Deep tillage of amendments using specialized equipment in land reclamation
by Matthew Luke Marsh

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Rehabilitation
Montana State University

Abstract:
Many disturbed lands around the world are contaminated with various undesirable elements making the reestablishment of vegetation very difficult or impossible. Most of these sites require some type of amendments to the soil in order to make them more amenable to plant growth. The incorporation of these amendments to a sufficient depth to maximize plant growth is often difficult. The pieces of equipment that can incorporate amendments into the soil profile to a sufficient depth are very limited in number and ability.

This study focuses on two different pieces of specialized equipment utilized for the deep incorporation of amendments. The first is, the Baker Plow. The Baker Plow is a large disc plow used mainly in the South for the deep tillage of soils. The second piece of equipment is the BOMAG MPH-100. It is a large rotary mixer used primarily for the pulverizing of asphalt on highway construction projects.

Several variables were analyzed both qualitatively and quantitatively. Each piece of equipment was evaluated for its ability to work on varying types of soils and terrain, its cost effectiveness, the depth to which it can incorporate amendments, and its ability to uniformly mix amendments into a soil profile.

Both pieces of equipment performed well in the fine textured tailings sites selected for this study. The Baker Plow and the BOMAG MPH-100 were both slowed somewhat at the high rock fragment content sites, but both machines performed adequately. The cost analyses was slightly more favorable for the Baker Plow than the BOMAG MPH-100 due mostly to the purchasing price of the BOMAG and its slower net production. There were not great differences in the depth of amendment. incorporation between the two pieces of equipment. The uniformity of amendment incorporation greatly favored the BOMAG MPH-100.

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APPROVAL

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Matthew Luke Marsh

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

November 28, 1994 — Date

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Date 30 Nov 94

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ABSTRACT

Many disturbed lands around the world are contaminated with various undesirable elements making the reestablishment of vegetation very difficult or impossible. Most of these sites require some type of amendments to the soil in order to make them more amenable to plant growth. The incorporation of these amendments to a sufficient depth to maximize plant growth is often difficult. The pieces of equipment that can incorporate amendments into the soil profile to a sufficient depth are very limited in number and ability.

This study focuses on two different pieces of specialized equipment utilized for the deep incorporation of amendments. The first is the Baker Plow. The Baker Plow is a large disc plow used mainly in the South for the deep tillage of soils. The second piece of equipment is the BOMAG MPH-100. It is a large rotary mixer used primarily for the pulverizing of asphalt on highway construction projects.

Several variables were analyzed both qualitatively and quantitatively. Each piece of equipment was evaluated for its ability to work on varying types of soils and terrain, its cost effectiveness, the depth to which it can incorporate amendments, and its ability to uniformly mix amendments into a soil profile.

Both pieces of equipment performed well in the fine textured tailings sites selected for this study. The Baker Plow and the BOMAG MPH-100 were both slowed somewhat at the high rock fragment content sites, but both machines performed adequately. The cost analyses was slightly more favorable for the Baker Plow than the BOMAG MPH-100 due mostly to the purchasing price of the BOMAG and its slower net production. There were not great differences in the depth of amendment incorporation between the two pieces of equipment. The uniformity of amendment incorporation greatly favored the BOMAG MPH-100.

INTRODUCTION

Land reclamation attempts in the Anaconda, Montana area have taken two basic strategies (Jensen 1993):

(1) Retrieving suitable soil and using it to cover contaminated soil to a 12-18 inch depth.

(2) Ameliorating on-site contaminated materials to produce an acceptable growth medium.

The retrieval and use of a suitable coversoil for many areas is a cost prohibitive alternative due to nonavailability and/or length of haul of the coversoil. Therefore, this study focuses on the on-site amelioration of contaminated material. A cost effective and long lasting method of ameliorating contaminated wastes and soils is needed, both to deter pollution and to enhance the appearance of disturbed sites (Smith and Bradshaw 1972).

Soils contaminated with wastes that do not support sufficient vegetation are often amended with neutralizing amendments or organic material. A significant barrier in a large portion of on-site amelioration attempts has been the deep incorporation of amendments into unsuitable soils. Equipment used in most active disturbed land reclamation today will uniformly incorporate amendments to the 12 to 14 inch depth (Dollhopf 1992). Although many of the disturbed lands in this country may have unsuitable soil profiles that are many feet deep, amending the top 1.75 to 2 feet of these profiles is a reasonable goal for successful plant establishment.

In this study, two unique pieces of equipment were used to incorporate amendments into the soil profile. The first was the Baker Plow for which the manufacturer specifies a working depth of 30 inches (Figure 1). The second

Figure 1. Baker Plow equipped with three discs.

was the BOMAG MPH-100 Rotary Mixer (Figure 2). The manufacturer specifies a maximum working depth of 19 inches for this piece of equipment.

Figure 2. BOMAG MPH-100 Rotary Mixer.

The Baker Plow and BOMAG MPH-100 were used to incorporate neutralizing amendments and manure into smelter wastes and contaminate soils at several locations within the Anaconda Superfund Site near Anaconda, Montana (Figure 3). This work was carried out under the Anaconda Revegetation Treatability Study (ARTS) project. The ARTS project was being conducted by the Reclamation Research Unit at Montana State University (Reclamation Research Unit 1993).

There were four objectives for this study. The first objective was to evaluate the equipment for effectiveness on varying types of terrain and soil. The second objective

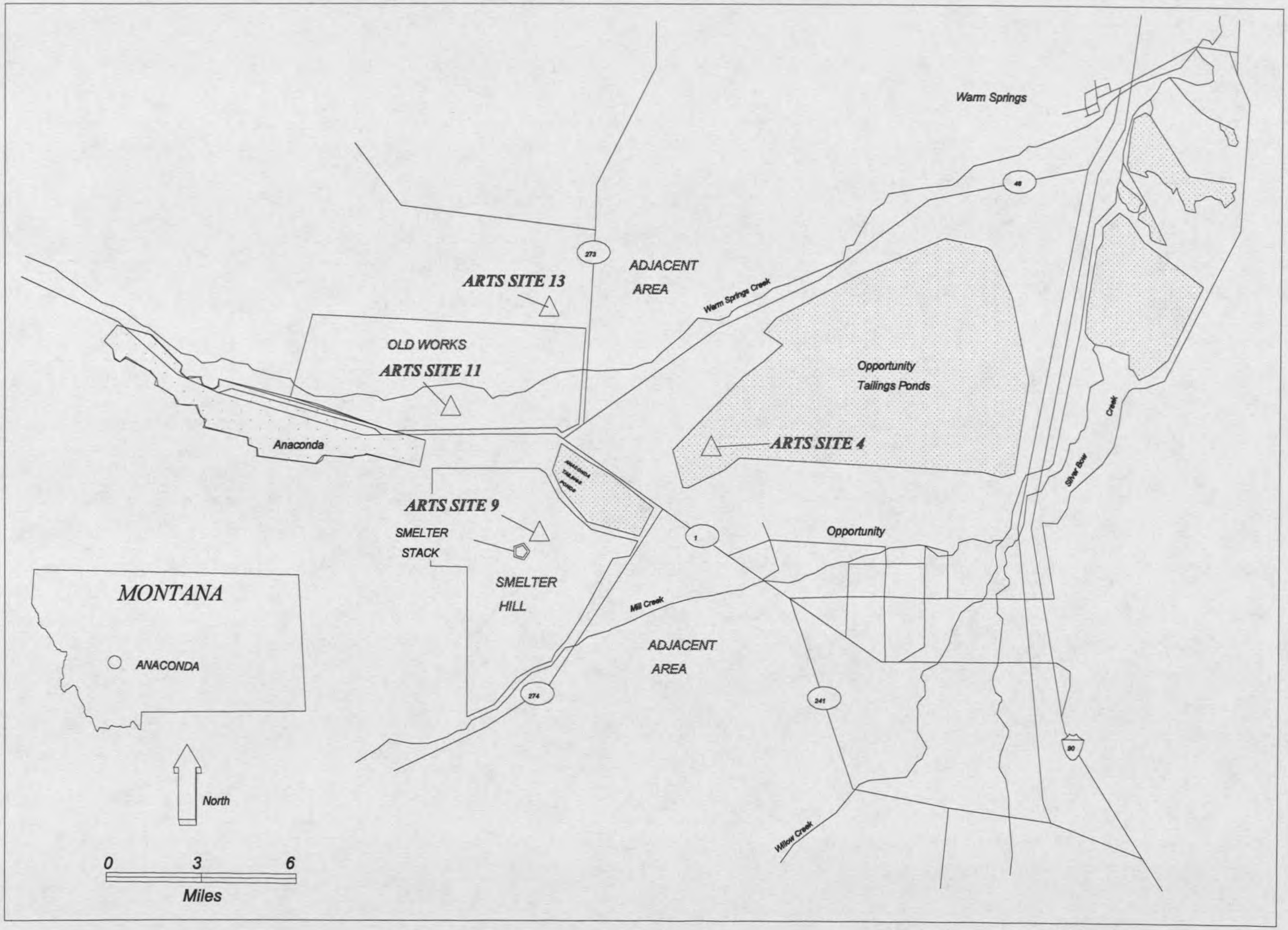


Figure 3. Location of the Anaconda Smelter Superfund Site.

was to evaluate the cost effectiveness of the equipment. The third objective was to evaluate the depth of amendment incorporation for each piece of equipment. The final objective was to evaluate the equipment for uniformity of amendment incorporation.

LITERATURE REVIEW

Information on amendment incorporation into disturbed lands presents various different pieces of equipment. The most common pieces of equipment used for amendment incorporation are standard agricultural implements such as chisel plows, discs, and moldboard plows. Other types of equipment tend to be very specialized and range from large discs and plows to surface miners.

Although standard agricultural equipment may be set at the 14 inch soil depth, or deeper, they typically do not incorporate surface applied amendments much deeper than 10 inches (Dollhopf 1992). A type of specialized equipment that has been used to incorporate amendments into soils is the agricultural rototiller (Figure 4). Although agricultural rototillers mix the soil and amendments very well, they can typically incorporate amendments only to 10 inches or less.

Two other types of specialized equipment that have been used for amendment incorporation are the bulldozer ripper shank (Figure 5) and the vibratory ripper shank (Figure 6). Rippers vary in length and configuration. Most of them are very narrow in width and may reach very deep into the soil, but the amendment typically does not get incorporated below the 6 inch depth for standard rippers and the 15 inch depth for the vibratory ripper (Ralston 1988, Hooks et al. 1987).

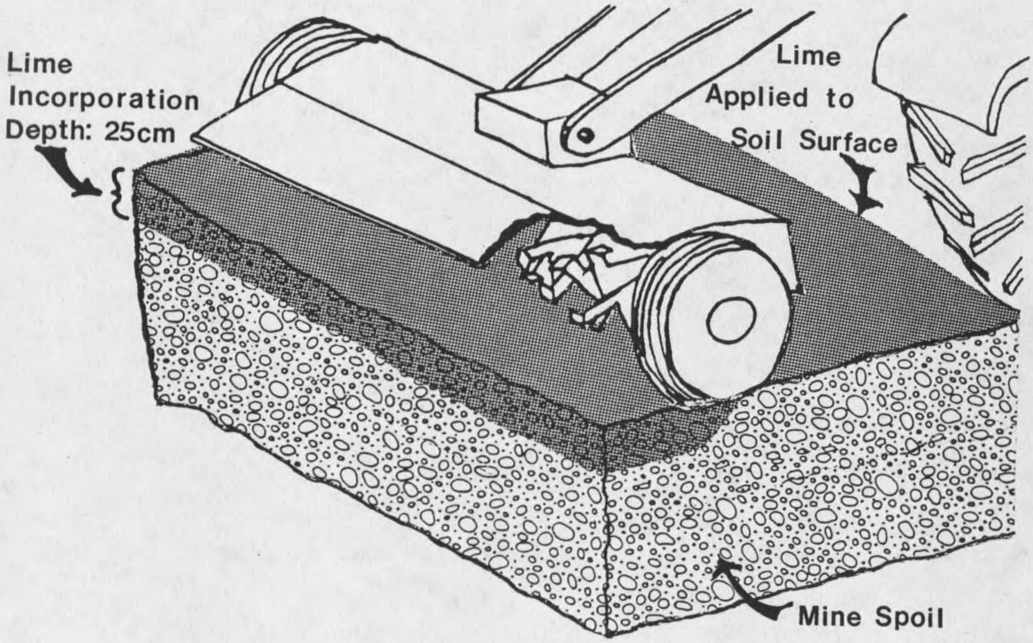


Figure 4. Incorporation to 10 inches with an agricultural rototiller (Dollhopf 1992).

Figure 5. Two ripper shanks ripping to 2 feet with a D8N dozer.

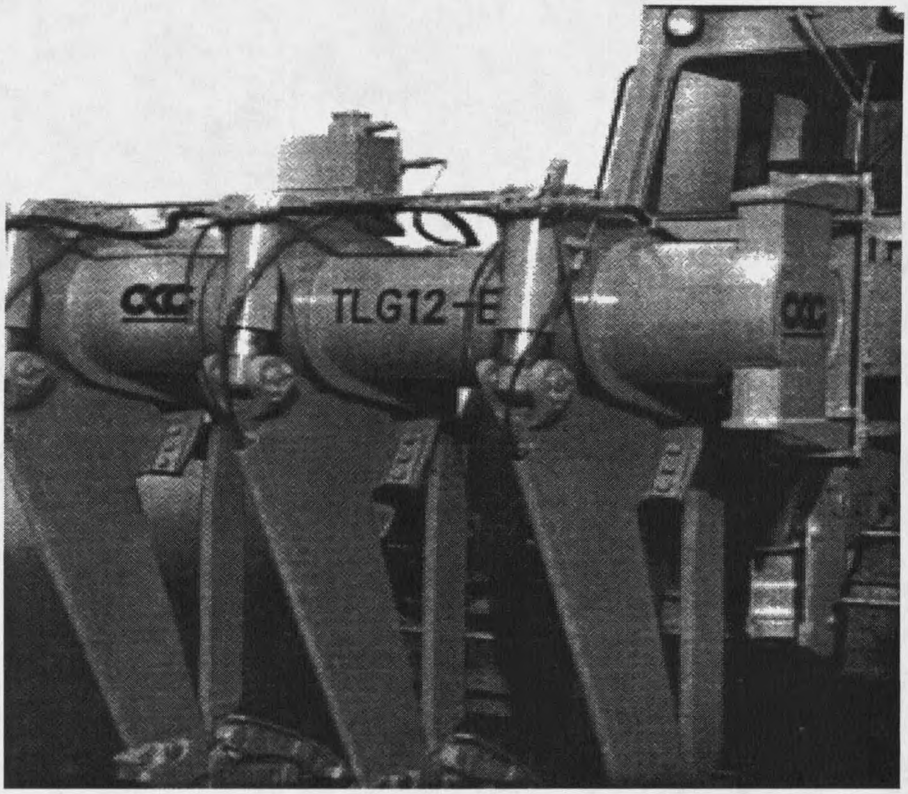


Figure 6. The Kaelble-Gmeinder TLG-12B Vibratory Subsoiler (Dollhopf 1992).

Specialized deep plows have also been developed to till the soil at the 4 foot depth. One such plow used by Schafer and Associates is the Dika plow (Figure 7) (Schafer and Associates et al. 1989). Another deep plow is being used at a coal mine in Texas. This plow is called the Towner plow (Figure 8) and has been modified from a moldboard plow to a disc type plow. The Towner Plow is used to plow the soil to a depth of 4 feet. This takes place in a several step process of liming, stripping particular soil depths, and plowing multiple depths (Frisbee 1993). Although these deep plows attain sufficient depths, their degree and uniformity of mixing is less than desired.

Figure 7. The Dika Plow can be used to plow soil to the 4 foot depth (Dollhopf 1992).

Figure 8. The Towner Plow with four moldboard plow shares (Dollhopf 1992).

The final piece of specialized equipment mentioned in this report is the surface miner (Figure 9). One particular surface miner will excavate material to a depth of greater than 8 feet. The liming agent would conceivably be added to the contaminated material as it is placed onto the machines conveyer system. The mixed product would then be deposited adjacent or to the rear of the machine off of the conveyer system. This method of neutralizing amendment incorporation does a successful job of incorporating liming agents to the 4 foot depth (Dollhopf 1992). The cost of this type of machine is high, which makes this type of soil remediation prohibitive at most sites.

Figure 9. The Krupp KSM-2000 Surface Miner excavating minesoil into a haul truck.

MATERIALS AND METHODS

Site Description

This study took place at the Anaconda Superfund Site (Figure 3) located in Southwestern Montana, approximately 25 miles northwest of Butte in the vicinity of the town of Anaconda. The climate at Anaconda was semiarid with long and cold winters, comparably cool summers, little precipitation, and moderate winds. The average annual temperature measured at Anaconda (1906-1985) had a mean of 42.4° F (Tetra Tech 1987). For the period 1951 through 1974, the average annual precipitation measured at the East Anaconda weather station was 13.7 inches. The average evaporation measured between April and June during 1974 through 1978 was 48.9 inches (NOAA 1977; Tetra Tech 1987). The same period of 1951 through 1978 had a mean annual snowfall of 63 inches. May through June received approximately 33 percent of the annual precipitation, while April through June received roughly 66 percent of the precipitation (Tetra Tech 1987).

The specific subareas of the site were Smelter Hill (ARTS Site 9), Old Works Area (ARTS Site 11), Drag Strip Area (ARTS Site 13), and the Opportunity Ponds (ARTS Site 4) (Figure 3).

Subarea Description

ARTS Site 9 was a strip of land 150 feet wide by 1400 feet long (4.8 acres) on the east side of Smelter Hill (Figure 10). The only area where a neutralizing agent was required on this plot was an acid area (0.77 acres) just below the haul road that divides the plot in half. The slopes of this plot varied from approximately 4.5:1 to 2.7:1. This site had areas that are very high (up to 75%) in rock fragment content with large boulders (greater than 2 feet in diameter) in some areas, while other areas (near the bottom of the plot) had medium rock fragment percentages (22%) and finer soil textures (sandy loam) (Reclamation Research Unit 1993). Rock fragments were defined as consolidated particles greater than 0.08 inches in diameter. They differed from coarse fragments in that they included particles greater than 10 inches in diameter (Hossner 1988). Controls for this site were soil test pits to the north and south of the test plot in the locations shown on Figure 10.

ARTS Site 11 was near the Arbiter Plant approximately 1 mile east of Anaconda in the Old Works Operable Unit of the Anaconda Superfund Site (Figure 11). It measured 145 feet wide and 300 feet long (1 acre). The Baker Plow was assigned to one half of the plot and the BOMAG MPH-100 was assigned to the other half of the plot. A one quarter acre control plot was established 87.5 feet to the east of this plot. The soil at this site had a low pH (2.95 to 5.02) and high (up to 34%) rock fragment content (Reclamation Research Unit 1993).

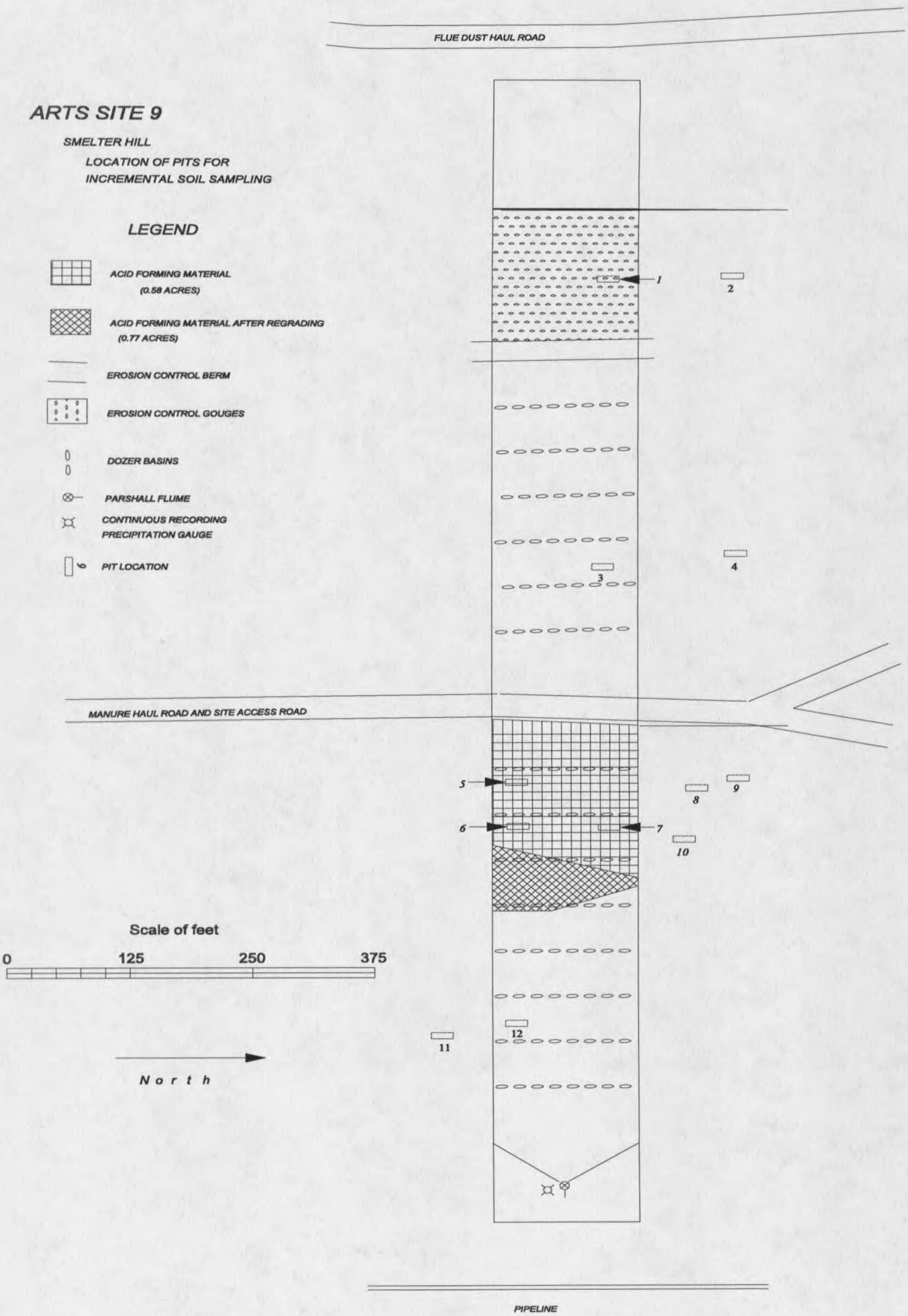


Figure 10. ARTS Site 9 (Smelter Hill).

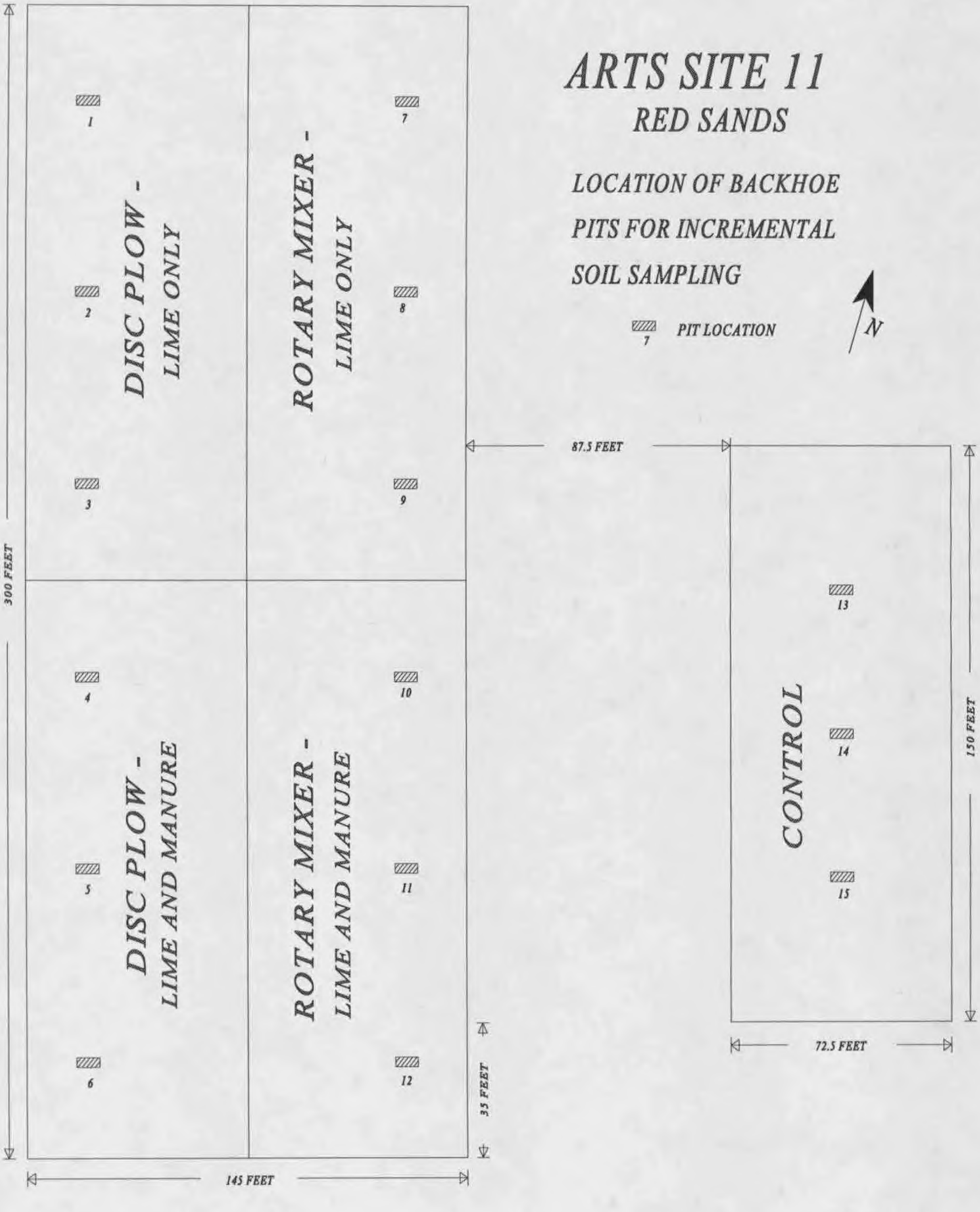


Figure 11. ARTS Site 11 (Old Works).

ARTS Site 13 was located approximately one quarter mile east of the old drag strip in an ARTS adjacent area (Figure 12). Incorporation equipment tests were conducted on three small demonstration plots adjacent to the current ARTS Site 13. The first plot was a control plot measuring 10 feet in width by 40 feet in length. The second plot received the BOMAG MPH-100 incorporation and measured 8 feet in width and 40 feet in length. The third plot received the Baker Plow incorporation and measured 10 feet in width and 40 feet in length. The soil at this site had a low to medium pH (4.0 to 7.7) to a depth of 12 inches and a medium (21) to high (59) rock fragment percentage (Reclamation Research Unit 1993).

ARTS Site 4 was located in the Opportunity A Pond (Figure 13). It was approximately 3.5 miles east of Anaconda. It consisted of three small demonstration plots with the same dimensions as the ARTS Site 13 plots. The soil at this site was fine textured (loam to silt loam) tailings material and had a low pH (2.88 to 5.59).

Test Plot Treatments

ARTS Site 9 was treated with three amendments. Manure was applied to the entire 4.8 acre site at the rate of 371 cubic yards per acre. It was spread with a standard agricultural manure spreader. The acid area just below the haul road (Figure 10) was amended with liming agent at a rate of 526 tons (dry weight) per acre per 24 inch depth. The liming agent used was from a weathered stockpile on Smelter Hill. It consisted of a mixture of CaO, $Ca(OH)_2$, and $CaCO_3$. It had a $CaCO_3$ equivalence of 112.4 (Horwitz 1975). The liming agent was applied with a Terragator fertilizer

Figure 12. ARTS Site 13 (Drag Strip).

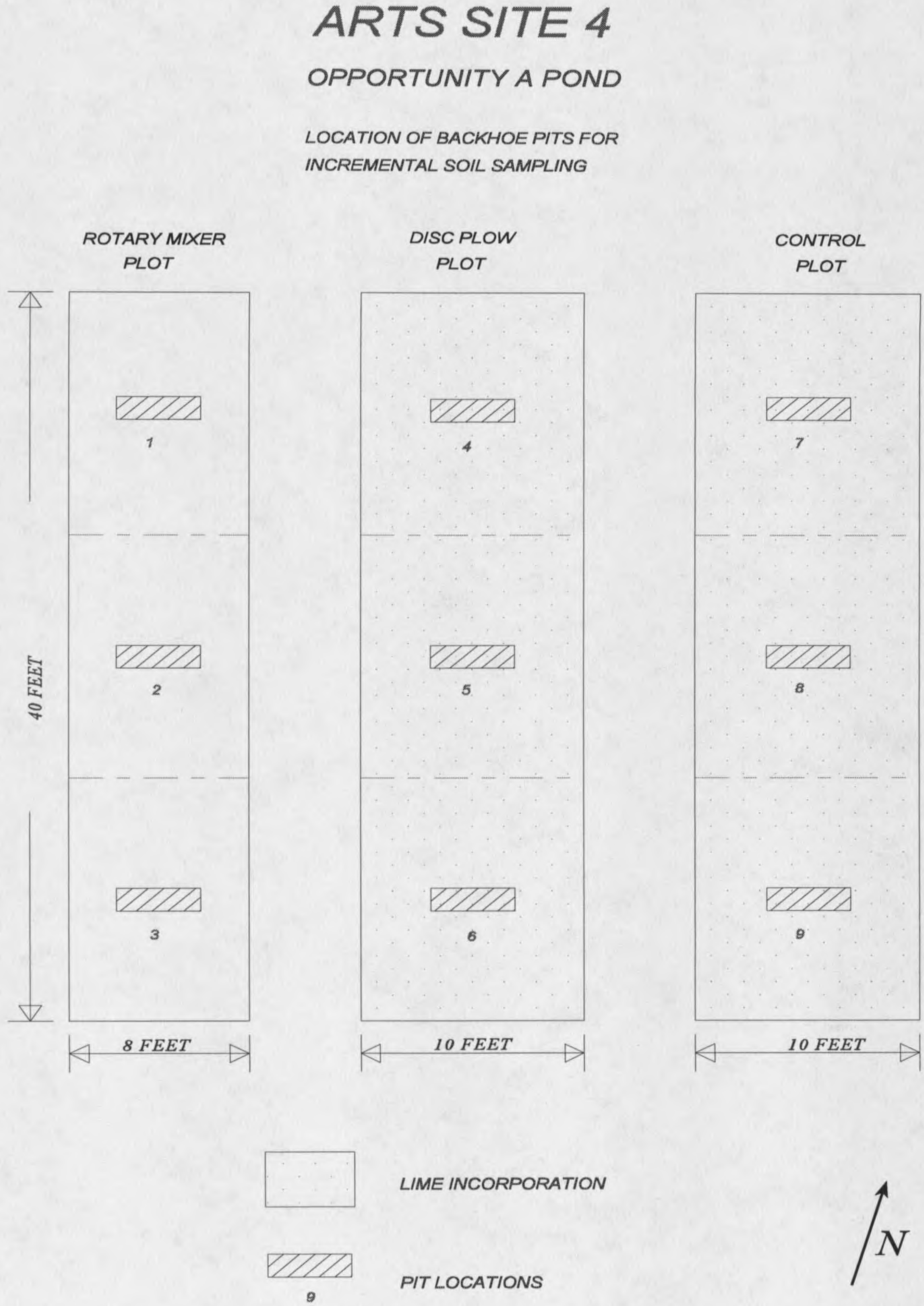


Figure 13. ARTS Site 4 (Opportunity A Pond).

spreader. Fertilizer also was applied to the entire site at 600 pounds per acre of 11-55-0 (N-P_2O_5-K_2O) and 2 pounds of boron per acre. The fertilizer and boron were put on at the same time with a small tractor mounted fertilizer spreader. The entire site was ripped to the 24 inch depth and was tilled with the Baker Plow to that depth. There were many areas of the plot that had steep slope angles (2.7:1 to 4.5:1). Part of these steep slopes received gouges (a rounded soil pit approximately 1 foot wide, 2 to 3 feet long, and 6 to 8 inches deep) for erosion protection. The gouges were constructed with no spacing in between individual gouges with a frequency of 2378 gouges per acre. The gouges on Site 9 (Smelter Hill) are located as portrayed in Figure 10. Other parts of these steep slopes received dozer basins (a large rounded soil pit approximately 7 feet wide, 15 feet long, and 20 inches deep) for erosion protection. The dozer basins were constructed in rows perpendicular to the slope with a frequency of 8 to 10 basins per row. The dozer basin rows were 50 feet apart and are located as portrayed in Figure 10. An erosion control berm was built approximately one fourth of the distance down the slope (Figure 10).

ARTS Site 11 was treated with three amendments. One half of the site was treated with manure at 269 cubic yards per acre (Figure 11). The entire one acre site was treated with liming agent from the Smelter Hill stockpile at 221 tons per acre per 24 inch depth. It was divided into four quarter sections consisting of the following individual treatments: Baker Plow incorporation with liming agent, Baker Plow incorporation with liming agent and manure, BOMAG MPH-100 incorporation with liming agent, and BOMAG MPH-100 incorporation with liming agent and manure.

The entire site was also fertilized with 450 pounds per acre of 10-25-35 (N-P_2O_5-K_2O) and 2 pounds per acre of boron. Each one quarter acre subdivision received either the Baker Plow tillage to the 24 inch depth or the BOMAG MPH-100 incorporation to the 19 inch depth.

ARTS Site 13 received two treatments. On the plot with the BOMAG MPH-100 incorporation (8 feet by 40 feet), one half of the plot received liming agent from the Smelter Hill stockpile (applied by hand) at the rate of 16.3 tons per acre. The other half of the plot received manure (applied by hand) at the rate of 269 cubic yards per acre. The entire plot that received the Baker Plow incorporation (10 feet by 40 feet) received manure as a treatment (Figure 12).

ARTS Site 4 received just one treatment. The plot that received the Baker Plow incorporation and the plot that received the BOMAG MPH-100 incorporation both received liming agent from the Smelter Hill stockpile (applied by hand) at a rate of 62 tons per acre per 24 inch depth (Figure 13).

Equipment Description

The Baker Plow "S" series Heavy Duty model disc plow was manufactured by JBK Manufacturing in Roscoe, Texas (Figure 14). It was a three point hitch mounted, in furrow, reversible plow with 32 inch diameter discs for plow bottoms. For this study the tool bar was equipped with three discs for plowing. Other models with up to six discs were also available from the manufacturer. Other disc sizes from 28 to 42 inches in diameter were also available. The plow frame was made of heavy box beam

Figure 14. The Baker Plow with three mounted discs.

construction with the discs spaced 18 inches apart along the main axis beam. The plow shanks that hold the discs to the frame were 3 inches in diameter. These shanks were made of heat treated C4140 steel, with shear bolt protection. The bearing type on the end of the shank that holds the revolving disc was a Timken roller. A 16 inch stroke hydraulic cylinder was used to reverse the direction of the plow by swinging the plow to the opposite side of the plow frame. The manufacturer specified the maximum plowing depth of this model of disc plow to be 30 inches. A John Deere 8430 four wheel drive tractor was used to pull this plow.

The BOMAG MPH-100 Soil Stabilizer deep mix package rotary mixer was manufactured in Springfield, Ohio by BOMAG USA which is a unit of AMCA International Corporation (Figure 15). The MPH 100 was a fully hydraulic stabilizer with no mechanical drive components. This rotary mixer system was composed of two main elements, the drive element and the rotary mixer element. The drive element was powered by a 304 horsepower diesel engine. It had a two speed mechanical transmission and a hydrostatic propulsion drive system. The rotary mixer element was 79 inches wide and consisted of a 60 inch diameter rotor with 19.2 inch mixing arms off of the rotor. There were 70 carbide tipped steel cutting teeth, one at the end of

Figure 15. The BOMAG MPH 100 Soil Stabilizer rotary mixer.

each of the mixing arms (Figure 16). It was powered on each end of the rotor by a radial piston motor. The rotor speed ranged from 0 to 135 revolutions per minute. The maximum mixing depth for the MPH 100 deep mix system was stated by the manufacturer as 19 inches.

Figure 16. The BOMAG MPH 100 deep mix rotor.

Sampling Description

The first objective was to evaluate the ability of the equipment to work on varying types of terrain and soil. This was a qualitative objective accomplished by field observation and professional judgement.

The second objective was to evaluate the cost effectiveness of the equipment. This was accomplished by a cost analysis derived from equipment operational costs in the field and production measurements.

Soil sampling was performed to address the final two objectives of this study. The third objective was to evaluate the depth of amendment incorporation for each piece of equipment. The amendments evaluated in this study were liming agent and manure. Methods used to evaluate the depth of manure incorporation will follow that of the liming agent. The depth of liming agent incorporation was evaluated by three methods.

The first evaluation method for liming agent incorporation was by simple visual inspection of the plow layer looking down the soil profile. After the soil pit (approximately 40 inches long, 24 inches wide, and 40 inches deep) was excavated, the plow layer was distinguishable by the looseness of the soil in the upper profile compared to the more consolidated unplowed layer lower in the soil profile. The presence of white colored liming agent in the upper soil profile was also a good indicator for the depth of amendment incorporation.

The second evaluation method was spraying one side of the open soil pit with pH indicator spray. Orbeco-Hellige Reagent N Triplex Indicator was used as the pH indicator spray. This indicator was a liquid spray that changes colors when sprayed on soils with pH levels ranging from 4.0 to 8.5. If soils had pH levels less than 4.0, the spray indicated a pH of 4.0. Likewise, if the soils had pH levels greater than 8.5, the spray indicated a pH of 8.5. Once the pit was sprayed, a wire frame (36 inches by 36 inches) with 2 inch by 2 inch grids was placed on the soil pit face. The pH readings were then taken from the grid by 2 inch increments down and across the soil grid profile.

The third evaluation method was the procurement of soil samples in depth increments and then analyzing the samples for pH in the laboratory. The method of pH analysis used was Method 21c in Chapter 6 of the USDA Agricultural Handbook No. 60 (U.S. Salinity Laboratory Staff 1954). The depth increments used were 0 to 8 inches, 8 to 16 inches, 16 to 24 inches, and 24 to 32 inches. However, if the amended zone of incorporation was less than one of the lower limits of the depth increments, then the actual depth of incorporation was used for that increment. For example, if the depth of incorporation was 14 inches, the second depth increment was 8 to 14 inches. If the depth of incorporation was 18 inches, then the second depth increment was 8 to 18 inches.

The first method of inspection proposed for the depth of manure incorporation was by simple visual inspection. The dark coloration of the soils and the approximate same coloration of the manure made this method of inspection not practical and inaccurate. Therefore, visual inspection of the depth of manure incorporation was not performed.

The second evaluation method was the procurement of soil samples in depth increments and then analyzing the samples for percent organic matter in the laboratory. The method of organic matter analysis used was a modified Walkley/Black method (Sims and Haby 1971). The depth increments used were the same as those used for the incremental sampling for pH analysis. The soil pits used were also the same pits used for incremental liming agent sampling. For the location of these pits, refer to the appropriate incremental sampling figure given for pH analysis. Three of the four sites received a manure treatment. They are Site 9 (Smelter Hill), Site 11 (Red Sands), and Site 13 (Drag Strip). The target depth for manure incorporation on all three sites was 24 inches. At Site 9 (Smelter Hill) the Baker Plow was the only piece of equipment used for the incorporation of manure.

The fourth and final objective of this study was to determine how uniform each piece of equipment distributed amendments in the soil profile. Due to its color characteristics, the liming agent was the amendment chosen to evaluate for this portion of the study. It was evaluated by the use of the same data collected in the determination of liming agent depth by pH indicator spraying.

Rather than choosing one particular cutoff level for pH assessment, the uniformity of liming agent incorporation was assessed at three differing pH levels. The levels of pH that were selected for this assessment were greater than or equal to 7.0, greater than 6.0, and greater than 5.5. The percent of the amended zone at the selected pH level was simply calculated by counting the number of 2 inch by 2 inch squares on the grid sheet that were equal to or above the selected pH value and then dividing that number of squares by the total number of squares. For example on Site 9 (Smelter Hill), there were 136 values out of 180 values that had a pH greater than 6.0. The amended zone in this example was 10 depth increments deep and 18 values wide giving a total of 180 values. This equates to 75.6 percent of this particular soil profile amended to a pH of greater than 6.0.

Statistical Analysis

Analysis of variance (ANOVA) was used to detect the differences between the depth of incorporation of amendments for each piece of machinery and for differences between the amended soils and the undisturbed control soils. In order for the analysis of variance to be valid, three requirements must be fulfilled. Data must be collected in a random manner. Data must be independent from one another. Data must have a normal distribution. The first requirement was met by careful field methods. All sampling locations were assigned randomly within a given plot subdivision. To insure independent samples, all data were analyzed in the order they were collected as suggested by Sokal and Rohlf (1969). The last requirement was analyzed by performing tests for skewness and kurtosis.

Table 1 lists the skewness value, kurtosis value, and sample size of each set of data analyzed by ANOVA. Skewness and kurtosis are given at the 95 percent confidence level as analyzed by SigmaStat (Dell 1994). Out of the 30 data sets analyzed for skewness, 15 of the sets failed the test. Eight of the data sets that failed had more high values than low values skewing data to the positive side of zero. Seven of the data

Table 1. Skewness and kurtosis values for data sets analyzed with ANOVA.

Description	Skewness	Kurtosis	Sample size
Grid pH values:			
Site 9 Baker Plow	0.32*	1.24*	324
Site 9 Baker Plow and control	0.61*	2.06*	648
Site 11 Baker Plow	0.67*	1.80*	324
Site 11 BOMAG	- 0.37*	1.21*	324
Site 11 Control	0.00	0.99*	324
Site 13 BOMAG	0.32*	3.75*	288
Site 13 BOMAG and control	- 1.72*	2.48*	576
Site 4 Baker Plow	0.96*	2.53*	324
Site 4 BOMAG	- 0.36*	1.55*	324
Site 4 Control	3.90*	16.28*	324
Incremental pH values:			
Site 9 Baker Plow	- 0.87	2.40	12
Site 9 Control	0.75	2.02	12
Site 11 Baker Plow	- 0.62	1.62*	24
Site 11 BOMAG	- 1.02*	2.44	24
Site 11 Control	0.73	1.84	12
Site 13 Baker Plow	- 1.54*	4.91*	12
Site 13 BOMAG and control	- 1.93*	6.39*	24
Site 4 Baker Plow	0.37	2.83	12
Site 4 BOMAG	- 0.66	2.18	12
Site 4 Control	0.31	1.70	12
Incremental organic matter values:			
Site 9 Baker Plow	0.68	3.25	24
Site 9 Control	2.15*	8.39*	24
Site 11 Baker Plow	0.60	2.58	12
Site 11 BOMAG	- 0.11	2.07	12
Site 11 Control	1.57*	4.85*	12
Site 13 Baker Plow	0.05	1.58*	12
Site 13 BOMAG	- 0.07	1.50*	12
Site 13 Control	- 0.36	2.01	12
Maximum depth values:			
Site 11	- 0.69	2.48	12
Site 4	- 2.34*	8.56*	6

* The marked values failed the test specified at the top of their column.

sets that failed had more low values than high values skewing the data to the negative side of zero. Out of the 30 data sets analyzed for kurtosis, 18 of the sets failed the test. Ten of the data sets that failed were below the kurtosis range for their given sample size making data within those sets broader than a normal distribution. Eight of the data sets that failed were above the kurtosis range for their given sample size making data within those sets narrower than a normal distribution (Taylor 1990). The failures listed in Table 1 for grid data can be attributed to the way data were collected. All grid data were in the 4.0 to 8.5 pH range with many values in each data set having pH levels near either the 4.0 or the 8.5 pH cutoff level. Failures listed in Table 1 can be attributed to the goals set for site remediation. The goal was to generate values in the treated data sets with high values, while the controls remain at low values. Due to many of the data sets failing these two tests for normality, these data must be interpreted with caution. Normalization of failed data sets was attempted, but unsuccessful for all failed data sets.

The least significant differences (LSD) test (Student's t) with $p < 0.05$ was used to determine differences between those variables which had a significant effect as determined by ANOVA. The computer programs used to analyze these data were the Montana State University statistical computer program "MSUSTAT" (Lund 1993) and "SigmaStat" (Dell 1994). All ANOVA and LSD results are contained in Appendix D.

RESULTS AND DISCUSSION

Equipment Effectiveness on Varying Terrain and Soil

The first objective was to evaluate the ability of the equipment to work on varying types of terrain and soil. The Baker Plow was tested for steep slope remediation on ARTS Site 9 (Smelter Hill), which had slopes ranging in steepness from 4.5:1 (22%) to 2.7:1 (37%). A John Deere 8430 four wheel drive tractor was used to pull the plow. The plow could not be effectively pulled up the slope due to insufficient traction. However, the plow worked effectively being pulled down the slope. The BOMAG MPH-100 was not evaluated for steep slope remediation. Next, the equipment was evaluated for effectiveness in differing rock fragment content soils. The Baker Plow was evaluated for soils with no rock fragments on Site 4 (Opportunity A Pond) and high (up to 76%) rock fragments on Sites 9 (Smelter Hill), 11 (Red Sands), and 13 (Drag Strip) (Reclamation Research Unit 1993). The plow worked effectively in the rock fragments on all of the sites.

The BOMAG MPH-100 was evaluated for soils with no rock fragments on Site 4 (Opportunity A Pond) and high (34 to 59%) rock fragments on Sites 11 (Red Sands) and 13 (Drag Strip) (Reclamation Research Unit 1993). The mixer worked effectively on Site 4 (Opportunity A Pond) in regards to overland speed, degree of mixing, and did not have any mechanical malfunctions. On Site 11 (Red Sands) and Site 13 (Drag Strip) the overland speed of the mixer was slowed appreciably (from 110 feet per minute to 77 feet per minute). The rocks at both sites were hard crystalline alluvial deposited glacial till rocks. The brittle carbide tips on the digging teeth of the mixer were easily chipped off by the large number of rock fragments. Each tooth had approximately one inch of wear surface available and once the carbide tips were chipped off, the steel would gradually wear down to its base. This drastically reduced the time of use for each tooth, and resulted in stops to replace used teeth. Also, these high rock fragment content soils caused other maintenance problems with the rotary mixer. The hydraulic seal on one of the two orbital motors that drive the digging rotor degraded, causing the shut down of the rotary mixer just as Site 11 (Red Sands) was being completed. The rotary mixer would not have been able to continue without the replacement of that seal or the entire orbital motor.

Cost Effectiveness

The second objective was to evaluate the cost effectiveness of the equipment. The cost analysis (Table 2 and Table 3) compares the two pieces of equipment. As shown in Table 2, the capital cost of the BOMAG MPH-100 was approximately 2.3 to 6.8 times more expensive than the Baker Plow. The operating costs of the BOMAG MPH-100 were from 2.6 (in tailings) to 8.0 (in rocky material) times more expensive than those for the Baker Plow. However, these operating expense figures were derived from one incorporation pass over the test plot for each piece of equipment. From research, it was estimated that the Baker Plow must make from five to seven incorporation passes in order to thoroughly mix the applied amendments. As shown in

Table 3, the adjustment for the number of passes increases the operating costs of the Baker Plow in tailings to a level 1.9 to 2.7 times more costly than the BOMAG MPH-100 tailings value. It also increases the operating costs of the Baker Plow in rocky material to a level 1.1 to 1.6 times less expensive than the BOMAG MPH-100. The BOMAG MPH-100, as it is designed now, may be cost prohibitive on sites with high rock fragment content when compared to the capital and operating costs of the Baker Plow. However, with design improvement, a rotary mixer may be developed with simple changes (such as a more wear resistant cutting tooth) to better deal with high rock fragment sites. This would reduce operating costs of the improved rotary mixer in high rock fragment materials and may make it a more cost feasible piece of equipment in high rock fragment materials than the Baker Plow.

Table 2. Cost analysis based on a single incorporation pass.

	BAKER PLOW	BOMAG MPH-100
CAPITAL COST	plow: \$7000 + tractor: \$30,000 to \$100,000	\$250,000
PRODUCTION		
Tailings	0.6 acre/hour/pass	0.5 acre/hour/pass
Rocky area	0.5 acre/hour/pass	0.35 acre/hour/pass
OPERATING COST		
maintenance, fuel, and wages	tailings: \$35/hour rocky: \$45/hour	tailings: \$76/hour rocky: \$251/hour
Totals (per acre):		
Tailings	\$58 per acre/pass	\$152 per acre/pass
Rocky area	\$90 per acre/pass	\$717 per acre/pass

Table 3. Cost analysis based on multiple incorporation passes.

	BAKER PLOW	BOMAG MPH-100
PRODUCTION		
Tailings	0.6 acre/hour/pass	0.5 acre/hour/pass
Rocky area	0.5 acre/hour/pass	0.35 acre/hour/pass
OPERATING COST		
maintenance, fuel, and wages	tailings: $35/hour rocky: $45/hour	tailings: $76/hour rocky: $251/hour
NUMBER OF PASSES	5 to 7	1
Totals (per acre):		
Tailings	$290 - $406 per acre	$152 per acre
Rocky area	$450 - $630 per acre	$717 per acre

Depth of Amendment Incorporation

The third objective was to evaluate the depth of amendment incorporation for each piece of equipment. The amendments evaluated in this study were liming agent and manure.

Determination of Depth of Liming Agent Incorporation by Visual Inspection

The values noted in Table 4 give the maximum depth of liming agent incorporation for each piece of equipment for the four individual ARTS sites. Both pieces of equipment were used and can be compared on ARTS Site 11 (Red Sands) and Site 4 (Opportunity A Pond). The mean liming agent maximum incorporation depth for the Baker Plow on Site 11 (Red Sands) was 19.2 inches in comparison with 22.5 inches for

Table 4. Maximum depth of liming agent incorporation by visual inspection.

Location	Baker Plow (inches)	BOMAG MPH-100 (inches)	Mean Depth (inches)
Site 11 (Red Sands)			
Pit 1	20		
Pit 2	22		
Pit 3	22		
Pit 4	16		19.2 A*
Pit 5	18		
Pit 6	17		
Pit 07		22	
Pit 08		21	
Pit 09		24	22.5 B*
Pit 10		24	
Pit 11		23	
Pit 12		21	
Site 4 (Opportunity A Pond)			
Pit 1		26	
Pit 2		25	25.7 A*
Pit 3		26	
Pit 4	26		
Pit 5	26		23.7 A*
Pit 6	19		
Site 9 (Smelter Hill)			
Pit 5	20		
Pit 6	20		
Pit 7	24		
Site 13 (Drag Strip)			
Pit 7		24	
Pit 8		15	
Pit 9		14	

* Values within a given site followed by the same letter are not significantly different.

the BOMAG MPH-100. These values reveal a significant difference ($p < .05$) in depths of incorporation between the two pieces of equipment (Table 23, Appendix D). The mean liming agent maximum incorporation depth for the Baker Plow on Site 4 (Opportunity A Pond) was 23.7 inches in comparison with 25.7 inches for the BOMAG MPH-100. These values are not significantly different ($p < .05$) from one another (Table 24, Appendix D). The target depth of incorporation at these two sites was 19 inches for the BOMAG MPH-100 and 24 inches for the Baker Plow. At Site 9 (Smelter Hill) and Site 13 (Drag Strip) the target depth of incorporation for the Baker Plow was 24 inches. At Site 13 (Drag Strip) the target depth of incorporation for the BOMAG MPH-100 was 12 inches. The depths of incorporation that exceeded the target depths can be explained by the presence of a swell factor (up to 36.8%) in the amended soil profile.

Recalling the description of these two sites points out that Site 11 (Red Sands) was a high (34%) rock fragment site, while Site 4 (Opportunity A Pond) was a tailings site. One would expect both pieces of equipment to be able to incorporate equally well in a finely textured material like the tailings of Site 4 (Opportunity A Pond). Also one might expect the large percentage of rock fragments of Site 11 (Red Sands) to affect the penetration of the equipment. This difference of soil materials between the two sites explains why the mean depths of incorporation were deeper in the finer (loam to silt loam) textured soils of Site 4 (Opportunity A Pond). The significant difference of liming agent incorporation mean depths between equipment in Site 11 (Red Sands) soils suggests that the Baker Plow did not incorporate liming agent into rocky soils as deep as the BOMAG MPH-100.

Determination of Depth of Liming Agent Incorporation by pH Indicator Spraying

The second evaluation method was spraying one side of the open soil pit with pH indicator spray. Tables 6 through 15 in Appendix A display the pH values obtained from the grid squares at each excavation pit.

Site 9 (Smelter Hill). Two soil pits at Site 9 (Smelter Hill) were sprayed for pH analysis. One pit was sprayed in the Baker Plow acid area (pit 6) and one pit was sprayed in the acid control area (pit 8). For the location of these pits refer to Figure 10. Normally the most suitable pH for most plants is somewhere between 6.0 and 7.5 (Troeh and Thompson 1993). The target depth for liming agent incorporation at Site 9 (Smelter Hill) was 24 inches.

As shown in Figure 17 the top 20 inches of the Baker Plow soil profile have significantly ($p < .05$) higher mean pH levels than the bottom 16 inches (Table 25, Appendix D). The second point is that the top 18 inches of the Baker Plow soil profile have significantly ($p < .05$) higher mean pH levels than the corresponding depths of the control soil profile (Table 25, Appendix D).

The points drawn reveal that the Baker Plow amended the soil at this particular pit location to the 20 inch depth. Also, if a pH of 6.0 is chosen as the minimum pH for optimal plant growth, the Baker Plow successfully amended the soil at this particular site to a depth of 18 inches.

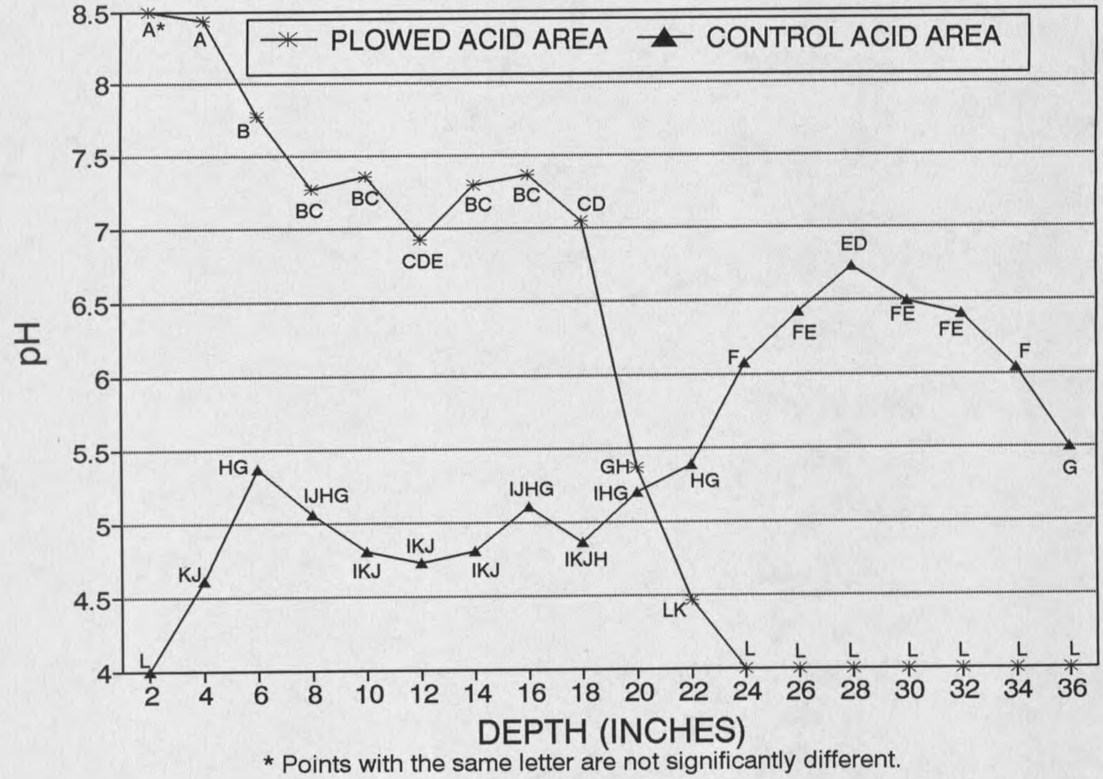
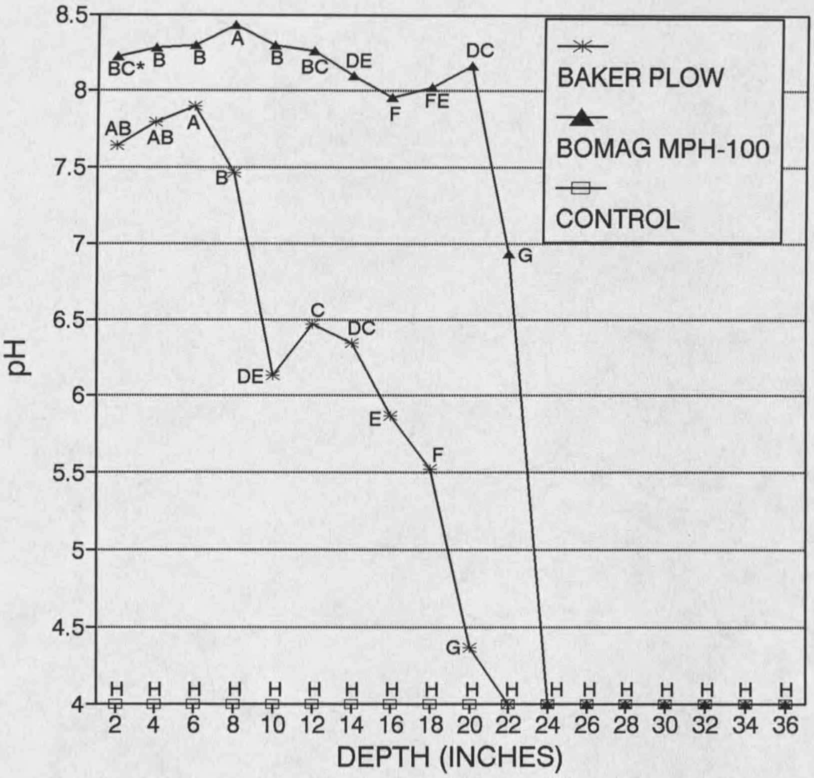


Figure 17. Site 9 (Smelter Hill) mean pH grid data.

<u>Site 11 (Red Sands)</u>. Three soil pits at Site 11 (Red Sands) were sprayed for pH analysis. One pit was sprayed in the Baker Plow area (pit 3), one pit was sprayed in the BOMAG MPH-100 area (pit 9), and one pit was sprayed in the control area (pit 13). For the location of these pits refer to Figure 11. The target depth for liming agent incorporation at Site 11 (Red Sands) was 24 inches for the Baker Plow and 19 inches for the BOMAG MPH-100.

Figure 18 describes the mean pH changes for the equipment and control as depth goes from 2 to 36 inches. After the Baker Plow treatment, the mean pH levels were significantly ($p < .05$) higher for the upper 20 inches in comparison to the lower 16



* Points on the same line with the same letter are not significantly different.

Figure 18. Site 11 (Red Sands) mean pH grid data.

inches and the corresponding control levels (Table 26, Appendix D). After the BOMAG MPH-100 treatment, the mean pH levels were significantly ($p < .05$) higher for the upper 22 inches in comparison to the lower 14 inches and the corresponding control levels (Table 27, Appendix D). If a pH of 6.0 is chosen as the minimum suitable pH for plant growth, the Baker Plow successfully amended the soil profile to a depth of 14 inches and the BOMAG MPH-100 successfully amended the soil profile to a depth of 22 inches.

With both pieces of equipment being used at this site, some comparisons between equipment can be made. Once again recalling the high (34%) rock fragment content of the soil at this site, Figure 18 demonstrates that the BOMAG MPH-100 successfully incorporated liming agent deeper into the soil profile in high rock fragment soils than the Baker Plow.

Site 13 (Drag Strip). Two soil pits at Site 13 (Drag Strip) were sprayed for pH analysis. One pit was sprayed in the BOMAG MPH-100 area (pit 9) and one pit was sprayed in the control area (pit 1). For the location of these pits refer to Figure 12. Recall that this site was only contaminated in the upper 10 inches of the soil profile. Therefore, the target depth for liming agent incorporation at Site 13 (Drag Strip) was only 12 inches.

Figure 19 describes the mean pH changes for the BOMAG MPH-100 and the control at Site 13 (Drag Strip). The statistical analysis of data revealed a significant ($p < .05$) difference in the upper 6 inches from the lower 26 inches of the control soil profile (Table 28, Appendix D). The control soil profile had mean pH levels of 4.01 to 5.59 in the upper 6 inches and mean pH levels of 6.01 to 7.03 in the lower 26 inches. As the figure demonstrates, after the BOMAG MPH-100 treatment, mean pH levels for the upper 16 inches were significantly ($p < .05$) higher than those of the control (Table 28, Appendix D). This demonstrates the ability of the BOMAG MPH-100 to be set at a particular intermediate depth and mix amendments into soil successfully.

Site 4 (Opportunity A Pond). Three soil pits at Site 4 (Opportunity A Pond) were sprayed for pH analysis. One pit was sprayed in the Baker Plow area (pit 5), one pit was sprayed in the BOMAG MPH-100 area (pit 3), and one pit was sprayed in the

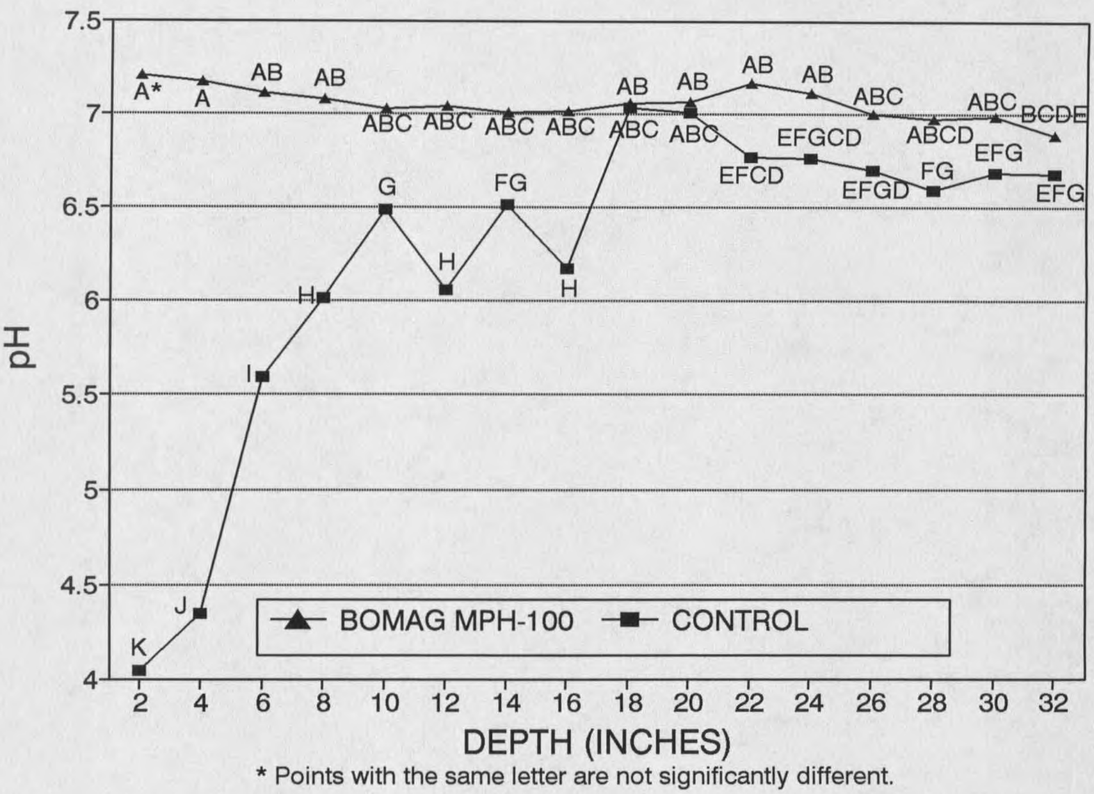


Figure 19. Site 13 (Drag Strip) mean pH grid data.

control area (pit 9). For the location of these pits refer to Figure 13. The target depth for liming agent incorporation at Site 4 (Opportunity A Pond) was 24 inches for the Baker Plow and 19 inches for the BOMAG MPH-100.

Figure 20 describes the mean pH values for each piece of equipment and the control at this site. After the Baker Plow treatment, the mean pH levels were significantly ($p < .05$) higher for the 0 through 24 inch depth increments in comparison to the lower 12 inches and the corresponding control levels (Table 29, Appendix D). After the BOMAG MPH-100 treatment, the mean pH levels were significantly ($p < .05$) higher for the 2 through 32 inch depth increments in

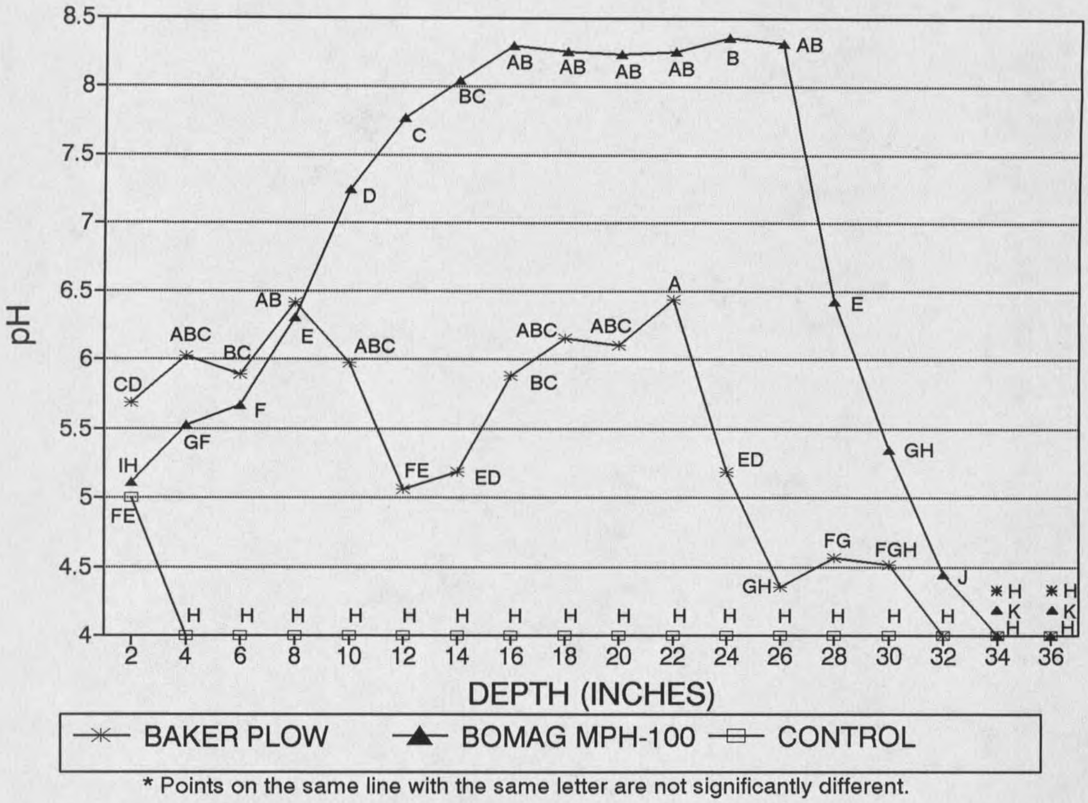


Figure 20. Site 4 (Opportunity A Pond) mean pH grid data.

comparison to the control (Table 30, Appendix D). If a pH of 6.0 is chosen as the minimum suitable pH for plant growth, the Baker Plow successfully amended the soil profile at the 2 to 4 inch depth, at the 6 to 8 inch depth, and from 16 to 22 inches. The BOMAG MPH-100 successfully amended the soil profile from 6 to 28 inches. The lower pH values (4.0 to 6.0) in the upper 6 inches of the BOMAG MPH-100 soil profile and intermittently throughout the Baker Plow amended profile can be explained by the tailings texture at this site. Unlike the previous three sites which have medium to coarse soils, the materials at this site were fine textured tailings. These tailings were wet when amended. The clumping effect of these wet tailings tended to make the amendment of these clumps that are formed when plowed or mixed very difficult. The soil mixed in clumps with the liming agent amending any unconsolidated soil between clumps and on the surface of these clumps.

Determination of Depth of Liming Agent Incorporation by Incremental Sampling

The third evaluation method was the procurement of soil samples in depth increments and then analyzing the samples for pH in the laboratory. Data tables for pH values of incremental samples are shown in Appendix B (Tables 16 through 19).

Site 9 (Smelter Hill). Incremental samples for pH analysis were taken from six pits at this site. Three of the soil pits (pit 5, 6, and 7) were in the Baker Plow acid area and three of the soil pits (pit 8, 9, and 10) were in the control acid area. For the location of these pits refer to Figure 10. The target depth of liming agent incorporation at Site 9 (Smelter Hill) was 24 inches.

Figure 21 describes the mean pH values for the generic depth increments one through four. At Site 9 (Smelter Hill) the Baker Plow was the only piece of equipment used for incorporation of liming agent. As Figure 21 demonstrates, after the Baker Plow treatment, mean pH levels were significantly ($p < .05$) higher for the upper 3 depth increments in comparison to the lower increment and the corresponding control increments (Table 31 Appendix D). The Baker Plow successfully amended the top three increments (approximately 0 to 24 inches) of the soil profiles in the acid area of Site 9 (Smelter Hill). Since depth increments were used, a specific maximum depth of

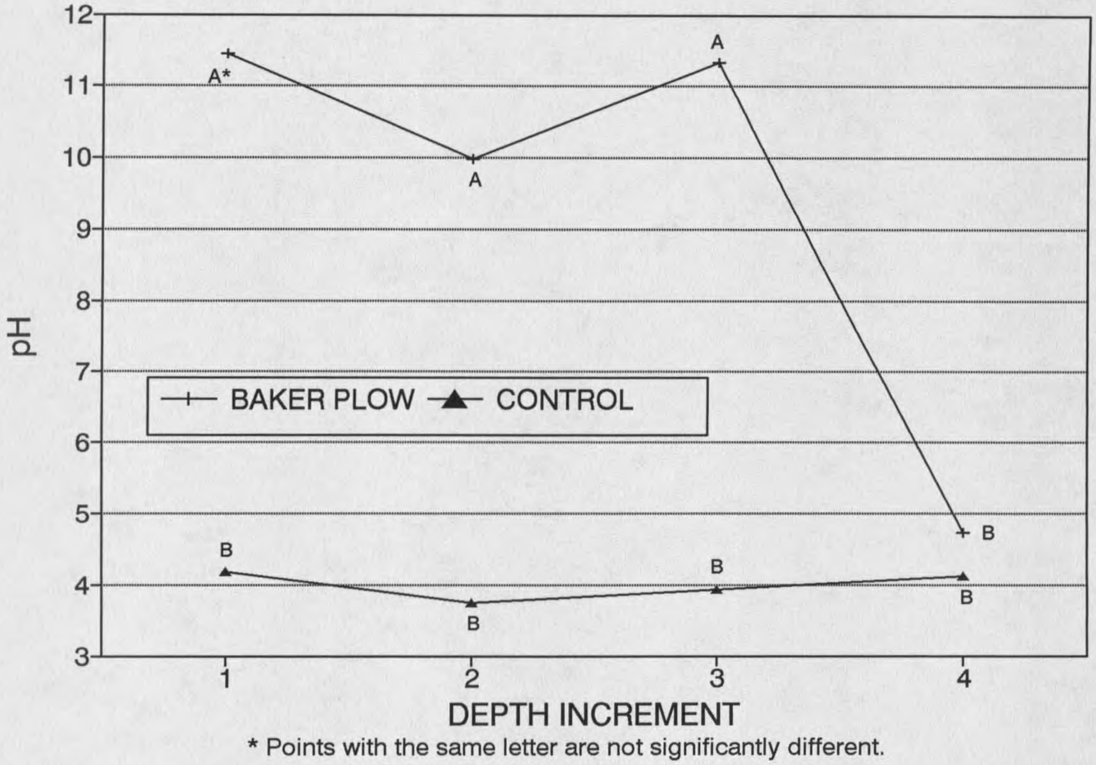


Figure 21. Site 9 (Smelter Hill) mean pH incremental sampling data.

incorporation cannot be given. Therefore, the maximum depth of incorporation for the Baker Plow on this site is given as the depth increment of 16 to 24 inches.

Site 11 (Red Sands). Incremental samples for pH analysis were taken from 15 pits at this site. Six of the soil pits (pits 1 through 6) were in the Baker Plow area, six of the soil pits (pits 7 through 12) were in the BOMAG MPH-100 area, and three of the soil pits (pits 13 through 15) were in the control area. For the location of these pits refer to Figure 11. The target depth of liming agent incorporation at Site 11 (Red Sands) was 24 inches for the Baker Plow and 19 inches for the BOMAG MPH-100.

Figure 22 describes the mean pH values for the generic depth increments one through four for the Baker plow samples, BOMAG MPH-100 samples, and control samples. After both the Baker Plow treatment and the BOMAG MPH-100 treatment, the mean pH levels were significantly ($p < .05$) higher for all three of the upper depth increments in comparison to the lower increment and the corresponding control increments (Tables 32 and 33, Appendix D). Therefore, the maximum depth of incorporation for each piece of equipment on this site by incremental sampling is given as the depth increment of 16 to 24 inches.

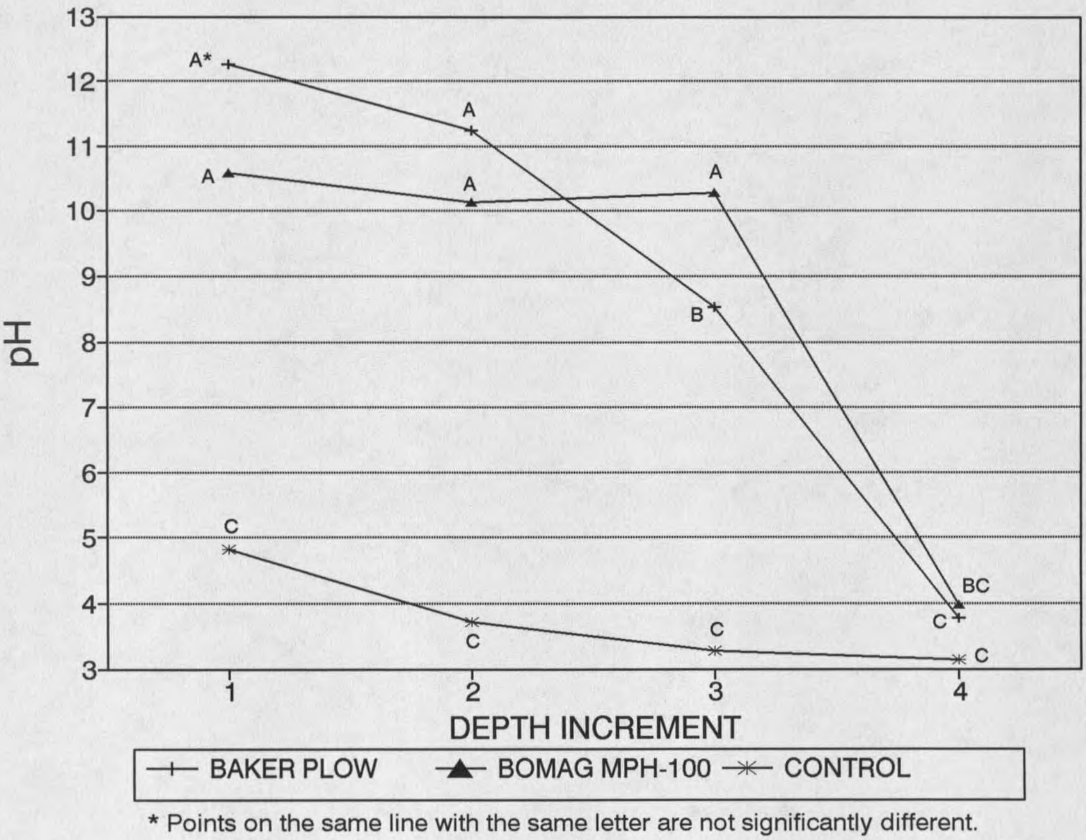


Figure 22. Site 11 (Red Sands) mean pH incremental sampling data.

Site 13 (Drag Strip). Incremental samples for pH analysis were taken from 12 pits at this site. Three of the soil pits (pits 10 through 12) were in the Baker Plow area, six of the soil pits (pits 4 through 9) were in the BOMAG MPH-100, area and three of the soil pits (pits 1 through 3) were in the control area. For the location of these pits refer to Figure 12. The target depth of liming agent incorporation at Site 13 (Drag Strip) was 12 inches.

Figure 23 describes the mean pH values for the generic depth increments one through four for the Baker plow samples, BOMAG MPH-100 samples, and control samples. After the BOMAG MPH-100 treatment, the mean pH level was significantly

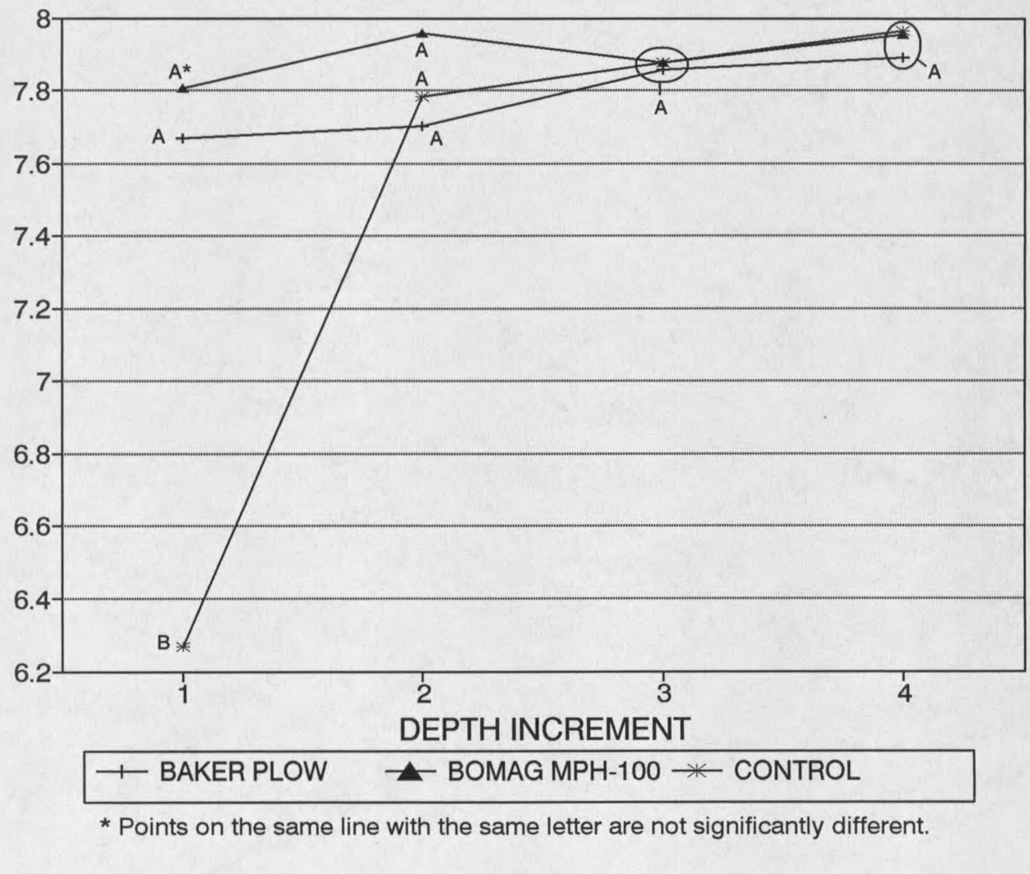


Figure 23. Site 13 (Drag Strip) mean pH incremental sampling data.

($p < .05$) higher for the upper depth increment in comparison to the mean pH level of the upper control increment (Table 34, Appendix D). Figure 23 also shows the three lower increments of the control plot with pH levels in the seven to eight range. Therefore, it was not necessary to amend the lower three increments.

The Baker Plow plot at this site did not receive a liming agent as an amendment. However, approximately 8 to 12 inches deep there was a calcareous layer of alluvial soil at this site. After the Baker Plow treatment, the mean pH level for the upper increment was significantly ($p < .05$) higher in comparison to the upper control increment (Table 35, Appendix D). The presence of the calcareous soil at this site allowed the Baker Plow to successfully amend the upper increment to an acceptable level.

Site 4 (Opportunity A Pond). Incremental samples for pH analysis were taken from 9 pits at this site. Three of the soil pits (pits 4 through 6) were in the Baker Plow area, three of the soil pits (pits 1 through 3) were in the BOMAG MPH-100, area and three of the soil pits (pits 7 through 9) were in the control area. For the location of these pits refer to Figure 13. The target depth of liming agent incorporation at Site 4 was 24 inches for the Baker Plow and 19 inches for the BOMAG MPH-100.

Figure 24 describes the mean pH values for the generic depth increments one through four for the Baker plow samples, BOMAG MPH-100 samples, and control samples. After the Baker Plow treatment, the mean pH levels were significantly ($p < .05$) higher for the upper three depth increments in comparison to the lower increment and to all but the second increment of the control (Table 36, Appendix D).

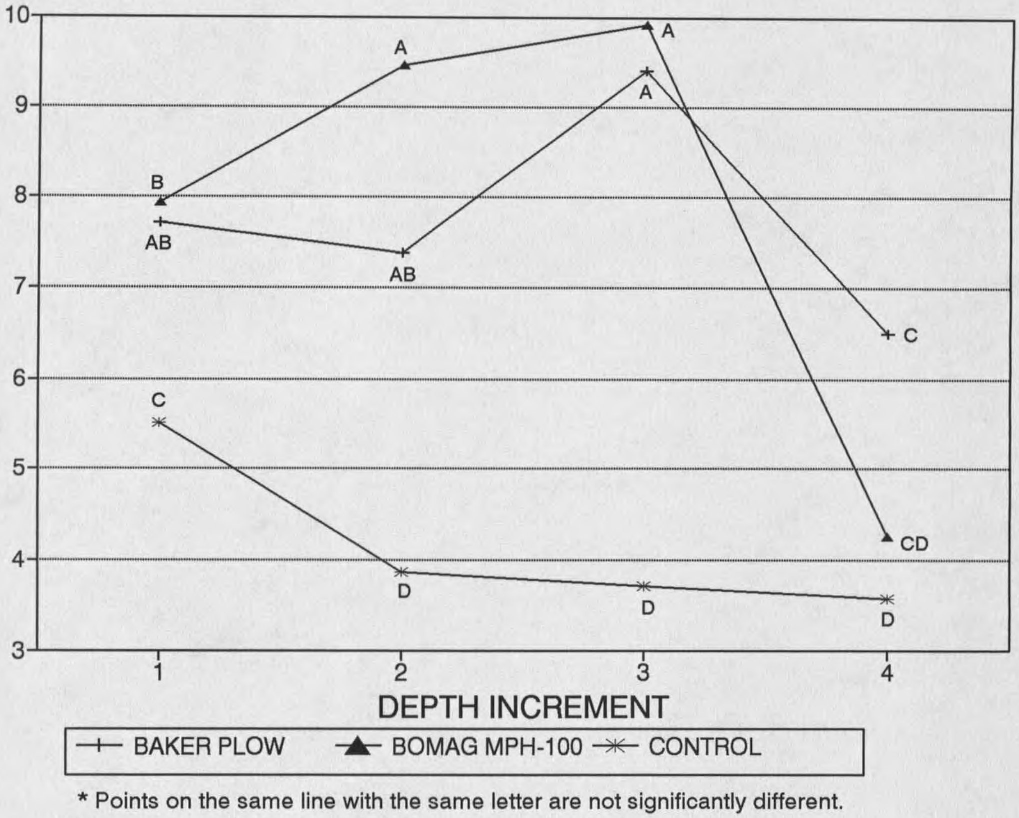


Figure 24. Site 4 (Opportunity A Pond) mean pH incremental sampling data.

After the BOMAG MPH-100 treatment, the mean pH levels were significantly ($p < .05$) higher for the upper three depth increments in comparison to the lower increment and all of the control increments (Table 37, Appendix D). Therefore, the maximum depth of incorporation for both pieces of equipment on this site is given as the depth increment of 16 to 24 inches.

Determination of Depth of Organic Matter Incorporation by Incremental Sampling

The second evaluation method was the taking of soil samples in depth increments and then analyzing the samples for percent organic matter in the laboratory. Data tables for organic matter values of incremental samples are shown in Appendix C (Tables 20 through 22).

Site 9 (Smelter Hill). Incremental samples for organic matter analysis were taken from all 12 pits at this site. Six of the soil pits (pit 1, 3, 5, 6, 7, and 12) were in the Baker Plow area and six of the soil pits (pit 2, 4, 8, 9, 10, and 11) were in the control area. For the location of these pits refer to Figure 10. The target depth of manure incorporation at Site 9 (Smelter Hill) was 24 inches.

As Figure 25 demonstrates, after the Baker Plow treatment, the mean organic matter levels were significantly ($p < .05$) higher in the upper increment of the soil

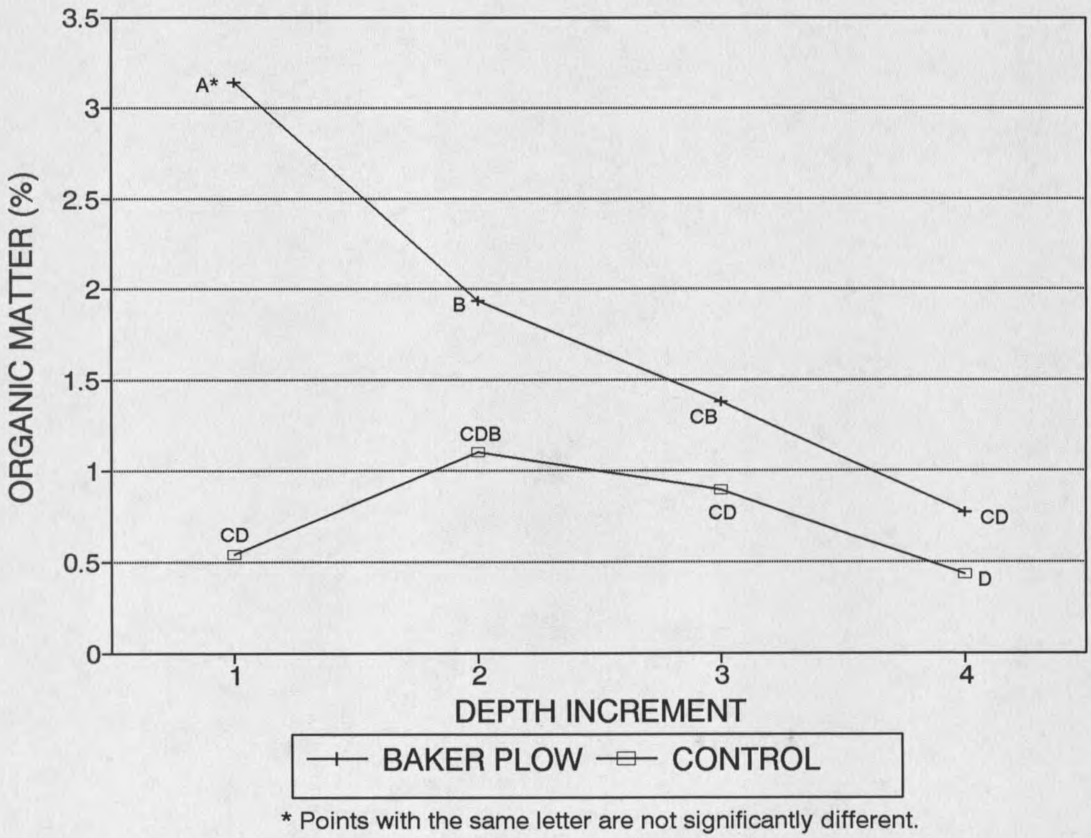


Figure 25. Site 9 (Smelter Hill) mean organic matter percentage data.

profiles in comparison to the levels in the lower increments and in comparison to the upper increment of the control (Table 38, Appendix D). If 3 percent is chosen as the target level of soil organic matter, then the upper depth increment at Site 9 (Smelter Hill) was the only successfully amended portion of the soil profile in regards to organic matter.

Site 11 (Red Sands). Incremental samples for organic matter analysis were taken from all 15 pits at this site. Six of the soil pits (pits 1 through 6) were in the Baker Plow area, six of the soil pits (pits 7 through 12) were in the BOMAG MPH-100 area, and three of the soil pits (pits 13 through 15) were in the control area. For the location of these pits refer to Figure 11. The target depth of organic matter incorporation at Site 11 (Red Sands) was 24 inches.

Figure 26 describes the mean organic matter percentages for the generic depth increments one through four for the Baker Plow samples, BOMAG MPH-100 samples, and control samples. After the Baker Plow treatment, the mean organic matter levels were significantly ($p < .05$) higher for the upper two increments in comparison to the lower two increments and in comparison to the lower three increments of the control (Table 39, Appendix D). After the BOMAG MPH-100 treatment, the mean organic matter levels were significantly ($p < .05$) higher for the upper three increments in comparison to the lower increment. Also, the first and third increments of the BOMAG MPH-100 treatment had significantly higher organic matter levels after treatment than the corresponding control increments (Table 40, Appendix D). If 3 percent organic matter is chosen as the target level, neither the Baker Plow nor the

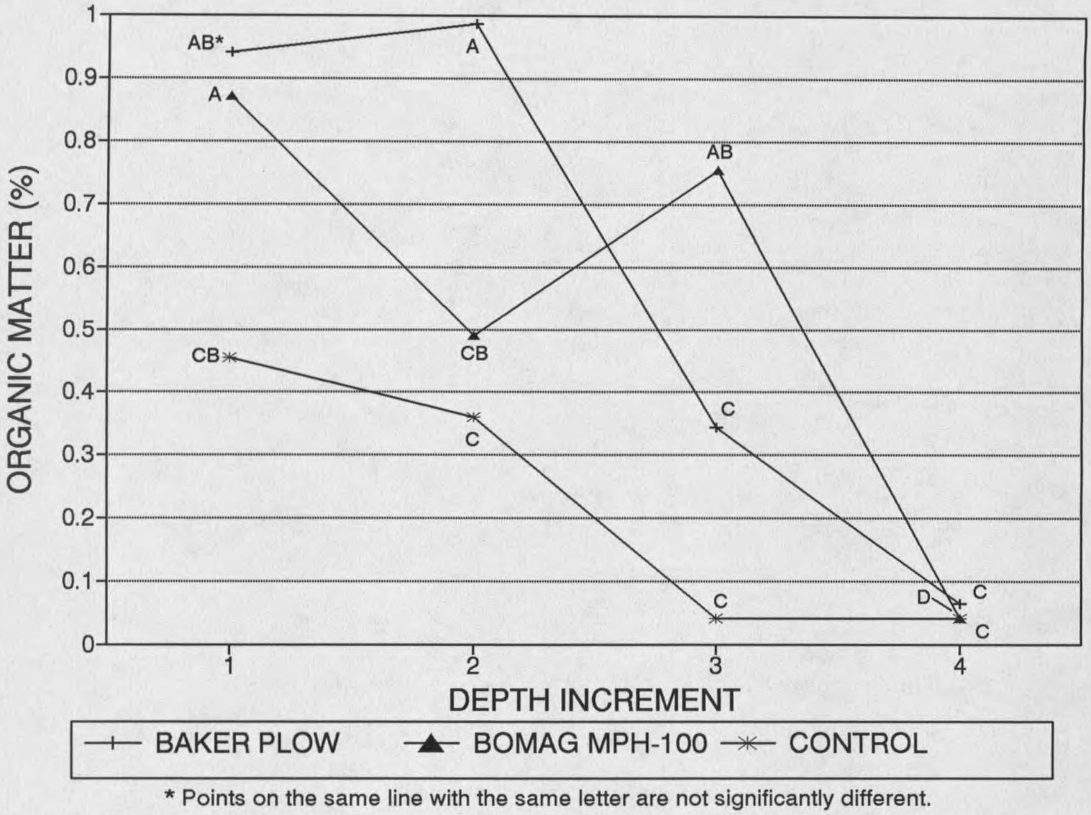


Figure 26. Site 11 (Red Sands) mean organic matter percentage data.

BOMAG MPH-100 successfully amended any of the depth increments at this site in regards to soil organic matter percentage.

Site 13 (Drag Strip). Incremental samples for organic matter analysis were taken from nine pits at this site. Three of the soil pits (pits 10 through 12) were in the Baker Plow area, three of the soil pits (pits 4 through 6) were in the BOMAG MPH-100 area, and three of the soil pits (pits 1 through 3) were in the control area. For the location of these pits refer to Figure 12. The target depth of manure incorporation at Site 13 (Drag Strip) was 24 inches.

Figure 27 describes the mean organic matter percentages for the generic depth increments one through four for the Baker Plow samples, BOMAG MPH-100 samples, and control samples. After the Baker Plow treatment, the mean organic matter levels were significantly ($p < .05$) higher for the upper two increments in comparison to the lower two increments and in comparison to the lower two increments of the control (Table 41, Appendix D). After the BOMAG MPH-100 treatment, the mean organic matter levels were significantly ($p < .05$) higher for the upper three increments in comparison to the lower increment and in comparison to the lower two increments of the control (Table 42, Appendix D). If 3 percent organic matter is chosen as the

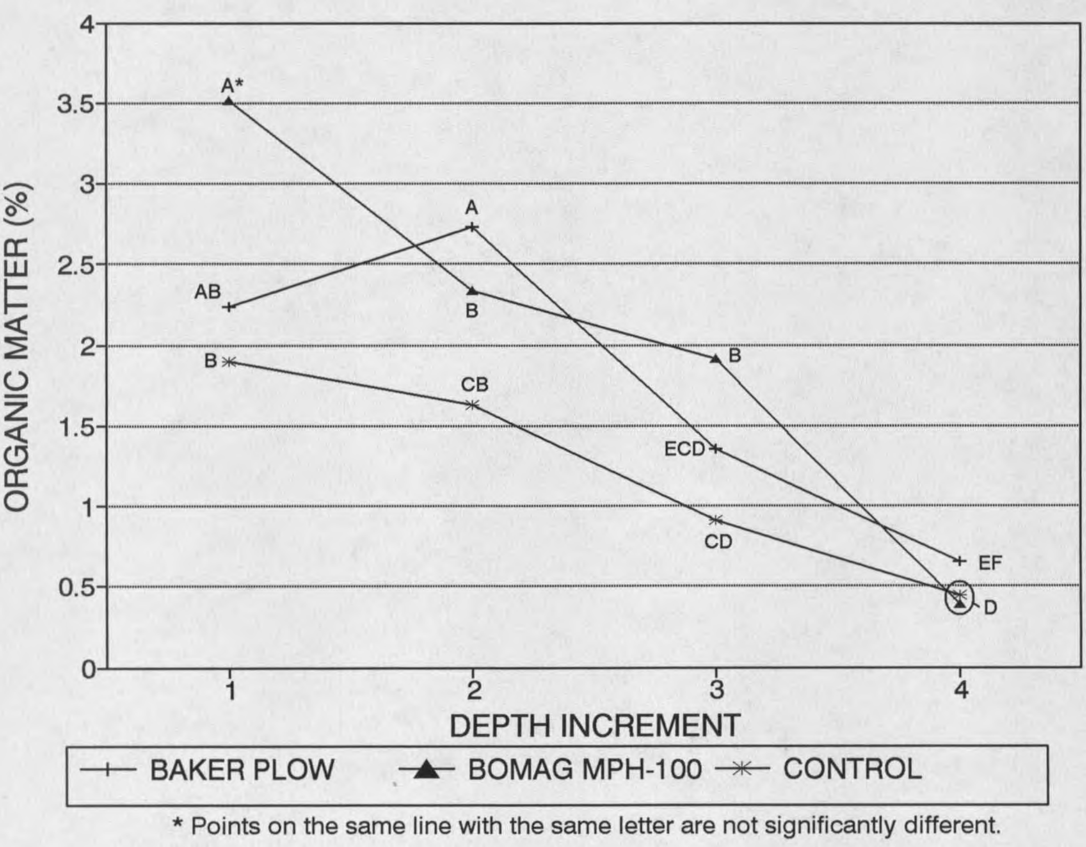


Figure 27. Site 13 (Drag Strip) mean organic matter percentage data.

target level, the upper depth increment for the BOMAG MPH-100 was the only increment that the soil organic matter percentage was increased to an acceptable level.

Uniformity of Amendment Incorporation

The fourth and final objective of this study was to determine how uniform each piece of equipment distributed amendments in the soil profile. Data tables of the pH values taken from the grids are shown in Appendix A (Tables 6 through 15).

Figure 28 describes the uniformity of incorporation at a pH of 7.0 or greater for the amended zone at individual sites. It characterizes three sites each for the Baker

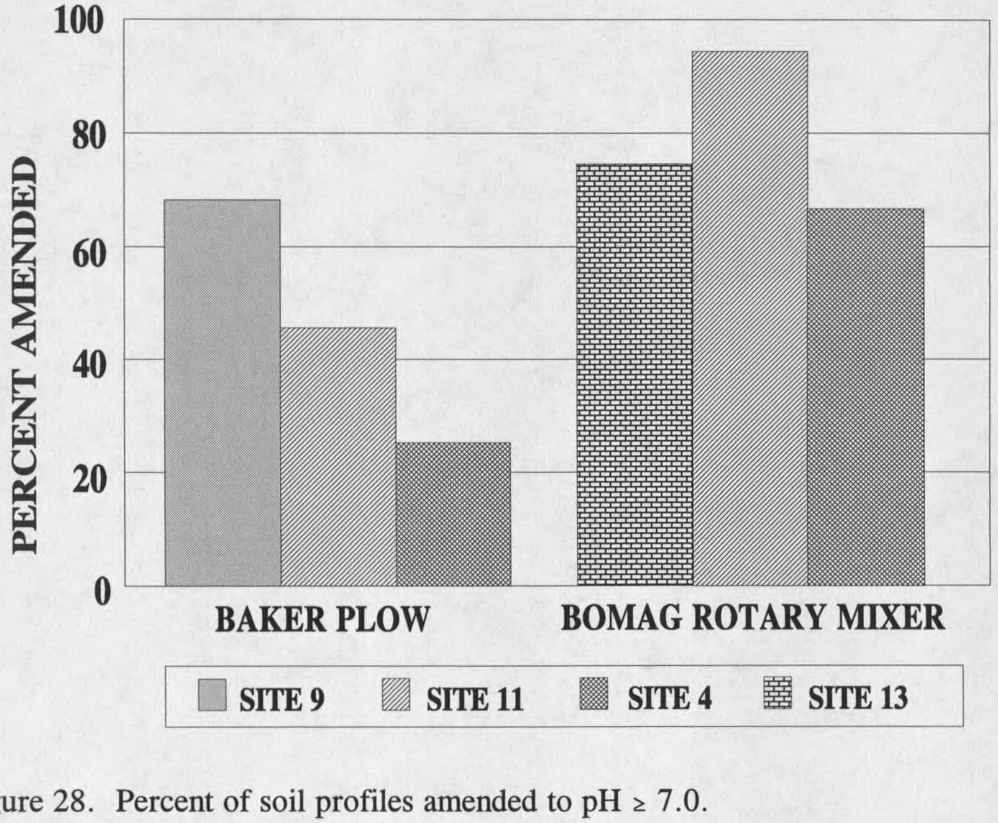


Figure 28. Percent of soil profiles amended to pH ≥ 7.0.

Plow (Site 9 (Smelter Hill), Site 11 (Red Sands), and Site 4 (Opportunity A Pond)) and the BOMAG MPH-100 (Site 13 (Drag Strip), Site 11 (Red Sands), and Site 4 (Opportunity A Pond)). The important point of this figure is that on Site 11 (Red Sands) and Site 4 (Opportunity A Pond) where both the Baker Plow and the BOMAG MPH-100 were used the uniformity of incorporation attained with the BOMAG MPH-100 was more than double the percentage for the Baker Plow. This conclusion is due to the difference in mixing styles of the two pieces of equipment. The rotary mixing of the BOMAG MPH-100 seems to mix more thorough than the plowing action of the Baker Plow. In order to obtain a similar uniformity of incorporation in comparison to the BOMAG MPH-100, the Baker Plow must make several passes.

Figure 29 describes the uniformity of incorporation at pH levels greater than 6.0. The notable element in this diagram is the 28.9 percent and 40.2 percent greater uniformity of incorporation of the BOMAG MPH-100 than the Baker Plow at sites 11 (Red Sands) and 4 (Opportunity A Pond), respectively. Also notable on this diagram is that the BOMAG MPH-100 achieved 100 percent uniformity of incorporation at sites 11 (Red Sands) and 13 (Drag Strip) for assessment at pH levels of greater than 6.0.

Figure 30 characterizes the uniformity of incorporation at pH levels of greater than 5.5. A notable element in this diagram is the 30.6 percent and 41.4 percent greater uniformity of incorporation of the BOMAG MPH-100 than the Baker Plow at Sites 11 (Red Sands) and 4 (Opportunity A Pond), respectively. Also notable on this diagram is that the BOMAG MPH-100 achieved 100 percent uniformity of incorporation at Sites 11 (Red Sands) and 13 (Drag Strip) for assessment at pH levels of greater than 5.5.

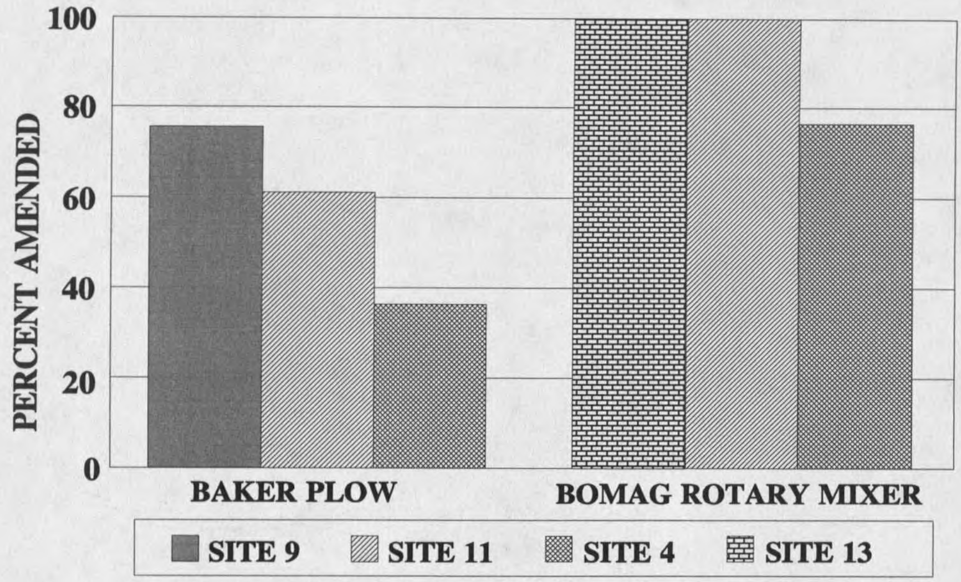


Figure 29. Percent of soil profiles amended to pH > 6.0.

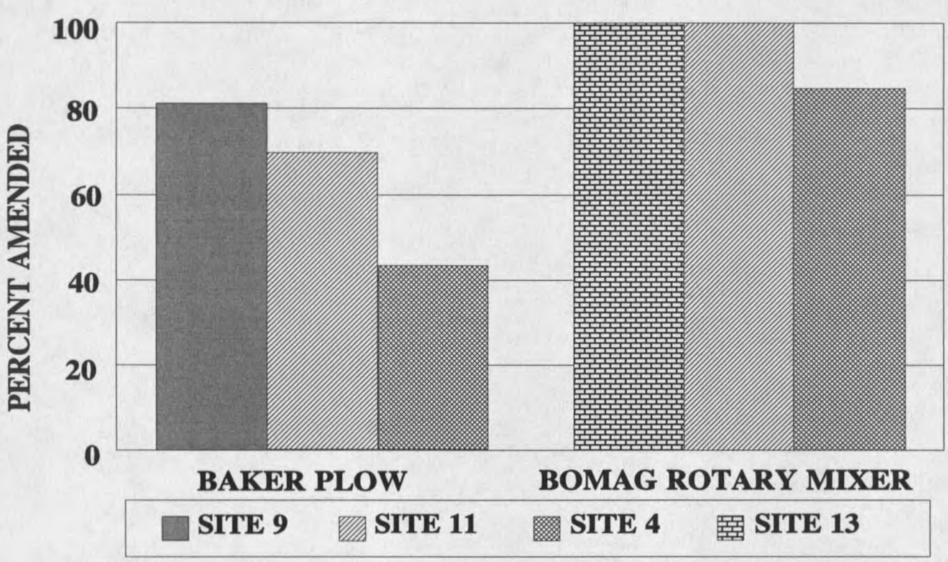


Figure 30. Percent of soil profiles amended to pH > 5.5.

The only notable difference between this figure and the previous two figures is the increase in the Baker Plow percentages for each site at this pH level.

SUMMARY AND CONCLUSIONS

The first objective of this study was to evaluate the equipment for effectiveness on varying types of terrain and soil. The ability of the Baker Plow to effectively work on the steep slopes of ARTS Site 9 (Smelter Hill) gives the Baker Plow more versatility in this evaluation category than other types of equipment such as the rotary mixer that are unable to work on steep slopes. The Baker Plow also performed adequately in the high (34 to 59) percentage rock fragment soils at ARTS Sites 11 and 13. The BOMAG MPH-100 performed adequately in the high rock fragment soils, but with more difficulty than the Baker Plow. Both the Baker Plow and the BOMAG MPH-100 performed very well in the mine tailings at ARTS Site 4 (Opportunity A Pond).

The second objective was to evaluate the cost effectiveness of the equipment. The capital cost of the Baker Plow which is approximately 2.3 to 6.8 times less expensive than the BOMAG MPH-100 makes the Baker Plow less costly to purchase. However, the BOMAG MPH-100 requires only one to two passes over the working area to mix the desired amendments, while the Baker Plow requires several passes over the working area to thoroughly mix the desired amendments making the operating costs comparable.

The third objective was to evaluate the depth of amendment incorporation for each piece of equipment. At Site 11 (Red Sands) which was the high (34%) rock fragment site, the BOMAG MPH-100's mean maximum depth of incorporation was 22.5 inches, which was slightly deeper than the Baker Plow's mean maximum depth of 19.2 inches. One explanation for this difference in depths is that at Site 11 (Red Sands) the operator was not quite familiar with the machine and how deep it could penetrate into rocky material was not yet fully determined at this time. However, at Site 4 (Opportunity A Pond) which was the tailings site, there were no significant differences in maximum incorporation depths. The pH indicator spraying of the soil pits at Site 11 (Red Sands) and Site 4 (Opportunity A Pond) where both pieces of equipment were used on the same site, reveals that the BOMAG MPH-100 successfully amended both sites from 6 to 8 inches deeper than the Baker Plow.

The final objective was to evaluate the equipment for uniformity of amendment incorporation. The BOMAG MPH-100 was found to more uniformly incorporate the liming agent to a much greater degree of mixing than the Baker Plow. It was observed in the field that there seemed to be no difference in the depths or uniformity of incorporation for the different types of amendments. Several passes over the work area with the Baker Plow may help increase its ability to more uniformly incorporate amendments.

To summarize the points drawn in this study, a list of the major advantages and disadvantages of each piece of equipment is listed in Table 5.

Table 5. Equipment advantages and disadvantages.

	BAKER PLOW	BOMAG MPH-100
ADVANTAGE	1. Able to work on steep slopes 2. Lower capital costs 3. Slightly higher production	1. Only requires one or two passes to incorporate amendments uniformly
DISADVANTAGE	1. Requires multiple passes to uniformly incorporate amendments	1. Not designed to work on steep slopes 2. High capital cost 3. Slightly lower production

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APPENDICES

APPENDIX A

GRID pH VALUES

Table 6. Amendment incorporation uniformity pH assessment for Site 9.

Excavation Pit # 6
Date Sampled: October 11, 1993

Amendment: Lime and manure
Incorporation Equipment: Baker Plow

Placement of grid on vertical wall: West wall of pit.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
4"	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.0	8.1	8.3	8.5	8.5	8.5	8.5	8.5
6"	8.5	8.4	8.5	8.1	5.8	5.2	5.9	8.0	8.5	8.3	8.4	7.6	6.4	8.4	8.5	8.5	8.5	8.5
8"	7.9	8.1	8.1	7.4	4.9	4.1	5.8	8.5	8.5	8.5	8.3	6.0	4.7	6.2	8.4	8.5	8.5	8.5
10"	6.1	8.2	7.9	8.3	8.4	7.9	8.5	7.0	8.4	8.5	8.5	6.6	4.8	4.5	5.2	6.7	8.5	8.5
12"	4.9	7.1	8.0	7.0	8.5	8.5	8.5	8.3	5.3	8.2	8.5	8.5	6.7	4.1	4.1	4.3	6.2	7.9
14"	4.8	6.0	8.0	7.9	8.5	8.5	8.5	8.4	5.1	6.9	8.5	8.5	8.4	6.9	5.1	5.2	6.1	7.8
16"	4.9	5.1	8.1	8.5	8.5	8.5	8.5	8.4	5.6	7.8	8.5	8.5	8.4	6.9	5.1	5.8	7.3	8.2
18"	4.1	4.0	5.0	7.7	8.5	8.5	8.5	8.5	8.5	6.2	5.3	5.8	6.1	6.9	7.9	8.5	8.5	8.5
20"	4.0	4.0	4.0	4.3	5.4	7.2	7.8	7.8	6.0	4.4	4.2	4.1	4.0	4.0	4.2	5.0	7.9	8.4
22"	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.2	6.3	7.8	5.9
24"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
26"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
28"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
30"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
32"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
34"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
36"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*

* pH of 4.0 or less.

Table 7. Amendment incorporation uniformity pH assessment for Site 9.

Excavation Pit # 8
Date Sampled: October 11, 1993

Amendment: None (Control)
Incorporation Equipment: None

Placement of grid on vertical wall: West wall of pit.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
4"	5.5	5.2	4.8	4.6	4.9	4.8	4.4	4.3	4.1	4.2	4.1	4.0	4.3	4.4	4.6	4.6	5.1	5.0
6"	5.8	5.6	5.2	4.9	4.8	5.1	5.3	4.9	5.7	5.9	6.1	5.6	5.5	5.8	5.9	5.4	4.7	4.5
8"	5.2	5.4	5.3	4.4	4.8	4.3	4.5	4.6	4.6	5.2	5.4	5.5	5.5	5.8	5.6	5.2	4.8	5.0
10"	4.6	4.3	4.3	4.4	4.3	4.2	4.7	5.1	4.6	4.7	4.9	5.0	5.1	5.3	4.9	5.3	5.3	5.4
12"	4.4	4.2	4.2	4.3	4.5	4.8	4.7	4.9	5.6	4.7	4.5	4.3	4.7	5.3	4.9	5.0	4.8	5.2
14"	4.0	4.0	4.0	4.0	4.3	4.0	4.3	4.5	5.1	5.7	5.5	4.9	5.8	5.6	5.5	5.0	5.0	5.3
16"	4.0	4.0	4.1	4.2	4.2	4.6	4.8	5.3	5.0	5.3	5.4	6.1	6.2	5.7	5.5	5.8	6.0	5.7
18"	4.0	4.3	4.3	4.3	4.3	4.4	4.7	4.7	5.4	5.5	4.8	4.6	4.9	5.1	5.5	5.8	5.8	5.1
20"	4.1	4.1	4.4	4.3	4.5	4.7	5.0	5.2	5.8	6.0	5.6	5.4	5.4	5.5	5.9	6.1	5.7	5.9
22"	6.3	6.1	5.8	5.6	5.6	5.3	5.1	5.1	6.2	6.5	4.9	5.0	4.3	4.2	4.7	4.7	5.5	6.1
24"	7.0	6.8	6.7	6.4	5.9	6.1	6.2	6.2	6.4	6.3	6.9	6.5	5.5	5.1	4.3	4.7	5.6	6.7
26"	6.6	6.7	6.9	6.8	5.2	5.8	6.3	6.7	6.5	6.5	6.6	6.9	6.8	6.5	6.1	6.2	6.3	6.3
28"	6.8	6.6	6.6	6.7	5.7	5.9	5.7	6.3	6.9	6.9	6.9	7.1	7.3	7.3	7.3	7.2	7.0	7.0
30"	6.6	6.3	6.5	6.6	6.5	5.7	5.8	5.8	6.2	6.4	6.5	6.8	6.7	6.7	6.9	6.9	6.9	7.0
32"	6.6	5.4	6.3	6.3	6.2	5.9	6.2	6.3	6.4	6.6	6.5	6.5	6.7	6.6	6.6	6.5	6.7	6.9
34"	5.2	5.2	5.2	5.9	5.4	5.4	6.0	6.3	6.2	6.6	6.6	6.3	5.9	6.2	6.6	6.1	6.7	6.9
36"	4.9	4.9	4.8	4.7	4.8	4.9	5.9	5.2	5.5	6.0	5.8	6.0	5.8	5.8	5.9	5.6	5.9	6.5

* pH of 4.0 or less.

Table 8. Amendment incorporation uniformity pH assessment for Site 11.

Excavation Pit # 3
Date Sampled: October 5, 1993

Amendment: Lime
Incorporation Equipment: Baker Plow

Placement of grid on vertical wall: Centered in pit wall face on the north side of pit.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	8.5	8.5	8.5	8.5	8.5	8.2	8.0	7.2	5.3	6.8	5.9	7.9	7.8	8.3	7.4	7.4	7.9	6.9
4"	8.0	8.5	8.5	8.5	8.3	8.4	8.0	7.6	6.8	6.0	7.9	8.1	7.6	7.7	8.1	7.9	7.0	7.4
6"	8.5	8.5	8.5	8.5	8.5	8.3	7.9	7.8	6.8	6.9	8.0	8.0	7.4	7.8	7.5	7.4	8.0	7.9
8"	8.5	8.5	8.5	8.3	8.3	8.0	7.0	6.5	6.7	6.9	7.8	8.0	7.2	7.0	6.8	6.2	6.9	7.3
10"	8.5	8.3	8.3	8.1	5.3	5.5	4.7	5.1	5.3	6.0	7.7	6.0	4.6	4.8	5.0	4.4	5.1	7.6
12"	8.2	6.2	7.6	6.7	6.8	5.7	6.4	7.2	6.7	6.9	7.9	4.3	4.7	4.9	4.9	5.8	7.6	7.9
14"	7.3	7.3	7.6	8.2	7.7	7.5	7.8	7.1	6.2	5.9	5.3	4.1	4.1	4.8	4.9	5.7	5.8	6.9
16"	5.4	6.3	6.4	6.9	7.0	7.1	7.2	5.6	5.5	5.1	4.6	4.3	4.1	4.9	5.6	6.9	6.7	6.1
18"	4.9	5.1	5.0	5.5	5.3	4.8	4.6	4.9	5.6	5.6	5.1	5.0	5.3	6.6	5.9	6.3	6.2	7.7
20"	4.5	4.4	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.9	6.0
22"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
24"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
26"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
28"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
30"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
32"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
34"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
36"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*

* pH of 4.0 or less.

Table 9. Amendment incorporation uniformity pH assessment for Site 11.

Excavation Pit # 9
Date Sampled: October 5, 1993

Amendment: Lime
Incorporation Equipment: BoMag Rotary Mixer

Placement of grid on vertical wall: On the east portion of the south pit face.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	8.5	7.8	8.3	7.9	8.0	8.5	8.4	8.4	8.1	8.0	8.5	8.2	8.5	8.5	8.4	8.3	7.8	7.9
4"	8.5	8.3	8.5	8.1	8.5	8.5	8.3	8.5	8.3	8.1	8.4	8.5	8.1	8.2	8.0	8.0	8.4	7.9
6"	8.5	8.4	8.4	8.4	8.3	8.3	8.3	8.4	8.1	8.1	8.0	8.5	8.3	8.2	8.5	8.5	8.0	8.1
8"	8.5	8.4	8.3	8.5	8.5	8.4	8.4	8.5	8.3	8.5	8.3	8.5	8.5	8.5	8.5	8.5	8.3	8.3
10"	8.3	8.5	8.3	8.2	8.5	8.5	7.9	8.0	7.7	7.8	8.4	8.5	8.2	8.5	8.5	8.5	8.5	8.5
12"	8.4	8.4	8.5	8.4	8.4	8.3	8.1	8.1	8.0	7.5	7.8	8.5	8.2	8.3	8.5	8.5	8.4	8.4
14"	7.4	7.3	7.7	8.5	8.5	8.4	8.3	8.5	8.2	7.9	7.8	8.0	8.3	8.4	8.5	8.1	7.9	8.1
16"	7.4	7.3	7.4	8.0	8.5	8.0	7.9	8.5	8.5	7.9	7.6	7.9	8.1	8.5	8.5	7.8	7.7	7.7
18"	7.7	7.8	7.7	7.6	8.1	8.2	8.1	8.1	8.0	8.2	7.9	8.1	8.5	8.5	8.3	8.0	7.9	7.8
20"	8.4	8.2	8.0	7.8	8.1	8.5	8.4	7.7	8.2	8.1	7.8	7.9	8.5	8.5	8.3	8.2	8.4	8.0
22"	6.6	6.9	7.7	7.4	7.5	7.5	7.3	7.2	6.9	6.8	6.2	6.2	7.0	6.5	6.4	6.9	6.9	6.9
24"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
26"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
28"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
30"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
32"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
34"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
36"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*

* pH of 4.0 or less.

Table 10. Amendment incorporation uniformity pH assessment for Site 11.

Excavation Pit # 13
Date Sampled: October 5, 1993

Amendment: None (Control)
Incorporation Equipment: None

Placement of grid on vertical wall: Centered on north pit wall.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
4"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
6"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
8"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
10"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
12"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
14"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
16"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
18"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
20"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
22"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
24"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
26"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
28"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
30"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
32"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
34"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
36"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*

* pH of 4.0 or less.

Table 11. Amendment incorporation uniformity pH assessment for Site 13.

Excavation Pit # 1
Date Sampled: October 5, 1993

Amendment: None (Control)
Incorporation Equipment: None

Placement of grid on vertical wall: Centered on west pit wall.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	4.0	4.2	4.2	4.0	4.0	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.1	4.1	4.0	4.0	4.0
4"	4.4	4.6	4.6	4.3	4.2	4.5	4.7	4.4	4.4	4.2	4.3	4.3	4.2	4.2	4.4	4.3	4.1	4.1
6"	5.6	7.7	6.8	6.2	5.9	5.0	7.0	6.9	5.7	4.9	5.2	4.6	5.0	4.9	4.8	5.2	4.7	4.6
8"	6.9	7.7	6.7	7.0	6.5	5.9	6.4	4.9	5.1	5.0	5.0	5.0	5.7	5.9	6.1	6.3	6.3	5.8
10"	5.5	5.7	5.3	7.2	6.8	7.4	7.9	7.7	6.8	6.5	6.3	6.0	6.8	5.0	5.4	7.4	6.6	6.4
12"	6.2	6.1	5.7	5.5	5.4	6.6	7.0	6.9	5.9	7.4	6.7	6.7	4.9	4.8	5.2	6.6	5.9	5.5
14"	7.0	6.8	6.1	7.1	7.1	7.8	6.9	6.2	6.6	7.1	6.9	6.0	5.4	5.4	5.8	6.4	6.5	6.1
16"	7.8	7.7	7.0	6.5	5.8	6.2	6.4	6.1	6.0	5.9	5.8	5.8	5.8	5.8	5.4	5.4	5.7	6.0
18"	6.7	6.8	6.9	6.4	7.2	7.0	6.5	7.3	8.1	7.8	7.3	7.2	7.1	7.4	6.7	5.9	7.4	6.9
20"	7.2	6.6	7.0	6.6	6.9	6.8	6.8	7.5	7.8	7.7	7.4	7.1	6.8	6.1	6.5	6.9	7.3	7.1
22"	6.4	7.3	7.2	6.9	6.7	6.6	7.0	6.4	6.9	6.8	7.1	6.9	6.7	6.3	6.5	6.7	7.3	6.2
24"	6.5	7.0	6.5	6.9	7.0	6.5	6.9	6.5	7.2	7.5	6.7	5.9	6.7	6.7	6.6	7.2	6.9	6.5
26"	7.3	5.9	6.2	6.7	6.5	6.3	6.4	6.7	7.0	6.6	6.4	6.4	7.1	7.0	7.3	7.3	6.9	6.6
28"	6.0	6.4	7.0	6.5	5.9	6.2	6.5	6.8	6.8	6.7	6.4	6.8	7.1	6.9	6.8	6.6	6.6	6.6
30"	6.4	6.3	7.1	6.5	6.9	6.8	6.8	7.1	6.7	6.9	6.8	6.8	6.8	6.8	6.3	6.2	6.7	6.4
32"	6.5	6.3	6.8	6.5	6.5	6.6	6.8	7.3	6.9	6.9	6.6	6.8	6.9	7.2	5.9	6.4	6.5	6.8
34"																		
36"																		

Table 12. Amendment incorporation uniformity pH assessment for Site 13.

Excavation Pit # 9
Date Sampled: October 5, 1993

Amendment: Lime
Incorporation Equipment: BoMag Rotary Mixer

Placement of grid on vertical wall: West pit face.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	7.7	7.0	7.4	7.6	7.8	7.0	6.8	7.2	7.4	7.3	6.9	6.8	6.9	7.0	7.2	7.2	7.4	7.1
4"	7.1	7.2	7.1	7.5	7.8	7.1	7.0	7.3	7.5	7.4	7.0	6.9	7.1	7.0	7.0	6.9	7.2	7.0
6"	7.1	7.8	7.6	7.0	7.1	7.3	7.1	7.2	7.2	7.0	7.0	7.0	7.1	7.1	7.1	6.9	6.7	6.8
8"	6.8	7.3	7.3	7.1	7.4	7.5	7.1	7.0	7.0	7.1	7.1	7.3	7.4	7.0	6.9	6.8	6.5	6.8
10"	7.1	7.3	7.4	7.3	7.1	7.0	7.0	6.9	7.2	7.1	7.2	7.0	7.0	6.8	6.9	6.7	6.7	6.8
12"	6.9	6.8	7.0	7.1	7.1	7.2	7.0	7.3	7.2	7.1	7.2	7.2	7.1	7.2	7.1	6.9	6.6	6.7
14"	6.8	7.0	7.1	7.1	6.9	6.9	7.3	7.7	7.4	7.2	7.1	7.0	7.0	7.0	6.8	6.6	6.6	6.7
16"	6.8	6.9	7.0	7.2	7.1	7.1	7.1	7.4	7.6	7.1	6.9	6.8	6.8	6.7	6.9	7.0	7.0	6.9
18"	7.1	7.0	7.2	7.1	7.0	7.0	7.2	7.5	7.3	7.3	7.2	7.1	7.0	6.9	6.7	6.8	7.0	6.7
20"	7.0	7.2	7.2	7.1	7.1	7.0	7.2	7.6	7.3	7.1	7.0	7.0	6.9	7.2	6.8	6.8	7.0	6.7
22"	6.9	7.2	7.1	7.3	7.2	7.3	7.2	7.7	7.5	6.9	7.2	7.0	7.0	7.2	7.2	7.1	7.1	7.0
24"	7.0	7.2	7.2	7.3	7.3	7.1	7.3	7.4	7.4	6.6	6.8	6.8	7.1	7.3	7.2	7.2	6.9	6.9
26"	7.0	7.0	6.4	6.8	6.9	7.2	7.3	7.1	7.1	7.3	7.2	7.1	7.2	7.2	7.0	7.1	6.6	6.5
28"	7.0	6.9	7.0	6.8	6.7	7.2	7.4	7.2	7.0	7.1	7.2	7.1	7.1	6.8	7.0	6.9	6.5	6.6
30"	6.8	7.0	6.9	7.1	6.7	7.0	7.1	7.0	6.9	7.1	7.0	7.1	7.2	7.3	6.8	7.1	6.9	6.8
32"	6.6	6.9	6.9	7.2	7.1	6.8	6.8	7.0	6.9	6.9	6.8	7.0	7.0	6.7	6.6	6.7	7.1	7.0
34"																		
36"																		

Table 13. Amendment incorporation uniformity pH assessment for Site 4.

Excavation Pit # 3
Date Sampled: October 6, 1993

Amendment: Lime
Incorporation Equipment: BoMag Rotary Mixer

Placement of grid on vertical wall: South pit face.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	4.4	4.9	5.0	4.2	5.2	5.3	5.8	6.2	5.1	5.6	5.5	5.0	4.6	4.4	4.5	4.8	5.7	5.8
4"	4.7	4.5	4.8	5.3	5.6	6.1	6.5	6.8	6.2	6.0	5.3	5.1	5.5	5.9	5.2	5.5	5.3	5.2
6"	5.2	5.4	5.9	5.7	6.4	4.9	5.2	5.8	6.1	5.3	5.5	5.6	5.5	6.4	6.5	5.7	5.1	5.8
8"	4.6	6.7	7.0	7.1	6.8	6.1	5.8	5.5	5.8	5.3	5.4	6.0	6.9	6.9	7.4	7.1	6.7	6.4
10"	7.8	7.9	8.0	7.7	7.8	7.5	6.8	6.6	5.9	5.8	5.7	6.7	7.3	7.7	7.5	7.8	7.9	8.0
12"	7.7	7.9	8.4	8.3	8.0	8.2	7.7	6.9	6.1	7.5	6.6	7.8	7.7	7.8	7.9	8.4	8.5	8.5
14"	7.8	7.7	7.9	8.3	8.1	8.3	7.6	6.9	7.4	7.7	8.5	8.3	8.5	8.1	8.2	8.5	8.5	8.5
16"	8.5	8.4	8.1	8.3	8.2	8.1	8.0	8.0	8.3	8.3	8.5	8.5	8.4	8.1	8.2	8.5	8.5	8.5
18"	7.9	8.1	8.2	8.3	8.1	8.2	8.2	8.1	8.4	8.5	8.5	8.2	8.1	8.1	8.3	8.5	8.5	8.5
20"	7.9	7.8	8.0	8.3	8.3	8.2	7.9	8.0	8.3	8.5	8.5	8.3	8.1	8.2	8.5	8.5	8.5	8.5
22"	7.8	7.8	7.9	8.0	8.2	8.0	8.1	8.1	8.4	8.5	8.5	8.5	8.4	8.5	8.5	8.5	8.5	8.5
24"	7.8	8.0	8.1	8.2	8.2	8.3	8.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
26"	8.0	8.3	8.2	8.2	8.2	8.2	8.2	8.0	8.1	8.3	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
28"	5.1	5.5	5.4	5.8	6.2	6.5	6.5	5.3	5.2	5.5	6.3	8.5	8.5	8.5	7.7	6.6	6.1	6.5
30"	4.6	4.4	5.0	4.9	4.4	4.3	4.9	4.8	4.5	4.3	4.7	8.5	7.9	6.7	6.6	6.2	4.9	4.7
32"	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0	4.0	4.0	5.8	5.3	5.1	5.6	5.2	4.0	4.0
34"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
36"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*

* pH of 4.0 or less.

Table 14. Amendment incorporation uniformity pH assessment for Site 4.

Excavation Pit # 5
Date Sampled: October 6, 1993

Amendment: Lime
Incorporation Equipment: Baker Plow

Placement of grid on vertical wall: North pit wall.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	8.4	8.5	8.4	8.4	8.4	8.5	6.0	4.8	4.0	4.0	4.1	4.0	4.2	4.4	4.1	4.1	4.1	4.0
4"	8.5	8.4	8.3	8.3	8.0	8.5	5.3	4.8	4.1	4.0	4.1	4.1	4.6	6.7	5.1	4.8	5.3	5.5
6"	8.3	7.9	7.7	6.5	7.4	7.8	5.4	4.0	4.1	4.0	4.0	4.2	4.7	4.9	5.1	4.6	7.3	8.1
8"	8.0	7.8	7.5	7.4	7.9	7.8	6.4	4.7	6.9	6.0	4.2	4.3	4.7	5.7	6.0	6.2	7.8	6.2
10"	6.5	6.3	6.4	7.0	6.8	7.2	8.2	5.0	8.1	5.0	4.0	4.2	4.4	4.3	6.3	6.9	6.5	4.5
12"	4.9	4.8	4.7	5.9	6.4	5.8	5.0	5.0	7.7	5.2	4.0	4.1	4.2	4.7	5.0	4.9	4.8	4.0
14"	4.6	5.3	6.6	8.3	6.4	4.1	4.1	5.5	5.4	4.9	4.2	4.4	5.7	4.7	4.2	4.4	4.9	5.6
16"	5.0	5.8	7.5	8.5	8.1	5.6	4.9	4.1	4.1	4.3	4.1	5.1	5.0	4.9	6.1	7.1	7.7	7.9
18"	4.8	4.5	5.0	5.8	5.5	6.7	5.3	5.2	6.4	8.1	6.9	4.9	5.0	5.6	7.4	7.8	8.0	7.9
20"	5.0	5.1	4.7	5.3	4.9	4.4	4.3	5.2	7.8	8.3	7.3	4.5	4.3	7.1	7.8	7.5	8.0	8.3
22"	5.5	5.2	5.9	6.4	7.3	5.8	5.2	4.9	6.0	8.2	5.7	7.5	4.4	6.2	7.3	8.0	8.2	8.3
24"	4.3	4.3	4.6	4.5	4.7	4.1	4.4	4.6	5.2	6.3	5.3	4.5	4.2	5.2	6.4	6.3	6.9	7.5
26"	4.1	4.1	4.3	4.2	4.2	4.2	4.2	4.4	4.8	5.0	4.8	4.0	4.1	4.2	4.1	4.2	4.5	4.9
28"	4.8	5.1	4.5	4.0	4.1	5.2	4.2	4.3	5.9	6.1	4.7	4.1	4.1	4.1	4.0	4.3	4.2	4.5
30"	4.2	4.1	4.1	4.3	4.2	5.0	4.3	4.7	5.2	6.0	5.1	4.0	4.6	4.6	4.0	4.1	4.3	4.4
32"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
34"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
36"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*

* pH of 4.0 or less.

Table 15. Amendment incorporation uniformity pH assessment for Site 4.

Excavation Pit # 9
Date Sampled: October 6, 1993

Amendment: None (Control)
Incorporation Equipment: None

Placement of grid on vertical wall: North wall of pit.

	0-2"	2-4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	16-18"	18-20"	20-22"	22-24"	24-26"	26-28"	28-30"	30-32"	32-34"	34-36"
2"	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
4"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
6"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
8"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
10"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
12"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
14"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
16"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
18"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
20"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
22"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
24"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
26"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
28"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
30"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
32"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
34"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*
36"	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*	4.0*

* pH of 4.0 or less.

APPENDIX B

pH INCREMENTAL DATA

Table 16. pH data for ARTS Site 9.

SAMPLE	INCREMENT	pH	SAMPLE	INCREMENT	pH
ARTS09-P1-M-BP-08	A	7.47	ARTS09-P7-LM-BP-08	A	9.90
ARTS09-P1-M-BP-817	B	6.92	ARTS09-P7-LM-BP-816	B	12.2
ARTS09-P1-M-BP-1724	C	6.95	ARTS09-P7-LM-BP-1624	C	12.26
ARTS09-P1-M-BP-2432	D	7.39	ARTS09-P7-LM-BP-2432	D	4.20
ARTS09-P2-C-08	A	7.18	ARTS09-P8-C-08	A	5.84
ARTS09-P2-C-816	B	6.43	ARTS09-P8-C-816	B	4.78
ARTS09-P2-C-1624	C	5.87	ARTS09-P8-C-1624	C	6.04
ARTS09-P2-C-2432	D	6.04	ARTS09-P8-C-2432	D	6.35
ARTS09-P3-M-BP-08	A	6.09	ARTS09-P9-C-08	A	3.56
ARTS09-P3-M-BP-816	B	8.09	ARTS09-P9-C-816	B	3.49
ARTS09-P3-M-BP-1624	C	7.85	ARTS09-P9-C-1624	C	2.52
ARTS09-P3-M-BP-2430	D	7.96	ARTS09-P9-C-2432	D	2.39
ARTS09-P4-C-05	A	7.60	ARTS09-P10-C-08	A	3.16
ARTS09-P4-C-511	B	6.43	ARTS09-P10-C-816	B	2.93
ARTS09-P4-C-1124	C	6.97	ARTS09-P10-C-816R	B	2.81
ARTS09-P4-C-2432	D	7.01	ARTS09-P10-C-1624	C	3.23
ARTS09-P5-LM-BP-08	A	12.28	ARTS09-P10-C-2432	D	3.60
ARTS09-P5-LM-BP-08R	A	12.12	ARTS09-P11-C-08	A	7.80
ARTS09-P5-LM-BP-816	B	9.11	ARTS09-P11-C-816	B	8.11
ARTS09-P5-LM-BP-1620	C	10.88	ARTS09-P11-C-1624	C	8.78
ARTS09-P5-LM-BP-2032	D	3.91	ARTS09-P11-C-2432	D	12.39
ARTS09-P6-LM-BP-08	A	12.17	ARTS09-P12-M-BP-08	A	8.27
ARTS09-P6-LM-BP-816	B	8.65	ARTS09-P12-M-BP-816	B	8.16
ARTS09-P6-LM-BP-1620	C	10.85	ARTS09-P12-M-BP-1624	C	8.92
ARTS09-P6-LM-BP-2032	D	6.05	ARTS09-P12-M-BP-2432	D	8.41

Table 17. pH data for ARTS Site 11.

SAMPLE	INCREMENT	pH
ARTS11-P1-L-BP-08	A	12.23
ARTS11-P1-L-BP-816	B	11.33
ARTS11-P1-L-BP-1620	C	9.13
ARTS11-P1-L-BP-2032	D	3.78
ARTS11-P2-L-BP-08	A	12.31
ARTS11-P2-L-BP-816	B	10.01
ARTS11-P2-L-BP-1620	C	9.35
ARTS11-P2-L-BP-2032	D	3.36
ARTS11-P3-L-BP-08	A	12.24
ARTS11-P3-L-BP-816	B	12.28
ARTS11-P3-L-BP-1622	C	12.31
ARTS11-P3-L-BP-2232	D	4.21
ARTS11-P4-LM-BP-08	A	12.33
ARTS11-P4-LM-BP-816	B	11.51
ARTS11-P4-LM-BP-1624	C	3.76
ARTS11-P4-LM-BP-2432	D	4.30
ARTS11-P5-LM-BP-08	A	12.28
ARTS11-P5-LM-BP-816	B	10.08
ARTS11-P5-LM-BP-1618	C	8.03
ARTS11-P5-LM-BP-1832	D	3.35
ARTS11-P6-LM-BP-08	A	12.21
ARTS11-P6-LM-BP-816	B	12.22
ARTS11-P6-LM-BP-1617	C	8.65
ARTS11-P6-LM-BP-1732	D	3.66
ARTS11-P7-L-BRM-08	A	9.80
ARTS11-P7-L-BRM-816	B	9.64
ARTS11-P7-L-BRM-1622	C	10.02
ARTS11-P7-L-BRM-2232	D	4.36
ARTS11-P8-L-BRM-08	A	9.91
ARTS11-P8-L-BRM-816	B	9.51
ARTS11-P8-L-BRM-1621	C	9.41
ARTS11-P8-L-BRM-2132	D	4.16
ARTS11-P8-L-BRM-2132R	D	3.83
ARTS11-P9-L-BRM-08	A	10.93
ARTS11-P9-L-BRM-816	B	11.04
ARTS11-P9-L-BRM-1622	C	10.05
ARTS11-P9-L-BRM-2232	D	3.15
ARTS11-P10-LM-BRM-08	A	10.38
ARTS11-P10-LM-BRM-816	B	9.80
ARTS11-P10-LM-BRM-1624	C	12.08
ARTS11-P10-LM-BRM-2432	D	3.99
ARTS11-P11-LM-BRM-08	A	12.27
ARTS11-P11-LM-BRM-816	B	9.92
ARTS11-P11-LM-BRM-1623	C	9.91
ARTS11-P11-LM-BRM-2332	D	3.89
ARTS11-P12-LM-BRM-08	A	10.21
ARTS11-P12-LM-BRM-816	B	10.87
ARTS11-P12-LM-BRM-1621	C	10.20
ARTS11-P12-LM-BRM-2132	D	4.28
ARTS11-P13-C-08	A	5.02
ARTS11-P13-C-08R	A	4.89
ARTS11-P13-C-816	B	3.52
ARTS11-P13-C-1624	C	3.10
ARTS11-P13-C-2432	D	2.95
ARTS11-P14-C-08	A	4.71
ARTS11-P14-C-816	B	3.33
ARTS11-P14-C-1624	C	3.09
ARTS11-P14-C-2432	D	3.06
ARTS11-P15-C-08	A	4.74
ARTS11-P15-C-816	B	4.29
ARTS11-P15-C-1624	C	3.63
ARTS11-P15-C-2432	D	3.39

Table 18. pH data for ARTS Site 13.

SAMPLE	INCREMENT	pH	SAMPLE	INCREMENT	pH
ARTS13-P1-C-08	A	6.36	ARTS13-P7-L-BRM-08	A	7.54
ARTS13-P1-C-816	B	7.87	ARTS13-P7-L-BRM-816	B	7.75
ARTS13-P1-C-1624	C	7.82	ARTS13-P7-L-BRM-1624	C	7.74
ARTS13-P1-C-2432	D	8.09	ARTS13-P7-L-BRM-2432	D	7.90
ARTS13-P2-C-08	A	6.49	ARTS13-P8-L-BRM-08	A	8.00
ARTS13-P2-C-816	B	7.72	ARTS13-P8-L-BRM-815	B	8.56
ARTS13-P2-C-1624	C	8.06	ARTS13-P8-L-BRM-1524	C	8.09
ARTS13-P2-C-2432	D	8.08	ARTS13-P8-L-BRM-1524R	C	8.05
ARTS13-P3-C-08	A	5.96	ARTS13-P8-L-BRM-2432	D	8.11
ARTS13-P3-C-816	B	7.76	ARTS13-P9-L-BRM-08	A	8.16
ARTS13-P3-C-816R	B	7.80	ARTS13-P9-L-BRM-814	B	8.01
ARTS13-P3-C-1624	C	7.75	ARTS13-P9-L-BRM-1424	C	8.06
ARTS13-P3-C-2432	D	7.72	ARTS13-P9-L-BRM-2432	D	8.00
ARTS13-P4-M-BRM-08	A	7.68	ARTS13-P10-M-BP-08	A	8.10
ARTS13-P4-M-BRM-816	B	7.89	ARTS13-P10-M-BP-816	B	7.86
ARTS13-P4-M-BRM-1626	C	7.89	ARTS13-P10-M-BP-1624	C	7.97
ARTS13-P4-M-BRM-2632	D	8.02	ARTS13-P10-M-BP-2432	D	8.01
ARTS13-P5-M-BRM-08	A	7.85	ARTS13-P11-M-BP-08	A	7.77
ARTS13-P5-M-BRM-816	B	7.98	ARTS13-P11-M-BP-816	B	7.94
ARTS13-P5-M-BRM-1625	C	7.90	ARTS13-P11-M-BP-1624	C	7.83
ARTS13-P5-M-BRM-2532	D	7.98	ARTS13-P11-M-BP-2432	D	7.85
ARTS13-P6-M-BRM-08	A	7.62	ARTS13-P12-M-BP-08	A	7.14
ARTS13-P6-M-BRM-816	B	7.56	ARTS13-P12-M-BP-816	B	7.31
ARTS13-P6-M-BRM-1624	C	7.58	ARTS13-P12-M-BP-1624	C	7.77
ARTS13-P6-M-BRM-2432	D	7.72	ARTS13-P12-M-BP-2432	D	7.81

Table 19. pH data for ARTS Site 4.

SAMPLE	INCREMENT	pH	SAMPLE	INCREMENT	pH
ARTS04-P1-L-BRM-08	A	8.35	ARTS04-P5-L-BP-1626	C	12.40
ARTS04-P1-L-BRM-816	B	11.02	ARTS04-P5-L-BP-2632	D	3.94
ARTS04-P1-L-BRM-1624	C	10.46	ARTS04-P6-L-BP-08	A	9.47
ARTS04-P1-L-BRM-2432	D	4.35	ARTS04-P6-L-BP-08R	A	6.98
ARTS04-P1-L-BRM-2432R	D	4.34	ARTS04-P6-L-BP-816	B	7.44
ARTS04-P2-L-BRM-08	A	7.74	ARTS04-P6-L-BP-1619	C	9.81
ARTS04-P2-L-BRM-816	B	8.76	ARTS04-P6-L-BP-1932	D	12.20
ARTS04-P2-L-BRM-1625	C	9.41	ARTS04-P7-C-08	A	4.83
ARTS04-P2-L-BRM-2532	D	4.29	ARTS04-P7-C-816	B	4.05
ARTS04-P3-L-BRM-08	A	7.71	ARTS04-P7-C-1624	C	2.94
ARTS04-P3-L-BRM-816	B	8.59	ARTS04-P7-C-2432	D	2.90
ARTS04-P3-L-BRM-1626	C	9.86	ARTS04-P8-C-08	A	5.59
ARTS04-P3-L-BRM-2632	D	4.14	ARTS04-P8-C-816	B	3.04
ARTS04-P4-L-BP-08	A	5.69	ARTS04-P8-C-1624	C	2.88
ARTS04-P4-L-BP-816	B	7.40	ARTS04-P8-C-2432	D	3.31
ARTS04-P4-L-BP-1626	C	6.01	ARTS04-P9-C-08	A	6.13
ARTS04-P4-L-BP-2632	D	3.38	ARTS04-P9-C-816	B	4.50
ARTS04-P5-L-BP-08	A	7.97	ARTS04-P9-C-1624	C	5.31
ARTS04-P5-L-BP-816	B	7.31	ARTS04-P9-C-2432	D	4.48

APPENDIX C

ORGANIC MATTER INCREMENTAL DATA

Table 20. Organic matter (OM) data for ARTS Site 9.

SAMPLE	INCREMENT	OM
ARTS09-P1-M-BP-08	A	3.40
ARTS09-P1-M-BP-817	B	3.54
ARTS09-P1-M-BP-1724	C	0.15
ARTS09-P1-M-BP-2432	D	0.10
ARTS09-P2-C-08	A	0.55
ARTS09-P2-C-816	B	0.76
ARTS09-P2-C-1624	C	1.02
ARTS09-P2-C-2432	D	0.42
ARTS09-P3-M-BP-08	A	5.07
ARTS09-P3-M-BP-816	B	0.70
ARTS09-P3-M-BP-1624	C	0.72
ARTS09-P3-M-BP-2430	D	0.74
ARTS09-P4-C-05	A	0.37
ARTS09-P4-C-511	B	2.88
ARTS09-P4-C-1124	C	1.08
ARTS09-P4-C-2432	D	0.12
ARTS09-P5-LM-BP-08	A	2.99
ARTS09-P5-LM-BP-08R	A	2.83
ARTS09-P5-LM-BP-816	B	2.66
ARTS09-P5-LM-BP-1620	C	2.79
ARTS09-P5-LM-BP-2032	D	1.35
ARTS09-P6-LM-BP-08	A	2.15
ARTS09-P6-LM-BP-816	B	2.02
ARTS09-P6-LM-BP-1620	C	2.04
ARTS09-P6-LM-BP-2032	D	1.08

SAMPLE	INCREMENT	OM
ARTS09-P7-LM-BP-08	A	3.29
ARTS09-P7-LM-BP-816	B	1.61
ARTS09-P7-LM-BP-1624	C	1.99
ARTS09-P7-LM-BP-2432	D	1.25
ARTS09-P8-C-08	A	0.25
ARTS09-P8-C-816	B	0.57
ARTS09-P8-C-1624	C	0.42
ARTS09-P8-C-2432	D	0.32
ARTS09-P9-C-08	A	1.26
ARTS09-P9-C-816	B	1.61
ARTS09-P9-C-1624	C	1.75
ARTS09-P9-C-2432	D	0.44
ARTS09-P10-C-08	A	0.55
ARTS09-P10-C-816	B	0.48
ARTS09-P10-C-816R	B	0.79
ARTS09-P10-C-1624	C	0.69
ARTS09-P10-C-2432	D	0.79
ARTS09-P11-C-08	A	0.25
ARTS09-P11-C-816	B	0.31
ARTS09-P11-C-1624	C	0.40
ARTS09-P11-C-2432	D	0.50
ARTS09-P12-M-BP-08	A	1.96
ARTS09-P12-M-BP-816	B	1.06
ARTS09-P12-M-BP-1624	C	0.57
ARTS09-P12-M-BP-2432	D	0.11

Table 21. Organic matter (OM) data for ARTS Site 11.

SAMPLE	INCREMENT	OM
ARTS11-P1-L-BP-08	A	-
ARTS11-P1-L-BP-816	B	-
ARTS11-P1-L-BP-1620	C	-
ARTS11-P1-L-BP-2032	D	-
ARTS11-P2-L-BP-08	A	-
ARTS11-P2-L-BP-816	B	-
ARTS11-P2-L-BP-1620	C	-
ARTS11-P2-L-BP-2032	D	-
ARTS11-P3-L-BP-08	A	-
ARTS11-P3-L-BP-816	B	-
ARTS11-P3-L-BP-1622	C	-
ARTS11-P3-L-BP-2232	D	-
ARTS11-P4-LM-BP-08	A	1.26
ARTS11-P4-LM-BP-816	B	0.85
ARTS11-P4-LM-BP-1624	C	<.05
ARTS11-P4-LM-BP-2432	D	<.05
ARTS11-P5-LM-BP-08	A	0.90
ARTS11-P5-LM-BP-816	B	0.55
ARTS11-P5-LM-BP-1618	C	0.65
ARTS11-P5-LM-BP-1832	D	0.06
ARTS11-P6-LM-BP-08	A	0.66
ARTS11-P6-LM-BP-816	B	1.56
ARTS11-P6-LM-BP-1617	C	0.34
ARTS11-P6-LM-BP-1732	D	0.09
ARTS11-P7-L-BRM-08	A	-
ARTS11-P7-L-BRM-816	B	-
ARTS11-P7-L-BRM-1622	C	-
ARTS11-P7-L-BRM-2232	D	-
ARTS11-P8-L-BRM-08	A	-
ARTS11-P8-L-BRM-816	B	-
ARTS11-P8-L-BRM-1621	C	-
ARTS11-P8-L-BRM-2132	D	-
ARTS11-P8-L-BRM-2132R	D	-
ARTS11-P9-L-BRM-08	A	-
ARTS11-P9-L-BRM-816	B	-
ARTS11-P9-L-BRM-1622	C	-
ARTS11-P9-L-BRM-2232	D	-
ARTS11-P10-LM-BRM-08	A	0.86
ARTS11-P10-LM-BRM-816	B	0.51
ARTS11-P10-LM-BRM-1624	C	1.13
ARTS11-P10-LM-BRM-2432	D	<.05
ARTS11-P11-LM-BRM-08	A	0.82
ARTS11-P11-LM-BRM-816	B	0.47
ARTS11-P11-LM-BRM-1623	C	0.67
ARTS11-P11-LM-BRM-2332	D	<.05
ARTS11-P12-LM-BRM-08	A	0.93
ARTS11-P12-LM-BRM-816	B	0.49
ARTS11-P12-LM-BRM-1621	C	0.46
ARTS11-P12-LM-BRM-2132	D	<.05
ARTS11-P13-C-08	A	0.23
ARTS11-P13-C-08R	A	0.37
ARTS11-P13-C-816	B	0.55
ARTS11-P13-C-1624	C	<.05
ARTS11-P13-C-2432	D	<.05
ARTS11-P14-C-08	A	0.90
ARTS11-P14-C-816	B	<.05
ARTS11-P14-C-1624	C	<.05
ARTS11-P14-C-2432	D	<.05
ARTS11-P15-C-08	A	0.23
ARTS11-P15-C-816	B	0.49
ARTS11-P15-C-1624	C	<.05
ARTS11-P15-C-2432	D	<.05

Table 22. Organic matter (OM) data for ARTS Site 13.

SAMPLE	INCREMENT	OM
ARTS13-P1-C-08	A	2.04
ARTS13-P1-C-816	B	1.97
ARTS13-P1-C-1624	C	0.79
ARTS13-P1-C-2432	D	<.05
ARTS13-P2-C-08	A	2.08
ARTS13-P2-C-816	B	1.64
ARTS13-P2-C-1624	C	0.61
ARTS13-P2-C-2432	D	0.26
ARTS13-P3-C-08	A	1.57
ARTS13-P3-C-816	B	1.26
ARTS13-P3-C-816R	B	1.32
ARTS13-P3-C-1624	C	1.32
ARTS13-P3-C-2432	D	1.02
ARTS13-P4-M-BRM-08	A	3.51
ARTS13-P4-M-BRM-816	B	1.20
ARTS13-P4-M-BRM-1626	C	1.18
ARTS13-P4-M-BRM-2632	D	0.48
ARTS13-P5-M-BRM-08	A	3.05
ARTS13-P5-M-BRM-816	B	3.22
ARTS13-P5-M-BRM-1625	C	2.67
ARTS13-P5-M-BRM-2532	D	0.15
ARTS13-P6-M-BRM-08	A	3.98
ARTS13-P6-M-BRM-816	B	2.59
ARTS13-P6-M-BRM-1624	C	1.89
ARTS13-P6-M-BRM-2432	D	0.54
ARTS13-P7-L-BRM-08	A	-
ARTS13-P7-L-BRM-816	B	-
ARTS13-P7-L-BRM-1624	C	-
ARTS13-P7-L-BRM-2432	D	-
ARTS13-P8-L-BRM-08	A	-
ARTS13-P8-L-BRM-815	B	-
ARTS13-P8-L-BRM-1524	C	-
ARTS13-P8-L-BRM-1524R	C	-
ARTS13-P8-L-BRM-2432	D	-
ARTS13-P9-L-BRM-08	A	-
ARTS13-P9-L-BRM-814	B	-
ARTS13-P9-L-BRM-1424	C	-
ARTS13-P9-L-BRM-2432	D	-
ARTS13-P10-M-BP-08	A	1.23
ARTS13-P10-M-BP-816	B	2.18
ARTS13-P10-M-BP-1624	C	0.94
ARTS13-P10-M-BP-2432	D	0.68
ARTS13-P11-M-BP-08	A	2.91
ARTS13-P11-M-BP-816	B	2.97
ARTS13-P11-M-BP-1624	C	1.38
ARTS13-P11-M-BP-2432	D	0.22
ARTS13-P12-M-BP-08	A	2.58
ARTS13-P12-M-BP-816	B	3.03
ARTS13-P12-M-BP-1624	C	1.75
ARTS13-P12-M-BP-2432	D	1.05

APPENDIX D

STATISTICAL TABLES

Table 23. Analysis of variance for maximum depth of incorporation at ARTS Site 11.

Model structure: Equipment
For variable: Depth

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Equipment	1	33.3	33.33	7.87	0.0186
Residual	10	42.3	4.23		
Total	11	75.7			

Table 24. Analysis of variance for maximum depth of incorporation at ARTS Site 4.

Model structure: Equipment
For variable: Depth

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Equipment	1	6.00	6.00	0.720	0.4439
Residual	4	33.33	8.33		
Total	5	39.33			

Table 25. Analysis of variance and least significant difference of Baker Plow grid pH values versus control grid pH values at ARTS Site 9 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	35	1204.5	34.42	51.56	<0.001
Residual	612	408.52	0.668		
Total	647	1613.1			

LSD ANALYSIS: Baker Plow

Depth (inches)	Mean pH	
0-2	8.50 A	*
2-4	8.44 A	
4-6	7.78 B	
6-8	7.27 BC	
8-10	7.36 BC	
10-12	6.92 CDE	
12-14	7.29 BC	
14-16	7.37 BC	
16-18	7.06 CD	
18-20	5.37 GH	
20-22	4.46 LK	
22-24	4.00 L	
24-26	4.00 L	
26-28	4.00 L	
28-30	4.00 L	
30-32	4.00 L	
32-34	4.00 L	
34-36	4.00 L	

LSD ANALYSIS: Control

Depth (inches)	Mean pH
0-2	4.00 L
2-4	4.61 KJ
4-6	5.37 HG
6-8	5.06 I JHG
8-10	4.80 IKJ
10-12	4.72 IKJ
12-14	4.81 IKJ
14-16	5.11 I JHG
16-18	4.86 IKJH
18-20	5.20 I HG
20-22	5.39 HG
22-24	6.07 F
24-26	6.43 FE
26-28	6.73 ED
28-30	6.49 FE
30-32	6.41 FE
32-34	6.04 F
34-36	5.49 G

* Numbers followed by the same letter are not significantly different.

Table 26. Analysis of variance and least significant difference of Baker Plow grid pH values versus control grid pH values at ARTS Site 11 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	35	1059.7	30.28	115.88	<0.001
Residual	612	159.90	0.261		
Total	647	1219.5			

LSD ANALYSIS: Baker Plow

Depth (inches)	Mean pH
0-2	7.64 AB *
2-4	7.79 AB
4-6	7.90 A
6-8	7.47 B
8-10	6.13 DE
10-12	6.47 C
12-14	6.34 D C
14-16	5.87 E
16-18	5.52 F
18-20	4.37 G
20-22	4.00 H
22-24	4.00 H
24-26	4.00 H
26-28	4.00 H
28-30	4.00 H
30-32	4.00 H
32-34	4.00 H
34-36	4.00 H

LSD ANALYSIS: Control

Depth (inches)	Mean pH
0-2	4.00 H
2-4	4.00 H
4-6	4.00 H
6-8	4.00 H
8-10	4.00 H
10-12	4.00 H
12-14	4.00 H
14-16	4.00 H
16-18	4.00 H
18-20	4.00 H
20-22	4.00 H
22-24	4.00 H
24-26	4.00 H
26-28	4.00 H
28-30	4.00 H
30-32	4.00 H
32-34	4.00 H
34-36	4.00 H

* Numbers followed by the same letter are not significantly different.

Table 27. Analysis of variance and least significant difference of BOMAG MPH-100 grid pH values versus control grid pH values at ARTS Site 11 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	35	2327.4	66.50	2560	<0.001
Residual	612	15.894	0.026		
Total	647	2343.3			

LSD ANALYSIS: BOMAG MPH-100

Depth (inches)	Mean pH	
0-2	8.22	BC *
2-4	8.28	B
4-6	8.29	B
6-8	8.43	A
8-10	8.29	B
10-12	8.26	BC
12-14	8.10	DE
14-16	7.96	F
16-18	8.03	F E
18-20	8.17	DC
20-22	6.93	G
22-24	4.00	H
24-26	4.00	H
26-28	4.00	H
28-30	4.00	H
30-32	4.00	H
32-34	4.00	H
34-36	4.00	H

LSD ANALYSIS: Control

Depth (inches)	Mean pH	
0-2	4.00	H
2-4	4.00	H
4-6	4.00	H
6-8	4.00	H
8-10	4.00	H
10-12	4.00	H
12-14	4.00	H
14-16	4.00	H
16-18	4.00	H
18-20	4.00	H
20-22	4.00	H
22-24	4.00	H
24-26	4.00	H
26-28	4.00	H
28-30	4.00	H
30-32	4.00	H
32-34	4.00	H
34-36	4.00	H

* Numbers followed by the same letter are not significantly different.

Table 28. Analysis of variance and least significant difference of BOMAG MPH-100 grid pH values versus control grid pH values at ARTS Site 13 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	31	311.75	10.06	55.64	<0.001
Residual	544	98.32	0.181		
Total	575	410.07			

LSD ANALYSIS: BOMAG MPH-100

Depth (inches)	Mean pH	
0-2	7.21	A *
2-4	7.17	A
4-6	7.12	AB
6-8	7.08	AB
8-10	7.03	ABC
10-12	7.04	ABC
12-14	7.01	ABC
14-16	7.02	ABC
16-18	7.06	AB
18-20	7.07	AB
20-22	7.17	AB
22-24	7.11	AB
24-26	7.00	ABC
26-28	6.97	ABCD
28-30	6.99	ABC
30-32	6.89	BCDE

LSD ANALYSIS: Control

Depth (inches)	Mean pH	
0-2	4.04	K
2-4	4.34	J
4-6	5.59	I
6-8	6.01	H
8-10	6.48	G
10-12	6.06	H
12-14	6.51	FG
14-16	6.17	H
16-18	7.03	AB C
18-20	7.01	AB C
20-22	6.77	EF CD
22-24	6.76	EFGCD
24-26	6.70	EFG D
26-28	6.59	FG
28-30	6.68	EFG
30-32	6.68	EFG

* Numbers followed by the same letter are not significantly different.

Table 29. Analysis of variance and least significant difference of Baker Plow grid pH values versus control grid pH values at ARTS Site 4 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	35	501.8	14.34	20.12	<0.001
Residual	612	436.0	0.712		
Total	647	937.7			

LSD ANALYSIS: Baker Plow

Depth (inches)	Mean pH	
0-2	5.69	CD *
2-4	6.02	ABC
4-6	5.89	BC
6-8	6.42	AB
8-10	5.98	ABC
10-12	5.06	FE
12-14	5.18	E D
14-16	5.88	BC
16-18	6.16	ABC
18-20	6.10	ABC
20-22	6.44	A
22-24	5.18	E D
24-26	4.35	GH
26-28	4.57	FG
28-30	4.51	FGH
30-32	4.00	H
32-34	4.00	H
34-36	4.00	H

LSD ANALYSIS: Control

Depth (inches)	Mean pH	
0-2	5.00	FE
2-4	4.00	H
4-6	4.00	H
6-8	4.00	H
8-10	4.00	H
10-12	4.00	H
12-14	4.00	H
14-16	4.00	H
16-18	4.00	H
18-20	4.00	H
20-22	4.00	H
22-24	4.00	H
24-26	4.00	H
26-28	4.00	H
28-30	4.00	H
30-32	4.00	H
32-34	4.00	H
34-36	4.00	H

* Numbers followed by the same letter are not significantly different.

Table 30. Analysis of variance and least significant difference of BOMAG MPH-100 grid pH values versus control grid pH values at ARTS Site 4 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	35	1915.5	54.73	304.3	<0.001
Residual	612	110.07	0.180		
Total	647	2025.5			

LSD ANALYSIS: BOMAG MPH-100

Depth (inches)	Mean pH
0-2	5.11 I H *
2-4	5.53 GF
4-6	5.67 F
6-8	6.31 E
8-10	7.24 D
10-12	7.77 C
12-14	8.04 BC
14-16	8.30 AB
16-18	8.26 AB
18-20	8.24 AB
20-22	8.26 AB
22-24	8.36 B
24-26	8.32 AB
26-28	6.43 E
28-30	5.35 GH
30-32	4.44 J
32-34	4.00 K
34-36	4.00 K

LSD ANALYSIS: Control

Depth (inches)	Mean pH
0-2	5.00 I
2-4	4.00 K
4-6	4.00 K
6-8	4.00 K
8-10	4.00 K
10-12	4.00 K
12-14	4.00 K
14-16	4.00 K
16-18	4.00 K
18-20	4.00 K
20-22	4.00 K
22-24	4.00 K
24-26	4.00 K
26-28	4.00 K
28-30	4.00 K
30-32	4.00 K
32-34	4.00 K
34-36	4.00 K

* Numbers followed by the same letter are not significantly different.

Table 31. Analysis of variance and least significant difference of Baker Plow incremental pH values versus control incremental pH values at ARTS Site 9 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	264.6	37.80	16.71	<0.001
Residual	16	36.20	2.263		
Total	23	300.8			

LSD ANALYSIS: Baker Plow

Depth (increment)	Mean pH
A **	11.5 A *
B	9.99 A
C	11.3 A
D	4.72 B

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	4.19 B
B	3.73 B
C	3.93 B
D	4.11 B

* Numbers followed by the same letter are not significantly different.
** Depth increments 1,2,3, and 4 are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 32. Analysis of variance and least significant difference of Baker Plow incremental pH values versus control incremental pH values at ARTS Site 11 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	482.2	68.9	42.83	<0.001
Residual	28	45.03	1.61		
Total	35	527.3			

LSD ANALYSIS: Baker Plow

Depth (increment)	Mean pH
A **	12.3 A *
B	11.2 A
C	8.54 B
D	3.78 C

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	4.82 C
B	3.71 C
C	3.27 C
D	3.13 C

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 33. Analysis of variance and least significant difference of BOMAG MPH-100 incremental pH values versus control incremental pH values at ARTS Site 11 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	388.3	55.47	124.6	<0.001
Residual	28	12.46	0.445		
Total	35	400.7			

LSD ANALYSIS: BOMAG MPH-100

Depth (increment)	Mean pH
A **	10.6 A *
B	10.1 A
C	10.3 A
D	3.97 BC

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	4.82 B
B	3.71 BC
C	3.27 C
D	3.13 C

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 34. Analysis of variance and least significant difference of BOMAG MPH-100 incremental pH values versus control incremental pH values at ARTS Site 13 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	7.531	1.076	18.06	<0.001
Residual	16	0.953	0.060		
Total	23	8.484			

LSD ANALYSIS: BOMAG MPH-100

Depth (increment)	Mean pH
A **	7.90 A *
B	8.11 A
C	7.96 A
D	8.00 A

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	6.27 B
B	7.78 A
C	7.88 A
D	7.96 A

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 35. Analysis of variance and least significant difference of Baker Plow incremental pH values versus control incremental pH values at ARTS Site 13 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	6.727	0.961	18.15	<0.001
Residual	16	0.847	0.053		
Total	23	7.574			

LSD ANALYSIS: Baker Plow

Depth (increment)	Mean pH
A **	7.98 A *
B	7.91 A
C	7.61 A
D	7.63 A

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	6.27 B
B	7.78 A
C	7.88 A
D	7.96 A

* Numbers followed by the same letter are not significantly different.
** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 36. Analysis of variance and least significant difference of Baker Plow incremental pH values versus control incremental pH values at ARTS Site 4 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	110.1	15.73	7.14	0.0006
Residual	16	35.23	2.202		
Total	23	145.3			

LSD ANALYSIS: Baker Plow

Depth (increment)	Mean pH
A **	7.71 AB *
B	7.38 AB
C	9.41 A
D	3.64 C

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	5.52 BC
B	3.86 C
C	3.71 C
D	3.56 C

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 37. Analysis of variance and least significant difference of BOMAG MPH-100 incremental pH values versus control incremental pH values at ARTS Site 4 for depth of incorporation assessment.

Model structure: Depth
For variable: pH

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	149.9	21.42	29.35	<0.001
Residual	16	11.68	0.730		
Total	23	161.6			

LSD ANALYSIS: BOMAG MPH-100

Depth (increment)	Mean pH
A **	7.93 B *
B	9.46 A
C	9.91 A
D	4.26 CD

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	5.52 C
B	3.86 D
C	3.71 D
D	3.56 D

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 38. Analysis of variance and least significant difference of Baker Plow incremental organic matter values versus control incremental organic matter values at ARTS Site 9 for depth of incorporation assessment.

Model structure: Depth
For variable: Organic matter

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	33.69	4.813	7.48	<0.001
Residual	40	25.75	0.644		
Total	47	59.44			

LSD ANALYSIS: Baker Plow

Depth (increment)	Mean pH
A **	3.14 A *
B	1.93 B
C	1.38 CB
D	0.77 CD

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	0.54 CD
B	1.10 CDB
C	0.89 CD
D	0.43 D

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 39. Analysis of variance and least significant difference of Baker Plow incremental organic matter values versus control incremental organic matter values at ARTS Site 11 for depth of incorporation assessment.

Model structure: Depth
For variable: Organic matter

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	3.048	0.435	5.11	0.0033
Residual	16	1.363	0.085		
Total	23	4.410			

LSD ANALYSIS: Baker Plow

Depth (increment)	Mean pH
A **	0.94 AB *
B	0.99 A
C	0.34 C
D	0.06 C

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	0.45 CB
B	0.36 C
C	0.04 C
D	0.04 C

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 40. Analysis of variance and least significant difference of BOMAG MPH-100 incremental organic matter values versus control incremental organic matter values at ARTS Site 11 for depth of incorporation assessment.

Model structure: Depth
For variable: Organic matter

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	2.233	0.319	7.33	0.0005
Residual	16	0.697	0.044		
Total	23	2.929			

LSD ANALYSIS: BOMAG MPH-100

Depth (increment)	Mean pH
A **	0.87 A *
B	0.49 CB
C	0.75 AB
D	0.04 D

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	0.45 CB
B	0.36 CD
C	0.04 D
D	0.04 D

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 41. Analysis of variance and least significant difference of Baker Plow incremental organic matter values versus control incremental organic matter values at ARTS Site 13 for depth of incorporation assessment.

Model structure: Depth
For variable: Organic matter

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	13.32	1.903	7.76	0.0004
Residual	16	3.924	0.245		
Total	23	17.25			

LSD ANALYSIS: Baker Plow

Depth (increment)	Mean pH
A **	2.24 AB *
B	2.73 A
C	1.36 E CD
D	0.65 EF

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	1.90 ABC
B	1.62 BCD
C	0.91 EF D
D	0.44 F

* Numbers followed by the same letter are not significantly different.
** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32

Table 42. Analysis of variance and least significant difference of BOMAG MPH-100 incremental organic matter values versus control incremental organic matter values at ARTS Site 13 for depth of incorporation assessment.

Model structure: Depth
For variable: Organic matter

ANOVA

Source	D.F.	Sum of Squares	Mean Square	F-value	P-value
Depth	7	23.02	3.289	10.56	0.0001
Residual	16	4.983	0.311		
Total	23	28.01			

LSD ANALYSIS: BOMAG MPH-100

Depth (increment)	Mean pH
A **	3.51 A *
B	2.34 B
C	1.91 B
D	0.39 D

LSD ANALYSIS: Control

Depth (increment)	Mean pH
A **	1.90 B
B	1.62 CB
C	0.91 CD
D	0.44 D

* Numbers followed by the same letter are not significantly different.

** Depth increments A,B,C, and D are generally the follow measurements in inches:
A - 0 to 8, B - 8 to 16, C - 16 to 24, D - 24 to 32