The Revegetation of Drastically Disturbed Lands

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Abstract

During the development of natural resources such as forests and minerals, and in the construction of infrastructure and mega-projects, areas of land are disturbed and in many cases remain so for extended periods of time. For the purpose of this project, land is considered to be drastically disturbed if the native vegetation and animal communities have been removed and the topsoil is lost or altered, exposing a biologically barren subsoil surface condition. There are two basic approaches that can be taken in revegetating drastically disturbed sites devoid of topsoil or organic matter, they are: (1) Allow natural succession to take place; or (2) Give succession a "kickstart".

The purpose of this study was to identify and evaluate revegetation strategies and techniques which may serve to "kickstart" succession on drastically disturbed lands within the Manitoba Model Forest (MMF) region. The objectives of this study were: (1) To identify and review the revegetation strategies and techniques currently being used by various agencies; (2) To assess the identified revegetation strategies and techniques for use in Manitoba; (3) To evaluate the chosen revegetation strategies and techniques through field trials; (4) To make recommendations for the revegetation of drastically disturbed lands based upon the review of strategies and techniques, and the results of field studies with the principles of sustainable development in mind.

Field trials were used to assess the potential of hydroseeding and mulching around established trees and shrubs in the revegetation of drastically disturbed lands within Manitoba and the MMF. Materials tested included currently available hydroseeding products, including a bonded fiber matrix and a wood fiber product with tackifiers. These exhibited excellent adhesion on a variety of slope conditions as well as supporting germination rates of 50-80%. In addition, a paper mill sludge was evaluated for its potential as a component of a hydroseeding slurry and as a protective mulch (both as a dry mulch and a "hydromulch") for established trees and shrubs (Jackpine, *Pinus banksiana*; White spruce, *Picea glauca*; Buffaloberry (soap berry), *Schepherdia argentia*; Dogwood, *Cornus stolonifera*; Acute willow, *Salix acutifolia*; Wild rose, *Rosa sp.*; Hawthorn, *Crataegus arnoldiana*).

The paper sludge was easily applied as a slurry, exhibited excellent erosion control properties and supported germination rates of 60-80%. Results showed that the protective mulches had almost no effect on over-wintering success of the plants, with survival rates ranging from 94-100% in all treatments (with only one species, buffalo berry, at 88%). Regarding plant quality as related to the effects of the treatments, the plants receiving the 'hydromulch' treatment exhibited the best quality ratings. Five of the seven species benefited from the dry mulch treatment versus the control treatment, with only hawthorn and Jackpine not showing any derived benefits. Recommendations include: (1) utilizing commercially available hydroseeding products as a technique for revegetating drastically disturbed sites in Manitoba; (2) further research into the use of the paper mill sludge is a hydroseeding component; (3) utilizing the paper sludge, both as a dry mulch and 'hydromulch' to provide protection for established trees and shrubs, and (4) further research into the use of the dry mulch to provide impetus for succession based upon its apparent ability to support the establishment of pioneer and ruderal species in the trials.

Introduction

During the development of natural resources such as forests and minerals, and in the construction of infrastructure and mega projects, areas of land are disturbed and in many cases remain so for extended periods of time. For the purpose of this project, land is considered to be drastically disturbed if the native vegetation and animal communities have been removed and the topsoil is lost or altered, exposing a biologically barren subsoil surface condition.

Revegetating Drastically Disturbed Lands

There are two basic approaches that can be taken when revegetating drastically disturbed sites devoid of topsoil or organic matter, they are:

1. Allow natural succession to take place. This entails the establishment of pioneer plant species on sites lacking any topsoil or organic matter. With time, stabilization of the soil by root systems reduces erosion, the development of a thin organic layer takes place a result of decomposition, which in turn will encourage establishment by other plants and eventually leads to a climax community; or
2. Give succession a "kickstart". Provide inputs, to what ever degree is necessary based on the desired goal for the disturbed site. Inputs can be as simple as drill seeding with grasses and legumes, providing fertilizers to aid establishment, etc.. Once a vegetative cover has been established, further inputs can then be made to encourage desired species to grow, such as pulp wood tree species, or nature can be left alone to take its course.

The Manitoba Model Forest Program

This project originated with the Manitoba Model Forest Program (MMF), who identified drastically disturbed lands as sites which require revegetation in order to provide for the sustainable use of forest resources. The objectives of the MMF Program are:

1. To accelerate the implementation of sustainable development in the practice of forestry;
2. To apply new and innovative approaches, procedures, techniques and concepts in the management of forests; and
3. To test and demonstrate the best forestry practices utilizing the most advanced technology and forest practices available.

(Canadian Forestry Service 1996)

Purpose and Objectives

The purpose of this study is to identify and evaluate revegetation strategies and techniques which may serve to "kickstart" succession on drastically disturbed lands. The objectives of this study are: (1) To identify and review the revegetation strategies and techniques currently being used by various agencies; (2) To assess the identified revegetation strategies and techniques for use in Manitoba; (3) To evaluate the chosen revegetation strategies and techniques through field trials; and (4) To make recommendations for the revegetation of drastically disturbed lands based upon the review of strategies and techniques, and the results of field studies.

Methodology

The following approaches were selected for evaluation by field trials:
- Hydroseeding
- Protective mulches for tree and shrub plantings in the form of a paper mill sludge

Pine Falls Paper Company Paper Mill Sludge

In June 1996, the Pine Falls Paper Company (PFPC) located within the MMF, began to produce a biosolid waste material (also known as paper sludge) as a result of the operation of its new waste treatment plant. This material represents a sustainable source of organic mulch. Although literature showed that this type of material had been utilized as a soil amendment (Thacker and Macyk 1995), its use as a protective mulch was limited and as a component of a hydroseeding slurry was not documented. It was therefore decided that the material would be evaluated as a protective mulch for established plants rather than as a soil amendment and as a possible component of a hydroseeding slurry.

Site Selection

One of the most readily available drastically disturbed lands within Manitoba comes in the form sand and gravel pits. They are characterized by extreme slopes, are usually devoid of any topsoil materials and are typically not revegetated. In consultations with Mr. Stan Kaczanowski, Regional Forester, Manitoba Department of Natural Resources, and Mr. Brian Bailey, Rehabilitation Specialist, Manitoba Department of Energy and Mines, appropriate sand and gravel pits were selected as locations for field trials.

Field Trials

The field trail component of the practicum was divided into two parts:
- Part One: Evaluation of the Hydroseeding technique and products; and
- Part Two: Evaluation of a Paper Mill Sludge as a protective mulch for established plant material.

Part One: Evaluation of the Hydroseeding technique and products

Hydroseeding Treatments

The hydroseeding treatments were:

- Mat, Inc. Soil Guard^{TM}, tackifier , red clover and annual rye grass
- Mat, Inc. Soil Guard^{TM}, tackifier and Pickseed Canada Inc.'s "Custom Forage Mixture" (8% common cinquefoil, 8% white clover, 10% perennial ryegrass, 20% common bromegrass, 20% creeping red fescue, 10% rangeland alfalfa, 24% fylking kentucky bluegrass), pre-soaked.
- Canfor's Ecoaegis^{TM} and Pickseed Canada Inc.'s "Custom Forage Mixture", pre-soaked.
- Canfor's Ecofiber^{TM} and Pickseed Canada Inc.'s "Custom Forage Mixture", pre-soaked.
- Mat Inc. Soil Guard^{TM}, red clover and annual rye grass.
- PFPC based hydro mulch, red clover and annual rye grass.
- PFPC based hydro mulch with Jackpine (*Pinus banksiana*) seed.

Performance evaluation of the hydroseeding products included field notes and photographs taken during inspections of the treatments. The following set of 'subjective' criteria were also used to assess performance:
- The ability of the product to remain intact and viable;

- The approximate degree of "weed" (or undesirable plants) control provided; and
- The estimated rate of germination (when applicable).

Part Two: Evaluation of a Paper Mill Sludge as a protective mulch for established plant material.

Plant Selection

The plants selected were native to the boreal forest of the MMF and/or an economically important species. They included: Acute willow, *Salix acutifolia*; Buffaloberry (soapberry), *Schepherdia argentia*; Dogwood, *Cornus stolonifera*; Hawthorn, *Crataegus arnoldiana;* Jackpine*, *Pinus banksiana*; White spruce*, *Picea glauca*; Wild rose, *Rosa sp.*. The acute willow came in the form of dormant cuttings (approximately ten centimeters long) with the remaining plant material coming as bare root stock from PFRA. The nursery stock (*) was two years old, having been originally grown in 'cells' for two seasons, then kept in cold storage until needed. The PFRA material was one year old.

Tree and Shrub Field Trial Plot Design

Trials plots consisted of the three treatments each with twenty eight (28) 1.0 meter x 1.8 meter plots per treatment, for a total of eighty four (84) plots. Each plot was cleared of any existing vegetation then five plants of each species was planted within each plot, as shown in Figure 1, Plot Layouts. Four replications of each plant species took place within each treatment. Twenty (20) plants were installed per treatment, for a total of sixty (60) plants per species. The total number of plants installed per treatment was n = 140, for a total number of plants installed being n = 420.

Protective Mulch Treatment

The Protective Mulch treatments:

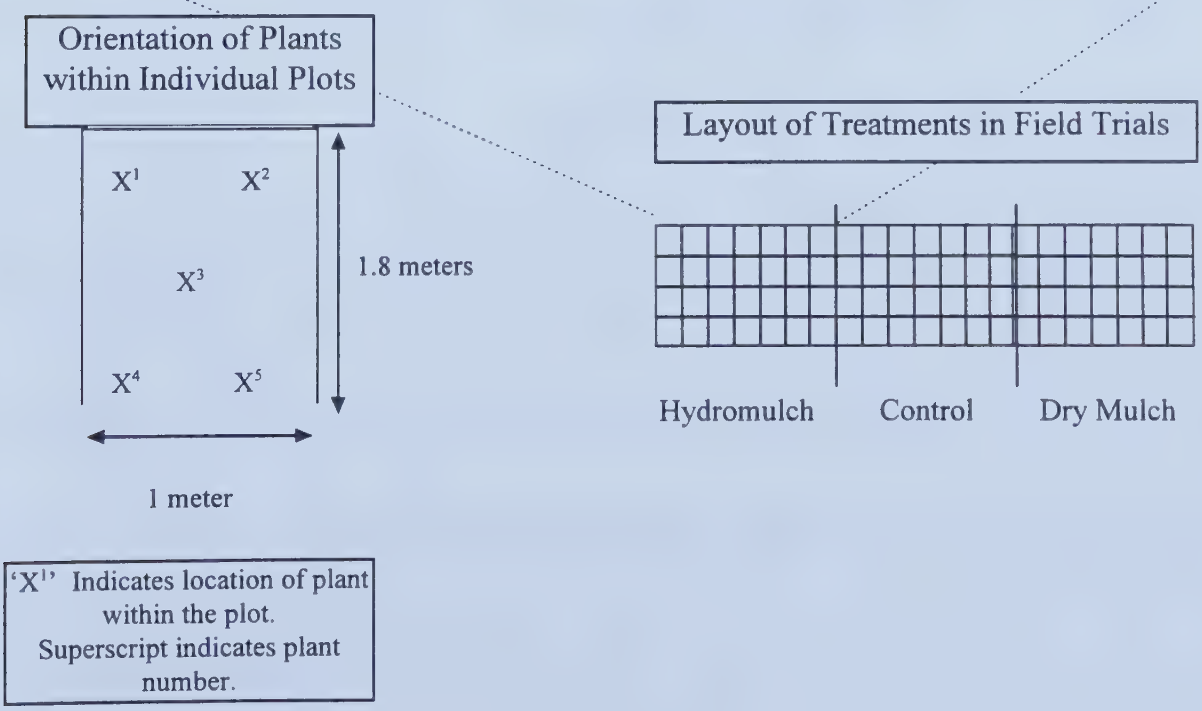
- Treatment 1: (Control) Established plant material with no protective mulch.
- Treatment 2: (Dry mulch) Established plant material with dry PFPC paper sludge as a protective mulch.
- Treatment 3: (Hydromulch) Established plant material with PFPC sludge used as the base for a protective layer of 'hydromulch'.

Treatment Application

Once the plants were well established the dry mulch and 'hydromulch' treatments were applied (July 18th and 19th, 1996 respectively). Watering of the plants was discontinued and weeding of the plots was done only once (mid August, 1996). The dry mulch was applied to the surface and around the established plants using wheelbarrows and spreading it with rakes to a thickness of eight to ten centimeters. The 'hydromulch' was applied with a hydroseeding machine, operated by Mr. Mark Myrowich of Mid-Canada Hydroseeding Ltd..

Figure 1: Plot Layouts

Hawthorn	Dogwood	White Spruce	Acute Willow	Buffalo-berry	Rose	Jackpine
Acute Willow	White Spruce	Buffalo-berry	Dogwood	Hawthorn	Jackpine	Rose
Jackpine	Buffalo-berry	Rose	Acute Willow	Dogwood	White Spruce	Hawthorn
Rose	Buffalo-berry	Dogwood	White Spruce	Hawthorn	Acute Willow	Jackpine



Evaluating Performance

Plant performance was evaluated by recording mortality rates, specifically overwintering survival rates, and by assessing overall plant quality as per Kennedy (1984) and Larson *et al.* (1993). The criteria used to evaluate individual plant performance appear in Table 1, Plant Quality Ranking and Assessment Criteria. The assessment of plant quality was done in June 1997, approximately one year after the installation of the plant materials when the deciduous plants had fully developed their leaves and conifers showed new growth as indicated by the development of candles.

Rank	Description	Criteria
4	Very Good Health	• All leaves exhibit good colour and rigor. • Branches full and normally developed. • New growth exhibited. • Superior specimen
3	Good Health	• No dead leaves on entire stem. • Branches full and developed. • New growth evident.
2	Moderate Health	• 25 % or less dead leaves on entire stem.
1	Poor Health	• 75% or greater dead leaves on entire stem

Table 1: Plant Quality Ranking and Assessment Criteria

(Adapted from Kennedy 1984, Larson *et al.* 1993)

Statistical Analysis

Statistical analysis included ANOVA, F-tests and t-tests to determine whether or not the differences in plant quality between treatments were significant.

Results and Discussion

Part One: Evaluation of the Hydroseeding technique and products

- Mat, Inc. Soil Guard™ , Canfor's Ecoaegis™ , and Canfor's Ecofiber™

The ability of the product to remain intact and viable.

All three treatments Mat, Inc. Soil Guard™ , Canfor's Ecoaegis™ , and Canfor's Ecofiber™ performed equally well. A site visit, in June 1997, found that all the materials had begun to break down. However, they remained intact and viable and erosion of the bank material was not observed.

Approximate degree of weed control provided.

No observable weed growth was observed to have taken place in either growing season (1996 and 1997) in any of the treatments.

The estimated germination rate.

On those sites where germination took place, the estimated rate ranged from 50% to 80%, with the latter rates observed in the bottom of rills.

- PFPC based hydro mulch.

The ability of the product to remain intact and viable.

It was observed that as the PFPC material dried it shrank into 'patties', but did remain in place. These patties were approximately ten to twenty centimeters across in size with gaps in between of one to three centimeters. The material adhered well to the surface and appeared to mold itself to the shape of the surface. There was no discernible erosion of the treatment area observed in the first year (1996) and a very limited amount in the second year (1997). The product remained intact and viable.

Approximate degree of weed control provided.

Estimated weed growth in the first growing year (1996) was less than 10% and approximately 10 to 20% in the second year (1997). It was only within the gaps between the patties that weed growth took place.

The estimated germination rate.

A germination rate of 60-80% was observed. The higher rate (80%) being observed in the rills and the lower rate (60%) being observed on the crests and flatter areas of the treatment site.

- Jackpine Seed in PFPC based hydro mulch.

The ability of the product to remain intact and viable.

Observations for this treatment are similar to those of the previous application.

Approximate degree of weed control provided.

The same observations were made as in the previous treatment.

The estimated germination rate.

No germination of the Jackpine seed was observed to take place.

Part Two: Evaluation of a Paper Mill Sludge as a protective mulch for established plant material.
Mortality

The over-wintering success rate was the first criteria used to evaluate the effects of the treatments on plant performance. The results appear in Table 2, Over-wintering Success Rates.

Species	Viable plants (fall 1996)			Viable Plants (spring 1997)			Survival Rate (%)		
	Hydro	Control	Dry	Hydro	Control	Dry	Hydro	Control	Dry
Hawthorn *Crataegus arnoldiana*	20	17	20	19	17	19	95	100	95
Dogwood *Cornus stolonifera*	17	20	20	16	20	20	94	100	100
White Spruce *Picea glauca*	20	20	20	20	20	20	100	100	100
Acute Willow *Salix acutifolia*	15	13	4	15	13	4	100	100	100
Buffaloberry *Schepherdia argentia*	18	17	19	18	15	19	100	88	100
Rose *Rosa sp.*	19	20	20	19	20	20	100	100	100
Jackpine *Pinus banksiana*	20	16	14	20	16	14	100	100	100

Table 2: Over-wintering Success Rates

For all species and in all treatments the survive rates ranged from 94% to 100%, except for the control treatment of the buffaloberry in which only 88% of the plants in the control survived. Total survival rates for all treatments, including the control, were excellent. The anomaly in the results was in the number of acute willow that were alive in the fall of 1996. The willow did not establish well at the outset of the trials, with only four specimens of the dry mulch treatment remaining viable entering the winter. This fact is reiterated in the results of the plant quality evaluation that follows. It should be noted however, that from the time the treatments were applied, no other plants were lost.

Evaluating Plant Quality

Table 3, Ranking of Treatments, provides a comparison of the performance of the quality of the plants between species as related to treatments. The average plant quality values recorded were arranged in descending order. The plant quality rankings were found to be statistically significant.

Plant	Ranking of Treatments (from highest assessed quality to lowest)		
Hawthorn	Hydromulch (3.35)	Control (2.27)	Dry mulch (2.18)
Dogwood	Hydromulch (3.87)	Dry mulch (3.20)	Control (2.08)
White Spruce	Hydromulch (3.35)	Dry mulch (2.60)	Control (1.90)
Acute Willow	Hydromulch (3.88)	Dry mulch (3.00)	Control (1.69)
Buffaloberry	Hydromulch (2.78)	Dry mulch (2.26)	Control (1.60)
Rose	Hydromulch (3.43)	Dry mulch (3.35)	Control (2.25)
Jackpine	Hydromulch (3.15)	Control (1.99)	Dry mulch (1.93)

Table 3: Ranking of Treatments (based upon overall plant performance).

Hydromulch

As can be seen from Table 3 the highest quality plants for all species were associated with the hydromulch treatment. The plant quality of the hydromulch treatment ranged from a low of 2.78 (Buffaloberry) to a high of 3.88 (Acute Willow). The most striking difference between the treatments was in size of the plants. Growth by the hydromulched plants was in some cases double that of their counterparts in the dry and control treatments and was exhibited by extensive branching and large bark green leaves in the deciduous species and by extensive leader growth and needle production in the coniferous species. The size differentiation of the plants of the hydromulch treatment versus the control ranged from approximately 20% as exhibited by the dogwood, to 200% by the rose. The remaining species in the hydromulch treatment were observed to be between 20% and 100% larger than those of the control. When comparing the plants of the hydromulch versus those of the dry mulch, the former ranged from having no discernible difference in size, (Jackpine), to being 100% larger (rose). There was also no chlorosis observed in the hydromulched plants.

Dry mulch

The quality of the plants in the dry mulch ranged from a low of 1.93 (Jackpine) to a high of 3.35 (Rose). Five of the species produced better quality plants in the dry mulch treatment versus the control, with Hawthorn and Jackpine being the exceptions. New growth was also observed by plants of the dry mulch treatment. The plants of the dry mulch treatments were characterized by excellent colour. Some chlorosis was observed, however this was limited to four or five individual plants and was not associated with any one species in particular.

Control

The plants in the control had plant quality values ranging from 1.60 (Buffaloberry) to 2.27 (Hawthorn). The plants were small in comparison to those in the other treatments, chlorotic and devoid of substantial vegetation.

Capacity as a Seed Bed

The dry mulch appeared to support the establishment of other plant species, with up to 100% ground coverage observed by the end of the 1997 growing season.

Conclusions and Recommendations

Hydroseeding

The results of this research indicate that hydroseeding is a viable and versatile technique for the revegetation of drastically disturbed lands. All of the products tested were able to form stable mats on a variety of soil surfaces and under a variety of conditions thus providing erosion control, weed suppression and for the establishment of desirable plant species. Even under extremely harsh conditions, such as slopes of 1:1 and areas of severe rilling, the vegetation became established with no further inputs being necessary.

The use of the Pine Falls Paper Company paper sludge as a component of a hydroseeding slurry also proved promising. Its level of performance in critical areas rivaled that of the commercially proven products. It was able to form a relatively stable mat on both flat and sloped conditions and remained intact for two growing seasons; adhered well to variety of surfaces thus resisting erosion; and, exhibited the ability to support exceptional germination rates of 60 - 80%. The lack of germination by the Jackpine seed could be attributed to a lack of stratification, although no germination was observed in the second year either (Kaczanowski pers comm 1997). The failure of the clover and annual rye grasses after they germinated is most likely due to desiccation as there was a lack of precipitation at a critical period of time in the establishment of these seeds. Even the commercially proven products only continued to support plant growth in the rills, where both product and much needed moisture accumulated. These results underscore the importance of timing the use of hydroseeding with periods and seasons of precipitation and low temperatures so that success rates can be higher. Pre-soaking the seeds prior to their use may have had a detrimental affect on germination rates. Pre-soaking would have stimulated the seeds to begin germinating, making them very susceptible to desiccation by the subsequent lack of moisture (there was no precipitation on the treatment areas for three weeks after the hydroseeding took place). In general, the hydroseeding products were able to form a stable mat that provided erosion control on slopes, reduced competition by weeds and resulted in high rates of germination when sufficient amounts of precipitation were available. Hydroseeding would therefore be an excellent approach for the revegetation of drastically disturbed sites. The use of the PFPC paper sludge as a component of a hydroseeding slurry also shows potential as it preformed well in the parameters used to evaluate hydroseeding products. It was able to form a stable mat, provided good erosion control, acted as an effective weed barrier and began breaking down with time.

Protective Mulches

The over-wintering success assessment was inconclusive as there was almost no difference observed in mortality between those plants protected by mulches versus those in the control. The only species that showed that it may benefit from the mulches was the buffaloberry, which had a survival rate of 88% without mulching as compared to 100% with mulching. The reason for the extraordinary ability of the plants to overwinter may be related to the following factors. Firstly, the plants were very well established in 1996, having been planted in June and being regularly watered until the application of the treatments some six weeks later. Secondly, the 1996 - 1997 winter was characterized by some of the highest accumulations of snow in the last century (Anderson pers comm 1998). The exceptional amount of snow fall would provide an excellent insulating layer that would have protected the plants from the extremely cold temperatures that also characterized the 1996 - 1997 winter season. In addition, the thicker snow layer would have provided protection from browsers. The greater accumulation of snow would have been followed by a higher than normal spring runoff in 1997, thus providing the plants with an excellent start in the spring. These climatic factors, coupled with the fact that the plants were well established the previous growing season, may have contributed to the high survival rates observed.

In contrast, the results of the plant quality assessment suggest that plants were able to derive benefit from the use of the paper sludge as a protective mulch, both as a dry mulch and as a "hydromulch". All seven species under the hydromulch treatment were characterized by large green leaves, a lack of chlorosis and the presence of new and vigorous growth. Both the tree and herbaceous species benefited. Literature reviewed lists the benefits of mulches as being moisture and nutrient retention and better plant quality as a result of reduced competition from weeds. Both mulch treatments appear to provide these benefits, with the hydromulch being particularly effective. It was able to form a durable and stable mat that adhered itself to the surface of the treatment sites on a variety of surfaces from sandy soils to gravel/sand soils. As a result there was little erosion of the surface covered by the hydromulch on slopes with gradients of up to 3:1 with no rilling of these areas being observed. The material remained viable and intact for two growing seasons and therefore resisted erosion by both wind and rain. The hydromulch also provide excellent weed control with the establishment of undesired plant species never exceeding 20% of the plot area. As a result, the competition for limited nutrients and moisture was eliminated, allowing the desired plants to flourish.

The dry mulch treatment produced plants somewhat poorer in quality than those of the hydromulch, however they were still superior to those of the control. This is most likely attributable to the lack of ability of the dry mulch to suppress undesired plants to establish themselves. Infestation rates approached 100% by the end of the second growing season and the presence of these plants resulted in competition between the desired trees and shrubs and the undesired species for the limited nutrients and moisture on the sites. However, what is important is that ruderals were able to establish themselves quite easily on the dry mulch material. By providing the necessary conditions for the re-establishment of pioneer species the process of natural revegetation of the drastically disturbed site was greatly enhanced. The dry mulch was very susceptible to both wind and water erosion, and over the two growing seasons it accumulated at the bottom of rills and was transported up to two feet downhill of the perimeter of the plots. The material lacked the ability to form a resilient and erosion resistant mat. The use of this material may therefore be limited to areas with little or no slope where erosion is not a concern.

As has been noted, all seven plant species performed best in the hydromulch treatments. Only the Jackpine and Hawthorn failed to draw any apparent benefit from the dry mulch. Chlorosis was found to be exhibited by all plants in the control, while none was observed among the plants in the two mulch treatments. The most resilient plant was the rose. It was observed as a pioneer species at the site and is naturally establishing itself along the periphery of the borrow pit. The surprise of the group was the acute willow. If it became established, it flourished under the mulch treatments, particularly the hydromulch. However, the need for protection could limit its usefulness. The performance of buffaloberry was surprisingly disappointing in that although it is capable of fixing nitrogen, its performance was the poorest of all the plants in the control treatment and also received the lowest quality ranking in the hydromulch treatment. It usefulness in revegetation may therefore be limited. Although the hawthorn benefited from the hydromulch, it was also able to grow satisfactorily under the control conditions. This suggests that it could also be useful as a pioneer species where mulching was not available, and would thrive in circumstances where mulching was available. The dogwood benefited greatly from the mulches and would require such protection if it is to be used in similar conditions. The Jackpine responded very well to the hydromulch treatment and poorest to the dry mulch treatment. If planting of this species was required on sites with slopes, then the use of the hydromulch would be beneficial to the revegetative effort. On areas with little or no slope, this species would draw little benefit from the application of mulches. Conversely, the white spruce responded very well to both mulches and as such, any project to revegetate an area with this species could benefit from the use of a protective mulch.

In conclusion, the benefits of the hydromulch appear to be related to its ability to suppress the growth of undesired plants, thus reducing or eliminating competition for nutrients and moisture; in its capacity to control erosion, thus providing for a stable growing medium; and finally in its ability to retain moisture either by reducing movement of water across its surface and thereby allowing for its infiltration and/or by reducing its loss through evaporation. The dry mulch material supported the establishment of ruderals. It appears to possess the necessary qualities to provide for the re-establishment of pioneer species, thus the process of natural revegetation of the drastically disturbed site was greatly enhanced. Overall, the PFPC paper sludge exhibited the characteristics important to be an effective and protective mulch and as such should be strongly considered in revegetation approaches of drastically disturbed sites. It could prove to be of benefit on sites with even the slightest of slopes, such as ditches, rights of way, temporary logging and access roads, and borrow pits including sand and gravel pits. In situations where the goal is to revegetate with desired species, then the use of the hydromulch would be an appropriate technique.

The results of this project suggest that hydroseeding and protective mulches would be excellent techniques in efforts to "kickstart" the natural revegetation of drastically disturbed lands within Manitoba and the Manitoba Model Forest region.

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This practicum has been recognized for its contribution to the pursuit of sustainable development by receiving a nomination for a 1997 Province of Manitoba Sustainable Development Award of Excellence, in the category of research and development.

Reclamation and Restoration of Settled Landscapes

September 27th – 30th, 1998
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