# LIMESTONE QUARRY MINE RECLAMATION PROJECT AT MEDUSA CEMENT COMPANY, A CASE STUDY

By

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Abstract: Biosolids have been applied to the spoil piles on the Medusa mining site in Charlevoix, Michigan for over twenty years. Biosolids applications and soil testing have been recorded since 1978. The original work involved the establishment of vegetation on a capped spoil pile of cement kiln dust (CKD). Several different biosolids treatment areas were established to determine the best method of vegetation establishment and biosolids application methods. This report will examine existing vegetation on the spoil piles. The use of biosolids has increased the vegetative cover and has established an organic layer that has stabilized the soil. The areas where the biosolids were applied had a lesser variety of species than the untreated areas. The untreated areas had less cover, but a greater variety of vegetation species.

Additional key words: vegetation establishment, plant succession, plant ecology, site planning, biosolids

## Introduction

In 1978 John Campbell, (Landscape Architect at Site Planning and Development, Charlevoix, Michigan), began a research project on using biosolids in the revegetation of the Medusa Cement Company's mine site, located in Charlevoix, Michigan. Continued biosolids applications have improved the soil conditions on site, and increased the vegetative cover where the biosolids were applied. Biosolids are the composted remains of municipal sewage treatment plants. The purpose of this study is to report on revegetation success on an existing mine reclamation project where biosolids have been applied for soil amendments. The goal of this report is to gather the available data to use as a basis for understanding the existing site conditions. The objectives are:

1. to describe the original study at the limestone quarry; [1]
2. to assess the existing data that have been accumulated over the past twenty years;
3. to describe those plant species that are currently on the site.

## Literature Review

This discussion will focus on vegetation establishment on drastically disturbed soils of shale and limestone quarries, such as those at the Medusa mine site. Numerous studies have established the importance of legumes, grasses and shrubs as the initial plant groups needed for establishment of wildlife habitat cover, soil enrichment and stabilization to reduce erosion. (Coppin & Bradshaw 1982, Skaller 1983, McMullen & Stacks 1984, Inouye & Tilman 1995). Biosolids has been utilized successfully as an additive to facilitate revegetation of various mine spoils (Stucky & Newman 1977). Biosolids typically contains 1-10% nitrogen by mass (USEPA 1983), and repeated land application can substantially raise the nitrogen status of a soil (Brockway *et al.* 1986). With the use of organic nutrients found in biosolids, soil organic matter content and soil structure improves and long term fertility increases at a substantially faster rate (Joost *et al.* 1987).

Many areas will revegetate naturally, depending on the type of mine waste. However, natural regeneration is mainly limited to surface overburden piles and quarry extractions. For example, a 20-year-old overburden pile may support grass, shrub and tree vegetation (Borovsky 1979, Leisman 1957). In contrast, unseeded kiln dust piles can still be devoid of

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vegetation after 20 years (Lizak & O'Reilly 1994, Dickerson 1972).

The studies that were conducted through the 1970s and 1980s have proven that the uses of organic soil amendments were far superior to chemical amendments. Plant successional studies have been limited and geared more towards the coal industry and agriculture. Therefore, documentation of changes in vegetation cover is critical to the development of effective long-term revegetation strategies.

## Description of the Study Area

The Medusa Cement Company is located in Michigan's northwest lower peninsula along 2.1 miles of Lake Michigan shoreline, and southwest of the City of Charlevoix. The 43.5-acre study area is located on the northeastern portion of the property adjacent to the City of Charlevoix Waste Water Treatment Plant (WWTP), residential properties, and Lake Michigan. The study site ranges from 15 to 33 meters above Lake Michigan. The spoil piles and quarry walls create the vertical relief of the site. The soils where the biosolids are applied are type two clay, sand and limestone with pH of 7.5 to 9.0, (City of Charlevoix WWTP Residuals Management Plan 1991). An average of 550,000 gallons of biosolids at approximately 6% solids (41.33 tons) were applied to the Medusa mine reclamation project annually until the practice was discontinued in 1998.

The original project consisted of two overburden piles. The northern spoil pile consisted of all overburden materials and the southern spoil pile consisted of a six foot cap of precipitation dust (cement kiln dust, CKD) from the cement making process. During the mid to late 1980s the area between the two piles was filled in with CKD and covered with an overburden cap, and the site remains this way at the present.

The constraints of the present study were primarily associated with deriving information from the original study conducted by Mr. Campbell in the early 1970s, and the inability to find complete records of biosolids and soil sample information. Data from several years were not available because of records disposal after the information retention time limit. Due to pending legal issues associated with CKD leachates into Lake Michigan, only limited information was available.

## Original Study

A long-range reclamation plan was initiated in 1976 at the Medusa site and completed in 1978, and this is the site that the present case study is derived from. After early trials with various fertilization methods from the original studies, the use of biosolids was determined to be the best aid in vegetation establishment. In 1977 a small reclamation project was begun to establish a basis for biosolids application rate. Ten experimental plots were laid out using a variety of groundcover seeding mixtures, trees, soil bed preparations, fertilization mixtures, and were mulched or irrigated at different rates. Seed mixtures included various quantities of grasses, legumes and wildflowers. Observations were made to calculate germination and percent cover for each seed mixture the first two season. Those trees that showed promise in 1977 are listed in Table I.

Table I. The vegetation determined to be best adjusted to site conditions:

| **Trees** | | **1977** | **Survival Rate 1978** | **Used in 1979** |
|---|---|---|---|---|
| *Acer platanoides* | Norway Maple | x | 95% | x |
| *Betula maximowicziana* | Monarch Birch | x | | |
| *Betula nigra* | River Birch | x | | |
| *Betula papyrifera* | Paper Birch | x | 100% | x |
| *Betula populifolia* | Yellow Birch | x | | |
| *Fraxinus americana* | White Ash | x | | |
| *Fraxinus pennsylvanica* | Green Ash | x | | |
| *Populas Hybrid 2-06* | Poplar Hybrid 2-06 | x | 84% | x |
| *Thuja occidentalis* | Eastern White Cedar | x | 87% | x |
| *Sorbus aucuparia* | European Mountain Ash | | 60% | x |
| *Quercus robur* | English Oak | | 57% | |
| *Quercus borealis* | Oak | | 52% | |
| *Pinus Sylvestris* | White Pine | | 47% | |
| **Groundcovers** | | | | |
| *Coronilla varia* | Penngift Crownvetch | | | |
| *Melitotus alba* | White Sweet Clover | | | |
| *Secale cereale* | Perennial Rye Grass | | | |
| *Elymus, Lolium perenne* | Grasses & Wildflowers | | | |

The north slope of the north overburden pile, treatment area 5 (TA-5), had a 3'x9'x80' furrow or trench created, which was then filled with biosolids. One-hundred seventy-six trees consisting of 1-1/2" to 2-1/2" caliper trees were planted 10 feet on center. The deciduous tree species used during 1978 in treatment area TA-5 and their survival rates are listed in Table I.

The large scale reclamation project was begun in the summer of 1979 using the past trials as the determination for vegetation establishment at Medusa. Tree seedlings that survived 80% or better the year before were planted on the north overburden spoil pile (Table I). Five-thousand four-hundred 18-24" seedlings were planted the second year at a rate of about 400 trees per acre. Their survival rate averaged about 92% after the first year, but, by 1983 only 35% of the trees survived, primarily the European Mountain Ash, *Populus* Hybrid (clone 2-06), and White Cedar. This area was also hydroseeded with: Crownvetch (*Coronilla varia,* L.), White Sweet Clover (*Melitotus alba,* L.), Rye (*Secale cereale,* L.), and wildflowers.

The south overburden pile treatment area (TA-4) was hydroseeded with a grass seed mixture of Rye, Kentucky Bluegrass (*Poa pratensis,* L.), Red Fescue (*Festuca rubra* 'Pennlawn', L.), White Sweet Clover, and Crownvetch. Additional fertilizer, 6-24-24 (NPK), and irrigation ware used the first season. Treatment area (TA-2), the south slope of the south overburden pile, was hydroseeded with Crownvetch, White Sweet Clover, Rye 'Manhatten', Red Fescue 'Baron', Red Fescue 'Nugget', Red Fescue 'Pennlawn', and *Elymus.*

After initial establishment of vegetation, biosolids were the only method of fertilization used. Monthly soil, biosolids, and groundwater analysis was performed for the first two years. After no adverse affects were shown, annual soil samples were taken only from the biosolids applied areas for analysis to determine biosolids application rates and to monitor chemical loading. Average annual biosolids applications were between 500,000-600,000 gallons or about 9,000-10,000 gallons per acre.

## Sources of Data & Data Collection Plan

The data used for the present case study include physical and site specific information pertaining directly to the study. The historic data were obtained through interviews and by examining the projects past files, including the environmental assessment documents, permits, testing procedures, monitoring records, vegetation growth rates, and long term management data for biosolids applications. The site-specific data included: soil and biosolids test results obtained from WWTP, Site Planning Development (SPD) dead files, and attempts to contact past testing labs. Data were not available for specific years because the labs either did not keep records for this extended length of time or would not release the information. The vegetation survey was conducted May 27-August 30, 1997 through direct field observations. Photographs were taken during these site visits, with early photo records supplied by SPD.

The 1997 vegetation survey divided the site into five different treatment areas. The vegetation was identified and stem counts performed in 60 quarter meter plots for each treatment area. The five different treatment areas were: (TA-1) the control plot, a disturbed area that has not been seeded and has not received biosolids applications; (TA-2) a disturbed area that has been seeded but has not had any biosolids applications; (TA-3) an area that has not been seeded but has had bi-monthly biosolids applications; (TA-4) a disturbed area that was both seeded and had biosolids applied bi-monthly; (TA-5) a disturbed area that was originally trenched with only one year of biosolids applied (Figure 1). Each of these treatment areas was of different size and numbers are to be adjusted to represent equal distribution. The data collection of herbaceous plant species, their numbers, and establishment of tree counts will be used to determine frequency, density, and abundance from each of the five treatment areas.

## Methodology & Procedures

The measuring technique used was the Random Plot Method (Cain & de Oliveria Castro 1959, Phillips 1958, Barbour *et al.* 1987). This involved locating 60 different ¼ meter plots in each of the five treatment areas. This number of plots meets the Braun-Blanquet (1932) definition of adequate plot sample curve. The plots were determined using a random number table to establish the number of paces and the direction of travel. The edge effects were avoided by omitting counts until the road areas were crossed then resuming the count into the remaining area. The pin ball effect, the bouncing off at the same deflective angle at the edge of study area, was used when reaching the limits of the treatment areas. Each plot was surveyed for number count, identification of species type, and the total cover for all species. Only those species with stems located within the ¼ meter

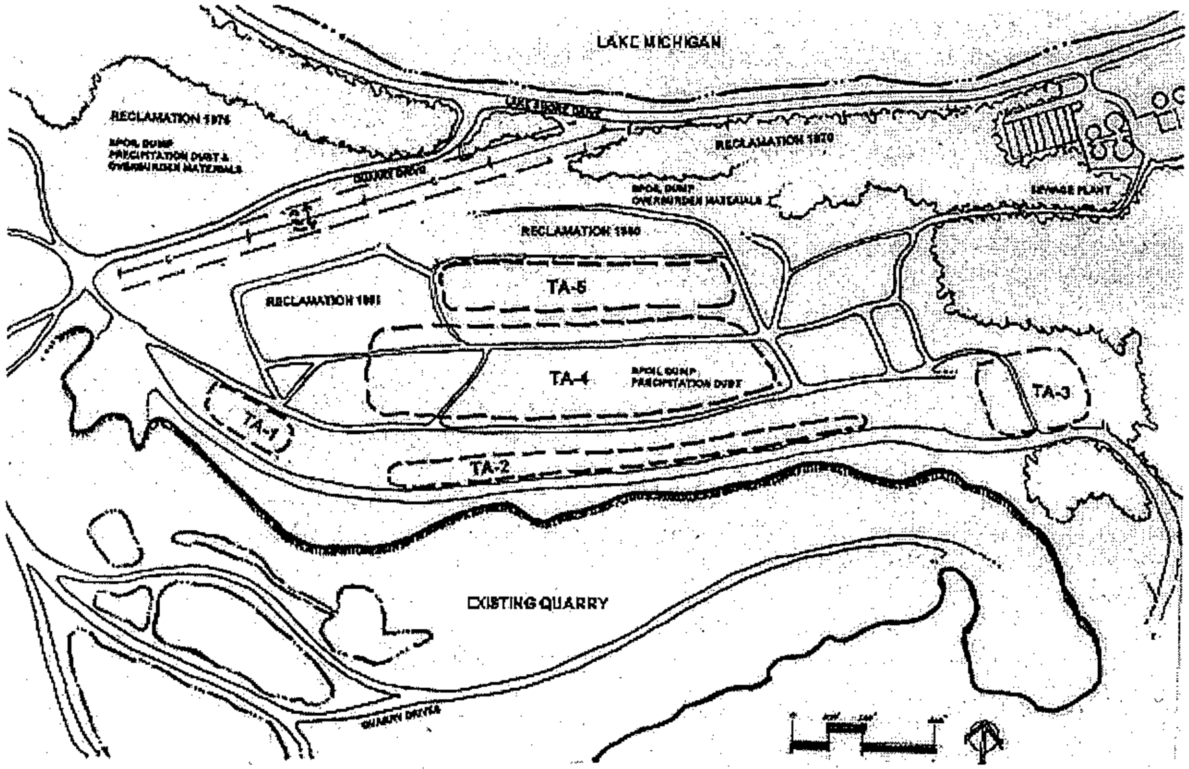


Figure 1. Reclamation Site Map

plots were counted; trees were only mentioned if they fell within a plot. A photographic record was also made for future reference for each plot. Each photograph included a north determination and a card that recorded date, plot number, and treatment area. Samples of vegetation were added to the card. Only one area, TA-5, contains trees of greater than or equal to 4 inch diameter greater at breast height (DBH). All of the trees in this area were planted as part of the original reclamation project.

Treatment data for each area were recorded in a table (Arnold Harmon *et al.* 1999) that noted whether moss or trees were present. Both counts and species of forbs and grasses were recorded. Simple averages were calculated and used for the discussion. This included presence of Crownvetch, moss, grass and forbs. The data collection of herbaceous plant species, their numbers, and tree establishment counts were used to determine frequency, density, and abundance of vegetation for each of the five treatment areas. This in turn compared the number of variety of each species within the various treatment areas. A table was created that included the forbs that were grouped into total number of identified varieties in each plot, greatest number of identified varieties per plot, plots with forbs only, plots with Crownvetch, and plots with both forbs and grasses (Arnold Harmon *et al.* 1999). The data on grass was broken down into total number of identified varieties, greatest number of identified species per plot, plots that contain grasses only, plots that contain grass, and the percent area surveyed for each treatment area. Visual observations as to percent cover were noted in each area.

## Results

### Difference Between Areas

All areas were on disturbed soil with different treatments added for vegetation establishment. Treatment area (TA-1), the control plot, was on overburden materials that have not had any seeding or biosolids applied. The site is approximately 836 square meters located on the west side of the study area. Volunteer trees are becoming established in this area. The area vegetation coverage is approximately 60 to 75% and has a diverse population.

Treatment area (TA-2) is a disturbed area that has been seeded but has not had any biosolids applied. The southern exposure and steep slopes are not conducive for moisture retention. The site is approximately 3,260 square meters located on the south side of the overburden spoil pile. It has a two-foot cap of overburden on cement kiln dust (CKD) with a slope of 35-40%. In several areas the cap has slid down the hill and exposed the CKD. Vegetation is not present in these areas. Several volunteer trees and small shrubs/scrub vegetation are becoming established. In the remaining area vegetation coverage is approximately 75 to 90% and consists of a diverse population.

Treatment area (TA-3) has not been seeded but has had bi-monthly biosolids applications. The site is approximately 3,261 square meters located on the east side of the study area. This lower plateau area is adjacent to the Charlevoix WWTP. The vegetation coverage in this area is approximately 85 to 95% and has a somewhat diverse population.

Treatment area (TA-4) is a disturbed area that was both seeded and had bi-monthly biosolids applications. The site is approximately 22,483 square meters located on the highest part of the overburden spoil pile, and is a relatively flat area. The area vegetation coverage is approximately 90 to 100% and has large areas of monocultures.

Treatment area (TA-5) is a disturbed area that was originally trenched in 1978 and had only one year of biosolids applied and consisted of both injection and surface applications. The site is approximately 14,865 square meters and is located on the north side of the study area. The north facing slopes trap moisture from Lake Michigan and has a slower evapotranspiration rate than the south facing slopes in TA-2. The resulting microclimates in these two areas have affected vegetation growth. The area has approximately 85 to 95% vegetative cover and has a somewhat diverse population. This is the only area in which trees were planted. Tables were created for each of the treatment areas from the information collected on the ¼ $m^2$ plot for each area (Arnold Harmon *et al.* 1999).

<u>Existing Vegetation</u>

Treatment area TA-1 has a large variety of forb species with some grasses. Most grass is located at the eastern portion where the exposure to the wind and elements was the least. Forbs outnumber grasses both in numbers and variety in this area. At this time Spotted Knapweed (*Centaurea maculosa,* L.) was the dominant species. Other species present are Wild Columbine (*Aquilegia canadensis,* L.), White Sweet Clover, (*Melilotus alba,* L.), Black Medic (*Medicago lupulina,* L.), *Brassica* spp., *Poa* spp., *Festuca* species, and to a lesser degree, Ox-eye Daisy (*Chrysanthemum leucanthemun,* L.), Wild Strawberry (*Fragaria virginiana,* L.), with a variety of unknowns. Invasive trees and shrubs include Paper Birch (*Betula papriyrifera,* L.), Red-Osier Dogwood (*Cornus stolonifera,* L.), and American Linden (*Tila americana,* L.). Moss was present throughout the area, but is not a part of this study. Vegetative coverage is sparse in places where soils are thin and organic matter is absent.

Treatment area TA-2 has several areas of bare soil where the CKD is exposed and the highly alkaline soil has not allowed plant establishment. Also present are large limestone rocks where the angle of repose has allowed most of the soil to slough down the slope. Forbs outnumber grasses in both numbers and variety in this area. Vegetative coverage is greater here than in area TA-1. Spotted knapweed was the dominant species. Other species present were grasses of the *Poa* species, *Festusa* species, *Agropyron* species, *Elymus* species, and the forbs *Brassica* species, White Sweet Clover, Ox-eye Daisy, and to a lesser degree Viper's Bugloss (*Echium vulgare,* L.) Poison Ivy (*Toxicodendron radicans,* L.), and a variety of unknowns. Many of the original planted species are still present in this area. Surprisingly, almost no Crownvetch is located on the lower slopes, even though the species is present near the top.

Treatment area TA-3 has a considerable amount of grasses, but most are shorter varieties. More varieties of forbs are present here than in TA-4, where biosolids were also applied. Percent vegetative cover in this area is more varied with a cover of 75 to 100% range. At this time Crownvetch and Bull Thistle (*Cirsium vulgare,* L.) are the dominant species. Other species present are Prickly Lettuce (*Lactuca serriola,* L.), White Sweet Clover, *Poa* species, *Festusa* species, *Agropyron* species, *Elymus* species, Common Dandelion, (*Taraxacum officinale,* L.) and, to a lesser degree, Spotted Knapweed and a number of varieties of unknowns.

The grasses were the dominant plants in treatment area TA-4, and Crownvetch was the dominant forb. Most forb species were present only during the early portion of the season and were of a limited number of different species. The largest populations of forb were located along the roadways creating edge effects to what is largely a grass prairie. Vegetative coverage in this area was almost 100%, except in the early spring. According to Mr. Campbell of Site Planning Development the amounts of white sweet clover and crown vetch vary from year to year on a seven-year cyclical basis. At the time of observation the Crownvetch was the dominant species of the two. Other species present are Black Medic, *Poa* species, *Festusca* species, *Agropyron* species, *Elymus* species, and, to a lesser degree, Spotted Knapweed, Prickly Lettuce, Common Burdock (*Arctium minus,* L.) and a limited number of varieties of unknowns. Much of the originally planted species are still present in this area.

Grasses were the dominant species in treatment area TA-5, with Crownvetch, Common Burdock and Bull Thistle being the dominant forbs. The largest populations of forbs were grouped in colonies, which were distributed throughout the site. This area is the only area that contained trees, thus the shade produced affected some of the species present. Vegetative coverage in this area was generally 90 to 100%. At this time grasses were the dominant species these included, *Poa* species, *Festusca* species, *Agropyron* species, and *Elymus* species. Other species present are White Sweet Clover, Mustard species, and to a lesser degree, Spotted Knapweed, Prickly Lettuce and variety of unknowns. Much of the original planted species are still present in this area.

## Interpretation

The data collected during the course of the summer of 1997 formed the basis for the following discussion. The bulk of the study consisted of vegetation analysis. The data comparison between forbs and grasses looked at the number and variety of species, whether a plot contained the species or not, and a comparison of the amount of area surveyed in relation to overall area for each treatment location.

The high pH of both the biosolids and soil at the beginning of the reclamation project were reduced over time. The pH of the soil samples ranged from 8.5 to 12.7 in 1977-78. In the available data from the 1980's the pH ranged from 7.8-8.5 and in the early to mid 1990s the pH fell to a range of 7.24-7.52. Since 1996 the pH has increased to 9.22. There is not a large degree of increase in the pH from the biosolids or from the drying bed data to affect the soil enough to show the increase of pH in the existing soil. Some fluctuation is expected but the degree of increase in a relatively short period of time is not readily explainable. Fallout from air particles from the cement kiln emissions and quarrying process could be one possibility. Another possibility could be the upward leaching of alkaline salts from the CKD.

The variation in aspect affected the plant growth and establishment by increasing the available moisture on the northern slope of area TA-5, which is adjacent to Lake Michigan. The shade from the existing tree, and orientation away from the sun, reduces the evapotranspiration in this. Area TA-2 has higher evapotranspiration because of the southern orientation and limited vegetative cover. The flatter areas of TA-3 and TA-4 along with the addition of biosolids appear to increase available moisture to these areas. The eastern portion of the study area, TA-3, has a well-established vegetative cover, particularly grasses, because of its protected location. The control plot TA-1 is in the most exposed area, where wind continually erodes the area and the sun increases the evapotranspiration rate. This erosion is evident where grasses have not become established to hold the soil in place. These modified microclimates, I believe, have affected the vegetation establishment and plant successions.

The vegetative cover is greater on site where the addition of biosolids have affected soil chemistry and water holding capacity. These treatment locations tend to show larger plant colonies that form visual mosaic patterns in the landscape. Grasses are the predominant species in areas TA-3, TA-4, and TA-5, with Crownvetch being the predominant forb. Treatment areas TA-1 and TA-2 have a greater variety of species present on them and are predominately covered by forbs, Spotted Knapweed being the dominant species (Table II).

The vegetation analysis included ecological guilds/groupings of the moss layer, herb layer, understory, emphemerals, and overstory. The moss layer was present only in TA-1 where 27% of the plots contained moss, and in TA-2 where 3% of the plots contained moss. The overstory layer is located in only in TA-5 and is not thick enough to create an understory layer. The emphemerals are limited to spring varieties.

Table II. Vegetation Analysis from 1997 Survey:

| | DATA | **TA-1** | TA-1 % | **TA-2** | TA-2 % | **TA-3** | TA-3 % | **TA-4** | TA-4 % | **TA-5** | TA-5 % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **FORBS** | Total # of Identified varieties of forbs | 7 | | 12 | | 6 | | 5 | | 4 | |
| | Greatest # of identified varieties of forbs per plot | 9 | | 7 | | 4 | | 3 | | 5 | |
| | Plots that contain forbs only | 2 | 0.03 | 9 | 0.15 | 6 | 0.10 | 1 | 0.02 | 4 | 0.07 |
| | Plots that contain forbs | 60 | 1.00 | 54 | 0.90 | 42 | 0.70 | 41 | 0.68 | 54 | 0.90 |
| | Plots that contain *Coronilla varia* | 0 | 0.00 | 0 | 0.00 | 33 | 0.55 | 50 | 0.83 | 53 | 0.88 |
| | Plots that contain forbs in addition to *Coronilla varia* | 0 | 0.00 | 0 | 0.00 | 8 | 0.13 | 30 | 0.50 | 42 | 0.70 |
| | Plots that contain both forbs and grasses | 58 | 0.97 | 45 | 0.75 | 41 | 0.68 | 51 | 0.85 | 40 | 0.67 |
| **GRASS** | Total # of Identified varieties of grasses | 2 | 0.03 | 2 | 0.03 | 5 | 0.08 | 6 | 0.10 | 3 | 0.05 |
| | Greatest # of identified varieties of grasses per plot | 6 | 0.10 | 5 | 0.08 | 4 | 0.07 | 6 | 0.10 | 3 | 0.05 |
| | Plots that contain grasses only | 0 | 0.00 | 2 | 0.03 | 13 | 0.22 | 8 | 0.13 | 6 | 0.10 |
| | Plots that contain grasses | 58 | 0.97 | 47 | 0.78 | 54 | 0.90 | 60 | 1.00 | 54 | 0.90 |
| **NOTES** | Contains Trees >4" DBH | 0 | | 0 | | 0 | | 0 | | yes | |
| | Contains a shrub layer | yes | | 0 | | 0 | | 0 | | 0 | |
| | Contains a moss layer | yes | | yes | | 0 | | 0 | | 0 | |
| | Plots devoid of vegetation | 0 | | 4 | | 0 | | 0 | | 0 | |
| **AREA** | Study area size in meters | 836 | | 3,260 | | 3,261 | | 22,483 | | 14,865 | |
| | Percentage of area surveyed | 0.018 | | 0.005 | | 0.005 | | 0.0007 | | 0.001 | |

A tree survey of 1 inch saplings may give a better understanding of the volunteer species that have become established in the TA-1, TA-2 and TA-5 areas. Most of the existing trees in this area consisted of *Populus* species that showed signs of disease and death and several Scotch Pines (*Pinus sylvestris,* L.) are in good health. European Mountain Ash (*Sorbus aucuparia,* L.), is also present in varying degrees of health. There are several Paper Birch *(Betula papyrifera,* L.) still remaining from the original plantings, and a few volunteers of a wide range of ages. European Mountain Ash (*Sorbus aucuparia,* L.) is also present in varying degrees of health. The volunteer woody species that are present throughout the reclamation project include Paper Birch, Eastern Cottenwood (*Populus deltoides*, L.), and Red-osier Dogwood. These are typical species in old field plant succession studies.

The forbs exhibited the greatest variety in treatment areas TA-1 and TA-2, and the fewest varieties in TA-5. This statement is based on identified forbs and not on the total of the unknowns. If all species were identified, I believe that a greater distribution of variety would be evident. A better indication would be to look at the difference in the greatest number of variety of forbs located in a single plot. Nine varieties of forbs were located in a single plot in TA-1 whereas the greatest number of forb species located in TA-4 was only three and this occurred during the early season before the grass cover blocked out the sunlight. In the areas where Crownvetch was the predominant forb, it screened out most other vegetation once an overhead canopy was established. One hundred percent of the plots in TA-1 contained forbs whereas only eighty-three percent of TA-4 contained forbs.

Grasses dominated treatment areas TA-3, TA-4, and TA-5 both in varieties and quantities. One hundred percent of TA-4 plots contained grasses in the vegetative mixture, whereas only 78% of the plots in TA-3 contained grasses. Of the three treatment areas the largest variety of grass species per plot was located in TA-3, and the least in TA-5. Twenty-two percent of TA-3 contained plots of grasses only, whereas TA-1 did not contain any plots consisting of grasses only. Plots that contained both forbs and grasses were greatest in number in treatment area TA-1 (97%) and least in number in TA-5 (67%).

## Summary & Conclusions

The vegetation survey conducted during the 1997 season shows what species are representative of a reclamation project where different soil treatments are applied over the long-term. As this reclamation project and other research supports (Sommers 1977, Stucky & Newman 1977, Schafer *et al.* 1980, Jenny 1980, Sopper 1993) substantial vegetative cover is reached with the addition of soil additives to increase soil building properties. Where natural vegetation succession is allowed to progress on its own, stress factors create a greater variety of plant species (Biodini & Redente 1986). Because of the disturbance on the site, a large variety of vegetative species have become established. Because the reclamation site has several areas which have undergone different treatments, different vegetation mosaics have been created.

Those locations at Medusa where biosolids were applied have a good vegetative cover and show less erosion than those areas where slopes are steeper and vegetative cover was less. Biosolids applications have greatly increased vegetative coverage, but have also limited the number of varieties of vegetation species that exist there. The biosolids treated areas have a greater grass consistency. If a site is left to develop on its own, there seems to be a greater diversity within the plant community. Old field pioneer vegetation species are present on the least treated areas.

Due to existing concerns of contamination in Lake Charlevoix from the seepage of alkaline leachate from the cement kiln dust, the biosolids applications were ceased in 1998. It would be interesting to see the effects of plant succession once the site has been left to continue on its own. How will the lack of nutrients and moisture affect the species present? Are there enough organic matter and soil nutrients to support the existing vegetation densities? What species will become dominant over time?

This study was begun with the intent of being able to establish a baseline for future studies. Information needed for a more complete study would include: bulk density, percent clay, percent electric conductivity, hydraulic penetration, percent organic matter, and percent slopes. Vegetation analysis would include more complete species identification, percent cover determination, diversity, plant species dominance, species association and composition, species frequency, and species character and origin. Bulk density of biomass and chemical analysis of revegetation could be measured to detect toxic chemical uptake.

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