REHABILITATION POTENTIAL OF RIPARIAN SYSTEMS DISTURBED BY PLACER MINING IN INTERIOR ALASKA[1]

by

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Abstract. Placer mining severely disrupts the structure and function of riparian ecosystems. Successful planning for the rehabilitation of drastically disturbed lands requires an assessment of the disturbance and a systematic analysis of the rehabilitation potential. Site investigations and preliminary research results were used to analyze the rehabilitation potential of a placer-mined valley in interior Alaska. Revegetation trials were begun in 1990 to identify the site variables having the greatest influence on seed recruitment and germination and seedling emergence. Proximity to water table and presence of fines in the seedbed were found to be key variables in the willow establishment process. In 1991 the trials were expanded in order to focus on seedbed preparation and irrigation variables. Results from the 1990 and 1991 field seasons are being used to design prescriptions for a demonstration rehabilitation project involving a 1-km reach of Birch Creek. The intention of the project is to demonstrate that the full land use potential of Birch Creek, including the recreational, scenic, and wildlife habitat values, can be achieved through a proper rehabilitation approach.

Additional Key Words: riparian, stream rehabilitation, placer mining, revegetation

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Introduction

The geomorphic stability of stream channels and the difficulties in revegetating arctic floodplains are considered to be key factors limiting the rehabilitation potential of riparian systems disturbed by placer mining in interior Alaska (Van Haveren 1989, 1991). Healthy riparian systems are important for fishery habitat, moose habitat, flood attenuation, and water quality maintenance (USDI-BLM 1988). Recovering the land use potential of sites drastically altered by placer mining will require successful rehabilitation and proper management of the disturbed riparian zones.

The geographic focus of our investigations is the Circle Mining District, specifically the Birch Creek watershed, in interior Alaska. Since Birch Creek is classified as a National Wild and Scenic River approximately 7 river miles below active placer mining, there is considerable interest in rehabilitating placer mines in the headwaters of this basin to protect the downstream recreation resource.

The overall project goal is to demonstrate, at an operational scale, successful rehabilitation of a disturbed valley segment, including the active stream channel, floodplain, and adjacent upland areas. Our project strategy includes selecting a stable valley and stream channel configuration that will also facilitate the natural vegetation colonization of the site, determining a method for successful willow recruitment from seed, and demonstrating a variety of rehabilitation techniques on the study area. The project phases are: 1) project site selection and initial observations, 2) seedbed treatment study, 3) shallow groundwater monitoring, 4) hydrologic design and detailed rehabilitation plan, 5) site grading and willow transplants, 6) seedbed preparation and seeding; and 7) monitoring. This paper addresses the first two project phases.

Gold was first reported in the Birch Creek region in 1893. Most of the important placers were discovered and opened up in the following year. By 1896 placer gold mining was well underway in the Circle Mining District and has been nearly continuous, but cyclical, ever since. Placer deposits occur in two forms: 1) residual or hillside placers and 2) stream placers. Residual or hillside placers are found above the stream channels and did not form as a result of fluvial action. Stream placers were classified by Mertie (1937) as either ancient or recent. Ancient placers are found either in buried stream channels or on benches above the existing drainage system. Recent placers are found in the existing stream network. Most of the placer mining activity in the Birch Creek basin has concentrated on recent placers and, therefore, the disturbance is concentrated in the active stream channels and adjacent floodplains.

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In a typical placer mining operation, crawler-type tractors are used to scrape away the vegetation mat and silt and organic layers that overlay the valley alluvium. Coarser gravels and fractured bedrock that do not contain gold-bearing rocks may also be treated as overburden and piled at the perimeter of the operation as waste rock. The gold-bearing material is then moved by tractor or front-end loader to the processing plant, where it is screened and sorted to remove larger rocks. A variety of methods are employed to extract the gold from the sorted material. The basic principle, however, is the same for all methods. Since gold has a higher specific gravity than the material it is associated with, gravity and water are used to separate and wash the gold particles from the rock fragments. Placer gold is sometimes referred to as "free gold" because it is not tied up in an ore complex.

The separation and washing process—commonly called "sluicing"— results in a large quantity of clay- and silt-sized material at the bottom end of the processing plant. Because the plants are located in the valley bottoms close to the placer deposits, miners were accustomed to discharging the tailings directly to the stream channel. Current regulations require the use of settling ponds to trap effluent from the plants. Coarser tailings drop out of suspension quickly, but the finer particles may continue in suspension after the water enters the stream channel. Large quantities of valley alluvium are processed in a typical placer operation, resulting in substantial volumes of both waste rock and tailings.

Placer mining has been shown to result in an increase in the sedimentation of stream channels (with sediment coming from mine operations as well as from roads); loss of riparian vegetation and associated soils; elimination of streambanks and floodplains, diversion of stream channels; loss of meanders and pools; widening of channels; change in substrate; adverse changes in water quality; depressed aquatic invertebrate populations; and elimination of fish habitat (Weber and Post 1985, USDI-BLM 1988). Resuspension of deposited sediments occurs at high flows, but bankfull flows are insufficient for removing fine sediments that settle into gravel substrate and negatively affect grayling habitat. Most importantly, placer mining generally affects the entire valley floor morphology and may result in a net loss of valley alluvium from the mined valley segment. This may profoundly affect stream channel stability and make stream channel rehabilitation more difficult.

Site Description

Because of their close proximity to Fairbanks, Alaska, and reasonably good access via the Steese Highway, the Circle Mining District and Birch Creek watershed were chosen as the general location for a research/demonstration site. The Birch Creek watershed is located between 65 and 66 degrees north latitude and between 144 and 146 degrees west longitude and has a drainage area of 5570 km^2 above the Steese Highway Bridge (Figure 1). Birch Creek ranges in elevation from approximately 120 m at its confluence with the Yukon River to approximately 1500 m at the watershed divide. Birch Creek drains about one-eighth of the total area of the Yukon-Tanana Uplands Physiographic Province, which is part of the Great Central Plateau Province of interior Alaska. This region is a rolling upland characterized by discontinuous groups of higher mountains and ridge crests of relatively uniform height. Ridge tops vary from about 800 m to nearly 1500 m above sea level and a few summits exceed 1500 m.

The geology of the Birch Creek watershed is complex. The predominant rock is early pre-Cambrian Birch Creek schist with narrow bands of Quaternary alluvium found in the valleys of Birch Creek and its major tributaries. The Birch Creek schist consists of recrystallized sedimentary rocks, which are very resistant to erosion. Chemical weathering does not occur under the frozen ground conditions found throughout the watershed. Weathering is primarily by freeze-thaw action. This region escaped glaciation during the Pleistocene, but some alpine glaciers were present above the 1200 m level. Many of the headwater streams flow through wide, open valleys that are disproportionately large in comparison to their stream channels.

Mean annual precipitation in the central portion of the basin is 260 mm with 60 to 70 percent of that coming as rain between June and September. Snowfall averages about 130 cm, but the moisture content is quite low. Although precipitation records are not available for the higher elevations in the basin, rainfall and snowfall totals probably increase with elevation. Summers are cool and often rainy, while winters are very cold and relatively dry. A mean annual temperature of -9 °C is responsible for the discontinuous permafrost found throughout the region.

A mosaic of vegetation communities has developed within the Birch Creek watershed in response to a variety of environmental factors, including climate, physiography, surficial geology, soil type, permafrost occurrence, and disturbances such as fire, flooding, and human activity. On the lower slopes, the better-drained sites contain herbaceous plants, mosses, and lichens. Poorly-drained sites are characterized by alder, willow, sedge tussocks, sphagnum, and lichens. The upper slopes support deciduous forests, including birch on silt-loam ridges; black spruce on gentler, colder, and poorly drained sites (especially north-facing slopes); and white spruce on the drier south and west-facing slopes.

Riparian communities include white spruce and cottonwood in the lower stream reaches and tall and low shrubs in the upper drainages. White spruce is the climax tree species on floodplains, while the poplar-spruce community is considered an intermediate stage. Willows occupy floodplains during the earliest successional stages. Riparian shrub communities may be tall shrub or low shrub in form. The tall shrub community includes willow thickets and shrub swamps of alder and willow. Low shrub communities may be dwarf birch/ericaceous shrub bog, mixed shrub/sedge tussock bog, shrub birch/willow, and willow/graminoid bog. Some ripar-

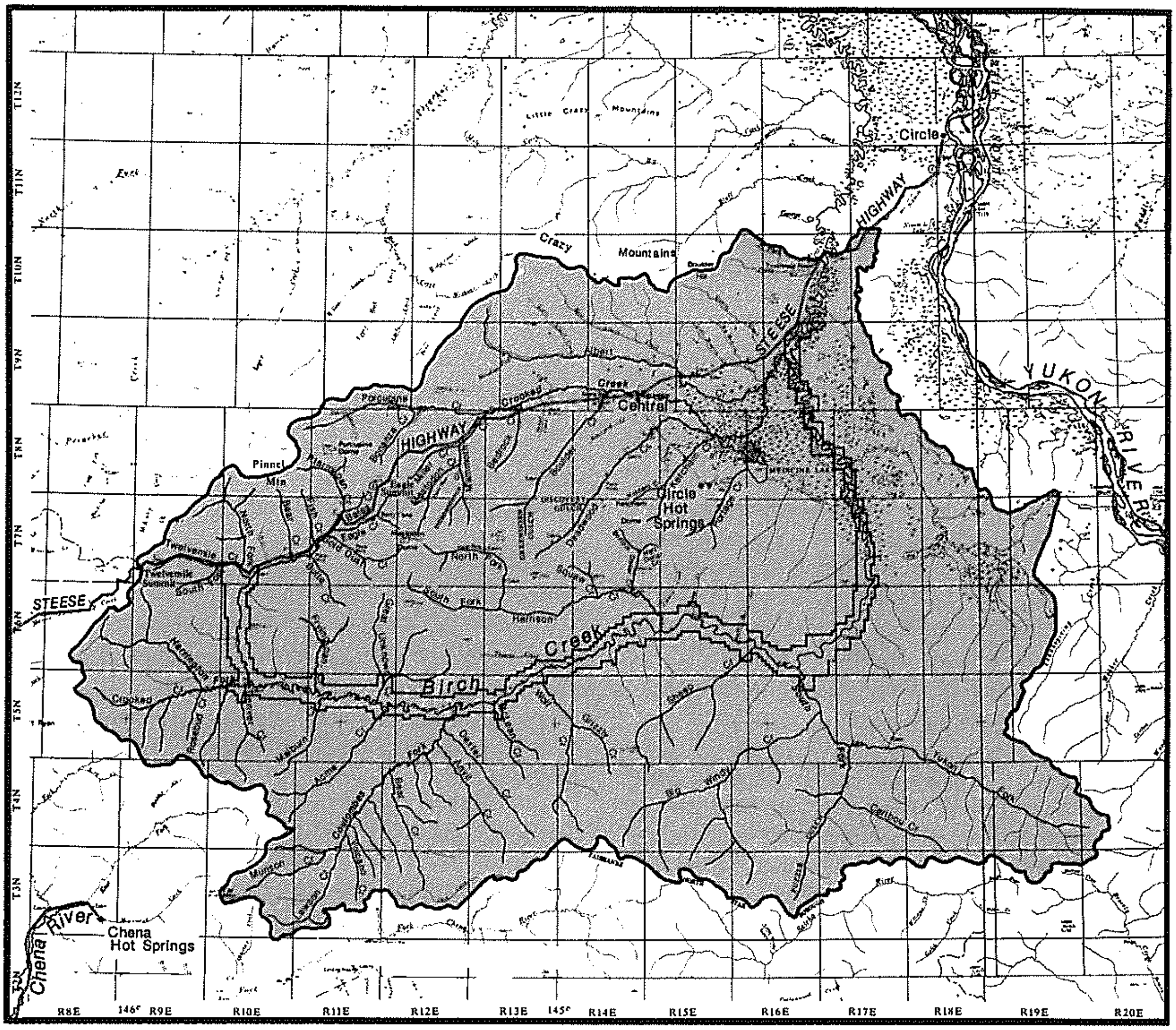

Figure 1. Location map, Birch Creek watershed, interior Alaska.

ian zones are essentially barren due to extensive placer mining activities.

Soils are shallow and poorly developed. Permafrost is quite extensive except in the channels and floodplains of perennial streams. Because of these factors, there is little water storage capacity in the soil. The vegetation layer is quite complex and deep due to the slow rates of decomposition and is capable of storing all the precipitation from smaller storms. Evaporation rates are low and the vegetation-organic layer may stay at or close to saturation throughout the summer.

This region experiences large convective storm events that can produce rainfall amounts of 6 cm or greater. Because of its low storage capacity and saturated mantle conditions, the Birch Creek watershed, particularly at higher elevations, cannot store rainfall of large magnitude. Prindle (1905) observed that Birch Creek was capable of rising several feet in a few hours following rain and then quickly receded back to normal levels. He attributed this quick hydrologic response to the presence of frozen ground. One would expect such "flashiness" to produce very high peak discharges, and indeed that is the case. The peak of record for many gaged streams in interior Alaska occurred in August of 1967 in response to a summer rainstorm. Placer mine rehabilitation must take into account the probability of experiencing these high flow events.

Project Approach and Methods

Our basic approach to placer mine rehabilitation in the Birch Creek drainage is to 1) achieve geomorphic and hydrologic stability throughout the disturbed valley segment, 2) prepare a landscape surface and seedbed conducive to the establishment of willow, and 3) promote the natural plant succession observed on disturbed riparian areas in interior Alaska.

Feltleaf willow (*Salix alaxensis*) is the key species in ecological succession on placer tailings in the Birch Creek watershed. We believe that once willow is established as the pioneer species, vegetation succession will proceed naturally toward the desired riparian vegetation community. A model of primary vegetation succession developed by Viereck (1970) and Walker et al. (1986) for floodplains in interior Alaska is believed to be valid for the vegetation establishment and colonization of placer mine tailings. The succession model is shown in Figure 2. The model assumes a typical interior Alaska meandering stream eroding into a high bank on the outside of the meander bend and depositing point bars on the inside of the bend.

The bare silt or sand of the point bar is colonized in the first few years by willows that grow from seeds deposited on the moist surface of the point bar during high flow events. Two conditions are necessary for wind-dispersed willow seeds to become established: 1) soils or sediments that will hold water, and 2) water to keep the soils or sediments moist. Successful willow germination requires a moist seedbed such as that created by a fresh deposit of fine-grained stream sediments (Walker et al. 1986). In addition, willow seeds lose their viability quickly and thus seed dispersal must coincide with the presence of a moist substrate. Mature willows stabilize the sediment and grow very rapidly in the hydric-mesic conditions of a point bar.

Willow stands are invaded by balsam poplar. After approximately 20 years, the poplar attains dominance, crowds out the willow, and develops into a tree community. At lower elevations alder may occupy the site between the willow and poplar stages. Balsam poplar provides a high, open canopy with abundant shade and dominates the site until approximately 100 years into the succession. White spruce eventually invades the balsam poplar stands, overtops and shades the poplar, and becomes dominant.

The spruce phase consists of a moderately dense, but patchy, forest. Dropped needles contribute to the development of a deep mulch over the ground. Feather mosses combine with the mulch to form a dense and lush carpet, which acts as an excellent insulator and keeps the summer sun from warming the soil. Permafrost forms under the spruce stands and creates impermeable soils. The soils become wetter over many years and the white spruce trees are eventually toppled by the formation of ice lenses in the soil and then decay and add to the mulch layer. The climax ecosystem for these sites is muskeg, a type of peatland dominated by black spruce, heath plants, and *Sphagnum* mosses. Our rehabilitation approach is critically dependent upon this theory of vegetation succession.

The research site is on Birch Creek between Butte and Bear Creeks, approximately 6 stream miles above the start of the Birch Creek National Wild River corridor. The revegetation study area is located specifically on an abandoned mining claim within the S1/2, S1/2 sec. 24, T. 7 N., R. 10 E., Fairbanks Meridian, and is visible from the Steese Highway near Milepost 98.5. The site has excellent access from the Highway.

Initial Screening of Site Variables

During the 1990 field season we concentrated on selecting those variables important to the establishment of feltleaf willow on placer mine spoil and tailings. From field observa-

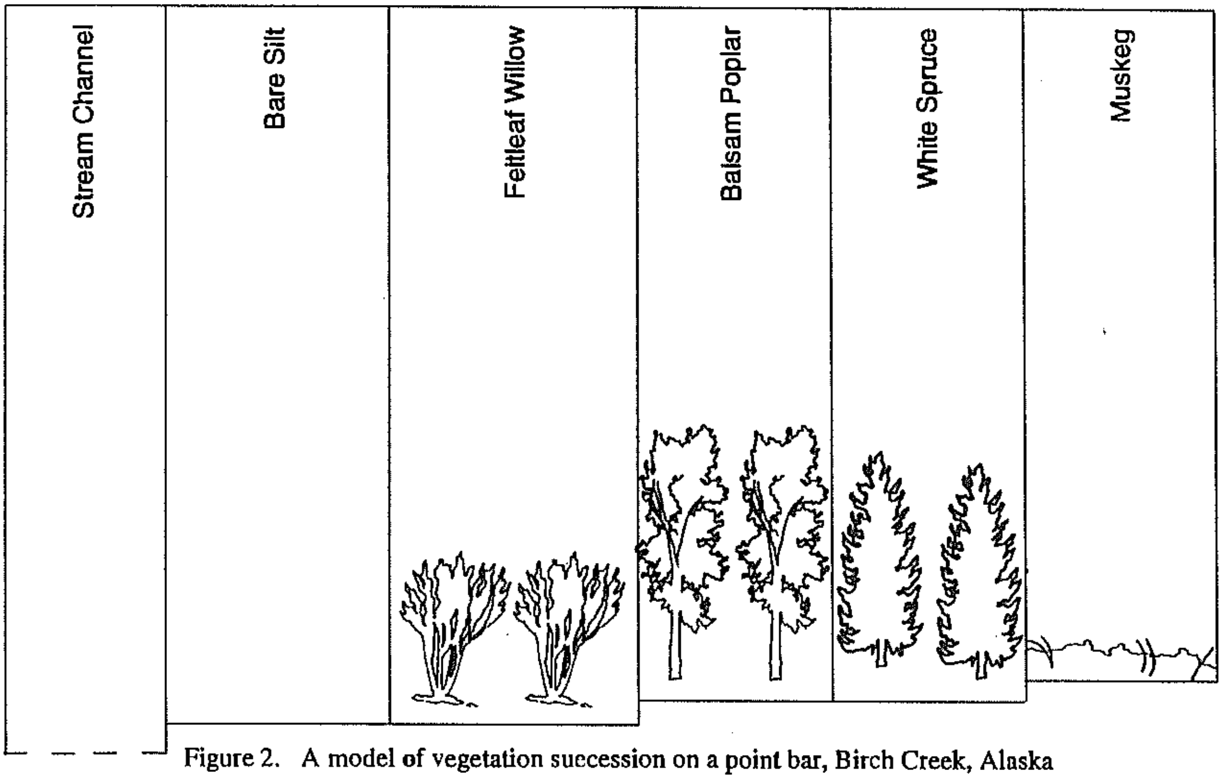

Figure 2. A model of vegetation succession on a point bar, Birch Creek, Alaska (after Viereck 1970).

tions of spoil and tailings on the study site and adjacent areas, the key variables influencing vegetation establishment appeared to be the proximity to water table and the presence of "fines" within the top few centimeters of the tailings/spoil piles.

Preliminary revegetation trials were initiated in May, 1990, to examine the influence of water table, sprinkler irrigation, topsoil, and fertilizer on seed recruitment and germination, seedling survivability, and stem cutting survivability.

Three relatively level plots, each 2 m by 20 m, were located at 0.2, 1.2, and 2.2 m above the water level of a sedimentation pond in regraded spoil and tailings material. Water levels were determined with a rod and level. The differences in elevation above the pond surface were expected to have an influence on vegetation establishment. On each plot the spoil/tailings surface was raked smooth to completely remove any existing vegetation and large rocks, and to provide a fresh, uniform surface. The plots were each split into five 2 m by 4 m subplots. Each plot received the same treatments. Subplot 1 received 2 cm of water by sprinkler irrigation twice weekly. Subplot 2 was the control. Subplots 3 and 4 received approximately 1.5 cm of humic peat from an adjacent muskeg. This peat was partially decomposed, fine-textured, and not fibrous. Subplot 3 was watered in the same manner as Subplot 1, while Subplot 4 was not watered. Subplot 5 received granular 16-16-16 fertilizer at the rate of 560 kg/ha and the same watering treatment as Subplots 1 and 3. These treatments are summarized in Table 1.

Table 1. Plot design and treatments for screening of site variables.

Subplot Number	1	2	3	4	5
Treatment	Twice-weekly watering	Control	Peaty topsoil & watering	Peaty topsoil	Fertilizer & watering

The same treatment configuration was used on all three plots. Each subplot was divided into four 1 m by 2 m microplots for the purpose of counting established seedlings.

Watering was accomplished twice weekly from late May until late August. Water level readings were taken periodically with a rod and level as the sedimentation pond receded. After the subplots were treated in late May we planted 10 feltleaf willow cuttings (30 to 45 cm length) approximately 15 cm deep in each of the 15 subplots. Willow seed was dispersed in early June by waving willow branches with mature catkins around the plots. At the end of summer all seedlings in each subplot were counted and tabulated by species. Stem cutting survival was measured in May 1991.

Seedbed Treatments

Based on the 1990 results, we designed a field trial to evaluate the influence of 1) frequency of sprinkler irrigation and 2) depth of topsoil on willow germination. A tailings pile approximately 0.5 hectare in area adjacent to the Birch Creek channel was graded smooth with a small crawler tractor in late May. The site was about 2 m above the water surface elevation. The experimental design consisted of three control plots, three plots watered daily, and three plots watered twice weekly. Each plot was subdivided into six subplots, 4.0 m^2 in size. Two subplots received a 5-cm topdressing of a high peat content soil, two subplots received a 1.25-cm topdressing of the soil, and the remaining two subplots received no soil. The watering treatment consisted of applying approximately 2.5 cm of water with a garden-type sprinkler. When nearby clones of feltleaf willow began to disperse their seed in early June, stem cuttings were taken and waved as uniformly as possible over the plots. Whole catkins were also dropped onto each of the subplots. Willow seedlings were counted on each subplot in early September.

Results and Discussion

Initial Screening of Site Variables

Stem cutting survivability was strongly influenced by elevation above the water table as indexed by the pond water surface. Only two of 50 stem cuttings survived on the highest elevation plot and one of 50 on the middle plot. However, 18 of 50 cuttings survived on Plot C, the lowest plot, where the rooting zone was moist throughout the summer.

We had previously theorized that willows would germinate and establish best on bare mineral soil and that topdressing, especially peaty material high in organic matter, would retard willow germination and establishment. However, the topdressing significantly increased the number of willow seedlings established. The total number of feltleaf willow seedlings counted in each subplot is shown in Table 2. The total number of balsam poplar seedlings counted are shown in

Table 2. Willow recruitment during summer 1990. Values are total counts of willow seedlings per subplot.

Plot	Treatment					
	1	2	3	4	5	Mean
A (highest)	4	0	16	8	16	9
B (middle)	32	28	76	32	0	34
C (lowest)	16	52	224	256	176	145
Mean	17	27	105	99	64	62

Table 3. A few other plants, including grasses and herbaceous dicots, had become established in the subplots but could not be identified as to species. Willow recruitment was highest in Plot C, the plot closest to the water table. An analysis of variance for willow recruitment indicates that the watering and topdressing treatments both had significant treatment effects. Subplots that were watered and received topdressing had significantly higher willow recruitment than the other subplots.

Table 3. Balsam poplar recruitment during summer 1990. Values are total counts of balsam poplar seedlings per subplot.

Plot	Treatment					
	1	2	3	4	5	Mean
A (highest)	0	0	0	0	2	0.4
B (middle)	0	0	2	2	0	0.8
C (lowest)	0	0	0	4	20	4.8
Mean	0.0	0.0	0.7	2.0	7.3	2.0

We were surprised at the large number of balsam poplar seedlings found in the plots. A total of 30 poplars were counted on all three plots, 24 of which were in Plot C.

Seedbed Treatment

Willow seedling establishment was strongly influenced by both watering frequency and topdressing depth, as indicated in Table 4. Willow seedling counts were significantly higher on those subplots that received both water and 5 cm of topdressing. Daily watering resulted in fewer seedlings on the bare and 1.25-cm topdressing subplots as compared to the twice-weekly watering. We attribute this to "seed wash" where the daily watering continually moved the seeds around and did not offer the opportunity to germinate. According to analysis-of-variance results, the topdressing treatment was significant (5-percent level) and the watering treatment was highly significant (1-percent level). The interaction (watering x topdressing) was also significant (5-percent level).

Table 4. Willow germination in response to watering and soil depth treatments, 1991. Germination is expressed as average counts of willow seedlings per subplot.

Watering Frequency	Topdressing Depth, cm			
	0	1.25	5.0	Mean
Daily	57	33	208	100
Twice Weekly	76	114	135	108
None	5	0	3	3
Mean	46	49	115	70

Summary

Depth to water table is probably the overriding variable in the establishment of feltleaf willow on placer tailings at the Birch Creek study site. Above the influence of the water table, watering at least twice weekly and the addition of a 5-cm deep peaty topdressing greatly enhances the germination and establishment of willow. Natural rainfall would of course be preferable to sprinkler irrigation, but moisture is needed at the time willow seeds mature. Unfortunately, in interior Alaska, willow seed dispersal occurs in late May and early June, the driest period of the growing season. Supplemental water appears necessary in the absence of a high water table. The topdressing provides a seedbed with a high water-holding capacity and favorable germination microenvironment. The topdressing may also serve as a seed bank for a large variety of native seeds.

We are encouraged by these preliminary results. It appears that feltleaf willow can be established on both wet and dry sites with a minimal amount of effort. The seedling establishment plots will be monitored over the next few years to determine survivability of the willow seedlings. Revegetation prescriptions for the demonstration phase of the project will be based on the results of the 1990 and 1991 field trials.

We have initiated detailed rehabilitation planning on a 1-km reach of the Birch Creek valley. Topographic surveys and mapping will be completed during 1992. Site regrading, including the channel reconstruction, will commence in 1993. Pre-mining aerial photographs are being used to determine geomorphic characteristics of the undisturbed valley and channel of Birch Creek. Channel surveys will be conducted during the 1992 field season to augment the aerial photography data. These data will be used in the initial channel design for the demonstration reach following methods prescribed by Beschta (1989) and Jackson and Van Haveren (1984). Willow poles and stem cuttings will be planted in late summer 1993. Final seedbed preparation and seeding will occur in spring 1994.

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