DETERMINING OPTIMAL INITIAL STOCKING DENSITIES DURING MINE RECLAMATION[1]

by

Peter R. Guy and J. Cam Bateman[2]

Abstract. The purpose of this study was to describe ways of determining what planting densities should be used on reclaimed land. Data were collected to rate various species on their 'aggressiveness' or their ability to colonize new areas. Recommendations were made on what planting densities would lead to the development of three different plant communities on reclaimed tar sands in northern Alberta.

Introduction

The "Guidelines for the Reclamation of Land in Alberta" (Alberta Land Conservation and Reclamation Council, 1977) state:

> "where the prescribed post-disturbance land use is the establishment of permanent vegetation suitable for wildlife habitat, the operator is responsible for the establishment of various species and numbers of trees, grasses, forbs and shrubs of a density and composition which will provide food and cover for wildlife, consistent with the ecological zone of the region and satisfactory to the Approving Authority".

Because the target densities and species composition of wildlife habitat on reclaimed areas have to be consistent with the ecological zone of the region, routine field work in the areas surrounding the area to be reclaimed provides this information. What is less simple to determine is what planting densities should be used to ensure that the target densities are achieved.

Some Concepts of Reclonization

We believed that the target densities could be met in two ways by (1) establishing a few plants of each species and allowing natural succession, regeneration and immigration to take place; or (2) by establishing many plants of each species and allowing natural mortality and competition to take place.

These were termed the primary innoculum and the secondary innoculum, respectively the terms having been derived from the ecological concepts of primary and secondary succession. Primary succession is defined as "development which begins on an area that has not been previously occupied by a community", and secondary succession as "community development proceeding in an area from which a community was removed" (Odum 1971). Secondary succession is more rapid than primary succession because some organisms or their disseminules are already present, and previously occu-

[1]Paper presented at the conference Reclamation, A Global Perspective, held in Calgary, Alberta, Canada August 27-31, 1989.

[2]Peter Guy is a Biologist and Cam Bateman a Forester with Monenco Consultants Limited, Calgary, Alberta, Canada, T2P 3W3.

Proceedings America Society of Mining and Reclamation, 1989 pp 317-326
DOI: 10.21000/JASMR89010317

https://doi.org/10.21000/JASMR89010317

pied lands are more receptive to community development than sterile areas.

The species densities established in a secondary innoculum would be close to those found in climax communities; the species densities established in a primary innoculum are much less but over time these will result in densities equal to those in climax communities i.e. will succeed toward the density of a secondary innoculum. The major difference in these two alternatives is the time frame and this has important ramifications to the approach industry might adopt when initiating a reclamation project.

The time taken for a community to progress through secondary succession and the stocking densities of the major species involved are well documented (e.g. Odum 1971). However, the time taken and the densities of plants involved in primary succession are not well documented, making it very difficult to formulate stocking density recommendations. The time factor is dependent both on the silvical characteristics of the individual species involved and on the edaphic conditions. The ideas that follow are based primarily on the silvical characteristics because it is believed that ultimately these will be the major factors controlling community development on reclaimed sites throughout Alberta.

Species Aggressiveness

To meet the objective of this study information on silvical characteristics that determine the "aggressiveness" of a species was collected. The rate of spread of a species is determined by characteristics such as: (1) the primary means of reproduction, (2) reproductive age, (3) seed viability, (4) seedbed requirements, (5) seed dispersal distance, (6) seedling survival rates, (7) degree of vegetative reproduction, (8) reaction to competition, (9) seed crop periodicity and (10) amount of seed produced. Stocking densities should be based on these characteristics: the premise being that over a given period, aggressive species will require lower stocking densities initially than less aggressive species. However, the aggressiveness of a species also depends on the site conditions encountered and the subsequent management procedures provided. For example, because suckering in aspen is dependent upon temperature and light, planting densities need be considerably less on south facing slopes than on north facing slopes because of the increased insolation. Removal of apical dominance has also been shown to be an effective means of increasing densities in aspen stands (Schier, Jones and Winokur 1985). This causes profuse and vigorous suckering, increasing aspen's aggressiveness. Where these management practices can be implemented, the initial stocking densities can be reduced.

The dependence of lodgepole pine on fire in natural situations is a classic example of factors affecting the regenerative potential of a species. Lodgepole pine is most aggressive on sites where repeated fires occur because it produces seed at an early age, and the amount of seed available for regeneration increases with time because the seed is held in serotinous cones. In formalizing this concept, Rowe and Scotter (1973) rated various coniferous species on their regenerative ability following fire. Jack pine was given the highest index because it stores a lot of seeds, it produces seeds when young, it has frost-hardy, rapidly growing seedlings and it grows well in full sunlight. On the other hand, white spruce was rated less highly, because it does not produce seed when young, it does not store its seeds, it is not frost-hardy and it prefers to grow in partially shaded sites. Therefore it is logical to assume that a higher initial stocking density of white spruce would be required to provide the same density as jack pine at a given age following a fire.

Following the lead of Rowe and

Scotter (1973), data for various species were compiled from the literature to determine how quickly a species could spread from seed alone. The age of earliest and abundant seed production, the number, periodicity and quality of seeds produced, dispersal distance, and viable seed to established seedling ratio are given (Table 1). Also included is the average seedling survival of each species at the Suncor site in northern Alberta.

Using these data, the expected rate of spread of these species by seed can be calculated. An example is given below for paper birch.

Assume: 1 paper birch planted in 1985 into an area with an organic seedbed

First seed produced: 1985 + 15 years = 2000 and every two years thereafter
Viable seed: 150 000 seeds produced x 20% viable = 30 000 viable seeds
Seedlings: 30 000 viable seeds ÷ 400 seeds/seedling on organic seedbeds = 75 seedlings
Seedling Survival: 75 seedlings x 20% survival = 15 established seedlings

These calculations show that one paper birch planted in 1985 will give rise to roughly 15 established seedlings in 2001, 2003, 2005 ... etc.

The number of established seedlings on mineral soil is increased by up to 300 in 2001 and every two years following (Table 1). The differences for seedling establishment between mineral soil and organic seedbeds for the other species are even more dramatic.

The same exercise for white spruce indicates approximately 14 seedlings will become established on organic seedbeds and up to 600 seedlings on mineral soil in the year 2006 and every three years thereafter.

The high rodent populations which frequently occur on reclaimed sites and the sod-forming nature of many herbaceous species used in reclamation, such as red top and bluegrasses, will limit reproduction from seed. However, some species have been reproduced successfully from seed on reclaimed areas. At the Victory Mine near Wabamun, Alberta, Manitoba maple, green ash and caragana have grown from seed in a plantation established in 1958 (Monenco Limited 1982). All three of these species are precocious seed producers and produce relatively large seeds capable of germinating in extreme conditions. However, the main avenue of establishment of deciduous species from an innoculum is likely to be from sucker and root sprouting rather than from seed.

Various deciduous species have been rated for their aggressiveness as invaders (Table 2). As data are limited, ratings are based on experience gained in reclamation programs throughout Alberta and through discussions with experts in woody plant establishment in Alberta. Some factors affecting the aggressiveness of a deciduous species are its ability to sucker, tolerance to heat and light and seed mobility. The time to seed bearing age is less important for deciduous species. Poplar seed is so highly mobile that seed will originate from the surrounding forest more often than from those planted, although species such as red-osier dogwood, bracted honeysuckle, and buckbrush have been known to produce seed on reclaimed areas just two years after planting (Monenco Limited 1983). Tolerance to heat and light is an important consideration in determining the aggressiveness of a species planted in open conditions. Combined with the silvicultural characteristics of each species the other most important factor affecting required initial stocking densities is the survival rate of the species.

Post-Mining Plant Communities - Suncor's Tailings Ponds

The location of the plant communities that become established will be governed primarily by drainage and topography. In the following discus-

TABLE 1
Seed and Seedbed Reproduction Variables

	White Spruce	Black Spruce	Paper Birch	Aspen	Balsam Poplar	Jack Pine	Alder	Tamarack	Bebbs Willow	Choke Cherry
Earliest Seed Production (year)	20	10	15	20	20	5-10	10	12-15	4	2
First abundant production (years)	45-60	25	40-70	50-70	20	40-50	25	40	25-75	n.d.
Seeds/tree	60 000 to 184 000[a]	3 500[b]	150 000[c]	1.5×10^6	1.5×10^6	11 000[f]	n.d.	300 000	n.d.	n.d.
Seed quality (percent of total crop)	45	47	20	95	95[e]	75	28	47	28	77
Dispersal Distance (m)	50-300	30	50	Long	Long[e]	Close to Parent	50	2x Height	Long	n.d.
Periodicity of seed crop (years)	3	4	2	4-5	1	4	1-4	3-6	1	1-2
Viable seed: seedlings ratio										
Mineral soil	12 to 24	3	20-400	1.4×10^6[h,i]	1.4×10^6[e,i]	6[j]	n.d.	n.d.	n.d.	5
Organic matter[g]	800 to 1000	100	400+	Impossible	Impossible	Impossible				
Seedling survival to 3 years (%)[k]	40	40	20[l]	20	5[m]	60[l]	5	4	10	30

Source: Zasada (1971). n.d. = no data
[a] Zasada (1971)
[b] From: 500 cones/tree (Zasada 1971); 11 000 cones/bushel; 3 oz. of seed/bushel of cones; 404 000 cleaned seed per pound (Fowells 1965)
[c] Assume a density of 1200 trees/ ha, 227 million seeds/ha (Zasada 1971) thus 189 367 seeds/tree, and thus conservatively 150 000
[d] Assumes 1000 catkins/tree (increase with age) (Fowells 1965) 1500 seeds/catkin for the closely related (P. tremula), and 100 seeds with cotton weighing 0.065 gms
[e] Thought to be same as aspen (Zasada 1971)
[f] Hellum (1983)
[g] Thickness of organic layer less than 8 cm except for black spruce (Zasada 1971)
[h] From: Shopik (1984) 700 gms of catkins/50 m^2, 100 seeds/0.065 gm (Fowells 1965), i.e. 1.0×10^6 seeds/50 m^2 with survival of 7.75 stems/50 m^2
[i] Seed viability very limited (Fowells 1965)
[j] On a burned seedbed (Ahlgren 1959)
[k] Conservative estimates from Shopik (1984 and 1985)
[l] Survival to end of 2 years (Shopik 1984)
[m] Low survival rate based on Monenco Limited (1983) and Shopik (1984 and 1985)

TABLE 2
Rating of Deciduous Trees and Shrubs on Silvical Characteristics Contributing to Successful Regeneration

Species	Suckering Ability	+	Tolerance to Heat and Light	+	Seedling Growth Rate	=	Aggressiveness
Northeast Poplar	5		5		5		15
Walker Poplar	5		5		5		15
Acute-leaf Willow	4		5		5		14
Balsam Poplar	5		5		4		14
Laurel-leaf Willow	4		5		5		14
Aspen	5		5		3		13
Glauca Willow	4		5		4		13
Rose	4		5		4		13
Sandbar Willow	4		5		4		13
Raspberry	4		4		3		11
Beaked Hazelnut	4		4		2		10
Bracted Honeysuckle	4		3		3		10
Choke Cherry	4		3		2		9
Pin Cherry	4		3		2		9
Red-osier Dogwood	3		3		3		9
Saskatoon	2		5		2		9
Green Alder	2		2		3		7
Paper Birch	2		3		2		7
Snowberry	3		1		2		6
Buffalo-berry	1		2		1		4

NOTE: Higher number means higher regeneration potential.

sion, recommendations are made for the establishment of plant communities, primarily for wildlife habitat, on the three main landforms, overburden, tailings sand slopes and tailings sand plateau areas associated with the post-mining environment on Suncor's lease area.

In poorly drained tailings sand and overburden areas a Poplar/Willow/-Alder/White Spruce association should be established. Portions of the tailings sand plateaus will have a very high water table. Such sites will be too moist for the establishment of jack pine. On moderately well and imperfectly drained overburden materials a White Spruce/Poplar/ Shrub community is recommended. The moisture conditions in these finer textured overburden materials is similar to that of the luvisolic soils on glacial till that support mixedwood stands in the natural environment. A White Spruce/Poplar/Shrub community is also suited to lower slope positions with northerly aspects on the tailings sand slopes. On off-mine sites these topographic positions are inhabited by mixedwood stands.

A Jack Pine/Poplar/Shrub community is recommended for the tailings sand slopes. The deciduous component of this community will, through suckering, aid in erosion control and stabilization of the slopes. However, competition from herbaceous species on these areas would have to be taken into consideration when determining innoculum planting densities. Survival rates on tailings sand slopes with competition from grass/legume species will be lower than where cereals are used because erosion is less of a concern.

On the well-drained tailings sand plateaus, our study indicated that a

Jack Pine/Poplar/Shrub community should be developed instead of the Jack Pine/ Bearberry/Lichen community previously recommended for these areas (Suncor Inc. Resources Group 1983) owing to the poor capability of this latter community to support wildlife.

Selection and Composition of Species for Wildlife Habitat

Selection of species for the creation of specific habitat types on reclaimed areas should be based upon: (1) the importance of the individual species in providing food or cover for wildlife; (2) the presence of the species in the natural community which is being re-established, and (3) the potential of the species to act as a pioneer or early successional species, noting that the composition of each plant community is extremely variable; both spatially and temporally.

Species composition in the natural communities is influenced predominantly by changes in microsite conditions. This same principle is expected to apply in the reclaimed landscape. Species more adapted to a specific microsite or those more competitive than their neighbor will succeed. In the design of an innoculum for the development of each community, the basic premise should be to provide a composition where each species has roughly equal opportunity to be represented in the final community. If each species has an equal opportunity to succeed, then those best adapted to each microsite or those with slight competitive advantages in each situation will dominate as the community develops.

The following sections specify plant species and composition for an innoculum for the development of each of the habitat types recommended.

Poplar/Willow/Alder/White Spruce. The moisture regime for areas where this community will be established will range from that found in the forest communities on alluvial soils to that found where this community has developed on gleyed soils. The most important species in these communities are balsam poplar, white spruce, alder, willow, dogwood and paper birch. As noted earlier, white spruce cannot be considered as an aggressive pioneer species. It is unable to reproduce vegetatively and does not produce seed for 20-30 years. White spruce is therefore not considered useful in providing an innoculum. In re-stocking white spruce on cutblocks harvested for timber, the normal practice is to plant in preferred locations seven years after the completion of logging. This practice allows for the introduction of spruce to occur in partially shaded sites as well as meeting the ten-year requirement of full stocking with three year old conifers. It is recommended that a similar strategy for the establishment of white spruce on reclaimed sites.

Because hybrid poplars and willow cultivars are some of the most aggressive species available for reclamation, they should be planted in this community. They will provide fast canopy closure and will ameliorate site conditions for the establishment of less tolerant understory species and white spruce.

The species composition of an innoculum which gives each of the recommended species roughly equal opportunity to be represented in the final stand can be calculated using the aggressiveness ratings developed earlier in the following way:

Species	Aggressiveness	Pro-rating	% Composition
Northwest poplar	15	1.00	7.4[a]
Walker poplar	15	1.00	7.4
Acute-leaf poplar	14	1.07	7.9
Balsam poplar	14	1.07	7.9
Laurel-leaf willow	14	1.07	7.9
Glauca willow	13	1.15	8.5
Sandbar willow	13	1.15	8.5
Dogwood	9	1.67	12.4
Alder	7	2.14	15.9
Paper birch	7	2.14	15.9
		13.46	100

[a] Pro-rated value expressed as a percentage of the total.

White Spruce/Poplar/Shrub. Mixedwood

communities will be established on moderately well and imperfectly drained overburden materials. These communities are floristically the most diverse in this area. The most common species in these communities off the mine are white spruce, aspen, alder, rose, willow, lowbush and highbush cranberry, saskatoon, red osier dogwood, bracted honeysuckle and snowberry.

Lowbush and highbush cranberry, bracted honeysuckle and snowberry have not yet been established in trials on the mine. Data on the performance and survival of these species on overburden materials is not yet known. For this reason they have not been included in the recommended species composition for the innoculum of the mixedwood communities.

As with the Poplar/Willow/Alder/White Spruce community, hybrid poplars and willow cultivars should be included in the species composition. The rapid growth exhibited by these species will ameliorate the site allowing native species to invade. They will also provide a light deciduous overstory for the introduction of white spruce.

The species composition recommended for an innoculum for the establishment of White Spruce/Poplar/Shrub communities on moderately well and imperfectly drained overburden materials is as follows:

Species	Aggressiveness	Pro-rating	% Composition
Northwest poplar	15	1.00	7.1[a]
Walker poplar	15	1.00	7.1
Acute-leaf willow	14	1.07	7.6
Balsam poplar	14	1.07	7.6
Laurel-leaf willow	14	1.07	7.6
Aspen	13	1.15	8.1
Glauca willow	13	1.15	8.1
Rose	13	1.15	8.1
Dogwood	9	1.67	11.8
Saskatoon	9	1.67	11.8
Alder	7	2.14	15.1
		14.14	100

a Pro-rated value expressed as a percentage of the total.

Jack Pine/Poplar/Shrub. This community type is transitional between Jack Pine/Bearberry/Lichen communities on well drained areas and aspen dominated deciduous stands. The most important species in this community are jack pine, aspen, saskatoon, rose, buffaloberry and alder. This community is recommended for both the well drained plateau areas and the dike slopes. The establishment of this community on the plateaus instead of a Jack Pine/Bearberry/ Lichen community will increase the value of these areas for wildlife habitat. It is recognized however that some site amelioration may be required to establish some of the species on the very rapidly drained areas. It may be more effective to manage these rapidly drained areas for commercial forestry purposes rather than for wildlife habitat due to the superior drought tolerance of jack pine exhibited on rapidly drained sites. In either scenario, the species composition recommended here can act as an innoculum for either a Jack Pine/Bearberry/Lichen community or a Jack Pine/Poplar/Shrub community because stocking densities of 150 stems/ha of jack pine contain sufficient seed for the establishment of a fully stocked jack pine stand. It is acknowledged that only open grown jack pine on dry sites will release seed and regenerate.

The species composition recommended for an innoculum for the establishment of Jack Pine/Poplar/ Shrub communities on tailings sand areas is as follows:

Species	Aggressiveness	Pro-rating	% Composition
Jack pine[a]	N/A	N/A	N/A
Northwest poplar	15	1.00	8.4
Walker poplar	15	1.00	8.4
Aspen	13	1.15	9.7
Rose	13	1.15	9.7
Saskatoon	9	1.67	14.1
Alder	7	2.14	18.0
Buffalo-berry	4	3.75	31.6
		11.86	100

a Jack pine omitted here as it is not a species which can reproduce vegetatively or invade by suckering. Its planting density is determined only by survival rates. It is included in the final prescription in Table 3.

b Pro-rated value expressed as a percentage of the total.

Recommended Innoculum Planting Densities

Table 3 shows recommended stocking densities of the most important species in the three recommended plant communities. Stocking rates for an innoculum of 300 and 600 surviving stems/ha are given for both tailings sand and overburden. Both of these surviving stock rates are considered sufficient for the development of each community. The difference between the two rates will be the amount of time necessary for the development of a complete canopy cover. There are no data to indicate the differences in the time frames required.

Survival rates used are those from Shopik (1984 and 1985) for tailings sand and overburden in either a sparse or established cover. Survival data are limited and do not allow for the provision of stocking rates for both grass/legume and cereal cover types. If survival rates are improved using new techniques (e.g. barley for cover crop, and larger, more vigorous stock), it is possible that initial stocking rates to obtain the innoculum of 300 and 600 surviving stems/ha can be reduced accordingly.

Jack pine densities in the Jack Pine/Poplar/Shrub community are specified to provide 150 surviving stems/ha for both tailings sand and overburden. This density is considered sufficient for the natural perpetuation of either a fully stocked pine stand or a mixed pine/deciduous stand.

White spruce stocking densities are not specified for the two communities where it appears. This species is not recommended for use as an innoculum but should be planted in densities commensurate with the final densities required following the establishment of a light overstory.

Acknowledgements

The ideas expressed here were first formulated during a study in which Suncor Inc. Resources Group required us to determine what innoculum stocking densities should be used on their reclaimed land with the objective being to reclaim the land in the same time frame as that following a disturbance such as fire. We thank Suncor Inc. Resources Group, especially Tim Shopik, for allowing us to publish these ideas.

Literature Cited

Ahlgren, C.E. 1959. Some effects on fire on forest reproduction in northeastern Minnesota. Journal of Forestry 57:194-200.

Alberta Land Conservation and Reclamation Council. 1977. Guidelines for the Reclamation of Land in Alberta. Alberta Environment and Alberta Energy and Natural Resources, Edmonton. n.p.

Fowells, H.A. 1965. Silvics of Forest Trees of the United States. U.S. Department of Agriculture, Agriculture handbook No. 271, Washington, D.C. 762 p.

Hellum, A.K. 1983. Seed production in serotinous cones of lodgepole pine. p. 23-27. In: Lodgepole Pine: Regeneration and Management (M. Murray ed.). The Proceedings of a Fourth International Workshop, Hinton, Alberta, August 17-19, 1982. Published by the Pacific Northwest Forest and Range Experiment Station and the U.S. Department of Agriculture, Portland, Oregon.

Monenco Limited. 1982. Whitewood Reclamation Monitoring. Report prepared for TransAlta Utilities Corporation, Calgary, March 1982.

Monenco Limited. 1983. Highvale Wildland Reclamation 1982. Report prepared for TransAlta Utilities Corporation, Calgary, March 1983.

Odum, E.P. 1971. Fundamentals of Ecology. 3rd Edition. W.B. Saunders Co. Toronto. 574 p.

Rowe, J.S. and G.W. Scotter. 1973.

TABLE 3

Recommended Innoculum Planting Densities for the Establishment of Three Plant Communities for Wildlife on Tailings Sand and Overburden

Community Type	Species	Percent of Total Stocking Density	Average Percent Survival: Tailings Sand	Average Percent Survival: Overburden	Innoculum Planting Density[a]: Tailing Sands 300	Tailing Sands 600	Overburden 300	Overburden 600
Poplar/Willow/Alder/White Spruce	Balsam poplar	8	-[b]	22	-	-	109	218
	Walker poplar	7	48	52	44	88	40	80
	Northwest poplar	7	48	52	44	88	40	80
	Acute-leaf willow	8	50	50	48	96	48	96
	Laurel-leaf willow	8	50	50	48	96	48	96
	Sandbar willow	9	-[e]	50	-	-	54	108
	Glauca willow	9	-[e]	50	-	-	54	108
	Alder	16	21	30[c]	229	458	160	320
	Dogwood	12	7	44	514	1028	82	164
	Paper birch	16	37	17	130	260	282	564
	Total	100			1057	2114	917	1834
White Spruce/Poplar/Shrub	Aspen	8	48	62	50	100	39	78
	Balsam poplar	8	-[b]	22	-	-	109	218
	Walker poplar	7	48	52	44	88	40	80
	Northwest poplar	7	48	52	44	88	40	80
	Glauca willow	8	-[e]	50	-	-	48	96
	Laurel-leaf willow	8	50	50	48	96	48	96
	Acute-leaf willow	8	50	50	48	96	48	96
	Alder	15	21	30	214	428	150	300
	Rose	8	64	70	38	76	34	68
	Saskatoon	12	23	56	156	312	64	128
	Dogwood	12	7	44	514	1028	82	164
	Total	101			1156	2312	702	1404
Jack Pine/Poplar/Shrub	Jack pine	N/A[d]	33	54	450	450	278	278
	Aspen	10	12	48	250	500	63	126
	Northwest poplar	8	48	52	50	100	46	92
	Walker poplar	8	48	52	50	100	46	92
	Saskatoon	14	17	23	247	494	183	366
	Alder	18	21	30	257	514	180	360
	Rose	10	64	70	47	94	43	86
	Buffalo-berry	32	42	55	229	458	175	350
	Total	100			1580	3160	1014	2028

[a] Planting Densities for final innoculums of 300 and 600 plants/ha given.
[b] Balsam Poplar excluded due to very low survival on tailings sand.
[c] Assumed that Alder survival 10% higher than on tailings sand.
[d] Not applicable - in the absence of fire jack pine does not regenerate.
[e] Glauca and Sandbar Willow omitted in tailings sand due to very low survival.

Fire in the boreal forest. Quaternary Research 3(3): 444-464.
http://dx.doi.org/10.1016/0033-5894(73)90008-2

Schier, G.A., J.R. Jones and R.P. Winokur. 1985. Vegetative regeneration. p. 29-33. In: Aspen: Ecology and Management in the Western United States (N.V. DeByle and R.P. Winokur eds). U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-119, Fort Collins.

Shopik, T.D. 1984. Afforestation Program 1983 Progress Reports. Suncor Inc. Oil Sands Group.

Shopik, T.D. 1985. Afforestation Program 1984 Progress Reports. Suncor Inc. Oil Sand Group.

Suncor Inc. Resources Group. 1983. Suncor Oil Sands Division - Development and Reclamation Plan 1984 to 2005. Report submitted to Alberta Government, Land Conservation and Reclamation Council. December 1983.

Zasada, J.C. 1971. Natural regeneration and interior Alaska forests - seed, seedbed and vegetative reproduction considerations. p. 231-246. In: Proceedings, Fire in the Northern Environment - a Symposium (C.W. Slaughter, R.J. Barney and G.M. Hansen eds.). U.S. Department of Agriculture, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.