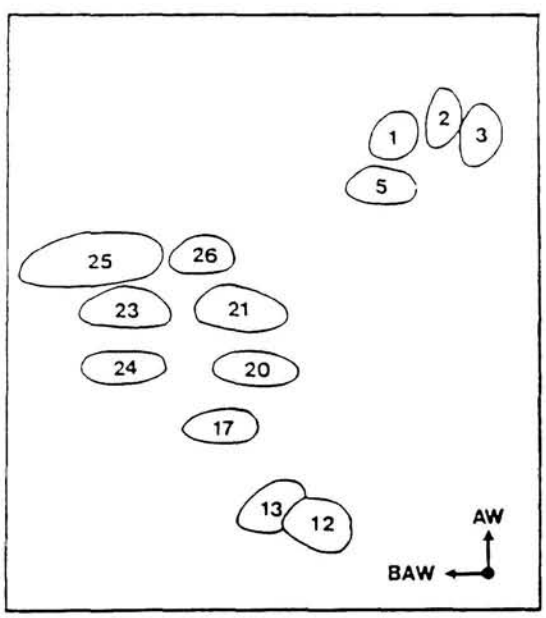


After identification of the three taxa profiles, I analyzed the 366 trees of the sample and noted the absence or presence of each of the compounds. The data matrix produced was studied by correspondence analysis (Figure 12.4). On the resulting plot, several groups can be distinguished clearly: individuals with profiles which matched that of *P. angustifolia*, *P. balsamifera* subsp.

Figure 12.3. Flavonoid profiles of the pure *Populus* taxa studied: a- *P. angustifolia* from Gunnison, Colorado, and Stand-Off, Alberta; b- *P. balsamifera* subsp. *balsamifera* from Plamondon and High Level, Alberta; c- *P. balsamifera* subsp. *trichocarpa* from Boston Bar and Savona, British Columbia.



a-



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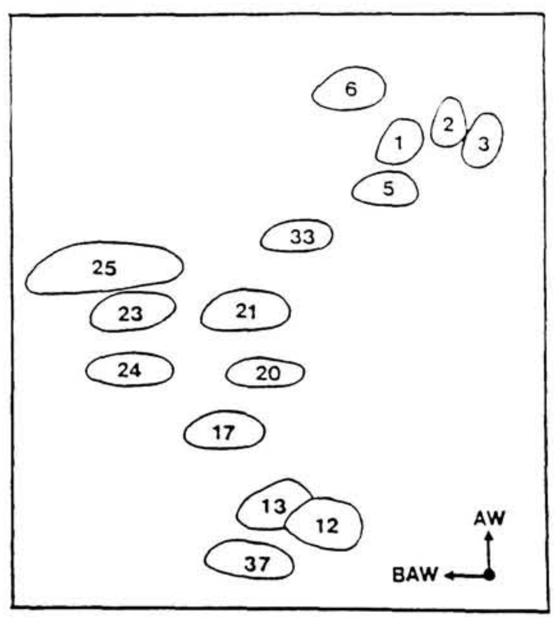
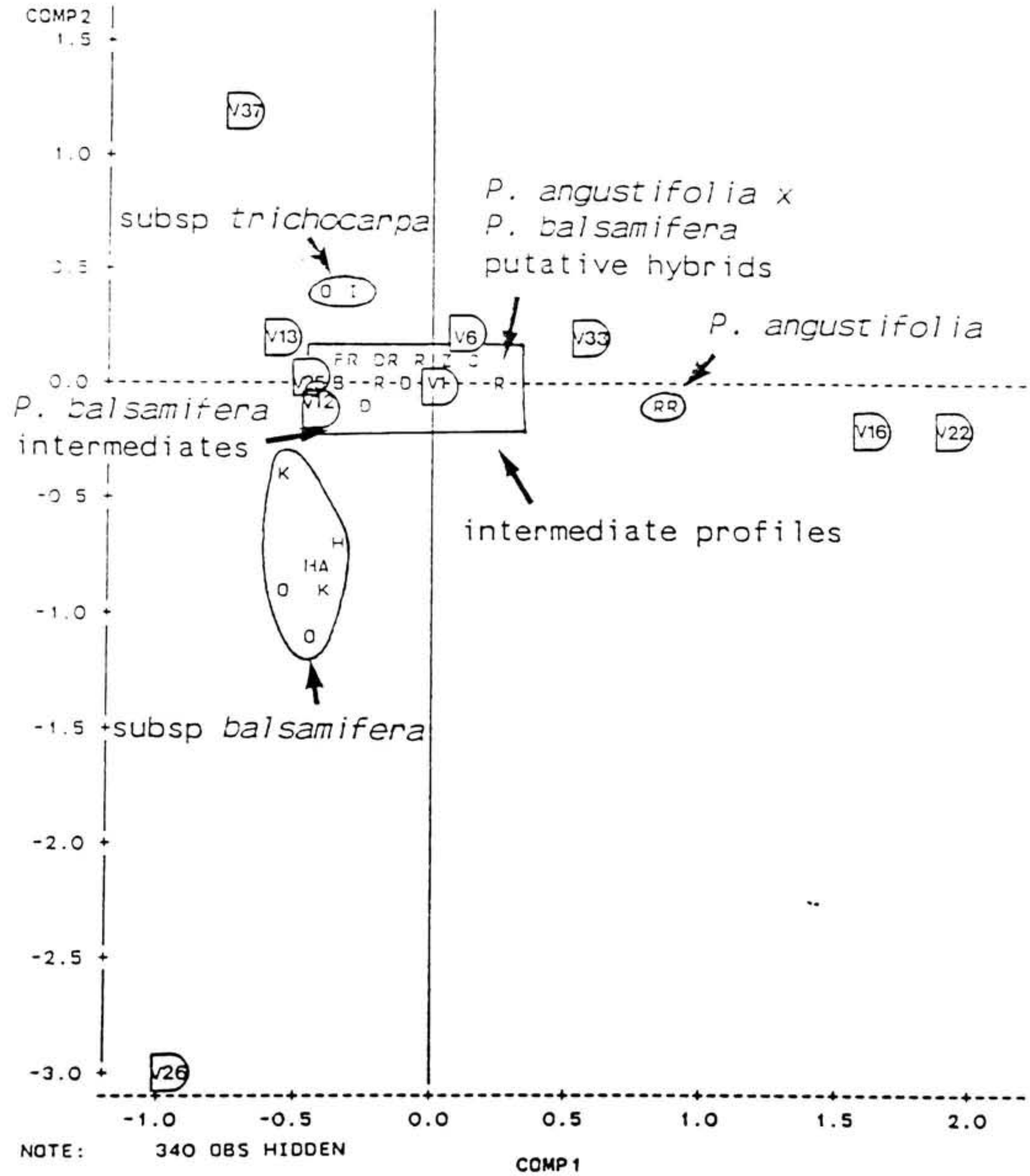


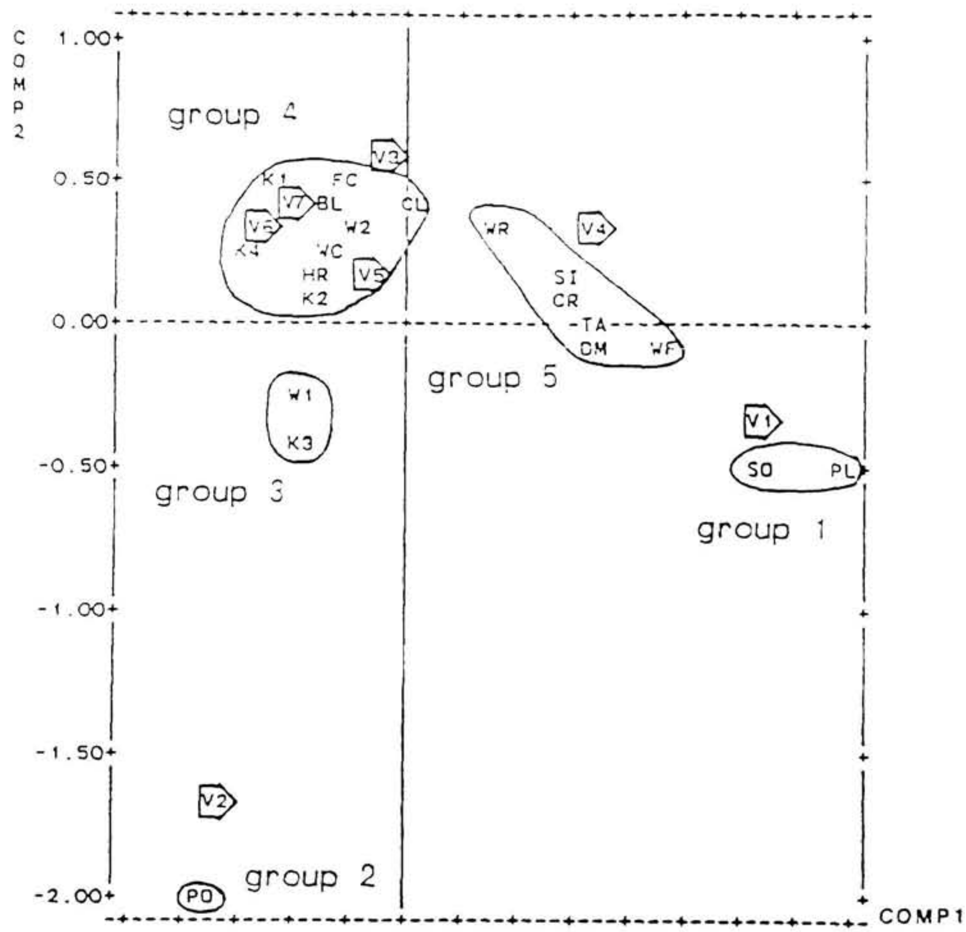
c-

Figure 12.4. Correspondence analysis plot (first 2 principal axes) of the flavonoid dot matrix. Each letter plotted corresponds to an individual and indicates its location code listed in Table 12.1. Number of individuals sampled: *P. angustifolia*- 71; *P. angustifolia* x *P. balsamifera* putative hybrids - 20; *P. balsamifera* subsp. *balsamifera*- 30; *P. balsamifera* intermediates - 212; and *P. balsamifera* subsp. *trichocarpa* - 24. Flavonoid characters are represented by letters and numbers (e.g. V22 = flavonoid 22).



trichocarpa, or subsp. *balsamifera* and some profiles of individuals which are intermediate between two groups. The intermediate individuals were intermediate between *P. angustifolia* and

Figure 12.5. Correspondence analysis plot (first 2 principal axes) of the flavonoid profile distribution in the 21 *Populus* locations. Group 1 is *P. angustifolia* locations. Groups 2 and 3 are locations with a large number of *P. balsamifera* subsp. *balsamifera* profiles. Group 4 contains *P. balsamifera* locations, and Group 5 is locations with both *P. angustifolia* and *P. balsamifera* plus putative hybrids. *P. angustifolia* profiles are represented in V1; *P. balsamifera* subsp. *balsamifera* profiles in V2; *P. balsamifera* subsp. *trichocarpa* profiles in V3; *P. angustifolia* x *P. balsamifera* intermediate profiles in V4; *P. balsamifera* intermediates tending to subsp. *balsamifera* profiles in V5; *P. balsamifera* intermediate profiles in V6; and *P. balsamifera* intermediates tending to subsp. *trichocarpa* profiles in V6.



P. balsamifera or intermediate between the two subspecies of *P. balsamifera*.

When looking at these intermediate profiles in these two groups, six different subgroups of these profiles can be characterized. First, three types of intermediate existed between *P. angustifolia* and *P. balsamifera*. And secondly, three types of intermediates were observed between *P. balsamifera* subsp. *balsamifera* and subsp. *trichocarpa* - one type more towards subsp. *trichocarpa*, one towards subsp. *balsamifera* and the third one is intermediate.

The distribution of these different types of flavonoid profiles in each location was also studied by correspondence analysis. On the plot we can see locations composed exclusively of *P. angustifolia* and populations composed exclusively of *P. balsamifera*, and also locations having both species plus intermediates (Figure 12.5).

Among the *P. balsamifera* locations, Police Outpost is the only one which is represented almost exclusively by subsp. *balsamifera*. All of the other locations are mixed, even if the tendency towards subsp. *balsamifera* is stronger.

As a conclusion, I would like to return to the taxonomical problems that I presented earlier. The first problem regards *P. balsamifera* status. In southwestern Alberta, the study of flavonoid chemistry showed that the two subspecies defined by Brayshaw (1965) are connected by many intermediate forms which indicates a lack of efficient breeding isolation mechanisms between the two taxa. Also the study of the two subspecies flavonoid profiles showed only subtle differences of the sugar pattern. Therefore, the two subspecies status should be kept for these taxa, at least in southwestern Alberta.

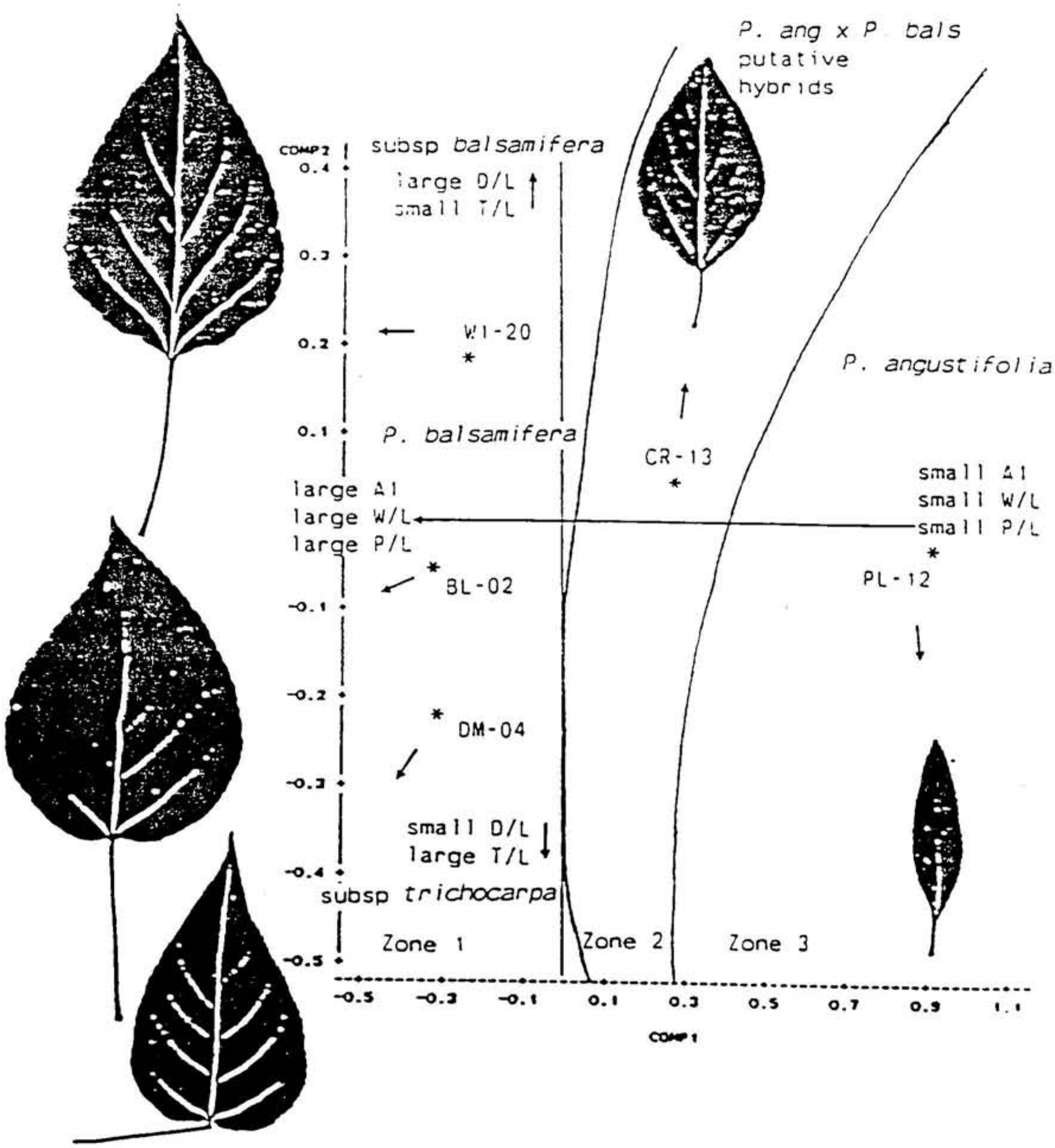
To solve the second problem, the flavonoid chemistry did serve to provide a distinction between the two subspecies of *P. balsamifera*. And finally, the distinction of six groups of intermediates of *P. angustifolia* x *P. balsamifera* putative hybrids were made possible using flavonoid chemistry.

Thus, the study of flavonoid chemistry served as a useful complement to analysis of foliar morphology (Figure 12.6) enabling the clarification of the taxonomic status of riparian poplars of southwestern Alberta.

Literature cited

Brayshaw, T.C., 1965. Native Poplars of Southern Alberta and Their Hybrids, Department of Forestry Publication No. 1109, Ottawa. 40pp.

Figure 12.6. Correspondence analysis plot (first two principal axes) of the transformed morphological data matrix. The different trends of leaf shape exhibited in the population are illustrated with leaf examples. Zone 1 contains *P. balsamifera*. W1-20 is at the extreme for *P. balsamifera* subsp. *balsamifera* and was collected from Waterton. DM-04 is at the extreme for *P. balsamifera* subsp. *trichocarpa* and was collected from the Daisy May location. BL-02 is a *P. balsamifera* intermediate collected from near Beauvais Lake. Zone 2 contains *P. angustifolia* x *P. balsamifera* putative hybrids. CR-13 was collected from near the Castle River. Zone 3 contains *P. angustifolia*.PL-12 was collected from the Park Lake location.



13. Ecology of the Riverbottom Forest on St. Mary River, Lee Creek, and Belly River in Southwestern Alberta

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I began my studies of cottonwood trees in 1970 as a result of personal interest. I have probably lived 98% of my life under cottonwood trees, most of the time in Cardston, Alberta where I had access to the riverbottom forest on Lee Creek. I chose to study the riverbottom forest for several reasons. At the time it seemed as if there was probably no possibility of forest destruction, there were no federal or provincial agencies involved, and I did not have to ask permission for access by letter. I knew almost all the landowners personally and they were, without exception, happy to see me come. They did not know what I was doing with my studies. One landowner suggested that perhaps someday I could get a real job.

For the St. Mary River I worked from the Montana/Alberta border, downstream to the head of the reservoir. I studied Lee Creek from the little place called Beazer, to the confluence with the St. Mary. The Belly river was surveyed from the Highway 5 bridge to where it meets the Waterton River.

I chose the upstream beginnings of the riverbottom forest where it becomes a unique entity. Here the rivers have just left the aspen groveland and have something of a prairie nature. I knew very little about what really went on in the riverbottom forest when I began. I worked out my own methods and followed some things I found in my literature research. But I did know full well that these streams flooded every spring sometime during the last two weeks of May and the first two weeks of June. They flooded because spring rain coincided with, and perhaps helped, snow melt in the Rocky Mountains so that everything came downhill at once.

A number of authors have reported on these riparian gallery forests. However, none specifically for southern Alberta as of 1970. Moss had described the distribution in general and mentioned poplar hybridization, but the best help I found was Brayshaw. Brayshaw had figured out the biggest problem I had, which was determining poplar species and their hybrids. So once I got hold of his work things settled in place and I was able to identify *Populus angustifolia*,and *Populus balsamifera*, including both of his subspecies, balsamifera and trichocarpa, and all the interesting hybrids on these three stretches of riverbottom.

Along the three rivers I picked ten major ecologic and taxonomic sites based largely on what looked to me like areas that had had the least disturbance. It wasn't hard to find that many and some good sites were left out. I learned that the forest was stratified. The upper levels were composed of the trees of the canopy, then a clumped shrub stratum, then thicker shrubs and finally the herbaceous plants on the forest floor. I collected plants, learned the flora and worked on methods

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for analyzing the data. I will concentrate only on the trees of the canopy and their reproduction (Tables 13.1 and 13.2).

Table 13.1. Summary of the mature tree stratum data from 10 riverbottom forest stands in southwestern Alberta.

Species	Trees per Hectare	Relative Density	Relative Dominance	Relative Frequency	Imperical Value
Populus angustifolia	91.5	32.3	29.5	32.7	94.5
P. balsamifera	88.9	31.4	27.7	30.8	89.9
P. X balsamifera	95.9	34.2	41.9	34.7	110.8
P. tremuloides	5.4	1.9	0.5	1.3	3.7
Picea glauca	0.6	0.2	0.4	0.5	1.1
TOTAL	283.4	100.0	100.0	100.0	300.0

Table 13.2. Summary of the tree reproduction data from 10 stands of mature riverbottom forest in southwestern Alberta.

Species	Saplings per Hectare	Relative Density	Relative Dominance	Relative Frequency	Imperical Value
Populus angustifolia	113.3	42.0	38.3	38.6	118.9
P. balsamifera	81.5	30.2	32.4	28.1	90.7
P. X balsamifera	65.0	24.1	25.2	29.8	79.1
P. tremuloides	9.2	3.4	3.9	3.1	10.4
Picea glauca	0.8	0.3	0.2	0.4	0.9
TOTAL	269.8	100.0	100.0	100.0	300.0

Of the methods investigated, the point quarter method seemed to work best for the trees and their reproduction, so it was used to generate data on the usual things. The density of trees in the forest is the characteristic I am most interested in reporting to you today. As I worked my way through analyzing these mature stands of riverbottom forest, it became apparent to me that somehow the gravel bars had a considerable bearing on the riverbottom forest. I was in no hurry. I had the summers free every year. I just sat and thought and worked my way up and down the rivers and tried not to be pestered too much by mosquitoes. I had no deadlines so that left me the winters for library work and asking questions here and there.

I learned that riverbottom forest development, at least on these three streams, coincided with gravel bar formation. These were meandering streams without a real static equilibrium. They changed and changed and changed, in a state of dynamic equilibrium. Degradation and agradation occur each year but the large changes occurred during late May and early June when the stream flow peaked. These streams have a strange inability to adjust their width in accordance with their velocity, so they meander this way and then the other, tearing away at the mature forest on the outside bends and laying down new gravel on the inside bends.

As I started to figure out where the new trees were, I found that pioneer stands of *P. angustifolia, P. balsamifera* and hybrids occurred only on the gravel bars, never on sandbars. There were a few *Populus tremuloides* here and there as well. When I started looking at the composition of the gravel, everyone said that it was just gravel, and once you've seen gravel you've seen all there is to see of gravel. However, it turned out that on the gravel bars with good populations of young trees, the gravel was about 61% rock larger than 0.5 cm in diameter and about 39% less than 0.5 cm in diameter. I also found that sandbar willow *(Salix interior)*grew only in places where everything would pass through a 0.5 cm screen, but cottonwoods never appeared at these sites.

The gravel bars formed by annual flooding were available to poplar seed invasion by late June. Seeds would be distributed on every new gravel bar. Some of the new gravel bars survived the first, second and subsequent years, some did not. The loss of many or most seedlings every year is not a problem because we all remember how many seeds cottonwood trees produce.

Successful seedlings had to cope with submergence during flooding on average 4 days in subsequent years. For example in one year, there were three days of flooding during which I watched three big gravel bars. Two of those gravel bars emerged unscathed. The little trees about 1 m. high were bent over and muddy and there was a little silt and debris on top of the gravel. But, two or three days later they were up and growing and the first rain washed them clean. On the third gravel bar, not a trace of the former vegetation remained. The gravel bar was covered with brand new gravel, slick and clean. This process goes on year after year in a somewhat random pattern. There is no way of predicting what will actually happen.

A number of terrace levels often form in these riverbottoms. At the lowest level is the open water of the river itself. Then the new gravel bars form the first terrace. Then the riverbottom forest seems to develop on the second terrace. There may be third and fourth terraces, but invariably as you go up each step, you come out on what was, or maybe still is, the old fescue prairie grassland. Never did I see evidence of the cottonwoods being able to move into those third and fourth terraces, covered by grassland. They seem to know their place and stay there.

Unfortunately, quite a few of those third and fourth terraces are now farmed. The second terrace is usually quite safe from overbank flooding. In 1964 and 1975 there was overbank flooding but not a great deal of damage. The most damage to an old stand is the slow year by year lateral erosion of the stream bank. The roots are first exposed, and gravel and sand carried by the water debark the roots and stems. As the support erodes away, the trees topple into the river. This is such a slow process we do not notice it happening too much and it does not seem to cause any great loss to the riverbottom forest.

In the mature forest I found that the density of *P. angustifolia, P. balsamifera* and a hybrid that I called AB or AxB or *xbalsamifera* averaged out to 91.5, 88.9 and 96.9 trees per hectare respectively for the ten stands. That is for trees greater than 5 cm dbh. It was nice to see that many, but what surprised me was that of trees less than 5cm dbh there were also very many: *angustifolia*, 113; *balsamifera*, 81.5; and the hybrids, 65 per hectare. I did not think that mature stands would regenerate themselves, but apparently they do. The regeneration is not always by suckering Occasionally seeds must land in favorable place under their parents, germinate and grow. If no disturbance occurs, it seems to me that the forest can perpetuate itself pretty well forever.

Not only must the understory of small poplar trees be undisturbed, but the other three levels as well. The clumped shrubs, the thicket shrubs and the herbaceous plants must not be disturbed because the whole system is a very complex interaction between the four layers. One of the best places remaining to see this stratification on the streams I studied, is in the lower end of Woolford Provincial Park. The upper end has taken a most interesting beating, but the lower end has been left pretty much alone and you can see very nicely the stratification of the forest on the St. Mary River

Unfortunately, disturbance has occurred over the years with some of the better looking stands. These groves were thought to be nice places to live. Sheep and cattle grazing over the last hundred years has totally removed the understory and the reproduction of some of those forests. Deliberate clearing has also been done in a few places, especially where communities have tremendous amounts of manpower to brush out the area.

Beaver are a minor problem; a major problem if it's your forest they're working on. But interestingly enough, there's no logging, no saw timber or firewood removal except by Boy Scouts having their little campouts. There is no clearing for farming because once you look under that thin layer of silt and sand there is nothing under there but good old gravel. That means of course that gravel mining is a problem. There are many people who wish to gravel mine, without realizing that the slightest change made to a gravel bar affects the meander system of that river for years.

The oldest tree found was an AB hybrid poplar on Lee Creek that was, in 1973, 250 years old. The oldest on the St. Mary River, also an AB hybrid, was 160 years old in 1973. The height of the largest trees ranged from 13 to 22 meters. All in all there are 41 species of woody plants and about 250 more of herbaceous plants in the river bottom forests of southwestern Alberta that I studied.

A good example of river bottom forest ruination, can be found in Cardston, Alberta along Lee Creek. The townspeople have managed finally to ruin just about every living thing that grew higher than Kentucky blue grass in that town. I can say this because I grew up in Cardston, and I have made that point to them many, many times.

The second part of my discussion is relative to cottonwood seed germination. When I was beginning in biology, a botanist told the little story that cottonwood seeds do not germinate. They have no viability. How did he know that? Because although millions and millions of cottonwood seeds fall to the ground, we are not overrun by cottonwoods. Therefore they must not germinate. In contrast, Ware and Penfound had reported that germination of *Populus deltoides* on the lower Missouri and Mississippi rivers was rather good. I decided to test the viability of local poplars. I collected seeds just as the capsules were dehiscing around the latter part of June and ordinary riverbottom gravel. I filled numerous gallon cans without any holes in the bottom with sand, and saturated them with river water. I did not want any drainage. I wanted the water to settle, evaporate, and draw down as it does on an ordinary gravel bar. I then planted 25 or 35 seeds of each kind just on top of the sand as they would fall from the trees onto the gravel bars in the river. I placed the cans in the sun right next to a riverbottom forest so the climate was the same. Every second day, I planted another set of cans from the same batch of seeds.

The seeds germinated like it was their fondest wish in all the world. Some started the very day after they were planted. Within 8 - 14 days all the germination you would ever get was done. *P. angustifolia* had 94% germination from seeds that were planted just two days after I collected them. Average germination for all was 68%, but on day 10, germination was nil. *Balsamifera* had 92% germination after two days and had the best germination average of 74%. By day 10, germination was only 4%. Best germination for hybrids was 91% with an average germination of 58%. On day 10, germination was nil.

These cottonwood seeds have a very short time to get their job done. They depend on the rain and the floods to soak the gravel bars. These sites must then be drained so the surface is no longer under water. And finally a generous wind is needed to spread the seeds everywhere. A lucky few land on the gravel bars and germinate. The rest land in the rose bushes and that is the end of it. At good sites you find that gravel bars are carpeted with seedlings. Over the years some survive, but most do not. Enough survive in the long run to perpetuate the forest.

I was very happy to find out that the poplars were producing viable seeds. I tested the viability of the Russian Poplar hybrids that were planted many years ago in Cardston, and found that their seeds will germinate readily in these tin cans too. Quaking aspen will also germinate readily under these conditions. I started to mistrust a lot of the things I had been told early on. Maybe they had been told to encourage me to try these tests, you never know.

In summary, these seeds need two things. They need gravel beds about 60% rock, 40% sand, and they need water saturated to the surface at frequent intervals. They need a high water table throughout the rest of the time. If you dig down you find out that cottonwood trees always keep their toes in the water. That is how they survive.

There are a number of ways that riparian cottonwood forests can be taken away from us. I really do not want to see that happen, but I do not know what to do about it except to buy up all the cottonwood trees I can afford.

On the St. Mary River just above Woolford Park in the autumn, the heavy, mature, dense forest looks like it will last. Further back is a grassland terrace with the third terraces being farmed.

This part of the river meets its end at the reservoir whose flooding has caused the destruction of many nice cottonwood groves. Downstream of the dam there is a long stretch with no cottonwood groves at all.

Many of the cottonwood places are extremely beautiful. People like to live on the floodplain, but the wise ones always build up on the higher terraces. Many of those who built down in the forest ultimately lost their homes. One of the nicest forest stands is Cardwell's Island on the St. Mary River. We know this stand has been there since the first settlers came into southern Alberta because the upper Fort Benton trail crossed the St. Mary at this point on its way to Fort Macleod.

Many of the ranchers who own land with cottonwood forests think highly of them. They do not use them much for grazing in many cases. They like to sit and enjoy the trees.

Across the St. Mary River frm Woolford Provincial Park is a forest that was cleared over the years by sheep grazing, cattle grazing, and human labour. There is only a little bit of grass on the ground. Everything that interfered with the sheep operation was taken out. There was not much damage to the mature trees themselves, and some examples are 140 years old. The main problem is in the loss of the forest stratification.

Woolford Provincial Park was built down in the riverbottom forest and since it was built, the second terrace riverbottom forest has been cut back and cut back by the river. Park staff have put in a number of gravel deflectors that only made the conditions worse. Every year the Park people decide that they can conquer the river and every year they fail.

1975 was a high-water flood year in much of southern Alberta. Contrary to expectations that large areas of forest would be ruined, not much damage actually occurred. The cottonwoods are well rooted and many of them can stand up to flooding. The flood of 1964 that went through the town of Cardston did not eliminate these trees although the water was nine feet above the ordinary level of Lee Creek.

The course of Lee Creek through the town of Cardston has changed over the years. The town mined gravel beside the stream encouraging it to change its course. Finally, the entire forest through the town of Cardston that was so much beloved by myself and other residents is gone. In it's place you can now view the Remington Carriage Collection.

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14. Poplar Seeds and Seedlings along the St. Mary, Belly and Waterton Rivers, Alberta

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In the summer of 1989, surveys were undertaken to determine the densities of poplar seed fall on suitable establishment sites along the St. Mary, Belly and Waterton Rivers of southern Alberta. The germination success of the seeds and the fate of the germinated seedlings were also followed through the summer. This presentation will first examine the status along the undammed Belly River, and then analyse the Waterton and St. Mary Rivers which are dammed.

Two sites were studied on each river. One site was selected on the reach upstream of the dams on St. Mary and Waterton Rivers, and one site downstream from the dams (Table 14.1). Along the Belly River sites were selected upstream and downstream from the Belly River Weir. All of the upstream sites were above 1100 m in elevation, whereas the downstream sites were below 1100 m.

Table 14.1. River sites surveyed for seed and seedling densities in 1989.

River	Reach	Highway Bridge	Distance from Dam (km)	Elevation (m)	Species Present
Belly					
	Upstream	#800	22	1161	*P. balsamifera, angustifolia*
	Downstream	#505	10	1062	*P. balsamifera*
Waterton					
	Upstream	unnamed	20	1234	*P. balsamifera*
	Downstream	#810	30	1041	*P. balsamifera*
St. Mary					
	Upstream	Hwy 5	24	1140	*P. balsamifera, angustifolia*
	Downstream	Stand-Off	88	850	*P. balsamifera, deltoides*

Sites with two species present also supported hybrids of the two parent species.

The reach downstream of the St. Mary Dam is almost denuded of poplars until near Pothole Creek. This scarcity is due to a historical absence of cottonwoods along the reach (Dawson, 1885) coupled with a forest decline following river damming and water diversion in the early 1950's (Rood and

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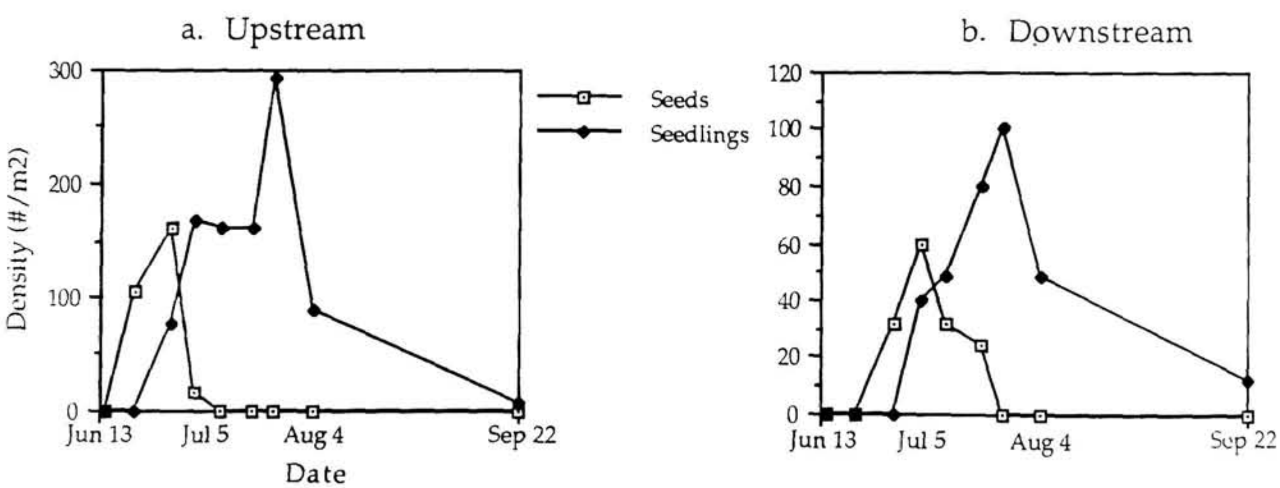
Heinze-Milne, 1989). Surveys in 1986 through 1988, found the reach to be almost void of small poplars suggesting that the reach would have a severe deficiency of poplar seeds and seedlings. Therefore, the site selected on the St. Mary River downstream of the dam for this study was about midway between the inflow of Pothole Creek and the confluence of the St. Mary and the Oldman Rivers. Although the inflow of Pothole Creek will moderate the hydrological pattern somewhat at this site, it is expected that the presence of seeds and survival of seedlings will still be influenced by the operation of the St. Mary Dam.

Two quadrats of one square meter were established at each of the six sites. The quadrats were located on the river bank slightly below the high water level in areas of sandy-gravel substrate and free of competing vegetation. The sites were monitored at about two week intervals to follow seed release and seedling establishment and growth.

At the the upper Belly River site, seed density peaked at about of 160 seeds per m^2 in late June and declined thereafter (Fig. 14.1a). No seeds were detected after July 11. Maximum seedling density was approximately 300 seedlings per m^2, on about July 26. Seedling density declined through August and September, while the river receded.

Figure 14.1. Densities of poplar seeds and seedlings upstream and downstream of the Belly River weir in 1989.

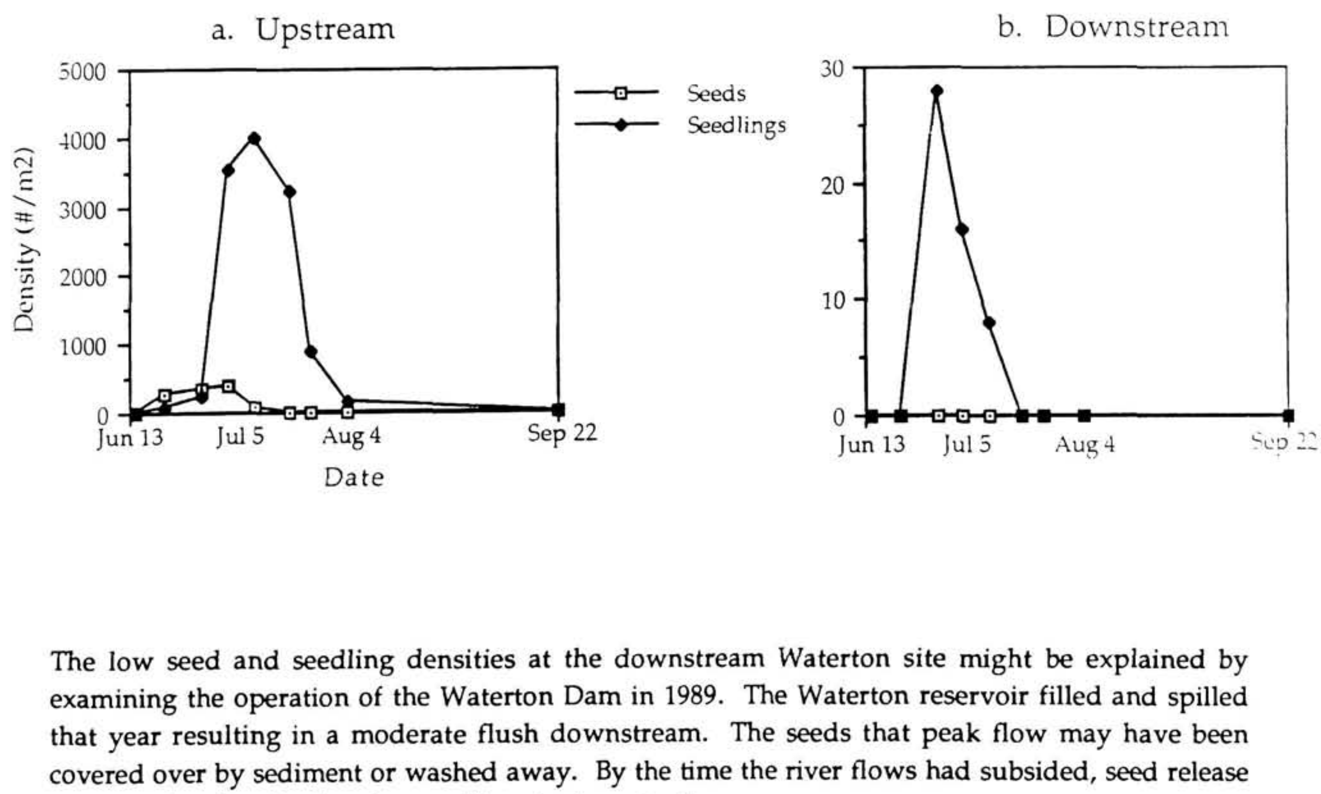


The apparent discrepancy between seed and seedling densities probably resulted from two factors. First, seedling density is a cumulative value whereas seed density is an instantaneous count. As seeds fall and germinate, they are removed from the seed pool and added to the seedling population. The seeds are also very small and may be overlooked or covered with silt or sediment, resulting in an underestimation of their density. Seedlings are larger and grow out from the sediment deposits, revealing their presence.

Along the lower Belly River, seed density peaked at about 60 seeds per m^2 on July 5 and declined through to mid-July (Figure 14.1b). First seedlings were observed in late June and by July 26 there were about 100 seedlings per m^2. There were about three-fold higher densities of seeds and seedlings at the upstream site as compared to the downstream site. Site inspections revealed no major difference between the sites although there were slightly more trees at the upstream site to produce seed.

The upper reaches of the Waterton River showed a large difference between the seed densities and the density of germinated seedlings (Fig. 14.2a). On July 5, approximately 400 seeds per m^2 were counted at this site and approximately two weeks later an estimated 4000 germinated seedlings per m^2 were observed. In contrast, no seeds and only about 28 germinated seedlings per m^2 were found at the lower Waterton site by June 29.

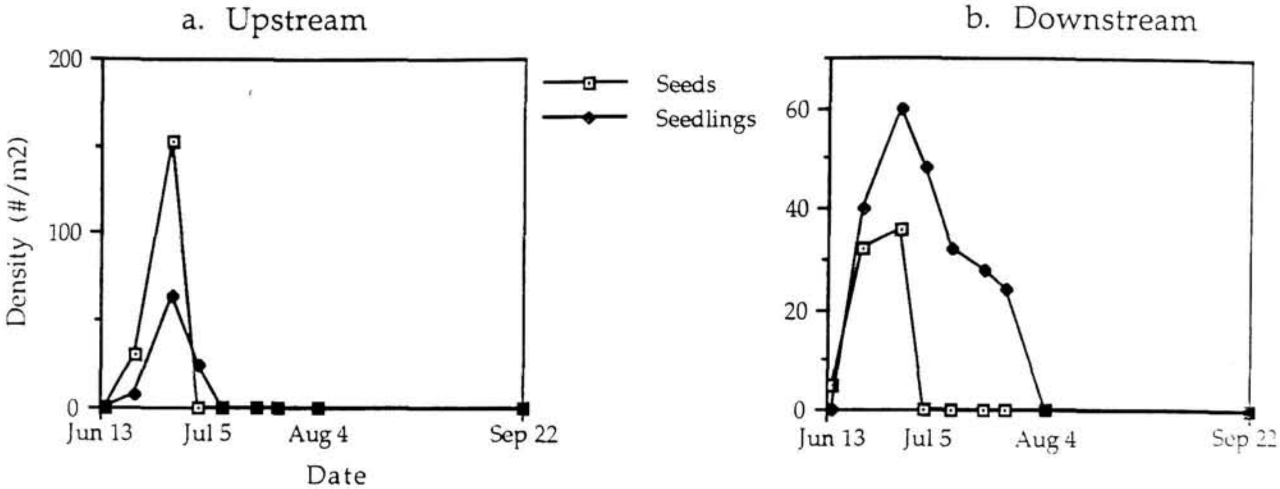
Figure 14.2. Densities of poplar seeds and seedlings upstream and downstream of the Waterton reservoir in 1989.



The low seed and seedling densities at the downstream Waterton site might be explained by examining the operation of the Waterton Dam in 1989. The Waterton reservoir filled and spilled that year resulting in a moderate flush downstream. The seeds that peak flow may have been covered over by sediment or washed away. By the time the river flows had subsided, seed release was completed and only a few seedlings had survived.

Seed density peaked at about 160 per m^2 on June 13 along the St. Mary River uptream of the St. Mary River Dam (Fig. 14.3a). The maximum germinated seedling density was about 65 per m^2 on June 13. At the lower St. Mary site, a peak of about 35 seeds per m^2 were observed on June 29, and final germinated seedling densities reached about 60 per m^2 at that time.

Figure 14.3. Densities of poplar seeds and seedlings upstream and downstream of the St. Mary reservoir in 1989.



Slightly increased seed production and germination was found along the upper versus lower sites of the undammed Belly River (Table 14.2). There was a greater reduction in both the number of seeds and germinated seedlings downstream of the Waterton Dam when compared to the upstream site. Although the densities of germinated seedlings was similar along both the upper and lower St. Mary sites, seed counts were lower at the downstream St. Mary site. If a site between the St. Mary River Dam and Pothole Creek had been selected a difference similar to that found along the Waterton River would be expected.

The observed decrease in seed and seedling density downstream from the Waterton Dam may be related to the problem of poplar forest decline downstream from river dams (Rood and Mahoney, 1990). A decrease in the number of trees downstream of the dam (Rood and Heinze-Milne, 1989) would reduce the seed source and the number of seeds released each year. Further, the stresses that increased the mortality of trees downstream from the dam could also reduce the vigor of the remaining trees, resulting in the production of fewer seeds per remaining tree.

Although seedling densities in the study ranged to over 1000 per m^2 few seedlings remained by mid-summer, 1989. Seedling mortality was complete at most sites studied. The cause for the observed mortality is uncertain. It was noted however, that river levels declined substantially in all reaches, leaving the seedlings in dry sites during the hot period of late summer. At that time many seedlings leaves were dessicated indicating that they were suffering from drought stress. This could have caused or at least contributed to their mortality.

Poplar seeds are extremely small and have little nutritional reserve to support them during periods of seedling stress. The seeds germinate rapidly, but also lose their viability rapidly. Poplars must therefore rely on the production of copious quantities of rapidly germinating seeds so that a few may establish on sites suitable for subsequent growth and maturation. This is a classic example of the 'r-selection' ecological strategy.

Table 14.2. Maximum poplar seed and seedling densities and dates for upstream and downstream reaches of the Belly, Waterton and St. Mary Rivers, 1989. The ratio of up/down provides a measure of the change in density of seeds and seedlings between the upstream and downstream sites for each river.

River	Reach	Seeds		Seedlings	
		Density (per m^2)	Date	Density (per m^2)	Date
Belly					
	Upstream	160	June 29	290	July 26
	Downstream	60	July 5	90	July 26
	ratio up/down	2.7		3.2	
Waterton					
	Upstream	400	July 5	4000	July 11
	Downstream	0		26	June 29
	ratio up/down			154	
St. Mary					
	Upstream	160	June 29	65	June 29
	Downstream	35	June 29	60	June 29
	ratio up/down	4.6		1.1	

The densities of seeds and seedlings observed at these sites indicates that initial establishment is not the principal limitation to riparian poplar forest replenishment. The loss of virtually all seedlings at the sites over the course of the summer suggests that this is a vulnerable phase of the poplar life cycle. Further studies on poplar forest maintenance and decline therefore need to focus on factors affecting seedling survival. Programs aimed at poplar forest recovery should be directed at improving seedling survival.

This study supports the general observation that successful poplar seedling replenishment occurs occasionally and irregularly. Although the hydrological conditions necessary for seedling survival are becoming more clear (Rood and Mahoney, 1990), it is certain that 1989 was not one of those occasional favorable years for poplar seedling survival along the Oldman River tributaries. In 1989, the seedlings died, probably succumbing to drought stress.

The results from this study are preliminary as they involve only a single season. It is necessary to observe seed and seedling development during additional years with different hydrological conditions to confirm these results. Studies in 1990 and 1991 are planned to include the same quadrats and to monitor seed and seedling densities along transects perpendicular to the rivers. Using transects should enable the assessment of seedling establishment and survival at various streambank elevations.

Finally, although seed and seedling densities were apparently reduced downstream from each dam, some seedlings remained. Each of these sites therefore retain a capability for poplar seedling replenishment. If the specific cause(s) of the previous forest decline can be identified and mitigated (Rood and Mahoney, 1990), there remains optimism that the riparian forests of all three rivers may be preserved. Downstream from water control structures there may even be opportunities to enhance poplar forest replenishment by regulating flows to provide the hydrological conditions that are favorable for poplar seedling survival.

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15. The Importance of Riparian Forests for Prairie Birds: A case study - Dinosaur Provincial Park, Alberta

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Most of this work was done as part of my Master's degree at the University of Calgary in the Geography Department. Tim Myres in the Biology Department assisted with the ornithology components. I investigated bird populations and riparian habits in 1986 and 1988. I then went on to look at bird populations in some of the surrounding badland and prairie habitats to make a more complete study of the area. The latter study was funded by the Alberta Recreation, Parks and Wildlife Foundation.

Dinosaur Provincial Park is the section of the Red Deer River that I studied. The park is near Brooks, not Drumheller, as everybody thinks. Figure 15.1 shows that riparian habitats are quite extensive along the lower reaches of the Red Deer River.

The objectives of my thesis research were to determine the species composition and breeding densities of the birds, and the diversities of the various habitat types present within the riparian zone in Dinosaur Provincial Park. I also wanted to stress the importance of the various habitat components such as vegetation composition and habitat structure in the riparian zone for birds and the extent to which bird populations use riparian habitats exclusively. Thirdly, I wanted to predict the impact of habitat modifications on bird populations in the riparian zone. The third objective is becoming more important these days. In general, riparian habitats are being modified extremely and in some cases eliminated completely. I attempted to determine what effect these changes are having on the bird populations.

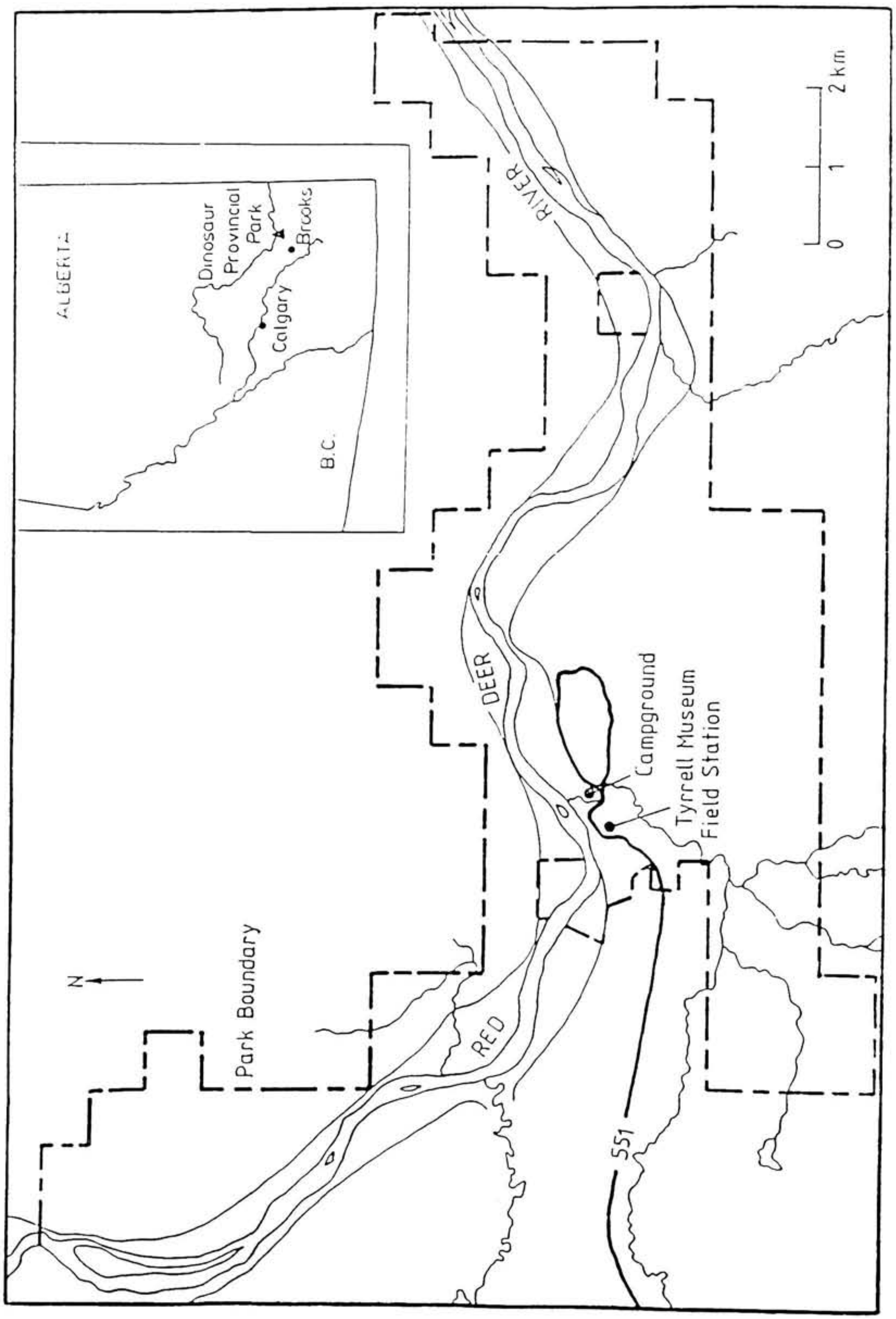
Of the different habitats that I studied during the three years that I was doing research, the most important ones for discussion at this conference were the floodplain habitats; sagebrush flats, shrubland, cottonwood forests and the willow shrubland close to the river. I also looked at species composition on river flats and cutbanks.

I used Emlen's line transect method for censusing. I established belt transects in each of the habitat types on the floodplain. I recorded several data on each sighting of a bird. I was then able to calculate the breeding bird density in each of the transects and the bird species diversity.

Bird species diversity is an index commonly used in bird studies. It does not simply tell you the number of species in an area, but it takes into account the proportion. If you had 100 different birds in an area, 99 of one species and one of another, you would have a very low diversity bird index of about 0.05. If you had 100 birds, again two different species, but 50 of one and 50 of another, it would be a little higher, around 0.7. Bird species diversities range from 0 (if only one species is present), to around three or a little higher.

In: Rood, S.B., and J.M. Mahoney (eds.), 1991. The Biology and Management of Southern Alberta's Cottonwoods. University of Lethbridge, Alberta.

Figure 15.1. Dinosaur Provincial Park in southern Alberta.



I also looked at bird species composition. This required finding as many different species as possible. After censusing along the transects for three hours in the morning, I would head off into the badlands, floodplain or some of the more remote parts of the park to see what I could find. I did find a few species that were unusual, but most of them were what was expected.

In the prairie habitat a breeding bird density of 32 to 40 breeding pairs per 40 hectares was commonly found (Table 15.1). Bird species diversity was fairly low in the prairie and badland habitats (Table 15.1). Eroding badlands and natural drainage channels yield a little higher breeding bird densities (69 and 58 pairs per hectare). Along the floodplain, and especially in the cottonwood forest, up to 706 pairs of breeding birds were recorded for 40 hectares. This is very high.

Table 15.1. Breeding Bird Densities and Diversities

Habitat	Bird Density (pairs/40ha)	BSD	Breeding Species
Plains Prairie	32.0	1.28	10
Rolling Prairie	38.3	1.00	4
Eroding Badlands	69.6	1.58	17
Natural Channel	58.3	1.55	11
Irrigation-fed Creek	364.0	2.75	26
Sagebrush	255.6	1.84	10
Shrubland	549.9	2.47	32
Cottonwood Forest	706.8	2.70	31
Willow	294.0	1.91	9

The irrigation fed valley habitat is a mixture of riparian and badland vegetation with a few cottonwood trees, a lot of thorny buffaloberry and some badlands plant species. The large variation in vegetation encourages a mix of badland birds and riparian birds, so there are a large number of different species in one area. This results in high bird species diversity values. I always tell really keen birders, that do not have much time, that the best place to go birding in Dinosaur Park is Little Sandhill Creek because you can see the most species in the shortest time.

Table 15.1 shows the species diversity values for the areas that I surveyed. The willow habitats and cottonwood forest had very high values of2.7.

I compared the breeding bird densities that I found with other studies done in Alberta and the United States. There has been a lot of study on bird populations in the riparian habitats in the United States, especially with Johnson's group. Similar breeding bird densities of 700 per 40 hectares seems to be the number that comes up again and again for riparian habitats. This supports the values found along the Red Deer River in Dinosaur Park.

Few similar studies have been done in Alberta. Table 15.2 lists a few of the studies and gives some habitat types found in Alberta and their associated breeding bird density values. Nothing really compares with the values I found for the riparian habitats of Dinosaur Park. The highest Alberta value I found was for aspen woodland in Banff Park (Table 15.2). It is similar across Canada and the only report that came close to 700 was a study done in Assiniboine Park, again in aspen woodland, and that was reported in the low 600's. I can not say that riparian habitats have the highest breeding bird densities in Canada because there have not been that many studies of this kind. Certainly some of the highest breeding bird densities are found in riparian habitats.

Table 15.2. Breeding Bird Densities Calculated in other Alberta Studies

Location	Vegetation Type	Pairs per 40ha
Medicine Lake	Mature poplar stand	356.8
Jasper National Park (Jacques Creek)	Tall willow woodland	149.6
Jasper National Park (Signal Mountain)	Alpine Meadow	16.0
Banff National Park (Moraine Lake)	Subalpine Spruce-Fir Forest	70.4
Banff National Park (Parker Ridge)	Timberline Fir	42.2
Banff National Park (Carrot Creek)	Aspen Woodland	358.0
Banff National Park (Eisenhower Jct.)	Lodgepole Pine Forest	55.2
Sheep River	White Spruce Forest	321.6
Hand Hills	Prairie Grassland ungrazed	129.6
Hand Hills	Cultivated Grassland	8.0

Another interesting, unexpected observation was that 75% of the bird species that bred in the riparian zone, bred exclusively in that area. The are not found in the badland or prairie habitats. They were exclusively woodland birds. That shows how reliant many of the birds in Dinosaur Park are on the riparian habitats. If the riparian habitats are lost, the birds that depend on those habitats are also lost since there is no other suitable habitat for them.

There area a number of reasons for these very high bird densities in the riparian forests. Firstly, but not necessarily the most important reason, is the structural diversity found in riparian forests. Dr. Shaw touched on this a little bit with his discussion of the various vegetation layers that develop in a cottonwood forest. Certainly the vertical diversity of a canopy layer, a tall shrub layer, a low shrub layer and herbaceous layer provides many different niches for a variety of bird species. There is also a great horizontal habitat diversity. Anyone that has tried walking through a riparian area will have noticed the sudden changes from an open grassy area to thick thorny buffaloberry bushes. I believe this also contributes towards the high breeding bird densities in that it provides niches for birds that like open areas with just a few trees as well as those that like clumps of trees with fairly high densities of cottonwood trees.

I also analysed the foraging guilds. A foraging guild is a group of birds that eat the same things and use the same method of collecting and eating them. For example, a group of birds that forage and eat insects on trees would be a foraging guild. All the guilds that I found in Dinosaur Park were represented in the cottonwood habitat. The willow and sagebrush habitats contained less than half of the foraging guilds recorded. This demonstrates that there are a lot more niches in the cottonwood forests compared to other habitat types.

Other factors that contributed towards high breeding bird densities, included the "oasis effect". This occurs when a large number of birds are concentrated in a small area because there is not a lot of habitat outside that area for them. There is also a high density of insects which may contribute to the high breeding bird densities. There are a lot of backwater swales in Dinosaur Park where water sits for the whole summer. I am sure these wet areas contribute towards the high breeding bird densities and the food available for a lot of the bird species. The swales are also an alternate source of open water to the river.

Most of the riparian habitat in Dinosaur Park, or a lot of it, is within the natural preserve and is very difficult to access without going through private land. Therefore it was very rare that I would encounter anyone while I was doing my research. The general lack of human disturbance in the area presumably benefitted the bird population.

The presence of very large blocks of habitat improved habitat diversity and encouraged the bird population. Some examples of the Milk River shown by Dave Reid had very small patches of riparian habitat along the river. There are areas where large patches so occur along the MIlk River, but they are relatively small compared to areas that Dr. Shaw showed along the Waterton and Belly rivers. Island biogeographical theory states that the larger the area of habitat, the greater the number of species that will be found in that habitat. The large tracts in Dinosaur Park would therefore contribute to the high breeding bird density, or at least the high bird species diversity within this particular area of cottonwood forest.

Predicting the effect of modifications to the cottonwood forest requires estimating the effects based on the lifecycle requirements of each bird species and the data on population abundance that I collected in the bird census. I compared to this data to five scenarios to see what the effect would be.

The first scenario was the removal of overstory vegetation from the flood plain. This is something that has been reported over the last few days as a not uncommon occurrence. Secondly, the reduction of woody vegetation to narrow strips along the river edge; a situation that is common outside of Dinosaur Provincial Park along the Red Deer River. The removal of 50% of the woody canopy was considered third, and fourthly the removal of 50% of the shrub and woody canopy. These are often the disturbances that occur when a campground is built in a riparian area. The human disturbance factor was not take into consideration although it would have an added impact. Fifthly, the removal of 50% of shrubs alone was considered. This occurs with grazing, although in some places the entire understory may be removed.

These results are simply predictions to give an idea of what one might expect were these things to happen in Dinosaur Park. I think a lot of these general trends can be transferred to other areas in southern Alberta. Table 15.3 shows that 72% of the species that breed in the riparian zone could disappear under Scenario 1. The loss would be due to inadequate habitat or food for them. A further 14% would be reduced in numbers. These would be species that could use other habitats, but would prefer the cottonwoods if they were available.

Table 15.3. Prediction of percentage of species lost as a result of habitat modifications.

% of Species Recorded Breeding in Riparian Zone:	All Woody Vegetation Removed	Woody Vegetation Reduced to Narrow Strips	50% Woody Canopy Removed	50% Woody Canopy and 50% Shrubs Thinned	50% Shrubs Thinned
Eliminated	72%	31%	0%	6%	6%
Reduced	14%	46%	23%	40%	26%
Unchanged	0%	6%	69%	46%	60%
Increased	14%	14%	0%	0%	0%
Insufficient	0%	3%	8%	8%	8%

If woody vegetation was reduced to narrow strips (Scenario 2), different species would be eliminated. These are woodland species that need a large forest gallery in which to live. Narrow strips of woodland are not the kind of habitat that they would use. The loss of area of that habitat would likely cause a 46% reduction in the number of species inventoried.

The less dramatic effects or modifications, also cause a reduction in the number of bird species due to a loss of habitat and fewer feeding and nesting opportunities. Scenarios 3 and 4 could cause a 40%

reduction in bird species, but if the human disturbance factor is added, the loss would increase to include those species that are very vulnerable to human disturbance.

To conclude, it is obvious that riparian habitats are extremely important for prairie bird populations. These habitats support breeding bird densities and diversities considerably higher than those found in other prairie habitats. the elimination or modification of riparian habitats will result in a greatly impoverished bird fauna on our prairies.

16. A Model for Assessing the Impact of Altered River Flows on Riparian Poplars in Southwestern Alberta

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Some earlier presentations have indicated that there is cause for concern for the future of riparian cottonwoods in southern Alberta. Other presentations have identified critical elements in the biology of cottonwoods that could be limiting cottonwood replenishment. The direct factors reducing cottonwood abundance that have been discussed include grazing, cutting, or burning the forests. Indirect factors are hydrological alterations that reduce seedling establishment or the rate of regrowth, and lowered river sediment loads that limit the sites available for poplar replenishment.

Some of these elements can be integrated to produce a model that estimates the effect of changes to the flow regime of a river on riparian poplars. Change in hydrological pattern is just one factor affecting the survival of riparian forests. Other factors can also interact with river flow to determine the future of the forests.

Our studies have been focused in a geographical area different from many of those described in the literature. Most published reports are about prairie rivers. These rivers have a relatively low gradient, carry a high sediment load, and have flood peaks that rise and recede relatively slowly. Prairie rivers usually meander broadly and rapidly. For these rivers, sediment deposition during the meandering process appears to be important for building new seedling germination sites for riparian poplars.

In contrast, we have studied foothills rivers with much steeper gradients. These rivers flow over gravel or cobble beds and do not accumulate as heavy a sediment load. Flow peaks are fairly sharp, rising and receding very quickly. These rivers are usually straighter than prairie rivers and tend to braid more than meander. Where meandering does occur, it is less dynamic than along prairie rivers.

These differences in river type are probably important when developing management programs. Plans that are effective along foothill rivers may not work along prairie rivers, and vice versa. Other than the type of river involved, characteristics such as the poplar species found in the forest, the substrates of the flood plain and embankments, and changes in the flow regime need to be considered in building effective management programs.

Figure 16.1 presents a general hydrograph for a foothills river showing the hydrological factors important for poplar seedling survival through the first year. Some researchers consider large peak flows (Fig. 16.1, I) to be the most significant factor in cottonwood establishment and have attempted to relate cottonwood establishment to specific flood events. The timing of seed release is

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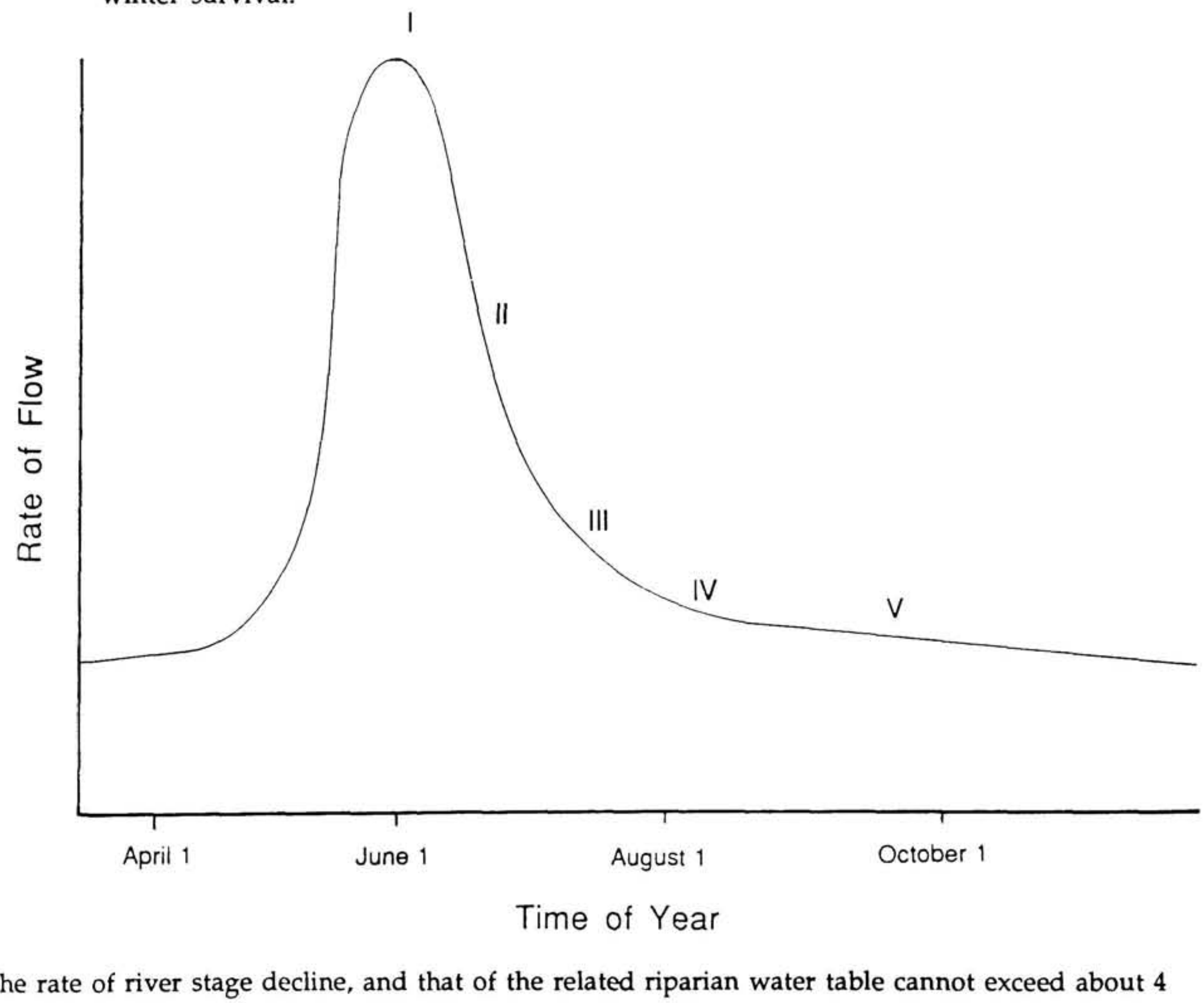
important so that seeds are released when river flows are receding (Fig. 16. 1, II). Seeds released prior to river stage decline will be flooded and washed away by rising water levels.

Figure 16.1. A general hydrograph for a river from the foothills of Alberta. The hydrological factors important for poplar seedling establishment are:

I. Peak flows to prepare germination sites,
II. Receding flows at time of seed release to expose new germination sites,
III. A gradual decline in water table level to limit seedling drought stress and promote root development,
IV. Adequate summer flows to meet high water demands, and
V. Minimum autumn flows to establish a good water balance and improve over winter survival.

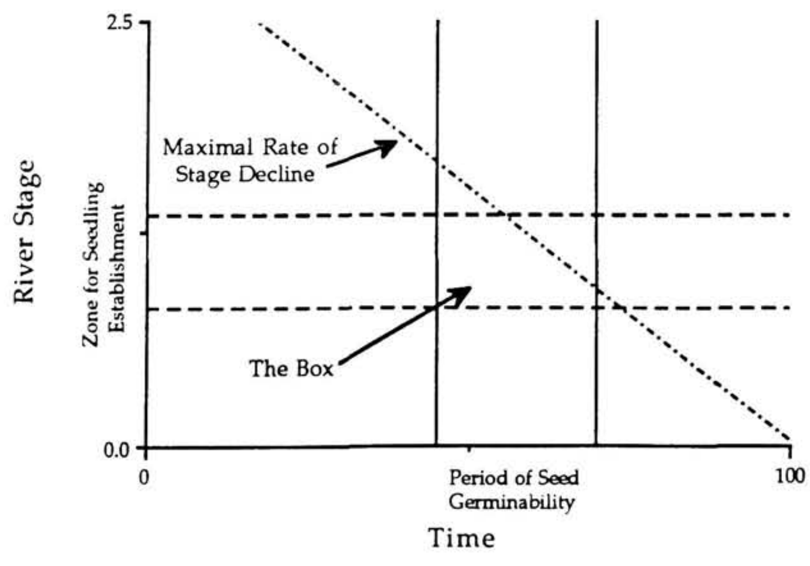


The rate of river stage decline, and that of the related riparian water table cannot exceed about 4 cm per day (Fig. 16.1, III). Poplars are phreatophytic depending mainly on groundwater supplies for moisture. Inability to maintain root contact with the declining water table will lead to drought stress and death. Research with rhizopods has shown that water table declines of about 4 cm per day have a detrimental effect on poplar seedling growth and that faster rates of decline are likely to be lethal (Mahoney and Rood, 1991; Rood and Mahoney, 1991).

Summer river flows must also be adequate to nurture seedlings through the season (Fig. 16.1, IV). Summer flows that encourage poplar growth will help seedlings survive the first season. The fifth factor, late summer and autumn flows (Fig. 16.1, V), has received little research attention. These flows are probably important for establishing a good water balance before winter. A good water balance will help poplars withstand the desiccating effects of cold temperatures and warm Chinook winds that can dry out seedlings very quickly.

These basic hydrological requirements for seedling establishment and survival were incorporated in a model of the conditions essential for poplar seedling success. The model framework (Fig. 16.2) is defined by river stage and the time of year. The river stage is important as it identifies a zone along the river bank in which poplar seedlings can survive. An upper bank elevation can be determined for successful poplar establishment. If seeds land on sites above this elevation, seedling root growth will not be adequate to tap deep groundwater sources by the end of the growing season. These seedlings will suffer drought stress and die. A lower bank elevation for seedling survival can also be determined. Seedlings establishing below this line are likely to be either scoured by ice or flooding the following year, or covered with fresh sediment deposited by the flood. These limits result in the formation of characteristic bands of poplar along river banks of the foothills and western prairies.

Figure 16.2. Model framework showing the box and the maximum survivable rate of water table decline for poplar seedlings in southern Alberta.



A critical period for successful poplar seedling establishment occurs every year. The period starts with the onset of seed release and continues through the period of seed release, usually four to six weeks. The critical period ends about one week after seed release is complete, when seeds have either germinated or lost their germinability.

The limits set by river stage and the period of seed release define the area that we refer to as the 'box'. The box identifies the zone along the river bank that will be important for poplar seedling establishment for a specific period of time.

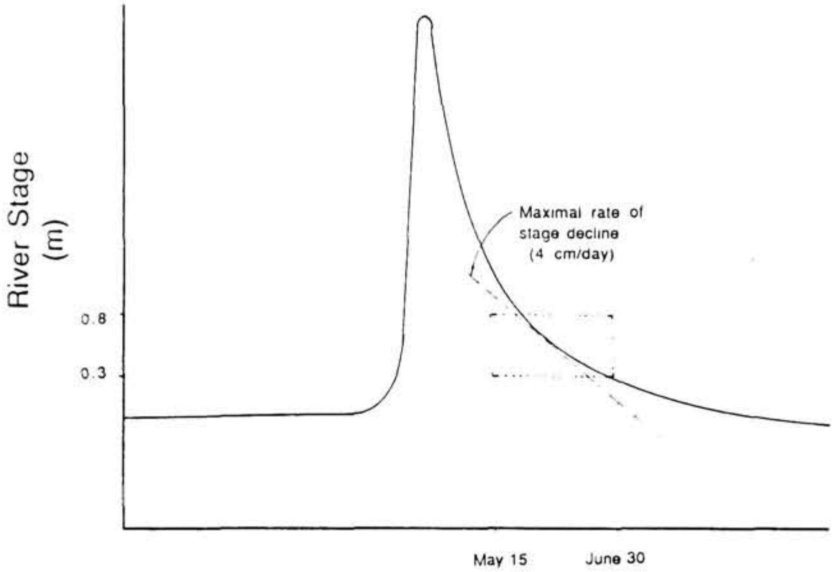
A third element can be added to the model. As noted in Figure 16.1, the river stage must be declining at the time of seedling establishment for successful establishment to occur. Results from experiments with rhizopods indicate that the rate of stage decline should be less than 5 cm per day to limit drought induced mortality in the seedlings. Although a constant water table will cause the formation of a shallow root system that may not withstand subsequent scouring, a constant water table will not limit poplar establishment and survival over the first growing season. A gradually declining water table is preferable as it promotes poplar establishment by exposing additional areas for seed germination and encourages deep root development in new seedlings. The optimal rates of water table decline will vary for specific river situations depending on the species involved and the texture of the substrate (Mahoney and Rood, 1991; Rood and Mahoney, 1991). For this model, a line representing the maximum survivable rate of river stage decline, with a slope of 4 cm per day can be added to the box (Fig. 16.2).

Figure 16.3 relates the model to a general hydrograph showing what could be ideal conditions for poplar seedling establishment. A peak flow precedes the box to set up fresh seed beds. Within the box, the early stage decline is too rapid for seedlings to maintain root contact with the declining water supply. The stage decline in the latter part of the box is slower than the maximum survivable rate. Seedlings established at this time should be able to maintain contact with the water supply as it declines.

This model can be used to explain why poplar establishment is not successful every year under natural conditions. Although, the elements that define the box are relatively constant, natural hydrological patterns vary from year to year. If peak flows come too early in the season, they may taper to low levels before seed release so that the hydrograph falls below the box (Fig 16.4a). When seeds are released, they germinate on sites at a very low elevation and are likely to be scoured away the next spring. Seeds released in years when peak flows are later in the spring will be washed away by higher flows that same year (Fig. 16.4b). Seedlings that are successful initially will be established at elevations too high for root penetration to the late summer water tables. These seedlings will probably suffer drought stress and die during the summer.

The effect of artificial flow patterns on poplar seedling establishment can also be estimated with this model. Figure 16.4c illustrates one scenario that occurs downstream from some dams in southern Alberta. Shortly after peak flows, the dam is closed causing an abrupt decline in downstream flows. In this case the rate of water table decline is too great for the roots to maintain contact with the water supply so seedlings die during the first season. This is probably the critical factor underlying the observed decline of poplar forests downstream of the St. Mary River Dam.

Figure 16.3. Model framework showing the relationship between a generalized hydrograph and the "box" and the survivable rate of water table decline for poplar seedlings in southern Alberta.



A second type of flow alteration is shown in Figure 16.4d. Initially it appears that a stabilized flow during seed release would be beneficial to riparian poplars. Although initial seedling survival may be good, root development would be shallow making the seedlings vulnerable to subsequent scouring or flooding. Stabilized flows also limit the zone and areas available for seedling establishment to a relatively narrow band along the river bank.

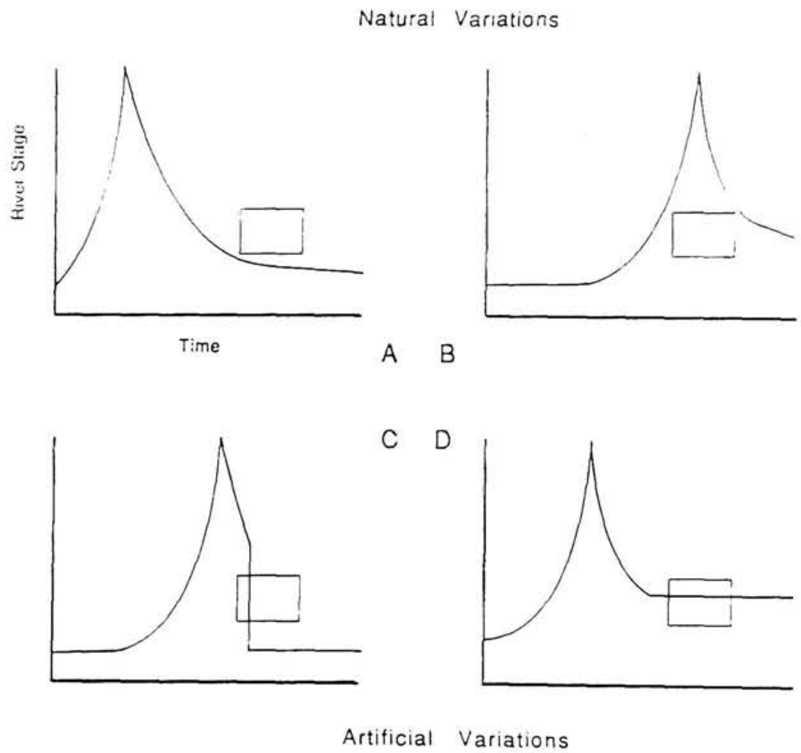
Given our current understanding of poplar ecology and physiology, this model presents a reasonable mechanism for estimating the impact of altered flow regimes on poplar establishment. The model can be validated by analysing historic flows and identifying the years that should have been favorable for poplar establishment. This would lead to the development of an expected age structure for the poplar forest. A comparison of the expected age structure with the actual age structure of the forest should show a correlation between good establishment years identified by the model and years of good establishment in the population.

Once validated, the model can be used as a predictive tool. Flow rates expected under particular circumstances, such as with the operation of a dam, can be estimated through computer simulations. The hydrographs generated would be compared to the model to determine the expected occurrence of successful establishment years. This projection can be compared to values derived from natural flow scenarios and the overall impact of the development estimated. If the analysis is completed before implementation of the operating guidelines for the dam, it may be possible to alter the release patterns for the benefit of downstream riparian forests without the significant use of stored water.

The model does not consider the effects of precipitation, temperature, wind, sunlight or other factors that undoubtedly affect the the success of developing seedlings; nor does the model address factors that may be important to poplar survival in other parts of the life cycle. Because of geofluvial differences, the model is probably more applicable to poplars growing along foothill rivers than to those of prairie rivers.

Figure 16.4. Variations in river flows and their relation to the "box".

a. Peak flow receding to minimum levels before the onset of seed release,
b. Peak flow receding to minimum levels after seed germinability has ended,
c. Abrupt reduction of river flows during the period of seed germinability, and
d. Constant flow regulation during the period of seed germinability.



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17. Riparian Vegetation and Water Management: Issues, questions, answers.

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I will talk about water resources planning: where we are, where I see us going over the next few years, and how that relates to questions that arise from these meetings. We have been talking about the rivers of the south Saskatchewan River basin and the Milk River. These are all rivers that have been manipulated to some degree. There is probably more manipulation in these systems than most Albertans are aware of. But, at the same time, there is probably less control of these rivers than many of us think.

There are no water management structures on the Milk River in Alberta or major withdrawals from that river. There is however, flow augmentation by diversion from the St. Mary to the Milk River in the summer months in the United States. The water flows through Canada and is picked up again in Montana at the eastern crossing into the United States.

The Red Deer River has the Dickson Dam that started operation earlier in the 1980's. There are some withdrawals, a few with auspicious names like Dead Fish Diversion. The Dickson Dam catches a portion of the spring flow, and then fills more gradually over the summer months. That stored water is used to maintain downstream flows throughout the winter months. It is, therefore, a flow regulation structure since it releases back to the natural river channel all of the water it stores.

As shown earlier (Cordes, 1991), the Bow River is the system that has been the most altered for the longest time in the province. There is a network of seven or eight hydro electric reservoirs on the Bow and its tributaries (Figure 17.1). A hydro electric reservoir is operated to store water when in abundance for use during peak demand periods; usually the winter months. The Bow is also dammed to provide for municipal water supplies as is the Elbow River.

The irrigation system of southern Alberta is even more complex (Figure 17.2). The Bow River has three major diversions flowing into the irrigation system. One is the Western Irrigation District (WID) Canal, the second is the Carseland Dam Diversion through McGregor, Travers and Little Bow Reservoirs into the Little Bow River system. This transfer system has been in existence for a long time. The Eastern Irrigation District (EID) diversion is the final major diverter from the Bow River. There are minor diversions from the Highwood River at the Little Bow Diversion and one called Squaw Coulee. Further south there is a major diversion coming from the Oldman River, the Lethbridge Northern Irrigation District (LNID) headworks, over to Keho Lake. There are dams and diversions from the Waterton, St. Mary and Belly rivers as well.

What do these developments do to the system? A hydro electric reservoir stores water during spring and summer for winter peak demand. In general, the effect on the Bow River has been to even

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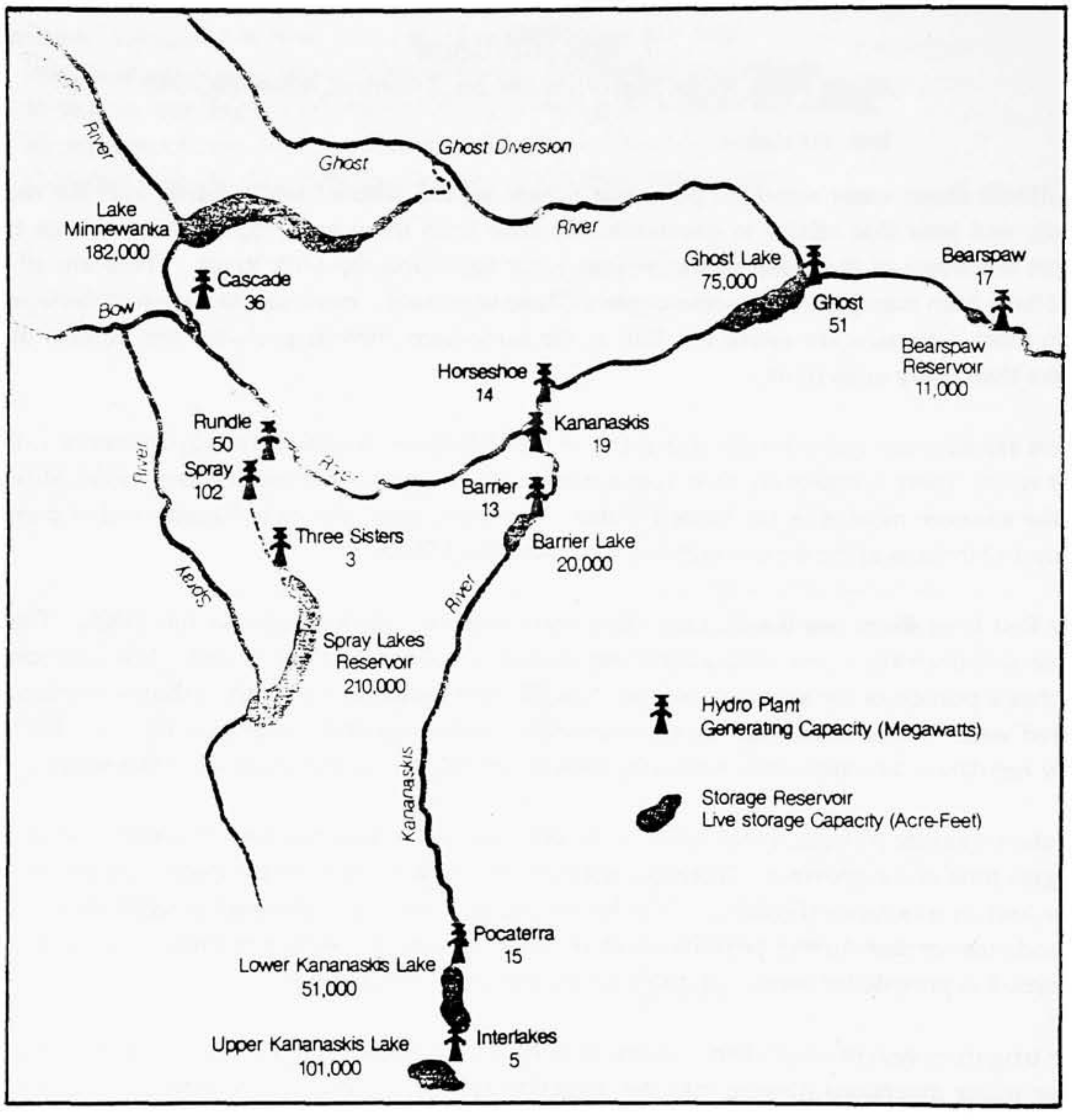
Figure 17.1. Storage and generating capacity for the hydro system along the Bow River (Alberta Environment, 1984).

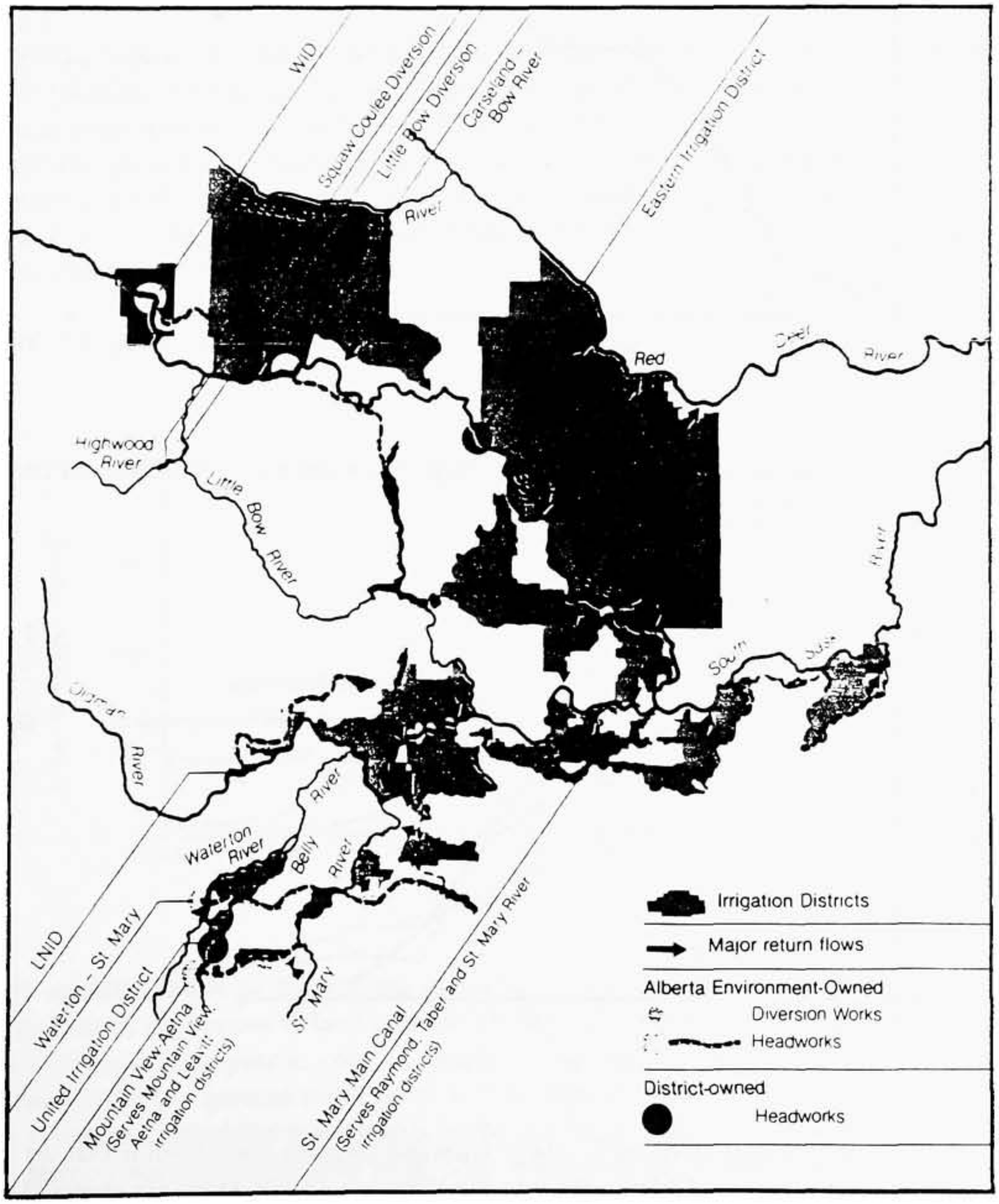


out the flows throughout the year by reducing the peak and augmenting flows for the rest of the year. However, some of the reservoirs are operated to supply daily peaking. Figure 17.3 shows the 24 hour release pattern below a reservoir operated to supply daily energy demands.

An irrigation reservoir, on the other hand, is operated to capture a portion of the spring flood for use later in the irrigation season. Figure 17.4 shows a generalized natural hydrograph compared to the period of peak irrigation demand. It can be seen that peak water supply occurs somewhat before the peak irrigation demands on an annual basis.

Diversion structures such as the LNID Headworks, simply divert a portion of the flow of the river by a weir into a canal. Within Alberta, diversion weirs do not divert much of the spring flow because they are not sized to divert a high proportion of peak river flows. During the summer, when flows are low or when there are a series of weirs, such as along the Bow River, the river gets smaller and smaller as it flows downstream as a greater portion of the flow is diverted. These diversions accumulate until, in places like Police Point, only a very small river remains in the summer months. Those are the simple facts of the present irrigation system.

Figure 17.2. Irrigation water supply systems in the South Saskatchewan River Basin (Alberta Environment, 1984).



The St. Mary reservoir, like the Waterton, is not simply a storage reservoir that releases water into the natural channel. It is a storage reservoir with a canal diverting water from it. This is the underlying reason for the abrupt drops in the downstream flows noted earlier (Rood and Heinze-Milne, 1988; Mahoney and Rood, 1991). Once the spring floods have passed, the reservoir outflow is shut off and water is diverted into the canal to the irrigation districts.

Figure 17.3. The general pattern of energy production in the Bow River hydro system.

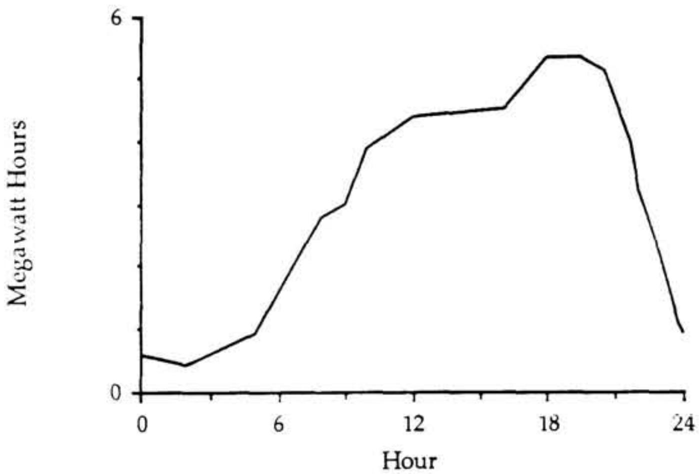
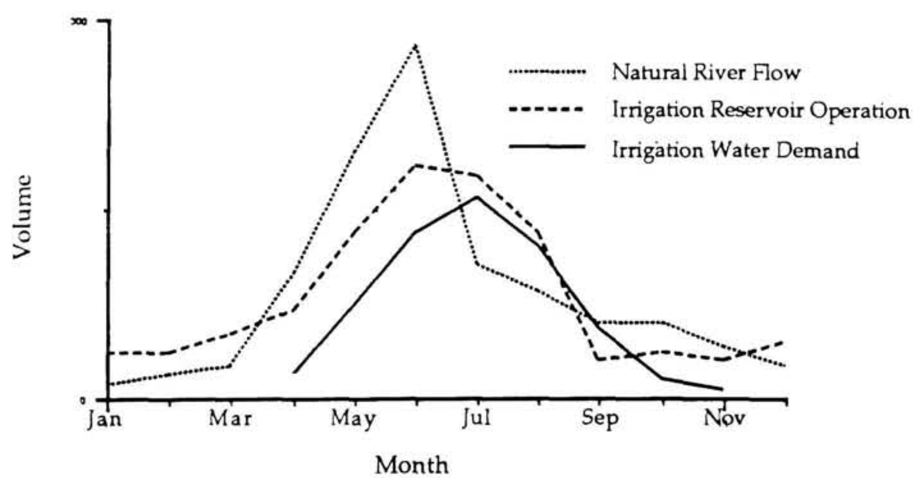


Figure 17.4. Seasonal relationships between natural flow, irrigation water demand, and irrigation storage reservoir operation.

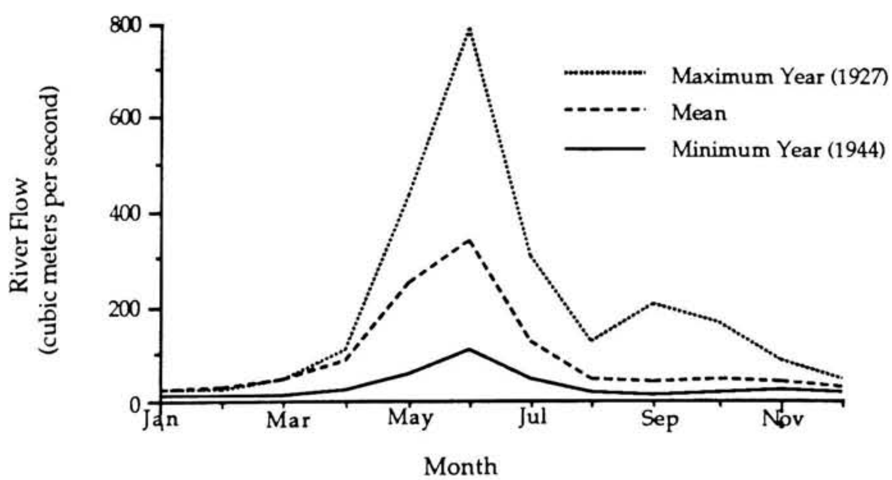


The difference between the Waterton and St. Mary dams and Oldman River Dam is that we cannot, even if we wanted to, operate the Oldman the way the Waterton and St. Mary are operated. There will not be a canal coming off the Oldman Reservoir. The release is back to the natural channel. The portion of the peak flow captured is released back to the natural channel. Also, once the reservoir is full, which is projected by the end of May for the seven years out of ten, there is no alternative but to release at least the natural flow and possibly the natural flow plus augmentation.

As we have discovered on developing operation plans for the Oldman River Dam, all of these systems are interrelated. The manner in which we operate the Oldman depends in part on how we operate the remainder of these reservoirs. Thus, when we have evaluated the operating plans for the Oldman, we have also evaluated the effects on the Waterton, St. Mary, Belly rivers and all the other components of the South Saskatchewan River Basin.

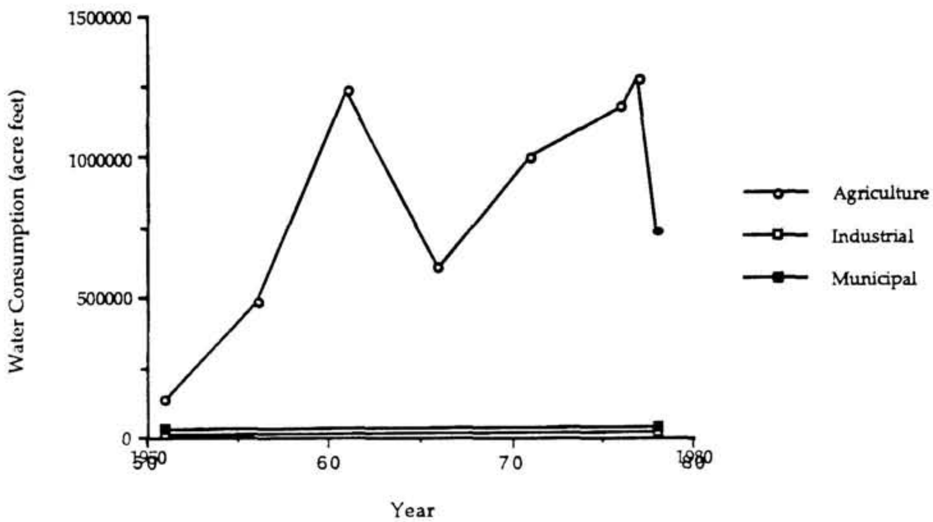
Everything I have presented so far is a simplification. Anyone who works in the natural sciences knows the idea of a normal year or a normal hydrograph is only conceptual. Figure 17.5 shows a series of hydrographs from the Oldman River at Lethbridge. The average, high and low years on record are represented. Obviously one cannot operate the dam to accommodate the range of flows expected in all of these years. The operation of the dam will not, therefore, have the same effect in every year. The dam may have substantial effects within the system on a very dry year. It will have a lesser effect on a very wet year.

Figure 17.5. Flows of the Oldman River near Lethbridge.



There are differences in the volume of water diverted for any given year. The expansion of irrigated land, the amount of land actually irrigated, and the amount of water required for a unit of land all change from year to year. A graph of irrigation use from 1951 through 1978 shows that although there is a general trend, there is considerable variation from year to year (Figure 17.6). This variation depends on factors such as the rainfall in a given year or whether the government paid farmers not grow crops that year. This means that our ability to predict irrigation demands will be less than perfect.

Figure 17.6. Historical water consumption in the South Saskatchewan River Basin.



One of the things that I would like to make clear is that with the systems we are discussing, we cannot moderate really large floods. The storage is simply not there. For example, the Dickson Dam on the Red Deer River, has a storage capacity of 150,000 acre feet. The mean annual flow of the Red Deer River is about 1,500,000 acre feet. The storage in that system is not enough to control major floods. Similarly, even with all the reservoirs on the Bow and the on and off stream storage on the Oldman, there is insufficient storage to moderate a major flood. In the case of the Oldman Dam, the reservoir will be filled by the end of May seven years out of ten. That means that floods of the one in two year size, or greater, will pass more or less unabated.

I cannot say the same for projects that are under consideration for the Milk River. It is a small river with a mean annual flow of just 256,000 acre feet. The largest reservoir under consideration right now in that system will hold 250,000 acre feet. I think that where the ability to moderate large floods has not been an issue for the other rivers, if the Milk River project proceeds, it may well be a legitimate question.

Where do we stand? I will say that I have been working on the Oldman Dam project for a number of years now. We are working on an operating plan for the reservoir that does take into consideration riparian vegetation. We have gone through a few iterations and will be going into yet another. Of course the work of the vegetation mitigation team is doing is helping us refine those plans.

We also have new projects on the books. We have the Little Bow Reservoir on the Little Bow River, although there are not any cottonwoods down there. There are, however, cottonwoods along the Highwood River and environmental studies for the project will include this riparian vegetation. The Pine Coulee Reservoir is offstream storage for Willow Creek. Willow Creek does have cottonwoods near its confluence with the Oldman River. There is a commitment on the part of the Alberta Government for full and formal, environmental impact assessments to be done on each of these new projects prior to the government committing to go ahead with them. The environmental impact assessments will examine the downstream or operational effects on riparian vegetation. Similar commitment will exist for the Milk River Reservoir if and when anyone decides to pursue it seriously.

There is another initiative underway. A few years ago, the Alberta Water Resources Commission released a report following a series of public hearings that said we should establish instream flow requirements for all major rivers in southern Alberta. The government has accepted that recommendation and is moving to set instream flows for all of the rivers in the South Saskatchewan River Basin. The following paper (Brodie, 1991) deals with the rationale and procedures that are to be followed.

What is meant by instream flows is simple - what flows do we need within those rivers to satisfy fish, water quality, riparian vegetation, and recreation needs, and how do we meet those needs in the licensing and operating guidelines for all these reservoirs? What we need to know is how much water is enough to sustain the riparian forests. That is the question. Are the flows we have seen along the Oldman River at Lethbridge over the past five years enough? Very low flows such as those at Lethbridge over the past five years occur naturally. The trees that are here now have obviously survived the low flows of the past. Can they survive low flows five years in a row? If flooding is necessary, how often and to what degree? To what degree are other influences significant in the maintenance of these riparian forests? Alberta Environment, the department that will ultimately operate these reservoirs, and administers the water management system that licences water, can make adjustments to meet the instream flow requirements once they are established. That is were your help is needed.

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18. Alberta's Process for Establishing Instream Flow Needs and its Riparian Vegetation Component

Christine Brodie
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In Southern Alberta water is a valuable resource that has many consumptive or "out-of-stream" demands placed on it by agricultural, municipal, residential and industrial uses. Recently, there has been a growing interest in maintaining and protecting river flows for "in-stream" uses.

The instream flow regime of a river affects a variety of organisms that live in or use the river or its associated riparian habitats. The rivers provide habitat for fish species and other aquatic life. The associated riparian habitats are often highly productive ecosystems that support a variety of plant life and provide habitat for numerous bird, terrestrial and semi-aquatic wildlife species.

Other instream uses affected by river flows are water quality, aesthetics and recreational activities.

The flow requirements for protection of these resource values are often termed "Instream Flow Needs" or "IFN". Several IFN methodologies exist for the various resources requiring flow management and protection - fish, water quality, recreation and riparian vegetation.

The primary focus of IFN has been related historically to fish resources. The Instream Flow Incremental Methodology (IFIM), developed by the U.S. Fish and Wildlife Service, is often a preferred method for determining the instream flow requirements for sport fish species. The objective of this method is to derive relationships between stream discharge and physical habitat availability for the fish species and life stages of interest. These relationships, together with natural flow data and flow requirements for the maintenance of suitable water quality, are used to define instream flows required to protect the target fish species.

The IFIM can be applied to other resources requiring flow protection (aquatic invertebrates, coarse fish and minnow species) and is currently being used to develop flow protection requirements for riparian vegetation (i.e. cottonwoods). Other IFN methodologies for riparian vegetation are being investigated and the field is opening up to new approaches and technologies.

RIPARIAN VEGETATION COMPONENT

Riparian vegetation is an important component of the IFN process for many southern Alberta rivers. The riparian woodlands offer a moist and shaded refuge for livestock and wildlife in an otherwise semi-arid and open grassland environment. Several of the plant species providing this refuge, in particular the plains cottonwood (*Populus deltoides*), are dependent upon a stable water supply and periodic spring flooding to survive. Changes to the flow regime can affect the rate of growth

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and the rate of cottonwood seedling establishment.

In addition to wildlife, riparian vegetation is linked with the fisheries component (i.e. provision of cover, shade and food) and the recreation component (i.e. picnic and campsite areas).

The objectives of the riparian vegetation/wildlife component of the IFN process include:

1. Identify existing riparian vegetation communities in the study area including the species present, extent of cover, density and distribution.

2. Determine the importance of the riparian vegetation communities as habitat for fish, wildlife, cattle and recreation.

3. Determine the relationship between instream flows and the growth or survival of riparian vegetation that is critical for habitat or recreational purposes.

4. Determine possible causes of impacts that have already occurred due to flow regulation, land use, browsing, grazing or pesticide use.

5. Access potential impacts of proposed changes to the existing flow regime on downstream riparian vegetation communities.

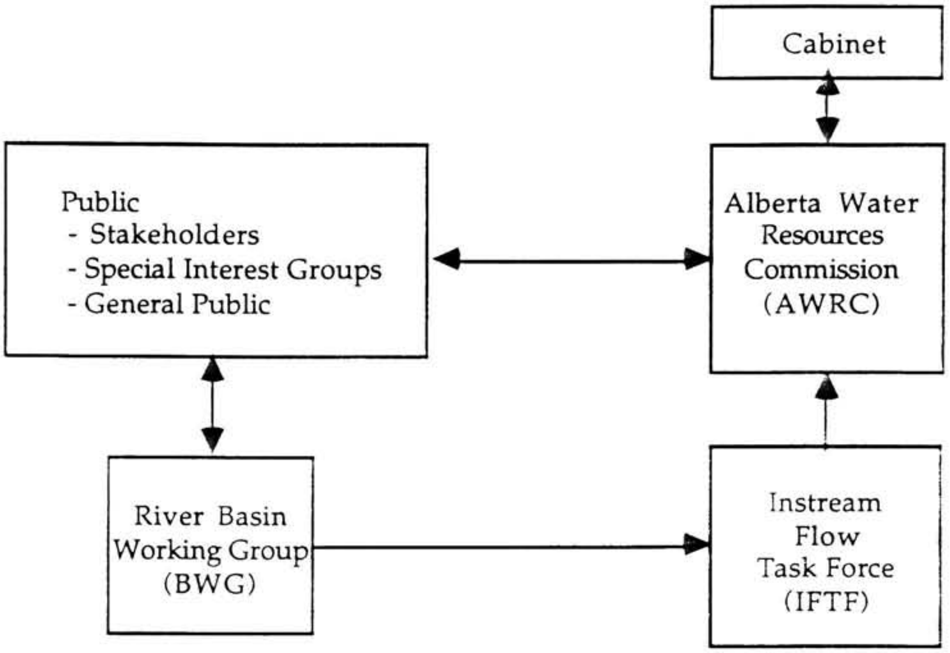
6. Determine methods for maintaining or recovering riparian vegetation communities.

Inventories of riparian vegetation communities are essential baseline data needed to be able to assess and monitor potential impacts. However, the timing of IFN studies does not always permit comprehensive field studies. Existing information from any previous work in the study area is acquired first. A work plan that addresses the data gaps is then prepared and work schedules and budgets are allotted.

The determination of flow requirements for cottonwood trees is a difficult task and methodologies in this discipline are in the formative stage. Work is continuing on establishing the cause and effect relationships between flow regimes and riparian vegetation. Modified flow regimes are examined to determine the possible impacts on riparian vegetation. From this assessment, reservoir release recommendations can be made (eg. spring flows to stimulate flooding) and any other possible mitigative techniques can be considered to minimize impacts (eg. fencing of sensitive areas, planting).

Once the riparian vegetation component work plan is complete, its flow recommendations are compiled with those of all the other instream uses and an attempt at striking a balance between all the needs is made. Compromises must also be made between instream and consumptive uses or diversions.

Figure 18.1. Planning and management strategy for establishing instream flow needs for Alberta streams.



INSTREAM FLOW PROCESS

In the fall of 1988, Alberta Environment initiated a provincial planning and management strategy for establishing instream flow needs (IFN) for Alberta streams. The process is set up to define flows required to protect instream uses on critical river reaches. Instream uses of water traditionally include the protection of fish habitat, the maintenance or improvement of water quality, and recreational activities. Riparian vegetation is a key component in maintaining the ecology of rivers or streams and is essential for the wildlife resources and recreational activities associated with rivers or streams.

The IFN process involves the interaction of four major groups: the Alberta Water Recourses Commission (AWRC), the Interdepartmental Instream Flow Task Force (IFTF), the Interdepartmental River Basin Working Groups (BWG) and the public. Representatives of five provincial government departments are members of the IFTF and the BWGs: Alberta Environment (Chair), Alberta Forestry, Lands and Wildlife, Alberta Agriculture, Alberta Municipal Affairs, and Alberta Recreation and Parks. The Alberta Water Resources Commission is also represented on the IFTF and plays a key role in the approval of the recommendations forwarded from BWGs and the IFTF. Figure 18.1 graphically outlines the reporting levels of the provincial IFN process.

Priorities for river basins to be worked on are set by the IFTF. The southern Alberta river basins are the primary focus of the IFN process due to a combination of relatively limited water supply and high irrigation demands. River basins that have been priorized are the Bow River Basin (Highwood River), the Oldman River Basin (St. Mary, Belly and Waterton Rivers and Willow Creek) and the Red Deer River Basin (Red Deer River). Several other creeks and rivers within these major southern basins have also been identified as critical and they will soon be addressed in the IFN process.

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