Development of a Field Procedure to Evaluate the Reforestation Potential of Reclaimed Surface-Mined Land

Final Report

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CHAPTER ONE

INTRODUCTION

In the United States, 5.93 million acres (2.4 million ha) have been affected by coal mining since 1930 (Zeleznik and Skousen, 1996). Surface coal mine production has been steadily rising for the past three years as the demand for energy increases (Anon., 2007a). In 2006, coal production on surface mine operations yielded more than 803 million tons in the U.S. Only 358 million tons of coal were produced by underground operations (Anon., 2007a). More than two-thirds of the coal produced in the United States is produced via surface mine operations. This trend has been constant for the past decade.

Kentucky has been well known for its intensive coal mining for decades. Coal-fired power plants account for 91% of all the electricity generated in Kentucky. Kentucky's coal industry reported $3.25 billion sold out of state during the 04-05 Fiscal Year. Kentucky mine operators have also received 27 national achievement awards over the past 16 years for outstanding achievements in reclamation. Kentucky has contributed just under $1 billion of the nearly $7.5 billion to the Federal Abandoned Mine Land Fund (FAMLF) since it was started in 1978 (Anon., 2007b).

It is no secret that surface mining results in a significant temporary disturbance to the land. Large volumes of overburden must be removed to enable the extraction of metal, nonmetal, and fossil fuel reserves. Typically the coal seams are close to the surface, but the overburden material must be removed to expose the coal deposit. Due to the Surface Mining Control and Reclamation Act of 1977 (SMCRA) (PL 95-87), the federal government has placed more stringent environmental responsibility on the mining companies. This law requires a refundable bond to guarantee proper reclamation on post-mined lands.

As a minimum, SMCRA requires the coal companies to restore the land use capability to its pre-mined conditions or even superior use. Unless special permitting is approved, this requires the land must be returned to its approximate original contour (AOC). Prior to SMCRA, some companies simply pushed the overburden aside resulting in sediment filling up the stream channels, which prompted the formation of the FAMLF. Sediment has tremendous impacts on aquatic life in streams. This led legislatures to require stabilization of the land to eliminate such harmful environmental impacts. Many thought that stabilization required excessive compaction. That was a simple answer to the problem posed; however, they did not foresee the problems it would create in establishing forests.

SMCRA standardized surface mine reclamation on a national level. Some states, such as Kentucky and West Virginia, had reclamation laws prior to SMCRA, but enforcement was inconsistent. Reclamation is defined as “the restoration of mined lands to profitable uses” (Barnhisel, 2005). This is an involved process and includes removing overburden to expose the coal (often times storing the topsoil until grading is completed), removing the coal, recontouring the disturbed land, and establishing vegetative cover.

Reclamation is important for a number of reasons. To the public, it is important because it minimizes the environmental impact, and it protects streams and other water sources from filling with sediment. It is important to the coal industry because of legal requirements and the amount of reclamation bonds that a company must post. The current bond rate for a surface mine is approximately $100-500 per acre of disturbed land (Anon., 1998). The Office of Surface Mining, Reclamation and Enforcement regulates compliance with these laws.

This study focuses on reclamation for reforestation purposes. Reclamation methods vary somewhat for different regions and different postmining land uses (Sweigard, 2006). SMCRA has inadvertently led to excessive compaction, which has been linked to decreased tree survival (Graves et al., 2000). This occurs due to decreased root penetration and diminished permeability as a result of the excessive compaction on these reclaimed mined lands. The natural interaction between the soil and plant roots is extremely complex.

The Appalachian Region consists primarily of mountainous terrain with well-established forests. The native trees in this area have adapted to grow in minimal soil depths. Grubbing (clearing) the land of all wooded materials is the first phase of surface mining and it often eliminates the majority of the topsoil present in this region. However, since forestland was present prior to mining, reforestation is the preferred post-mining land-use in the area, if local conditions do not indicate the need for some higher level of development. Growth rates observed on the majority of compacted lands indicate the need for regulatory review. Due to the disappearance of valuable hardwood trees in the region, the Appalachian Regional Reforestation Initiative (ARRI) has been created (Anon., 2007c). The participants are advocates for reclamation methods that are favorable for reforestation.

One major obstacle facing reforestation in the Appalachian Region is establishing a proper growing medium. The organization advocates the creation of a suitable growing medium with minimal depth of 4 feet composed of weathered sandstone or the best available material covered with topsoil where available. The upper four feet of material is to be very loosely graded to prevent excessive compaction of the growing medium. It is believed that under these conditions trees will be able to flourish due to the limited resistance offered to the roots as they explore for nutrients. As the tree roots flourish, so to will the branches and leaves above the earth's surface.

1.1 Problem Statement

Over a period of several years, researchers at the University of Kentucky and other institutions have proven that reestablishing trees on surface mined land while following the widely-held interpretation of SMCRA is a daunting task. The common concensus among regulators and industry representatives was that to comply with the grading requirements of the law, excessive compaction was routinely necessary. The grading and compaction of the replaced soil material during reclamation was to such an extent that the tree roots are unable to penetrate the soil sufficiently to enable proper growth and development of trees (Graves, et al., 1995). Excessive compaction has a detrimental effect on both tree survival and growth (Burger, et al., 2005).

Reforestation is a desirable use for these lands for a number of reasons including tax incentives, increased carbon capture, esthetics, the value of the hardwoods, and reduced soil erosion. However, the establishment of proper growth characteristics in the spoil is essential for success. On sites reclaimed as forestlands, a suitable survival rate must be achieved to warrant the final stage of bond release and to relieve the company of its liability. Future income from tree growth characteristics is also at stake on forestlands.

In 1996, the Kentucky Environmental Quality Commission expressed concerns to Governor Paul E. Patton and the Natural Resources and Environmental Protection Cabinet (NREPC) that current reclamation techniques were hindering proper growth and development of trees. In response to the report, a working group was established to evaluate the current reclamation policies and practices as they affect tree growth and survival (Anon., 2006). The key parties involved in this group included professionals from the industry, environmental groups, the U.S. Office of Surface Mining, the University of Kentucky, the Department of Fish and Wildlife Resources, the Department of Natural Resources and its Division of Forestry, and the Department of Surface Mining Reclamation and Enforcement (True, 2005).

Months of work followed to demonstrate that minimizing compaction during the recontouring process would effectively ensure survival and proper development of forests on reclaimed mined lands. This work resulted in the Reclamation Advisory Memorandum (RAM) #124, which was released to the public in 1997. There has been nearly a 15 % increase of permit applications proposing forestlands (i.e. trees and shrubs) for post-mining lands since then. The University of Kentucky has been involved in ongoing reforestation research at the Starfire Mine, since 1996. The major goal of this research is to establish methods for maximizing growth of hardwood species on post-mined lands. Bulk density, moisture content, penetration resistance, penetration depth, tree survival, and tree dimensions have all been monitored as part of this study. Research results have supported the guidance contained in RAM #124.

The new phase of the study that is the subject of this report is aimed at removing equipment barriers and developing a portable mechanism for evaluating the maximum penetration depth (refusal depth) and soil resistance parameters. By adapting a portable measuring technique to evaluate the soil resistance and depth to refusal that is not attached to a tractor, infinite flexibility is offered to the user with respect to field conditions. “Increased penetrometer resistance is correlated with compaction when all other factors are held constant” (Baver et al., 1972). Bulk density, also, is increased with excessive compaction. The common method of measurement is to use nuclear density gauges for density. There are a couple of different ways to measure the density, but typically a probe from the unit is inserted into the ground at a known depth and the amount of radiation is measured at the base of the unit on the surface. Gamma rays are released from the end of the rod and the amount of gamma rays that reach the surface unit measures a density and moisture content for the strata (Anon., 2007d).

As part of the ongoing study at the University of Kentucky, a static cone penetrometer was used to determine the soil strength properties such as soil resistance and maximum penetration depth on reclaimed mine lands for the past decade. This model incorporates a very similar design to that used by Hooks and Jansen in Illinois (Hooks and Jansen, 1986). The research plots designed for this study were developed to allow accessibility for obtaining measurements using a tractor. However, in real world applications where RAM #124 is being applied, the ground surface and slope offer great obstacles for the tractor's use. This limits the ability to assess spoil characteristics on most reclaimed sites. Therefore, a dynamic cone penetrometer has been considered that does not have this limitation on mobility.

The dynamic cone penetrometer had generally been used only on farmland to yield penetration depth to refusal and soil resistance parameters (Triggs, 1988). The current research intends to illustrate that this low-cost technique is applicable in evaluating the reforestation potential of reclaimed surface-mined land under any conditions encountered in the field. Previous studies have illustrated that there is a relationship between the degree of compaction resulting from various reclamation methods, growth characteristics of trees, and the physical growing medium (Conrad, 2002).

1.2 Scope of Work

Data was obtained from various research plots incorporating a number of different reclamation techniques and tree species to support the investigation. Both the static cone penetrometer and the dynamic cone penetrometer were used and evaluated based on their field performance and reliability. Similar research studies were also analyzed.

The major objectives of this study are as follows:

1) Establish initial values for comparison of depth to refusal and soil resistance using both the static and dynamic cone penetrometer. This was conducted at both the eastern and the western part of the state of Kentucky. Conclude whether the dynamic cone penetrometer is applicable in both locations. Measure values and validity of data at different depth increments for reassurance.

2) Establish multiple year data at the Starfire reforestation research location. These test plots were constructed to allow accessibility for the tractor but most typical forest reclamation sites are not. Multiple reclamation techniques were conducted at this location, which provides a suitable basis for comparing the effectiveness of the dynamic cone penetrometer to the static cone penetrometer. Incorporation of these techniques may be useful for future studies.

3) Develop a standard procedure that can be applied in the field under all circumstances to evaluate the physical characteristics of the replaced root growth medium as it relates to reforestation success.

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil/Mine Spoil Characteristics

Native Appalachian soils are young shallow soils (Inceptisols) or soils that have undergone extensive nutrient depletion through leaching (Utisols) (True, 2005). Appalachian soils are often low in clay content, highly variable (Roberts et al., 1988) and typically have a high (35 – 70 %) rock fragment content (Pedersen et al., 1980; Ciolkosz et al., 1985; Thurman and Sencindiver, 1986; Roberts et al., 1988). Proper reclamation is obtainable by replacing the old medium with a new or improved growth medium more suitable for vegetation (Rogowski, 1990). According to past researchers (followed closely by ARRI), to reforest mined lands to productive forestlands, three steps must be conducted. A suitable overburden must be selected and placed at the surface. Compaction should be minimized or prevented if possible. Finally, ground cover compatible with trees should be utilized to warrant tree survival and growth (Torbert, 1996).

The Appalachian Regional Reforestation Initiative has established a Forestry Reclamation Approach (FRA) to provide successful reforestation on surface-mined lands. The Forestry Reclamation Approach has been confirmed by research and is listed below (Anon., 2005a):

- Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and comprised of topsoil, weathered sandstone and/or the best available material.
- Loosely grade the topsoil or topsoil substitutes established in step one to create a non-compacted growth medium.
- Use ground covers that are compatible with growing trees.
- Plant two types of trees – early succession species for wildlife and soil stability, and commercially variable crop trees.
- Use proper tree planting techniques.

2.2 Evaluating Compaction

The most common method of evaluating soil compaction has been to measure the soil density. Density is defined as unit mass per unit volume. This is commonly expressed in lb/ft^3. From the units, as more mass is confined to the same area, the density will increase. The dry bulk density is the most frequent parameter to characterize the state of the soil compaction (Panayiotopoulos et al., 1994).

Soil compaction has a number of causes, including overuse of machinery, intensive cropping, short crop rotations, intensive grazing and inappropriate soil management (Hamza and Anderson, 2005). Compaction is useful in a number of settings. It provides the soil with increased strength, incompressibility, low pearmeability, and for years it has been believed to reduce soil erosion (Kalinski, 2006).

Natural compaction can occur over centuries and once the overburden material (soil and rock) is moved from its original location, there is a swell factor associated with it due to the increased pore spaces that results. Swell factors for general rock overburden material may be found in various geotechnical textbooks, but general ranges are about 25 - 30%. Compaction helps to condense the swelled material. The laws pertaining to runoff from a mine site are very strict to limit environmental impacts. Compaction is also necessary when constructing sediment ponds or embankment structures. Compaction of the material is the key to reduce the pore space and chance of a sediment washout (Hunt, 2006).

Compaction has several drawbacks associated with it. It decreases porosity (pore or void space between soil particles), water infiltration, water holding capacity, and adversely affects nutrient supply. It decreases soil physical fertility by reducing pore space leading to additional fertilizer applications and increased production cost. Hamza and Anderson (2005) reported, “A detrimental sequence then occurs of reduced plant growth leading to lower inputs of fresh organic matter in the soil, reduced nutrient recycling and mineralization, reduced activities of micro-organisms, and increased wear and tear on cultivation machinery.” For many years compaction has been believed to result in retarded growth patterns for various plant species. Fulton and Wells (2005) reported “Heavy earthmoving equipment during reclamation tends to generate root-limiting bulk densities that adversely affect plant growth thereby decreasing yields.”

Under current reclamation practices, prime farmland soils are difficult to reclaim. Compaction also has drawbacks linked to its use in the industry. A hollowfill is constructed from the spoil material that is permitted to be placed into hollows constructing more level terrain. These fills are constructed in benches with established vegetation enabling reduced runoff velocities and provide adequate slope stability (405 KAR1:141, 1979). A sediment pond is placed at the base of these hollow fills to trap sediment runoff. Excessive compaction leads to increased runoff velocities due to the limited infiltration of the material, which results in sediment transport to the pond from the hollow fill material (Halbert, 2007).

Many techniques to reduce soil compaction have been described by Hamza and Anderson (2005). These techniques include reducing pressure on the soil by increasing surface area of rubber tires or decreasing the axle load of equipment, reducing the number of passes by farm machinery, reducing the frequency of animal grazing, controlling the traffic, alleviating compaction via deep ripping, using crop rotations with deep, strong taproots, and maintaining an appropriate base saturation ratio. Hydraulic conductivity can be described as the ease with which water can move through pore spaces. Once the soil becomes completely saturated, the hydraulic conductivity will reach a stagnate level. Compacting the soil at optimum moisture content has an increased amount of compaction associated with it (Hamza and Anderson, 2005). This will drastically reduce the remaining pore space available in the soil once it dries. Due to Kentucky’s temperate climate and annual rainfall, compaction seldomly occurs above wet of the optimum level.

2.3 Indirect Measurements of Soil Strength: Average Penetration Resistance and Maximum Penetration Depth

Soil resistance is best described as the soil’s ability to withstand penetration of an object while a load is applied to a contact area. Soil resistance has identical units to pressure or stress (force per area). The most common practice for evaluating soil resistance is to use cone penetrometers. Researchers have theorized that soil strength is the most important limiting factor reducing the root growth (Taylor and Gardner, 1963; Taylor and Burnett, 1964). If soil strength is too high, the root growth is stopped altogether (Taylor and Ratliff, 1969). There have been very successful studies concluding that a relationship exists between soil bulk density and root growth (Conrad, 2002), however soil strength is argued to be a better method of measurement because it more accurately reflects the resistance encountered by the root when it enters the soil (Phillips and Kirkham, 1962).

Both penetrometer resistance and bulk density data have been used to predict root length density in the lower portion of the root zone using linear regression models (Thompson et al., 1987). This is governed by the load bearing pressure experienced as the rod penetrates the soil. Leaves have elongated at a substantial delayed rate (approximately 50 % decrease) when grown in soils with increased resistance to penetration (Beemster el al., 1996). In some instances, penetrometer resistance data are capable of being collected and analyzed quicker and easier than bulk density and may prove to be more useful and more economical for future prediction of root system performances on mine soils (Thompson et al., 1987).

Generally, penetration resistance increases with depth. As the voids shrink, the soil's ability to be penetrated decreases. This is a result of the increased strength of the soil previously noted. Some penetrometers measure depths greater than 100 inches in cohesive clay strata. The maximum penetration depth will decrease particularly in rocky, superior compressive strength spoil material such as sandstone. The relationship between root length density and penetrometer resistance gets closer with increased maximum penetration depth (Thompson et al., 1987).

2.4 Barriers to Reforestation

Various environmental factors have been associated with tree growth characteristics. These factors are sunlight, temperature, carbon dioxide, predators, plant competition, water, oxygen, nutrients, and acidity (Lyle, 1987). It may be argued that sunlight, temperature, carbon dioxide, and animal predators are not under human control. However, the reclamation processes of constructing a suitable growing medium and obtaining adequate ground cover give some control over the amount of water, oxygen, nutrients, soil acidity, and plant competition.

There are three types of pores in soils resulting from the particle sizes. These types are macropores, capillary or mesopores, and micropores. The macropores are greater than 50 μm. They are the largest pores and do not retain water well as it is often lost due to gravitational forces (Sikora, 2006). Earlier researchers like, Jones and Kunze, (2004) believed, the loss of macro-pore space via soil compaction has the greatest impact on water and air movement. Mesopores range from 0.2 to 50 μm. It has been discovered that these pores hold the majority of the water available to plant roots (Sikora, 2006). The micropore is the smallest and sizes are below 0.2 μm. The water is held so tightly to the soil particle by ion exchange bonding that the water molecule cannot be relinquished from the soil particles. The water present in this pore is, therefore, not available to the plant root.

Water is extremely important to the plant because it controls growth and transports nutrients used for cell production. The availability of water present for plant uptake is a function of soil texture, structure, organic matter, and depth (Lyle, 1987). The soil water holding capacity typically ranges from 10 kPa to 1600 kPa (Sikora, 2006). Water with tension below 33 kPa will drain through the soil to the water table by gravity, unless held in by the root zone (Rogowski, 1990). Four characteristics having a monumental impact on a soil's ability to absorb and store water include soil structure, soil texture, organic matter, and thickness (Lyle, 1987).

The particle sizes have a great impact on the movement and retention of water. Water generally passes through coarse sandy soils much quicker than soil high in clay content. This is a function of the porosity of the soil. Porosity is defined as the volume of void space divided by the total volume present. The void space is the location where oxygen and water may migrate and be stored. Water movement and retention has a tremendous impact on the water availability to plant roots. It is important to understand that too much water will deplete the soil and plant roots of oxygen which may be detrimental to plants. The movement of water through the soil is known as hydraulic conductivity. The hydraulic conductivity is a function of the size of the pores in the soil

(Hillel, 1980). Intermediate soil textures such as silt loams, sandy loams, sandy clay loams, and loams are most desirable for plant growth (Lyle, 1987).

Soil acidity has also been linked to poor plant growth. Acidity is often a result of excess iron and aluminum, which are both cations. A proper balance of nutrients, water and oxygen is needed for successful growth. The increased amount of one nutrient often limits other nutrients resulting in nutrient deficiencies. These deficiencies often result in visual abnormalities, such as changes in color, leaf index, and formation of spots, etc. Fertilizers containing N, P, and K compounds are often used to stabilize nutrient availabilities. Fertilizer containing calcium has proven to be most beneficial when trying to neutralize soil acidity.

Predators (animals) may devour a plant or the plant may become trampled or detached from the root by animal movement. The presence of other vegetation may also inhibit tree growth. Normally plant species compete with other plants for soil nutrients, sunlight, space, and water needed for growth. However, there has been evidence that some rhizobia (bacteria) species will actually bond to tree roots increasing the overall surface area and both species will benefit from this partnership (mutualism). Spacing of the plants is extremely important. It has long been believed that fish only get large enough to survive based on the tank (environment) provided to them, despite what the average growth is portrayed to be. A similar situation may constrain tree growth when they are planted too close together and the limbs meet and become confined as they grow.

Compaction can be linked to the majority of the factors affecting tree growth. Physical characteristics of the soil such as density, strength, moisture content, nutrients, texture, and structure are all affected. In extremely compacted soils, plant root growth is reduced along with vegetation success. It is nearly impossible to prevent all of the factors from occurring. However, it is important to be aware of these limiting factors and the process of how to remedy the situation. Compaction is attributed by some researchers to be the single most important factor effecting tree growth on mine soils (True, 2005). The degree of compaction is a function of the pressure applied to soil, soil structure, and soil characteristics (Graves et al., 2000).

2.5 Cone Penetrometers

A cone penetrometer is an instrument designed to provide a measure of the in-situ strength of various types of materials ranging from fine-grained, granular subgrades, granular base, to weakly cemented materials (Anon., 2005b). Both static and dynamic cone penetrometers have been used in the U.S. Different methods are used to apply the force to the cone, but generally, both methods yield soil resistance to vertical penetration (Jones and Kunze, 2004). Cone penetrometers are commonly used to evaluate soil compaction because of their rapid and economical operation (Perumpral, 1987).

Agricultural and engineering applications of cone penetrometers have been used to determine soil strength for years. Improvements to the dial gauge have led to mechanical chart recording (Hendrick, 1969, Howson, 1977). An electronic chart recording penetrometer has been developed (Prather et al., 1970). Abrupt changes in soil strength can be detected by continuous data recording (Anderson et al., 1980). Academic and industrial research has prompted the development of a constant velocity (static) recording penetrometer with digital data output.

A static cone penetrometer was developed for use on reclaimed post-mined lands at the University of Illinois by Hooks and Jansen (1986). This method is useful in estimating soil strength in mine soils where the amount and depth of compaction vary as a function of the reclamation method used (Hooks and Jansen, 1986). Results were obtained up to 44 in. of penetration depth. This easily repeatable test procedure proved to be successful in determining cone index (soil strength) and depth parameters. The cone index is reported in lb/in^2 or kPa (kN/m^2) units, which is equivalent to pressure or stress (Anon., 2004). Various methods have been developed to convert cone indexes into soil resistance values.

A static cone penetrometer following the American Society of Agricultural Engineers standard limits the measurability on agricultural and rangelands, due to equipment cost, repeatability, and data interpretation (Herrick and Jones, 2002). A modified dynamic cone penetrometer has been evaluated by Herrick and Jones in 2002 to determine penetration resistance based on the number of successive hammer blows required to obtain a certain depth. This dynamic penetrometer was tested on penetration depths up to 12 inches to incorporate most compaction problems in an agricultural setting. This method is appropriate in nearly all applications where a static cone penetrometer can be used. The particular design of various parameters is sensitive to soil moisture and texture, and should not be used as direct substitutes for values of soil bulk density to determine compaction.

Both static and dynamic cone penetrometers were used at three different test sites by Bolamey (1974). This study concluded that if soil particles did not exceed medium sand sizes, the static and dynamic cone resistance is virtually the same. Both devices were proven to be equal in consolidated clays or medium dense sand (Waschkowski, 1982). However, if there were gravel size particles present, the resistance appeared to be higher for the static cone penetrometer. Both findings by Bolamey were supported by another study published the same year by Puech et al. (1974). In dense sands, the resistance was nearly twice greater using the static penetrometer compared to the dynamic penetrometer.

Comparisons of the static and dynamic penetrometers have warranted caution by various researchers (Herrick and Jones, 2002). The major census seems to be the uncertain amount of actual energy input during dynamic testing. However, correlations between static and dynamic cone resistances have been established by using an empirical formula to account for energy lost by the penetrometer (Triggs and Liang, 1988). Despite advantages offered by using dynamic cone penetrometers, the dominant method of practice by engineers is still the static method (Tavenas, 1986).

Both static and dynamic penetrometers have been proven to yield useful information in regard to soil penetration and resistance measurements. Limited work has been documented on reclaimed mine soils, but similar interpretation between agriculture land and reclaimed land is anticipated. These measurements have been linked to bulk density in various articles, but no suitable replacement criteria were located.

CHAPTER THREE

CONE PENETROMETER BACKGROUND AND PROCEDURES

3.1 Equipment Background

There are multiple designs for both static and dynamic cone penetrometers. The support equipment differs significantly for both types of cone penetrometers. Choosing a design to best fit the needs of a specific project is extremely important. Efficiency, reliability, and accuracy are important in determining which type of penetrometer to use.

3.1.1 Static Cone Penetrometer (SCP)

Typical concerns expressed about SCP include equipment cost, repeatability, and range of soil resistance capable of being measured. There have been difficulties in comparing data collected using other penetrometers designed for different ranges of soil resistance (Fritton, 1990; Vyn and Raimbault, 1993).

Many designs are commercially available, but similar mechanics are involved in every case. Most SCPs consist of a cone-tipped rod attached to a pressure measuring device. There are design specifications noted for the rod set by the American Society of Agricultural Engineers (Anon., 1992). The measuring device is often a load cell. The load cell will have a built-in strain gauge which measures the resistance as the rod penetrates the ground. The depth is read by a transducer or some other type of linear measuring device operating on similar mechanics as the load cell. There must also be some type of recording station, either performed manually or by a computer. The rods are generally driven into the ground at a constant rate by a hydraulic cylinder. Therefore, these devices are often quite heavy and are attached to a vehicle, such as a farm tractor to provide mobility.

The SCP used to evaluate the test sites by the University of Kentucky researchers was simulated after Hooks and Jansen who conducted studies on reclaimed surface-mined lands in Illinois (Hooks and Jansen, 1986). A constant velocity of 1.14 in/sec (2.9

cm/sec) is used to compare soil strength given various reclamation methods. The constant velocity enables recorders to conclude that the frictional force on the cone is negligible and assume the only load applied is the force on the basal area of the cone from the load cell. There is a regulator on the hydraulic controls to retard the movement to the desired rate.

The rod is constructed with a 30° right circular cone point of 1 in^2 (6.54 cm^2) cross-sectional area and was fabricated using 1060 steel, welded to the shaft, and hardened (Hooks and Jansen, 1986). The shaft (rod) used by Hooks and Jansen was only 0.5 in^2 and immense bending occurred from the excessive load encountered by the post-mined strata in eastern Kentucky. Earlier, the University of Kentucky researchers had modified the shaft to 0.75 in^2 in an attempt to eliminate bending. The cone is hollowed one inch from the base to allow the rod to stabilize. The cone and rod are then welded to increase strength. Moderate bending still occurred, but care was taken not to exert an excessive force when refusal was encountered.

A tractor was used with a computer workstation mounted on its rear. The workstation consists of an operator’s chair, load cell, analog dial, Biopac Student Lab (BSL) Basics System, and a laptop computer. The probe is placed under a 2000 lb load cell. The area of the cone base is one inch so the total resistance obtainable with this design is 2000 psi. The compressive strength for run of mine (rom) spoil consisting of weathered shale and sandstone ranges from about 3500 to 8000 psi (Unrug, 2005). Compressive strength values for rock near surface excavations are shown in figure 3.1.1. Obviously, this testing procedure has almost no chance of penetrating or breaking this material if a moderately sized rock is encountered in its path.

A transducer is used to measure the penetration depth. This works on similar principles as the load cell’s dial gauge. The load cell and the transducer are attached to the BSL hardware, which is linked to a laptop. Electrical current is used to generate readings for both load and depth. When an alteration in the current is observed, it is reflected in the data and interpreted in terms of depth or resistance.

The BSL works similarly to a video camera. It takes images from the outside world and converts them to electrical format, which can be viewed on a television. Rather than recording visual images, the BSL records information about physical conditions and generates an electric signal read by the BSL software on the computer. This signal is converted into a visual format able to be seen on the computer screen. The computer memory is able to save these signals much like a VCR records images. It only takes 1/1000 second to appear on the screen once the signal is picked-up. The end result from the program is two graphs. One is depth vs. time and the other is load vs. time. With the constant velocity, the program is able to correct for delayed data.

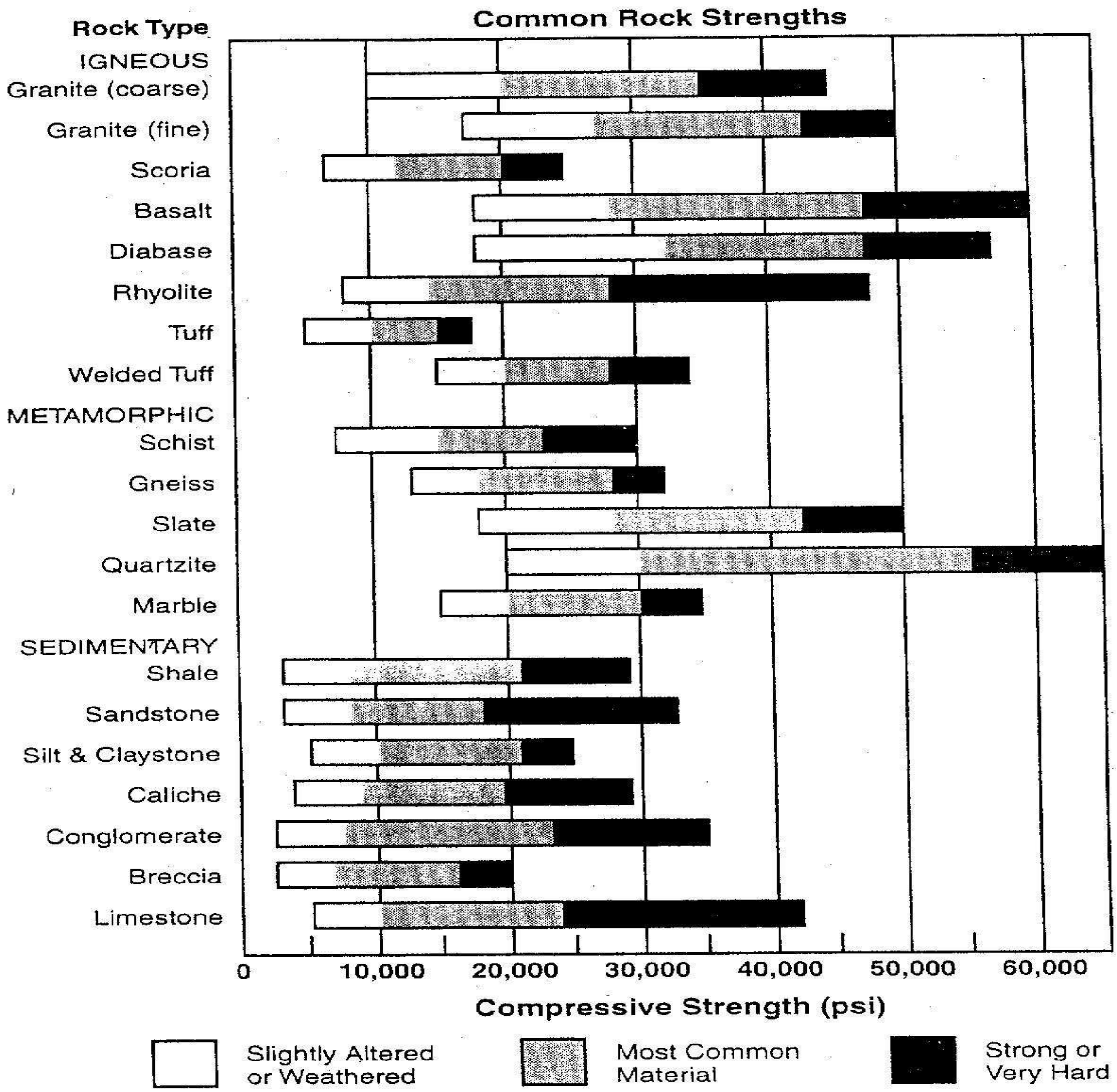

Figure 3.1.1 Compressive strength for the most commonly encountered rock near surface excavations. (Unrug)

The tractor has leg stands attached to each side of the workstation for safety. The legs are operated by hydraulic cylinders allowing them to be raised or lowered. The legs are lowered prior to obtaining a measurement to stabilize the workstation in case a rock is located in the rod's path which will either lift the tractor or bend the rod. The base of the legs is designed to avoid compressing the soil surface near the rod, which could cave the hole around the probe. Figure 3.1.2 shows the design for the SCP.

Figure 3.1.2 The workstation mounted on the rear of the tractor for collecting SCP measurements.

Following planting, tree roots are concentrated near the surface and most penetration tests reached refusal within 16 inches due to encountering boulders. Therefore, tests for this study were limited to that depth. The process of measuring penetration resistance is relatively easy, but a little time consuming. The tractor is driven into position. The legs are lowered and the tractor is stabilized. The probe is lowered onto the ground until the base is at the surface. The regulator is then pulled to maintain a constant velocity when penetrating the ground. The record button is pushed on the computer and the rod is lowered to its achievable penetration depth. The signals are sent to the computer and the output graphs are generated on the screen.

There are a few important notes which need to be made regarding this method. The load cell and transducer are laboratory tested nearly every month to ensure accurate readings are being conducted in the field. The load cell and transducer are calibrated for every cell prior to recordings. Initially, the load cell is checked at 0 lbs. Then a 20 lb block is placed on it and it is recalibrated on another computer channel. The transducer is first tested at 0 in distance. It is then recalibrated on another channel at 15 in. Once no fluctuation is observed in all four channels, the calibration process is complete.

3.1.2 Dynamic Cone Penetrometer (DCP)

The DCP used in this study is called the Wildcat Dynamic Cone Penetrometer. It is manufactured by Triggs Technology. The design is lightweight and relatively easy to transport. It is designed for one person to readily test for strength properties existing deep within the soil. This model can test penetration resistance to a depth of a few dozen feet. Triggs Technology intended to create a penetrometer capable of being transported by one person, small enough to fit in the trunk of a car, versatile enough to test any soil type, sensitive enough to differentiate between weak, medium, and strong soil and simple to interpret (Triggs and Simpson, 2005).

The DCP design is significantly different from the SCP described previously. This design utilizes standard penetration test (SPT) methodology to measure soil resistance rather than using constant penetration rate technology. The DCP has been evaluated side-by-side with SPT N values in various soil types to find correlations between the two measurement methods. The "N" is the sum of the number of blows needed to penetrate a known depth into a soil material. The number of blows required is an indication of the density of the ground, and it is used in many empirical geotechnical engineering formulas (Anon., 2007e).

A hammer weighing 35 lbs is attached to a rod and raised by the operator to a height of 15 inches. A plate is attached to the inside of the hammer to indicate when the proper height is obtained. It is important to minimize the loss of energy so care must be taken not to ram the hammer and the plate together. There is a 1.55 in^2 (10 cm^2) cone tip that must be placed on the end of the rod. The rods are typically manufactured in 3-ft segments and have a 1.1 in. diameter, which may be disconnected from one another to meet penetration depth requirements. These rods are designed with a hollow center to allow fluid flow just above the cone tip. Figure 3.1.3 shows the Wildcat DCP used as part of this study.

Figure 3.1.3 The Wildcat DCP used to test maximum penetration depth and soil resistance at the Starfire and Gibraltar Mines (shown without the slurry tank).

Cone tips differ slightly and there does not appear to be a standard set by any testing society. Lines are engraved indicating 4 inch increments on the rods. A 3.5 gallon fluid injection system pumps a cellulose and water mixture through the rods to minimize the friction on the rods. The undiminished kinetic energy from the hammer is transmitted to the cone allowing use of the Dutch Formula to determine cone resistance values, which may be defined as the ultimate bearing resistance of the cone (Triggs and Simpson, 2005). The empirical Dutch Formula and the parameters associated with it are listed below.

$$Rd = \frac{M^2 \times H \times N}{Ap(M + M' + Pa) \times 10}$$

Rd = dynamic cone resistance (lbs/in^2 or kg/cm^2)
M = fixed mass of the hammer (35 lbs ≈ 16 kg)
H = fixed height of hammer drop (15 in ≈ 38.1 cm)
N = number of blows per 4 in (10 cm) penetration – 50+ blows indicate excessive refusal
Ap = fixed projected area of cone (4 in ≈ 10 cm)
M’ = fixed mass of the driven-portion of the hammer (5.5 lbs ≈ 2.49 kg)
Pa = mass of rod string (7.19 lbs ≈ 3.26 kg)

The data recorder (person) only counts the number of blows required to achieve a 4 in penetration. In soft strata, the depth per blow could be a better method of evaluation. A simple spreadsheet has been developed to convert the number of blows (SPT) per 4 inch depth increment recorded in the field into cone resistances exerted on the cone as it penetrates the ground. Most of the parameters are fixed, so the Dutch Formula can be reduced to a simplistic form for this design.

3.2 Static and Dynamic Cone Penetrometer Comparisons

Both types of penetrometers analyzed are capable of yielding cone resistances and reducing the amount of friction present on the cones. Both methods are able to yield soil resistance values, which provide a different way of evaluating compaction than using only bulk density readings. There are some similarities and differences associated with the application of each design.

3.2.1 Applications

Static cone penetrometers measure the force required to push a cone through the soil at a constant velocity. The force is expressed as an index of soil strength (cone index) (Jones and Kunze, 2004). Cone indices are a function of cone properties and soil properties (ASAEb, 1999). A SCP with a 30° cone is recommended for characterization of soils (ASAEa, 1999). This configuration works in a wide variety of soils (Jones and Kunze, 2004). SCPs are widely used in agricultural soils (Radcliffe et al., 1989; Clark et al., 1993; Vyn and Raimbault, 1993; Mullins et al., 1994).

SCPs have some significant advantages over most DCPs. SCPs have well-documented and standardized methods of testing (Jones and Kunze, 2004). It is relatively easy to obtain data and there is a limited amount of physical labor associated with gathering the data. The computer output enables visual determination of the resistance which occurs at any measured depth.

A DCP is designed to measure the strength of fine-grained and granular subgrades, granular base and subbase materials, and weakly cemented materials (Anon., 2005). Standard tests have been performed using the DCP in strata ranging from gravel to very soft clay (Triggs and Liang, 1988). The adaptability of the DCP allows adaptation to local conditions and makes it capable of measuring either soft or hard soils (Jones and Kunze, 2004). In extremely soft soils, the depth of penetration after each blow is a better representation of the soil resistance (Anon., 2005b).

DCPs generate a known amount of kinetic energy at the cone base. This causes the cone to penetrate a distance through the soil (Herrick and Jones, 2002). The DCP offers some flexibility because either the number of blows to penetrate to a certain depth or the penetration depth per blow is measured to determine the cone index. The hammer drop distance, weight, and cone size may also be adjusted to produce varied results. Standard equations exist to account for these variations.

There are significant advantages associated with using a DCP for evaluation of soil resistance. DCPs yield more consistent results and have a greater range of repeatability since they are not subject to operator variability (Herrick and Jones, 2002). DCP data are more reliable than that of SCP due to the ease of repetition (Jones and Kunze, 2004). The major advantage of the DCP is the fact that it is portable and yields increased accessibility for nearly any field condition. The need for difficult maneuvering between measurements is eliminated.

DCPs have a significant reduced cost associated with them compared to common SCPs. An operator may be trained to use a DCP in only a few minutes. The equipment is very durable and maintenance is minimal (Jones and Kunze, 2004). There is nothing that needs to be recalibrated, so a great amount of time is saved. The data are obtainable at a relatively fast pace. Most of the time is spent transporting the DCP between data measurements.

3.2.2 Limitations

SCPs are relatively expensive and cumbersome. They generally require a tractor for mobility and the field plots must be designed to accommodate tractor access. Most sites that are reclaimed specifically for reforestation are not suited for farm tractors. SCPs must also penetrate the ground at a constant rate. They are designed to measure a relatively limited range of soil resistance (Herrick and Jones, 2002). The load cell limited the recordable soil resistance in this study. Mechanical static cone penetrometers do document compaction profiles resulting from the constant penetration rate (Jones and Kunze, 2004).

The electrical equipment is very sensitive to tractor movements and, therefore, recalibration of the equipment must occur very frequently with the SCPs. This is a problem because, if tests are performed under differential calibration conditions, there will be greater error associated with them.

Repeatability is questionable because operators generally develop slightly different penetrometer velocities based on physical strength of the strata and leverage (Herrick and Jones, 2002). Laboratory tests have concluded that these variations alone are able to result in 11 % variation in cone index for soil material (Fritton, 1990). There is also an error associated with conversion procedures while using different sized cones (Fritton, 1990).

DCPs also have some limitations associated with their use. The data gathering process is extremely labor intensive. Refusal (rock) is represented by 50 blows to achieve any 4 inch depth increment for the Wildcat DCP. Depending on the penetration depth required for tests, just below 100 blows may be required to only penetrate the ground 10 inches. Most DCPs are designed for one person's use, but significant time is lost through frequent rest breaks in more compacted strata.

There is no true representation indicating whether the equipment is level. A heavy duty level attached to the hammer mass would be extremely beneficial. The DCP used for this study results in approximately 20 % of the effective energy being lost outside the system for easy driving conditions in the form of heat and noise (Triggs and Simpson, 2005). This may lead to substantial overestimation of the true soil resistance.

Caution must be exercised when using the DCP. Soil resistance values reach 3150 psi using this mechanism. This is barely below the compressive strength of weathered shale and sandstone as shown in figure 3.1.1. There is a slight chance of breaking through small rock particles found in such a growth medium. The DCP tests do not truly indicate whether the soils are clay, silt, or sand (Triggs and Simpson, 2005).

Correlation between soil resistances and particles may be estimated, but accurate interpretation is limited.

Slurry is used in the particular design employed in this study to eliminate the effect of friction on the probe. The slurry is effective in reducing the role of friction, but the cone tips are often unable to be extracted from the ground once the test is complete. The increased lubrication and the fact that the test hole collapses on the sides of the cone cause the cone tip to become difficult to extract. A set screw has proven to be useful in preventing this under limited penetration depths (< 16 in).

3.2.3 Interpretation of Data

Soil resistance and maximum penetration depth are measurable with both types of penetrometers. The DCP has not been used in comparison with bulk density measurements before on reforested mined land. The DCP may be a good indicator of the soil density at a test location (Triggs and Liang, 1988).

This particular DCP was designed for evaluating foundations in civil engineering applications. Accessibility to buildings experiencing substantial settlement is a problem. Accessibility on reclaimed surface-mined sites is limited by vegetative cover and rough terrain. Similar problems call for similar solutions. It is believed that both penetrometers provide similar qualitative and quantitative characterization of site soil characteristics.

Testing of both a SCP and a DCP has been performed before at the same location by Bolamey in 1974. His study concluded that if soil particles did not exceed medium sand sizes, the static and dynamic cone resistance is virtually the same. In another study both devices were proven to be equal in consolidated clays by Waschkowski (1974). Waschkowski also noticed that if gravel size particles are present, the resistance appeared to be higher for the static cone penetrometer. Puech et al., (1974) reported supporting evidence for both theories. Puech et al., also reported that the resistance was nearly twice greater using the static penetrometer compared to the dynamic penetrometer when used in dense sand material.

CHAPTER FOUR

FIELD EXPERIMENTS

4.1 Site Locations and History

The original test sites (cells) for this project were located on the Starfire Mine, now renamed Big Elk Mine, which is located in Breathitt, Knott, and Perry Counties. The mine is operated by Trinity Coal Partners, LLC. These sites were planted in 1996, 1997, and 1999. The test cells are in the Noble, Kentucky United States Geological Survey (USGS) 7.5 Minute Quadrangle Map at latitude 37°23’30” north and longitude 83°08’50” west (Conrad, 2002). Preliminary tests were also conducted at the Gibraltar Mine. The Gibraltar Mine, owned by Peabody Energy in Muhlenberg County of western KY, was initially evaluated as part of this study in 2005. The sites located in Muhlenberg County are located at latitude 37°18’40” north and longitude 87°02’31” west (Anon., 2007f). Trees were planted on these test sites in the Gibraltar Mine over multiple years. Figure 4.1.1 shows the locations of several reclaimed surface-mined sites throughout the state that have been used for various reforestation research projects.

The topography at the Starfire Mine is typical to that in eastern KY. It consists of narrow ridges, valleys, and steep slopes. The average slope is approximately 50 % (True, 2005). Ridge tops are elevated nearly 800 ft. from the valley floor at Starfire (Conrad, 2002). The Starfire Mine has areas of relatively good drainage due to its topography. However, the Starfire Mine seemed to have slight drainage problems over the past couple of years in the compacted test plots. Rock outcrops are common along the slopes at this location. The predominant ground cover at the Starfire Mine is forestland (Conrad, 2002).

Coal deposits are found relatively close to the surface at the Starfire Mine. The Breathitt Formation includes four coal seams listed from bottom up: Hazard 7 Coal, Hazard 8 Coal, Hazard 9 Coal, and Hazard 10 Coal (True, 2005). There are two small rider seams available for extraction in this location that are associated with the Hazard 7 and the Hazard 9 seams (Anon., 2007g). The interburden strata that separates these seams totals less than 100 feet. Starfire has been mined for many years due to the accessibility to multiple seams and some unreclaimed surface-mined land still exists in the area (Conrad, 2002). The Lee Formation composed of sandstone, shale, coal, and siltstone is located below the Hazard 10 Coal seam.

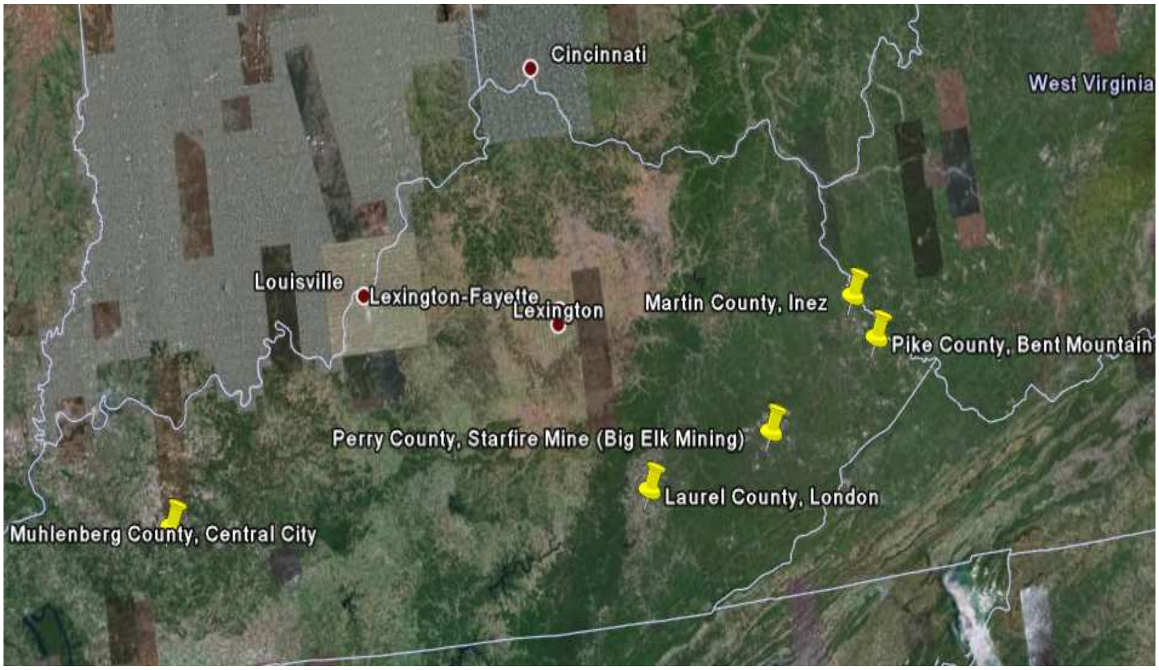

Figure 4.1.1 Location of the reclamation sites in the western and eastern part of Kentucky.

All four coal seams located in the Breathitt Formation are mined at the Starfire Mine. Several types of equipment have been used for overburden removal throughout the life of the mine. A dragline was only economically viable for removing overburden covering the Hazard 7 and 8 Coal seams. A power shovel was used with off-road trucks to remove overburden covering the Hazard 9 seam. The amount of overburden on Hazard 10 warranted the use of only front-end loaders, off-road trucks, and dozers to expose the coal (Conrad, 2002).

From the surface to the base of the Breathitt Formation (Hazard 7), there is about 300 feet of overburden which must be removed to extract the coal seams (Conrad, 2002). The dragline produces the largest spoil pile because of its increased overburden removal capabilities. Trucks are often used to assist in the reclamation process by filling the spaces between the spoil ridges. The final grading and shaping of the spoil material is performed by Caterpillar D11 dozers.

A substitute growing medium consisting of run of mine (rom) gray shale and sandstone between the Hazard Coal 7 and 8 seams was approved in the permit application. All the overburden strata at the site were tested to be equivalent or superior growing media compared with existing soils in the area. Prior to mining, a waiver was granted to the Starfire Mine for removal and stockpiling of the topsoil.

A large amount of the steeply sloping ridge and valley land has been altered to rolling hills. The land use has been modified from forestlands to a mixture of forestland, pastureland, and wildlife habitat (Conrad, 2002).

Peabody Energy is responsible for the mining and the reclamation processes at the Gibraltar Mine in Muhlenburg County. They have been honored with many reclamation awards for improving reforestation, improved fish and wildlife habitats, and productive cropland and pastureland at the Gibraltar Mine. The topography at the Gibraltar Mine in western Kentucky is generally flat to slightly rolling.

The last permit on the Gibraltar Mine produced 2.8 million raw tons of coal. The mineable seams in the area include from base to surface, Western Kentucky #11, Western Kentucky #12, Western Kentucky #13, and Western Kentucky #14. Production of the mine ceased in 2003 and the land was permitted for multiple reclamation uses including prime farmland, cropland, fish and wildlife, and pasture land.

Quickly after the implementation of SMCRA, it became apparent to some onlookers that excessive compaction was a more serious problem for establishing forest lands than ever imagined. In 1983, a thirteen acre site on the Gibraltar Mine was selected to undergo compaction alleviation (ripping) methods on compacted surface-mined land. It was concluded that ripping increased the survival of trees and greatly increased the initial growth (Williamson, no date).

In 2007, in addition to recording measurements at the Starfire Mine to compare loose-dumped, struck-off, and compacted reclamation methods, a virgin site was also chosen to record baseline data. A test location was selected near the Bethel Forestry Research Camp in eastern Kentucky. The approximate coordinates of the test location are 37°28’51.04” N and 83°07’44.48” W. This location is known as the *Bucklick*

Demonstration Area. It is located near the Breathitt and Knott county line. This area was established in 1968 and has been used to determine the effect of tree stalk diameter and vegetation control treatments on tree species. This area contains well-stocked oak, yellow popular, and red maple species that are used for training in tree and forest measurements (Anon., 2007h). Figure 4.1.2 shows the approximate location of the Bucklick Demonstration Area where readings were conducted on undisturbed land.

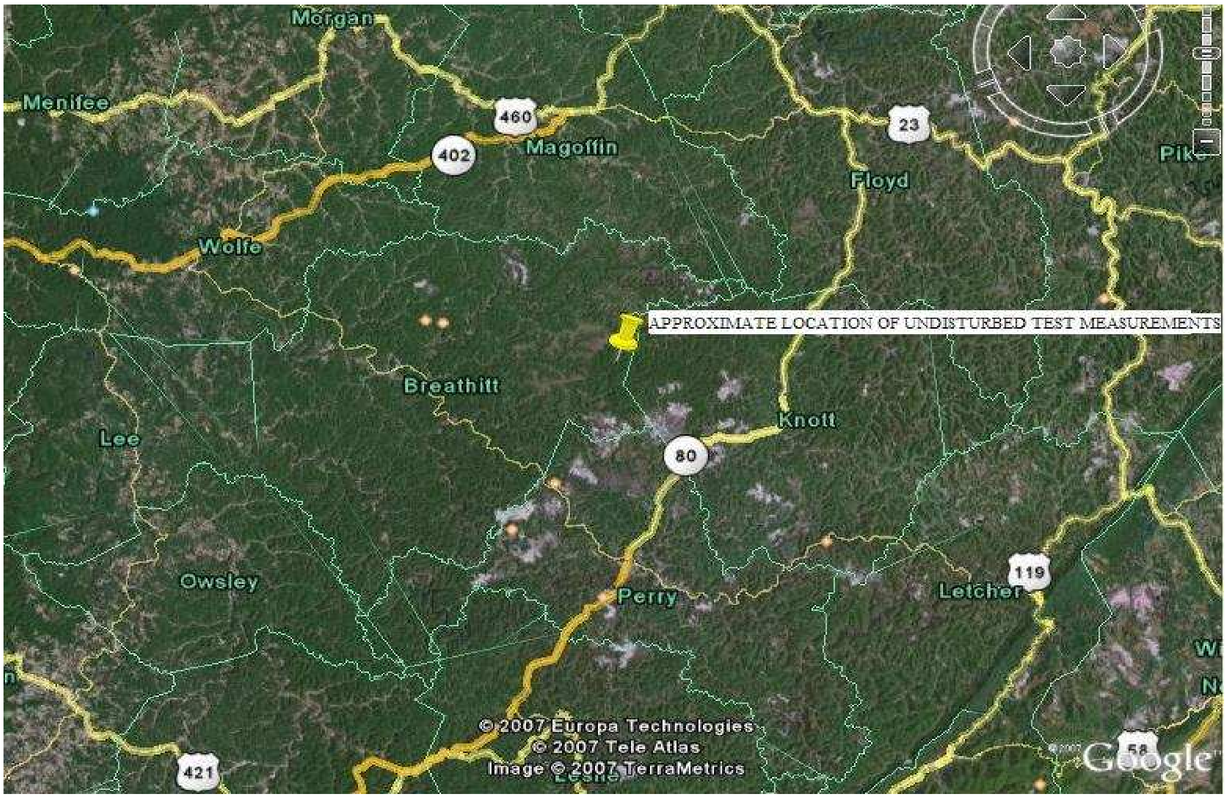

Figure 4.1.2 Location of the undisturbed test plot tested in the summer of 2007 at the Starfire Mine.

4.2 Site Layout and Design

There are fifteen test cells located at the Starfire Mine. Each cell is approximately 2.5 acres in size. Three cells for each of five different reclamation methods were constructed for analysis. The reclamation methods evaluated include compacted, struck-off (rough-graded), loose-dumped (uncompacted), tractor-ripped, and dozer-ripped. The tractor and dozer-ripped methods represent soil alleviation methods on previously compacted surface-mined land and were not planted until 1999. Reports have indicated that ripping previously compacted surface-mined lands using a single shaft or agricultural tillage practices greatly enhanced the ability to establish trees (Williamson, no date).

The bulk of the testing and analysis concentrates on the first three methods. The compacted cells were designed to represent the reclamation method practiced by the Starfire Mine to comply with the perceived requirements of PL 95-87. The compacted cells serve as control cells for this study (Conrad, 2002). A newly constructed compacted cell is shown in figure 4.2.1. The growing medium for the struck-off method was directly placed into position by a truck or dragline. A dozer pushed off the top of the spoil piles to moderately flatten the terrain. The dozers were limited to only one or two passes to grade the spoil material. No soil was placed on top of the spoil material in these cells. Figure 4.2.2 shows a struck-off cell located at the Starfire Mine. The struck-off method complies with RAM #124. This single dozer pass will limit the compaction of the spoil. This was viewed as an alternative reclamation method to balance the difference between compaction and loose-dumped. The growing medium on the loose-dumped cells was constructed by dumping the spoil directly from a haultruck. No grading was performed by a dozer on these cells. A newly constructed loose-dumped cell located at the Starfire Mine is shown in figure 4.2.3.

Figure 4.2.1 A newly constructed compacted reclamation plot at the Starfire Mine planted in 1996. (Conrad, 2002)

Figure 4.2.2 A newly constructed struck-off reclamation plot at the Starfire Mine planted in 1996. (Conrad, 2002)

Figure 4.2.3 A newly constructed loose-dumped reclamation plot at the Starfire Mine planted in 1996. (Conrad, 2002)

All research cells at the Starfire Mine were divided into 21 growth plots measuring approximately 4500 ft^2. There were 121 trees planted in each growth plot on a 6-ft. by 6-ft. spacing. Each growth plot contained a single tree specie. Seven tree species with economic value were repeated on three plots in each cell. There are two access roads separating the repeated plots into columns. The planted species include: eastern white pine (Pinus strobus), white ash (Fraxinus americana), black walnut (Juglans nigra), yellow poplar (Liridendron tulipfera), royal paulownia (Paulownia tormentosa), white oak (Queercus alba), and northern red oak (Quercus rubra) (True, 2005).

The intent of the 6-ft. by 6-ft. spacing was to leave enough room for mature tree growth. Tractor accessibility was not a concern because the plots were specifically designed to allow access from the road to the cells, for the penetrometer at the rear of the tractor to record data. The access roads were excessively compacted and are only for tractor access, therefore, no data analysis is performed on them. A typical layout of this design is shown in figure 4.2.4. This figure is not to scale, but shows a general plot layout divided into cells.

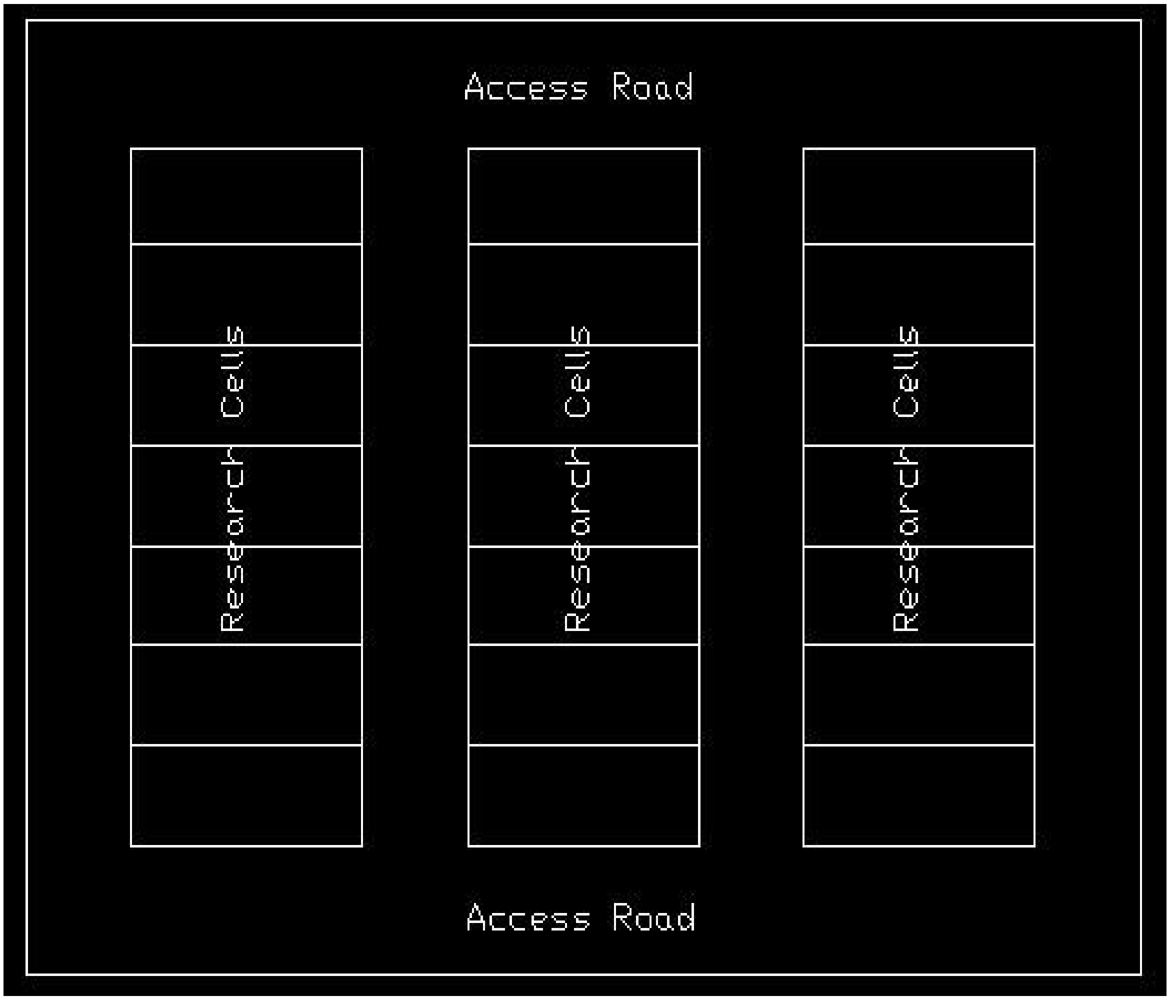

Figure 4.2.4 Typical layout of a plot with access roads at the Starfire Mine.

4.3 Data Collection

For nearly a decade, the University of Kentucky Mining Engineering Department has gathered data to examine certain physical soil properties of the growing medium of reclaimed surface-mined lands at the Starfire Mine. The data obtained include: dry bulk density, moisture content, maximum penetration depth, and penetration resistance.

The dry bulk density of the soil is collected using a Campbell-Pacific Nuclear (CPN) Inc. dual-probe nuclear density gauge (Sweigard and Bluestein, 1996). This gauge is shown in figure 4.3.1. At the Starfire Mine, density and static cone penetrometer readings were taken in the same holes. This was performed to minimize variations in dry bulk density values typically reported in soil compaction studies

(Graves, et al., 1995). Bulk density and moisture content values were recorded at 2 inches (5 cm), 6 inches (15 cm), and 12 inches (30 cm) depths whenever these penetration depths were achievable. The probe did not penetrate to the maximum depth every time so the bulk density data were only taken for the intervals available in that specific test hole. The bulk density data were not adjusted for rocks existing in the growing medium.

Figure 4.3.1 The Campbell-Pacific Nuclear (CPN) Inc. dual-probe nuclear density gauge used to record density measurements at the Starfire and Gibraltar Mines.

Proper equipment knowledge is essential for a successful study. Although two nuclear density gauges were available, they were not used on the same cell because they work on slightly different mechanics. The dual probe gauge sends nuclear signals from one rod tip to the other at the measuring depth. Signals are retarded if a dense medium is encountered. This gauge measures the average value existing in the soil strata at the located depth.

The holes for the dual gauge penetrometer are created using the static cone penetrometer mounted on the rear of a tractor. The rod closest to the driver-seat only penetrates the ground to provide a hole for measuring bulk density values with the dual probe gauge. The rod closest to the workstation is attached to the load cell and used to determine soil resistance values. The test holes for the Troxler nuclear density gauge are manually driven into the ground using a sledge hammer and 20 inch rod.

Penetration resistance was measured by a 2000 lbs. load cell and probe, connected to the computer. The ASAE standard 30° cone with one square inch cross sectional area at the base was used to record the soil resistance values. The penetration depth was measured using a displacement transducer. The maximum penetration depth was established when the probe could no longer penetrate the medium or when the maximum length of the 16 inch rod was reached (True, 2005). The Biopac Student Lab PRO computer software was used in conjunction with MP30 hardware to record the measured values for both penetration resistance and penetration depth. This method was used for the static cone penetrometer (SCP).

The test method for measuring maximum penetration depth and soil resistance using the dynamic cone penetrometer (DCP) varies compared to the SCP. The hammer weight was lifted and dropped repeatedly until 4 inch (10 cm) incremental depths were achieved. The number of hammer drops required to reach that depth was recorded. If the DCP was unable to penetrate the ground beyond a certain depth, that depth was recorded along with the number of blows to reach the maximum depth. The number of blows required was placed into the empirical Dutch Formula previously described, to obtain the soil resistance encountered.

At Starfire, the data were collected similarly in each of the reclamation plots. It is important to emphasize that there were a total of 28 readings taken from each test plot. Recall from figure 4.2.4 that the plots are divided into 21 cells. There are three columns of seven cells in each column, separated by access roads. These plots were designed to allow tractor access to the mine spoil from the interior access roads. The SCP is designed so the rod will extend beyond the road as the tractor is moved into position allowing measurements to be taken in the reclaimed spoil rather than the access road. A reading is taken on each side of the interior access road in each cell. The same pattern is followed in the other interior access road. This process accounts for a total of 28 measurements in each plot.

The bulk density, soil resistance, and maximum penetration depth are averaged for each plot tested. There are three replications of the loose-dumped, struck-off, and compacted reclamation methods at the Starfire Mine. A total of 84 measurements were recorded for each reclamation method. The results are displayed in the succeeding chapter both as a summary from each plot and a summary from each reclamation method. The measurements were taken using randomized systematic sampling techniques to reduce bias in measurements. Figure 4.3.2 illustrates the various types of sample techniques.

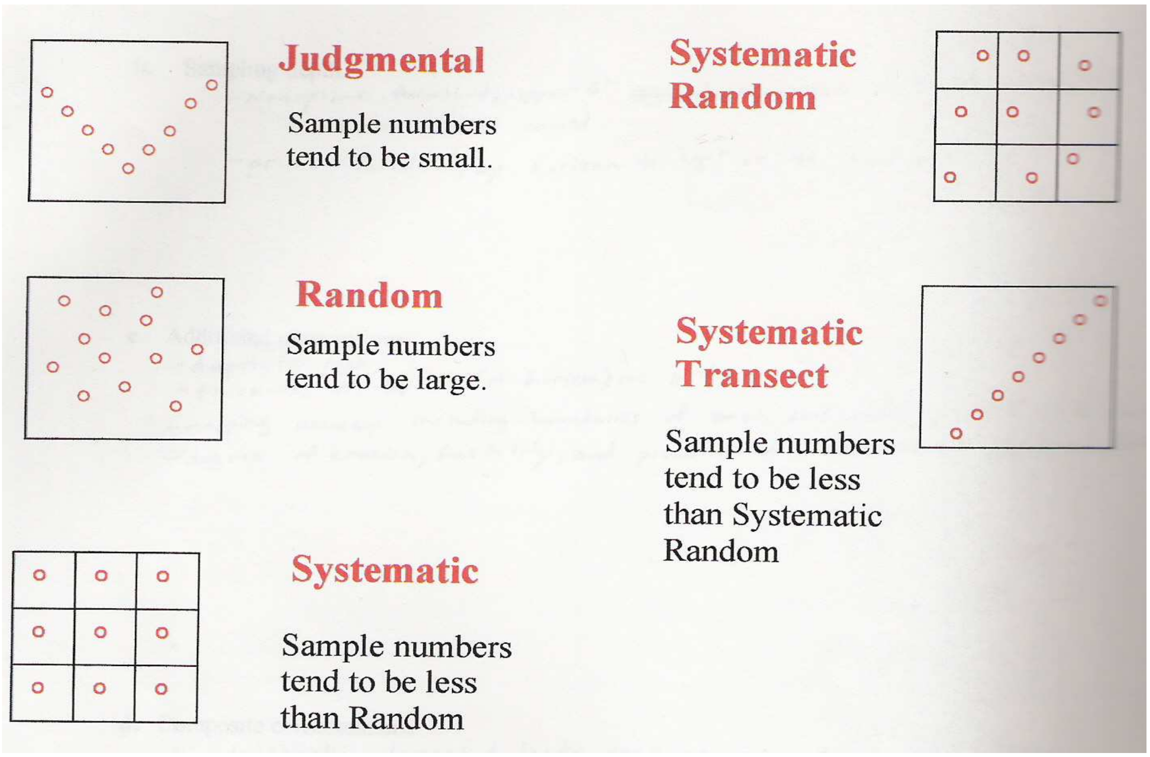

Figure 4.3.2 Various types of sampling techniques used to analysis statistical data. (Barnhisel, 2005)

In 2005, a dozer-ripped plot at the Starfire Mine was compared with a dozer-ripped plot located at the Gibraltar Mine using the DCP. The soil resistance and the maximum penetration depth were measured using both the DCP and the SCP. At the Gibraltar Mine, the SCP and the CPN gauge were originally used to record the corresponding soil parameters in 2005. There were only 16 measurements recorded with these two devices because of reduced plot area compared to the plot sizes at the Starfire Mine. During the initial testing stage to compare the DCP with the SCP, 50 measurements were taken rather than the normal 28 in each of the plots. Results are provided in the following chapter. Measurements were made first by the SCP and later that summer, 50 measurements were recorded using the DCP. The measurements were not recorded on a side-by-side basis.

In 2006, measurements were recorded for maximum penetration depth and soil resistance using both penetrometers at the Starfire Mine in all plots representing the loose-dumped, struck-off, and compacted reclamation methods. During that field season measurements were initially conducted using the SCP and a few weeks later, the measurements were conducted using the DCP. That year, the normal 28 measurements were made with each penetrometer, but no attempt was made to take the SCP and DCP measurements at the same location within each plot. Results were believed to have been somewhat skewed as a result of this sampling method. Graves, et. al (2005), says side-by-side comparisons yield more applicable results. The rock strata throughout the growing medium vary significantly. Since the measurements were not conducted on a side-by-side basis, there is a possibility that the sampling procedure contributed to the variability of the results.

In 2007, there were a few minor changes in the data collection process. The SCP and the DCP measurements were made utilizing side-by-side comparisons. This procedure was adopted in hopes of eliminating any bias which may have otherwise resulted from using systematic random sampling at different time periods with each of the penetrometers. All the measurements were conducted using a side-by-side comparison with the SCP and the DCP. The measurements were taken no more than six inches apart from each other to minimize the variability of encountering refusal for a portion of the readings with different devices.

In the previous field season, it may have been possible to encounter refusal while testing one device which would not necessarily be experienced by the other device. Also, this season was the first time any baseline data were collected from undisturbed land in this region. Data have been collected on various reclamation methods for nearly a decade using the SCP, but adequate access with the tractor had limited researchers' ability to obtain any baseline data on undisturbed land. There were 50 measurements taken with both penetrometers on the undisturbed land. The results from this site are compared with each of the reclamation methods in the next chapter.

CHAPTER FIVE

ANALYSIS AND INTERPRETATION OF DATA

5.1 Results and Interpretations

The DCP and the SCP were tested on several reclamation plots to compare the results obtained from various types of reclamation methods used on surface-mined land throughout eastern and western Kentucky. Dozer-ripped, compacted, loose-dumped, struck-off and undisturbed land were all tested using these two penetrometers. The penetrometers were used to measure the maximum penetration depth and soil resistance values associated with the various reclamation methods. These data were collected from 2005 to 2007.

The SCP has been used to measure soil resistance and maximum penetration depth values for the past decade at the Starfire test plots. The load cell measures the load applied per square inch of a cross-sectional cone area. The displacement transducer provides a penetration depth value for the applied load. The Biopac Software has been very beneficial in this process. The soil resistance is determined as the load being applied on a cross-sectional area.

In the subsequent field seasons of 2006 and 2007, the field work was confined to the Starfire Mine because the type of comparison being conducted was more meaningful for the conditions encountered at that mine. The complete set of depth of penetration to refusal measured using both the SCP and DCP are given in Appendix A. The soil resistance values measured by the SCP are located in Appendix B and the soil resistance values obtained with the DCP are in Appendix C.

5.2 Starfire Mine and Gibraltar Mine

In the summer of 2005, initial tests were conducted to compare the maximum penetration depth using the SCP and DCP in two locations for initial comparison purposes. There was one dozer-ripped plot selected at the Peabody Energy Gibraltar

Mine near Central City, Kentucky. The other plot selected was a dozer-ripped cell at the Starfire Mine near Hazard. These two cells were evaluated to determine if the DCP was appropriate for evaluating compaction at those locations.

5.2.1 Maximum Penetration Depth

The summer of 2005 was the first year tests were conducted in field conditions using the DCP. Measurements were made at the Starfire Mine and the Gibraltor Mine. Time constraints limited further analysis and testing methods using the DCP during the first field season. However, the SCP was also used at both locations for comparative purposes. The 165-ft. by 165-ft. (50-m by 50-m) plots were staked out prior to conducting field measurements. Measurements were taken on a dozer-ripped plot at each location. The maximum penetration depth resulting from the fifty random measurements taken in each plot are shown in table 5.2.1.1. The maximum penetration depths were only evaluated to a depth of 16 inches (40 cm). Therefore, if refusal was not encountered by the penetrometer prior to that depth, then 16 inches was recorded as the maximum penetration depth for that measurement.

Table 5.2.1.1: Penetration depth measured at the Starfire and Gibraltar Mines using the DCP and the SCP in 2005.

Soil Penetration Depth to Refusal (Maximum is – 16 in. – 40 cm)				
Location	**Static Cone Penetrometer**		**Dynamic Cone Penetrometer**	
	(in)	**(cm)**	**(in)**	**(cm)**
Starfire	13.2	33.5	14.6	37.1
Gibraltar	16.0	40.0	16.0	40.0

Every measurement at the Gibraltar Mine achieved the maximum penetration depth and was deemed unsuccessful in determining the penetration refusal in the first 16 inches of the growing medium. This site contained quite a bit of clayey soils near the surface with few large boulders. Therefore, neither device was useful for evaluating the maximum penetration depth at this site and the field work concentrated on the Starfire Mine in subsequent summers.

The SCP and DCP measurements were not taken side-by-side. The SCP values were measured a few months prior to obtaining the DCP measurements. The average maximum penetration depth measured at the Starfire plot using the SCP was 13.2 inches. The penetration depth achieved using the DCP was 14.6 inches. Nearly 1.4 inches more penetration was measured using the DCP. In this preliminary test, the DCP yielded a 10 % increase in maximum penetration depth compared to the SCP. The SCP is only capable of applying a 2000 lb/in.^{2} pressure compared to 3120 lb/in.^{2} produced by the DCP. Many measurements were only capable of penetrating the soil to a depth of 8 inches (20 cm) or less using the SCP. The difference in pressure capabilities between the two devices likely impacts the measured refusal depths even though the mechanics of penetration is different in both cases.

In 2006, readings were taken at the Starfire Mine using both the SCP and the DCP to determine the maximum penetration depth. Table 5.2.1.2 summarizes the data from the second field season measured at the Starfire Mine in each individual test plot. This season, the reclamation plots tested were different than those used in 2005. The comparison between the SCP and DCP focused on the struck-off, loose-dumped, and compacted reclamation plots because they had previously exhibited the greatest differences in maximum penetration depths.

Table 5.2.1.2: Maximum penetration depths measured on the struck-off, loose-dumped, and compacted plots at the Starfire Mine in 2006.

	Reclamation		Depth (in)	
Plot #	Method	Planted	SCP	DCP
1	Struck-off	97	13.4	15.0
2	Loose-dumped	97	14.1	14.8
3	Loose-dumped	97	14.6	14.9
4	Loose-dumped	97	13.7	14.6
5	Struck-off	97	11.5	13.7
6	Struck-off	97	14.3	15.1
7	Compacted	96	14.1	15.2
8	Compacted	96	13.1	14.3
9	Compacted	97	14.3	14.2

The data comparing reclamation methods are very similar within test plots with the exception of plot 5. Plot 5 demonstrates significant variability in maximum penetration depth compared to the other plots of the same treatment. Nearly a 2 inch (5 cm) decrease in refusal depth was recorded in this plot compared to any other plot where the SCP was used. A significant decrease in maximum penetration depth is also noticed when using the DCP. Both measurement devices recorded less penetration depth in this plot than the other plots tested. The reason for the decreased depth is believed to be related to the growing medium itself. Due to the tree spacing and survival success, the tractor is extremely limited in its mobility in this plot possibly affecting the representative nature of the test locations. These plots have high survival rates, but the stocks are not nearly as well developed as those on the loose-dumped plots. Excluding plot 5, the penetration depths measured by the SCP range from 13.1 to 14.6 inches and the maximum penetration depths measured by the DCP ranges from 14.2 to 15.1 inches.

Table 5.2.1.3 displays the average refusal depths for each reclamation method and the difference in maximum penetration depths using both measuring devices. The difference column from table 5.2.1.3 is the most significant factor. It is apparent that the numbers in the table vary slightly using each penetration device. The difference in penetration depth using the DCP was at least 0.7 inch greater than that measured using the SCP for all three reclamation methods tested. These values lead to an expected percentage increase of 5.5 % in the loose-dumped plots and 5 % in the compacted plots when measured by the DCP. The struck-off method actually yielded just over twice that with 1.5 inches of increased penetration depth. This is approximately 10.5 % greater than penetration depth achieved with the SCP and is extremely close to the percentage of increased penetration depth measured in dozer-ripped plot the previous year. However, this high deviation for the struck-off method may have occurred because of the discrepancy noted in plot 5. If plots 1 and 6 only were used to represent the struck-off method, the difference in penetration depth would also be 0.7 inch. This result leads to the assumption that some error was introduced in plot 5.

Table 5.2.1.3: Maximum penetration depth measured at the Starfire Mine in 2006.

Reclamation	SCP		DCP		Difference	
Method	(in)	(cm)	(in)	(cm)	(in)	(cm)
Loose-dumped	14.1	35.8	14.8	37.6	0.7	1.7
Struck-off	13.0	33.1	14.6	37.1	1.5	3.9
Compacted	13.8	35.2	14.6	37.0	0.7	1.8

Figure 5.2.1.1 below is a bar graph illustrating the difference in penetration depth reported in table 5.2.1.3. The figure does include the data from plot 5. The conclusion from this data gathered at the Starfire Mine in the summer of 2006 is the DCP will yield a

penetration refusal depth of at least 14.6 inches in compacted, struck-off, and loose-dumped reclamation methods. The DCP is not expected to yield maximum penetration depths in excess of 15 inches for any of the spoil conditions at the site. The SCP may only penetrate the soil 13.0 inches in the struck-off method. The maximum penetration depth is expected to increase to around 14 inches in both the compacted and loose-dumped reclamation methods. The SCP is not expected to penetrate any reclamation method tested much over 14 inches and the DCP regularly produces maximum penetration depths that range 5 % - 10 % greater than those produced by the SCP.

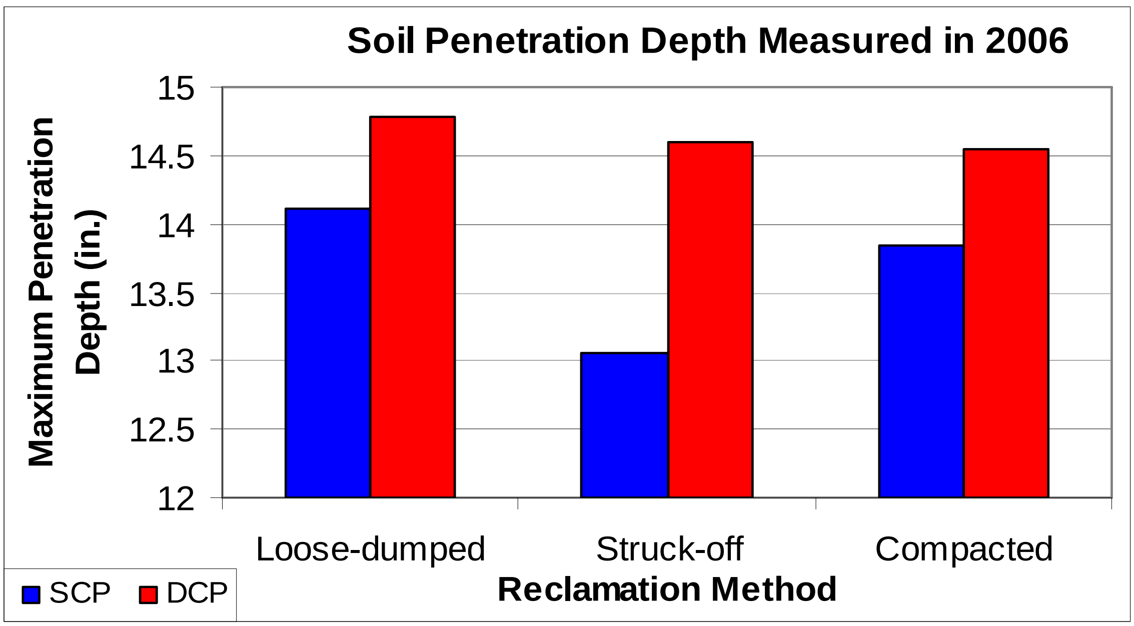

Figure 5.2.1.1: Maximum penetration depth collected at the Starfire Mine in 2006 using both the SCP and the DCP.

Not surprisingly, the maximum penetration depth using both devices is obtained from the loose-dumped plots. Surprisingly, the compacted plots yield penetration depths extremely close to the struck-off method using the DCP. The most surprising result is that the SCP yielded a greater penetration depth for the compacted plots compared to the struck-off plots. This may be explained by the fact that a D-11 dozer was used on both the struck-off and compacted plots. Although only one pass was made using the dozer on the struck-off, compared to at least four passes on the compacted cells, the surface pressure on that single path was still high due to the dozer size. A smaller dozer may prove to yield far different results of maximum penetration depths as a result of decreased surface pressure.

It may be concluded that the impact of compaction is noticed more during the initial few years following reclamation. After that, its impact may become minimal due to weathering, root penetration, and other biological activity. The change in spoil characteristics over time is the subject of another study currently being concluded by the project investigators.

In 2007, the maximum penetration depths of an undisturbed location were also analyzed. Table 5.2.1.4 compares the maximum penetration depths recorded at the Starfire Mine measured on loose-dumped, struck-off, compacted, and undisturbed land in the summer of 2007 using both the DCP and the SCP. The undisturbed test plot recorded nearly identical values for maximum penetration depth for both the SCP and the DCP. The maximum penetration depth was recorded to be just less than 16 inches. The average maximum penetration depth using the DCP was 15.8 inches (39.5 cm) and the average maximum penetration depth using the SCP was 15.9 inches (39.75 cm).

The values for the 2007 data by reclamation method and the differences between the SCP and DCP measurements are listed in table 5.2.1.5. The maximum depths measured in the loose-dumped plots were very close to that measured in the undisturbed location. The maximum penetration depth was 15.1 inches (37.75 cm) with the DCP and 14.7 inches (36.75 cm) with the SCP measured in the three loose-dumped plots. The DCP was able to achieve a maximum penetration depth within an inch of that measured by the same device on the undisturbed plot. The SCP had similar success recording slightly more than one inch difference between the undisturbed and loose-dumped plot. These results support the assumption that the loose-dumped reclamation method most closely reproduces the characteristics of natural land. There is no tree survival and growth characteristics data available from this undisturbed site; however, there have been numerous articles published illustrating the increased growth and survival of valuable hardwoods planted in loose-dumped spoil compared to compacted soil (Burger, 1988 and Conrad, 2002).

The maximum penetration depth measured by the SCP in the three struck-off plots was 11.4 inches (28.5 cm) and the average maximum penetration depth recorded using the DCP depth was 13.9 inches (34.75 cm). The least average penetration depth was recorded in the compacted plots in 2007. It should be noted that this year was a very dry field season. It was the first year since 2005 that there was no water standing in the compacted plots when data were collected. This may have some effect on the decreased penetration depth measured in the compacted and struck-off plots. The measured penetration depth on the compacted plots were 10.3 inches (25.75 cm) and 10.2 inches (25.5 cm) using the SCP and the DCP, respectively.

Table 5.2.1.4: Maximum penetration depths measured on the struck-off, loose-dumped, and compacted plots at the Starfire Mine in 2007.

	Reclamation		Depth (in)	
Plot #	Method	Planted	SCP	DCP
1	Struck-off	97	14.7	15.0
2	Loose-dumped	97	14.8	15.0
3	Loose-dumped	97	15.0	15.3
4	Loose-dumped	97	14.2	14.8
5	Struck-off	97	10.1	12.4
6	Struck-off	97	9.5	14.4
7	Compacted	96	10.6	10.2
8	Compacted	96	10.7	10.3
9	Compacted	97	9.7	10.3
0	Undisturbed	-	15.9	15.8

The 2007 maximum penetration depths follow the expected trend better than that recorded in 2006. In 2006, the greatest penetration depth was measured in the loose-dumped plots, followed by the compacted plots, and the lowest depth was recorded in the struck-off method. However, unlike the results from the previous year, nearly identical penetration depths were measured using the DCP in the struck-off and the loose-dumped reclamation methods. In the previous year the DCP yielded maximum penetration depths that were 5 – 10 % greater than those values obtained with the SCP. One possible reason is that much more care was exercised to make sure the measurements were taken on a true side-by-side basis. The maximum penetration depths recorded in both the struck-off and compacted plots differ dramatically from those recorded in 2006 with the SCP. The SCP does not appear to be as consistent as the DCP in comparing maximum penetration depth measurements for different reclamation methods from year to year.

In the previous season, the maximum penetration depths measured in these plots were 0.7 to 1.5 inches greater when using the DCP compared to the SCP. This trend was not seen in 2007. The undisturbed and loose-dumped plots had nearly identical maximum penetration depths using both devices. There was a slight increase in the deviation between these two devices in the loose-dumped plots which had a 0.4 inch (1 cm) increase using the DCP. This is an increase of nearly approximately 3 % (compared to 5 % in 2006) in maximum penetration depth using the DCP in 2007. In 2006, there was an increased penetration depth of 0.7 inch (1.75 cm) measured in the loose-dumped plots which is nearly double the difference measured in 2007, but it is still comparable. The struck-off method displayed the largest discrepancy in average maximum penetration depth which increased by 2.5 inches (6.25 cm) when using the DCP. This is nearly an 18 % increase (increasing from 10.5 % in 2006) in maximum penetration depth using the DCP in 2007. This was nearly an additional inch of increased penetration depth difference from 2006. However, the maximum penetration depth actually decreased from 14.6 inches (36.5 cm) in 2006 to 13.9 inches (34.75 cm) in 2007 using the DCP. The greater deviation in maximum penetration depth between the two devices for the struck-off plots may be an indication of the greater variability in compaction created by that reclamation method and the difficulty in accessing representative sites for measurements.

Table 5.2.1.5: Maximum penetration depth measured at the Starfire Mine in 2007 using the DCP and SCP.

Reclamation	Static		Dynamic		Difference	
Method	(in)	(cm)	(in)	(cm)	(in)	(cm)
Loose-dumped	14.7	36.7	15.1	37.6	0.4	1.0
Struck-off	11.4	28.6	13.9	34.8	2.5	6.3
Compacted	10.3	25.8	10.2	25.6	-0.1	-0.3
Undisturbed	15.9	39.8	15.8	39.5	-0.1	-0.3

The SCP actually recorded a 0.1 inch increase in average penetration depth in the compacted plot and the undisturbed land. These were the only two test locations in which the average penetration depth was greater using the SCP. However, this value accounts for less than 1 % difference compared to the entire penetration depth and is not considered significant. The maximum penetration depths are nearly identical in any event. However, the compacted plots did not have increased penetration depth using the DCP in 2007 compared to the values measured with the SCP. In 2006 the compacted plots exhibited nearly 5 % increase.

The 2007 data seems better suited for true comparison of these two devices since it was collected using side-by-side comparisons with the SCP and the DCP. The maximum penetration depth measured in the struck-off method and the compacted methods yielded a significant difference in maximum penetration depth compared to undisturbed lands. It is obvious that the closest replication of maximum penetration depth occurred in the loose-dumped plots. This is the reason for the dramatic increase in tree growth and survival rates in the loose-dumped plots. The maximum penetration depth information displayed in table 5.2.1.5 is shown graphically in figure 5.2.1.2.

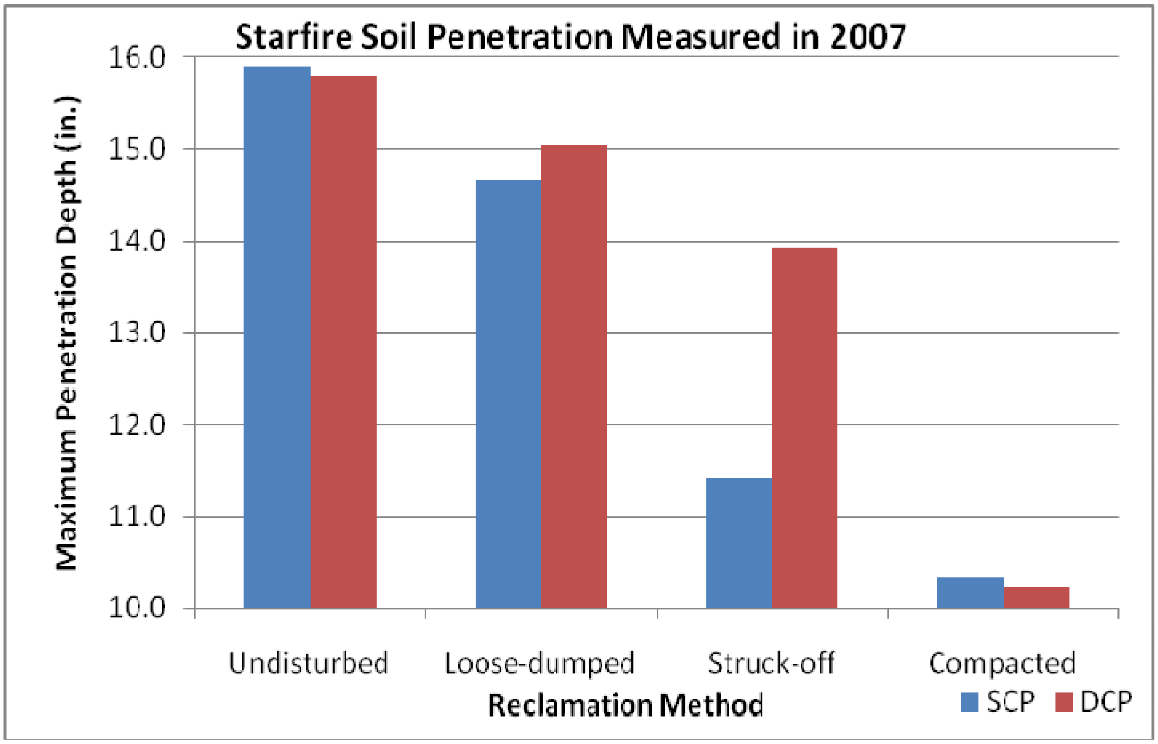

Figure 5.2.1.2: Penetration depth measured at the Starfire Mine in 2007 using both the SCP and the DCP.

The compacted plots display the smallest maximum penetration depth using both penetrometers. The struck-off method exhibits increased maximum penetration depth when the DCP is used. The loose-dumped method displays maximum penetration depth of approximately 15 inches (37.5 cm) with both penetrometers. The undisturbed plot exhibits maximum average penetration depth of nearly16 inches (40 cm), which approaches the penetration limit of the SCP used in this study. The DCP is expected to exhibit an increase in maximum penetration depth of 3-5 % in loose-dumped spoils, 10-18 % in struck-off spoils, 0-5 % in compacted spoils, and 0 % in undisturbed soil. However, it was also observed that the deviation between the SCP and the DCP measurements was reduced when care was taken to ensure the measurements were truly side-by-side. These results are extremely close with the exception of the struck-off method, which may be a greater indicator of the variability in the spoil conditions produced by the reclamation method than the variability caused by the measuring device. It appears that with some moderate adjustments, the DCP is capable of replacing the SCP in evaluating the maximum penetration depth of reclaimed surface-mined lands

5.2.2 Soil Resistance

The soil resistance was also analyzed as a function of depth to determine the relationship between the values measured with both penetrometers. In 2005, data were collected in the dozer-ripped plots located at the Starfire and Gibraltar Mines. The soil resistance was measured at corresponding 4 inch (10 cm) depth increments using the DCP and the SCP. The soil resistance values are shown in table 5.2.2.1. Recall that the maximum penetration depth at Peabody's Gibraltar Mine near Central City was 16 inches using both penetrometers for all 50 test measurements. The maximum penetration depths were identical and the soil resistance values are also nearly identical at this location. Therefore, it was determined in 2005 that due to lack of refusal encountered in the soil, further tests would not be performed at this location. Figure 5.2.2.1 shows how the penetration depth and soil resistance relate to each other at both locations using both penetrometers. The soil resistance measured at the Starfire Mine does not follow the exact same trend as that displayed at the Gibraltar Mine. The soil resistances do increase as the penetration depth increases. In this case, the graph of penetration resistance for the DCP parallels the graph for the SCP except the 16-inch depth where there is a slight reduction in resistance for the DCP.

Table 5.2.2.1: Soil resistance measured at the Starfire and Gibraltar Mines in the summer of 2005 using both penetrometers.

Soil Resistance (psi)					
Device	**Location**	**Incremental Depths**			
		(4 in, 10 cm)	**(8 in, 20 cm)**	**(12 in, 30 cm)**	**(16 in, 40 cm)**
DCP	**Starfire**	339.8	948.5	1467.9	1432.8
	Gibraltar	161.7	261.4	351.1	439.5
SCP	**Starfire**	175.2	567.5	1134.5	1394.0
	Gibraltar	130.9	251.5	339.4	450.4

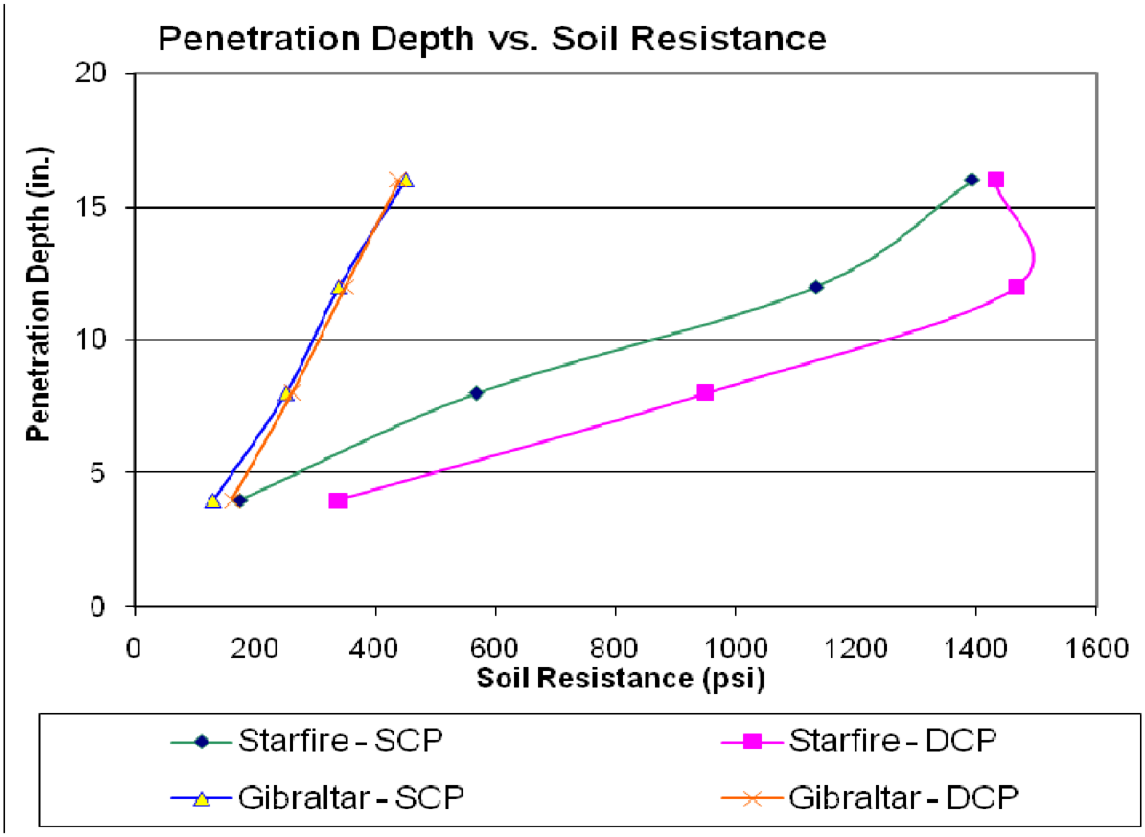

Figure 5.2.2.1: Penetration depth vs. soil resistance at the Starfire Mine collected using both penetrometers in 2005.

In the summer of 2006, the soil resistance values were measured again at the Starfire Mine. Emphasis was placed on the loose-dumped, struck-off and compacted reclaimed plots at this location. Both the SCP and the DCP were used to measure the soil resistance and maximum penetration depths. These measurements were not collected on a side-by-side basis. The increased penetration depth using the DCP has previously been noted. The soil resistances measured by the SCP in all of the three reclamation method were gathered in 2006 and are shown in table 5.2.2.2. Table 5.2.2.3 was also constructed showing similar data measured by the DCP. Figure 5.2.2.2 illustrates the soil resistance at 4 inch incremental penetration depths measured using both penetrometers. Despite the variation between the values measured with the two devices, there is a fairly uniform linear relationship between the two penetrometers. The struck-off method had the greatest soil resistance. Recalling from the maximum soil penetration depth, the SCP yielded the least penetration depth of any reclamation method tested. Nearly identical values for penetration depth were recorded using the DCP.

Table 5.2.2.2: Soil resistance measured at the Starfire Mine in 2006 using the SCP.

Reclamation Method	Soil resistance for incremental depths using Static Cone Penetrometer (psi)			
	(4in, 10cm)	(8in, 20cm)	(12in, 30cm)	(16in, 40cm)
Loose-dumped	103	396	727	956
Struck-off	253	704	1039	1315
Compacted	154	546	887	1093

Table 5.2.2.3: Soil resistance measured at the Starfire Mine in 2006 using the DCP.

Reclamation Method	Soil resistance for incremental depths using Dynamic Cone Penetrometer (psi)			
	(4in, 10cm)	(8in, 20cm)	(12in, 30cm)	(16in, 40cm)
Loose-dumped	153	398	760	1096
Struck-off	407	897	1273	1519
Compacted	215	567	1106	1425

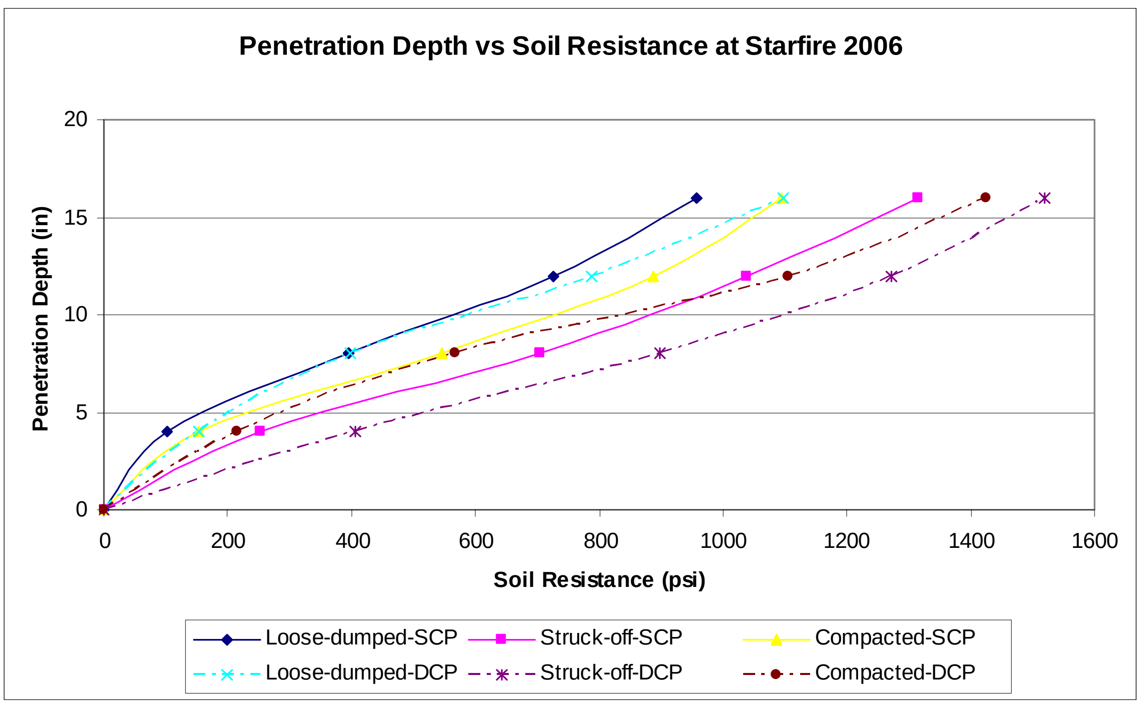

Figure 5.2.2.2: Penetration depth vs. soil resistance at the Starfire Mine collected using both penetrometers in 2006.

The soil resistance as a function of penetration depth was studied at the Starfire Mine again in the summer of 2007 using both penetrometers. The reclamation methods evaluated this summer include loose-dumped, struck-off, compacted, and undisturbed land. This is the first time soil resistance and penetration depth was recorded at an undisturbed location. Recall that there were three replicated plots evaluated for each of the loose-dumped, struck-off, and compacted reclamation methods. The undisturbed data were obtained from a single larger plot.

The soil resistance was measured on a side-by-side basis in 2007. The compacted plots did not have any standing water present when the data were collected this year. The soil resistance increased significantly in 2007 compared to the values measured in 2006 using both penetrometers.

Table 5.2.2.4 displays the average soil resistance at 4 inch (10 cm) incremental depths measured by the SCP for the variously tested reclamation methods located at the Starfire Mine in 2007. The undisturbed land yielded the least amount of measured soil resistance at each of the increments. The next lowest soil resistances were measured in the struck-off plots with the exception of the first 4 inch (10 cm) increment using the SCP. Surprisingly, the soil resistances measured in the loose-dumped plots were the highest measured by the SCP during 2007. These data help to confirm the earlier belief that while the SCP provides a reliable measurement for maximum penetration depth in this type of rocky spoil material, it is not a reliable source of penetration resistance data. Figure 5.2.2.3 illustrates the soil resistance values measured with the SCP.

Table 5.2.2.4: Soil resistance measured at the Starfire Mine in 2007 using the SCP.

Reclamation Method	Soil resistance for incremental depths using Static Cone Penetrometer (psi)			
	(4in, 10cm)	(8in, 20cm)	(12in, 30cm)	(16in, 40cm)
Undisturbed	187	408	548	701
Loose-dumped	314	1271	1715	1663
Struck-off	344	996	1175	1126
Compacted	286	1063	1462	1519

Table 5.2.2.5 displays the average soil resistance at 4 inch (10 cm) incremental depths measured by the DCP at the tested reclamation methods. The undisturbed land yielded the least soil resistance at each of the increments. The soil resistances measured in the loose-dumped plots were somewhat higher than the values measured on the undisturbed land for each depth increment. As expected, the struck-off sites and the compacted sites yielded the next higher penetration resistances, respectively.

Table 5.2.2.5: Soil resistance measured at the Starfire Mine in 2007 using the DCP.

Reclamation Method	Soil resistance for incremental depths using the Dynamic Cone Penetrometer (psi)			
	(4in, 10cm)	(8in, 20cm)	(12in, 30cm)	(16in, 40cm)
Undisturbed	200	418	634	782
Loose-dumped	372	817	1173	1594
Struck-off	408	1332	1928	2404
Compacted	604	1932	2852	3070

Figure 5.2.2.4 illustrates the soil resistances measured using the DCP at the Starfire Mine. The soil resistances displayed in this figure confirm the conclusions drawn from maximum penetration depth to refusal data at this location. The soil resistances measured in the loose-dumped plots are very close to that measured in the undisturbed plots. The values for soil resistance have a greater deviation between reclamation methods. As previously noted, the portable DCP evaluated in this study could serve as a suitable replacement for the SCP, and it seems to be a more suitable device for measuring both soil resistance and penetration depth on reclaimed surface-mined lands that consist primarily of rocky spoil material.

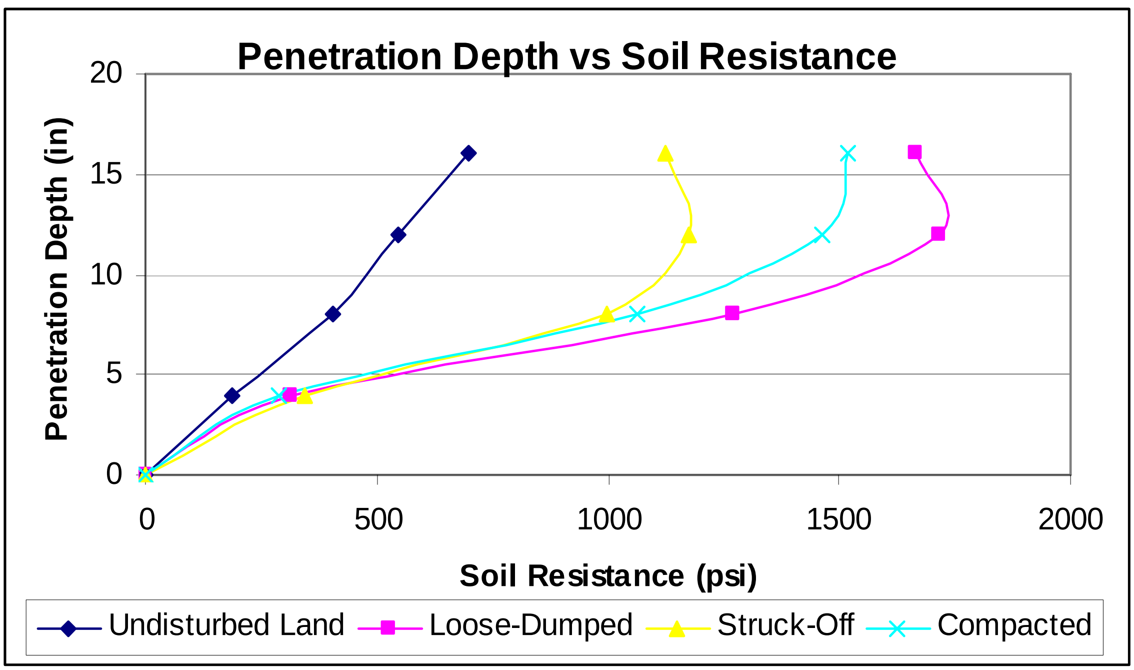

Figure 5.2.2.3: Penetration depth vs. soil resistance at the Starfire Mine collected using the SCP in 2007.

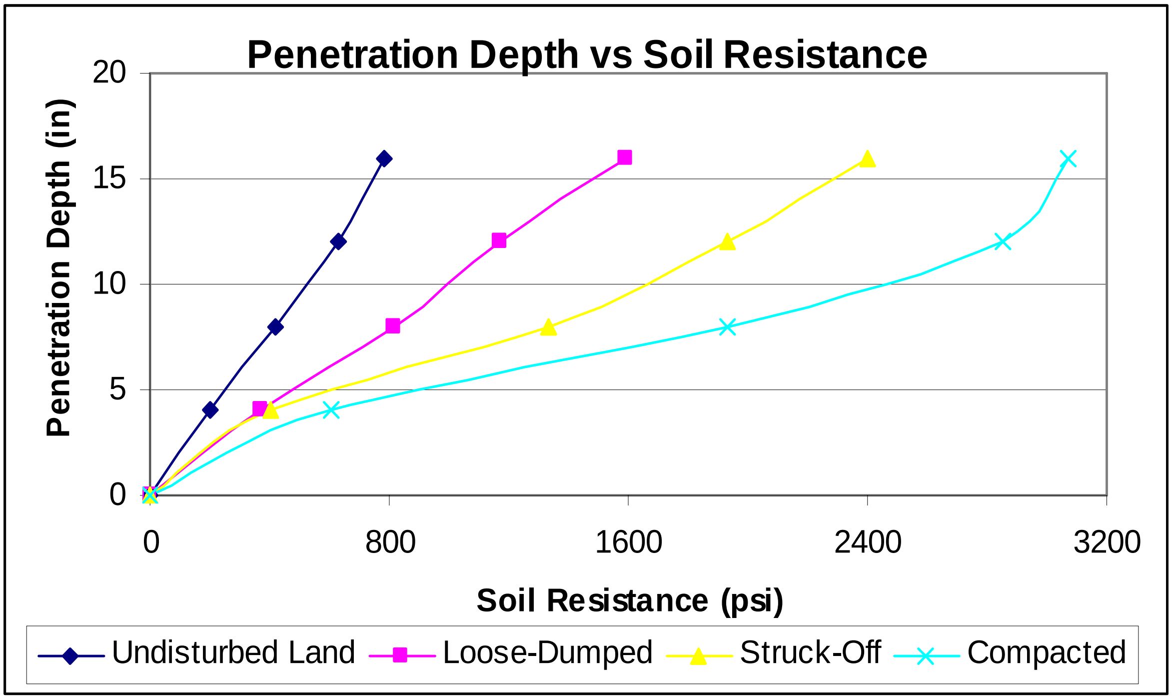

Figure 5.2.2.4: Penetration depth vs. soil resistance at the Starfire Mine collected using the DCP in 2007.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 Summary

The field investigation encompassed portions of three summers. The first field work was performed in the latter part of the summer of 2005. These preliminary tests were conducted on dozer-ripped sites at two locations: the Starfire Mine in eastern Kentucky and the Gibraltar Mine in western Kentucky. The Starfire Mine is characterized by rocky spoil consisting of a mixture of sandstone and shale. The surface material at the Gibraltar Mine consists of a clayey soil that is relatively free of large rocks. Maximum penetration depth and soil penetration resistance were measured using both the SCP and DCP.

The soil penetration resistance values measured at the Gibraltar Mine were very similar using both the SCP and DCP. The relationship between soil penetration resistance for the two devices was nearly linear at the Starfire site. However, the DCP measured approximately 300 psi more, except at the deepest interval. The maximum penetration depth achieved at the Starfire Mine with the DCP was 1.4 inches (10 %) greater than that measured with the SCP. However, at the Gibraltar Mine, the maximum penetration depth with both devices exceeded 16 inches, which is the measurement limit of the SCP. The preliminary results obtained with DCP on rocky spoil for both refusal depth and soil penetration resistance were encouraging. However, the comparison between the two devices on clayey mine spoil did not prove useful for refusal depth. Therefore, the remainder of the field effort focused on rocky run-of-mine spoil in eastern Kentucky.

The second field season utilized the reclamation cells at the Starfire Mine. The compacted, struck-off, and loose-dumped sites that were created as part of the earlier reforestation work were tested using both the SCP and DCP. Again, the refusal depth and soil penetration resistance were evaluated on each of the plots. The measurements were not taken on a side-by-side basis because there was a time lag between the application of the SCP and the DCP. Previous research has indicated that maximum penetration depth is a more useful parameter than soil penetration resistance for determining the suitability of rocky spoil to support trees but both measurements were made for the purpose of evaluating the DCP.

All three reclamation methods yielded greater refusal depths with the DCP compared to the SCP. On the compacted and loose-dumped sites, the additional penetration depth obtained with the DCP was 0.7 inch (approximately 5 %). On the struck-off site the additional depth was 1.5 inches or 10.5 %. More disconcerting, however, is that the total maximum refusal depth on the struck-off sites was considerably less than either the loose-dumped or compacted sites when measured with the SCP. This contradicted previous work at this site measured using the SCP. The discrepancy was attributed to the fact that the struck-off sites are probably more heterogeneous than the others due to the variable application of dozer pressure and, therefore, is more likely to produce divergent results. The soil penetration resistance measurements taken with the SCP and DCP on the three types of reclamation sites yielded results that are fairly consistent with the maximum penetration depth measurements. In each case, the relationship between the two devices is basically linear and the DCP measured anywhere from 0 % up to 49 % more resistance than the SCP.

The third field season concluded in the summer of 2007. Once again, the investigation focused on the reforestation reclamation plots at the Starfire Mine. Two additional features were included in the final set of measurements. First of all, an undisturbed site in the vicinity of the mine was evaluated for both maximum penetration depth and soil penetration resistance. Finally, care was taken to make sure all SCP and DCP measurements were taken on a side-by-side basis to minimize the impact of site heterogeneity.

In one sense, the maximum penetration depth measurements made in 2007 agreed better with previous studies at the site. The loose-dumped material had the greatest maximum penetration depth of the reclaimed sites; the compacted material had the least and the struck-off material had intermediate values. However, the deviation between the SCP and DCP measurements were less consistent than those measured during the previous field season.

The maximum penetration depths were nearly identical on the compacted and undisturbed test sites measured using both penetrometers. There was an additional 0.4 inch (approximately 3 %) of penetration depth measured with the DCP on the loose-dumped sites this year. This increase is very similar to that measured in the previous summer. This year, the maximum penetration depth increased on the struck-off plots to 2.5 inches or 18 % measured by the DCP. This is a significant increase from the measured penetration depth the previous year. This discovery further supports the belief that the struck-off sites are more heterogeneous due to the variable application of dozer pressure and, therefore, are more difficult to evaluate.

The soil penetration resistance followed the same pattern as the maximum penetration depth measured this year using the DCP. This pattern was not observed when resistance was measured by the SCP and the deviation in soil resistance values was decreased, mainly due to the decrease in the magnitude of those values. The greater deviation in soil resistance measured by the DCP is attributed to the increased instantaneous pressure provided to the tip of the cone resulting from the acceleration of the hammer mass.

The mechanics of the two penetrometers are significantly different. The SCP measured soil resistance delivered to a cone tip at a constant velocity. The constant velocity enables the resistant soil force to equal the total applied force measured. This penetrometer was developed to measure compaction variability on farmland. Side-by-side measurements have yielded much more consistent results with maximum penetration depth and soil resistance measured by the DCP on different reclamation methods. The DCP has also provided more consistent results with previously collected data which directly correlates with what has already been learned, given the different spoil conditions at the site. The DCP seems better suited for measuring both maximum penetration depth and soil resistance on rocky spoil than the SCP.

The DCP is also capable of eliminating the accessibility barrier from the field research. This is important for a number of reasons. For one reason, safe tractor accessibility is not possible for all reclamation locations. Another reason is, as reforestation develops, access is limited due to tree growth. The presence of rubber-tired vehicles also increases the amount of compaction by rearranging the soil skeleton of surface-mined reclaimed lands. These occurrences may be limited by utilizing the DCP studied in this report. The DCP allows the user to measure the maximum penetration depth and soil penetration resistance in nearly any field condition and is capable of conducting measurements in rough terrain, if needed.

The maximum penetration depth and soil penetration resistance have limited variability associated with them when measured by the DCP compared to previous data from various reclamation methods. On average, the increased maximum penetration depth is approximately 5 – 10 % greater for the reclamation methods tested than the values obtained with the SCP.

One major drawback of utilizing the DCP is the amount of physical energy required to conduct a statistically significant number of tests. This DCP was designed so that more than 50 blows per 4 inch increment indicate excessive refusal. The number of blows indicating excessive refusal may deviate when incorporating other DCP designs as the number of hammer strikes per depth increment is capable of exceeding 100 blows per test.

6.2 Recommended Test Procedure

The DCP offers the user a portable option for measuring penetration depth on reclaimed surface mined-lands. A relationship between penetration depth and tree survival on reclaimed surface-mined lands has previously been established. After performing initial test analysis to compare the DCP and the SCP, the following procedure is believed to be the optimal procedure for testing reclaimed surface-mined lands for average refusal depth and bulk density. This test procedure only addresses the minimization of soil compaction and does not address any issues related to the chemical composition of the soil.

1) A manageable area of interest must be staked off. For ease of measurement, a 50-foot by 50-foot square area should be used. This area should be representative of the entire reclaimed area.
2) Refusal depth measurements should be taken along with bulk density measurements because both are reliable soil characteristics of soil compaction.

The standard test procedures specified by the manufacturer of the equipment should be followed carefully.

3) The number of measurements recorded is determined by the reliability required. However, a minimum of 30 refusal depth measurements and 30 bulk density measurements should be made per study area.

4) Using the DCP, if an average refusal depth of 14 inches is achieved, the growing medium should be considered acceptable for reforestation purposes.

5) The soil resistance typically increases as the penetration depth increases. The soil resistance measured with a DCP should be less than 1200 psi at a depth of 12 inches.

6) Bulk density measurements should be made with a nuclear density gauge at depths of 2 inches and 12 inches. The average bulk density at 2 inches should not exceed 98 pcf and the average bulk density at 12 inches should not exceed 113 pcf for reforestation purposes.

6.3 Conclusions

The DCP evaluated in the report serves as an adequate alternative for accessing refusal depth on reclaimed surface-mined land for rocky spoil conditions. The DCP may also produce better results for soil penetration resistance than that measured by the SCP. Past researchers were not able to get good correlation between average penetration resistance and maximum penetration depth due to the presence of rocks in the spoil. The process of measuring the maximum penetration depth is simple, but very labor intensive. The SCP seems better suited to evaluate clayey or loamy soil without rocks present. The presence of rocks in the spoil places excessive limitations on SCP measurements for both penetration refusal and soil resistance. Therefore, the field procedure outlined in this report represents the best current method for evaluating the compaction condition of reclaimed land for reforestation purposes where the surface is not graded smoothly and large rocks are present.

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APPENDIX A

Maximum Penetration Depth Using Both Penetrometers

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 1

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
101		8.24	1790	2543	694
102		10.27	1094	1839	654
103		9.02	1350	2071	669
104		13.66	1035	2352	855
105		16	858	1974	644
106		16	531	1549	515
107		16	1071	1569	466
108		16	942	1661	539
109		8.79	1507	2641	942
110		16	969	1710	612
111		13.33	934	1580	513
112		10.27	462	1325	473
113		16	886	1528	533
114		13.5	1087	2455	886
115		6.05	1465	2549	1034
116		16	781	1634	557
117		13.14	1467	2317	913
118		5	1810	2182	538
119		11.84	1290	1977	735
120		16	732	2093	622
121		13.88	894	2206	754
122		14.04	1243	2012	783
123		11.42	1156	2237	895
124		16	1132	1794	593
125		11.81	1375	2314	652
126		16	960	1490	458
127		15	1310	1969	616
128		16	677	1510	411
Average		**13.0**	**1100**	**1967**	
Std.Dev					

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 2

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
201		16	571	989	279
202		6.5	1303	1899	672
203		16	706	1252	386
204		16	578	1052	306
205		16	380	752	225
206		16	645	1341	286
207		16	350	817	233
208		16	591	961	318
209		16	330	671	133
210		15.2	973	1524	476
211		16	998	1470	444
212		16	521	1064	352
213		16	319	535	130
214		16	299	729	234
215		16	464	928	254
216		16	574	996	325
217		10.96	1108	1695	642
218		16	811	1398	546
219		16	576	1029	328
220		16	472	900	315
221		14.95	865	1422	425
222		16	631	1362	393
223		13.69	1244	1803	643
224		13.44	805	1528	614
225		13.56	948	1709	647
226		16	387	653	200
227		16	713	1403	481
228		12.98	1016	1825	757
Average		**15.0**	**685**	**1204**	
Std.Dev		2.13	289	399	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 3

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
301		16	511	1071	346
302		16	395	792	207
303		14.25	893	1402	378
304		14.71	1144	1846	654
305		16	586	1221	483
306		5.48	1126	1738	576
307		15.2	1084	1753	527
308		16	286	431	112
309		16	157	259	70
310		16	1190	1881	698
311		16	643	1328	439
312		15.76	637	1329	388
313		16	873	1350	440
314		7.34	1009	2160	900
315		15	952	1541	602
316		16	407	713	261
317		16	657	1194	426
318		16	852	1383	415
319		16	244	501	178
320		16	1454	1896	585
321		12.24	1608	2266	851
322		13.16	1130	1950	745
323		15	1180	1998	703
324		5.7	1227	2309	913
325		16	701	1410	478
326		16	601	1158	356
327		8.48	841	1683	493
328		16	1248	1933	507
Average		**14.2**	**844**	**1446**	
Std.Dev		3.28	373	551	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 4

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
401		14.13	995	1404	261
402		13.57	1377	2155	627
403		15.55	1297	2203	581
404		13.56	1476	2341	658
405		12.44	1444	2138	602
406		14.57	1474	1903	557
407		15.66	995	1347	232
408		13.61	1261	2196	597
409		12.44	1437	2461	695
410		13.38	1223	1684	426
411		12.4	1220	1823	511
412		16	1300	1728	417
413		12.6	1630	2494	814
414		14.46	1338	2000	445
415		14.11	1001	1522	308
416		15.02	1439	2094	427
417		16	1265	1688	269
418		11.69	1259	2183	631
419		14.43	1308	1788	450
420		11.76	1381	2126	537
421		12.14	1338	2314	673
422		10.43	1428	1893	506
423		13.19	1342	1938	556
424		12.8	1454	2054	495
425		16	1719	2339	455
426		12.7	1554	2397	721
427		13.5	1689	2422	438
428		14.66	1509	2332	672
Average		**13.7**	**1363**	**2035**	
Std.Dev		1.46	183	320	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 5

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
501		10.95	1107	1787	609
502		11.62	717	1453	494
503		9.98	481	1386	528
504		9.3	684	1825	648
505		13.1	1014	2100	743
506		9.9	909	2141	836
507		12.91	862	1697	668
508		9.11	917	2074	837
509		9.73	1102	1840	628
510		8.88	1002	1834	743
511		11.24	695	1484	534
512		16	196	342	91
513		16	939	1611	536
514		11.1	826	1292	442
515		11.45	1213	2266	842
516		16	703	1341	383
517		16	606	1221	409
518		10.75	859	1581	551
519		16	1111	1963	343
520		9.11	1335	1922	628
521		10	1194	1839	699
522		11.95	1192	1698	469
523		16	691	1079	297
524		13.96	988	1712	601
525		16	412	936	314
526		8.15	1272	1968	775
527		16	951	1732	626
528		16	602	1052	362
Average		**12.4**	**878**	**1613**	
Std.Dev					

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 6

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
601		15.72	468	901	323
602		16	285	481	136
603		16	945	1613	600
604		10.1	812	1820	592
605		16	291	724	280
606		16	762	1496	426
607		16	348	588	152
608		16	783	1350	469
609		16	704	1176	289
610		13.85	888	1796	584
611		11.26	610	1404	443
612		12.66	833	1829	629
613		16	350	1085	280
614		11.58	930	1748	632
615		11.56	1010	1845	691
616		15.92	865	1615	428
617		16	860	1724	602
618		16	495	760	255
619		9.39	1017	2257	745
620		16	535	927	319
621		16	858	1317	361
622		12.57	891	1508	536
623		9.25	1133	1948	784
624		16	1033	1659	456
625		16	790	1411	419
626		13.57	931	1668	510
627		16	499	1190	363
628		11.23	904	1687	670
Average		**14.2**	**744**	**1412**	
Std.Dev		2.42	242	442	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 7

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
701		16	663	1056	312
702		10.3	947	1465	442
703		15.9	838	1323	473
704		16	447	706	231
705		16	465	931	264
706		16	161	227	51
707		16	497	966	321
708		14.43	1003	1489	518
709		16	771	1309	458
710		11.84	778	1400	511
711		8.21	1246	1667	599
712		13.9	938	1448	460
713		10.68	1024	1474	510
714		7.63	925	1421	480
715		16	545	1110	406
716		12.21	799	1191	385
717		14.23	973	1482	419
718		16	661	965	261
719		16	469	690	212
720		12.06	985	1386	489
721		9.92	708	1223	489
722		16	387	716	253
723		16	588	944	304
724		16	433	864	174
725		8.81	1119	1673	620
726		16	433	740	172
727		16	871	1320	429
728		16	377	780	278
Average		**13.9**	**716**	**1142**	
Std.Dev		2.86	273	358	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 8

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Resistance (psi) Maximum	Resistance (psi) Std.Dev
801		14.88	1024	1653	581
802		14.72	759	1716	728
803		16	703	1227	464
804		14.11	1362	1894	559
805		16	684	1164	403
806		13.83	1289	1810	556
807		14.47	1259	1880	650
808		13.88	1301	1876	619
809		15.6	1190	1600	471
810		16	1045	1573	539
811		14.07	1223	1800	635
812		16	1029	1536	500
813		8.52	1449	2073	640
814		13.97	1255	1805	543
815		7.01	1456	1917	592
816		14.37	942	1909	756
817		16	556	1060	309
818		16	669	1238	381
819		15.02	915	1501	437
820		16	746	1491	501
821		13.14	1314	1831	633
822		16	668	1309	467
823		14.89	1061	1774	612
824		7.94	1288	2061	787
825		7.22	1468	2030	712
826		13.32	1296	1955	705
827		8.15	928	1707	647
828		16	477	774	225
Average		**13.7**	**1048**	**1649**	
Std.Dev					

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 9

Test Dates 5/18/2005

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
901		11.65	1352	1767	453
902		15.32	1517	2509	782
903		9.91	1634	2123	603
904		16	1267	2145	420
905		13.5	1677	2393	669
906		10.84	1675	2405	589
907		15	1188	2193	590
908		16	1584	2203	164
909		10.44	2071	2704	872
910		10.51	1323	2020	577
911		9.37	1754	2667	895
912		16	1333	1867	440
913		16	1014	1538	367
914		11.82	1545	2452	804
915		12.47	1500	2318	637
916		12.96	1612	2363	680
917		15.5	1308	1840	393
918		16	1288	1609	355
919		16	1242	2045	494
920		12.8	1552	2419	804
921		16	1218	1867	492
922		16	1233	2002	385
923		7.91	1404	2350	670
924		12.9	1973	2736	751
925		12.16	1445	1907	591
926		16	1585	2398	758
927		16	1500	2056	524
928		12.13	1632	2329	661
Average		**13.5**	**1480**	**2187**	
Std.Dev					

STATIC CONE PENETROMETER FIELD DATA

Location: Starfire

Plot # 1

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi)		
			Mean	Maximum	Std.Dev
101		16	1553	2208	784
102		16	1477	2072	588
103		12.1	1055	1881	714
104		16	885	1589	568
105		7.3	834	2333	916
106		8.9	1636	2568	1032
107		15.6	1021	1933	724
108		13.9	1219	2092	732
109		13.2	1178	2149	837
110		12.3	1570	2503	1011
111		9.5	1331	2407	989
112		16	1390	2237	820
113		16	679	1163	374
114		13.9	1439	2260	915
115		12.8	1156	2427	1041
116		16	878	1505	523
117		13.3	1379	2426	1023
118		16	580	1518	366
119		13.9	1458	2455	940
120		15.3	1136	2282	783
121		7.2	1473	2521	1125
122		16	539	920	279
123		10	778	1495	550
124		11.5	1077	1849	782
125		9.3	1332	2402	1059
126		16	746	1878	623
127		15.3	1080	2261	817
128		16	700	1386	479
Average		**13.4**	**1128**	**2026**	
Std.Dev					

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 2

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
201		16	1164	1791	624
202		16	1140	1674	561
203		14.9	1589	2249	746
204		16	871	1938	585
205		16	793	1410	487
206		16	937	1858	679
207		14.2	1323	2244	893
208		12.9	1275	2314	897
209		16	1306	1970	668
210		16	1388	2173	600
211		14.9	1612	2157	668
212		10.2	1606	2499	1034
213		16	621	1265	430
214		9.4	1156	1819	739
215		10.1	1166	1819	734
216		12.5	1333	1915	575
217		12	1385	2045	645
218		16	860	1527	538
219		16	665	1645	552
220		16	70	200	87
221		16	848	1426	558
222		12.4	884	1753	682
223		10.3	664	1000	267
224		15.2	744	1374	496
225		13.1	1245	2139	824
226		10.3	1193	2324	1060
227		13.1	1383	2224	855
228		16	438	1106	300
Average		**14.1**	**1059**	**1781**	
Std.Dev		2.33	379	506	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 3

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi)		
			Mean	Maximum	Std.Dev
301		15.5	1532	2347	765
302		13.2	1639	2180	727
303		11.2	1485	2252	909
304		11.1	1652	2446	951
305		10.2	1510	2328	916
306		16	631	1270	363
307		16	209	334	100
308		16	494	1047	361
309		16			
310		16	461	1270	390
311		16	273	582	126
312		16	429	948	266
313		16	510	1340	323
314		16	812	1751	656
315		13.5	1438	2281	820
316		10.4	1246	2250	998
317		16	432	968	231
318		16	574	939	319
319		12.9	1294	2113	751
320		16	590	1153	400
321		11.7	1230	1916	720
322		16	1456	2097	745
323		16	937	1922	674
324		15.5	1317	2168	698
325		16	318	702	268
326		16	445	1042	304
327		10.9	1562	2357	844
328		16	658	1015	381
Average		**14.6**	**931**	**1593**	
Std.Dev		2.14	500	657	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 4

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
401		14.4	1466	2154	524
402		13.6	1746	2422	629
403		14.7	782	1235	169
404		14.6	1095	1760	296
405		13.8	1727	2324	677
406		14.2	1624	2112	513
407		9.2	1813	2598	800
408		14.3	1208	1635	336
409		13.5	1567	2251	706
410		9.1	1488	2453	783
411		9.8	1616	2288	700
412		14.4	1364	2365	485
413		14.9	1549	1890	355
414		14.9	1053	1656	264
415		14.7	1104	1450	300
416		14.9	1106	1511	323
417		14.3	1590	2091	507
418		14.9	1166	1507	293
419		9.5	1867	2445	667
420		14.7	669	1168	161
421		15.3	989	1471	265
422		15.1	948	1588	275
423		9.3	1639	2318	748
424		15.4	1417	2122	548
425		13.1	1840	2600	713
426		15.4	1060	1586	305
427		15.3	1339	1837	334
428		15.8	645	1670	317
Average		**13.7**	**1338**	**1947**	
Std.Dev		2.13	356	426	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 5

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
501		12.7	848	1802	755
502		7.9	1406	1981	691
503		15.1	1302	1919	622
504		7.7	1123	1850	731
505		10.8	1309	1982	649
506		9.9	1363	1830	565
507		13.2	1473	1851	522
508		8.2	1435	1903	681
509		14	1260	1779	445
510		7.7	1608	1936	506
511		10.2	1122	1892	691
512		13.3	1659	2401	699
513		10.4	878	1930	865
514		13.4	1335	1910	692
515		14.1	870	1692	729
516		14.3	1058	1470	408
517		14.1	1253	2013	706
518		16	821	1260	369
519		12.1	1508	2074	731
520		11.7	1228	2055	800
521		10.1	1558	2271	823
522		9.9	1579	2411	943
523		9.1	1358	2269	873
524		12.4	1449	2161	867
525		7.3	1564	2291	930
526		16	1404	1896	603
527		10.6	1331	2217	935
528		8.4	1275	2283	1046
Average		**11.5**	**1299**	**1976**	
Std.Dev		2.66			

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 6

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
601		15.4	472	1067	367
602		14.8	384	1081	417
603		16	797	1801	662
604		14.8	1182	2143	735
605		16	576	1023	319
606		16	766	1738	567
607		16	769	1322	475
608		15.5	1343	2130	704
609		15	1352	2280	815
610		16	864	1584	495
611		16	602	1364	403
612		15.9	744	1389	492
613		14.9	1121	1907	712
614		14.7	1168	1707	460
615		14.8	1388	2155	773
616		15.8	1388	2120	552
617		12.5	1207	2081	705
618		12.9	1303	1897	675
619		14.7	811	1356	403
620		16	601	1502	439
621		13.2	1232	2192	834
622		10.3	1707	2465	827
623		14.7	1464	1955	619
624		14.7	1362	2186	696
625		13.5	1569	2215	804
626		7.9	1656	2532	1040
627		9.3	1624	2553	935
628		12.9	1339	2013	642
Average		**14.3**	**1100**	**1849**	
Std.Dev		2.15	375	428	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 7

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
701		12.3	747	1134	416
702		16	739	1096	303
703		16	817	1281	437
704		9.4	757	1256	540
705		16	842	1236	395
706		16	731	1091	385
707		16	778	1297	446
708		12.1	1112	1880	688
709		16	450	692	276
710		8.9	635	1300	526
711		16	896	1187	337
712		16	783	1384	463
713		16	722	1069	356
714		13.9	650	1032	350
715		15.4	702	1144	376
716		10.6	774	1391	557
717		10.6	761	1300	550
718		16	504	797	218
719		16	823	1228	402
720		13.8	872	1256	450
721		16	818	1257	420
722		11.7	851	1347	461
723		12.8	781	1525	574
724		11.8	739	1306	541
725		16	768	1156	420
726		14	833	1366	425
727		16	611	879	301
728		14.3	895	1717	701
Average		**14.1**	**764**	**1236**	
Std.Dev		2.34	128	246	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 8

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
801		10.4	684	1214	485
802		16	929	1468	490
803		9.3	806	1243	471
804		11.1	894	1700	670
805		10.6	781	1421	581
806		11.5	941	1798	712
807		9	704	1196	454
808		9.3	1014	1678	648
809		12.6	829	1525	561
810		10.5	815	1273	423
811		9.6	827	1515	593
812		16	926	1409	458
813		16	804	1356	426
814		16	1181	1843	633
815		16	985	1435	413
816		16	787	1499	398
817		13.2	846	1321	416
818		11	1019	1804	678
819		13.2	635	1153	438
820		14.3	892	1734	581
821		9.7	905	1602	642
822		11.4	978	1745	672
823		16	726	1028	362
824		13.3	1068	1679	526
825		16	730	1077	389
826		16	580	905	278
827		16	668	966	253
828		16	880	1203	313
Average		**13.1**	**851**	**1421**	
Std.Dev					

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 9

Test Dates 6/1/2006

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	max	std dev
901		10.9	1065	1839	686
902		12	790	1230	519
903		16	1019	1348	390
904		14.2	1161	1825	665
905		14.8	879	1325	416
906		16	965	1545	485
907		14.5	878	1471	448
908		13.2	1025	1732	656
909		15	902	1387	446
910		16	443	1159	312
911		12.4	1374	1800	492
912		16	920	1481	442
913		13.3	1053	1520	444
914		16	1028	1378	400
915		16	547	969	253
916		16	765	1186	357
917		11.9	979	1453	426
918		15.9	982	1434	454
919		13.5	1063	1751	586
920		16	847	1473	353
921		16	847	1326	439
922		14.2	974	1582	516
923		16	637	1050	352
924		16	818	1240	383
925		13.2	766	1240	
926		15	877	1301	468
927		11.0	1094	1674	573
928		16.0	711	1749	618
Average		**14.1**	**907**	1194	303
Std.Dev					

Maximum Penetration Depths Measured in: 2006

Location: Starfire

	Reclamation		Depth (in)		Avg. Depth (in)	
Plot #	**Method**	**Planted**	**SCP**	**DCP**	**SCP**	**DCP**
1	Struck-off	97	13.4	15.0		
2	Loose-dumped	97	14.1	14.8	14.1	14.8
3	Loose-dumped	97	14.6	14.9		
4	Loose-dumped	97	13.7	14.6		
5	Struck-off	97	11.5	13.7	13.0	14.6
6	Struck-off	97	14.3	15.1		
7	Compacted	96	14.1	15.2	13.8	14.6
8	Compacted	96	13.1	14.3		
9	Compacted	97	14.3	14.2		

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 1

Test Dates 6/1/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi)		
			Mean	Maximum	Std.Dev
101		10.92	2138	3728	1389
102		11.78	1789	3440	1254
103		16	1734	3105	1070
104		9.74	3095	3961	1234
105		15	1715	3392	1186
106		16	737	2046	566
107		16	1419	2660	903
108		16	889	2874	862
109		16	561	1161	404
110		16	1554	3148	1168
111		16	1018	2701	979
112		16	586	1514	461
113		16	1004	3445	1179
114		16	1055	2297	691
115		16	1470	3185	1129
116		10.12	1511	3259	1217
117		11.4	2054	3410	1232
118		11.75	1468	3521	1377
119		10.54	2079	3631	1369
120		16	990	2954	732
121		16	3366	4566	1096
122		16	1642	2945	1025
123		16	1861	3069	975
124		16	2111	3186	1119
125		16	1453	2526	877
126		16	2299	3665	1530
127		16	594	1602	385
128		16	1855	3092	1130
Average		**14.7**	**1573**	**3003**	**1019**
Std.Dev					

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 2

Test Dates 6/3/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
201		15.17	1500	2359	594
202		16	1427	2214	643
203		15.15	1074	1866	552
204		9.61	2017	2882	784
205		14.44	1023	1875	445
206		15.28	1479	2157	599
207		14.13	1560	2527	784
208		13.7	1336	2105	512
209		10.07	2004	2591	696
210		11.91	1573	2174	648
211		16	1626	2174	588
212		15.1	906	1625	529
213		13.87	1269	2294	864
214		16	746	1325	461
215		16	665	1002	340
216		16	347	1035	260
217		16	535	946	284
218		15.88	1036	1879	559
219		16	363	1470	378
220		16	971	2406	668
221		16	1171	1767	520
222		16	733	1092	307
223		16	1185	2047	771
224		13.48	1691	2565	904
225		15.37	1604	2422	720
226		15.69	1007	1848	524
227		14.57	1361	2430	989
228		16	883	1605	461
Average		**14.8**	**1182**	**1953**	**585**
Std.Dev		1.78	450	533	191

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 3

Test Dates 6/5/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
301		16	1106	1909	550
302		16	940	1921	714
303		7.89	1715	2255	717
304		16	520	1513	368
305		15.59	1073	1993	530
306		16	344	626	169
307		15.42	174	292	66
308		15.34	872	1735	675
309		16	744	1426	422
310		15.6	913	1635	513
311		15.66	497	1453	265
312		13.6	1278	2266	878
313		15.67	840	1748	475
314		15.49	1324	2922	839
315		15.4	1148	2919	910
316		14.81	2268	2942	1025
317		15.59	2446	2947	796
318		15.58	650	2921	755
319		8.98	2734	2938	716
320		11.51	2404	2927	1075
321		14.83	1678	2919	747
322		15.7	1695	2929	771
323		16	1680	2933	750
324		16	1411	2630	1270
325		16	1552	2742	1154
326		16	1613	2519	1037
327		16	1089	2529	995
328		16	1989	2619	1049
Average		**15.0**	**1311**	**2254**	**723**
Std.Dev		2.07	661	741	298

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 4

Test Dates 6/7/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
401		15.08	1750	2658	906
402		15.3	1675	2468	972
403		16	1475	2844	1123
404		12.33	1929	2649	823
405		11.5	551	2750	846
406		16	1449	2768	1089
407		16	1215	2549	1124
408		15.03	1884	2749	1158
409		14.69	1517	2550	710
410		16	1773	2558	970
411		12.77	1682	2750	1076
412		15.19	1684	2649	976
413		11.3	1640	2468	874
414		10.54	1592	2568	1103
415		14.55	1725	2580	872
416		16	579	1134	235
417		12.01	1370	2323	952
418		15.14	1062	2378	650
419		9.35	1661	2340	598
420		15.33	1396	2353	662
421		16	1528	2368	1090
422		15.54	516	2332	1972
423		10.08		2349	
424		16	1273	2361	1460
425		14.78	417	2341	2100
426		16		2333	
427		16		2403	
428		14.29		2332	
Average		**14.2**	**1389**	**2461**	**1014**
Std.Dev		2.08	448	308	396

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 5

Test Dates 6/9/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi)		
			Mean	Maximum	Std.Dev
501		6.22	1090	2058	774
502		15.57	1083	1692	511
503		16	1198	1868	518
504		7.14	1353	2133	778
505		9.92	1193	2245	825
506		8.65	1453	2069	683
507		16	810	1732	563
508		8.5	1158	2072	719
509		9.3	1337	2099	665
510		12.92	1099	2177	684
511		8.55	1535	2248	612
512		7.87	1315	2094	699
513		5.32	1342	2128	846
514		10.82	1341	2144	606
515		16	724	1245	412
516		7.65	1383	2167	668
517		8.13	1521	2273	687
518		16	1136	1600	406
519		8.81	1367	2182	784
520		11.68	1191	2179	694
521		11.63	1103	2117	645
522		6.57	1521	2263	636
523		7.1	1349	2070	740
524		10.5	1209	2079	687
525		6.77	1303	2210	590
526		6.31	1274	2279	804
527		14.64	1259	2210	586
528		7.89	1425	2370	752
Average		**10.1**	**1253**	**2072**	**663**
Std.Dev		3.47			

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 6

Test Dates 6/11/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
601		8.39	1176	2111	752
602		8.85	1283	2179	619
603		14.2	1188	2101	616
604		8.62	1073	1875	566
605		10.34	1258	2215	761
606		8.68	1107	2056	661
607		7.36	1350	2122	673
608		14.34	1234	1747	494
609		15.02	974	2107	681
610		7.45	1212	2011	707
611		9.74	1364	2171	749
612		16	732	1798	467
613		7.92	1287	2031	687
614		7.15	1377	2197	762
615		16	585	1406	319
616		8.44	1112	2156	697
617		8.75	1275	2204	660
618		9.24	921	2156	792
619		9.33	1445	2357	771
620		8.84	1170	2126	629
621		7.71	1376	2402	787
622		6.89	1447	2558	910
623		10.07	1229	2335	747
624		5.71	1211	2244	814
625		7.04	1283	2233	742
626		7.55	1100	2145	768
627		5.53	1135	2191	905
628		10.34	1140	2052	738
Average		**9.5**	**1180**	**2117**	**696**
Std.Dev		2.99	199	222	127

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 7

Test Dates 6/13/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
701		8.35	1151	2183	705
702		6.87	1318	2329	748
703		7.33	1124	2034	756
704		6.35	1279	2265	840
705		10.98	1421	2204	654
706		8.84	1334	2204	697
707		6.21	1518	2089	675
708		8.18	1315	2245	749
709		12.19	1202	2037	569
710		15	1153	2259	788
711		8.02	1411	2172	576
712		11.53	1128	2166	759
713		10.2	1405	2318	789
714		9.87	1187	2202	795
715		9.73	1047	2145	819
716		7.79	1408	2325	815
717		12.61	1148	2164	751
718		9.83	1316	2305	854
719		15.29	1390	2240	680
720		10.86	1254	2237	774
721		9.51	1253	2164	768
722		10.72	1269	2280	839
723		12.39	1396	2279	718
724		10.07	1305	2128	735
725		11.11	1316	2088	694
726		15.04	1180	1801	578
727		15.34	793	1191	285
728		15.23	1533	1992	507
Average		**10.6**	**1270**	**2144**	
Std.Dev		2.81	155	224	

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 8

Test Dates 7/13/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)	Resistance (psi) Mean	Maximum	Std.Dev
801		10.93	1149	2210	782
802		10.12	1070	2297	846
803		10.45	1273	2260	830
804		11.37	1086	2186	853
805		9.8	1117	2361	888
806		9.34	1189	2300	887
807		8.5	1233	2221	866
808		9.69	1324	2261	851
809		9.11	1087	2193	816
810		7.3	975	2151	772
811		16	1111	2048	535
812		14.5	1189	2048	542
813		16	896	2050	668
814		9.64	1266	2257	805
815		11.08	1119	2164	792
816		9.46	1149	2166	822
817		16	727	1825	705
818		7.94	1293	2068	826
819		7.57	1065	1986	829
820		6.7	1169	2168	821
821		15.08	1317	2069	609
822		12.07	1239	2111	736
823		13.17	770	2164	679
824		11.39	1000	2000	723
825		3.73	498	1148	338
826					
827					
828					
Average		**10.7**	**1092**	**2108**	
Std.Dev					

STATIC CONE PENETROMETER FIELD DATA
Location: Starfire

Plot # 9

Test Dates 6/15/2007

Sample Number	Penetration time (sec)	Penetration Depth (inc)		Resistance (psi) Mean	max	std dev
901		9.9		1080	2119	670
902		7.26		1250	1992	493
903		5.88		1105	2149	725
904		15.63		1250	2012	638
905		16		1299	1953	518
906		5.84		1184	2201	819
907		6.08		1676	2372	744
908		7.45		1472	2279	760
909		8		1402	2317	843
910		10.79		1376	2259	748
911		13.81		1396	2126	645
912		9.71		1500	2297	713
913		15.82		1458	2164	708
914		9.47		1105	2282	789
915		16		1165	2031	676
916		9.18		1386	2553	906
917		9.1		991	2317	873
918		11.55		1444	2431	787
919		7.83		1623	2372	788
920		9.19		1746	2515	782
921		7.22		1801	2547	830
922		13.5		1726	2526	704
923		11.57		1887	2575	610
924		16		1759	2469	691
925		15		1530	2279	742
926		16		1071	1735	442
927		16.0		1163	1725	458
928		10.8		1715	2354	727
Average		**9.7**		**1413**	1194	303
Std.Dev						

Maximum Penetration Depths Measured in: 2007

Location: Starfire Mine

Plot #	Reclamation Method	Planted	Depth (in) SCP	Depth (in) DCP	Avg. Depth (in) SCP	Avg. Depth (in) DCP
1	Struck-off	97	14.7	15.0		
2	Loose-dumped	97	14.8	15.0	14.7	15.1
3	Loose-dumped	97	15.0	15.3		
4	Loose-dumped	97	14.2	14.8		
5	Struck-off	97	10.1	12.4	11.4	13.9
6	Struck-off	97	9.5	14.4		
7	Compacted	96	10.6	10.2	10.3	10.2
8	Compacted	96	10.7	10.3		
9	Compacted	97	9.7	10.3		
0	Undisturbed	-	15.9	15.8	15.9	15.8

APPENDIX B

Static Cone Penetrometer Soil Resistance Data

Location: **Starfire**
Plot: **1**
Test Date: **2006**

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	143.3	448.7	842.4	1572.7
2	274.3	1826.6	1316.8	1476.6
3	294.0	894.3	1100.5	
4	116.8	845.0	527.2	781.9
5	232.8	1600.0		
6	330.7	721.4		
7	299.0	594.7	541.4	1190.0
8	607.1	560.9	1386.3	
9	216.7	566.7	956.4	
10	62.8	846.9	860.7	
11	145.3	1215.0		
12	221.8	948.3	1730.4	1878.1
13	413.5	907.4	868.9	974.9
14	112.3	507.1	1468.1	
15	140.4	460.4	1222.6	
16	254.3	709.5	1093.5	1270.6
17	126.5	274.3	905.5	
18	285.4	622.6	1103.4	644.8
19	180.2	659.6	1310.3	
20	106.5	670.9	813.3	1680.9
21	116.9	870.2		
22	404.8	521.6	776.9	559.5
23	329.0	1002.0		
24	166.2	465.1	1592.9	
25	176.6	979.2		
26	479.5	737.4	604.2	769.2
27	252.6	687.0	1221.1	
28	126.9	477.7	687.9	1085.7
	236.3	772.2	1042.3	1157.1

Location: Starfire
Plot: 2
Test Date: 2006

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	106.8	487.4	1273.0	
2	262.8	834.4	1045.1	
3	193.2	897.8	759.8	
4	86.7	1249.7	1126.8	1155.6
5	125.7	487.2	885.1	1398.2
6	172.1	301.0	765.5	
7	30.6	503.7	1505.9	
8	106.2	432.5		
9	212.5	899.9	1279.0	
10	398.1	1196.3	815.4	
11	89.7	184.6	563.7	
12	139.3	346.0		
13	30.9	229.8	418.5	1083.9
14	8.2	530.2		
15	18.3	146.9	345.9	
16	244.7	378.0		
17	165.2	350.4	862.7	
18	115.3	320.9	908.0	
19	12.7	215.0	254.1	486.2
20	3.5	22.1	70.4	200.0
21	30.7	71.5	446.5	
22	52.2	174.5		
23		441.5	485.8	971.4
24	11.4	141.8	680.8	1037.5
25	18.4	296.5	700.0	
26	80.8	167.8		
27	29.8	259.4		
28	69.1	210.8	365.1	
	104.2	420.6	740.8	904.7

Location: **Starfire**
Plot: **3**
Test Date: **2006**

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	124.1	461.8	869.7	
2	234.1	680.5		
3	14.7	226.1		
4	110.2	888.2		
5	69.5	338.1		
6	22.2	402.0	957.9	1109.3
7	84.1	155.5	207.3	334.3
8	72.6	299.1	163.6	1047.5
9				
10	22.8	201.3	537.4	1270.9
11	43.5	223.8	418.9	582.4
12	14.9	125.4	576.6	948.3
13	116.0	476.2	726.4	1340.8
14	39.6	307.8	791.0	1751.6
15	67.7	346.3	1199.2	
16	4.7	320.6		
17	217.1	347.2	423.1	599.4
18	104.9	479.2	732.1	936.6
19	100.5	534.6	1282.8	
20	30.7	145.7	861.8	1017.7
21	96.7	266.0		
22	76.9	276.4	1480.1	2097.3
23	14.6	333.4	829.6	1522.1
24	55.9	373.8	709.9	
25	7.9	60.5	350.0	662.5
26	34.4	367.2	779.4	532.1
27	85.5	330.4		
28	31.0	270.3	814.5	1016.0
	70.2	342.1	735.6	1048.0

Location: Starfire
Plot: 4
Test Date: 2006

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	131.7	315.0	867.6	
2	299.4	550.5	1010.8	
3	90.7	502.6	508.8	1038.2
4	157.0	526.8	718.2	1260.1
5	22.5	369.5	1039.1	
6	140.6	650.5	1006.7	
7	205.6			
8	153.5	274.5	854.5	
9	102.6	480.2	938.7	
10	163.1	626.9		
11	123.4	529.8		
12	187.5	635.2	898.9	
13	215.5	628.6	811.1	1098.8
14	244.4	482.8	713.4	956.1
15	149.8	639.9	849.0	950.4
16	238.0	678.6	730.7	849.5
17	111.5	433.7	721.7	975.2
18	172.9	204.8	822.6	882.8
19	105.4	497.4		
20				
21	63.4	253.9	535.6	741.3
22	1.0	225.6	452.0	688.5
23	94.5	236.6		
24	74.1	250.5	394.9	624.4
25	57.6	190.5	737.4	1000.5
26	50.4	182.7	448.2	
27	114.1	273.6	312.5	837.7
28			150.1	
	133.5	425.6	705.6	915.7

Location: Starfire
Plot: 5
Test Date: 2006

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	102.5	663.4	1548.1	
2	194.3	1693.1		
3	219.8	737.1	1284.3	
4	131.5	742.8		
5	261.4	1033.3		
6	472.1	726.3		
7	214.9	890.5	1690.7	1799.4
8	117.1	720.5		
9	354.7	607.1	1232.6	1615.8
10	377.2	679.8		
11	116.5	565.3		
12	195.8	663.2	1208.0	
13	233.8	409.5		
14	211.7	374.7	1084.1	
15	122.1	452.9	1154.6	1602.9
16	340.5	537.1	1111.8	1453.8
17	117.0	418.2	973.4	2013.0
18	109.6	354.1	685.6	1260.4
19	143.3	397.2		
20	147.3	407.1	934.8	
21	168.1	897.6	995.6	
22	133.8	544.0		
23	170.1	631.4		
24	181.1	519.7	1021.2	
25	189.3	1033.4		
26	418.3	1083.2		
27	202.5	594.2		
28	315.7	973.6		
	212.9	691.1	1148.1	1624.2

Location: Starfire
Plot: 6
Test Date: 2006

Soil Resistance (psi) at Incremental Depths				
Measurement #	4 in (10 cm)	8 in (20 cm)	12 in (30 cm)	16 in (40 cm)
1				
2	428.1	759.0	468.9	542.4
3	468.6	1062.3		
4	492.0	739.8		
5	401.4			
6	230.9	660.9	707.2	
7	327.7			
8	447.7	758.7		
9	585.3	841.6		
10	265.4	493.9	737.8	
11	392.4			
12	140.4	207.5		
13	247.6			
14	250.5	628.9	764.4	847.4
15	111.3	695.4		
16				
17	106.9			
18	90.4	550.4	949.0	
19	327.5	637.3	1229.5	1450.1
20	347.3	698.1		
21	301.1	456.8	1163.3	
22				
23	383.3	679.3		
24	220.0	600.2	1047.2	1692.2
25	294.6	657.9		
26	351.8	568.2		
27	278.9	638.6	1226.1	1411.2
28	264.1	616.4	958.8	1039.3
	310.2	647.6	925.2	1163.8

Location: **Starfire**
Plot: **7**
Test Date: **2006**

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	145.7	570.4	968.1	
2	311.1	638.8	974.5	887.2
3	60.9	409.8	901.6	1123.0
4	116.5	462.1		
5	252.3	723.9	954.6	1148.8
6	94.9	508.2	908.5	1040.0
7	217.0	609.7	880.7	1154.0
8	138.5	570.7	881.0	
9	88.0	475.9	646.4	658.4
10	159.4	462.7		
11	227.7	504.2	1042.7	1147.8
12	40.8	650.6	792.0	1018.2
13	138.6	513.4	807.2	1017.8
14	165.9	591.2	690.3	
15	139.7	653.8	692.8	876.6
16	108.1	687.5		
17	163.4	405.7		
18	196.0	393.0	703.4	596.3
19	97.4	550.5	807.5	933.5
20	115.7	548.6	1024.7	
21	76.6	359.8	824.4	1071.0
22	208.2	346.0	975.4	
23	109.9	302.8	1083.8	
24	22.3	119.6	817.6	
25	31.4	483.7	946.7	1044.7
26	162.2	396.6	851.9	
27	79.2	482.0	725.0	793.4
28	98.7	608.8	1420.1	
	134.5	501.1	888.4	967.4

Location: Starfire
Plot: 8
Test Date: 2006

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	174.7	644.3	1103.4	
2	148.6	780.0	952.9	1197.2
3	121.1	628.0	997.7	
4	38.6	360.0	1165.4	
5	41.0	398.9	1105.3	
6	59.7	356.9	963.0	1592.2
7	190.1	592.3	978.2	
8	99.0	813.3	1448.4	
9	152.9	456.8	1029.0	
10	232.6	485.8	1020.9	
11	73.1	513.3	1082.8	
12	204.4	611.5	948.4	1216.0
13	45.9	464.8	1088.1	1107.8
14	148.7	726.4	856.9	1346.7
15	110.3	718.7	1070.8	1258.1
16	164.6	607.8	851.2	1241.7
17	191.7	646.9	927.4	1146.4
18	129.4	805.2	1419.8	
19	93.0	396.1	768.9	1037.7
20	115.3	469.0	748.7	1166.7
21	122.2	917.8		
22	222.3	1206.6		
23	50.8	574.8	908.1	1000.3
24	291.1	724.1	1025.1	1525.5
25	30.6	440.8	905.0	997.2
26	79.0	443.9	655.2	689.5
27	223.4	651.4	792.4	911.2
28	296.1	799.2	1061.6	1128.5
	137.5	615.5	995.2	1160.2

Location: Starfire
Plot: 9
Test Date: 2006

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	105.4	503.1	958.6	
2	88.2	345.0	573.5	
3	295.3	585.3	900.6	1248.1
4	73.4	691.6	970.4	1476.9
5	153.7	531.1	722.6	1278.3
6	111.6	521.0	662.1	1254.1
7	166.6	422.3	807.5	
8	161.9	600.6		
9	114.9	428.6	623.6	1137.9
10	143.1	282.6	355.7	851.5
11	306.4	703.6	1301.7	
12	315.2	980.6	1326.3	
13	148.0	472.5	864.9	1241.8
14	420.6	743.4	960.3	
15	223.1	594.3	831.4	1265.9
16	110.2	384.1	514.3	695.0
17	189.7	432.2	566.5	996.2
18	338.2	625.4	845.7	
19	318.8	525.9	804.1	1406.3
20	180.4	518.7	879.2	
21	262.0	549.5	834.6	974.0
22	184.8	444.3	733.1	1255.8
23	135.4	430.3	606.6	1368.6
24	89.7	243.1	392.1	937.5
25	168.7	380.0	567.5	1170.0
26	113.7	412.9	538.1	1267.2
27	95.5	541.9	1130.7	
28	291.7	664.5	744.9	913.3
	189.5	519.9	778.4	1152.1

Location: **Starfire**
Plot: **1**
Test Date: **2007**

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	1083.6	1007.5		
2	377.0	761.6	2127.7	
3	299.4	472.6	1662.6	2879.0
4	361.0	620.4	758.9	
5	212.2	939.5	1480.6	
6	158.7	682.9	1506.6	837.5
7	164.4	915.9	1647.1	2287.0
8	22.7	153.8	499.8	891.0
9	78.4	278.1	274.7	784.6
10	55.5	467.9	1043.7	1319.5
11	10.9	120.8	456.4	993.6
12	69.9	157.6	255.9	565.8
13		251.1	415.3	331.7
14	108.2	485.6	1000.2	1256.9
15	44.4	527.0	937.8	1019.6
16	103.5	588.7		
17	218.6	537.7	1613.5	
18	22.3	433.2		
19		360.0	1038.4	
20	66.1	284.9	649.4	1005.0
21	190.7	1303.6	1729.2	
22	325.7	493.4	2425.1	
23	244.1	951.2	1344.6	1898.5
24	169.4	617.2	1137.1	1642.9
25	161.2	544.9	1366.1	1506.0
26	93.4	422.5	700.9	1154.2
27	119.8	421.0	635.0	1268.0
28	268.7	904.3	1769.7	2393.1
average =	193.4	560.9	1139.1	1335.2

Location: Starfire
Plot: 2
Test Date: 2007

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	214.5	1264.0	2054.8	1996.9
2	350.2	1163.3	2031.8	982.4
3	340.9	724.7	896.9	1157.5
4	432.4	1692.9	1575.8	
5	165.5	1414.2	1849.6	1569.7
6	556.2	1024.8	751.9	1421.5
7	459.5	887.9	1764.2	
8	271.2	803.4	1158.1	
9	49.3	393.5	2290.7	
10	346.5	1639.0	2373.9	
11	254.3	924.3	1653.9	1995.1
12	136.6	766.0	857.9	
13	53.2	248.5	1078.5	
14	195.4	257.3	718.5	854.0
15	75.1	479.4	355.5	771.6
16	28.1	379.0	588.1	222.4
17	96.7	307.0	641.8	835.6
18	183.5	1273.9	1609.2	725.1
19	76.8	96.2	874.1	437.9
20	876.8	1691.7	676.3	1114.7
21	170.1	891.9	1543.7	1409.7
22	284.9	759.9	1011.4	898.5
23	207.9	444.9	576.8	1847.3
24	288.7	601.9	1744.8	
25	204.0	956.6	2171.6	1734.4
26				
27	58.9	179.2	804.8	
28	229.3	685.1	1273.8	1265.6
	244.7	813.0	1293.6	1180.0

Location: Starfire
Plot: 3
Test Date: 2007

Soil Resistance (psi) at Incremental Depths				
Measurement #	4 in (10 cm)	8 in (20 cm)	12 in (30 cm)	16 in (40 cm)
1		227.7	901.4	1326.2
2	81.5	564.3	1532.1	1325.3
3	124.9	1383.6		
4	190.1	443.2	731.8	847.6
5	366.8	1039.7	1671.8	1202.3
6	113.4	411.1	506.5	459.0
7	100.0	217.0	187.6	198.5
8	291.0	308.5	222.1	1092.6
9	72.1	854.9	917.0	2789.5
10	50.9	803.7	1468.3	1260.6
11	155.2	712.9	590.5	610.6
12	202.6	284.9	470.7	774.4
13	172.4	590.7	1427.2	1027.9
14	224.9	676.9	1202.9	1006.1
15	148.6	893.9	1400.6	2329.6
16	120.7	1069.8	1207.4	
17	53.6	518.5	685.0	439.7
18	141.3	780.4	1021.3	556.7
19	297.8	1679.7		
20	141.9	837.5	1919.5	
21	531.0	843.3	1818.8	2919.5
22	52.0	1690.3	2728.7	732.5
23	343.6	1928.4	2928.6	2928.6
24	110.0	374.7	484.4	1938.4
25	270.7	2130.2	2919.5	2919.5
26	1006.8	2919.5	2919.5	2919.5
27	107.3	1000.9	1931.8	2929.2
28	191.9	488.0	2319.3	2919.5
	209.7	916.9	1389.0	1560.5

Location: Starfire
Plot: 4
Test Date: 2007

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	51.8	1672.7	2657.6	2657.6
2	192.0	1548.5	2657.6	2657.6
3	306.6	2310.0	2758.4	1566.2
4	192.9	1353.6	2748.8	
5	397.3	2686.8	2749.8	
6	152.2	1829.2	2116.7	2098.1
7	603.7	2748.8	2495.7	727.6
8	454.3	2607.6	2749.2	2749.2
9	593.9	1945.6	2750.2	2750.2
10	566.6	1765.7	2758.4	2758.4
11	150.4	2260.9	2749.8	2749.8
12	477.3	1730.6	2748.8	2748.8
13	915.6	2438.7	2768.4	2768.4
14	359.5	2654.0	2768.4	
15	1331.3	2749.7	2749.7	
16	784.2	1133.7	1133.7	1133.7
17	166.6	2323.2	2323.2	
18	693.6	2327.8	1326.4	1656.7
19	632.6	2323.2	2323.2	
20	853.8	2341.9	2208.6	2323.2
21	356.3	2323.2	2323.2	2323.2
22				
23				
24		728.7	2323.2	2323.2
25				
26				
27				
28				
	487.3	2082.0	2463.1	2249.5

Location: **Starfire**
Plot: **5**
Test Date: **2007**

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	443.0	1400.1		
2	245.6	669.4	977.3	1618.6
3	337.9	737.6	1373.1	1523.7
4	235.0	1358.4		
5	299.1	998.0		
6	319.1	1606.0		
7	96.7	87.4	901.0	1432.3
8	191.8	1358.9		
9	351.9	1164.5		
10	426.9	925.7	1004.3	
11	734.9			
12	419.5	1549.3		
13	704.0			
14	699.5	1545.8		
15	264.2	989.7	1167.6	1128.9
16	722.3	1543.8		
17	628.4	1687.9		
18	438.7	1127.0	1431.2	1315.9
19	284.4	1421.0		
20	522.4	1009.1		
21	344.2	1047.4	1717.6	
22	431.2			
23	292.6	1584.1		
24	525.8	893.7		
25	538.0			
26	401.0			
27	386.5	1095.7	1445.7	1617.0
28	807.2	1858.0		
	431.8	1202.5	1252.2	1439.4

Location: Starfire
Plot: 6
Test Date: 2007

Soil Resistance (psi) at Incremental Depths				
Measurement #	4 in (10 cm)	8 in (20 cm)	12 in (30 cm)	16 in (40 cm)
1	230.2	910.0		
2	785.1			
3	213.1	915.6	1413.7	
4	162.1	1022.9		
5	230.1	1106.3		
6	497.7	1393.2		
7	570.4	1578.5		
8	535.8	1067.0	1506.3	
9	340.7	556.1	978.5	
10	250.4	1430.8		
11	620.8	1685.3		
12	301.6	888.9	1384.7	698.2
13	300.9	1598.2		
14	603.3			
15	648.9	790.9	381.8	511.6
16	574.1			
17	533.9	1507.9		
18	292.1	738.7		
19	170.6	1303.0		
20	617.6	1459.2		
21	536.3	1677.8		
22	440.4	1501.6		
23	272.5	1237.8		
24	552.4			
25	290.6	1524.0		
26	360.5	1260.9		
27	252.3			
28	186.1	998.3		
	406.1	1224.0	1133.0	604.9

Location: Starfire
Plot: 7
Test Date: 2007

Soil Resistance (psi) at Incremental Depths				
Measurement #	**4 in (10 cm)**	**8 in (20 cm)**	**12 in (30 cm)**	**16 in (40 cm)**
1	494.0	1256.1		
2	660.8			
3	497.5	1717.2		
4	571.8			
5	475.9	1121.8	1888.2	
6	501.1	1507.1		
7	765.0			
8	676.8	1343.1		
9	247.0	1045.1	1685.2	
10	68.2	642.5	1467.7	
11	513.0	1418.2		
12	234.8	742.4	1811.5	
13	288.9	1443.9		
14	155.8	1044.2		
15	139.6	713.7		
16	168.4	1524.3		
17	80.0	721.0	1646.8	
18	145.2	1001.0		
19	150.6	1019.5	1451.9	1881.5
20	182.3	1055.3	1845.6	
21	198.1	1083.7		
22	249.3	1168.3		
23	280.7	946.3	1638.7	
24	222.0	1050.1		
25	445.1	1294.1	1862.0	
26	186.5	677.1	1317.4	1673.3
27	501.1	834.4	1026.8	1011.3
28	454.8	1459.4	1906.8	1772.8
	341.2	1113.2	1629.0	1584.7

Location: Starfire
Plot: 8
Test Date: 2007

Soil Resistance (psi) at Incremental Depths				
Measurement #	4 in (10 cm)	8 in (20 cm)	12 in (30 cm)	16 in (40 cm)
1	108.5	969.3	1717.0	
2	238.3	903.9		
3	121.6	914.3		
4	142.2	786.8		
5	135.9	852.1		
6	82.7	804.2		
7	65.0	974.6		
8	209.9	1114.3		
9	164.6	1034.6		
10	168.0	915.4		
11	298.2	1127.9	1750.4	
12	244.4	1049.8	1687.3	
13	159.1	336.1	378.9	979.3
14	160.0	1001.3		
15	82.2	200.6	185.0	1069.9
16	110.8	830.3		
17	160.4	1150.5		
18	489.4	1422.4		
19	229.6	878.8	1456.9	1718.6
20	247.1	746.0	1700.7	
21	282.3	1071.0	741.2	
22				
23				
24				
25				
26				
27				
28				
	185.7	908.8	1202.2	1255.9

Location: Starfire
Plot: 9
Test Date: 2007

Soil Resistance (psi) at Incremental Depths				
Measurement #	4 in (10 cm)	8 in (20 cm)	12 in (30 cm)	16 in (40 cm)
1	274.7	1011.3		
2	396.9	843.1		
3	622.0			
4	105.5	787.3	1344.1	1878.2
5	279.6	1120.6	1812.5	1435.0
6	307.0			
7	736.3			
8	337.5	1598.7		
9	257.2	1399.5		
10	319.6	1253.3		
11	177.3	897.3	1583.0	
12	468.3	1398.2		
13	177.2	747.2	1502.5	2050.2
14	245.5	926.3		
15	108.8	593.8	1008.3	1624.1
16	230.8	1240.9		
17	102.9	450.0		
18	277.9	906.7	1853.4	
19	385.5	1886.1		
20	362.1	1698.2		
21	479.0	2134.6		
22	345.0	1285.7	1789.4	
23	414.9	1327.0	1936.7	
24	209.9	1017.8	1870.2	2087.6
25	211.2	893.3	1603.5	
26	420.6	1056.7	1396.3	1417.0
27	654.1	966.5	948.3	1515.3
28	385.4	1708.3		
	331.9	1165.9	1554.0	1715.3

Location: Starfire
Plot: Bucklick Forestry Area
Test Date: 2007

Soil Resistance (psi) at Incremental Depths				
Measurement #	4 in (10 cm)	8 in (20 cm)	12 in (30 cm)	16 in (40 cm)
1	84.4	302.9	566.6	
2	142.3	426.7	669.6	730.8
3	118.4	246.8	492.0	719.8
4	128.3	265.8	362.4	548.0
5	200.1	357.3	620.0	838.9
6	151.9	160.1	517.2	1320.2
7	91.1	200.1	340.3	443.7
8	157.3	263.4	314.7	492.2
9	195.9	363.0	429.4	265.5
10	193.8	282.1	379.1	868.2
11	128.4	226.6	304.1	550.9
12	217.8	284.2	315.5	458.0
13	23.6	136.9	520.9	818.4
14	97.0	260.4	383.9	421.3
15	280.7	370.4	633.0	762.5
16	329.3	417.1	424.9	402.8
17	134.8	622.4	765.0	755.2
18	269.8	227.0	456.1	483.3
19	144.5	368.6	522.3	634.6
20	323.7	557.8	511.9	1025.7
21	227.1	576.7	945.3	773.6
22	325.3	339.6	546.8	988.7
23	223.7	451.4	601.5	808.9
24	99.4	428.5	622.4	695.0
25	271.1	594.6	745.0	872.6
26	144.7	331.8	649.5	853.7
27	207.6	493.5	676.6	862.9
28	326.3	530.2	286.3	512.6
29	300.1	1069.6	1179.9	859.3
30	238.1	316.2	458.8	1811.7
31	203.4	773.9	694.8	1028.2
32	70.0	522.3	1020.1	728.9
33	477.8	690.0	836.9	856.2
34	313.2	517.4	598.9	546.3
35	75.8	469.7	607.3	624.6
36	265.3	666.8	696.6	552.5
37	78.2	602.5	622.4	948.7
38	56.0	212.2	382.3	576.0
39	153.1	563.5	799.9	754.6
40	172.2	459.8	526.9	594.7
41	314.6	585.3	629.2	720.0
42	137.1	302.4	430.1	423.4
43	79.6	241.0	559.0	780.2

44	62.5	181.2	454.0	788.9
45	139.8	187.0	214.4	502.9
46	89.6	164.1	187.0	243.0
47	231.4	360.5	299.2	445.5
48	163.5	277.2	282.5	344.3
49	130.7	654.5	647.9	573.4
50	363.4	472.6	680.0	740.7
	187.1	407.5	548.2	701.1

APPENDIX C

Dynamic Cone Penetrometer Soil Resistance Data

	Date	End of August 2006				Location	Starfire						
	Weather	Clear				Cell #	Cell #1, Struck off						

Starfire - Cell #1 -

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	7	31.1	442.3	22	97.7	1389.6	26	115.4	1641.4	28	124.3	1768.0	40
	2	7	31.1	442.3	13	57.7	820.7	26	115.4	1641.4	25	111	1578.8	40
	3	9	40	568.9	25	111	1578.8	27	119.9	1705.4	30	133.2	1894.5	40
	4	5	22.2	315.8	9	40	568.9	16	71	1009.9	29	128.8	1832.0	40
	5	12	53.3	758.1	20	88.8	1263.0	21	93.2	1325.6	3	13.3	189.2	35
	6	6	26.6	378.3	8	35.5	504.9	16	71	1009.9	25	111	1578.8	40
	7	7	31.1	442.3	11	48.8	694.1	17	75.5	1073.9	2	8.9	126.6	35
	8	4	17.8	253.2	7	31.1	442.3	15	66.6	947.3	18	79.9	1136.4	40
	9	10	44.4	631.5	22	97.7	1389.6	26	115.4	1641.4	1	4.4	62.6	35
	10	9	40	568.9	16	71	1009.9	35	155.4	2210.3	6	26.6	378.3	30
	11	6	26.6	378.3	16	71	1009.9	23	102.1	1452.2	26	115.4	1641.4	40
	12	5	22.2	315.8	10	44.4	631.5	19	84.4	1200.5	28	124.3	1768.0	40
	13	6	26.6	378.3	13	57.7	820.7	15	66.6	947.3	50	222	3157.6	30
	14	6	26.6	378.3	10	44.4	631.5	9	40	568.9	12	53.3	758.1	40
	15	5	22.2	315.8	20	88.8	1263.0	16	71	1009.9	50	222	3157.6	30
	16	8	35.5	504.9	18	79.9	1136.4	25	111	1578.8	23	102.1	1452.2	40
	17	6	26.6	378.3	23	102.1	1452.2	27	119.9	1705.4	19	84.4	1200.5	35
	18	8	35.5	504.9	17	75.5	1073.9	28	124.3	1768.0	33	146.5	2083.7	40
	19	5	22.2	315.8	6	26.6	378.3	13	57.7	820.7	22	97.7	1389.6	40
	20	7	31.1	442.3	17	75.5	1073.9	26	115.4	1641.4	13	57.7	820.7	35

	21	11	48.8	694.1	22	97.7	1389.6	24	106.6	1516.2	29	128.8	1832.0	40
	22	8	35.5	504.9	20	88.8	1263.0	21	93.2	1325.6	26	115.4	1641.4	40
	23	8	35.5	504.9	18	79.9	1136.4	20	88.8	1263.0	24	106.6	1516.2	40
	24	7	31.1	442.3	17	75.5	1073.9	21	93.2	1325.6	27	119.9	1705.4	40
	25	10	44.4	631.5	16	71	1009.9	22	97.7	1389.6	28	124.3	1768.0	40
	26	6	26.6	378.3	14	62.2	884.7	23	102.1	1452.2	24	106.6	1516.2	40
	27	8	35.5	504.9	13	57.7	820.7	16	71	1009.9	20	88.8	1263.0	40
	28	5	22.2	315.8	12	53.3	758.1	19	84.4	1200.5	23	102.1	1452.2	40
									maximum average penetration depth (cm) =					38.0
Avg =		7.2		453.3	15.5		981.1	21.1		1335.1	23		1452.5	15.0
Mode =		6			22			26			28			
Std dev =		2.0	8.8	124.6	5.8	25.7	365.0	6.5	29.0	412.3	13.7	60.9	866.0	

Date	First September 2006	Location	Starfire
Weather	Cloudy, Cool	Cell #	Cell #2 (uncompacted)

Starfire Cell #2 - loose dumped

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	5	22.2	315.8	13	57.7	820.7	24	106.6	1516.2	16	71	1009.9	40
	2	3	13.3	189.2	5	22.2	315.8	9	40	568.9	11	48.8	694.1	40
	3	2	8.9	126.6	7	31.1	442.3	15	66.6	947.3	10	44.4	631.5	40
	4	3	13.3	189.2	9	40	568.9	10	44.4	631.5	12	53.3	758.1	40
	5	3	13.3	189.2	6	26.6	378.3	12	53.3	758.1	9	40	568.9	40
	6	4	17.8	253.2	10	44.4	631.5	25	111	1578.8	18	79.9	1136.4	40
	7	6	26.6	378.3	11	48.8	694.1	25	111	1578.8	50	222	3157.6	30
	8	2	8.9	126.6	6	26.6	378.3	15	66.6	947.3	50	222	3157.6	30
	9	3	13.3	189.2	12	53.3	758.1	14	62.2	884.7	22	97.7	1389.6	40
	10	4	17.8	253.2	16	71	1009.9	18	79.9	1136.4	50	222	3157.6	30
	11	4	17.8	253.2	15	66.6	947.3	20	88.8	1263.0	8	35.5	504.9	40
	12	3	13.3	189.2	5	22.2	315.8	9	40	568.9	5	22.2	315.8	40
	13	4	17.8	253.2	9	40	568.9	16	71	1009.9	20	88.8	1263.0	40
	14	3	13.3	189.2	17	75.5	1073.9	18	79.9	1136.4	19	84.4	1200.5	40
	15	1	4.4	62.6	2	8.9	126.6	4	17.8	253.2	50	222	3157.6	30
	16	4	17.8	253.2	10	44.4	631.5	18	79.9	1136.4	26	115.4	1641.4	40
	17	3	13.3	189.2	9	40	568.9	17	75.5	1073.9	19	84.4	1200.5	40
	18	2	8.9	126.6	2	8.9	126.6	3	13.3	189.2	4	17.8	253.2	40
	19	1	4.4	62.6	3	13.3	189.2	4	17.8	253.2	3	13.3	189.2	40
	20	3	13.3	189.2	4	17.8	253.2	10	44.4	631.5	13	57.7	820.7	40
	21	2	8.9	126.6	2	8.9	126.6	5	22.2	315.8	6	26.6	378.3	40
	22	2	8.9	126.6	2	8.9	126.6	6	26.6	378.3	8	35.5	504.9	40

	23	1	4.4	62.6	4	17.8	253.2	5	22.2	315.8	10	44.4	631.5	40
	24	2	8.9	126.6	5	22.2	315.8	12	53.3	758.1	10	44.4	631.5	40
	25	2	8.9	126.6	6	26.6	378.3	6	26.6	378.3	16	71	1009.9	40
	26	3	13.3	189.2	10	44.4	631.5	12	53.3	758.1	6	26.6	378.3	35
	27	1	4.4	62.6	3	13.3	189.2	12	53.3	758.1	7	31.1	442.3	40
	28	3	13.3	189.2	6	26.6	378.3	50	222	3157.6	50	222	3157.6	20
									maximum average penetration depth (cm) =					37.7
Avg =		2.8		178.1	7.5		471.4	14.1		888.7	18.9		1190.8	14.8
Mode =		3			9			18			50			
Std dev =		1.2	5.5	77.5	4.5	20.1	285.7	6.7	29.6	421.3	16.2	71.9	1022.4	

Date	First September 2006	Location	Starfire
Weather	Cloudy, Cool	Cell #	Cell #3 (uncompacted)

Starfire Cell #3 - loose dumped

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	1	4.4	62.6	4	17.8	253.2	5	22.2	315.8	6	26.6	378.3	40
	2	2	8.9	126.6	3	13.3	189.2	3	13.3	189.2	4	17.8	253.2	40
	3	4	17.8	253.2	12	53.3	758.1	16	71	1009.9	12	53.3	758.1	40
	4	1	4.4	62.6	2	8.9	126.6	3	13.3	189.2	10	44.4	631.5	40
	5	3	13.3	189.2	6	26.6	378.3	7	31.1	442.3	12	53.3	758.1	40
	6	2	8.9	126.6	4	17.8	253.2	3	13.3	189.2	3	13.3	189.2	40
	7	2	8.9	126.6	6	26.6	378.3	10	44.4	631.5	13	57.7	820.7	40
	8	2	8.9	126.6	9	40	568.9	13	57.7	820.7	15	66.6	947.3	40
	9	2	8.9	126.6	8	35.5	504.9	9	40	568.9	5	22.2	315.8	40
	10	2	8.9	126.6	3	13.3	189.2	8	35.5	504.9	10	44.4	631.5	40
	11	2	8.9	126.6	5	22.2	315.8	7	31.1	442.3	12	53.3	758.1	40
	12	1	4.4	62.6	2	8.9	126.6	50	222	3157.6	50	222	3157.6	20
	13	2	8.9	126.6	3	13.3	189.2	7	31.1	442.3	7	31.1	442.3	40
	14	3	13.3	189.2	9	40	568.9	50	222	3157.6	50	222	3157.6	25
	15	3	13.3	189.2	5	22.2	315.8	20	88.8	1263.0	6	26.6	378.3	40
	16	3	13.3	189.2	6	26.6	378.3	12	53.3	758.1	8	35.5	504.9	40
	17	3	13.3	189.2	8	35.5	504.9	14	62.2	884.7	50	222	3157.6	30
	18	2	8.9	126.6	3	13.3	189.2	3	13.3	189.2	3	13.3	189.2	40
	19	3	13.3	189.2	7	31.1	442.3	11	48.8	694.1	10	44.4	631.5	40
	20	3	13.3	189.2	6	26.6	378.3	11	48.8	694.1	6	26.6	378.3	40
	21	3	13.3	189.2	12	53.3	758.1	20	88.8	1263.0	10	44.4	631.5	40
	22	1	4.4	62.6	2	8.9	126.6	3	13.3	189.2	9	40	568.9	40
	23	2	8.9	126.6	4	17.8	253.2	11	48.8	694.1	10	44.4	631.5	35

	24	3	13.3	189.2	9	40	568.9	13	57.7	820.7	11	48.8	694.1	40
	25	2	8.9	126.6	3	13.3	189.2	9	40	568.9	6	26.6	378.3	40
	26	3	13.3	189.2	9	40	568.9	13	57.7	820.7	50	222	3157.6	30
	27	2	8.9	126.6	4	17.8	253.2	10	44.4	631.5	6	26.6	378.3	40
	28	2	8.9	126.6	7	31.1	442.3	12	53.3	758.1	14	62.2	884.7	40
									maximum average penetration depth (cm) =					37.9
Avg =		2.3		144.3	5.8		363.2	12.6		796.1	13.8		920.1	14.9
Mode =		2			3			3			6			
Std dev =		0.8	3.6	50.7	2.7	11.9	169.6	13.4	59.6	848.3	15.6	69.4	987.2	

Date First September 2006 Location Starfire
Weather Cloudy, Cool Cell # Cell #4 (rough grade)

Starfire Cell #4 loose dumped

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	4	17.8	253.2	8	35.5	504.9	9	40	568.9	11	48.8	694.1	35
	2	2	8.9	126.6	6	26.6	378.3	12	53.3	758.1	15	66.6	947.3	40
	3	4	17.8	253.2	25	111	1578.8	22	97.7	1389.6	19	84.4	1200.5	25
	4	1	4.4	62.6	3	13.3	189.2	11	48.8	694.1	18	79.9	1136.4	40
	5	3	13.3	189.2	11	48.8	694.1	20	88.8	1263.0	17	75.5	1073.9	40
	6	2	8.9	126.6	2	8.9	126.6	5	22.2	315.8	8	35.5	504.9	40
	7	3	13.3	189.2	3	13.3	189.2	4	17.8	253.2	13	57.7	820.7	25
	8	2	8.9	126.6	4	17.8	253.2	18	79.9	1136.4	15	66.6	947.3	40
	9	1	4.4	62.6	4	17.8	253.2	9	40	568.9	24	106.6	1516.2	40
	10	1	4.4	62.6	3	13.3	189.2	20	88.8	1263.0	22	97.7	1389.6	40
	11	3	13.3	189.2	11	48.8	694.1	17	75.5	1073.9	50	222	3157.6	30
	12	1	4.4	62.6	3	13.3	189.2	8	35.5	504.9	13	57.7	820.7	40
	13	1	4.4	62.6	3	13.3	189.2	14	62.2	884.7	26	115.4	1641.4	40
	14	3	13.3	189.2	9	40	568.9	7	31.1	442.3	14	62.2	884.7	40
	15	2	8.9	126.6	7	31.1	442.3	5	22.2	315.8	50	222	3157.6	30
	16	2	8.9	126.6	4	17.8	253.2	16	71	1009.9	21	93.2	1325.6	40
	17	2	8.9	126.6	7	31.1	442.3	8	35.5	504.9	4	17.8	253.2	40
	18	2	8.9	126.6	2	8.9	126.6	9	40	568.9	10	44.4	631.5	40
	19	1	4.4	62.6	3	13.3	189.2	8	35.5	504.9	14	62.2	884.7	40
	20	2	8.9	126.6	8	35.5	504.9	19	84.4	1200.5	50	222	3157.6	30
	21	1	4.4	62.6	2	8.9	126.6	9	40	568.9	28	124.3	1768.0	40
	22	1	4.4	62.6	1	4.4	62.6	4	17.8	253.2	4	17.8	253.2	40
	23	2	8.9	126.6	3	13.3	189.2	6	26.6	378.3	8	35.5	504.9	40
	24	3	13.3	189.2	8	35.5	504.9	13	57.7	820.7	19	84.4	1200.5	35

	25	1	4.4	62.6	2	8.9	126.6	5	22.2	315.8	9	40	568.9	30
	26	3	13.3	189.2	3	13.3	189.2	3	13.3	189.2	8	35.5	504.9	40
	27	4	17.8	253.2	7	31.1	442.3	6	26.6	378.3	15	66.6	947.3	40
	28	3	13.3	189.2	7	31.1	442.3	14	62.2	884.7	17	75.5	1073.9	40
									maximum average penetration depth (cm) =					37.1
Avg =		2.1		135.2	5.7		358.6	10.8		679.0	18.6		1177.4	14.6
Mode =		2			3			9			50			
Std dev =		1.0	4.3	61.4	5.3	23.4	332.3	5.7	25.4	361.0	13.7	60.8	864.7	

Date: First September 2006
Location: Starfire
Weather: Cloudy, Cool
Cell #: Cell #5 (rough grade - uncompacted)

Starfire - cell #5 - struck off - uncompacted

Sample Number (#)	Blows at DEPTH 10 (cm) (#)	Soil Resistance (kg/cm2)	Soil Resistance (psi)	Blows at DEPTH 20 (cm) (#)	Soil Resistance (kg/cm2)	Soil Resistance (psi)	Blows at DEPTH 30 (cm) (#)	Soil Resistance (kg/cm2)	Soil Resistance (psi)	Blows at DEPTH 40 (cm) (#)	Soil Resistance (kg/cm2)	Soil Resistance (psi)	Depth of penetration (cm)
N-values 1	3	13.3	189.2	14	62.2	884.7	26	115.4	1641.4	13	57.7	820.7	35
2	5	22.2	315.8	14	62.2	884.7	22	97.7	1389.6	25	111	1578.8	40
3	6	26.6	378.3	18	79.9	1136.4	21	93.2	1325.6	20	88.8	1263.0	40
4	6	26.6	378.3	15	66.6	947.3	16	71	1009.9	50	222	3157.6	25
5	6	26.6	378.3	14	62.2	884.7	29	128.8	1832.0	27	119.9	1705.4	40
6	6	26.6	378.3	19	84.4	1200.5	25	111	1578.8	50	222	3157.6	35
7	8	35.5	504.9	18	79.9	1136.4	22	97.7	1389.6	21	93.2	1325.6	40
8	5	22.2	315.8	17	75.5	1073.9	21	93.2	1325.6	50	222	3157.6	35
9	6	26.6	378.3	15	66.6	947.3	24	106.6	1516.2	50	222	3157.6	33
10	5	22.2	315.8	15	66.6	947.3	23	102.1	1452.2	19	84.4	1200.5	40
11	8	35.5	504.9	16	71	1009.9	18	79.9	1136.4	22	97.7	1389.6	40
12	5	22.2	315.8	14	62.2	884.7	20	88.8	1263.0	19	84.4	1200.5	35
13	9	40	568.9	23	102.1	1452.2	50	222	3157.6	50	222	3157.6	25
14	9	40	568.9	18	79.9	1136.4	22	97.7	1389.6	23	102.1	1452.2	40
15	5	22.2	315.8	9	40	568.9	17	75.5	1073.9	12	53.3	758.1	40
16	5	22.2	315.8	6	26.6	378.3	6	26.6	378.3	18	79.9	1136.4	40
17	4	17.8	253.2	7	31.1	442.3	15	66.6	947.3	16	71	1009.9	25
18	5	22.2	315.8	11	48.8	694.1	18	79.9	1136.4	19	84.4	1200.5	30
19	7	31.1	442.3	17	75.5	1073.9	21	93.2	1325.6	23	102.1	1452.2	25
20	6	26.6	378.3	17	75.5	1073.9	22	97.7	1389.6	23	102.1	1452.2	40
21	5	22.2	315.8	17	75.5	1073.9	28	124.3	1768.0	50	222	3157.6	20
22	9	40	568.9	15	66.6	947.3	26	115.4	1641.4	50	222	3157.6	20
23	6	26.6	378.3	20	88.8	1263.0	23	102.1	1452.2	30	133.2	1894.5	35
24	6	26.6	378.3	12	53.3	758.1	11	48.8	694.1	21	93.2	1325.6	40

25	5	22.2	315.8	13	57.7	820.7	18	79.9	1136.4	22	97.7	1389.6	40
26	7	31.1	442.3	14	62.2	884.7	19	84.4	1200.5	31	137.6	1957.1	35
27	6	26.6	378.3	12	53.3	758.1	21	93.2	1325.6	23	102.1	1452.2	40
28	10	44.4	631.5	18	79.9	1136.4	20	88.8	1263.0	26	115.4	1641.4	40
								maximum average penetration depth (cm) =					34.8
Avg =	6.2		390.1	14.9		942.9	21.6		1362.1	28.6		1811.0	13.7
Mode =	5			14			22			50			
Std dev =	1.6	7.0	99.3	4.1	18.2	259.4	8.2	36.3	516.0	13.8	61.3	871.3	

Date	First September 2006	Location	Starfire
Weather	Clear	Cell #	Cell #6 (Rough Grade)

Starfire - Cell #6 - struck off

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	8	35.5	504.9	12	53.3	758.1	15	66.6	947.3	24	106.6	1516.2	40
	2	6	26.6	378.3	7	31.1	442.3	11	48.8	694.1	16	71	1009.9	40
	3	5	22.2	315.8	6	26.6	378.3	16	71	1009.9	28	124.4	1769.4	40
	4	8	35.5	504.9	16	71	1009.9	21	93.2	1325.6	27	119.9	1705.4	40
	5	7	31.1	442.3	10	44.4	631.5	24	106.6	1516.2	26	115.4	1641.4	40
	6	5	22.2	315.8	10	44.4	631.5	17	75.5	1073.9	15	66.6	947.3	40
	7	4	17.8	253.2	12	53.3	758.1	18	79.9	1136.4	19	84.4	1200.5	40
	8	4	17.8	253.2	6	26.6	378.3	10	44.4	631.5	50	222	3157.6	35
	9	5	22.2	315.8	13	57.7	820.7	11	48.8	694.1	4	17.8	253.2	40
	10	5	22.2	315.8	10	44.4	631.5	8	35.5	504.9	18	79.9	1136.4	40
	11	4	17.8	253.2	15	66.6	947.3	17	75.5	1073.9	15	66.6	947.3	40
	12	8	35.5	504.9	19	84.4	1200.5	21	93.2	1325.6	18	79.9	1136.4	40
	13	10	44.4	631.5	17	75.5	1073.9	22	97.7	1389.6	50	222	3157.6	30
	14	4	17.8	253.2	11	48.8	694.1	16	71	1009.9	13	57.7	820.7	35
	15	3	13.3	189.2	9	40	568.9	16	71	1009.9	15	66.6	947.3	40
	16	4	17.8	253.2	11	48.8	694.1	19	84.4	1200.5	16	71	1009.9	35
	17	4	17.8	253.2	12	53.3	758.1	20	88.8	1263.0	18	79.9	1136.4	40
	18	6	26.6	378.3	17	75.5	1073.9	22	97.7	1389.6	20	88.8	1263.0	40
	19	5	22.2	315.8	12	53.3	758.1	26	115.4	1641.4	16	71	1009.9	35
	20	7	31.1	442.3	10	44.4	631.5	13	57.7	820.7	15	66.6	947.3	40
	21	9	40	568.9	10	44.4	631.5	28	124.3	1768.0	14	62.2	884.7	35
	22	8	35.5	504.9	17	75.5	1073.9	22	97.7	1389.6	19	84.4	1200.5	40
	23	6	26.6	378.3	19	84.4	1200.5	21	93.2	1325.6	19	84.4	1200.5	40
	24	8	35.5	504.9	22	97.7	1389.6	18	79.9	1136.4	20	88.8	1263.0	35

	25	10	44.4	631.5	8	35.5	504.9	17	75.5	1073.9	24	106.6	1516.2	40
	26	7	31.1	442.3	12	53.3	758.1	16	71	1009.9	15	66.6	947.3	40
	27	3	13.3	189.2	8	35.5	504.9	15	66.6	947.3	21	93.2	1325.6	40
	28	4	17.8	253.2	9	40	568.9	17	75.5	1073.9	18	79.9	1136.4	35
										maximum average penetration depth (cm) =				38.4
Avg =		6.0		376.7	12.1		766.9	17.8		1120.8	20.6		1292.4	15.1
Mode =		4			12			16			15			
Std dev =		1.8	8.2	116.4	3.6	16.0	228.2	4.9	21.6	307.6	11.2	50.0	710.5	

Date	Middle September 2006	Location	Starfire
Weather	Cloudy, Cool	Cell #	Cell #7 (compacted) - Planted 1996

cell 7 - compacted

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	8	35.5	504.9	14	62.2	884.7	21	93.2	1325.6	19	84.4	1200.5	40
	2	4	17.8	253.2	7	31.1	442.3	15	66.6	947.3	29	128.8	1832.0	35
	3	3	13.3	189.2	4	17.8	253.2	33	146.5	2083.7	50	222	3157.6	30
	4	4	17.8	253.2	7	31.1	442.3	8	35.5	504.9	13	57.7	820.7	40
	5	4	17.8	253.2	15	66.6	947.3	14	62.2	884.7	15	66.6	947.3	35
	6	2	8.9	126.6	3	13.3	189.2	7	31.1	442.3	12	53.3	758.1	40
	7	2	8.9	126.6	3	13.3	189.2	5	22.2	315.8	8	35.5	504.9	40
	8	3	13.3	189.2	7	31.1	442.3	11	48.8	694.1	7	31.1	442.3	40
	9	2	8.9	126.6	7	31.1	442.3	9	40	568.9	7	31.1	442.3	40
	10	3	13.3	189.2	7	31.1	442.3	13	57.7	820.7	14	62.2	884.7	35
	11	2	8.9	126.6	3	13.3	189.2	7	31.1	442.3	15	66.6	947.3	40
	12	2	8.9	126.6	6	26.6	378.3	20	88.8	1263.0	13	57.7	820.7	40
	13	3	13.3	189.2	7	31.1	442.3	15	66.6	947.3	17	75.5	1073.9	40
	14	2	8.9	126.6	6	26.6	378.3	16	71	1009.9	16	71	1009.9	40
	15	2	8.9	126.6	13	57.7	820.7	10	44.4	631.5	12	53.3	758.1	40
	16	3	13.3	189.2	9	40	568.9	14	62.2	884.7	15	66.6	947.3	40
	17	2	8.9	126.6	7	31.1	442.3	9	40	568.9	14	62.2	884.7	40
	18	3	13.3	189.2	4	17.8	253.2	8	35.5	504.9	13	57.7	820.7	40
	19	3	13.3	189.2	7	31.1	442.3	7	31.1	442.3	12	53.3	758.1	40
	20	4	17.8	253.2	8	35.5	504.9	10	44.4	631.5	18	79.9	1136.4	40
	21	3	13.3	189.2	10	44.4	631.5	11	48.8	694.1	24	106.6	1516.2	40
	22	3	13.3	189.2	11	48.8	694.1	26	115.4	1641.4	21	93.2	1325.6	35
	23	3	13.3	189.2	5	22.2	315.8	12	53.3	758.1	12	53.3	758.1	35
	24	4	17.8	253.2	5	22.2	315.8	11	48.8	694.1	20	88.8	1263.0	40

	25	2	8.9	126.6	7	31.1	442.3	10	44.4	631.5	11	48.8	694.1	40
	26	2	8.9	126.6	8	35.5	504.9	11	48.8	694.1	12	53.3	758.1	35
	27	2	8.9	126.6	5	22.2	315.8	11	48.8	694.1	14	62.2	884.7	40
	28	3	13.3	189.2	7	31.1	442.3	12	53.3	758.1	16	71	1009.9	40
									maximum average penetration depth (cm) =					38.6
Avg =		3.0		187.3	7.2		455.7	12.7		802.9	16.0		1012.8	15.2
Mode =		2			7			7			13			
Std dev =		1.4	6.2	88.0	3.4	15.2	215.5	6.5	28.9	410.9	9.3	41.4	588.7	

Date: End September 2006
Weather: Clear
Location: Starfire - Planted 1996
Cell #: Cell #8 (compacted)

cell 8 - compacted

	Sample Number (#)	Blows at DEPTH 10 (cm) (#)	Soil Resistance (kg/cm2)	Soil Resistance (psi)	Blows at DEPTH 20 (cm) (#)	Soil Resistance (kg/cm2)	Soil Resistance (psi)	Blows at DEPTH 30 (cm) (#)	Soil Resistance (kg/cm2)	Soil Resistance (psi)	Blows at DEPTH 40 (cm) (#)	Soil Resistance (kg/cm2)	Soil Resistance (psi)	Depth of penetration (cm)
N-values	1	6	26.6	378.3	16	71	1009.9	27	119.9	1705.4	24	106.6	1516.2	40
	2	6	26.6	378.3	18	79.9	1136.4	40	177.6	2526.1	34	151	2147.7	40
	3	6	26.6	378.3	16	71	1009.9	21	93.2	1325.6	48	213.1	3031.0	40
	4	7	31.1	442.3	18	79.9	1136.4	32	142.1	2021.1	29	128.8	1832.0	40
	5	6	26.6	378.3	9	40	568.9	11	48.8	694.1	10	44.4	631.5	40
	6	4	17.8	253.2	12	53.3	758.1	14	62.2	884.7	16	71	1009.9	40
	7	2	8.9	126.6	8	35.5	504.9	10	44.4	631.5	11	48.8	694.1	40
	8	2	8.9	126.6	5	22.2	315.8	7	31.1	442.3	16	71	1009.9	40
	9	2	8.9	126.6	3	13.3	189.2	7	31.1	442.3	18	79.9	1136.4	40
	10	3	13.3	189.2	6	26.6	378.3	11	48.8	694.1	13	57.7	820.7	40
	11	4	17.8	253.2	9	40	568.9	14	62.2	884.7	17	75.5	1073.9	40
	12	4	17.8	253.2	6	26.6	378.3	10	44.4	631.5	15	66.6	947.3	40
	13	4	17.8	253.2	14	62.2	884.7	21	93.2	1325.6	20	88.8	1263.0	40
	14	4	17.8	253.2	19	84.4	1200.5	26	115.4	1641.4	36	159.8	2272.9	40
	15	2	8.9	126.6	15	66.6	947.3	50	222	3157.6	50	222	3157.6	25
	16	3	13.3	189.2	10	44.4	631.5	22	97.7	1389.6	50	222	3157.6	30
	17	3	13.3	189.2	12	53.3	758.1	23	102.1	1452.2	13	57.7	820.7	40
	18	4	17.8	253.2	6	26.6	378.3	20	88.8	1263.0	50	222	3157.6	35
	19	3	13.3	189.2	12	53.3	758.1	20	88.8	1263.0	25	111	1578.8	40
	20	4	17.8	253.2	20	88.8	1263.0	24	106.6	1516.2	50	222	3157.6	30
	21	4	17.8	253.2	12	53.3	758.1	50	222	3157.6	50	222	3157.6	20
	22	6	26.6	378.3	20	88.8	1263.0	50	222	3157.6	50	222	3157.6	20
	23	6	26.6	378.3	17	75.5	1073.9	50	222	3157.6	50	222	3157.6	20
	24	2	8.9	126.6	7	31.1	442.3	20	88.8	1263.0	11	48.8	694.1	40

	25	5	22.2	315.8	11	48.8	694.1	20	88.8	1263.0	20	88.8	1263.0	40
	26	6	26.6	378.3	19	84.4	1200.5	25	111	1578.8	50	222	3157.6	35
	27	4	17.8	253.2	10	44.4	631.5	18	79.9	1136.4	15	66.6	947.3	40
	28	4	17.8	253.2	13	57.7	820.7	17	75.5	1073.9	19	84.4	1200.5	40
									maximum average penetration depth (cm) =					36.3
Avg =		4.1		261.7	12.3		773.6	20.5		1488.6	27.3		1826.8	14.3
Mode =		4			12			21			50			
Std dev =		1.5	6.8	97.0	5.2	22.9	325.4	11.1	49.1	698.9	15.0	66.5	945.2	

Date First October 2006 Location Starfire - Planted 1996
Weather Clear Cell # Cell #9 (compacted)

cell 9 - compacted

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	6	26.6	378.3	9	40	568.9	15	66.6	947.3	8	35.5	504.9	40
	2	4	17.8	253.2	12	53.3	758.1	15	66.6	947.3	16	71	1009.9	40
	3	2	8.9	126.6	7	31.1	442.3	7	31.1	442.3	18	79.9	1136.4	40
	4	3	13.3	189.2	12	53.3	758.1	16	71	1009.9	50	222	3157.6	20
	5	5	22.2	315.8	8	35.5	504.9	10	44.4	631.5	13	57.7	820.7	40
	6	2	8.9	126.6	4	17.8	253.2	12	53.3	758.1	13	57.7	820.7	40
	7	2	8.9	126.6	4	17.8	253.2	15	66.6	947.3	15	66.6	947.3	40
	8	2	8.9	126.6	5	22.2	315.8	8	35.5	504.9	12	53.3	758.1	40
	9	3	13.3	189.2	5	22.2	315.8	9	40	568.9	16	71	1009.9	40
	10	3	13.3	189.2	10	44.4	631.5	22	97.7	1389.6	50	222	3157.6	35
	11	3	13.3	189.2	7	31.1	442.3	5	22.2	315.8	6	26.6	378.3	40
	12	2	8.9	126.6	4	17.8	253.2	9	40	568.9	9	40	568.9	40
	13	2	8.9	126.6	5	22.2	315.8	18	79.9	1136.4	11	48.8	694.1	40
	14	2	8.9	126.6	6	26.6	378.3	8	35.5	504.9	17	75.5	1073.9	40
	15	2	8.9	126.6	6	26.6	378.3	9	40	568.9	9	40	568.9	40
	16	3	13.3	189.2	8	35.5	504.9	6	26.6	378.3	50	222	3157.6	35
	17	3	13.3	189.2	9	40	568.9	9	40	568.9	14	62.2	884.7	40
	18	4	17.8	253.2	5	22.2	315.8	7	31.1	442.3	8	35.5	504.9	40
	19	2	8.9	126.6	6	26.6	378.3	10	44.4	631.5	15	66.6	947.3	40
	20	2	8.9	126.6	7	31.1	442.3	16	71	1009.9	9	40	568.9	40
	21	2	8.9	126.6	6	26.6	378.3	23	101.1	1438.0	50	222	3157.6	20
	22	6	26.6	378.3	10	44.4	631.5	16	71	1009.9	20	88.8	1263.0	40
	23	3	13.3	189.2	8	35.5	504.9	13	57.7	820.7	19	84.4	1200.5	40
	24	4	17.8	253.2	12	53.3	758.1	50	222	3157.6	50	222	3157.6	20

	25	2	8.9	126.6	6	26.6	378.3	50	222	3157.6	50	222	3157.6	20
	26	4	17.8	253.2	9	40	568.9	13	57.7	820.7	18	79.9	1136.4	40
	27	6	26.6	378.3	10	44.4	631.5	15	66.6	947.3	20	88.8	1263.0	40
	28	3	13.3	189.2	9	40	568.9	50	222	3157.6	50	222	3157.6	20
									maximum average penetration depth (cm) =					36.1
Avg =		3.1		196.3	7.5		471.5	11.3		1027.9	18.0		1434.4	14.2
Mode =		2			5			9			50			
Std dev =		1.1	5.0	71.6	2.5	10.9	155.4	4.6	20.3	288.3	14.2	63.1	897.4	

Date: Jun-07
Weather: Clear
Location: Starfire
Cell #: Cell #1, Struck off

Starfire - Cell #1 - stuck off

Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values													
1	4	17.8	253.2	25	111	1578.8	50	222	3157.6	50	222	3157.6	20
2	3	13.3	189.2	20	88.8	1263.0	16	71	1009.9	24	106.6	1516.2	40
3	3	13.3	189.2	18	79.9	1136.4	21	93.2	1325.6	50	222	3157.6	35
4	5	22.2	315.8	10	44.4	631.5	21	93.2	1325.6	32	142.1	2021.1	40
5	3	13.3	189.2	7	31.1	442.3	15	66.6	947.3	10	44.4	631.5	40
6	4	17.8	253.2	16	71	1009.9	21	93.2	1325.6	20	88.8	1263.0	40
7	3	13.3	189.2	8	35.5	504.9	18	79.9	1136.4	36	159.8	2272.9	40
8	3	13.3	189.2	6	26.6	378.3	13	57.7	820.7	31	137.6	1957.1	40
9	4	17.8	253.2	9	40	568.9	18	79.9	1136.4	37	164.3	2336.9	40
10	3	13.3	189.2	8	35.5	504.9	25	111	1578.8	48	213.1	3031.0	40
11	3	13.3	189.2	7	31.1	442.3	13	57.7	820.7	27	119.9	1705.4	40
12	2	8.9	126.6	8	35.5	504.9	6	26.6	378.3	8	35.5	504.9	40
13	3	13.3	189.2	6	26.6	378.3	11	48.8	694.1	14	62.2	884.7	40
14	4	17.8	253.2	24	106.6	1516.2	12	53.3	758.1	14	62.2	884.7	40
15	5	22.2	315.8	11	48.8	694.1	12	53.3	758.1	19	84.4	1200.5	40
16	4	17.8	253.2	6	26.6	378.3	50	222	3157.6	50	222	3157.6	25
17	5	22.2	315.8	10	44.4	631.5	21	93.2	1325.6	50	222	3157.6	32.5
18	6	26.6	378.3	15	66.6	947.3	18	79.9	1136.4	15	66.6	947.3	40
19	3	13.3	189.2	12	53.3	758.1	23	102.1	1452.2	21	93.2	1325.6	40
20	3	13.3	189.2	16	71	1009.9	28	124.3	1768.0	42	186.5	2652.7	40
21	3	13.3	189.2	8	35.5	504.9	12	53.3	758.1	47	208.7	2968.4	40
22	4	17.8	253.2	12	53.3	758.1	25	111	1578.8	50	222	3157.6	35
23	3	13.3	189.2	6	26.6	378.3	12	53.3	758.1	21	93.2	1325.6	40
24	3	13.3	189.2	6	26.6	378.3	13	57.7	820.7	21	93.2	1325.6	40

25	3	13.3	189.2	4	17.8	253.2	9	40	568.9	25	111	1578.8	40
26	4	17.8	253.2	7	31.1	442.3	10	44.4	631.5	14	62.2	884.7	40
27	4	17.8	253.2	16	71	1009.9	23	102.1	1452.2	32	142.1	2021.1	40
28	5	22.2	315.8	12	53.3	758.1	16	71	1009.9	25	111	1578.8	40
								maximum average penetration depth (cm) =					38.1
Avg =	3.6		230.1	11.2		705.8	19.0		1199.7	29.8		1878.8	15.0
Mode =	3			8			21			50			
Std dev =	1.0	4.4	62.5	6.0	26.5	377.3	11.4	50.4	717.3	14.7	65.4	930.5	

Date	Jun-07	Location	Starfire
Weather	Clear	Cell #	Cell #2 (uncompacted)

Starfire Cell #2 - loose dumped

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	8	35.5	504.9	30	133.2	1894.5	15	66.6	947.3	50	222	3157.6	35
	2	4	17.8	253.2	7	31.1	442.3	11	48.8	694.1	7	31.1	442.3	40
	3	6	26.6	378.3	21	93.2	1325.6	16	71	1009.9	19	84.4	1200.5	40
	4	5	22.2	315.8	19	84.4	1200.5	21	93.2	1325.6	32	142.1	2021.1	40
	5	6	26.6	378.3	12	53.3	758.1	15	66.6	947.3	24	106.6	1516.2	40
	6	7	31.1	442.3	19	84.4	1200.5	31	137.6	1957.1	38	168.7	2399.5	40
	7	11	48.8	694.1	24	106.6	1516.2	27	119.9	1705.4	50	222	3157.6	32
	8	10	44.4	631.5	25	111	1578.8	33	146.5	2083.7	36	159.8	2272.9	40
	9	14	62.2	884.7	16	71	1009.9	23	102.1	1452.2	39	173.6	2469.2	40
	10	6	26.6	378.3	15	66.6	947.3	20	88.8	1263.0	22	97.7	1389.6	40
	11	4	17.8	253.2	10	44.4	631.5	8	35.5	504.9	12	53.3	758.1	40
	12	3	13.3	189.2	13	57.7	820.7	19	84.4	1200.5	50	222	3157.6	31
	13	3	13.3	189.2	13	57.7	820.7	16	71	1009.9	25	111	1578.8	40
	14	5	22.2	315.8	5	22.2	315.8	9	40	568.9	24	106.6	1516.2	40
	15	5	22.2	315.8	13	57.7	820.7	21	93.2	1325.6	28	124.3	1768.0	40
	16	7	31.1	442.3	17	75.5	1073.9	23	102.1	1452.2	31	137.6	1957.1	40
	17	3	13.3	189.2	8	35.5	504.9	5	22.2	315.8	20	88.8	1263.0	40
	18	4	17.8	253.2	7	31.1	442.3	8	35.5	504.9	8	35.5	504.9	40
	19	3	13.3	189.2	13	57.7	820.7	14	62.2	884.7	10	44.4	631.5	40
	20	6	26.6	378.3	18	79.9	1136.4	17	75.5	1073.9	28	124.3	1768.0	40
	21	5	22.2	315.8	15	66.6	947.3	16	71	1009.9	26	115.4	1641.4	40
	22	3	13.3	189.2	11	48.8	694.1	15	66.6	947.3	20	88.8	1263.0	40
	23	5	22.2	315.8	10	44.4	631.5	17	75.5	1073.9	19	84.4	1200.5	40
	24	3	13.3	189.2	9	40	568.9	13	57.7	820.7	24	106.6	1516.2	40

25	5	22.2	315.8	8	35.5	504.9	9	40	568.9	11	48.8	694.1	40
26	5	22.2	315.8	16	71	1009.9	17	75.5	1073.9	28	124.3	1768.0	40
27	6	26.6	378.3	3	13.3	189.2	7	31.1	442.3	9	40	568.9	40
28	5	22.2	315.8	10	44.4	631.5	17	75.5	1073.9	50	222	3157.6	32.5
29	6	26.6	378.3	8	35.5	504.9	13	57.7	820.7	24	106.6	1516.2	40
30	4	17.8	253.2	15	66.6	947.3	17	75.5	1073.9	35	222	3157.6	40
31	6	26.6	378.3	27	119.9	1705.4	27	119.9	1705.4	50	222	3157.6	32.5
32	5	22.2	315.8	13	57.7	820.7	50	222	3157.6	50	222	3157.6	20
								maximum average penetration depth (cm) =					38.2
Avg =	5.6		351.2	14.1		888.0	17.8		1124.8	28.1		1804.0	15.0
Mode =	6			13			15			50			
Std dev =	2.9	13.0	184.4	6.5	29.1	413.3	7.6	33.6	477.5	13.4	59.4	845.3	

Date	Jun-07	Location	Starfire
Weather	Clear	Cell #	Cell #3 (uncompacted)

Starfire Cell #3 - loose dumped

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	6	26.6	378.3	14	62.2	884.7	16	71	1009.9	9	40	568.9	40
	2	2	8.9	126.6	3	13.3	189.2	8	35.5	504.9	4	17.8	253.2	40
	3	4	17.8	253.2	14	62.2	884.7	18	79.9	1136.4	50	222	3157.6	35
	4	8	35.5	504.9	14	62.2	884.7	15	66.6	947.3	10	44.4	631.5	40
	5	8	35.5	504.9	16	71	1009.9	20	88.8	1263.0	24	106.6	1516.2	40
	6	3	13.3	189.2	5	22.2	315.8	8	35.5	504.9	10	44.4	631.5	40
	7	7	31.1	442.3	17	75.5	1073.9	13	57.7	820.7	5	22.2	315.8	40
	8	8	35.5	504.9	12	53.3	758.1	17	75.5	1073.9	19	84.4	1200.5	40
	9	5	22.2	315.8	5	22.2	315.8	7	31.1	442.3	15	66.6	947.3	40
	10	7	31.1	442.3	13	57.7	820.7	17	75.5	1073.9	14	62.2	884.7	40
	11	7	31.1	442.3	12	53.3	758.1	12	53.3	758.1	14	62.2	884.7	40
	12	6	26.6	378.3	13	57.7	820.7	12	53.3	758.1	17	75.5	1073.9	40
	13	3	13.3	189.2	6	26.6	378.3	6	26.6	378.3	7	31.1	442.3	40
	14	7	31.1	442.3	10	44.4	631.5	15	66.6	947.3	26	115.4	1641.4	40
	15	8	35.5	504.9	15	66.6	947.3	22	97.7	1389.6	27	119.9	1705.4	40
	16	4	17.8	253.2	3	13.3	189.2	2	8.9	126.6	4	17.8	253.2	40
	17	3	13.3	189.2	5	22.2	315.8	9	40	568.9	14	62.2	884.7	40
	18	9	40	568.9	13	57.7	820.7	18	79.9	1136.4	25	111	1578.8	40
	19	3	13.3	189.2	16	71	1009.9	50	222	3157.6	50	222	3157.6	25
	20	2	8.9	126.6	13	57.7	820.7	15	66.6	947.3	20	88.8	1263.0	40
	21	4	17.8	253.2	13	57.7	820.7	15	66.6	947.3	24	106.6	1516.2	40
	22	9	40	568.9	22	97.7	1389.6	11	48.8	694.1	50	222	3157.6	35
	23	7	31.1	442.3	17	75.5	1073.9	18	79.9	1136.4	28	124.3	1768.0	40
	24	7	31.1	442.3	21	93.2	1325.6	24	106.6	1516.2	26	115.4	1641.4	40

25	3	13.3	189.2	6	26.6	378.3	8	35.5	504.9	13	57.7	820.7	40
26	6	26.6	378.3	10	44.4	631.5	15	66.6	947.3	24	106.6	1516.2	40
27	6	26.6	378.3	11	48.8	694.1	13	57.7	820.7	26	115.4	1641.4	40
28	5	22.2	315.8	3	13.3	189.2	14	62.2	884.7	50	222	3157.6	31
29	5	22.2	315.8	7	31.1	442.3	9	40	568.9	4	17.8	253.2	40
30	5	22.2	315.8	6	26.6	378.3	4	17.8	253.2	7	31.1	442.3	40
31	2	8.9	126.6	4	17.8	253.2	5	22.2	315.8	4	17.8	253.2	40
32	9	40	568.9	2	8.9	126.6	19	84.4	1200.5	11	48.8	694.1	40
								maximum average penetration depth (cm) =					38.9
Avg =	5.6		351.3	10.7		672.9	14.2		898.0	19.7		1245.4	15.3
Mode =	8			13			15			14			
Std dev =	2.3	10.2	145.6	4.6	20.6	293.1	9.7	43.2	614.0	13.0	57.9	823.4	

Date Jun-07 Location Starfire

Weather Clear Cell # Cell #4 (rough grade)

Starfire Cell #4 loose dumped

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	5	22.2	315.8	10	44.4	631.5	21	93.2	1325.6	19	84.4	1200.5	40
	2	7	31.1	442.3	17	75.5	1073.9	19	84.4	1200.5	26	115.4	1641.4	40
	3	5	22.2	315.8	11	48.8	694.1	27	119.9	1705.4	14	62.2	884.7	40
	4	11	48.8	694.1	15	66.6	947.3	25	111	1578.8	16	71	1009.9	40
	5	8	35.5	504.9	34	151	2147.7	38	168.7	2399.5	50	222	3157.6	31
	6	6	26.6	378.3	20	88.8	1263.0	32	142.1	2021.1	10	44.4	631.5	40
	7	10	44.4	631.5	18	79.9	1136.4	16	71	1009.9	15	66.6	947.3	40
	8	6	26.6	378.3	8	35.5	504.9	8	35.5	504.9	26	115.4	1641.4	40
	9	9	40	568.9	18	79.9	1136.4	21	93.2	1325.6	24	106.6	1516.2	40
	10	9	40	568.9	18	79.9	1136.4	25	111	1578.8	32	142.1	2021.1	40
	11	6	26.6	378.3	20	88.8	1263.0	24	106.6	1516.2	34	151	2147.7	40
	12	7	31.1	442.3	11	48.8	694.1	17	75.5	1073.9	28	124.3	1768.0	40
	13	5	22.2	315.8	11	48.8	694.1	25	111	1578.8	22	97.7	1389.6	40
	14	4	17.8	253.2	27	119.9	1705.4	50	222	3157.6	50	222	3157.6	24
	15	6	26.6	378.3	10	44.4	631.5	26	115.4	1641.4	38	168.7	2399.5	40
	16	15	66.6	947.3	18	79.9	1136.4	34	151	2147.7	50	222	3157.6	35
	17	8	35.5	504.9	13	57.7	820.7	50	222	3157.6	50	222	3157.6	25
	18	6	26.6	378.3	12	53.3	758.1	12	53.3	758.1	27	119.9	1705.4	40
	19	7	31.1	442.3	19	84.4	1200.5	14	62.2	884.7	14	62.2	884.7	40
	20	5	22.2	315.8	8	35.5	504.9	11	48.8	694.1	10	44.4	631.5	40
	21	5	22.2	315.8	14	62.2	884.7	19	84.4	1200.5	31	137.6	1957.1	40
	22	5	22.2	315.8	8	35.5	504.9	22	97.7	1389.6	24	106.6	1516.2	40
	23	6	26.6	378.3	18	79.9	1136.4	15	66.6	947.3	43	190.9	2715.2	40
	24	6	26.6	378.3	9	40	568.9	24	106.6	1516.2	31	137.6	1957.1	40

25	8	35.5	504.9	10	44.4	631.5	50	222	3157.6	50	222	3157.6	22
26	7	31.1	442.3	11	48.8	694.1	16	71	1009.9	24	106.6	1516.2	40
27	3	13.3	189.2	6	26.6	378.3	10	44.4	631.5	7	31.1	442.3	40
28	4	17.8	253.2	12	53.3	758.1	20	88.8	1263.0	26	115.4	1641.4	40
29	8	35.5	504.9	16	71	1009.9	50	222	3157.6	50	222	3157.6	25
30	3	13.3	189.2	10	44.4	631.5	19	84.4	1200.5	28	124.3	1768.0	40
31	4	17.8	253.2	11	48.8	694.1	6	26.6	378.3	4	17.8	253.2	40
32	5	22.2	315.8	18	35.5	504.9	12	53.3	758.1	5	22.2	315.8	40
										maximum average penetration depth (cm) =			37.6
Avg =	6.5		412.4	14.4		889.9	23.7		1495.9	27.4		1732.8	14.8
Mode =	5			18			25			50			
Std dev =	2.6	11.5	163.8	6.5	28.9	411.0	11.6	51.4	730.5	13.7	61.0	867.0	

Date Jun-07 | Location Starfire

Weather Clear | Cell # Cell #5 (rough grade - uncompacted)

Starfire - cell #5 - struck off - uncompacted

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	16	71	1009.9	30	133.2	1894.5	26	115.4	1641.4	36	159.8	2272.9	40
	2	8	35.5	504.9	17	75.5	1073.9	14	62.2	884.7	31	137.6	1957.1	40
	3	4	17.8	253.2	15	66.6	947.3	20	88.8	1263.0	24	106.6	1516.2	40
	4	7	31.1	442.3	18	79.9	1136.4	50	222	3157.6	50	222	3157.6	22.5
	5	7	31.1	442.3	22	97.7	1389.6	16	71	1009.9	50	222	3157.6	35
	6	5	22.2	315.8	25	111	1578.8	27	119.9	1705.4	18	79.9	1136.4	40
	7	2	8.9	126.6	12	53.3	758.1	19	84.4	1200.5	24	106.6	1516.2	40
	8	7	31.1	442.3	50	222	3157.6	50	222	3157.6	50	222	3157.6	18
	9	8	35.5	504.9	17	75.5	1073.9	35	155.4	2210.3	26	115.4	1641.4	40
	10	8	35.5	504.9	17	75.5	1073.9	34	151	2147.7	50	222	3157.6	36
	11	7	31.1	442.3	19	84.4	1200.5	50	222	3157.6	50	222	3157.6	25
	12	11	48.8	694.1	28	124.3	1768.0	17	75.5	1073.9	22	97.7	1389.6	40
	13	12	53.3	758.1	17	75.5	1073.9	50	222	3157.6	50	222	3157.6	21
	14	12	53.3	758.1	50	222	3157.6	50	222	3157.6	50	222	3157.6	17.5
	15	8	35.5	504.9	10	44.4	631.5	15	66.6	947.3	21	93.2	1325.6	40
	16	9	40	568.9	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
	17	14	62.2	884.7	22	97.7	1389.6	19	84.4	1200.5	50	222	3157.6	31
	18	9	40	568.9	18	79.9	1136.4	50	222	3157.6	50	222	3157.6	28
	19	12	53.3	758.1	49	217.6	3095.0	50	222	3157.6	50	222	3157.6	20
	20	8	35.5	504.9	20	88.8	1263.0	3	13.3	189.2	50	222	3157.6	35
	21	11	48.8	694.1	25	111	1578.8	20	88.8	1263.0	28	124.3	1768.0	40
	22	4	17.8	253.2	15	66.6	947.3	19	84.4	1200.5	18	79.9	1136.4	40
	23	10	44.4	631.5	14	62.2	884.7	26	115.4	1641.4	17	75.5	1073.9	40
	24	2	8.9	126.6	15	66.6	947.3	22	97.7	1389.6	50	222	3157.6	32.5

	25	5	22.2	315.8	12	53.3	758.1	50	222	3157.6	50	222	3157.6	28
	26	12	53.3	758.1	12	53.3	758.1	50	222	3157.6	50	222	3157.6	25
	27	3	13.3	189.2	12	53.3	758.1	10	44.4	631.5	20	88.8	1263.0	40
	28	7	31.1	442.3	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
									maximum average penetration depth (cm) =					31.6
Avg =		8.1		514.3	23.6		1491.0	31.9		2011.9	38.8		2447.1	12.4
Mode =		8			17			50			50			
Std dev =		3.4	14.9	212.0	13.4	59.5	846.0	16.4	72.6	1032.8	12.9	57.4	816.2	

Date	Jun-07	Location	Starfire
Weather	Clear	Cell #	Cell #6 (Rough Grade)

Starfire - Cell #6 - struck off

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	7	31.1	442.3	26	115.4	1641.4	31	137.6	1957.1	50	222	3157.6	32
	2	6	26.6	378.3	28	124.3	1768.0	50	222	3157.6	50	222	3157.6	25
	3	10	44.4	631.5	15	66.6	947.3	23	102.1	1452.2	30	133.2	1894.5	40
	4	8	35.5	504.9	37	164.3	2336.9	50	222	3157.6	50	222	3157.6	31
	5	2	8.9	126.6	27	119.9	1705.4	34	151	2147.7	40	177.6	2526.1	40
	6	7	31.1	442.3	36	159.8	2272.9	45	199.8	2841.8	50	222	3157.6	30
	7	9	40	568.9	50	222	3157.6	50	222	3157.6	50	222	3157.6	12.5
	8	2	8.9	126.6	5	22.2	315.8	14	62.2	884.7	13	57.7	820.7	40
	9	4	17.8	253.2	8	35.5	504.9	30	133.2	1894.5	43	190.9	2715.2	40
	10	6	26.6	378.3	29	128.8	1832.0	50	222	3157.6	50	222	3157.6	25
	11	3	13.3	189.2	5	22.2	315.8	5	22.2	315.8	15	66.6	947.3	40
	12	6	26.6	378.3	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
	13	9	40	568.9	32	142.1	2021.1	29	128.8	1832.0	50	222	3157.6	32.5
	14	4	17.8	253.2	8	35.5	504.9	35	155.4	2210.3	50	222	3157.6	36
	15	9	40	568.9	30	133.2	1894.5	50	222	3157.6	50	222	3157.6	20
	16	5	22.2	315.8	18	79.9	1136.4	50	222	3157.6	50	222	3157.6	22.5
	17	5	22.2	315.8	24	106.6	1516.2	50	222	3157.6	50	222	3157.6	25
	18	9	40	568.9	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
	19	13	57.7	820.7	33	146.5	2083.7	20	88.8	1263.0	50	222	3157.6	35
	20	10	44.4	631.5	27	119.9	1705.4	49	217.6	3095.0	50	222	3157.6	30
	21	6	26.6	378.3	23	102.1	1452.2	34	151	2147.7	38	168.7	2399.5	40
	22	13	57.7	820.7	35	155.4	2210.3	50	222	3157.6	50	222	3157.6	25
	23	9	40	568.9	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
	24	8	35.5	504.9	25	111	1578.8	50	222	3157.6	50	222	3157.6	20

	25	12	53.3	758.1	24	106.6	1516.2	50	222	3157.6	50	222	3157.6	20
	26	11	48.8	694.1	32	142.1	2021.1	50	222	3157.6	50	222	3157.6	25
	27	12	53.3	758.1	49	217.6	3095.0	50	222	3157.6	50	222	3157.6	20
	28	7	31.1	442.3	22	97.7	1389.6	41	182	2588.6	50	222	3157.6	30
									maximum average penetration depth (cm) =					36.5
Avg =		7.6		478.2	28.5		1799.9	40.7		2571.2	45.7		2884.6	14.4
Mode =		9			50			50			50			
Std dev =		2.9	13.1	185.6	14.1	62.5	889.3	14.3	63.6	904.5	11.6	51.4	731.5	

Date	Jun-07
Weather	Clear
Location	Starfire
Cell #	Cell #7 (compacted) - Planted 1996

cell 7 - compacted

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	11	48.8	694.1	39	173.6	2469.2	50	222	3157.6	50	222	3157.6	22
	2	11	48.8	694.1	32	142.1	2021.1	50	222	3157.6	50	222	3157.6	22
	3	9	40	568.9	34	151	2147.7	50	222	3157.6	50	222	3157.6	27.5
	4	8	35.5	504.9	47	208.7	2968.4	50	222	3157.6	50	222	3157.6	2
	5	11	48.8	694.1	33	146.5	2083.7	50	222	3157.6	50	222	3157.6	25
	6	10	44.4	631.5	16	71	1009.9	50	222	3157.6	50	222	3157.6	25
	7	9	40	568.9	28	124.3	1768.0	48	213.1	3031.0	50	222	3157.6	30
	8	6	26.6	378.3	17	75.5	1073.9	46	204.2	2904.4	50	222	3157.6	30
	9	12	53.3	758.1	37	164.3	2336.9	50	222	3157.6	50	222	3157.6	27.5
	10	8	35.5	504.9	22	97.7	1389.6	50	222	3157.6	50	222	3157.6	20
	11	8	35.5	504.9	19	84.4	1200.5	49	217.6	3095.0	38	168.7	2399.5	40
	12	11	48.8	694.1	23	102.1	1452.2	50	222	3157.6	50	222	3157.6	26
	13	8	35.5	504.9	25	111	1578.8	50	222	3157.6	50	222	3157.6	25
	14	8	35.5	504.9	32	142.1	2021.1	50	222	3157.6	50	222	3157.6	24
	15	12	53.3	758.1	39	173.6	2469.2	50	222	3157.6	50	222	3157.6	22.5
	16	11	48.8	694.1	39	173.6	2469.2	50	222	3157.6	50	222	3157.6	20
	17	12	53.3	758.1	26	115.4	1641.4	50	222	3157.6	50	222	3157.6	24
	18	9	40	568.9	33	146.5	2083.7	50	222	3157.6	50	222	3157.6	27.5
	19	11	48.8	694.1	18	79.9	1136.4	39	173.6	2469.2	50	222	3157.6	30
	20	8	35.5	504.9	35	155.4	2210.3	50	222	3157.6	50	222	3157.6	25
	21	8	35.5	504.9	27	119.9	1705.4	50	222	3157.6	50	222	3157.6	27
	22	8	35.5	504.9	30	133.2	1894.5	50	222	3157.6	50	222	3157.6	24
	23	10	44.4	631.5	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
	24	4	17.8	253.2	22	97.7	1389.6	34	151	2147.7	50	222	3157.6	32

	25	7	31.1	442.3	24	106.6	1516.2	50	222	3157.6	50	222	3157.6	26
	26	4	17.8	253.2	8	35.5	504.9	7	31.1	442.3	50	222	3157.6	38
	27	5	22.2	315.8	19	84.4	1200.5	22	97.7	1389.6	25	111	1578.8	40
	28	9	40	568.9	20	88.8	1263.0	50	222	3157.6	50	222	3157.6	25
									maximum average penetration depth (cm) =					25.8
Avg =		8.9		559.3	28.4		1791.5	46.3		2921.0	48.7		3074.1	10.2
Mode =		11			39			50			50			
Std dev =		1.8	7.8	110.9	8.7	38.7	549.8	2.6	11.3	161.2	2.7	11.9	169.5	

Date	Jun-07	Location	Starfire - Planted 1996
Weather	Clear	Cell #	Cell #8 (compacted)

cell 8 - compacted

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	9	40	568.9	35	155.4	2210.3	50	222	3157.6	50	222	3157.6	22
	2	8	35.5	504.9	24	106.6	1516.2	50	222	3157.6	50	222	3157.6	30
	3	9	40	568.9	19	84.4	1200.5	50	222	3157.6	50	222	3157.6	25
	4	13	57.7	820.7	23	102.1	1452.2	45	199.8	2841.8	50	222	3157.6	32
	5	10	44.4	631.5	50	222	3157.6	50	222	3157.6	50	222	3157.6	17
	6	4	17.8	253.2	40	177.6	2526.1	39	173.6	2469.2	50	222	3157.6	33
	7	7	31.1	442.3	50	222	3157.6	50	222	3157.6	50	222	3157.6	16
	8	11	48.8	694.1	29	128.8	1832.0	42	186.5	2652.7	33	146.5	2083.7	40
	9	8	35.5	504.9	30	133.2	1894.5	35	155.4	2210.3	50	222	3157.6	32
	10	10	44.4	631.5	36	159.8	2272.9	31	137.6	1957.1	50	222	3157.6	30
	11	10	44.4	631.5	18	79.9	1136.4	30	133.2	1894.5	50	222	3157.6	35
	12	8	35.5	504.9	27	119.9	1705.4	42	186.5	2652.7	50	222	3157.6	31
	13	10	44.4	631.5	50	222	3157.6	50	222	3157.6	50	222	3157.6	14
	14	8	35.5	504.9	39	173.6	2469.2	50	222	3157.6	50	222	3157.6	21
	15	9	40	568.9	28	124.3	1768.0	39	173.6	2469.2	50	222	3157.6	31
	16	8	35.5	504.9	40	177.6	2526.1	50	222	3157.6	50	222	3157.6	25
	17	15	66.6	947.3	50	222	3157.6	50	222	3157.6	50	222	3157.6	10
	18	9	40	568.9	50	222	3157.6	50	222	3157.6	50	222	3157.6	19
	19	8	35.5	504.9	21	93.2	1325.6	31	137.6	1957.1	50	222	3157.6	32
	20	10	44.4	631.5	37	164.3	2336.9	50	222	3157.6	50	222	3157.6	21
	21	11	48.8	694.1	29	128.8	1832.0	50	222	3157.6	50	222	3157.6	25
	22	9	40	568.9	22	97.7	1389.6	50	222	3157.6	50	222	3157.6	26
	23	8	35.5	504.9	29	128.8	1832.0	50	222	3157.6	50	222	3157.6	23
	24	11	48.8	694.1	23	102.1	1452.2	22	97.7	1389.6	30	133.2	1894.5	40

	25	13	57.7	820.7	32	142.1	2021.1	50	222	3157.6	50	222	3157.6	22
	26	9	40	568.9	29	128.8	1832.0	50	222	3157.6	50	222	3157.6	26
	27	13	57.7	820.7	30	133.2	1894.5	38	168.7	2399.5	50	222	3157.6	32
	28	13	57.7	820.7	49	217.6	3095.0	50	222	3157.6	50	222	3157.6	20
									maximum average penetration depth (cm) =					26.1
Avg =		9.7		611.2	33.5		2118.2	44.4		2806.2	48.7		3074.1	10.3
Mode =		8			50			50			50			
Std dev =		2.2	9.9	141.3	11.2	49.7	706.2	7.5	33.3	473.4	3.8	16.9	240.1	

Date	Jun-07	Location	Starfire - Planted 1996
Weather	Clear	Cell #	Cell #9 (compacted)

cell 9 - compacted

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	6	26.6	378.3	24	106.6	1516.2	50	222	3157.6	50	222	3157.6	25
	2	9	40	568.9	18	79.9	1136.4	50	222	3157.6	50	222	3157.6	25
	3	10	44.4	631.5	50	222	3157.6	50	222	3157.6	50	222	3157.6	18
	4	8	35.5	504.9	23	102.1	1452.2	50	222	3157.6	50	222	3157.6	26
	5	9	40	568.9	16	71	1009.9	50	222	3157.6	50	222	3157.6	28
	6	15	66.6	947.3	50	222	3157.6	50	222	3157.6	50	222	3157.6	16
	7	6	26.6	378.3	17	75.5	1073.9	50	222	3157.6	50	222	3157.6	25
	8	15	66.6	947.3	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
	9	12	53.3	758.1	43	190.9	2715.2	23	102.1	1452.2	50	222	3157.6	33
	10	13	57.7	820.7	32	142.1	2021.1	50	222	3157.6	50	222	3157.6	26
	11	14	62.2	884.7	50	222	3157.6	50	222	3157.6	50	222	3157.6	17
	12	9	40	568.9	35	155.4	2210.3	48	213.1	3031.0	50	222	3157.6	31
	13	9	40	568.9	23	102.1	1452.2	50	222	3157.6	50	222	3157.6	23
	14	12	53.3	758.1	24	106.6	1516.2	30	133.2	1894.5	37	164.3	2336.9	40
	15	10	44.4	631.5	26	115.4	1641.4	50	222	3157.6	50	222	3157.6	22
	16	11	48.8	694.1	28	124.3	1768.0	50	222	3157.6	50	222	3157.6	22
	17	7	31.1	442.3	30	133.2	1894.5	38	168.7	2399.5	50	222	3157.6	30
	18	7	31.1	442.3	24	106.6	1516.2	39	173.6	2469.2	50	222	3157.6	32
	19	7	31.1	442.3	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
	20	14	62.2	884.7	50	222	3157.6	50	222	3157.6	50	222	3157.6	15
	21	14	62.2	884.7	21	93.2	1325.6	26	115.4	1641.4	32	142.1	2021.1	40
	22	16	71	1009.9	26	115.4	1641.4	50	222	3157.6	50	222	3157.6	22.5
	23	9	40	568.9	17	75.5	1073.9	50	222	3157.6	50	222	3157.6	28
	24	8	35.5	504.9	22	97.7	1389.6	33	146.5	2083.7	38	168.7	2399.5	40

	25	9	40	568.9	24	106.6	1516.2	50	222	3157.6	50	222	3157.6	21
	26	7	31.1	442.3	19	84.4	1200.5	40	177.6	2526.1	50	222	3157.6	33
	27	9	40	568.9	24	106.6	1516.2	50	222	3157.6	50	222	3157.6	30
	28	9	40	568.9	21	93.2	1325.6	27	119.9	1705.4	50	222	3157.6	32
									maximum average penetration depth (cm) =					26.1
Avg =		10.1		640.7	29.9		1887.8	44.8		2828.5	48.5		3060.6	10.3
Mode =		9			50			50			50			
Std dev =		3.0	13.2	187.0	12.8	57.0	811.1	7.7	34.4	488.7	2.9	12.9	183.5	

Date	6/29-30/2007	Location	Bucklick Forestry Area
Weather	Clear	Cell #	undisturbed

cell 00 - undisturbed

	Sample Number	Blows at DEPTH 10 (cm)	Soil Resistance		Blows at DEPTH 20 (cm)	Soil Resistance		Blows at DEPTH 30 (cm)	Soil Resistance		Blows at DEPTH 40 (cm)	Soil Resistance		Depth of Penetration
	(#)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(#)	(kg/cm2)	(psi)	(cm)
N-values	1	2	8.9	126.6	3	13.3	189.2	7	31.1	442.3	9	40	568.9	40
	2	4	17.8	253.2	6	26.6	378.3	14	62.2	884.7	20	88.8	1263.0	40
	3	3	13.3	189.2	6	26.6	378.3	10	44.4	631.5	16	71	1009.9	40
	4	3	13.3	189.2	11	48.8	694.1	5	22.2	315.8	11	48.8	694.1	40
	5	2	8.9	126.6	6	26.6	378.3	7	31.1	442.3	6	26.6	378.3	40
	6	2	8.9	126.6	6	26.6	378.3	22	97.7	1389.6	50	222	3157.6	31
	7	2	8.9	126.6	4	17.8	253.2	7	31.1	442.3	6	26.6	378.3	40
	8	2	8.9	126.6	5	22.2	315.8	10	44.4	631.5	8	35.5	504.9	40
	9	3	13.3	189.2	6	26.6	378.3	7	31.1	442.3	3	13.3	189.2	40
	10	1	4.4	62.6	3	13.3	189.2	50	222	3157.6	50	222	3157.6	20
	11	1	4.4	62.6	6	26.6	378.3	8	35.5	504.9	11	48.8	694.1	40
	12	2	8.9	126.6	4	17.8	253.2	3	13.3	189.2	6	26.6	378.3	40
	13	1	4.4	62.6	2	8.9	126.6	8	35.5	504.9	18	79.9	1136.4	40
	14	2	8.9	126.6	5	22.2	315.8	7	31.1	442.3	8	35.5	504.9	40
	15	4	17.8	253.2	6	26.6	378.3	11	48.8	694.1	9	40	568.9	40
	16	5	22.2	315.8	5	22.2	315.8	9	40	568.9	9	40	568.9	40
	17	3	13.3	189.2	9	40	568.9	13	57.7	820.7	18	79.9	1136.4	40
	18	2	8.9	126.6	6	26.6	378.3	4	17.8	253.2	5	22.2	315.8	40
	19	5	22.2	315.8	10	44.4	631.5	11	48.8	694.1	12	53.3	758.1	40
	20	4	17.8	253.2	7	31.1	442.3	11	48.8	694.1	14	62.2	884.7	40
	21	3	13.3	189.2	6	26.6	378.3	7	31.1	442.3	10	44.4	631.5	40
	22	4	17.8	253.2	6	26.6	378.3	11	48.8	694.1	11	48.8	694.1	40
	23	4	17.8	253.2	8	35.5	504.9	10	44.4	631.5	15	66.6	947.3	40
	24	7	31.1	442.3	14	62.2	884.7	15	66.6	947.3	28	124.3	1768.0	40

25	6	26.6	378.3	10	44.4	631.5	7	31.1	442.3	13	57.7	820.7	40
26	4	17.8	253.2	6	26.6	378.3	12	53.3	758.1	13	57.7	820.7	40
27	1	4.4	62.6	10	44.4	631.5	9	40	568.9	12	53.3	758.1	40
28	6	26.6	378.3	16	71	1009.9	20	88.8	1263.0	18	79.9	1136.4	40
29	3	13.3	189.2	15	66.6	947.3	25	111	1578.8	23	102.1	1452.2	40
30	5	22.2	315.8	8	35.5	504.9	8	35.5	504.9	11	48.8	694.1	40
31	4	17.8	253.2	10	44.4	631.5	9	40	568.9	7	31.1	442.3	40
32	1	4.4	62.6	3	13.3	189.2	11	48.8	694.1	9	40	568.9	40
Sample Number	**Blows at DEPTH 10 (cm)**	**Soil Resistance**		**Blows at DEPTH 20 (cm)**	**Soil Resistance**		**Blows at DEPTH 30 (cm)**	**Soil Resistance**		**Blows at DEPTH 40 (cm)**	**Soil Resistance**		**Depth of Penetration (cm)**
33	4	17.8	253.2	10	44.4	631.5	15	66.6	947.3	10	44.4	631.5	40
34	5	22.2	315.8	7	31.1	442.3	12	53.3	758.1	13	57.7	820.7	40
35	6	26.6	378.3	8	35.5	504.9	8	35.5	504.9	6	26.6	378.3	40
36	3	13.3	189.2	7	31.1	442.3	11	48.8	694.1	10	44.4	631.5	40
37	4	17.8	253.2	8	35.5	504.9	11	48.8	694.1	12	53.3	758.1	40
38	2	8.9	126.6	4	17.8	253.2	7	31.1	442.3	11	48.8	694.1	40
39	2	8.9	126.6	5	22.2	315.8	4	17.8	253.2	6	26.6	378.3	40
40	4	17.8	253.2	7	31.1	442.3	6	26.6	378.3	7	31.1	442.3	40
41	5	22.2	315.8	8	35.5	504.9	10	44.4	631.5	9	40	568.9	40
42	2	8.9	126.6	2	8.9	126.6	2	8.9	126.6	6	26.6	378.3	40
43	2	8.9	126.6	5	22.2	315.8	6	26.6	378.3	8	35.5	504.9	40
44	2	8.9	126.6	2	8.9	126.6	4	17.8	253.2	9	40	568.9	40
45	3	13.3	189.2	5	22.2	315.8	5	22.2	315.8	8	35.5	504.9	40
46	1	4.4	62.6	1	4.4	62.6	1	4.4	62.6	5	22.2	315.8	40
47	2	8.9	126.6	2	8.9	126.6	4	17.8	253.2	4	17.8	253.2	40
48	2	8.9	126.6	7	31.1	442.3	5	22.2	315.8	4	17.8	253.2	40
49	3	13.3	189.2	5	22.2	315.8	7	31.1	442.3	10	44.4	631.5	40
50	5	22.2	315.8	10	44.4	631.5	16	71	1009.9	22	97.7	1389.6	40
								maximum average penetration depth (cm) =					39.4
Avg =	3.2		199.6	6.6		418.0	11.2		634.0	14.5		781.7	15.8

Mode =	2			6			7			9		
Std dev =	1.2	5.5	77.6	2.2	9.9	141.3	10.0	44.5	632.7	13.0	57.8	822.5