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BIOSOLID APPLICATION ON A LIMESTONE QUARRY MINE RECLAMATION PROJECT AT MEDUSA CEMENT COMPANY:

A Case Study

By

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ABSTRACT

LIMESTONE QUARRY MINE RECLAMATION PROJECT

AT MEDUSA CEMENT COMPANY

A Case Study

Patricia Kay Arnold Harmon

The application of biosolids on the Medusa mining site in Charlevoix, Michigan will form the bases of the study reported in this document. Biosolids have been applied to the spoil piles for over twenty years. Rates of biosolid applications and soil testing have been recorded, since 1978. This report will examine revegetation activities and the presence of heavy metals in the soil associated with biosolid applications. The use of biosolids has increased the vegetative cover and has established an organic layer that has stabilized the soil. The areas were the biosolids were applied increased the vegetative cover but consisted of a lesser variety of species than the untreated areas. The untreated areas had less cover thus affecting, the quantity of food and cover to support wildlife, and the amount of organics in the soil to establish the required vegetative cover to meet mine reclamation requirements. With the discontinuing of the biosolid application at the end of the 1997 season, the plant communities will evolve once more. Is there enough organic material to sustain the current populations and how has the added moisture affected the current populations? Data presented will aid in establishing a baseline to help answer these questions.

Key words: mine reclamation, vegetation establishment, plant succession, plant ecology, site planning

Dedicated to my two sons Jim and Scott.
Thank you for your patience and understanding when all was in turmoil.

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Thanks to those people that have made this project possible. Thank you Jon Burley for your guidance. Thank you "All Mighty Library Wizard," Tom Coccizolli, for all your help over the years. You have made research a much easier task. Thanks to Sam Crestwell for supplying the needed information from the sewage treatment plant. A special thanks to John Campbell for with out his early research and help with understanding the processes this project would not be possible. Thanks to both Tony Bauer and Bob Schutzki for your support and guidance.

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Chapter I Introduction

Background:

In nineteen seventy-eight John Campbell, (at Site Planning and Development, Charlevoix, Michigan), began a research project with the use of biosolids in the revegetation of the Medusa Cement Company's mine site, located in Charlevoix, Michigan. Continued biosolid applications have improved the soil conditions "on site," and increased the vegetative cover were the biosolids were applied. Campbell's original work involved the establishment of vegetation on a capped spoil pile of cement kiln dust (CKD). The use of several years of biosolids and soil testing were used to observe changes in the soil chemistry. The original CKD had a pH range of 10-13 and the cap of overburden materials pH ranges from 7.8-9. High concentrations of salt and magnesium were also present. Several different biosolid treatment areas were established to determine the best method of vegetation establishment and biosolid application methods.

Purpose of the Study:

The purpose of the study is to report on revegetation success on an existing mine reclamation project, where biosolids have been applied for soil amendments.

Statement of Goals/Objectives:

The goal of this report is to gather the existing available data to use as a bases for understanding the existing site conditions. This data can aid in the application biosolids for revegetation on mine reclamation sites. The objectives used to reach this goal are:

1. to describe those studies that have examine mine reclamation were biosolids have been used;
2. describe the original study at the limestone quarry;
3. to assess the existing data that has been accumulated over the past twenty years;
4. and to describe those plant species that are currently on the site.

Organization of Study:

The case study will review related literature (Chapter 2), present the historical background and introduce existing data. The related literature presents the physical properties that must be addressed on a site when biosolids are used for reclamation of soils. The historical data addresses the physical, social and to a limited effect the economics of the area. The methodology (in Chapter 3), describes the process of how the data was obtained and how it was relevant to the study. The discussion portion (Chapter 4), of the project introduces the study from its inception, through the present day. In the concluding remarks, possible future studies are presented.

Chapter II Review of the Literature

Introduction:

An examination of biosolids research reveals that the majority of the studies are on coal mining sites. The focus of this discussion however will be on those studies specifically relevant to reclamation of drastically disturbed soils at shale and limestone quarries sites. Of particular interest will be utilizing biosolids to reclaim soils on the Medusa mining site in Charlevoix Michigan. Unlike soils at many coal mining sites the soils at the Medusa site have a high pH, magnesium carbonate, and saline content. The understanding of vegitation succession on mine reclamation projects will increase the knowledge of those who must make decisions for continual reclaiming of disturbed soils. Adequate reclamation measures at Medusa and other sites will ensure effective formation of soil rebuilding materials. Though many similar concerns are universal to all barren mining sites, good ecological practices can be illustrated through monitoring and study of the materials used for soil building and vegitation establishment.

The main reason for use of biosolids is that it is an organic material high in nutrients that allows for a slow release of nitrogen. Biosolids contains significant amounts of nutrients and organic matter (Sommers 1977). This helps to increase vegetative litter that in turn increases microbial activity that enhances the reclamation potential of a mine site. Biosolids has been utilized successfully as an additive to facilitate revegetation of various mine spoils (Stucky *et al.* 1977). A higher application rate of biosolids can be used on disturbed soils because of the importance of establishing a vegetative cover. Use of inorganic fertilizers or natural succession may take over thirty years to establish native organic matter levels, soil structure and an A horizon development (Schafer 1980, Jenny 1980). With the use of organic nutrients found in biosolids, soil organic matter content and soil structure improves, and long term fertility and microbial activity increase at a substantially faster rate (Joost *et al.*1987). Because mine sites tend to be dry during the summer the use of liquid biosolid applications adds to the moisture content of the soil that helps establish vegetation.

Organic fertilizers have a higher nutrient content and exhibits a slower, steadier release of nitrogen. Biosolids are very beneficial in adding organic compounds that help build the soil structure into a viable means to support vegetation and adds to the beneficial movement of air and water through the soil. Biosolid are a slurry of water and organic solids that are high in organic matter, macronutrients (nitrogen, potassium and phosphorus), and micronutrients. The nitrogen accumulation has three important factors for the establishment of nutrients for plant use.

1) Nitrogen content is in a slowly available organic form.

2) The high organic content provides an energy source for soil microbes.

3) Sludge organic matters improve the poor spoil physical conditions from soil removal and compaction. (Sopper 1993)

The biosolids are best incorporated into the soil so as not to lose the gaseous form of nitrogen that is lost in the top dressing form of applications (Jacobs 1995). The drawback is there is a need for high rates of applications to show benefits.

The chemical components that make up the slurry that is land applicable are dependent on the products that go into it. The biosolids can be either aerobic or anaerobically digested; this process kills many of the harmful pathogens that are in human wastes. Aerobic digestion generally produces a more odorless, humus-like product and conserves more of the biosolid's nitrogen. Anaerobic digestion is more energy efficient, produces a biosolid that is more easily dewatered for transport, and generates a useful by-product, methane (Crohn 1995). The additions of industrial and household chemicals add heavy metals to the sludge. Monitoring the amount of biosolids applied and the concentration of chemical components is important to reduce the chances of contamination of soil and vegetation.

Soils:

Initially base line of the soils that are located at the site must be established to understand the chemical makeup of an area. These soil tests will determine the regime that biosolids can be applied to avoid the build up of heavy metals that affect plant growth. The barren soil properties are usually lacking in several macro and micronutrients and heavily burdened in others. The metals that are found in the soils have direct relationships to the metals found in the vegetation that grows upon the soil, (Sheltron *et al.* 1977).

The soil properties of barren soils are affected by both the physical and biological composition of the site. These two components are important to the success of long term vegetation establishment. The physical properties of many mine sites include low water holding capacity, low bulk density, compaction, and lack of air or water circulation. The need to first prepare the soil by aerating the soil through tilling improves soil structure, water and nutrient holding capacity. The addition of organic compounds adds the missing components needed for vegetation establishment. It has been found since low water holding capacities on barren soils create drought conditions, it is important to supplement

vegetation establishment through the use of irrigation (Sheltron *et al.* 1977). This illustrates how the use of biosolids has another advantage over other fertilizer practices.

The biological properties of disturbed soils are associated with the lack of nutrients and organic matter, contributed by alkaline soils, high pH, and lack of microbial activity. The addition of biosolids to the site adds the necessary nutrients that are needed to establish vegetation. 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).

An understanding of the physical and chemical characteristics of geologic and soil materials are needed, particularly geologic materials, since they constitute all or a majority of the seed bed (Long *et al.* 1982). The vegetation establishment and growth factors depend on other variables as well. One important saying, "Don't fight the site," refers to using plants that do well in the soils available. The accumulation of dead organic matter increases microbial activity; this in turn promotes good root growth and the downward movement of nutrients and water through the soil profile. The availability of the nutrients is determined by the pH, electrical conductivity, and metal toxicity of the soil. Each of the micro and macro nutrients have different pH requirements for plant availability.

The soil characteristics determine the soil additive recommendations. Lime supplies the soil with two essential plant nutrients, calcium and magnesium. Dolimitic limestone is high in calcium and magnesium, this being a readily available substance. Soil additives that bring down pH include the use of sulfur.

The Environmental Protection Agency has set standards for the use of municipal biosolids for land application. They restrict the use through the establishment of maximum amounts of trace metals that can be applied to agricultural lands. The maximum amounts are related to the soils cation exchange capacity (Sopper 1981). Industrial chemical additions to biosolids can contain toxic concentrations of trace metals.

Microbial Activity:

High levels of microorganism activity can be responsible for reducing soil borne pathogens such as pythium and rhizoctonia, and help release micronutrients that allow them to become available for plant use (Wilkinson 1995). The microbial populations help in the increase of the humus layer that increase the health on the disturbed site. It is this increased composition layer that is the indication of rapid ecosystem recovery. The use of microbes and bacteria to aid in the removal of PCBs and other toxic components are being studied in the Sacramento, California area (Public Works 1993). To date the high concentrations of heavy metals do not have an adverse affect on microbial populations (Sopper 1993).

Pathogens that are naturally found in biosolids can be eliminated through the decomposition process with the use of heat. The use of mesophilic anaerobic digestion proceeded by a mechanism renders most enteroviruses inactive (Straub *et al.* 1994).

Water Quality:

Ground and surface water quality are affected by the compaction, and percolation of the soil. The leaching, erosion, and run off that is affected by the physical makeup of the site can be altered to benefit the revegetation efforts. Vegetation increases water quality by better filtration and removal of heavy metals. Much of the research that is taking place today is focusing on the use of plants to remove heavy metals in soils (Environmental Science and Technology 1993). Over a two year application of biosolids on the Venango County mine site, no significant increases in the concentration of NO_2 -N or trace metals in the ground water were observed from several wells (Sopper 1981). No health hazards or adverse effects on the environment are known to have resulted from the use of large volumes of biosolids applied to the Lousisa County, Virginia mine site (Hinkle 1982). No significant effect of the biosolids were reported in the ground water.

Concerns for long term biosolid use include trace metal loading in vegetation and animals. The trace metal loading is dependent on various factors including soil pH, element concentrations, soil types and plant species (Boswell 1975; Chaney 1973; Furr *et al.* 1976). Short term elevated concentrations have been demonstrated in certain animal targeted organs but no long term studies have been conducted. Though most studies have proven a slight elevation in trace metals in plants and animals there are none that show toxic concern.

Vegetation:

Vegetation growth depends on soils, geology, fertilization, and amendments (Roberts *et al.* 1988). Growth response has been reported in many studies that have used sewage sludge. Among the problems, according to Robert's, associated with revegetation are the following: (1) adverse physical properties affecting, density, and water penetration; (2) extreme deficiencies of some major nutrients; (3) presence of toxic compounds or high salt concentrations and (4) wind blasting. The health of the reclaimed soils is measured by the dry matter yield of plant biosolids. The effects of various surface soils include poor drainage, lack of nutrients and trace metals.

The increase of vegetation stabilizes the soil to stop severe wind and water erosion. The establishment of herbaceous species first, followed by trees and shrubs have been demonstrated in several projects (Sheltron *et al.* 1977, Dickerson 1975, Donovan 1976). Without the establishment of grasses first there tends to be a greater degree of wind and soil erosion. This does not permit the establishment of larger vegetative species. Vegetative quality in the establishment of a reclaimed site is important to the visual impact of the perceived destruction of land through the mining process.

The establishment of vegetation on disturbed soils with the use of biosolids has been studied for many years. All studies confirm the use of sludge as the most beneficial in the establishment of plant material by increasing nitrogen (N), phosphorous (P) and potassium (K). The amount, methods, and applications may very but the results remain consistent. The variables that have created concern are the pathogens and toxic metal concentrations that can be accumulated to a degree of possible harm to humans and animals. Trace metals have been detected on plant materials. Heavy metals are shown to increase but not to any significant extent (Fresquez 1990). Concern that they might become a 'time bomb' reflects the belief that in twenty years we will be paying for the application of sewage sludge (Brown 1991). Studies of chorobenzenes in field soil with multiple biosolids applications have shown an increase in concentrations of Chlorobenzenes, (CB). The greatest increase of CB tended to occur once the biosolid applications stopped, in 1961. The CB concentrations have risen steadily since. One view maintains that industrial fall out from the air plays a part in the addition of toxic substances to the area (Wang 1995).

Research is being conducted for the use of plant materials to remove heavy metals from soils. Studies conducted by V. Dushenkov and colleagues are using such plants as Indian Mustard to absorb toxic chemicals. Dushenkov suggests rhizofiltration has applications for Pb abatement in a variety of industries (Environmental Sci. & Technology 1995). The use of Indian mustard (*Brassica juncea*, L.), in a study conducted by P.B.A.N. Kumar (1995) concluded that phyto extraction can be a "green" alternative to heavy metal soil redemption. Chemical loading can be avoided by monitoring the biosolids applications.

Reclamation Vegetation Succession Studies:

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 vegetation after 20 years (Lizak 1994, Dickerson 1972). Peak biomass accumulation can be reached within five years on treated areas (Packer 1982). Independent variables used in establishing vegetation are the amount of precipitation, length of growing season, nutrient additives and age of plants. Biomass production in native species and introduced species increased as precipitation and age of plants increased up to five years (Packer 1982).

The problem of allelopathy, when the absence of micro organisms are present, limits the growth of one species on another. For example the presence of some fescue grass inhibits the germination of some pine seeds and crown vetch inhibits new root growth of year old Red Oak seedlings (Allen 1978). Phennolic compounds seem to be one of the limiting factors. The difference between allelopathy and competition is difficult to separate scientifically.

Tree planting survival rate on iron ore tailings in Minnesota were for container grown red pine (*Pinus resinosa* L.), white spruce (*Picea glauca* L.), and jack pine (*Pinus resinosa* L.), (Dickinson *et al.* 1971). Stabilization of taconite tailing material first requires a relatively dense herbaceous cover. This helps to lower soil pH and allows for better survival rate of woody seedlings (Alm 1985).

Aspect effects survival rate and plant communities. South facing slopes had only 5-7 taxa formed 80% of the cover and north facing slopes had 16 taxa forming 80% of the cover on gravel pits slopes (Andreae 1981). The microclimates on south facing slopes had considerably more evapotranspirtion rate than north facing slopes. Diversity of microclimate encourages diversity for vegetation and wildlife habitats. Suitable vegetation species should be able to spontaneously develop a mosaic pattern that uniquely fits the environment (Alvarez *et al.* 1974).

Persistency and diversity of vegetation cover are two important factors in mine reclamation. Numerous studies have established the importance of legumes, grasses and shrubs are 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). Legumes are nitrogen fixing, grasses reduce soil erosion and shrubs allow for wildlife habitat cover. Root networks increase aeration and translocations of water and nutrients. Increased vegetative litter stabilizes the soil. The total and available soil-N increased during succession and that major species had individualistic, fairly Gaussian distributions along this temporal Nitrogen gradient (Tilman *et al.* 1987). Further studies by Tilman increased understanding of how nitrogen application rates and their consistency, affected succession differently up to about 3-6 years (Inouye *et al.* 1995). Both diversity and density in combination create an esthetically appealing area that also meets local to federal mine reclamation requirements.

Native vegetation species have proven to be a better protective ground cover that is used for soil erosion control, although introduced vegetation species is a superior forage producer (Packer 1982). Stress factors increased diversity in a community when biomass was reduced (Biodini 1986). Vegetation diversity increased were surface mining disturbed soils compared to undisturbed grassland soils (McMullen *et al.* 1984).

Summary:

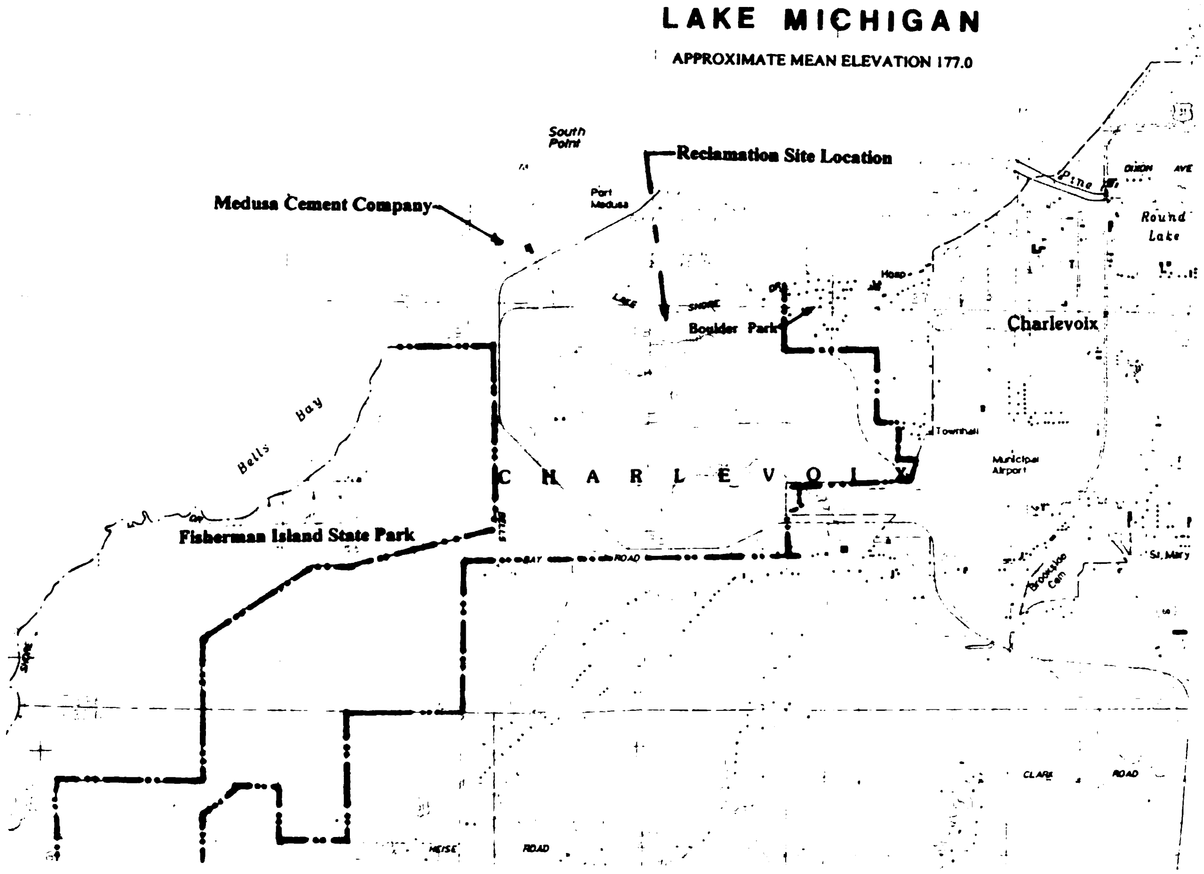
The studies that were conducted through the seventies and eighties have proven that the uses of organic soil amendments were far superior to chemical amendments. The Environmental Protection Agency (EPA) used these studies to sets standards to protect the health, safety and welfare of the public. If the guidelines set by the EPA are followed there is little chance of there being contamination of soils and vegetation. The continual monitoring of land application of biosolids for pathogen and toxins helps safe guard the environment. There is conflicting data about metal loading; most research indicates only slight elevations or equal metal toxicity between control sites and sludge applied sites. Most of the articles that voiced concern over metal loading lacked convincing supporting evidence. Long term studies of biosolid application sites for contamination of soils, vegetation and small animals have been initiated. The late eighties and nineties have expanded the knowledge of biosolid concentrations in vegetative and animal food chain concerns. Plant successional studies are only of limited concern, again geared more towards the coal industry and agriculture. Those attributed to the quarry industry are of limited numbers. Therefore, documentation of changes in vegetation cover is critical to the development of effective long term revegetation strategies.

Chapter III Description of the Study Area & Methods

General Location:

The Medusa Cement Company is located in Michigan's northwest lower peninsula along the Lake Michigan shoreline. Medusa is a limestone quarry two miles southwest of the City of Charlevoix in Charlevoix County (see Figure 3-1). The quarry is located on 556 acres where 2.2 million tons of ore are mined annually to produce 1.4 million tons of cement. The Fisherman's Island State Park is located to the west and southwest of the property. The state park was created in 1963 with the help of Medusa through land exchange and land donations. Bell's Bay Road, off US 31, is the access to both the plant and the state park. Lake Michigan borders from the northwest to the northeast of the property, comprising of 2.1 miles of shoreline. Lake Shore Drive and the Consumer Power Company right-of-way separates the lake from the study area. The southern edge is zoned commercial and light industry. To the southeast is the Charlevoix Airport, to the east is a residential area, Boulder Park, and the City of Charlevoix Sewage Treatment Plant. 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, Boulder Park and Lake Michigan, see the 1994 airphoto in Figure 3-2 and Figure 3-3.

Figure 3-1, **Site Location Map:**



United States Geological Survey, Charlevoix Quadrangle, 1983
Used with permission from USGS.

Contours and elevations in meters. Contour interval 5 meters.

Figure 3-2, **Medusa Air Photo:**

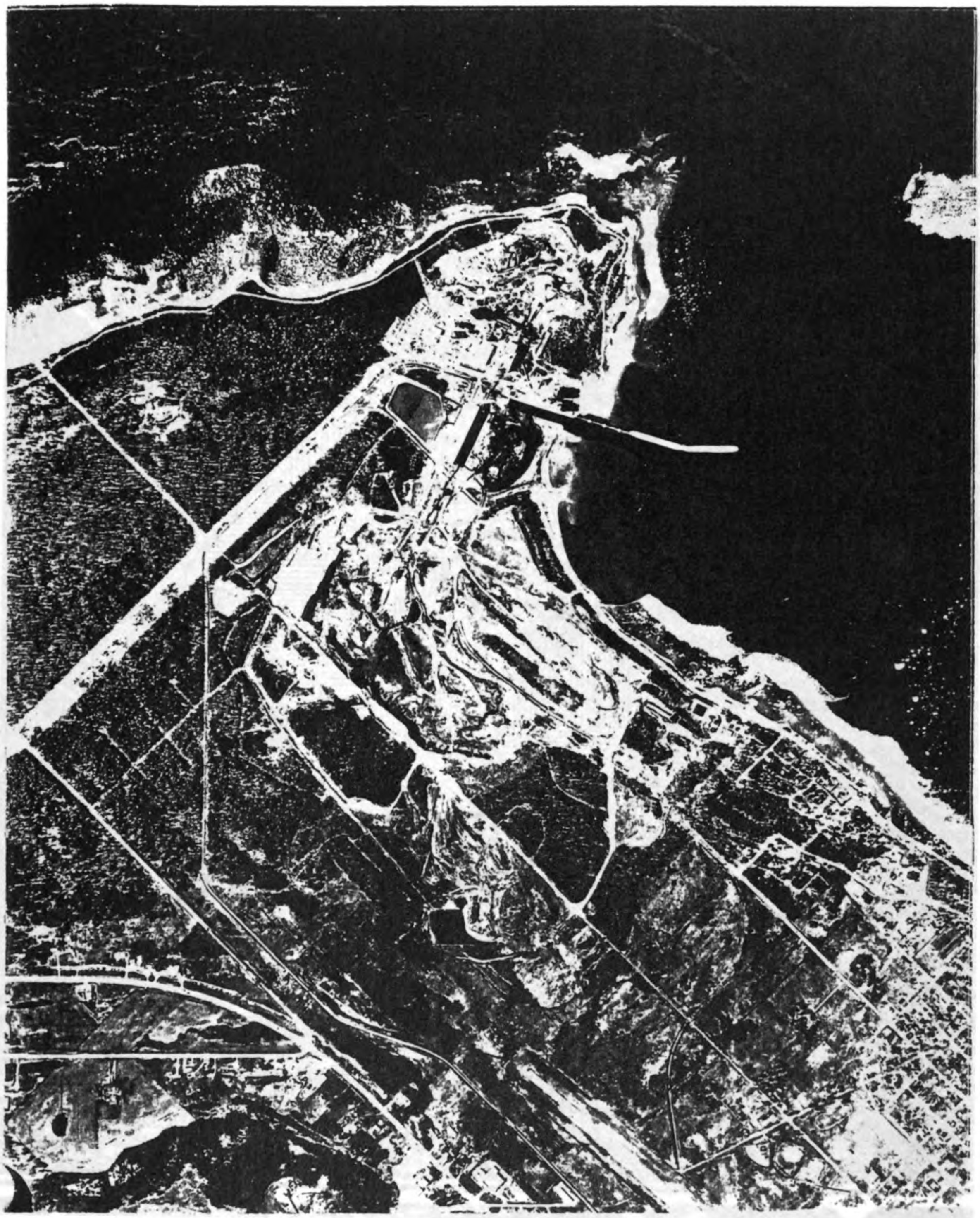
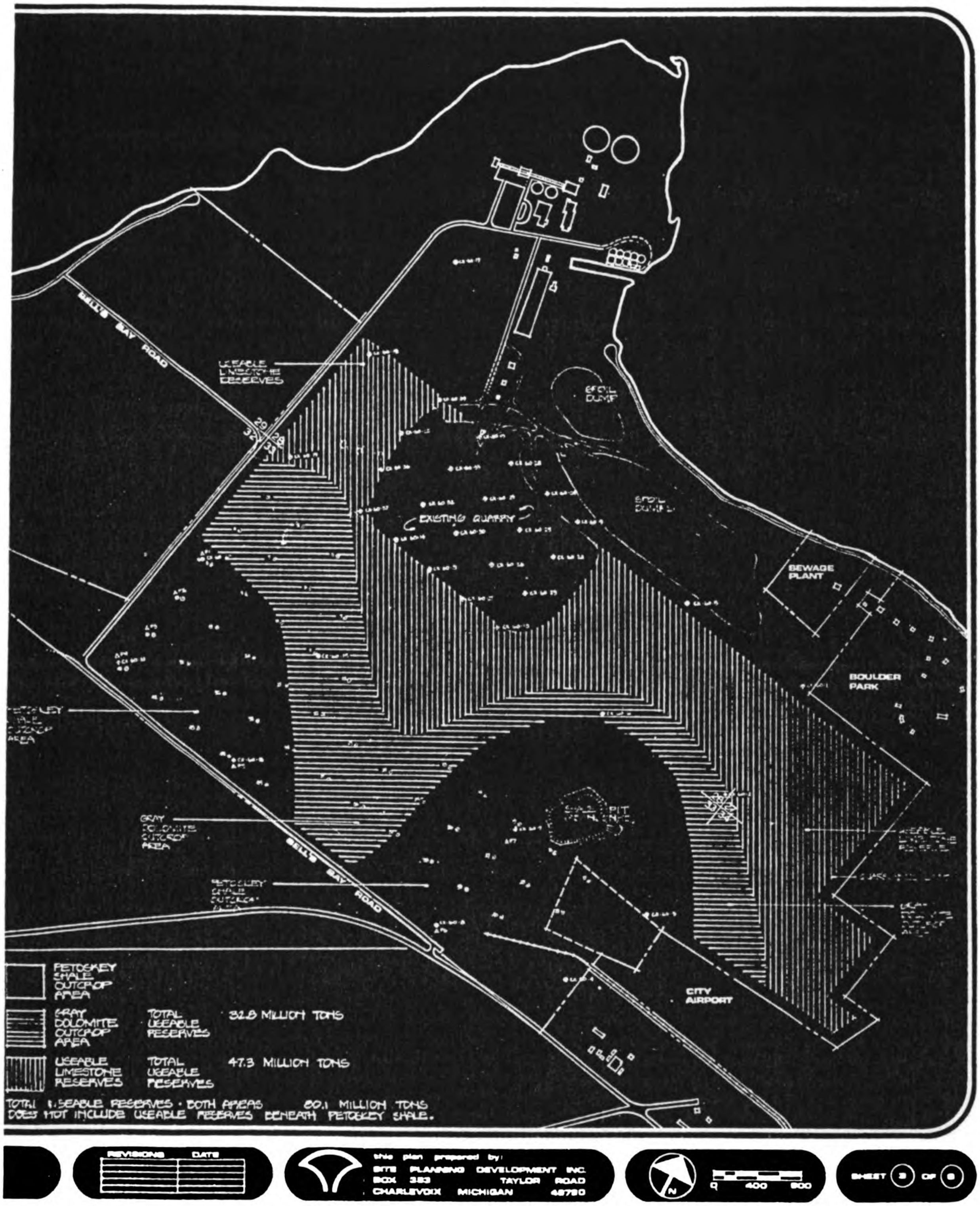


Photo taken 1974, by Michigan Department of Natural Resources

Used with permission from Site Planning Development, Inc.

Figure 3-3, **Geology for the Medusa Quarry:**



From Site Planning Development, Inc., 1978 Quarry Expansion Plan
Used with permission from Site Planning Development, Inc.

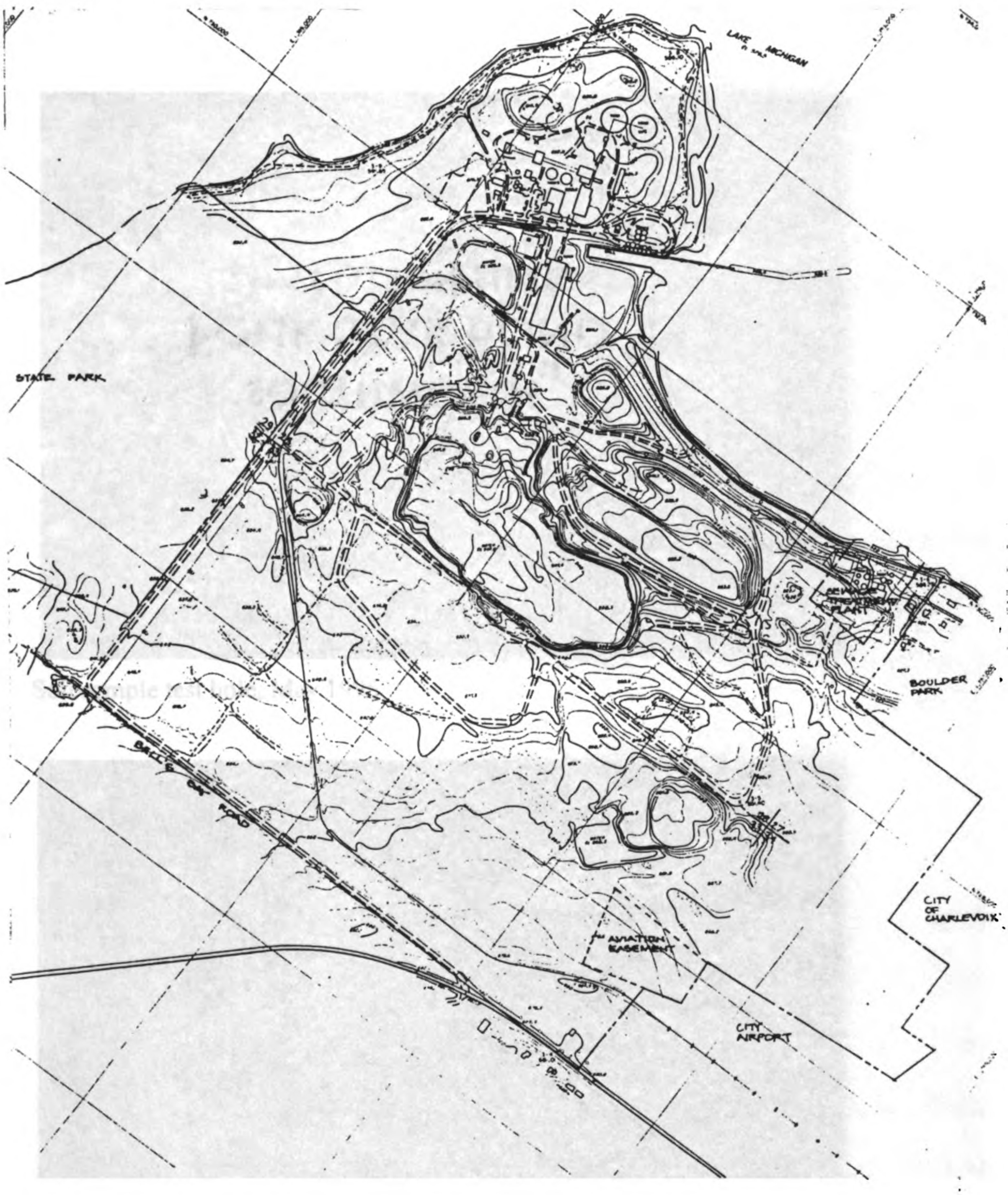
Geology:

The mining layers of the area were formed during the Palezoic Era when Michigan was covered by vast seas. Large deposits of marine limestone, dolomite, and rock salt were laid down and compressed by glaciation. Bedrock formations are Antrim Shale deposited during the Mississippian-Devonian Period and the Traverse Group deposited during the Middle Devonian Period. The Traverse Group consists of the Petoskey shale outcrop formation, Charlevoix Stage and Gravel Point stage (Pohl 1930). The extracted quarry materials include overburden, U. Limestone, U. Shale, Reef Zone, and L. Limestone, see Figure 3-3. Overburden materials are lake bed deposits and glacial till material consisting of non-stratified sand, silt, clay and boulders. Quarry extraction problems include the grade quality, Ca Co_3 concentrations and Magnesium Carbon.

Topography:

Because the glaciers moved across the area, the topography is relatively flat, with only the remaining hummock moraines as vertical relief. Land elevations on the Medusa property range from 177 to 200 meters above sea level, see Figure 3-4. The study site ranges from 15 to 33 meters above Lake Michigan were the vertical relief of the site is created by the spoil piles and quarry walls. The wind, parent material and drainage effects the creation of soils. The dull gray color of existing soils only a few centimeters under the surface indicates poor aeration, see Figure 3-5 (Unknown F 1960).

Figure 3-4, **Topography:**



From Site Planning Development, Inc., 1981 Reclamation Plan

Used with permission from Site Planing Development.

Figure 3-7, **Soils - Photos Taken During the 1995 Season:**

Soil sample test hole, May 1995

Access drive soil compaction May 1995.

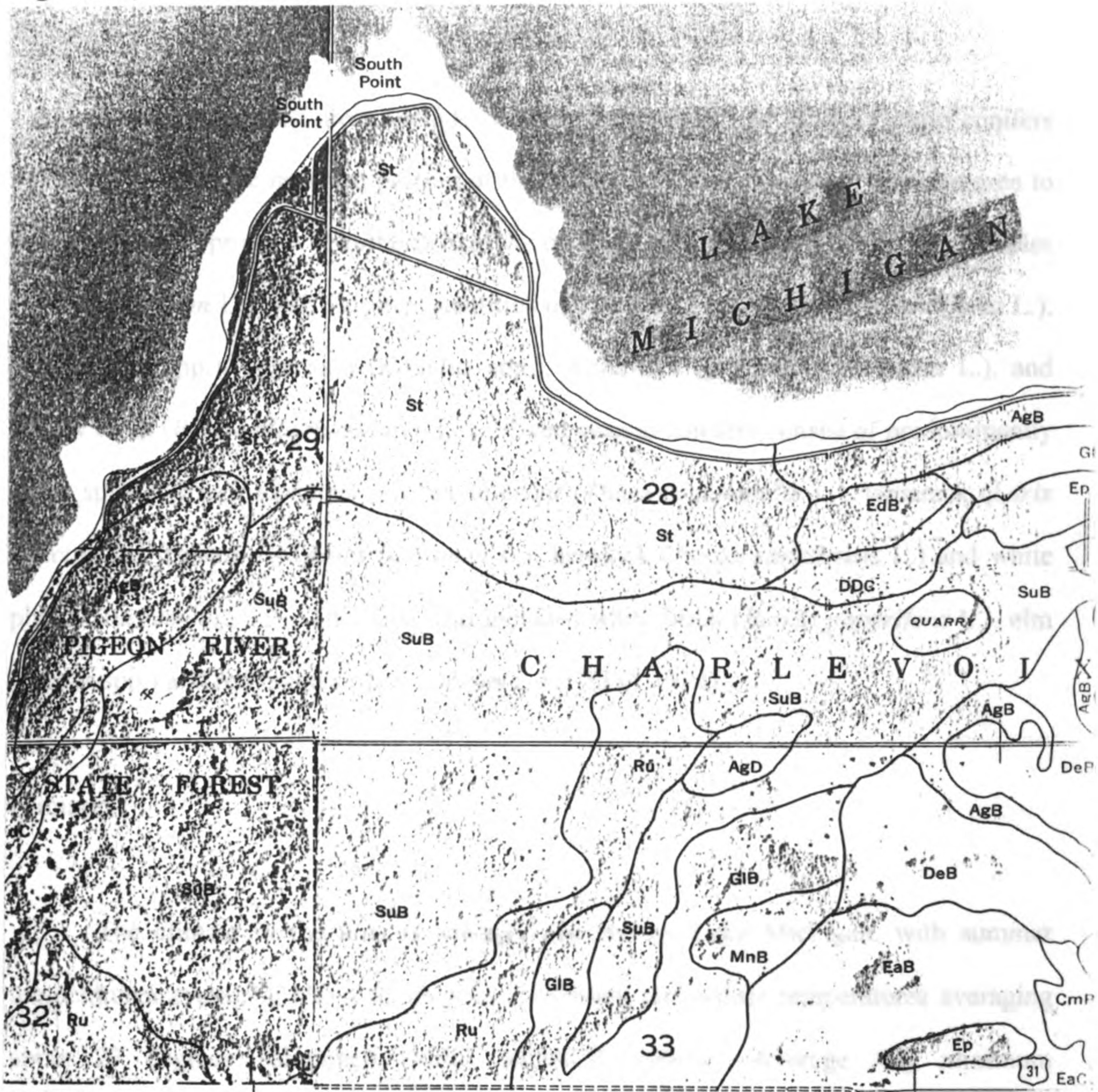
Soils:

The original soils on the site include; Stony Land with limestone outcroppings, Summerville stony sandy loam with 0 to 6% slopes, and Alpena gravely sandy loam with 0 to 6% slopes (USGS 1971). The soil series include both Deer Park-Dune land-Eastport association and Detour-Kiva association. Deer Park-Dune land-Eastport association is a well-drained, nearly level to very steep sandy soils on beach ridges and dunes. Detour-Kiva association is a somewhat poorly drained and well drained, nearly level to gently sloping loamy and sandy soils that are cobblly or gravely; on lake plains (USGS 1971), see Figure 3-6. The shallow soils are created by the organic compounds of a forest floor. The natural pH for the soils range from 5.6 to 8.1. The soils were the biosolids are applied are type two clay, sand and limestone with a pH of 7.5 to 9.0, (City of Charlevoix WWTP Residuals Management Plan 1991).

Hydrology:

The hydrology for the area was influence through the geological deposit formations. Depth to the water table is 0' to > 4' depending on the soil type. The Detour soils are those associated with the shallow water table and the rest varies in the >4' area (USGS 1971). Well logs for neighboring parcels indicate low to medium yields. Surface drainage drains mostly into the quarry the remaining runoff is caught in the McGeagh Creek, and two intermittent streams on the northwestern boundary and one across the south parcel (EIA 1980).

Figure 3-6, **Soils:**



AgB,D - Alpena gravely loam, 0-6% and 6-18% slopes
DDC - Deer Park-Dune land Association, rolling
DeB - Detour cobbly loam,0-6% slopes
EaB - East Lake loamy sand, 0-6% slopes
EdB - Eastport sand, 0-6% slopes
GlB - Gladwin loamy sand, 0-6% slopes
MnB - Menomeniee loamy sand, 0-6% slopes
Ru - Ruse Soils
SuB - Summerville stony sandy loam, 0-6% slopes

Taken from Soil Survey of Charlevoix County, Michigan - USDA Soils Map, 1974
Used with permission from USDA.

Vegetation:

Adjacent forested areas include northern hardwoods and mixed swamp conifers that are typical of the northern portion of the Medusa property and most adjacent area to the reclamation project. Northern hardwoods consist of predominantly sugar maples (*Acer saccharum* L.) with varying quantities of American beech (*Fagus grandifolia* L.), elm (*Ulmus* spp.), basswood (*Populus* spp.), white ash (*Fraxinus americana* L.), and yellow birch (*Betula alleghaniensis* L.). Mixed swamp conifers consist of predominantly black spruce (*Picea mariana* L.), white-cedar (*Thuja occidentalis* L.), tamarack (*Larix laricina* L.), balsam fir (*Abies balsamea* L.), hemlock (*Tsuga canadensis* L.) and white pine (*Pinus strobus* L.). This area also includes white birch (*Betula papyrifera* L.), elm (*Ulmus* spp.) and red maples (*Acer rubrum* L.) (USDA 1974).

Climate:

The climate in the area is strongly affected by Lake Michigan, with summer temperatures averaging about 62 degrees Fahrenheit and winter temperatures averaging about 27 degrees Fahrenheit (MSU, MDACP, 1990). Average July minimum temperatures are 59°F and average maximum temperatures are 76°F. There are 120 growing degree days and an annual rain fall average of 31.7 inches (USGS 1971). Most rain occurs in May through September. Average annual snowfall is 121", with average January temperatures of minimum 15°F and average maximums of 28°F. Fog is an important factor along Lake Michigan The height of the spoil pile traps the moisture on the north side of the study area and effects the precipitation rate.

Figure 3-7, **Precipitation Data**

CLIMATE OF CHARLEVOIX

Charlevoix, located in western Charlevoix County of the Northwest Lower Climatic Division, is bounded to the west by Lake Michigan and to the east by Lake Charlevoix. The terrain is gently rolling and is approximately 80% wooded. Soils are predominantly sand. For additional county soil information, please contact the Michigan Department of Agriculture (MDA)/Environmental Division/Soil Conservation Program, the USDA/Soil Conservation Service, the local Soil Conservation District, or the county Cooperative Extension Service (CES). For detailed county agricultural statistics please refer to the publication: "1988 County Food and Agricultural Development Statistics" produced by the MDA in cooperation with the USDA/Michigan Agricultural Statistics Service (MASS), or contact the MDA/Press and Public Affairs Division, the MASS, or the county CES.

The lake effect on Charlevoix's climate is significant throughout most of the year. The prevailing westerly winds, in combination with Lake Michigan to the west, produce this lake influence. The lake effect increases cloudiness and snowfall during the fall and winter and also modifies temperatures, keeping them cooler during the late spring and early summer, and warmer during the late fall and early winter. In the late winter as ice builds up on the lakes, Charlevoix is subjected to temperature variations which are more closely associated with interior locations. Diminished wind speeds or winds which do not traverse large unfrozen lakes often produce clearing skies and the colder temperatures expected at continental locations.

Because the day-to-day weather is controlled by the movement of pressure systems across the nation, this area seldom experiences prolonged periods of hot, humid weather in the summer or extreme cold during the winter. Long-term wind, humidity, and sunshine records are not available for this location, but these data should be similar to the following values which were observed at the National Weather Service Office in Alpena. The prevailing wind is south-westerly, averaging 8 mph. The strongest one-minute wind speed, 43 mph, was recorded in April 1963. The average 1 P.M. relative humidity varies from 51% for May to 74% for December, and averages 61% annually. The average percent possible sunshine varies from 27% for December to 67% for July, and averages 49% annually.

Precipitation was well distributed throughout the year with the crop season, April-September, receiving an average of 18.22 inches or 59% of the average annual total for the 1951-80 period. During this same period the average wettest month was September with 3.80 inches, while the average driest month was February with 1.40 inches. The following precipitation extremes, based on the time period of this station's published record, are: greatest observation-day total, 4.72 inches, recorded June 24, 1898; greatest monthly total, 9.70 inches, recorded September 1895; and least monthly total, 0.00 inches, recorded March 1910.

Summer precipitation comes mainly in the form of afternoon showers and thundershowers. Annually, thunderstorms will occur on an average of 27 days. Michigan is located on the northeast fringe of the Midwest tornado belt. The lower frequency of tornadoes occurring in Michigan may be, in part, the result of the colder water of Lake Michigan during the spring and early summer months, a prime period of tornado activity. During 1950-87, Michigan has averaged 15 tornadoes each year. During this same period, 2 tornadoes occurred within the county.

The 1950-51 through 1979-80 average seasonal snowfall was 97.2 inches. During this period, 118 days per season averaged 1 inch or more of snow on the ground, but varied greatly from season to season. The following snowfall extremes, based on the time period of this station's published record, are: greatest observation-day total, 20.5 inches, recorded November 11, 1950; greatest monthly total, 66.7 inches, recorded December 1985; greatest seasonal total, 164.5 inches, recorded during 1978-79; least seasonal total, 36.5 inches, recorded during 1902-03; and greatest snowdepth, 54 inches, recorded March 10, 1972.

Evaporation data from the Class "A" pan were not available for this station, but these data should be similar to those observed at Lake City. During 1960-80, the pan evaporation for May through October exceeded the average precipitation by 55%. Therefore, soil moisture replenishment during the fall and winter months plays an important role in the success of agriculture for this area. While drought occurs periodically, the Palmer Drought Index indicated drought conditions reached extreme severity only 2% of the time.

Station History of Charlevoix

Observations began on May 1, 1887 and continued through May 31, 1926. The records during this period are erratic and many of the locations are unknown. On June 1, 1926 the station was converted into a precipitation-only station while located at the USCG .5 mi. NW of the PO. On May 10, 1944 the station was located .6 mi. SSE of the PO. On April 1, 1945 the station was moved to a location .1 mi. NW of the PO. On April 1, 1947 the station was moved to a location 1.5 mi. NE of the PO. On May 1, 1948 the station was moved to a location .9 mi. SW of the PO. At an unknown date in 1950 the station was moved to a location .1 mi. NW of the PO. On August 2, 1957 the station was moved to a location .5 mi. SW of the PO. On February 19, 1966 the station was moved to the WWTP .2 mi. NE of the PO. On July 10, 1973 the station was moved to a new WWTP 1.1 mi. W of the PO. The station has been at this location to the present.

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CLIMATOLOGICAL SUMMARY
and
STATISTICS

Produced by
MICHIGAN DEPARTMENT OF AGRICULTURE
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In Cooperation With
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Department of Agricultural Engineering
Department of Geography
Michigan Agricultural Experiment Station
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Weather Service
National Climatic Data Center
1990

Used with permission from Michigan State University Climetology Department.

Demographics:

The city is known as a resort community, meaning that a majority of the income from the area is derived from those who are part-time residents or vacationers to the area. Populations according to the US Census for the time period that the study took place are 16,541 in 1970, 19,907in 1980 and 21,468 in 1990. There were 13,119 households with an average of 2.59 persons per household. The median age, as of 1990 was 34.7 years old. The per capita income was $11, 632 in 1990 with a medium household income of $24, 738. Population growth for the area is projected to be .59% (1990 Michigan Census Data). Five industrial sites were present in the City of Charlevoix and Charlevoix Township in 1990 and there is expected to be 9 acres set aside for industry by the year 2000. The economics for the area is service oriented. Retail, commercial and office comprises the downtown. The major employer for the area is Medusa Cement Company with 140 employees. There is a small industrial park on the north side of town comprised of five light industrial manufactures.

City of Charlevoix Water Treatment

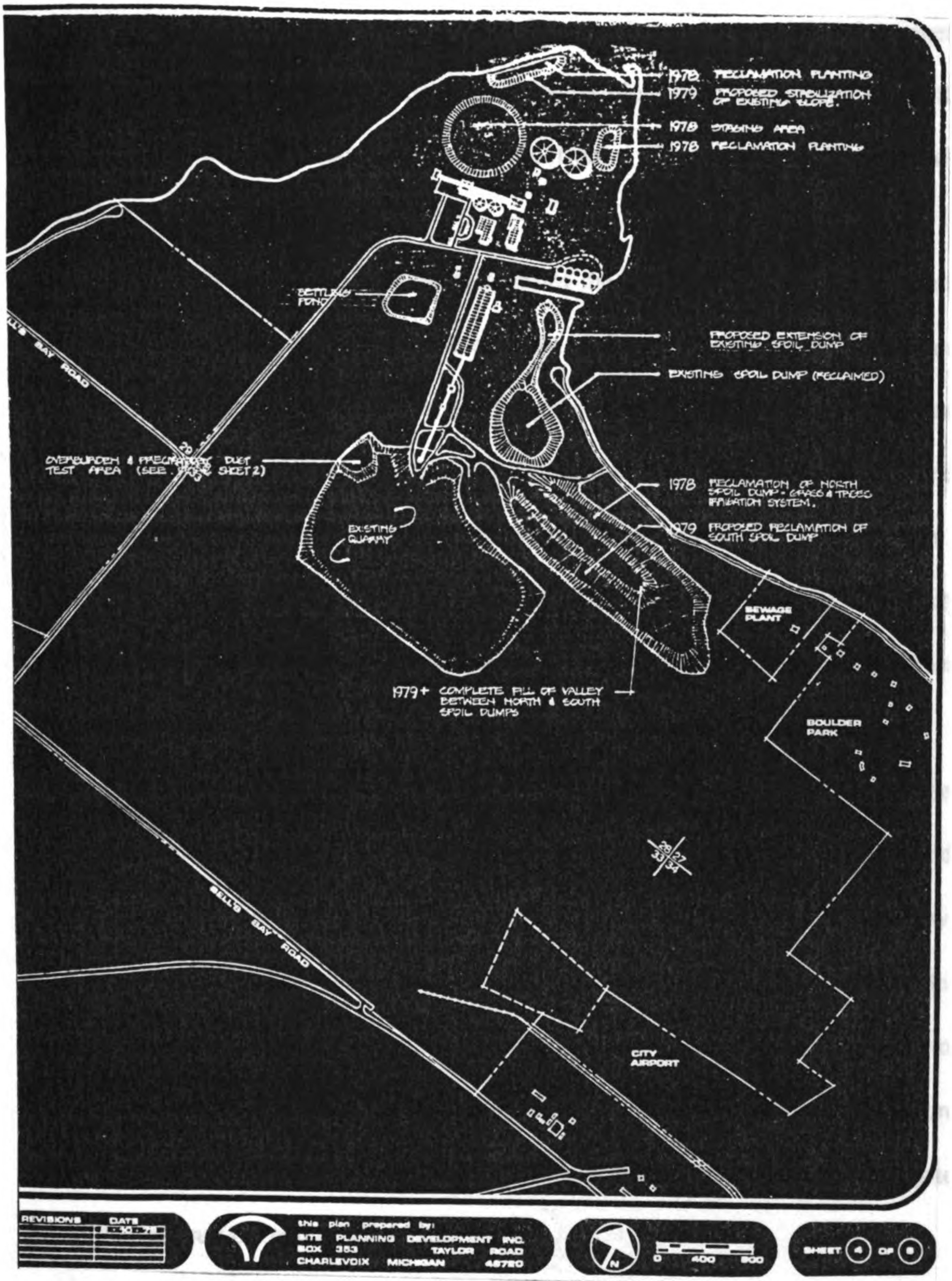
The City of Charlevoix obtains its water from Lake Michigan through a filtration bed of sand and gravel. The water treatment plant's capacity is 3,000,000 gallons per day with a pressure of 114lbs./sq.in. Additives to the water for drink-ability are fluoride, chlorine, and alum. In the past polymers and phosphates have been added.

The City of Charlevoix's Waste Water Treatment Plant (WWTP) processes the biosolids through the tertiary method, anaerobic digestion. The WWTP capacity is 277,000 gallons per day with a load of 300,000 gallons per day, a lagoon is used for up to 150 days of storage (Residuals Management Plan 1991). An average of 165,000 gallons of biosolids at approximately 6% solids (41.33 tons) are land applied to the Medusa mine reclamation project annually. A local farm is available for emergency use.

Historical Background:

In 1972 Site Planing Development began a small reclamation project (less than one acre) located on Bell's Bay Road. This area was developed into ten experimental plot areas to observe vegetation establishment. In 1974, an eleven acre reclamation project specification was developed for screening the cement plant from public view. In 1976 a 3-1/2 acre reclamation project was initiated for the Medusa's Ellsworth Shale Quarry. This site is located several miles away but used some of the initial testing results to develop the reclamation process the Medusa Charlevoix Site. Even though the summer of 1976 was droughty the site showed a 60% vegetative cover without irrigation. Irrigation was added the following summer for a 75-80% vegetative cover with healthier plant material. An additional 1-1/2 acres for wetland development was added to the Ellsworth reclamation site in 1977. Total reclamation at this location by 1983 was 25 acres. The long-range reclamation plan was initiated in 1976 at the Medusa Charlevoix site and completed in 1978, see Figure 3-10. The EIA addressed existing conditions and projected future use if the site once the mining process ceased. Through the EIA the

Figure 3-8, **Reclamation Area 1978:**



Proposed Quarry Expansion Plan, February 10, 1978
Used with permission from Site Planning Development, Inc.

importance of understanding the site specific conditions to determine the best methods for vegetation establishment stressed the need for experimental procedures for vegetation establishment. The main revegetation experimental plots were established in 1978, and this is the site that the case study is derived from. The experimental plots included ground covers and tree plantings.

The opportunities for biosolid disposal of the cities effluent are the proximity of the waste water treatment plant to the site, the ability to use higher concentrations of biosolids than other land applications, and the disposal of the by-products of urbanization. The reclamation sites proximity to Lake Michigan, the Charlevoix Airport and the neighboring residential areas increases the need to improved visual quality. The mine reclamation of disturbed area for vegetation establishment area increase the beauty for tourism and the environment by erosion control. The biosolid applications also increase the vegetation establishment for meeting the reclamation requirements for mining.

The constraints of the study consisted of the use of someone else's experiment to derive information from and the inability to find complete records of biosolids and soil sample information. Due to the pending legal issues at the Medusa Cement Company, only limited information was available. The high amounts of calcium chloride and magnesium are limiting factors for both the mining process and plant growth. Each of the different treatment areas has a different aspects. This will effect evapotranspiration that could potentially effect plant growth. The relationship to the lake limits the ability to use biosolids were run-off enters water bodies.

The opportunities offer great potential for increased benefits for all parties involved. The constraints are only limiting factors to a beneficial mine reclamation project.

After several trials with various fertilization methods, the use of biosolids were determined to be the best aid in vegetation establishment by both adding nutrients and water to the deficient soil. The use of biosolids also aided the community in disposal of it's waste at a lower cost. The 1978 reclamation plan called for use of the City of Charlevoix biosolids to be used for a soil conditioner. Three areas of the site were chosen for reclamation. Tree seedlings were to be planted on the north over burden pile, and a temporary irrigation system to be installed until the seedlings became established. The south overburden pile was to be revegetated with a grass and legume mixture. Finally, the Consumers Power right-of-way along Quarry Drive was to be revegetated, again and a special nitrogen formula added. In 1976 the right-of-way was vegetated and seedlings planted, but, Consumers power sprayed to kill all undergrowth. In 1993 the area was disturbed again by the Power Company to install new lines and once again revegetated, see Figure 3-9 photos and site location Figure 3-11 on pg. 31. This area, due to its multiple disturbances and managed control, is not a part of the study.

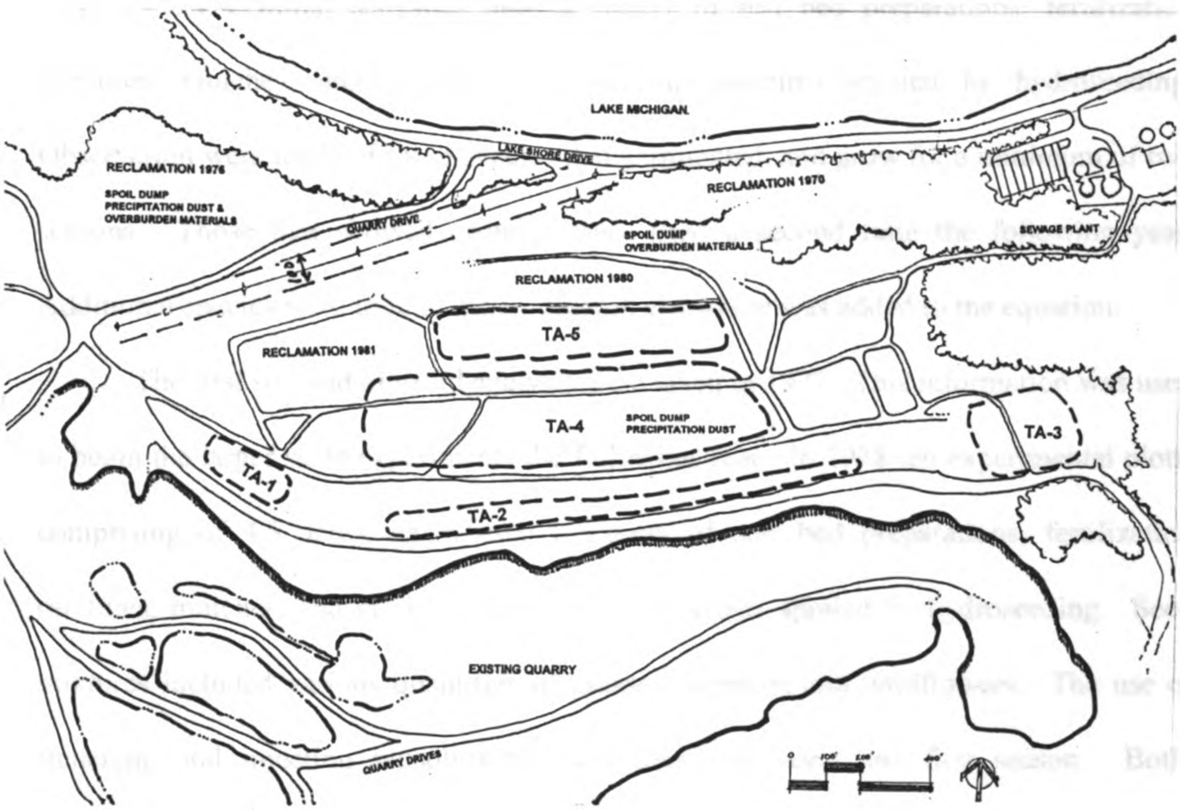
The original studies determined the plant materials best suited for vegetation establishment at Medusa. As the mining process continued additional areas were added for reclamation. The North and South spoil piles were eventually filled in with CKD and capped with overburden. Biosolids have been the preferred method of fertilization and moisture addition for increased soil building and vegetation establishment. The reclamation project has been beneficial to both the mining site for community acceptance and to the community for beneficial solid waste disposal.

Figure 3-9, **Consumers Power Line disturbance area:**

Photo A Taken in 1997, by Patricia Arnold Harmon

Photo B Taken in 1997, by Patricia Arnold Harmon
Access road and utility easement, disturbed again in 1995.

Figure 3-10, **Study Site, Treatment Area Locations:**



1997 locations for vegetation surveys.

TA-1 No seed or biosolids applied, control plot
TA-2 Seeded only no biosolids applied
TA-3 Not seeded, but biosolids applied
TA-4 Seeded and biosolids applied
TA-5 Seeded and trenched area were biosolids were only applied the first year.

Original Study:

The sever soils and harsh winter climate at the Medusa mining site required special research for specific vegitation that would be conducive to the site for reclamation purposes. The initial test sites used a variety of soil bed preparations, fertilization mixtures, mulches, and ground cover seeding mixtures applied by hydroseeding. Observation were made of those species that germinated, and grow for a minimum of two seasons. Those that showed promise were tried a second time the following year. Additional species were tried as other research elsewhere was added to the equation.

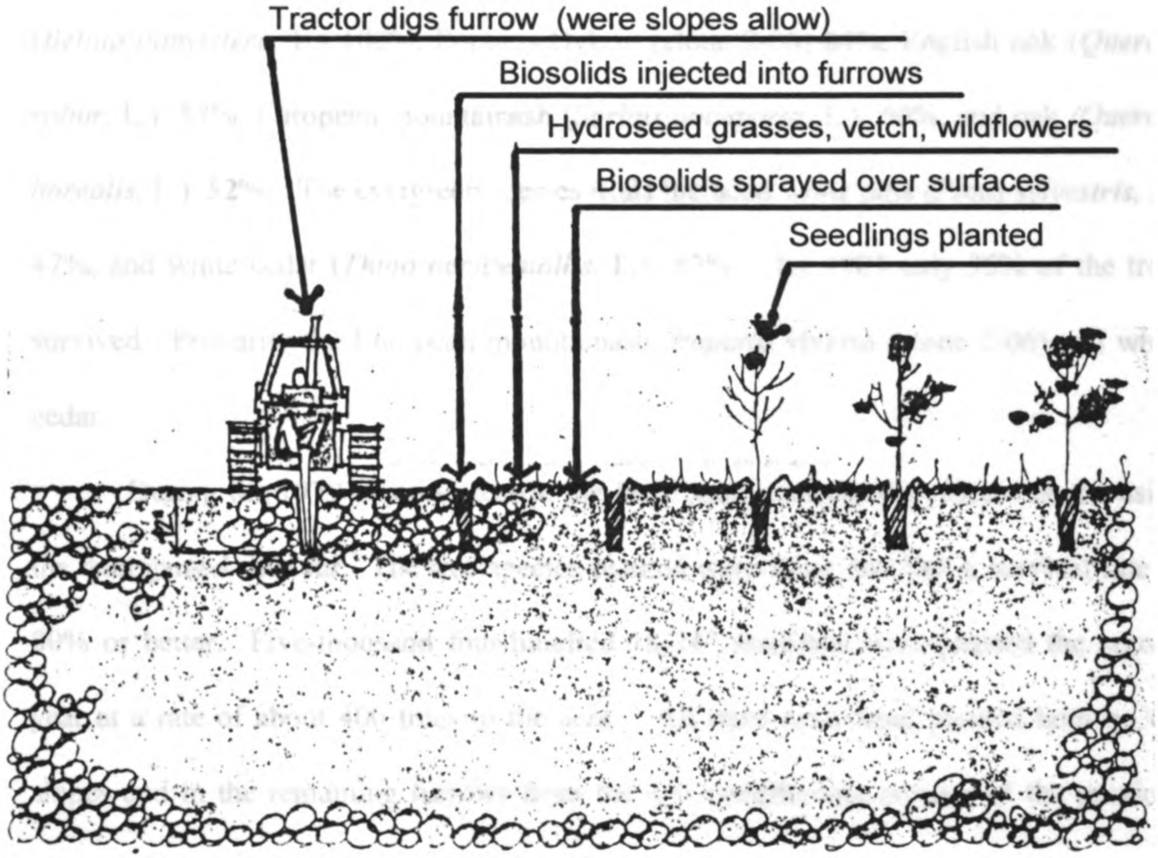
The first soil and biosolid analysis were taken in 1977. This information was used to begin the larger scale experiments the following year. In 1978 ten experimental plots, comprising of 4.5 acres, again used a variety of soil bed preparations, fertilization mixtures, mulches, and ground cover seeding mixtures applied by hydroseeding. Seed mixtures included various quantities of grasses, legumes and wildflowers. The use of trenching and injecting biosolids to plant trees was used this first season. Both, deciduous and evergreen tree species were also included in the experiments. These included: Norway maple (*Acer platanoides* L.), white birch (*Betula papyrifera* L.), Popular hybrid 2-06, moutain ash (*Sorbus aucuparia* L.), English oak (*Quercus robur* L.), and scotch pine (*Pinus sylvestris* L.). Plant species were tested for their tolerance to the nutrient deficient overburden and highly alkaline precipitator dust (CKD). Fertilization testing used a variety of formulations and rates to determine the best mixtures to adjust to the sever conditions of the site. No provision for irrigation were provided for this first year, but mulches were used at various application rates and types. This would give a stronger indication of which plant species would be the most appropriate for the site conditions. The fall of 1978 included the regarding of the north overburden pile, and hydroseeding approximately twelve acres. An irrigation system was installed to prepare for next season reclamation procedures.

The Summer of 1979 began the large scale reclamation that still exists today. The north spoil pile consisted of all overburden materials and the southern spoil pile consisted of a six foot cap of precipitation dust (CKD) from the cement making process. During the mid to late eighties the area was filled in with CKD and covered with an overburden cap, this is as the site is today. The reclamation is an ongoing process that adjusts to the site conditions.

Each of the different test plots were seeded at different rates, fertilized at different rates, and mulched or irrigated at different rates. Observations were made to calculate germination and percent cover the first year and again the second season. This was the process that determined the best species and method for establishment of vegetation.

Site Preparation:

Medusa used its own equipment to prepare the site for the spring 1978 reclamation. Bulldozes were used to grade and loosen the top layers of soil and the D9 for sub-soiling to a depth of thirty-six to forty-two inches. Slopes were graded to a maximum of 6%, were biosolids were to be applied. The D9 dug trenches 9' wide, 80' long and 36" deep into which biosolids where added. Then trees were planted at 10' o.c. using Osmocote for additional fertilization for every other plant. But, because of the extremely rocky soils, biosolid injections were not used after this first year. The furrows are still visible today and are referred to as treatment area TA-5. Fall hyroseeding was completed mid August and irrigation used for better seed germination. A graphic representation of the procedure follows:



(Figure 3-11) **RECLAMATION PLANTING PROCEDURE:**
(Used with permission from Site Planning Development, Inc., 1978 Management Plan)

Plant Species Selection:

After many trials of tree and ground cover testing and analysis, specific species were chosen for large scale plantings. The trials for trees species began in 1978 using a variety of native and hybrid plant species. A furrow or trench was created then filled with biosolids. One-hundred seventy-six trees were then planted 10' o.c. with additional fertilizer added to every other plant. Tree diameters ranged from 1-1/2" to 2-1/2". The deciduous tree species used the first year (1978) in treatment area TA-5 and their survival rates without irrigation were: Norway maple (*Acer platanoides,* L.) 95%, paper birch (*Betula papyrifera,* L.) 100%, Populus Hybrid (clone 2-06) 84%, English oak (*Quercus robur,* L.) 57%, European mountainash (*Sorbus aucuparia,* L.) 60%, and oak (*Quercus borealis,* L.) 52%. The evergreen species trials included white pine (*Pinus sylvestris,* L.) 47%, and white cedar (*Thuja occidentallis,* L.) 87%. By 1983 only 35% of the trees survived. Primarily the European mountainash, *Populus* Hybrid (clone 2-06) and white cedar.

During the 1979 planting season the large scale reclamation process began using the data gained thus far. The tree species planted were those that had a survival rate of 80% or better. Five-thousand four-hundred 18-24" seedlings were planted the second year at a rate of about 400 trees to the acre. All trees were hand planted both on the slopes and in the remaining furrows from the soil conditioning process of the previous season. Their survival rate with irrigation averaged about 92%.

Ground covers were put through a battery of tests that included different seeding mixtures, fertilization rates and methods, irrigation and mulching methods. The North overburden pile, along with the trees, was hyroseeded with: Crown vetch (*Coronilla varia,* L.) at 10 lbs. per acre; white sweet clover (*Melitotus alba,* L.) at 10 lbs. per acre; rye (*Secale cereale,* L.) at 20 lbs. per acre and wildflowers. The south overburden pile, treatment area (TA-4), was hydroseeded with a grass seed mixture of rye, Kentuky bluegrass (*Poa pratensis,* L.), red fescue (*Festua rubra* 'Pennlawn', L.), white sweet clover, crown vetch, and mulched with a product called Verdyol Mulch. Additional fertilizer, 6-24-24, is added the first season at a rate of 600 lbs. per acre. The area was also irrigated until vegetation become established. Treatment area ,TA-2, the south slope of the south overburden pile was hydroseeded at a rate of: Coronilla varia at 10 lbs. per acer; white sweet clover at 10 lbs. per acre; 40% *rye* 'Manhatten'; 20% red fescue 'Baron'; 20% red fescue 'Nugget'; 20% red fescue 'Pennlawn', and *Elymus* at 160 lbs per acer. Additional fertilizer, 6-24-24, is added the first season at a rate of 600 lbs. per acre. Coverage for all locations ranged from 80-100%.

Table 3-2. The vegetation determined to be best adjusted to sight conditions are:

Trees	
Acer platanoides	Norway Maple
Betula maximowicziana	Monarch Birch
Betula nigra	River Birch
Betula papyrifera	Paper Birch
Betula populifolia	Yellow Birch
Fraxinus americana	White ash
Fraxinus pennsylvanica	Green Ash
Populas Hybrid 2-06	Poplar Hybrid 2-06
Thuja occidentalis	Eastern White Cedar
Groundcovers	
Coronilla varia	Penngift Crownvetch
Melitotus alba	White Sweet Clover
Secale cereale,	Perennial rye grass seed mixture
Elymus, Lolium perenne	Grasses & Wildflowers

Method of Vegitation Establishment:

Various methods were tried in order to gain and maintain better vegetation establishment. The temporary irrigation system was only used the first and second season during extreme dry spells. Mulches were added as part of the hydroseeding process to maintain moisture better. Fertilizers rates were based on soil sample test results and biosolid additions. Most of these methods were only used the first season for immediate vegetation establishment, long term biosolid additions being the only exception.

Soil samples were taken in March 1978 and used to determine fertilization rates, see Table 3-2A. Soil type and pH were also determined to be 2 clay, sand and limestone, with pH ranges of 7.5-9.0. Original pH levels at these location in 1977 ranged from 8.5-12.6. Kiln dust pH ranged from 10.8-13.0. The pH was also monitored to determine liming needs, a normal requirement for soil analysis. Loading rates for 1978 were 35 Nitrogen pounds per acre, 230 P_2O_5 pounds per acre and 70 K_2O pounds per acre, no lime is needed. This data was used as part of the testing of vegetation establishment trials.

Fertilization rates used during the 1979 planting season were determined by the Cooperative Extension Service. They were as follows: trees 160 N lb/ac., 200 P_2O_5 lb/ac., 70 K_2O lb/ac., no lime; ground covers trees 160 N lb/ac., 200 P_2O_5 lb/ac., 70 K_2O lb/ac. Biosolids were used as a portion of these requirements and to add moisture and organics.

Beginning May 1, 1979, the full scale biosolid applications were transported via Finn Hydroseeder to the reclamation site and continued till November. The first month surface land application was applied at approximately 40,000 gallons, or about 10,000 gallons per acre, or 2.5 dry tons per acre. Surface applications continued at a rate of 12,000 gallons per month. From the soil test the loading rates for nutrients and potential toxins were:

N	(14 lbs/ton) (2.5 ton/acre) =	35 lbs. N/acre
P	(92 lbs/ton) (2.5 ton/acre) =	230 lbs. P/acre
K	(2.6 lbs/ton) (2.5 ton/acre) =	6.5 lbs. K/acre
Pb	(.92 lbs/ton) (2.5 ton/acre) =	2.3 lbs. Pb/acre
Zn	(2.4 lbs/ton) (2.5 ton/acre) =	8.0 lbs. Zn/acre
Cu	(3.2 lbs/ton) (2.5 ton/acre) =	6.0 lbs. Cu/acre
Ni	(.13 lbs/ton) (2.5 ton/acre) =	.325 lbs. Ni/acre
Cd	(.07 lbs/ton) (2.5 ton/acre) =	.175 lbs. Cd/acre

Supplemental fertilizer was applied for vegetation establishment at a rate of 150 lbs. Per acre of $(NH_4)_2\ SO_4$. Biosolids were analyzed monthly, see Tables 3-3A-C and additional soil test were analyzed in October, to determine if any problems from biosolid applications would arise.

The first couple of years included monthly soil, biosolid and groundwater analysis. After no adverse affects were shown, than five soil samples are taken annually from the biosolid applied areas, for analysis to determine biosolid application rates and to monitor chemical loading. Biosolids and drying bed samples, (note: drying bed samples were not required until 1987), were also taken on an annual basis to monitor their content for excessive medals, see Tables 3-4A & 3-4B. This information was required for land application of solid waste permits.

Table 3-3A, **Available Soil Testing Data:**

SOIL TESTING DATA

	CKD	Overburden	Overburden	Old CKD								
	October #1	October #2	October #3	October #4	March #1	March #2	March #3	March #4	March #5	March #6		
	1977	**1977**	**1977**	**1977**	**1978**	**1978**	**1978**	**1978**	**1978**	**1978**	**1979**	**1980**
PARAMETERS												
SOIL pH	12.6	8.6	8.5	8.6	8.8	10.8	9.8	10.1	11.7	12.7		
Soil Texture	2	2	2	2	3	organic	organic	organic	organic	organic		
CEC me /100g												
TOTAL NUTRIENTS: %	%	%	%	%	%	%	%	%	%	%		
Phosphorus (P)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		
Potassium (K)	3.5	1.1	1.1	13.5	37.5	13.9	6.8	1.4	0.8	0.7		
Calcium (Ca)	94.4	94.9	94.8	82.3	59.1	85.4	92.2	97.5	98.5	98.9		
Magnesium (Mg)	2.0	4.0	4.1	4.2	3.4	0.7	1.0	1.1	0.7	0.4		
Total Kjeldahl Nitrogen												
Ammonium-Nitrogen												
TOTAL: mg/kg & ppm												
Arsenic												
Barium												
Cadmium												
Chromium												
Copper (Cu)												
Lead												
Mercury												
Molybdenum												
Nickel												
Selenium												
Silver												
Zinc (Zn)												

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Table 3-3B, **Available Soil Testing Data:**

SOIL TESTIN

								Nov. #1	Nov. #2				May #1	May #2
	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1988**	**1989**	**1990**	**1991**	**1992**	**1992**
PARAMETERS														
SOIL pH							8.5	8.1	7.8				8.8	6.6
Soil Texture														
CEC me /100g								17	29				17	17
TOTAL NUTRIENTS: %														
Phosphorus (P)								%	%					
Potassium (K)								3.0	4.0					
Calcium (Ca)								90.0	90.0					
Magnesium (Mg)								7.0	5.0					
Total Kjeldahl Nitrogen														
Ammonium-Nitrogen														
TOTAL: mg/kg & ppm													mg/kg	mg/kg
Arsenic													1.30	1.40
Barium													3.00	15.00
Cadmium													0.08	0.08
Chromium													4.70	5.00
Copper (Cu)													4.50	4.10
Lead													7.40	5.50
Mercury													0.00	0.00
Molybdenum														
Nickel														
Selenium													0.00	0.00
Silver													0.00	0.00
Zinc (Zn)													8.90	12.00
		PERM					PERM							
		change					change							

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Table 3-3C, **Available Soil Testing Data:**

SOIL TESTIN	May #3 1992	May #4 1992	May #5 1992	1993	April #1 1994	April #2 1994	April #3 1994	April #4 1994	April #5 1994	1995	May 1996	May 1997	1998
PARAMETERS													
SOIL pH	8.5	8.7	8.4		7.32	7.24	7.3	7.8	7.52		8.08	9.22	
Soil Texture											86.4	84.7	
CEC me /100g	17	17	17										
TOTAL NUTRIENTS: %													
Phosphorus (P)													
Potassium (K)													
Calcium (Ca)													
Magnesium (Mg)													
Total Kjeldahl Nitrogen													
Ammonium-Nitrogen													
TOTAL: mg/kg & ppm	mg/kg	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		mg/kg	ppm	
Arsenic	1.50	3.20	0.80		0.74	1.90	1.10	1.90	2.40		3.5	15000	
Barium	15.00	20.00	20.00		0.00	1.10	0.00	56.00	0.00		59	34000	
Cadmium	0.05	0.13	0.09		0.85	8.70	1.00	1.00	1.10		0.99	960	
Chromium	4.90	5.00	4.20		6.00	4.80	11.00	16.00	18.00		12	10000	
Copper (Cu)	6.70	5.60	20.00		3.70	21.00	9.10	37.00	7.90		9.7	7600	
Lead	6.30	8.70	5.20		13.00	0.03	16.00	27.00	27.00		21	21000	
Mercury	0.00	0.00	0.03		0.00	0.00	0.01	0.22	0.01		0.02	0	
Molybdenum											0.32	800	
Nickel											16	1300	
Selenium	0.00	0.00	0.00		0.07	0.08	0.00	0.14	0.32		0	0	
Silver	0.00	0.00	0.00		1.00	1.20	1.40	2.20	1.20		2.6	1700	
Zinc (Zn)	9.00	16.00	21.00		6.90	12.00	13.00	42.00	22.00		19	21000	
				PERM									PERM
				change									change

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Table 3-4A, **Available Biosolids Testing Data:**

BIOSOLIDS TESTING DATA

		September	Febuary	May	July	August	September	October	Nov. #1	Nov. #2	Nov. #3
	1977	**1978**	**1980**	**1980**	**1980**	**1980**	**1980**	**1980**	**1980**	**1980**	**1980**
PARAMETERS											
pH			7.90	8.50	8.20	8.60	8.50	9.00	8.50	8.20	8.60
% Solids		6.2	4.20	4.90	4.60	4.50	3.90	3.90	3.40	3.40	3.60
TOTAL NUTRIENTS: % or mg/kg		%	%	%	%	%	%	%	%	%	%
Phosphorus (P)		4.61	2.62	5.00	1.35	10.30	6.26	4.20	4.76	4.76	4.62
Potassium (K)		0.13	0.42	0.30	0.31	0.25	0.20	0.25	0.26	0.24	0.24
Calcium (Ca)											
Magnesium (Mg)											
Total Nitrogen		2.78	4.16	4.50	3.80	4.30	4.65	4.88	5.25	5.62	4.82
Total Kjeldahl Nitrogen (NH_4-N)		0.21	0.58	0.80	2.40	1.09	3.70	1.20	1.35	1.23	1.47
Ammonium-Nitrogen (NO_3-N)		0.00	0.00	0.02	0.01	<0.01	0.14	0.03	0.02	0.27	0.06
Nitrate Nitrogen											
Organic Nitrogon											
Sodium											
Cloride											
Sulfates											
TOTAL: mg/kg or ppm		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Arsenic											
Barium											
Cadmium (Cd)		36.00	20.00	14.00	12.00	12.00	13.00	13.00	16.00	14.00	15.00
Chromium (Cr)		680.00	200.00	160.00	150.00	170.00	130.00	120.00	120.00	120.00	110.00
Copper (Cu)		1200.00	2,000.00	2,000.00	2,100.00	2,300.00	1,800.00	1,800.00	1800.00	1800.00	1800.00
Lead (Pb)		460.00	740.00	700.00	640.00	700.00	500.00	420.00	430.00	420.00	410.00
Mercury											
Molybdenum											
Nickel (Ni)		65.00	100.00	96.00	87.00	95.00	81.00	54.00	65.00	64.00	66.00
Selenium											
Silver											
Zinc (Zn)		1600.00	2,400.00	2,300.00	2,100.00	2,200.00	2,100.00	1,900.00	2000.00	2000.00	2000.00
			Total metals based on oven dried solids.								

Prepared by Patricia K. Arnold Harmon 11/7/98

Table 3-4B, **Available Biosolids Testing Data:**

BIOSOLIDS TESTING												
	May	July	September							November		
	1981	**1981**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
PARAMETERS												
pH	8.70								8.5±			
% Solids	5.72	63.15	3.98							4.49		
TOTAL NUTRIENTS: % or mg/kg	%	mg/L	mg/kg							%		
Phosphorus (P)	0.293	3293.00	38668.00							3.03		
Potassium (K)	0.070	83.15	1285.00							0.14		
Calcium (Ca)										0.99		
Magnesium (Mg)										0.42		
Total Nitrogen												
Total Kjeldahl Nitrogen (NH_4-N)	1.161									5.06		
Ammonium-Nitrogen (NO_3-N)	0.623	3623.00	19497.00							1.08		
Nitrate Nitrogen	0.029	73.50	291.00							<0.02		
Organic Nitrogon	0.538	43.30	22211.00									
Sodium												
Cloride												
Sulfates												
TOTAL: mg/kg or ppm	mg/kg	mg/kg	mg/kg							mg/kg		
Arsenic										<10.0		
Barium												
Cadmium (Cd)	<4.4	0.99	6.27							4.00		
Chromium (Cr)	45.90	19.40	150.50							53.00		
Copper (Cu)	1599.60	100.96	532.90							580.00		
Lead (Pb)	179.20	11.90	213.40							67.00		
Mercury										<0.2		
Molybdenum										<5.0		
Nickel (Ni)	<4.4	0.79	15.67							<20.0		
Selenium										<5.0		
Silver												
Zinc (Zn)	1870.60	113.24	1655.00							690.00		
	PERM change								PERM change			

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Table 3-4C, **Available Biosolids Testing Data:**

BIOSOLIDS TESTING

	June #1 1991	June #2 1991	May 1992	December 1992	October 1993	March 1994	May 1995	April 1996	January 1997	1998
PARAMETERS										
pH							6.74	7.03	7.3	
% Solids		10.00			3.52	4.15	4.81	4.88	5.32	
TOTAL NUTRIENTS: % or mg/kg		mg/kg			%	%	%	%	%	
Phosphorus (P)		1120.00			0.18	0.27	20.00	.16*	0.33	
Potassium (K)		54.00			0.14	0.16	0.085	0.14	0.11	
Calcium (Ca)		3530.00			2.60	2.70	2.70	3.90	0.23	
Magnesium (Mg)		520.00			0.30	0.43	0.24	0.48	0.21	
Total Nitrogen										
Total Kjeldahl Nitrogen (NH_4-N)		1330.00			5.60	3.10	4.90	2.10	0.77	
Ammonium-Nitrogen (NO_3-N)		460.00			2.20	1.30	2.90	6.60	0.72	
Nitrate Nitrogen		45.00			0.046	0.013	0.00	0.39	0.0007	
Organic Nitrogon										
Sodium				140 mg/kg	0.19	0.14	0.17	0.18	0.18	
					%	%	mg/kg	mg/kg	mg/kg	
Cloride					0.83	0.37	4600.00	9600.00	39,000	
Sulfates					0.09	0.00	21000.00	3700.00	710	
TOTAL: mg/kg or ppm	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
Arsenic	<0.04	1.60	0.00	0.00	1.50	2.70	11.00	2.10	4.00	
Barium	<1.0		51.00	45.00	730.00	650.00	1300.00	1000.00	780.00	
Cadmium (Cd)	<0.2	0.50	0.00	0.00	7.70	19.00	6.00	11.00	16.00	
Chromium (Cr)	<0.3	7.50	5.90	4.10	67.00	81.00	120.00	94.00	94.00	
Copper (Cu)	<0.2	140.00	46.00	42.00	630.00	650.00	840.00	690.00	600.00	
Lead (Pb)	<0.4	39.00	4.80	5.40	62.00	69.00	65.00	61.00	54.00	
Mercury	<0.2	0.067	0.06	0.04	2.40	5.20	3.00	3.80	4.00	
Molybdenum		<0.3	0.00	0.00	0.00	1.10	8.40	8.80	7.00	
Nickel (Ni)		2.50	3.00	0.00	36.00	40.00	32.00	36.00	25.00	
Selenium	<0.04	<0.04	0.00	4.00	1.20	1.50	0.00	1.40	0.00	
Silver	<0.3		3.40	1.60	49.00	92.00	50.00	45.00	50.00	
Zinc (Zn)	2.30	160.00	60.00	58.00	1000.00	900.00	790.00	990.00	760.00	
					PERM change					PERM change

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Table 3-5A, **Available Drying Beds Testing Data:**

DRYING BEDS TEST DATA	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
PARAMETERS											
pH											
% Solids											
TOTAL NUTRIENTS: % or mg/kg											
Phosphorus (P)											
Potassium (k)											
Calcium (Ca)											
Magnesium (Mg)											
Total Kjeldahl Nitrogen (NO_3-N)											
Ammonium-Nitrogen (NH_4-N)											
Nitrate- Nitrogen											
Sodium (Na)											
Chloride											
Sulfates											
TOTAL: mg/kg											
Arsenic											
Barium											
Cadmium											
Chromium											
Copper											
Lead											
Mercury											
Molybdenum											
Nickel											
Selenium											
Silver											
Zinc											
					PERM change						

* Results are suspect due to % rcovery values outside the acceptance limits.

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Table 3-5B, **Available Drying Beds Testing Data:**

DRYING BEDS TEST DATA	October 1988	1989	1990	1991	1992	May 1993	May 1994	June 1995	July 1996	April 1997	1998
PARAMETERS											
pH	9.22							7.27	7.17	6.94	
% Solids	84.72					69.80	25.73	29.30	20.22	42.24	
TOTAL NUTRIENTS: % or mg/kg						%	%	%	%	%	
Phosphorus (P)						0.0022	1.40	4.00	.04*	4.40	
Potassium (k)						0.024	0.06	0.048	0.042	0.04	
Calcium (Ca)						1.500	3.00	2.80	2.70	1.90	
Magnesium (Mg)						0.001	0.40	0.21	0.33	0.36	
Total Kjeldahl Nitrogen (NO_3-N)						0.160	3.70	4.40	0.93	1.30	
Ammonium-Nitrogen (NH_4-N)						0.050	0.22	0.81	0.94	0.66	
Nitrate- Nitrogen						0.016	0.068	0.00	0.00	0.00	
Sodium (Na)						0.013	0.05	0.05	0.055	0.03	
						%	%	mg/kg	mg/kg	mg/kg	
Chloride						0.0054	0.21	2300.00	1000.00	0.00	
Sulfates						0.650	2.20	17000.00	13000.00	0.00	
TOTAL: mg/kg						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
Arsenic	15000					1.4	9.2	5.1	5.2	0.7	
Barium	34000					380	790.0	810	860	870	
Cadmium	960					3.4	6.0	5.4	5.7	6.4	
Chromium	10000					350	79.0	81	94	140	
Copper	7600					570	670.0	620	660	760	
Lead	21000					68	81	66	58	65	
Mercury	0					0.43	0	0.68	1.3	0.65	
Molybdenum	800					0	12	18	6.6	14	
Nickel	1300					16	21	27	28	25	
Selenium	0					1.1	2,600	0.58	0	0.25	
Silver	1700					39	46	42	37	48	
Zinc	21000					650	850	960	880	970	
						PERM change					PERM change
	NOTE: No drying bed data was available before 1988.										

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Management & Aftercare of Restored Lands:

Mining is an active process thus as additional soil disturbance occurred the methods learned in the original reclamation experiments where used to establish vegetation on the newly disturbed areas. These included grading, fertilization, seeding, irrigation, and biosolid applications. To date there are approximately 60 reclaimed acres. After initial establishment of vegetation, continual biosolid land applications were the only method of fertilization used to aid in the soil building process. Soil, biosolids and drying bed samples are taken annually for test analysis. This information is used for the permitting process of biosolids for land application, and used for monitoring chemical loading and determining biosolids application rate. The results of the available biosolids analysis are in Tables 3-2A, 3-2B, and 3-2C, the drying bed analysis is in Tables 3-3A, 3-3B and 3-3c, and the soil analysis are in , see Tables 3-4A and 3-4B. Soil samples were only taken from TA-3 and TA-4 areas because these were the only areas were long term biosolids were applied.

Land applied biosolids had to be monitored for environmental risk. The legal requirements for biosolids applications is permitted through the Michigan Department of Natural Resources (MDNR) and District #3 Health Department. The Program for Effective Residuals Management, (PERM), has been revamped about every five years during the course of the project. The most recent is expected to take affect July 1998. Each time the requirements changed it is reflected in the soil, and biosolids analysis. To date there has not been a problem with contamination of the reclamation site from biosolid applications.

The same applicator, Jerry Gerbelski, used the Finn hydoseeder for surface allocations for the entire twenty-five years. Average annual biosolid applications are between 500,00-600,000 gallons or about 9,000-10,000 gallons per acre. The amount of application is basted on the length of application season. Most season are May to October, but during mild winters applications can begin in April and finish in November. Season refers to whether the ground is frozen or not. Permitting does not allow application on frozen ground.

Sources of Data & Data Collection Plan:

The data used for this case study include physical, demographic and site specific information pertaining directly to the case study. The physical data obtained consisted of: geologic data from core samples on site and past studies of the area; location maps from 1983 United States Geological Survey Map (USGS); topological data from the 1981 Reclamation Plan presented by Site Planning Development, Inc.: soils, hydrology, vegetation and wildlife data from 1974 United States Department of Agriculture Soil Conservation Service (USDASCS); and 30 year climate data from Michigan Department of Agriculture Climatology Program at Michigan State University; and 1974 and 1994 airphotos from Site Planning Development, Inc., Michigan Department of Natural Resources (MDNR) and Abram Aerial Photography. The demographic information was obtained from: 1990 census data from the University of Michigan, Michigan Census Data; and City of Charlevoix water data from Michigan Department of Environmental Quality and the Long Term Management Plan for the Charlevoix Waste Water Treatment

Plant. The complete data source list can be found in the bibliography. The site specific data included: photography of the site taken 1980-2, 1995 and 1997; the vegetation survey was conducted during the summer of 1997; and biosolids and soil analysis from the City of Charlevoix Waste Water Treatment Plant (WWTP). While employed at Site Planning Development (SPD), I was able to survey the past files for relative information on the Medusa Reclamation Project. Most of the information collected consisted of historical data and long term management plans. I conducted interviews with John Campbell at SPD, Sam Crestwell at the WWTP, several employees that were employed during the initial testing period, and Jerry Gerbelski, from SPD, (the land applicator for the biosolids since the beginning of the project).

The data collection plan began with a literature review (Chapter 2), then I obtain the existing secondary data from the various sources listed above and finely to collect the primary data from field studies. While employed at SPD a search of old files revealed historical data and management information. Periodic interviews with Mr. Campbell and Mr. Crestwell brought basic understanding of the long term reclamation project. Soil and biosolid test results were obtained from WWTP, dead files and attempts to contact past testing labs. The Labs that I was able to contact either did not keep records for that extended length of time or would not release that information. The vegetation survey was conducted May 27 - August 30, 1997 through direct field observations. Photographs were taken during these site visits, with the early photo records supplied by SPD.

Methodology & Procedures:

The historic data was obtained through interviews and examining the projects past files. As an employee of Site Planing Development I was able to examine the old files pertaining to the reclamation project. John Campbell was readily available for explanation of project from it's inception to present project status. This included the environmental assessment documents, permits, testing procedures, monitoring, vegetation growth rates and long term management including biosolids application. The long term monitoring by the DEQ's permitting process allowed for soil, digested biosolids and drying bed analysis.

The gathered secondary testing data is presented in three different tables; biosolids, drying beds and soils. The soil test samples were obtained only were biosolids were applied. Each table was broken down into parameters, total nutrients and total heavy metals. Soil test results consisted of parameters of soil texture, soil pH and cation exchange capacity (CEC). The soil pH effects the plants ability to uptake nutrients. The CKD and limestone parent material are highly alkaline as the CKD testing data shows in Table 3-3A. The drying bed test data was not required in the initial study, but, was required later with the first data available in 1988. The tables for both the drying bed and biosolids included parameters for pH and percent solids. Depending on the lab used and the PERM requirements the recording of the macro and micro-nutrients varies between ppm, % and mg/kg. Not all the interim years were available. The dates that were available were: soil tests 1977-8, 1980, 1988, 1992, 1994, and 1996-7. Biosolid test results available include 1977, 1980-1, 1988, and 1991-7. The available test results were used to track soil pH, and chemistry.

Primary collected data included the soil samples from the spring of 1995 and vegetation collections obtained during the summer of 1997. The soil samples were obtained from five random sites were the biosolids were to be applied for the season. The process involved digging down 8-10" and removing 2" of soil. Between soil sample the tools were cleaned with a cleansing phosphate and rinsed with distilled water. Soil samples were than sent to the lab for analysis. The resulting information is found in Table 3-3C.

The 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, (see Figure 3-10 on page 28): (TA-1) = the control plot, a disturbed area that has not been seeded or received biosolids applications; (TA-2) a disturbed area that has been seeded but has not had any biosolid applications; (TA-3) = has not been seeded but has had continual biosolid applications; (TA-4) = a disturbed area that was both seeded and had biosolids applied continually; (TA-5) is a disturbed area that was originally trenched with only one year of biosolids applied. Each of these different treatment areas were of different sizes and numbers are to be adjusted to represent equal distribution. This information will be compared with the initial vegetation establishment at the inception of the project. The data collection of herbaceous plant species, their numbers, and establishment of tree counts will be used to determine frequency, density, abundance and from each of the five treatment areas.

The measuring technique used was the Random Plot Method (Cain 1959, Phillips 1958, Barbour *et al.* 1987). This involved the 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 was used when reaching the limits of the treatment areas. Each plot was surveyed for identification of species type, number of different species, percent cover for each species and the total cover for all species. Only those species with stems located with in the ¼ meter plots were counted, trees were calculated separately, although they were mentioned if they fell within a plot. A photographic record was also made for future reference of each plot. Each photograph included a north determination and card that recorded date, plot number and treatment area. Samples of vegetation were added to the card for future identification. The only one area, TA-5, contains trees of 4 inch diameter or greater at breast height, (DBH). All of the trees were planted as part of the reclamation project.

Each treatment area data was recorded into a table that recorded whether moss or trees were present Forbs and grasses was recorded for both counts and variety of species. Simple averages were calculated and used for the discussion. This included presence of crown vetch, presence of moss, presence of grass and presence of forbs. The data collection of herbaceous plant species, their numbers, and establishment of tree counts will be used to determine frequency, density, abundance and from each of the five treatment areas. This in turn compared the number of variety of each with in the various treatment areas or if there was any vegetation present at all. The table 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 crown vetch, plots with both forbs and grasses. The grass data 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 finely the percent area surveyed for each treatment area. visual observations as to percent cover were noted in each area, by comparing the stand with a chart.

Chapter IV Discussion

A. Case Study of Biosolids Application

"Although, Michigan law (Amended Mine Reclamation Act No. 92) does not require reclamation until a mining area is abandoned, Medusa Cement began revegetation experiments in the early stages of their Charlevoix quarry operation (Medusa North Publication, Summer 1978)."

Discussion:

The parameter of vegetation to be considered here is simply the total amount expressed as density, frequency and abundance accomplished by vegetation counts. Detailed data can be found in table 4-2, Vegetation Analysis. The present study area was grouped into five different treatment areas, see Figure 3-10 on page 28. All areas were on disturbed soil with different treatments added for vegetation establishment. Treatment area, (TA-1) the control plot, was on overburden materials and has never 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, see photos in Figure 4-2 and 4-3.

Treatment area (TA-2), is a disturbed area that has been seeded but has not had any biosolid 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 CKD with a slope of 45-50%. 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 has begun in small areas (see photos in Figure 4-4 and 4-5). In the remaining area vegetation coverage is approximately 75 to 90% and has a diverse population.

Treatment area (TA-3), has not been seeded but has had continual biosolid 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 area vegetation coverage is approximately 85 to 95% and has a somewhat diverse population. See photos in Figure 4-6 and 4-7.

Treatment area (TA-4), is a disturbed area that was both seeded and had continual biosolid 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 100% and has areas of mono-cultures or large population colonies. Several access drives run through this area (see figure 4-1). Here vegetation edge effects were omitted while conducting the flora survey. See photos in Figure 4-8 and 4-9.

Treatment area (TA-5), is a disturbed area that was originally trenched in 1978 and had only one year of biosolids applied by both injection and surface applications. The site is approximately 14,865 square meters located on the north side of the study area. The north facing slopes trap moisture from Lake Michigan and has a slower evpo-transpiration rate than the south facing slopes. This is and area TA-2 are two areas were aspect and the resulting micro climates have effected vegetation growth The area vegetation coverage is approximately 85 to 95% and has a somewhat diverse population. Trees were planted in this area and are the only place on the study site were trees have a DBH of greater than 4". See photos in Figure 4-10 and 4-11.

Trace Metal Loading:

The chemical results for biosolids, drying beds, and soils were obtained through Site Planning Development (SPD) and the City if Charlevoix Waste Water Treatment Plant (WWTP). Early biosolids data was obtain from SPD, while data from 1992 to present was supplied by WWTP. After the initial testing, SPD had the test results sent directly to the WWTP and did not receive copies of the results. The WWTP only keeps their analysis reports for five years. For this reason data was not available between 1981-1991. The testing labs and dates used were: Michigan State University, 1977-78, 1980, 1988; Aquatic Systems, Inc. 1981; _AR Laboratories, Inc. 1988; SEG Laboratories, Inc. 1991; Analytical Laboratories, Inc. 1992; Huron Valley Laboratories, Inc. 1993-1997. The resulting data was imputed into the following tables. The yearly biosolids testing results is located in Table 4-2. The yearly drying bed analysis is located is in Appendix A-12 & A-3. The yearly soil analysis for treatment areas TA-3 and TA-4 and is located Table 3A, 3B and 3C..

The Program for Effective Residual Management (PERM) determined the results data required. Each time the PERM requirements changed a slight variation in the chemicals annualized is apparent. Drying bed testing did not begin until 1988. The various lab reports give different quantity notations for several of the parameters. An example would be, the use of parts-per-million in the early biosolid analysis, is now being measured in milligrams-per-kilogram. Several other variation in notation are noted.

Unusually high concentrations of copper where found in the early chemical analysis of the biosolids. The final determination for these high concentration was, that much of the residential community was still using copper tubing for its plumbing and with the added chemicals for potable water the chemical reactions increased the copper in the discharge system. Other high concentration of metals in biosolids included lead and zinc. The various industrial inputs into the WWTP are believed to be the source of these concentrations.

Existing Vegetation:

Tables were created for each of the treatment areas from the information collected on each ¼ m^2 plot. The vegetation analysis table on page 76 summarizes the information collected. The frequency, density and variety are able to be calculated because of the gathered data looked at species and counts. The species inventory table on page72 is the accumulation of all species present on the reclamation study area.

Treatment area TA-1 has a large variety of forb species with some grass. Most grass is located at the most eastern portion were 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 dominate species. Other species present are wild columbine (*Aquilegia canadensi,s* L.), white sweet clover, (*Melilotus alba,*, L.), black medic (*Medicago lupulina,* L.), *Brassica* spp., *Poa* spp., *Festusa* species, and to a lesser degree ox-eye daisy (*Chrysanthemum leucanthemun,*, L.), wild strawberry (*Fragaria virginiana,* L.), with a variety of unknowns. Invasive tress and shrubs include paper birch (*Betula papriyrifera* L.), red-osier dogwood *(Cornus stolonifera,* L.), and American linden (*Tila americana,* L.). Moss is present throughout the area but is not a part of this study other than to note its presence. Coverage is sparse in places were soils are thin and organic matter absent. The range of coverage is demonstrated in the photographs found on page 63.

Treatment area TA-2 has several areas of nude soil were the CKD is exposed and the highly alkaline soil has not allowed plant establishment. Also present are large limestone rocks were the angle of repose has allowed most of the soil to sluff down the slope. Herbs outnumber grasses both in numbers and variety in this area. Coverage is as greater here than in the previous site. The range of coverage is demonstrated in the photographs found on page 65. At this time spotted knapweed was the dominate species. Other species present are from the grasses *Poa* species, *Festusa* species, *Agropyron* species, *Elymus* species, *Brassica* spp.,and from the forbs 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. Much of the original planted species are still present in this area. Surprisingly almost no crown vetch is present even though the species is present at the top of the slope.

Treatment area TA-3 has a considerable amount of grasses but are of a shorter variety. More varieties of forbs are present here than in TA-4 were biosolids are also applied. Coverage in this area is more varied, in 75 to 100% range. The range of coverage is demonstrated in the photographs found in Figure 4-7. At this time crown vetch and bull thistle (*cirsium vulgare*, L.) are the dominate 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 dominate plants in treatment area TA-4, with crown vetch being the dominate forb. Most herb species were present only during the early portion of the season and were only of a limited variety. The largest populations of herbs were located along the roadways creating edge effects to what is largely a grass prairie. Coverage in this area consisted of almost entirely 100% except in the early spring. The typical coverage is demonstrated in the photographs found in Figure 4-9. According to John Campbell the amounts of white sweet clover and crown vetch very from year to year and runs on a cyclical fashion. At this time the crown vetch was the dominate species. Other species present are black medic,, *Poa* species, *Festusa* 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 original planted species are still present in this area.

The grasses were the dominate species in treatment area TA-5, with crown vetch, common burdock and bull thistle being the dominate herbs. The largest populations of forbs were grouped in colonies and distributed throughout the site. This area is the only area that contained trees, thus the shade produced, affected some of the species present. Coverage in this area consisted of almost entirely 95 to 100%. The typical coverage is demonstrated in the photographs found in Figure 4-11. At this time grass was the dominate species. Other species present are white sweet clover, mustard species, *Poa* species, *Festusa* species, *Agropyron* species, *Elymus* 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.

Figure 4-1, **Photos Taken During the 1995 Season:**

Treatment Area TA-4
Both seed & biosolids were applied.

Photo A July 1995

Photo B July 1995

Figure 4-2, **EXISTING SITE CONDITIONS, 1997:**

Treatment Area, TA-1
Control Plot, no seed or biosolids were applied.

Photo A May 24, 1997

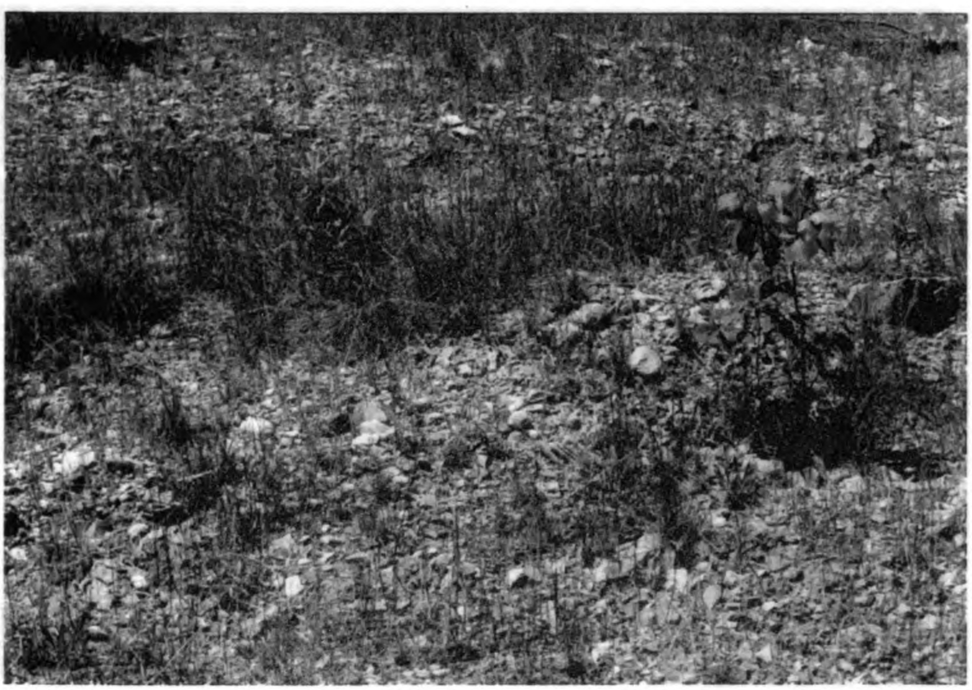
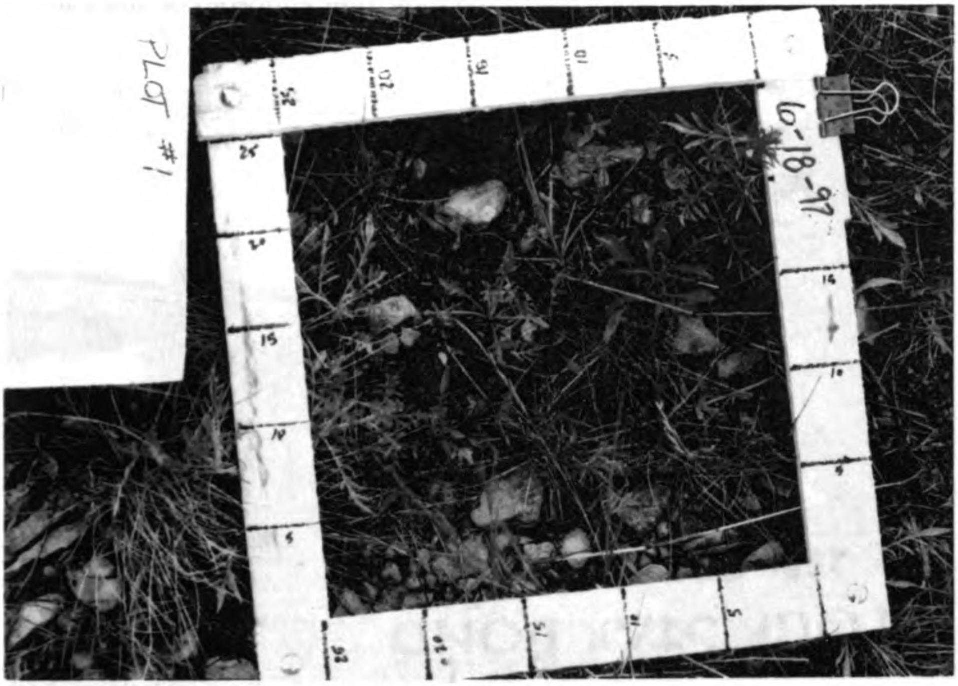


Photo B August 23, 1997

Figure 4-3, **EXISTING SITE CONDITIONS, 1997:**

Treatment Area, TA-1



Plot # 4 June 18, 1997

Plot # 60 August 23, 1997

Figure 4-4, **EXISTING SITE CONDITIONS, 1997:**

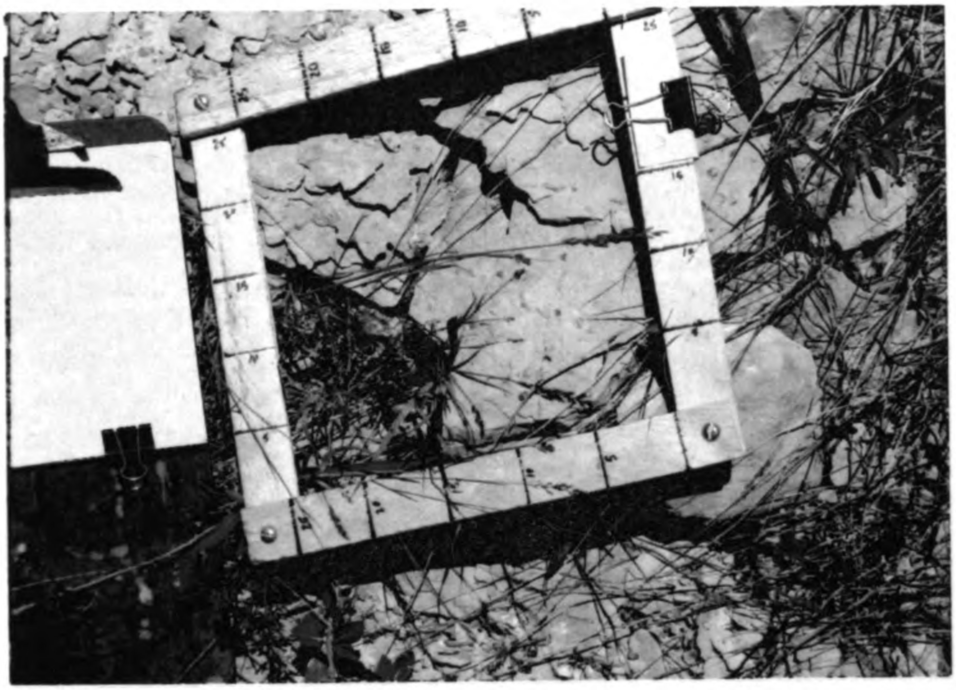
Treatment Area, TA-2
Seeded but no biosolids were applied.

Photo A June 18, 1997

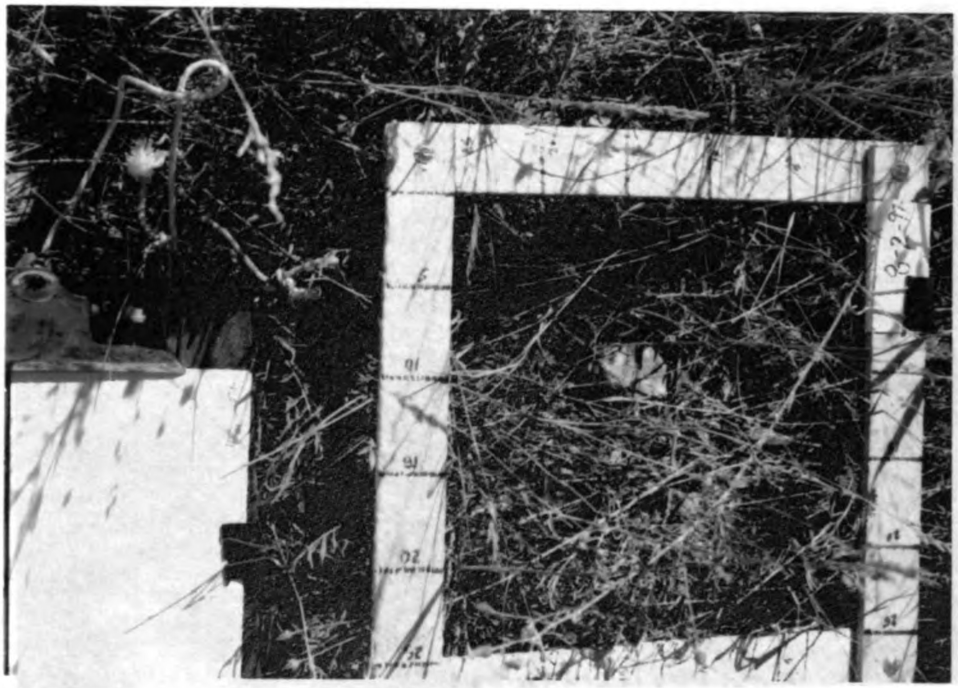
Photo B June 29, 1997

Figure 4-5, **EXISTING SITE CONDITIONS, 1997:**

Treatment Area, TA-2



Plot #4 June 28, 1997



Plot # 41 August 2, 1997

Figure 4-6, **EXISTING SITE CONDITIONS, 1997**

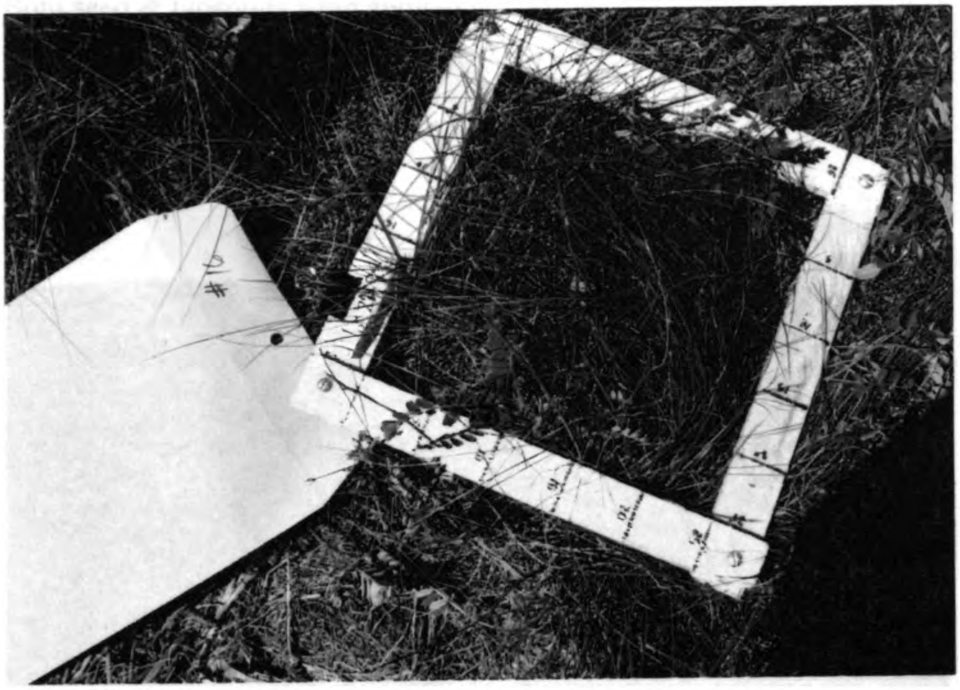
Treatment Area, TA-3
Not seeded, but, biosolids were applied.

Photo A May 24, 1997

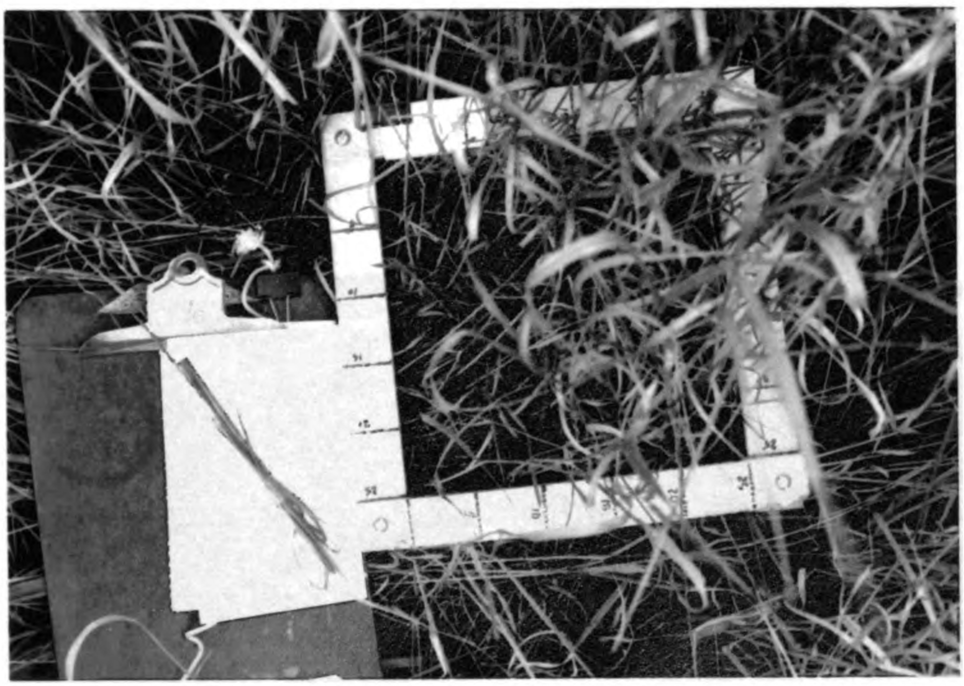
Photo B July 5, 1997

Figure 4-7, **EXISTING SITE CONDITIONS, 1997**

Treatment Area, TA-3



Plot # 16 June 22, 1997



Plot #49 August 16, 1997

Figure 4-8, **EXISTING SITE CONDITIONS, 1997**

Treatment Area, TA-4
Both seed & biosolids were applied.

Photo A June 24, 1995

Photo B August 16, 1997

Figure 4-9, **EXISTING SITE CONDITIONS, 1997**

Treatment Area, TA-4

Plot # 19 June 20, 1997

Plot # 48 August 16, 1997

Figure 4-10, **EXISTING SITE CONDITIONS, 1997**

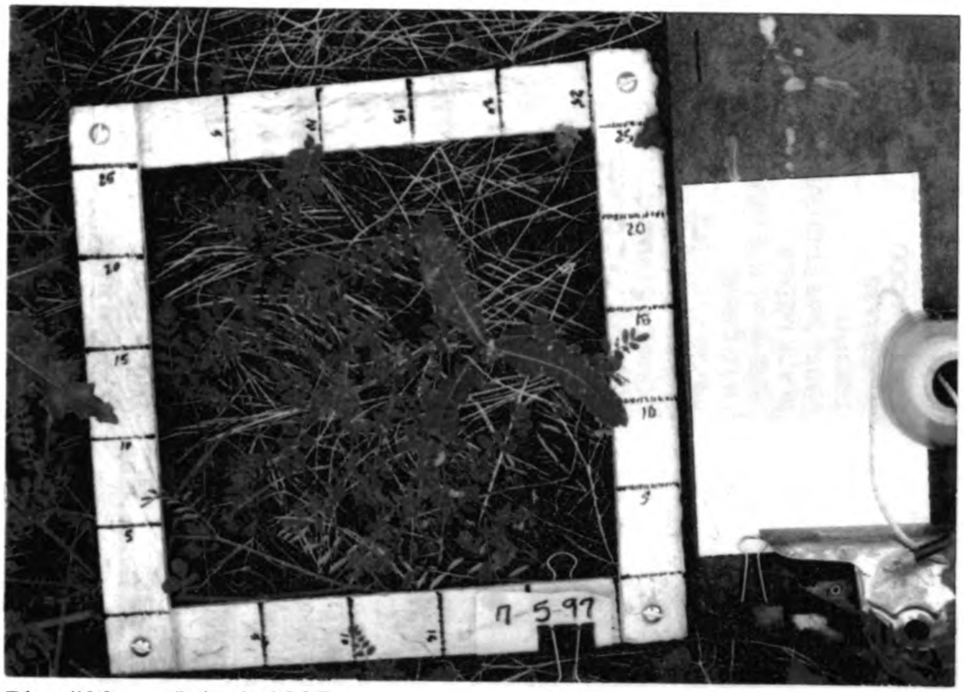
Treatment Area, TA-5
Trenched Area, seed and biosolids were applied in 1980 only.

Photo A May 24, 1997

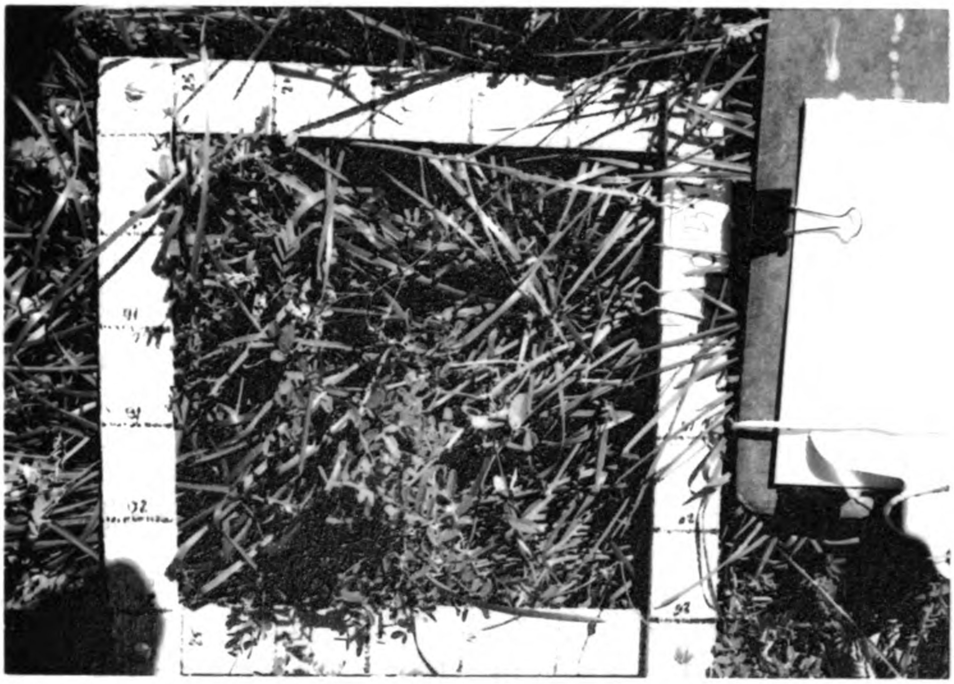
Photo B May 24, 1997

Figure 4-11, **EXISTING SITE CONDITIONS, 1997**

Treatment Area, TA-5



Plot #30 July 4, 1997



Plot # 55 August 23, 1997

Table 4-1, **Species Inventory:**

Species Inventory, 1997							
						SPECIES	
ACRONYM	N/A	C	W	WETNESS	PHYSIOG.	SCIENTIFIC NAME	COMMON NAME
AGRDAS	N	10	4	FACU-	N Grass	Agropyron dasystachyum	WHEAT GRASS
AQUCAN	N	5	1	FAC-	N Forb	Aquilegia canadensis	WILD COLUMBINE
ARCMIN	A	*	5	UPL	A Forb	ARCTIUM MINUS	COMMON BURDOCK
BARVUL	A	*	0	FAC	A Forb	BARBAREA VULGARIS	YELLOW ROCKET
BETPAP	N	2	2	FACU+	N Tree	Betula papyrifera	PAPER BIRCH
CENMAU	A	*	5	UPL	A Forb	CENTAUREA MACULOSA	SPOTTED KNAPWEED
CHEALB	A	*	1	FAC-	A Forb	CHENOPODIUM ALBUM	LAMB'S QUARTERS; "PIGWEED"
CHRLEU	A	*	5	[UPL]	A Forb	CHRYSANTHEMUM LEUCANTHEMUM	OX-EYE DAISY
CORSTO	N	2	-3	FACW	N Shrub	Cornus stolonifera	RED-OSIER DOGWOOD
CORVAR	A	*	5	UPL	A Forb	CORONILLA VARIA	CROWN-VETCH
DACGLO	A	*	3	FACU	A Grass	DACTYLIS GLOMERATA	ORCHARD GRASS
DAUCAR	A	*	5	UPL	A Forb	DAUCUS CAROTA	WILD CARROT; QUEEN-ANNE'S-LACE
ECHVUL	A	*	5	UPL	A Forb	ECHIUM VULGARE	VIPER'S BUGLOSS
ELYWIE	N	8	0	FAC	N Grass	Elymus wiegandii	WILD-RYE
EQUARV	N	0	0	FAC	N Fern	Equisetum arvense	COMMON or FIELD HORSETAIL
FESTEN	A	*	5	[UPL]	A Grass	FESTUCA TENUIFOLIA	FESCUE
FRAVIR	N	2	1	FAC-	N Forb	Fragaria virginiana	WILD STRAWBERRY
HORJUB	A	*	-1	FAC+	A Grass	HORDEUM JUBATUM	SQUIRREL-TAIL GRASS
IPOPUR	A	*	4	FACU-	A Forb	IPOMOEA PURPUREA	COMMON MORNING GLORY
JUNALP	N	5	-5	OBL	N Forb	Juncus alpinus	RUSH
LACSER	A	*	0	FAC	A Forb	LACTUCA SERRIOLA	PRICKLY LETTUCE
LEPCAM	A	*	5	UPL	A Forb	LEPIDIUM CAMPESTRE	FIELD CRESS
LOLPER	A	*	3	FACU	A Grass	LOLIUM PERENNE	PERENNIAL RYE GRASS
MEDLUP	A	*	1	FAC-	A Forb	MEDICAGO LUPULINA	BLACK MEDICK
MELALB	A	*	3	FACU	A Forb	MELILOTUS ALBA	WHITE SWEET-CLOVER
PHLPRA	A	*	3	FACU	A Grass	PHLEUM PRATENSE	TIMOTHY
POAAUT	N	10	0	FAC	N Grass	Poa autumnalis	BLUEGRASS
POPDEL	N	1	-1	FAC+	N Tree	Populus deltoides	COTTONWOOD
POTANS	N	5	-4	FACW+	N Forb	Potentilla anserina	SILVERWEED
SETVIR	A	*	5	UPL	A Grass	SETARIA VIRIDIS	GREEN FOXTAIL
SOLNEM	N	2	5	UPL	N Forb	Solidago nemoralis	OLD-FIELD GOLDENROD
SONASP	A	*	0	FAC	A Forb	SONCHUS ASPER	PRICKLY SOW THISTLE
TAROFF	A	*	3	FACU	A Forb	TARAXACUM OFFICINALE	COMMON DANDELION
TOXRAR	N	2	-1	FAC+	N Vine	Toxicodendron radicans	POISON-IVY
TRIFUC	A	*	5	[UPL]	A Forb	TRIFOLIUM FUCATUM	CLOVER

B. Examination of the Findings of the Study

Introduction:

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

Results and Interpretation:

The biosolid inventory describes the chemical output of the City of Charlevoix's Waste Water Treatment Plant. As industry change within the city, the level of toxins varies. The addition of these chemicals onto the reclamation project directly affects the toxin located in the soil. The chemical inventory of the soil before and during the process of biosolid additions increased several toxic chemicals but they never reached the EPA's level of contamination. The soil pH has decreased over time with the addition of biosolids and the creation of an organic layer. Originally copper, lead and zinc were a concern and needed to be monitored. Over time these chemicals have been reduced within the city's waste water treatment system and as indicated in the biosolids and drying bed data.

The soil information collected gives a basic understanding of soil pH and chemistry. As shown by 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 1990's 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 of the biosolids or within the drying bed data to effect the soil enough to show change. Some fluctuation is expected but the degree of increase in a relative short period of time is not readily explainable. Fallout from air particles from the cement kiln emissions and quarrying process could be one possibility.

The original biosolid test analysis indicated that the biosolids were high in potassium and phosphorus for fertilization, with only minimal amounts of available nitrogen. The data available only refers to the concern for high concentrations of copper, lead and zinc in the soil analysis but does not give data to input into the tables listed in Table 3-3. The chemical loading that has occurred varied throughout the site. This is demonstrated in the 1992 and 1994 soil testing results table. Five soil samples were taken during these years, and in each subsequent year. Although one plot had substantial difference in elevated copper, lead and zinc the average for all the samples, fall well within the limits the EPA has set for expectable standards for toxic chemicals. Copper had the greatest variation in each soil sample, the 0-56 mg/kg over the samples available. This data reflects the large increase in chemical additions from the biosolids applied in 1993 to the reclamation areas.

The variation in aspect affected the plant growth and establishment by increasing the moisture on the northern slope of TA-5 area, that is adjacent to Lake Michigan. Due to the shade from the existing trees and orientation away from the sun, reduces the evapotranspiration in this treatment area. The south facing slope of TA-2 in contrast has higher evapotranspiration because of the orientation of the slope and limited vegetative cover. The leveler areas of TA-3 and TA-4 and the addition of biosolids increase moisture addition to the site. The control plot TA-1 is in the most exposed area, where sun and wind continually erode the area. This erosion is evident were grasses have not become established to hold the soil in place. The eastern portion of the treatment study area has grasses established and a well established vegetative cover because of it's protected location. These modified micro climates, I believe, have affected the vegetation establishment and plant successions.

The vegetation on site varies most, were the additions of soil additives have effected soil chemistry and moisture. These treatment locations tend to show larger areas of plant colonies that form visual mosaic patterns in the landscape. Grasses are the predominate species in TA-3, TA-4, TA-5 areas, with crownvetch being the dominate forb. The vegetation in treatment area 1 and 2 have a greater variety of species present on them and are predominately covered by forbs, spotted knapweed being the dominate species.

The vegetation analysis included guilds ecological groupings of the moss layer, herb layer, understory, emphemerals and overstory. The vegetation analysis in Table 4-2 was tabulated from raw data tables created for each treatment area. The moss layer, herb layer, shrub layer and overhead are discussed as follows. The moss layer was present

Table 4-2: **VEGETATION ANALYSIS:**

VEGETATION ANALYSIS

Medusa Mine Reclaimation project 1997

	DATA	TA-1	TA-1 %	TA-2	TA-2 %	TA-3	TA-3 %	TA-4	TA-4 %	TA-5	TA-5 %
FORBS											
	Total # of Varieties of forbs	7		12		6		5		4	
	Greatest # of 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	30	0.50	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 additional forbs in addition to Coronilla varia	0	0.00	0	0.00	8	0.13	30	0.50	42	0.70
	Plots that contian both forbs and grasses	58	0.97	45	0.75	41	0.68	51	0.85	40	0.67
GRASS											
	Total # of Varieties of grasses	2	0.03	2	0.03	5	0.08	6	0.10	3	0.05
	Greatest # of 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	42	0.70	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	

only in TA-1 were 27% of the plots contained moss, and in TA-2 were 3% of the plots contained moss. The overstory layer is located in only in TA-5 and not thick enough to create an understory layer. The emphemerals are limited to spring varieties.

A tree survey of 1" saplings may have given a better understanding of the volunteer species that have become established in the TA-1, TA-2 and TA-5 areas. Vascular plants are larger than ¼ meter plots and were avoided with the intention of conducting individual survey on these species. The survey for the $\geq$4" DBH trees in TA-5 was not completed. Most of the existing trees in this area consisted of *Populus* species that showed signs of disease and death. Several scotch pine (*Pinus sylvestris,* L.) still remain and are in good health. There are several paper birch still remaining from the original plantings and wide range of age from volunteers. European Mountainash (*Sorbus aucuparia* L.), is also present in varies degrees of health. The volunteer woody species that are present throughout the reclamation project include white, eastern cottenwood (*Populus deltoids*, 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, TA-2, and the fewest varieties in TA-5. This statement is based on identified forbs and not on the total of the unknowns. Although, 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 where located in a single plot in TA-1 whereas the greatest number of forbs located in TA-4 was only three and this occurred during the early season before the grass cover blocked the sunlight reaching the prairie floor. The areas were crownvetch was the predominate forb 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 counts. The largest variety of grasses per plot was located in TA-3 and the least in TA-5. Twenty-two percent of TA-3 contained plots of only grasses whereas TA-1 did not contain any plots of totally grasses. One-hundred percent of TA-4 plots contained grasses whereas TA-3 only has 78% of the plots that contain grasses. Plots that contained both forbs and grass where greatest in treatment area TA-1 with 97% and the least in TA-5 were 67% of the plots contained both.

Treatment area size differences may affect the percentage of the vegetation that was surveyed. This can affect the species recorded. For example the 60, 1/4 meter^2 plots cover 15 meters of the 836 square meter plots of treatment area TA-1. The survey looks at 2% of the treatment area. Whereas the 15 meters of surveyed area in treatment area TA-4 looks at only .07% of the 22,483 square meter area. Treatment areas TA-2 and TA-3 were similar sized and looked at .5% of their area. Treatment area TA-5 surveyed .1% of the existing vegetation. Although only .07% of TA-4 was surveyed this area contained large mosaics of vegitation patterns were there was an advantage to covering a larger area than choosing a smaller portion to work with equally sized areas.

The use of biosolids has greatly improved the vegetative cover of the reclamation project. Those areas were the biosolids were applied has increased cover, created a deeper O horizon and increased the ability to support a greater wildlife habitat and populations. The reclamation project is a success from the stand point of vegetation establishment for visual improvement, wildlife habitat, soil erosion, and environmental improvement. The issue of variety vs. quality of cover can be debated and based on the desired outcome.

C. Case Study Interpretation

Alternatives/Potential:

The project results have gaps in the available data therefor a large portion of the results have been interpretations and inference used to guide my comments. The biosolids application project, as of the spring of 1998, has been terminated. An alkaline plum offshore from the Medusa property is a concern for the Michigan Department of Environmental Quality and the mining company and in the interest of the company the project was discontinued.

The actual vegetation survey conducted during the 1997 season has the ability to show what species are representative of a reclamation project were different soil treatments are applied over a long term project. As the reclamation project and the literature supports (Sommers 1997, Stucky *et al.* 1977, Schafer 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 progression on it's own, stress factors create a greater variety of plant species (Biodini 1986). The increase of diversity allows for the greater ability to support a variety of wildlife increases the food chain population. The introduction of non-native vegetative species to create better forage for grazing wildlife. Because of the disturbance on the site, a large variety of vegetative habitats have been created. The fact that the reclamation area has undergone several areas using different treatments has created different vegetation mosaics. This diversity encourages and supports a diversity of both vegetation and wildlife as Alvarez *et al.* (1974) indicated. Studies of wildlife could also indicate how these chemicals are affecting the food chain. The areas of native plant species on the disturbed site, although thin, have greater diversity as studies supported by McMullen *et al.* (1984).

The use of recorded plant species at the initiation of the projects allowed for the ability to see what has happened to those areas by comparing it to the vegetation that is existing in 1997. Since the biosolid applications have been discontinued in 1998, it will be interesting to see what happens to the site over the next several years.

Recommendations & Limitations/Constraints:

Twenty years of research have generated case studies that have been developed a frame work for biosolid applications (Stucky *et al.*1977, Sopper 1993, Brockway *et al.* 1986). The stringent guide lines for biosolids application set forth by the Clean Water Act of 1987, the Environmental Protection Act Part 503 Biosolids Rule and the Resource Conservation and Recovery Act have created safe standards for humans and animals. The Surface Mining Control and Reclamation Act of 1977 helped to add in the beneficial distribution of biosolids. The Surface Mining Control and Reclamation Act requires revegetation of mine sites as soon as possible after disturbance, and in order to accomplish the standards set forth in the Act the addition of a soil additives must be included to reach the time frame for the required vegetative cover. A two year study conducted by Sopper 1981 failed to detect any adverse effects from biosolid additions.

Through continuous high standards of permitting, and monitoring a successful policy for domestic sewage sludge can be developed. These can be demonstrated in the use of biosolids on barren soils at mining sites, and from the increase in crop production and the low cost for fertilization for land reclamation. Last but not least the production of biosolids is by everyone and the need to disperse it for benefits instead of occupying landfill space, will benefit everyone.

Applications & Feasibility:

The application of the study will aid in understanding revegetation techniques with the aid of biosolid additions for limestone quarry reclamation projects. Biosolids contains significant amounts of nutrients and organic matter (Sommers 1977). When handled correctly the use of biosolids for soil building has been proven through past studies to be a safe method of fertilization.

The use of biosolids to increase biomass on a reclamation project reduces erosion, and improves visual impacts to an area (Sheltron *et al.* 1977, Dickerson 1975, Donovan 1976). Those locations at Medusa were biosolids were applied have a good vegetation cover and show less erosion than those areas were slopes are steeper and biomass has not created a good thatch layer to reduce water and wind erosion. The concern for increasing toxins in the soil and subsequently the life forms it feeds, have not been substantiated. Most studies (Hinkle 1982, Fresquez 1990, Brown 1991, Sopper 1993) indicate that there are far greater benefits than determents to an area where biosolids have been added. The areas were biosolids are applied at Medusa have greatly increased the coverage, but, has limited the number of varieties of species of vegetation that exist there.

Chapter V Conclusion & Summary

The significant outcomes from this study indicates that by adding additional nutrients to the soil, better vegetative cover can be established. The diversity in the herb layer is less on treated areas than untreated areas. These treated areas have a greater grass consistancy. If a site is left to develop on its own, than there will be a greater diversity within the plant community, than were additional interference takes place. Old field pioneer vegetation species are present on the least treated areas. Observing the various long term treatments, on the Medusa mine reclamation project, will aid in deciding the best alternatives to establish the vegetative cover on other similar projects.

The overall significance of study looks at how natural soil additives effect vegetation establishment and plant succession. The study was begun with the intent of being able to establish a baseline for future studies. Suggestions for future studies include information needed for a more complete study that would include: bulk density, percent clay, percent electric conductivity, hydraulic penetration, percent organic matter, and percent slopes. Vegetation analysis would include a more complete species identification, percent cover determination, diversity, plant species dominance, species association and composition, species frequency, and species character and origin. Vegetation could be measured in bulk density of forage matter and chemical composition to detect toxic chemical uptake.

Due to the existing concerns of contamination in Lake Charlevoix from the seepage of alkaline from the cement kiln dust the biosolids applications were ceased in 1998. Because of the discontinuation of the biosolids applications to the study area it would be interesting to see the effects of plant succession once a site has been left to continue on its own. How will the lack of nutrient and moisture effect the species present? Is there a substantial O- horizon to support the existing densities? What species will become dominate over time?

The ability to reshape the landscape, for future use while extracting necessary minerals allows for creation of topographic forms for increased functional and esthetic landscape can be achieved for the final configurations for ecological restoration of the landscape. Revegetation with the aid of soil building techniques such as the biosolids applications benefit the City of Charlevoix, Medusa and local residents along with the local pathology and zoology of the area. This is accomplished for the wildlife, vegetation and tourism of the area. The biological project at work, over time, creates a living interaction for a sustainable ecosystem. Because of the juxtaposition of the site to the City of Charlevoix, the airport, the waste water treatment plant, Lake Michigan, and the residential community the need to protect the visual and ecology of the reclaimed land is important to future generations.

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Appendix:

Glossary:

For clarity the following words use the following definitions throughout the text.

Abundance is were each species is estimated as belonging to one of a limited number of abundance classes, usually five or six (Cain & Castro 1959).

Allelopathy is an inhibitor to germination and growth by release of toxic substances from one plant species to another, (Barbour *et al.* 1987). Toxicity or inhibiting factors of one plant on another.

Basal area is the measure of cross-section area of the trunk at 4.5" above the ground per unit area. In grasses it is the cross-section area of a bunch grass measured 1" above the ground per unit area. This is a measure of dominance.

Biological Unit is usually an organism type such as a tree or flower.

Biological Population is species based and is a collection of units with a common inheritance.

Biosolids are the processed solids that have been separated from the liquid portion of municipal wastewater during treatment. These separated solids contain primarily organic material, sand, grit, microorganisms and trace amounts of metals, and synthetic and naturally occurring chemicals. The solids can be further processed by several biological, chemical and physical methods (Online Available: http://waterquality.metrokc.gov/bmp/basic.htm#What).

Biomass is the above ground portion of a plant that has been dried. The dry matter is then weighted to determine biomass of the vegetation crop.

Cement kiln dust is the by product of cement production, usually of a limestone base.

Coverage is a measurement of area represented by the percentage of quadrant area beneath the canopy of a given species (Barbour, *et al.* 1987).

Density is the number stems per area.

Dominance is the plant(s) that strongly characterize the physiognomy and exerts the greatest control over the community as a whole (Cain 1959).

Edge effect is a change in structure such as a road or meadow that affects changes the floristic make-up of an adjacent area.

Floristic area is an area resulting from similarity in the individual areas of several species.

Frequency is the percentage of total quadrants that contains a given biological unit (Barbour, *etal.* 1987).

Gaussian distribution, or normal distribution, is a probability density function that approximates the distribution of many random variables (as the proportion of outcomes of a particular sort in a large number of independent repetitions of an experiment in which the probabilities remain constant from trial to trial) (Webster's 1987).

Importance refers to the relative contribution of a species to the entire community (Barbour, *et al.* 1987) by summing relative frequency, relative density and relative dominance.

Plant Community is a sociological unit of any rank, occupying a territory and having a characteristic composition and structure (Cain 1959).

Sampling Units is a community or stand of vegitation based on a statistical criteria. The sample sets the limits within which data analysis is applied and information about patterns revealed (Wildi & Orloci 1990).

Standard deviation is a standard unit of measurement of deviation or distance from the mean along the abscissa of a frequency distribution. A parameter that indicates the way in which a probability function or a probability density function is centered around the mean and that is equal to the square root of the moment in which the deviation from the mean is squared (Webster's 1987).

Variance is a measurement for describing the dispersion of data around the mean, square of the standard deviation (Ambrose 1995).