The Pennsylvania State University

The Graduate School

School of Forest Resources

IMPACTS OF DIRT AND GRAVEL ROAD DUST ON ROADSIDE ORGANIC FOREST SOILS AND ROADSIDE VEGETATION

A Thesis in

Forest Resources

by

Wade E. Brown

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The thesis of Wade E. Brown was reviewed and approved* by the following:

William E. Sharpe
Professor Emeritus of Forest Hydrology
Thesis Advisor

David DeWalle
Professor Emeritus of Forest Hydrology

Barry E. Scheetz
Professor of Materials, Civil & Nuclear Engineering

Michael G. Messina,
Professor of Forest Resources
Director of the School of Forest Resources

*Signatures are on file in the Graduate School

ABSTRACT

Dirt and gravel roads are capable of producing large amounts of dust. This dust comes from aggregate that is placed on the road surface. Aggregate may be either derived from local Bald Eagle formation sandstone bedrock (native) or from imported limestone material. Dust transported to adjacent soils from the road aggregate may alter soil chemistry. The focus of the study reports on the effects of imported limestone driving surface aggregate (DSA) and native DSA dust on roadside organic forest soils and roadside vegetation in central PA. Organic roadside forest soils and vegetation were sampled along gravel roads with both types of aggregate for comparison. Results indicated that fugitive road dust altered roadside soil chemistry, no matter the type of driving surface. However, limestone DSA aggregate dust altered roadside soil chemistry significantly more than the native aggregate dust and may aid in the establishment of invasive and/or exotic plants along forested road corridors by increasing pH levels in the roadside organic forest soils.

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Chapter 1

Introduction

Dirt and gravel roads are an important part of Pennsylvania's road system. These roads support four of the state's largest industries; tourism, agriculture, mining and forestry (logging). However, these roads come with factors not normally associated with paved roads. Dirt and gravel roads are capable of producing large amounts of dust, and this dust may affect the chemistry of adjacent forest soils.

When a vehicle drives over a dirt or gravel road the force of the tires pulverizes aggregate material on the road surface. Fines in the road surface are pulverized as the moisture in the road decrease, creating more dust under dry conditions (Addo et al. 2004). Once pulverized this material is subjected to turbulent wind caused by the moving vehicle (EPA 2005). Fine particles of aggregate are suspended in the air and transported to areas adjacent to the road. These airborne particles are referred to as fugitive dust. The more road traffic, the more fugitive dust generated (Sheridan et al. 2006). A 1983 Forest Service estimate is that for every vehicle traveling one mile of unpaved roadway once a day, every day for a year, one ton of dust was deposited along a corridor extending 500 feet on either side of the road (Frazer, 2003).

The amount of dust emissions that a road produces is also dependent on the "dirtiness" of the unpaved road surface. The road surface aggregate's resistance to abrasion and amount of fine materials contribute to the amount of road dust generated (Addo et al. 2004). The dirtiness is related to the amount of silt content and moisture content of the driving surface, which is dependent on the physical/mechanical properties of the aggregate used as the driving surface (Muleski and Cowherd 2002). Vehicle weight, speed and design also affect the amount of dust produced. As speed and weight increase, so does the amount of dust generated (Etyemezian et al. 2003). A study in Colorado obtained dust measurements at various vehicle speeds, from 20 to 50 mph, on an untreated gravel road over a length of one (1) mile. The results of the study show a linear relationship between vehicle speed and the amount of dust generated (Sanders & Addo 1993).

Estimates by the U.S. EPA are that unpaved roads contribute up to 40% of the total fugitive dust emitted to the atmosphere (EPA 1997). Fugitive dust less than 2.5 micrometers in diameter will stay suspended in the air. Large particles (greater than 2.5 µm in diameter) generally settle back to the ground. Prevailing winds and air movement also govern transport distances. Both fine and coarse dust are respirable, and are capable of causing aggravation to respiratory ailments, like asthma, and are a concern to those who reside near unpaved roads as well as those who use the roads for travel.

In addition to human health concerns, road dust can also have an impact on vegetation by covering the foliage and stunting growth by blocking sunlight, as well as clogging the plant stoma (Addo et al. 2004). As dust covers the leaf surfaces, leaf temperature and water loss increase, potentially leading to a decrease in photosynthesis and plant growth. Road dust may impact plant species present along gravel roads through alteration of the soil as well as the dust that falls on plant foliage (Frazer, 2003).

Since coarse dust falls closest to the road of its origin, it may alter the chemical composition of the soils adjacent to the road surface. A study performed in Spain illustrated that dust can alter soil chemistry over time (Machian and Navas 2000). This study showed that the input of mainly magnesium oxide dust from a magnesite calcination factory increased the soil pH from a value of 7 to 9.5 in some areas (Machian and Navas, 2000). The study was centered on an area that was subject to over 40 years of additional dust input, but dirt and gravel roads have been in use much longer than that in Central Pennsylvania. In addition to altering soil properties, the additional input of gravel dust may also impact vegetation located along the road corridor.

Improvements in regeneration of potted northern red oak (*Quercus rubra*) through the addition of calcium (Ca), magnesium (Mg), potassium (K), and phosphorous (P) to acidic forest soils has been documented (Hart & Sharpe

1997), and many of these minerals are present in limestone aggregate used for surfacing gravel roads in Pennsylvania.

A study by Viskari et al., (1997) utilized snow samples and moss bags to assess roadside airborne pollutants. The results showed an inverse correlation between airborne pollutant concentrations and distance from the road. Results from this study also showed that most pollutants are deposited within 30 meters (98.42 feet) of the road, but some components (Ca and chloride) were deposited up to 60 meters (196.85 feet) from the road. Hagen et al. (2006) studied wind erosion from a small field with erodible Amarillo fine sand loam soils. Thirty percent of the dust generated in the field was deposited within fifty (50) meters (164 feet) of the field, but a smaller percentage (12-15%) was deposited within the first ten (10) meters (32.8 feet) (Hagen et al. 2006).

A dust suppressant study performed by the Penn State Center for Dirt and Gravel Road Studies (CDGRS) also demonstrated similar results to those of Viskari et al. (1997). The CDGRS study placed dust-fall jars at distances of 30 feet (9.14 m), 60 feet (18.28 m) and 120 feet (36.57 m) from the road edge. The greatest amount of dust was collected 30 feet from the road, with a 66% decrease at 60 feet and an 83% decrease at 120 feet from the road (CDGRS 2003).

Review of literature indicated that the input of gravel dust over time can affect soil chemical composition. Also, gravel dust is capable of being transported by wind, with the majority of the larger dust particles being deposited within approximately 200 meters of the source. This study focused on the effects that limestone dust generated from limestone Driving Surface Aggregate (DSA) and native driving surface aggregate may have on the chemistry of roadside forest soils. The limestone DSA is a specification that was developed by the Center for Dirt and Gravel Road Studies at Penn State specifically for a driving surface on unpaved roads. The DSA contains five size gradations, with the maximum size being 1½" and the smallest size passing a sieve of 1/200th (#200 sieve) of an inch. DSA compacts densely and exhibits greater durability than other aggregate. However, DSA still generates dust. The native driving surface aggregate is aggregate that has been derived from outcropping bedrock in the physiographic region where the road is located.

Our objectives were to study the effects of fugitive limestone DSA road dust compared to native aggregate road dust in Central Pennsylvania. The objectives were 1) to determine effects of fugitive road dust on soil chemical properties by sampling the Organic soil horizons of the roadside forest soils and 2) determine fugitive dust effects on roadside vegetation.

Chapter 2

Methods

To determine if road dust generated from limestone DSA and native driving surface aggregate was affecting the chemistry of roadside soils, soil samples were taken along four different forest road segments. Of these four segments, two had limestone DSA as the driving surface, and the other two had native aggregate as the road surface. All four road segments were located in the Seven Mountains region of Central Pennsylvania in eastern hardwood forest. All the road segments lie in similar geological formations of Bald Eagle, Juniata and Reedsville Sandstone and lie in the same general azimuth (east to west) (Braker 1981). The road locations are described in Appendix 4. The general location of the roads and the study location map are shown in Figure 2-1.

Road segments were selected to meet the following criteria. They were located within the same geological province (Ridge and Valley) and similar geological formations. They had generally similar vegetative cover area along the road corridor. They were aligned in the same general azimuth. They contained suitable surface aggregate that had been in place for at least 4 years.

Pennsylvania

Figure **2-1**: Location Map of Study Area

The road segments that were studied were on Crowfield Road, Sand Mountain Road, and Pine Swamp Road. Crowfield Road had segments of both limestone DSA and native driving surface aggregate. Sand Mountain Road had a segment of limestone DSA and Pine Swamp Road had a segment of native driving surface aggregate. All of the roads were low traffic volume, unpaved roads, and as such, a traffic count was not done. However, a traffic count was performed on Crowfield Road by the Center for Dirt and Gravel Road Studies over a 4-month period in 2003. From August to November the mean daily traffic was 60 cars per day (CDGRS, 2003). It was assumed that the amount of travel was similar among the road segments.

Both of the Crowfield Road segments studied were underlain by the Reedsville Sandstone geological formation and situated on Laidig extremely stony loam, 8-25% slope (LcD), and Buchanan extremely stony loam, 8-25% slope (BxD) soil series. The Sand Mt. Road segments were underlain by Juniata and Bald Eagle Sandstone geological formations and were situated on Buchanan extremely stony loam, 0-8% slopes (BxB) and Hazelton extremely stony sandy loam 8-25% slopes (HSD) soil series. Pine Swamp Road was underlain by Bald Eagle Sandstone geological formation and was situated on BxB and LcD soils. The pH of all soil series is listed as having a range from 3.6 to 5.5. The effective cation exchange capacity (depth from 0"-6") of BxB and BxD was 2.4-6.9 meq/100 grams. HSD effective cation exchange capacity was 2.9-6.6 meq/100 grams, and LcD effective cation exchange capacity was 1.4-5.4 meq/100g. Soil series information was obtained from the NRCS (Web Soil Survey, 2009 http://websoilsurvey.nrcs.usda.gov/).

To determine if road dust generated from the road segments was having an impact on road side forest soils, soil samples were collected along each road segment. The samples consisted of the organic soil only, as any impacts from the road dust would be evident in the organic horizon before the underlying soils.

The limestone DSA segments had only been in place for five (5) years on Crowfield Road and six (6) years for Sand Mountain Road prior to this study. If dust effects were present we hypothesized that they would most likely occur first in the O horizon. All samples were analyzed at the Penn State Agricultural Analytical Services Laboratory.

Soil samples were collected perpendicular to each road segment at distances of 1 meter, 10 meters, 100 meters, and 200 meters as measured from the road edge (travel way). By sampling soils on each side of each road segment the effect of wind (direction) on dust deposition was taken into account. Three cross-sections were sampled on each road segment. Cross-sections were spaced 90 meters apart. On Crowfield Road, which contained both types of aggregates, the first cross-section of native aggregate was located more than 245 meters from the limestone aggregate segment (see Figure **2-2** for sampling plot layout).

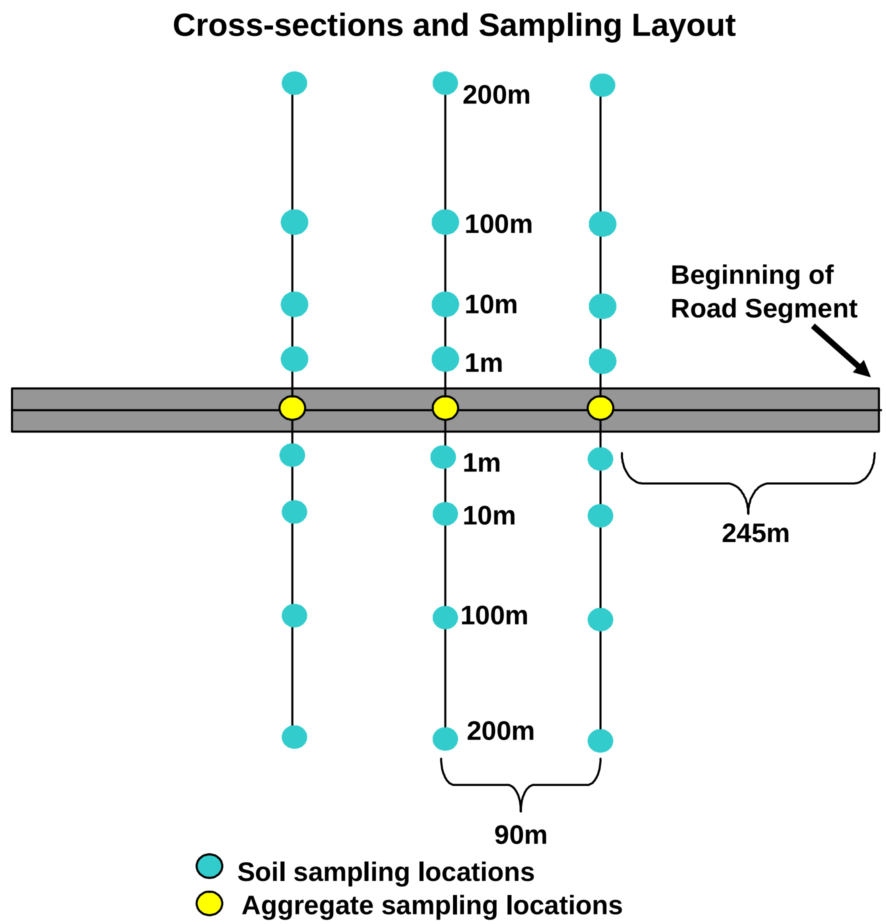


Figure **2-2**: Sampling plot layout

A dust-fall collection model developed by the CDGRS at the Pennsylvania State University was used to determine sampling distance from the road surface. The model (Figure 2-3) predicted minimal dust fall beyond 152 meters from dirt and gravel roads. A distance of 200 meters from the road edge was used as a reference sampling point for each cross-section. It should be noted that the 1 meter sampling point for all of the road segments and sampling locations was located within disturbed soil areas adjacent to the travel way.

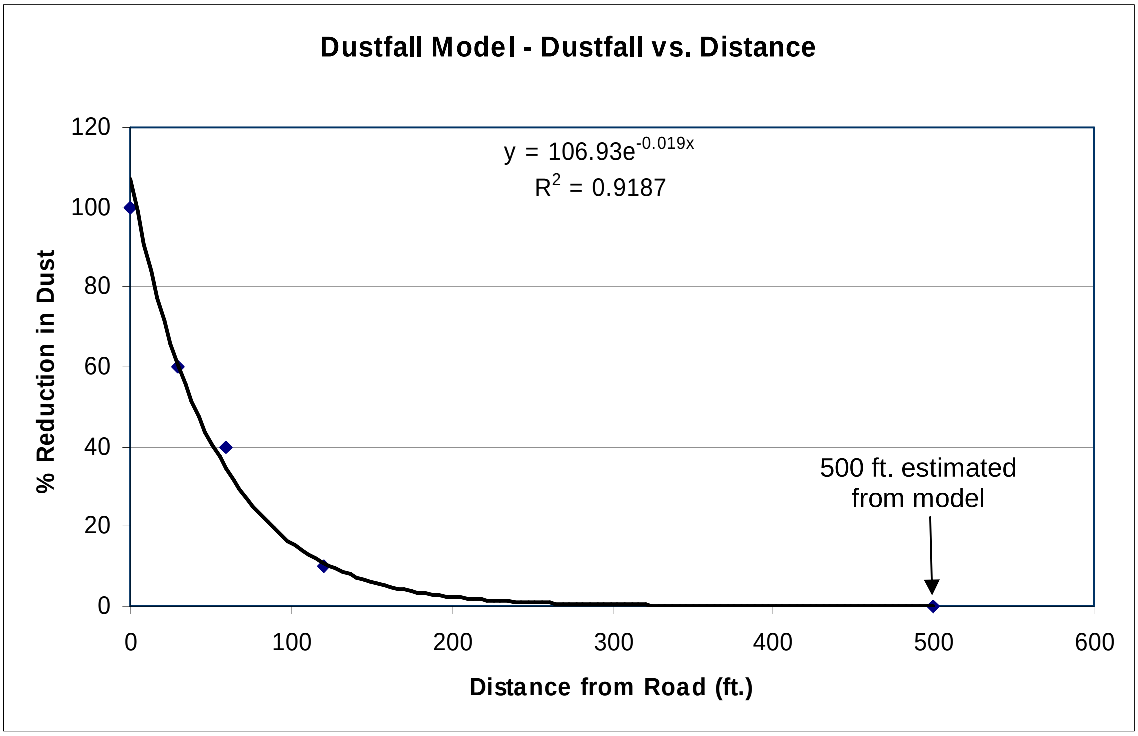


Figure **2-3**: Dust fall model – CDGRS, 2003 Dustfall White Deer Creek Road Dust Suppressant Testing.

Three soil samples were collected at each sampling point. The samples consisted of one Oi horizon sample and two from the Oe and Oa horizons combined (one sample for a Soil Fertility test and one for Aluminum Stress Test). The Oi horizon was composed of mainly undecomposed fallen leaves from the previous season, and the Oe and Oa horizons were comprised of moderate to almost completely decomposed plant material. The samples were collected collected during the Spring of 2006. The Oi samples were analyzed using techniques adapted for foliar analysis, Dry Ash Method (Miller 1998).

A combination of the Oe and Oa organic horizons was collected for the Soil Fertility Test and Aluminum Stress Test, with two composite samples of the Oe and Oa taken at each sampling location for analysis. The Soil Fertility Test was performed using the 1:1 Soil:Water pH (Eckert and Sims 1995), Mehlich 3 (Wolf and Beegle 1995), Mehlich Buffer pH (Mehlich 1976) and the Summation of Cations (Ross 1995) testing methods to determine the pH and nutrient concentrations. All elemental analyses for these three testing methods were performed using a Thermo 61E ICP; pH was obtained with a Thermo Orion electrode. All samples were weighed prior to analysis. High calcium (Ca) concentrations in eighty (80) of the Soil Fertility Test samples indicated the probable presence of soluble Ca; therefore, the Cation Exchange Capacity (CEC) and the percent saturations were calculated using a maximum exchangeable Ca concentration of 15 meq/100 grams for these samples. The samples that contained the probable presence of soluble Ca were located at all distances; from the 1 meter to the 200 meter sampling sites.

The Aluminum Stress Test was performed on weighed Oe and Oa samples to determine the Ca and aluminum (Al) (both in mg/kg) and the Ca:AL molar ratio. Generally, this test is used to evaluate the potential stress of Al on forest tree species when grown on soils with a pH less than 5.5. The test was a modified procedure from Joslin and Wolfe (Joslin and Wolfe, 1989). Soils were extracted at a 1:1 (soil:extract) ratio with 0.01 M $SrCl_2$ and the aluminum and calcium concentrations were measured by ICP.

Composite aggregate samples of each road segment were collected for mineral analysis. The composite samples were composed of three separate samples of road aggregate taken on each cross-section. These samples were analyzed for mineral composition through x-ray diffraction to help interpret the soil sample results. Photographs of the aggregate at the different study sites are presented in Appendix 3.

X-ray diffraction was performed at the Mineral Resources Laboratory at The Pennsylvania State University using a Scintag Theta-Theta diffractometer operated in the theta/2-theta mode and Cu K-alpha radiation target operated at 40mA and 30Kv with a Peltier air cooled detector (Kluge and Alexander, 1974). All sample data were collected on a zero-background off c-axis quartz substrate. X-ray diffraction made it possible to definitively separate the mineral components of the composite road surface aggregate samples collected from the road.

Statistical analysis of the soil samples was performed using an Analysis of Variance General Linear Model to determine what effects surface treatments of the road segments had on adjacent soils. The model used the means of the pH and minerals for each road segment and tested them to determine if road segment, direction (wind), distance, or a combination was significant. After testing for effects caused by the road segments (i.e. side and distance) further analysis was performed using a General Linear Model of the organic leaf layer samples using the Dunnett's Multiple Comparison with a reference site.

In this project, the 200 meter sampling site was used as a reference site for each road segment and then compared with the samples taken at the other distances from the road. The Dunnet's Multiple Comparison method provided the best comparisons between the sample groups and the reference, and allowed for inter-comparisons of the distances to the reference site to look at each distance individually. By using this method, any statistically significant differences between a specific distance and the reference site would be revealed. One-way ANOVA with Dunnett's Multiple Comparison utilizing a statistical alpha of 0.05 was used to compare the distance effects and determine if the test was statistically significant.

Vegetation was sampled at the 10-meter sampling sites along each road cross-section. Both sides of the road were sampled. A 10x10 meter square plot was sampled, using the 10-meter sampling point from the soil sample as the center of the plot. A 1x1 meter plot was nested inside the 10x10 meter plot. The 10x10-meter plot was used for sampling woody plant species, and the 1x1 meter plot was for seedling and herbaceous plant species. A count of each individual plant was recorded for each plot. Photographs of the inventoried plots can be seen in Appendix 3. Statistical analysis of the vegetation was performed using Analysis of Variance (ANOVA) One-way General Linear Model in Minitab, using the native driving surface aggregate road segment as the control and then comparing them to the limestone DSA road segments. An alpha value of 0.05 was used to determine the statistical significance of the results.

Chapter 3

Results - Road Surface Aggregate

The composite aggregate samples taken from each driving surface were analyzed using X-ray diffraction. The complete results are presented in Appendix 1. The results show that differences in mineral content between the driving surfaces existed. Crowfield Road was a limestone DSA driving surface and the x-ray diffraction showed that the main constituents were calcite ($CaCO_3$), dolomite (Ca Mg (CO_3)2, and quartz (SiO_2).

The Crowfield Road segment with the native driving surface aggregate contained calcite ($CaCO_3$), and dolomite (Ca Mg (CO_3) in the composite aggregate sample. It appears from these results that limestone aggregate had been previously applied to the road. The Sand Mt. limestone DSA aggregate contained calcite, dolomite, muscovite ($KAl_2Si_3AlO_1O(OH)2$) and quartz as the main constituents, which was very similar to the Crowfield Rd. limestone DSA aggregate. Based on the x-ray diffraction results, the only driving surface that was not impacted by limestone aggregate was Pine Swamp Rd., the main constituents of which were quartz, and muscovite. Since the Crowfield Rd. native aggregate segment was influenced by limestone aggregate, it was not suitable as a “native” aggregate material for statistical analysis.

Segment Surface Treatment

To determine effects of dust on the roadside soils related to segment (surface aggregate type), direction (right or left from road along transect), and distance from road (or any combination of these) the pH and the results of the Soil Fertility Test, Aluminum Stress Test and the Foliar Test (Oi horizon) were tested in the General Linear Model to compare the limestone DSA road segments of Crowfield Road and Sand Mountain Road against the native road segment of Pine Swamp Road. The pH values obtained from the Soil Fertility Test results were converted to hydrogen ion concentrations for statistical computation and then converted back to pH. The General Linear model showed no significant differences in pH between the surface treatments and direction (left or right from road). Both distance and road segment had statistically significant influences on roadside soil chemistry. The percent base saturation of the CEC from the Soil Fertility Test was significantly correlated with both distance and road segment, and the Ca:Al molar ratio from the Aluminum Stress Test was significantly correlated with road segment. Ca (ppm) and K (ppm) from the Soil Fertility Test and the Ca (mg/kg) and Al (mg/kg) concentrations from the Aluminum Stress Test were also significantly correlated with distance from the road. Mg and P results from the Soil Fertility Test from the Aluminum Stress Test were not significantly related to segment, direction and distance.

The Foliar Test (leaf litter, Oi) results were compared in the General Linear model in the same fashion as described in the previous paragraph. The road segment treatment (segment aggregate type), direction from road, and distance from road showed no effects on the concentrations of Al in the Oi. Distance was the only factor in the model that showed statistically significant effects on the concentrations of manganese (Mn), P, copper (Cu), Mg, and boron (B). The effect of distance was that the closer to the road segments, the higher the concentrations. Calcium concentrations were significantly affected by both distance and surface treatment of the road; with significantly higher Ca concentrations closer to the road and adjacent to road segments with limestone DSA in the road segment.

The General Linear Model results show that distance and segment surface had the greatest effect on the concentrations of elements found in the roadside O horizon. Distance and the segment surface treatment on the road had significant effects on the concentrations of minerals found in the roadside soils. The minerals in the limestone DSA road surface segments were found in significantly higher concentrations along the road edge, and then decreased in concentration the farther away from the road the samples were taken.

The percent base saturation concentrations along the limestone road segments were higher than the percent base saturation than the Pine Swamp Road native aggregate road segment. For example, the percent base saturation for the sampling points along the Pine Swamp Road segment ranged from 54% to 61%, while the percent base saturation for the sampling points for the limestone aggregate road surfaces ranged from 61% to 100% (illustrated in Figure 3-4). Comparison of distance effects on percent base saturation appears in the Distance section of this chapter.

The Oi horizons along the limestone DSA road segments had significantly higher amounts of P, Ca, Mg, Mn, Cu, and B when compared to the native driving surface aggregate segment of Pine Swamp Road. Only Al was significantly higher along the native aggregate road segment. Iron (Fe) and zinc (Zn) were not significantly different between the two (2) road surfaces.

Direction was analyzed in conjunction with the road surfaces. Direction did not have any significant impact on soil chemistry. There appeared to be no differences in soil chemistry impacts from one side of the road segment to the other, indicating that wind did not impact dust deposition along the forested road segments.

Oi Horizon results did not show any significant difference between the concentrations of aluminum between the limestone and native aggregate road surfaces; however Mn concentrations were significantly different. Mn concentrations were higher in the soil samples taken along the limestone road surfaces than from the native road surfaces.

From the analysis of the two (2) road surfaces, it was evident that the limestone DSA road surface dust had a greater effect on the composition of the roadside forest soils than did native surface aggregate dust.

Distance

From the results obtained from the General Linear Model, the effects of distance on the element concentrations found in the soil layers was further analyzed with one-way ANOVA using Dunnet's multiple comparisons. The reference site at 200 meters was used for comparison of element concentrations at the 10 and 100 meter sampling site along each road individual segment. The 1 meter sampling point was excluded from this analysis because it fell within the soil disturbance area along the road edge and in most cases did not have Oi and Oa + Oe soil horizons. The multiple comparison distance tests were segment specific and did not make comparisons between road segments. All of the road segment soil samples had changes in soil elements, demonstrating that the presence of the roads and the ensuing dust did effect the roadside soil composition; however the native aggregate soil chemistry were not statistically significantly altered at the 10 and 100 meter sampling points when compared to the 200 meter control sampling point. Observed forest stand density were similar between all four (4) road segments. The forest stand density could impact dust fall distances by impeding dust travel and deposition, however this was not measured in this study.

The native aggregate driving surface showed no significant differences in soil composition between the 200-meter reference site and the other distances. Oe and Oa horizon pH, Ca, K, and Mn concentrations were not significantly different when compared to the 200-meter control point for soil horizons analyzed. The mean pH concentrations at 10, 100 and 200 meters were, respectively, 4.2, 3.9 and 3.8. Ca concentrations for the Oe and Oa horizons at 10, 100 and 200 meters were, respectively, 3,337, 2,580, and 2,640 ppm. Mg concentrations for the Oe and Oa horizons at 10, 100 and 200 meters were, respectively, 355.6, 355.8, and 379 ppm. The results demonstrated that even the native driving surface aggregate dust appeared to increase Oe and Oa horizon pH and Ca, but the increases were not significant.

Unlike the native aggregate road segment, the dust from the limestone DSA road segments caused significant effects on roadside Oe and Oa horizon soil chemistry. Oe and Oa horizon pH was significantly higher at the and 10 meter sampling distances, but not the 100 meter sampling distance, when compared against the 200-meter control. At 100-meters, the pH and Ca from the Oe and Oa samples (Figures 3-1 and 3-2) and the mean Ca and percent Mn from the Oi samples were not significantly different than the 200-meter reference site concentrations.

Oe and Oa K concentrations were significantly lower at the 10-meter sampling sites when compared to the 200-meter reference site in the Oe and Oa horizons. The Oi percent calcium had concentrations that were higher at only the disturbed 1 meter sampling distance, with no significant differences between the control site and the 10 and 100 meter sampling sites.

Oe and Oa horizon pH data for the four (4) road segments are presented in Figure 3-1. All of the road segments had higher pH levels at the 10 meter sampling sites and these were significantly different from those at 100 and 200 meters for the limestone DSA segments. Mean pH's were higher at all distances for the soils along the limestone DSA segments when compared to the soil pH's adjacent to the native aggregate road segment. At 100m, the mean pH of the Crowfield Road native aggregate segment was higher than that of both of the limestone DSA segments. This is consistent with the mineral and elemental analysis of the road surface that suggested that the segment had limestone aggregate placed on it at one time.

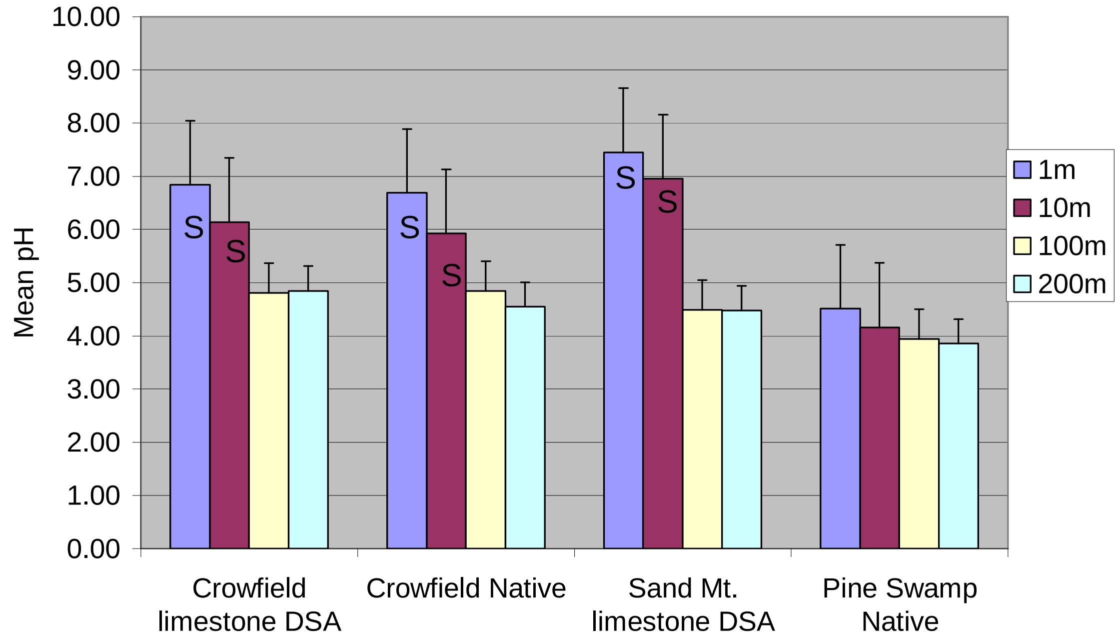


Figure **3-1**: Mean pH of Oe and Oa Horizon vs. Distance from Road Surface

Significance Test – Dunnet's Multiple Comparison

Distance Errors Bars +1 Standard Deviation

S = Statistically Significant Test Result, 200m utilized as Reference Point

Ca shows the same inverse relationship as pH between distance from the road edge and concentrations present in the soils. The closer to the road edge, the higher the concentration of Ca present in the soil. Figure **3-2** shows that the mean Ca in the soil was greatest along the limestone DSA road segments. However, at the 200 meter reference point the mean Ca for all of the road segments was greatly decreased when compared to the 10 meter sampling sites, regardless of the road surface. The Crowfield Road limestone DSA segment mean Ca concentrations in the Oe and Oa horizon at 10 meters was 6,723 ppm and 4,061 ppm at the 200 meters. The Pine Swamp Road segment had Ca concentrations of 3,337ppm at 10 meters and 2,640 ppm at the 200 meter reference site.

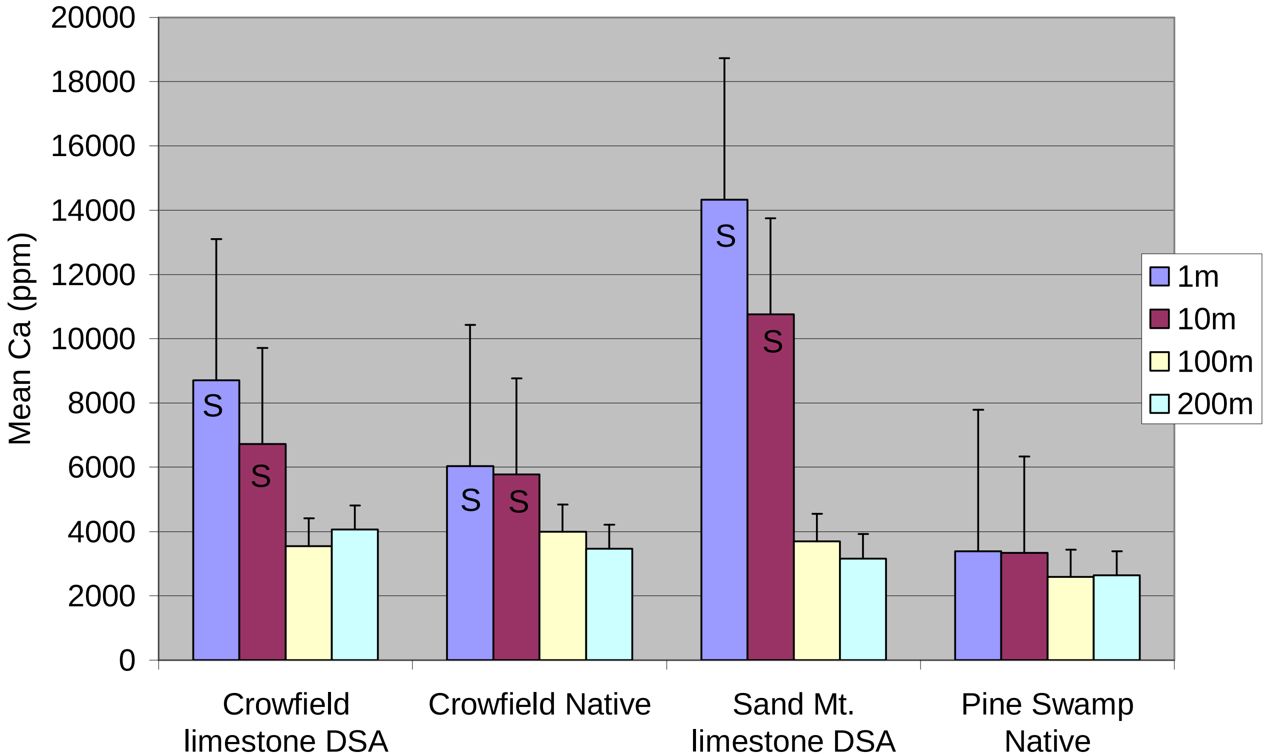


Figure **3-2**: Mean Ca of Oe and Oa Horizons vs. Distance from Road Surface
Significance Test – Dunnet's Multiple Comparison
Distance Errors Bars +1 Standard Deviation
S = Statistically Significant Test Result, 200m utilized as Reference Point

Mean Mg concentrations for the Oe and Oa horizons were significantly higher at the 10 m sites for the limestone DSA road segments (Figure 3-3). The concentrations present in the soil were consistently higher closer to the road edge and Mg concentrations decreased rapidly as distance from the road surface increased. The soils along Pine Swamp Road had significantly lower Mg concentrations (Figure **3-3**). These results are consistent with the x-ray diffraction results for the Pine Swamp Road aggregate.

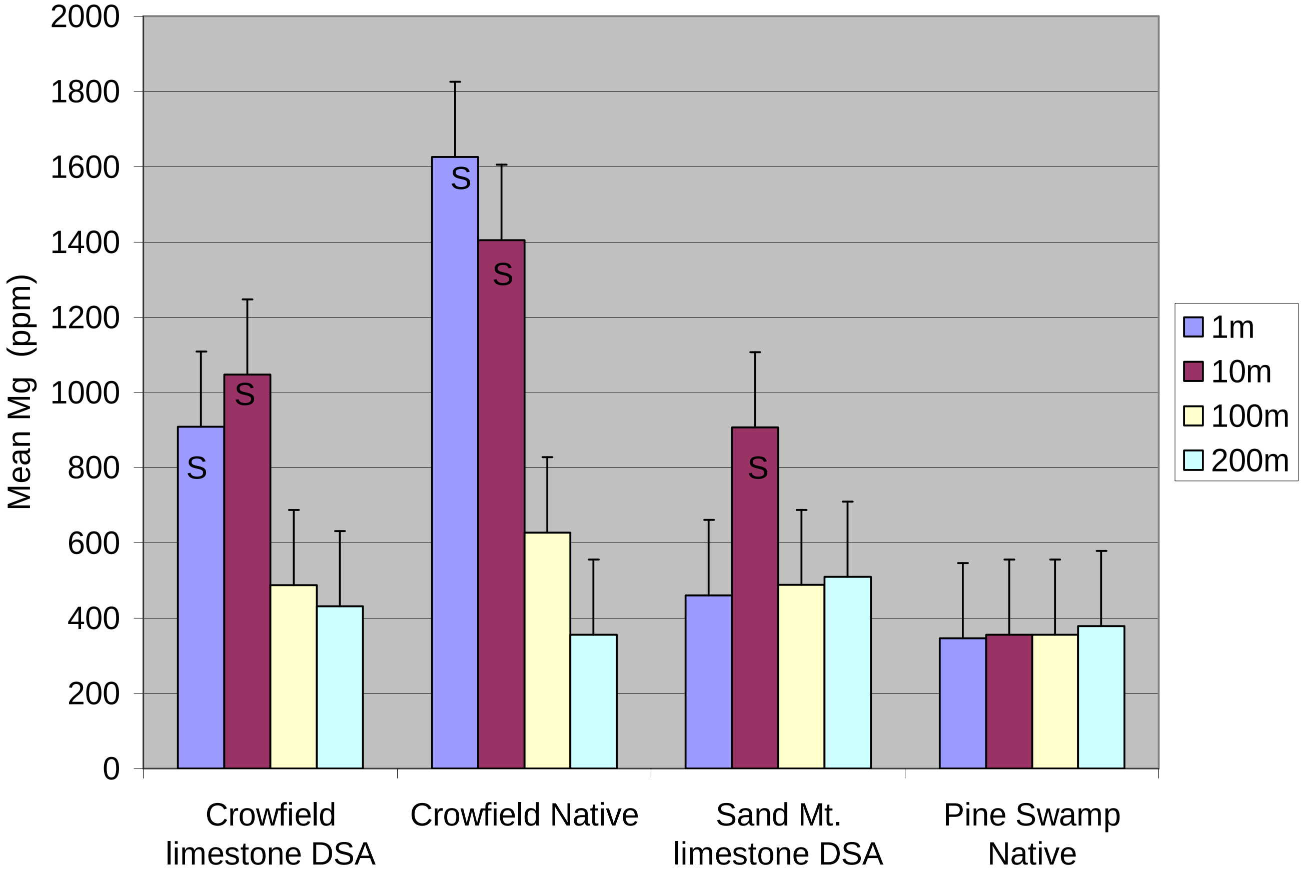


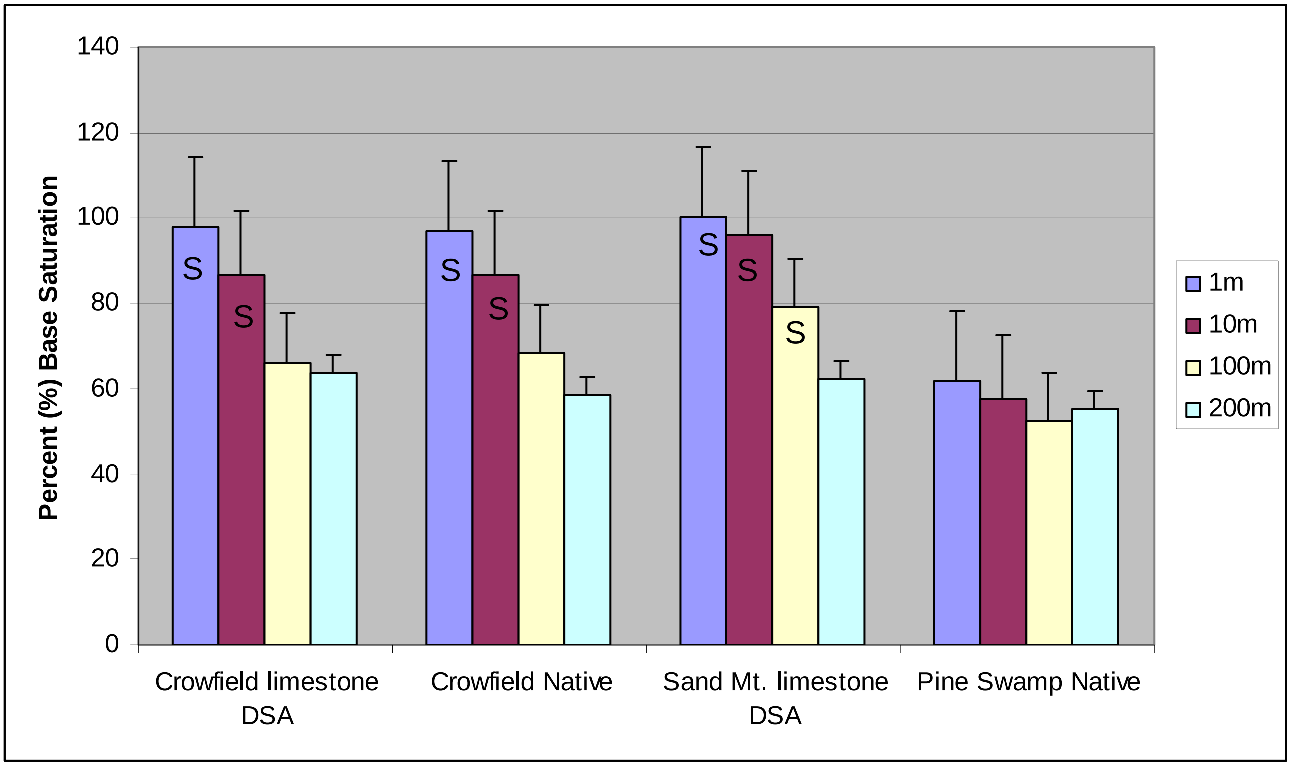
Figure **3-3**: Oi Horizon Mean Mg vs. Distance from Road Surface

Significance Test – Dunnet's Multiple Comparison

Distance Errors Bars +1 Standard Deviation

S = Statistically Significant Test Result, 200m utilized as Reference Point

Base saturation of the cation exchange capacity (CEC) in the Oe and Oa horizons was apparently influenced by the road surfaces with dolomite aggregate. Again the effects appeared to be the most pronounced at the 10m distance (Figure 3-4). At the reference sites (200m) there was less difference between the segments with dolomite and the ones without.



igure **3-4**: Oe & Oa Horizons Mean % Base Saturation vs. Distance from Road Surface

Significance Test – Dunnet's Multiple Comparison
Distance Errors Bars +1 Standard Deviation
S = Statistically Significant Test Result, 200m utilized as Reference Point

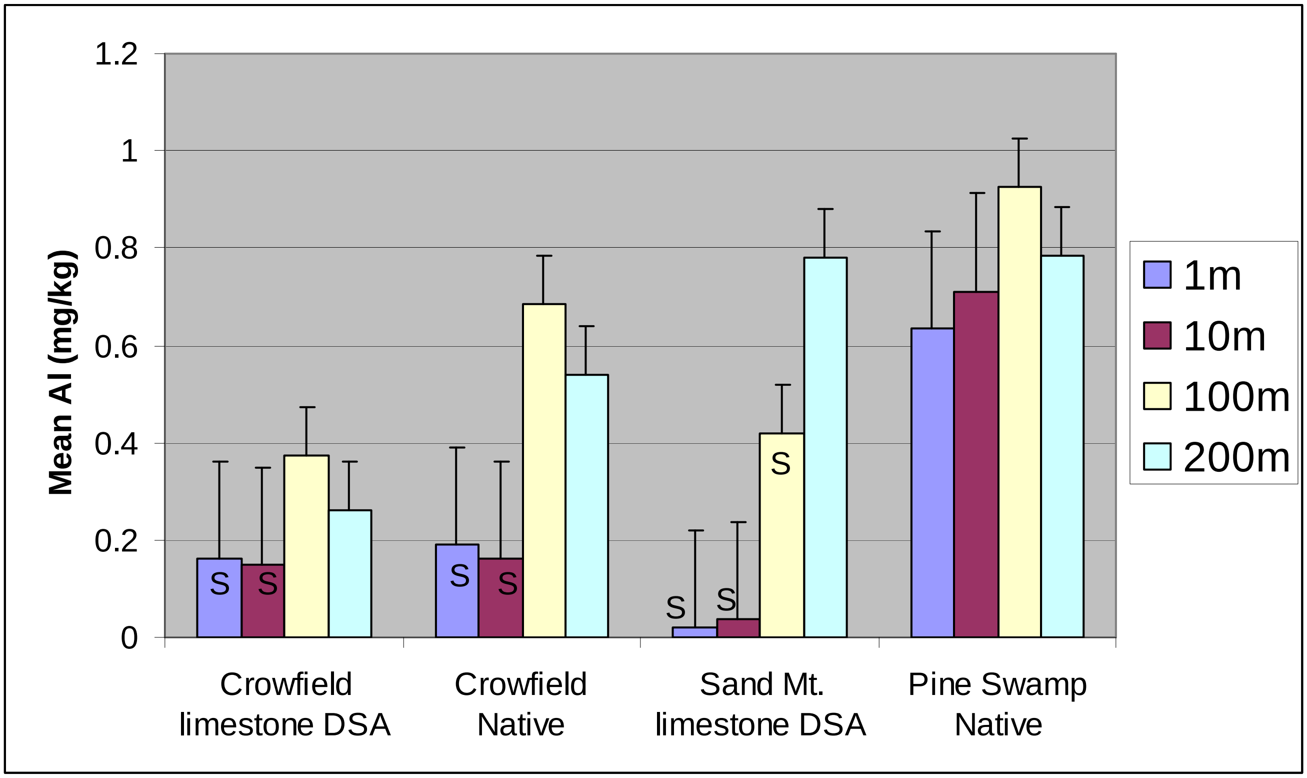


Figure **3-5**: Oe and Oa Horizon Extractable Al vs. Distance from the Road Surface

Significance Test – Dunnet's Multiple Comparison
Distance Errors Bars +1 Standard Deviation
S = Statistically Significant Test Result, 200m utilized as Reference Point

Mean Al concentrations (Figure 3-5) were significantly higher at the 10 meter sites for the Pine Swamp Road segment than the other road segments. At the 200 meter reference site these differences were reduced as was expected. The presence of higher concentrations of Ca and Mg for the road segments with dolomite would be expected to result in lower .01M $SrCl_2$ extractable Al. The data for Ca:Al ratio (Figure 3-6) are consistent with this thinking. The Ca:Al ratios of the Oa and Oe horizons follow inversely with lower Ca:Al ratios for the Pine Swamp Road segment and reference sites.

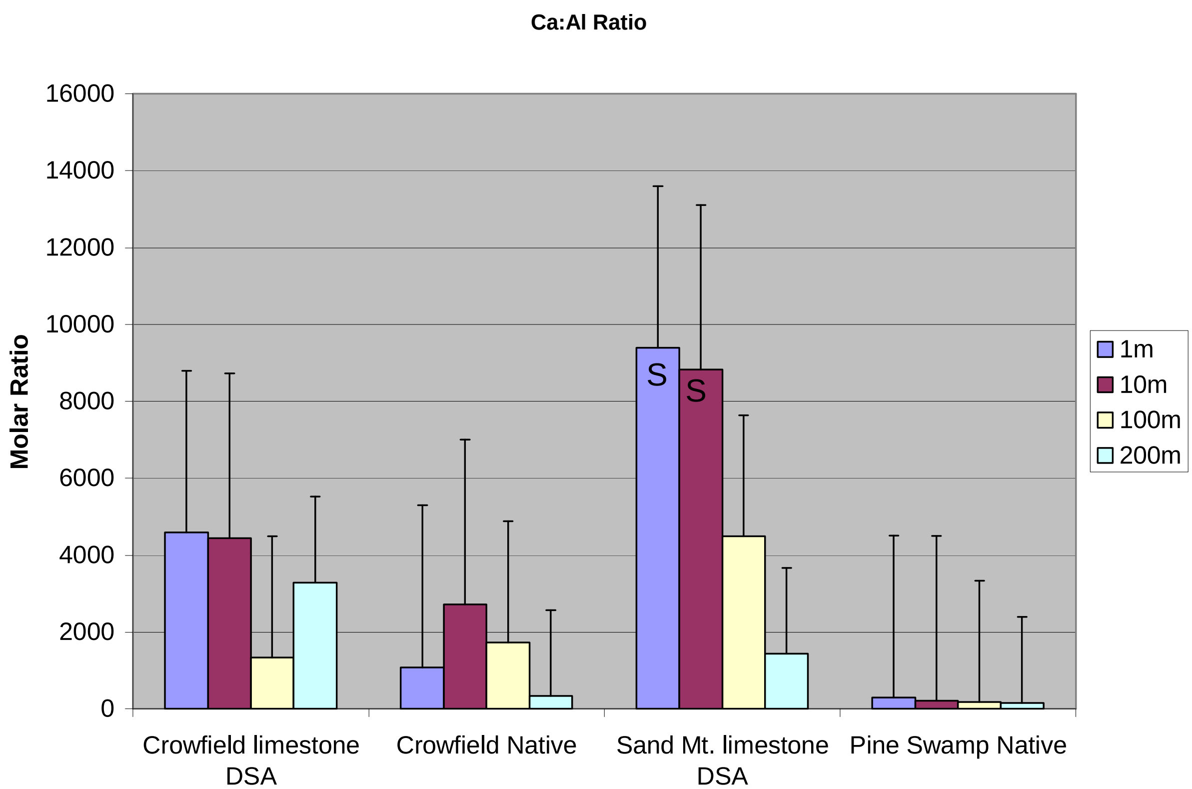


Figure **3-6**: Mean Ca:Al Ratio in Oe & Oa Horizon vs. Distance from the Road Surface

Significance Test – Dunnet's Multiple Comparison
Distance Errors Bars +1 Standard Deviation
S = Statistically Significant Test Result, 200m utilized as Reference Point

The Ca:Al ratio does not show a general trend or relationship for all four-road surfaces, as seen in Figure 3-6. However, when comparing the limestone DSA surfaces of Crowfield Road and Sand Mt. Road against the native aggregate surface of Pine Swamp Road, the Ca:Al ratio is greater along the limestone DSA road segments at the 10 meter sampling points.

The Ca:Al ratios for Oe and Oa horizons for the limestone DSA segments were significantly higher than the native aggregate segment. This finding appears to be consistent with the elemental content of these aggregates. The concentrations of Mn in the Oi horizon at the 10 and 100 meter points were tested against the 200-meter control point for each road segment. The concentrations of Mn were significantly lower at the 10-meter distances for both of the limestone DSA road surfaces when compared to the 200-meter control sites for these segments, as seen in Figure 3-7. Oi horizon Mn concentrations were lower closer to the road for all road surfaces, except for the Pine Swamp Road segment.

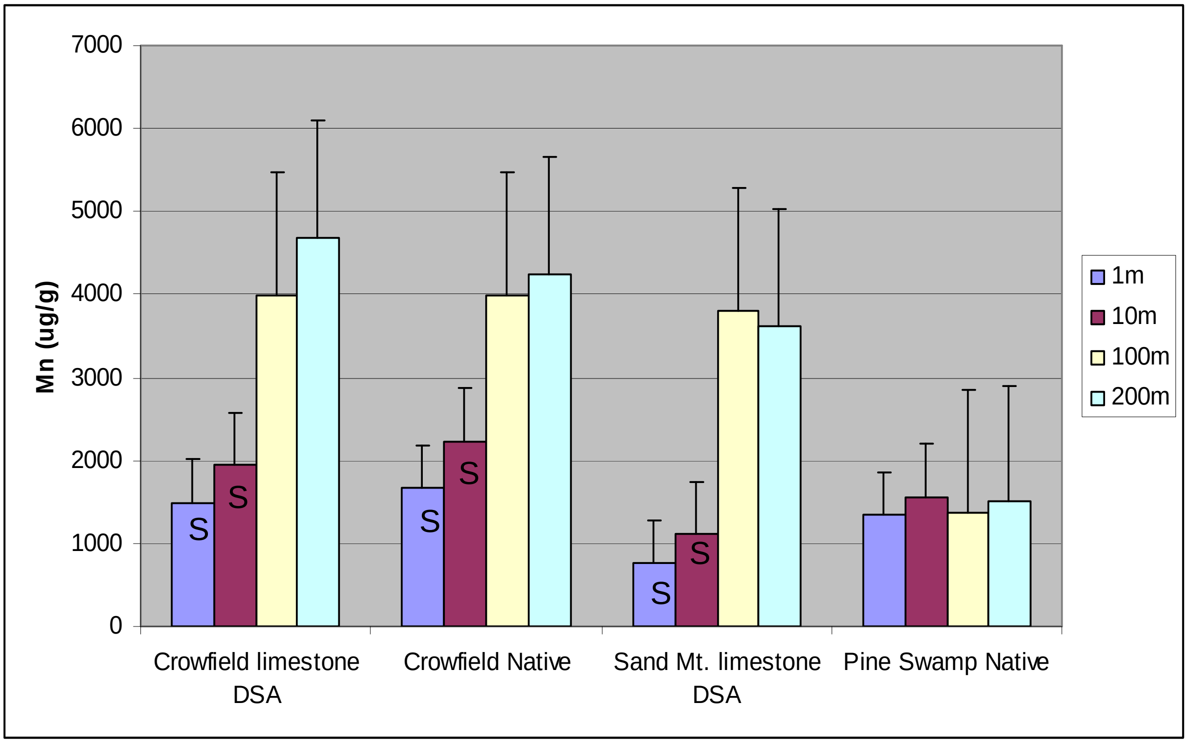


Figure **3-7**: Mean Mn in Oi Horizon vs. Distance from the Road Surface

Significance Test – Dunnet's Multiple Comparison
Distance Errors Bars +1 Standard Deviation
S = Statistically Significant Test Result, 200m utilized as Reference Point

The Significant Test Results Comparison Table **(**Figure 3-8) below compares sampling site distances for each road segment that was significantly different from the 200m reference site for the elements detailed in Figures 3-1 thru Figure 3-7. As illustrated in the table, significant organic soil impacts were most prevalent at the 1 and 10 meters sampling sites (as previously noted the 1 meter sampling sites were located in disturbed soil).

Road	Mean pH (Oe & Oi)	Mean Ca (Oe+Oi)	Mean Mg (Oi)	Mean Base Saturation (Oe & Oi)	Extractable Al (Oe & Oi)	Mean Ca:Al Ratio (Oe & Oi)	Mean Mn (Oi)
Crowfield Rd. Limestone DSA	1*, 10	1*, 10	1*, 10	1*, 10	1*, 10	-	1*, 10
Crowfield Rd. Native DSA	1*, 10	1*, 10	1*, 10	1*, 10	1*, 10	-	1*, 10
Sand Mt. Rd. Limestone DSA	1*, 10	1*, 10	10	1*, 10, 100	1*, 10, 100	1*, 10	1*, 10
Pine Swamp Rd. Native DSA	-	-	-	-	-	-	-

Figure **3**-**8**: Significant Test Results Comparison Table

Significance Test – Dunnet's Multiple Comparison

Numbers in table signify a significant test result at that sampling site distance (m).
** 1 meter sampling sites were located in disturbed soil*

Chapter 4

Results of Vegetation Analysis

Vegetation sampling was done in early May 2006. A later sampling date would have potentially yielded data for late emerging herbaceous plants, but time constraints did not permit selection of such a date. Sampling was performed along both sides of the road segments utilizing 10 x 10 meter squares for vegetation taller than 1.5 meters, and nested 1 meter squares for seedling and vegetation under 1.5 meters in height. The plots were laid out using the 10 meter soil sampling points as the center of the plots.

The vegetation study was performed to determine if a relationship existed between the use of the limestone DSA and invasive or exotic plants and plant diversity. Soil moisture, canopy density, micro-climate and micro-topography were not sampled. Observational results from the vegetation study appear to show a relationship between the limestone DSA and invasive/exotic plants. Along the road segments that had the limestone DSA, the occurrence of barberry (*Barberris spp.)* and multiflora rose (*Rosa multiflora)* was greater than at the native driving surface segments. The native driving surface segments resulted in greater numbers of native plant species that appear to prefer acidic soils, such as mountain laurel (*Kalmia latifolia*), lowbush blueberry (*Vaccinium augustifolium*) and teaberry (*Gaultheria procumbens*). The complete vegetation inventory can be found in Appendix 2.

Statistical analysis of the tree species (greater than 1.5 meters in height) inventory data using Minitab revealed that there was a statistically significant difference (p-value equal to 0.02; statistical alpha of 0.05) between the number of tree species found at the 10 meter distance along the limestone DSA segments when compared to the native aggregate segments. The limestone DSA road segment had considerably higher numbers of Japanese barberry *(Berberis thunbergii)* than did the native aggregate road segments. In contrast, the native aggregate road surface had higher numbers of mountain laurel (*Kalmia latifolia*) than the limestone DSA road segments. Statistical analysis of the herbaceous vegetation inventory (using the same model and criteria) also revealed statistically significant differences between the number herbaceous and seedling species found along each type of driving surface treatment (p-value equal to 0.01). Figure 4-1 shows the mean number of plants per road cross-section.

As shown in Figure 4-1, Pine Swamp Road had the highest average number of seedlings and herbaceous species per cross-section and the second highest average number of seedlings per cross-section. The mean pH at the 10 meter sampling site on Pine Swamp Road was 4.22 and as previously noted, the species of trees, shrubs and seedlings tallied along Pine Swamp Road were species that were tolerant of acidic soil, such as mountain laurel, chestnut oak and low-bush blueberry. For example, mountain laurel prefers soils that range in pH from approximately 4.5 to 5.0 (NRCS, 2009). Acid tolerant species were found along the three other road segments, but were present in higher numbers along Pine Swamp Road. The invasive plant species, such as Japanese barberry were inventoried along the limestone DSA road segments only. Japanese barberry prefers neutral pH soils, from 5.5 to 7.2, and the mean pH at the 10 meter soil sampling sites for the Crowfield Road and Sand Mt. Road limestone DSA segments were 6.00 and 7.03, respectively.

	Mean # Tree/Shrubs per Cross-Section	**Mean # Seedlings / Herbaceous Spp. per Cross-Section**
Crowfield Road DSA	45	101
Crowfield Road Native Aggregate	23	76
Sand Mt. Road DSA	25	36
Pine Swamp Road Native Aggregate	79	85

Figure **4-1**: Mean # of Plants per Road Cross-Section

From the statistical analysis results, it appears that dust from the limestone driving surfaces changed the soil chemistry enough to allow for greater invasive plant species establishment along these types of gravel roads. This is important because without the limestone dust impacts, the invasive plants observed may not be able to grow in the acidic soils typically found in this region of Central Pennsylvania. However, the invasive plants species were not observed within the forest even though their seeds are deposited by birds throughout the forest. The invasive plant species were only observed along the road and forest edge where dust deposition had the greatest impact on the soil chemistry. The vegetation study results support the hypothesis that the use of imported limestone aggregates for road surfacing may aid in the establishment of invasive and/or exotic plants to invade along forested road corridors.

Chapter 5

Conclusions

The overall conclusions from the study are that dirt and gravel road dust from both limestone DSA and native aggregate does affect the chemistry of roadside forest soils and vegetation. However, the limestone driving surface aggregate had a significantly greater effect on the roadside forest soils than the native driving aggregate. There was an overall inverse relationship between soil chemistry change and distance from the edge of the road. Road dust effects were greatest closest to the road edge. The chemical changes to roadside soils from limestone dust on the limestone DSA segments appeared to increase presence of invasive/exotic plant species more than native aggregate road dust road segments. Only one road segment with true native aggregate was sampled in the study and a broader survey is needed to test these preliminary observations.

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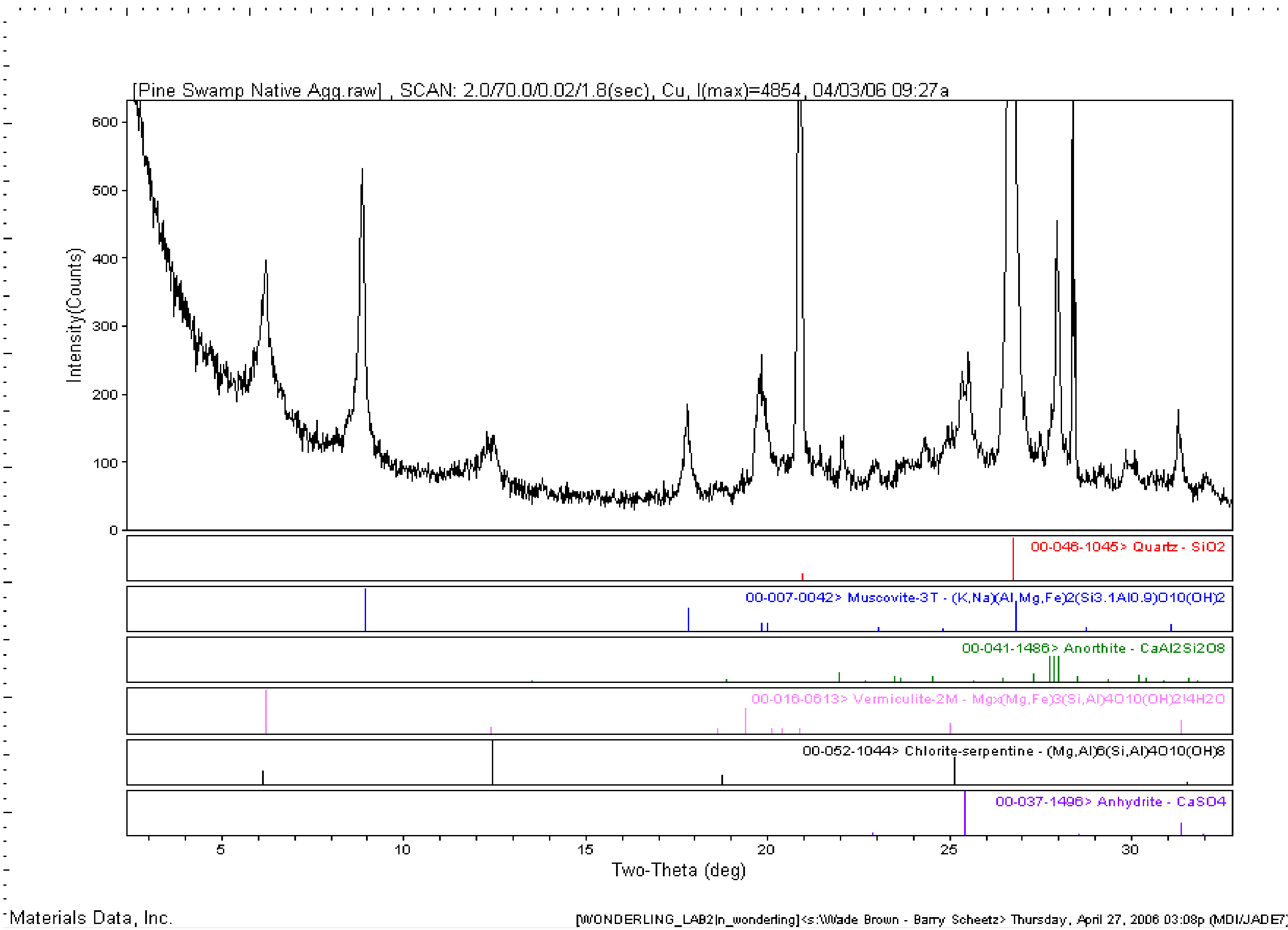
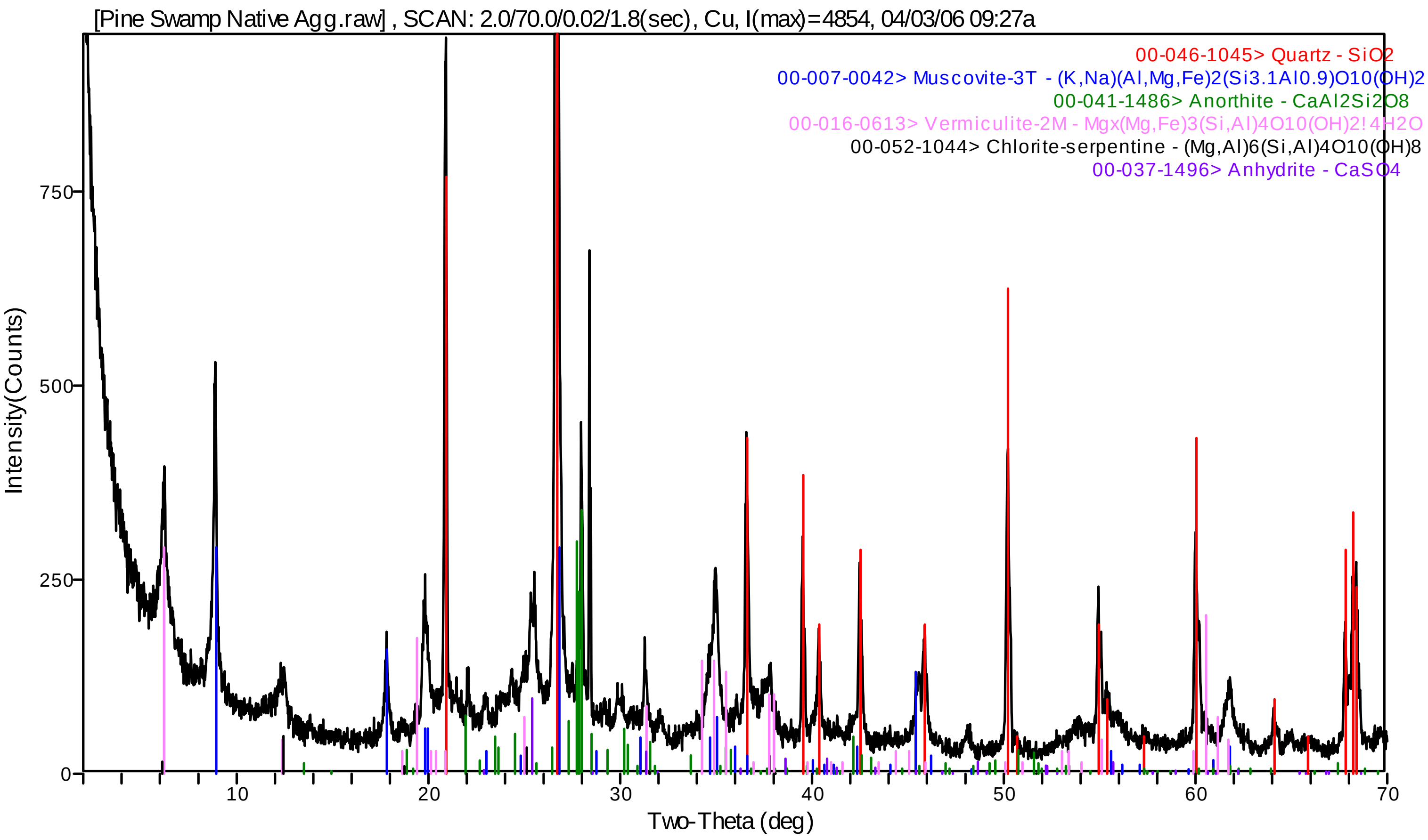
Appendix A: X-Ray Diffraction Results

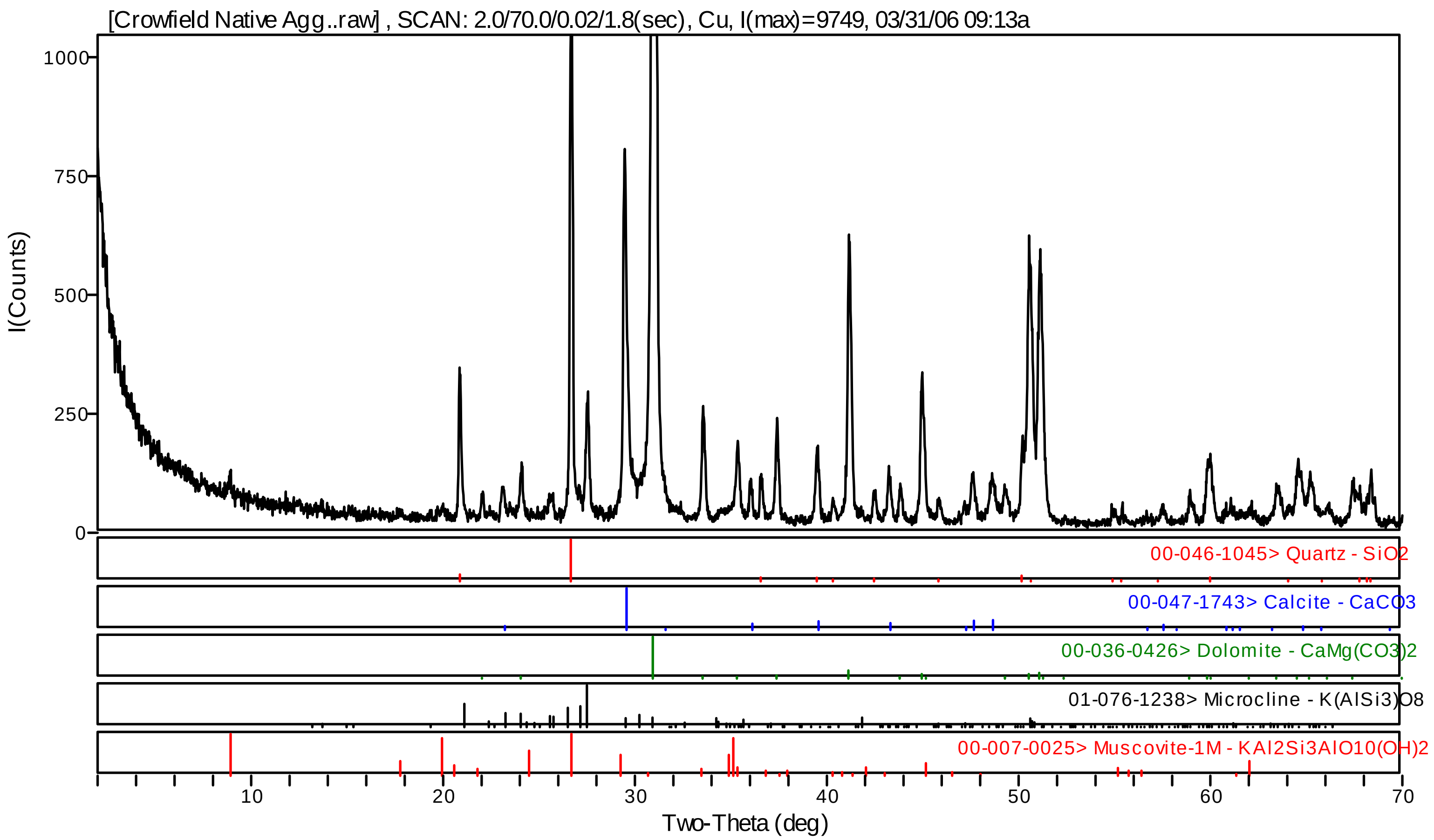
Pine Swamp Road X-Ray Diffraction Phase ID-2



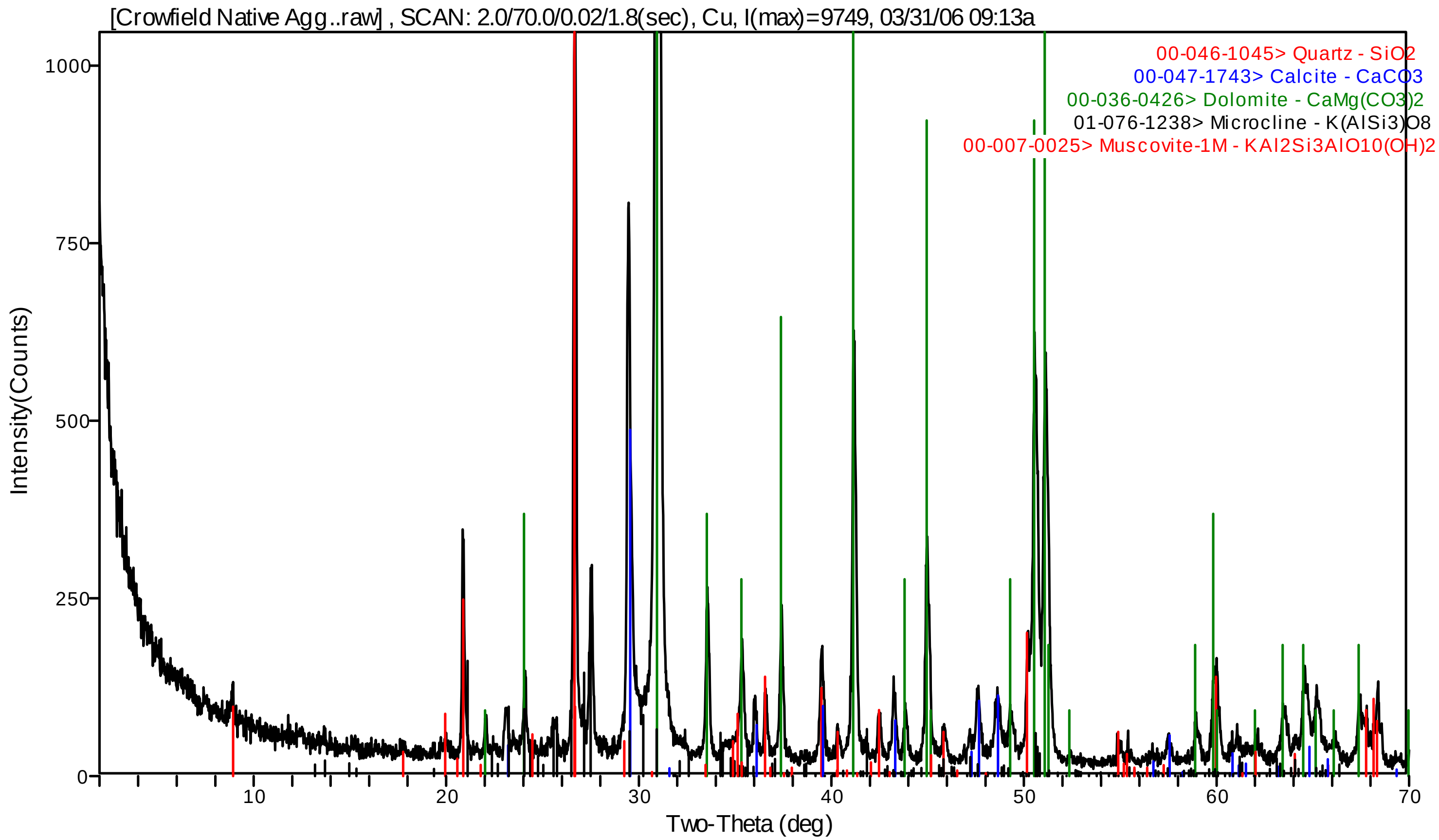
Pine Swamp Road X-ray Diffraction Phase ID-1



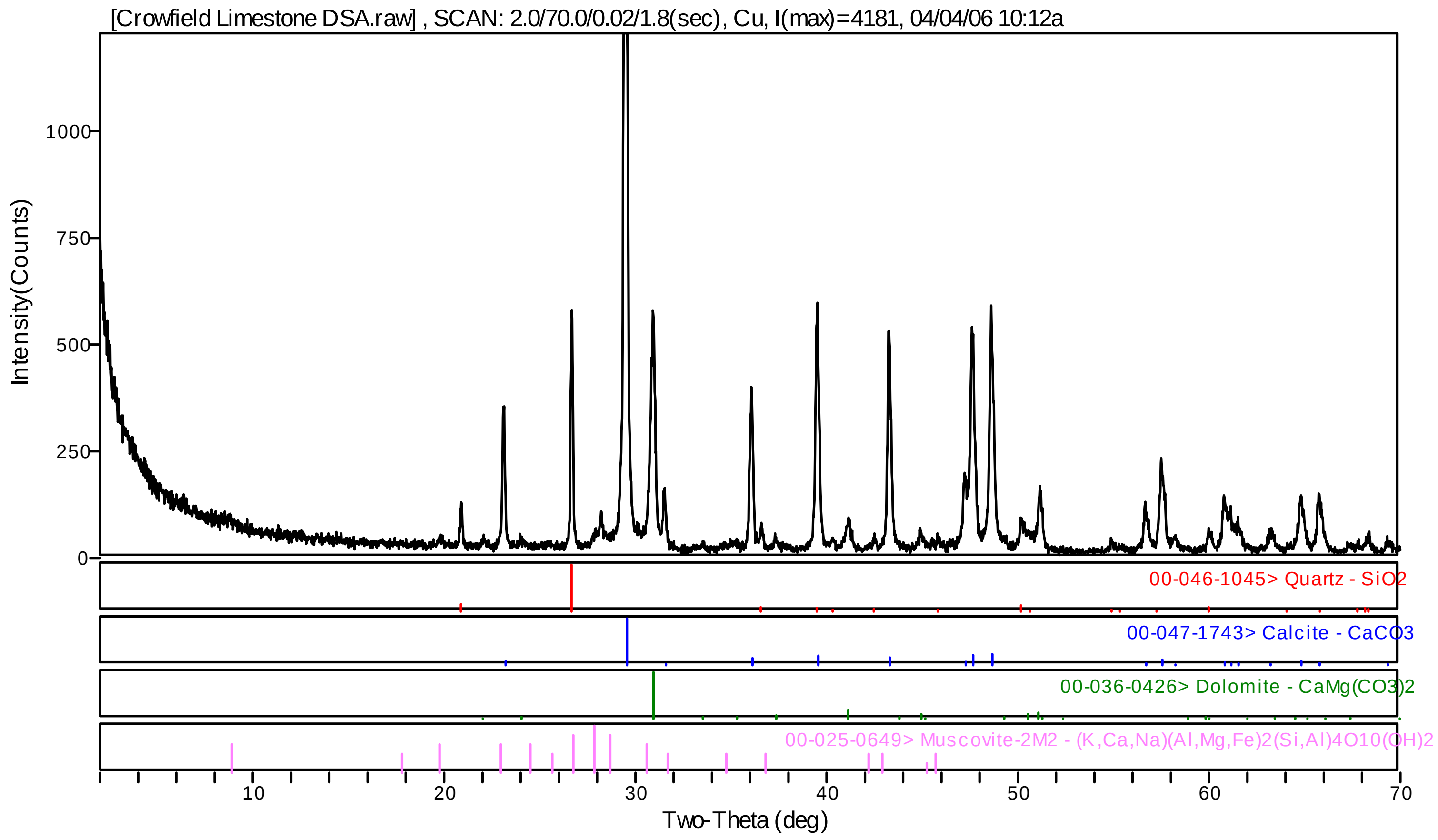
Crowfield Road Native Aggregate Phase ID-2



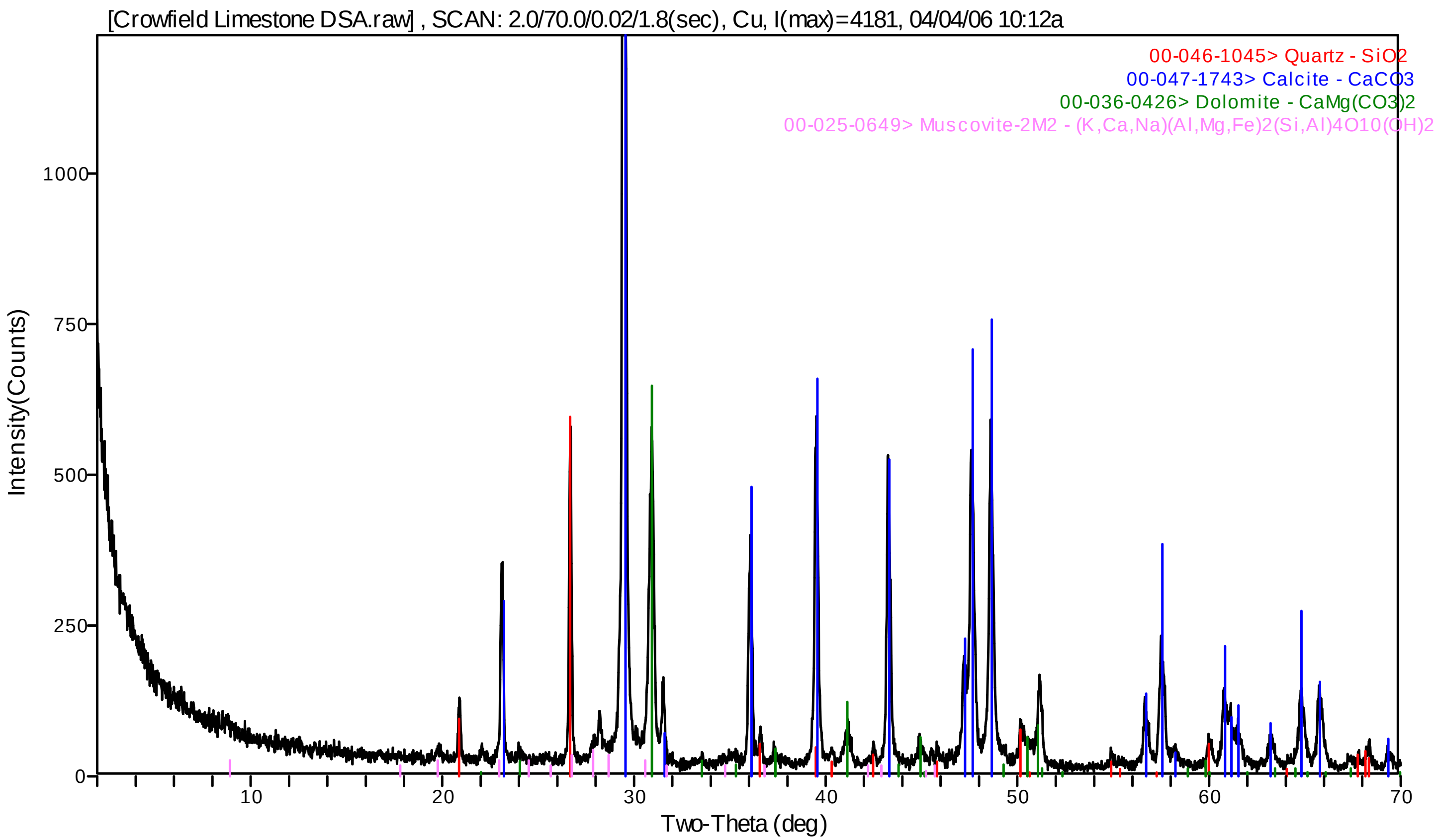
Crowfield Road Native Aggregate Phase ID-1



Crowfield Road Limestone DSA Phase ID-2



Crowfield Road Limestone DSA Phase ID-1



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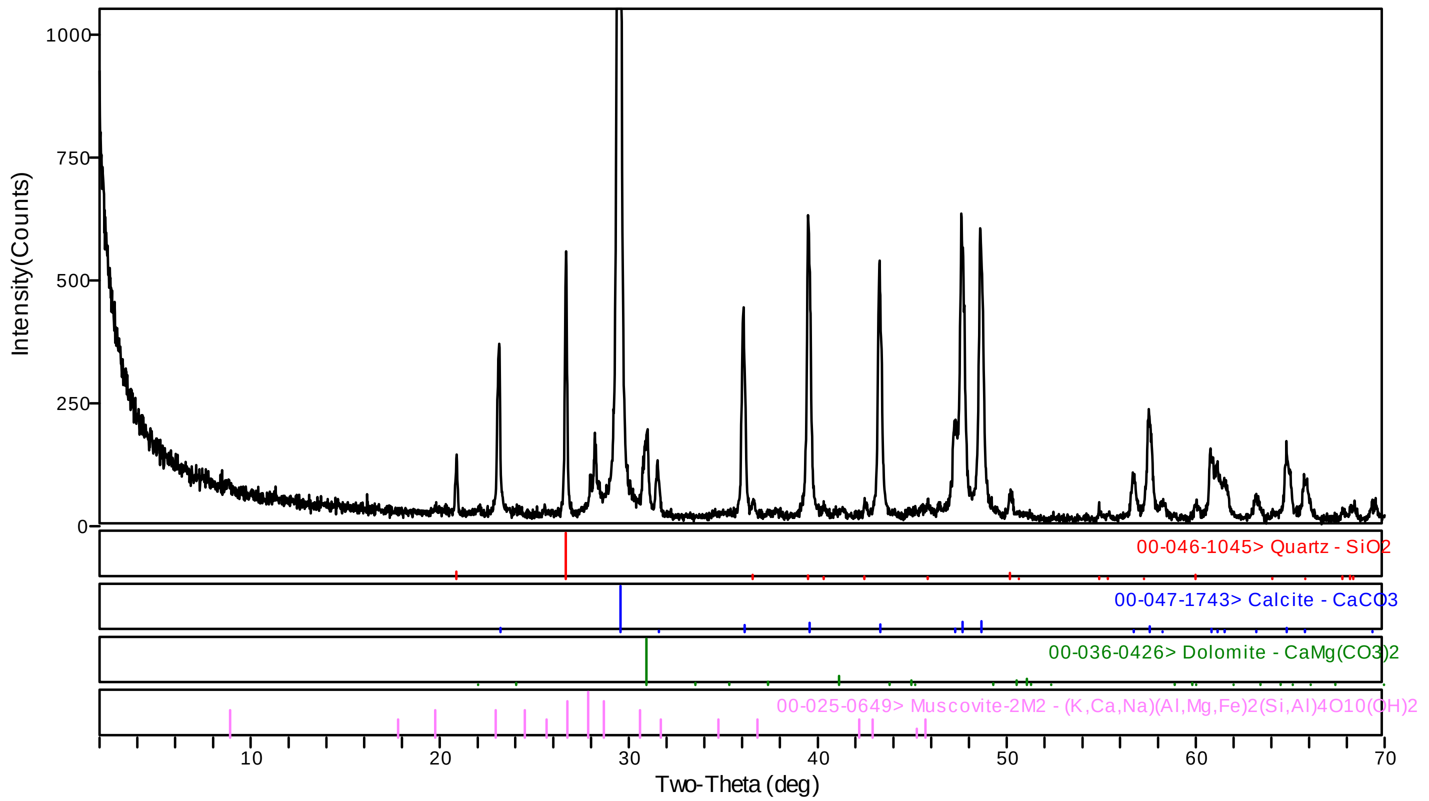
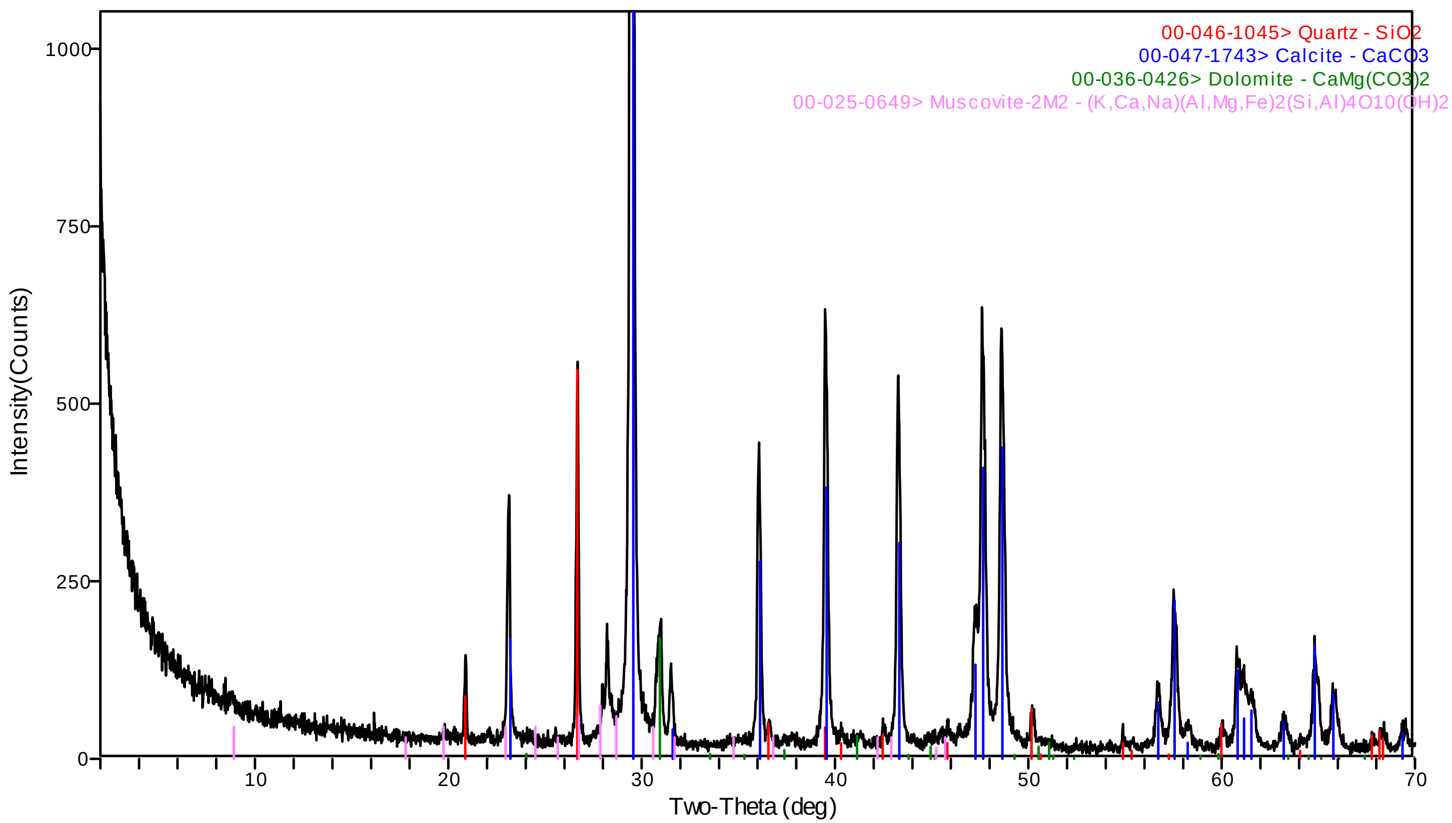
Sand Mt. Road Limestone DSA Phase ID-2



Sand Mt. Road Limestone DSA Phase ID-1



Appendix B: Vegetation Inventory

Vegetation Inventory, May 2006
Herbaceous Inventory

Crowfield Rd 1A	Left	Teaberry (*Gaultheria procumbens)*	23
		lowbush blueberry (*Vaccinium angustifolium*)	3
		Mt. laurel (*Kalmia latifolia)*	2
		Fern	9
		bedstraw (Gallium spp.)	12
		dwarf cinquefoil *(Potentilla canadensis)*	48
	Right	lowbush blueberry (*Vaccinium angustifolium*)	3
		Teaberry (*Gaultheria procumbens)*	4
		Grass	12
Crowfield Rd 1B	Left	Fern	3
		Teaberry (*Gaultheria procumbens)*	5
		Grass	3
	Right	Teaberry (*Gaultheria procumbens)*	5
		Mt. laurel (*Kalmia latifolia)*	2
		lowbush blueberry (*Vaccinium angustifolium*)	2
Crowfield Rd 1C	Left	Red maple *(Acer rubrum)*	1
		Teaberry (*Gaultheria procumbens)*	2
		Mt. laurel (*Kalmia latifolia)*	1
		Barberry *(Berberis thunbergii)*	1
	Right	Teaberry (*Gaultheria procumbens)*	6
		dwarf cinquefoil *(Potentilla canadensis)*	3
Crowfield Rd 2A	Left	Red maple *(Acer rubrum)*	4

		lowbush blueberry (*Vaccinium angustifolium*)	2
		Grass	1
	Right	Fern	5
		Red maple *(Acer rubrum)*	1
		lowbush blueberry (*Vaccinium angustifolium*)	5

Crowfield Rd 2B	Left	lowbush blueberry (*Vaccinium angustifolium*)	1
	Right	Red maple *(Acer rubrum)*	1
		lowbush blueberry (*Vaccinium angustifolium*)	1
		Mt. laurel (*Kalmia latifolia)*	2

Crowfield Rd 2C	Left	Mt. laurel (*Kalmia latifolia)*	3
		Fern	11
		lowbush blueberry (*Vaccinium angustifolium*)	4
	Right	dwarf cinquefoil *(Potentilla canadensis)*	5
		lowbush blueberry (*Vaccinium angustifolium*)	5
		Hemlock	1
		Barberry *(Berberis thunbergii)*	2
		Red maple *(Acer rubrum)*	2

Sand Mt. Rd. 3A	Left	Teaberry (*Gaultheria procumbens)*	3
		Mt. Laurel (*Kalmia latifolia)*	8
		lowbush blueberry (*Vaccinium angustifolium*)	2
	Right	lowbush blueberry (*Vaccinium angustifolium*)	16
		witch hazel *(Hamamelis virginiana)*	1
		Dandelion (*Taraxacum officinale)*	1

Sand Mt. Rd. 3B	Left	lowbush blueberry (*Vaccinium angustifolium*)	10
		bedstraw (Gallium spp.)	4
	Right	Teaberry (*Gaultheria procumbens)*	3
		Mt. Laurel (*Kalmia latifolia)*	3
		lowbush blueberry (*Vaccinium angustifolium*)	21
Sand Mt. Rd. 3C	Left	witch hazel *(Hamamelis virginiana)*	2
		red maple *(Acer rubrum)*	2
		lowbush blueberry (*Vaccinium angustifolium*)	5
	Right	bedstraw (Galium spp.)	7
		lowbush blueberry (*Vaccinium angustifolium*)	1
Pine Swamp Rd 4A	Left	autumn olive (*Elaeagnus umbellata)*	1
		Rubus spp.	1
		lowbush blueberry (*Vaccinium angustifolium*)	3
		Mt. laurel (*Kalmia latifolia)*	8
		Teaberry (*Gaultheria procumbens)*	3
	Right	Mt. laurel (*Kalmia latifolia)*	11
		lowbush blueberry (*Vaccinium angustifolium*)	8
		Teaberry (*Gaultheria procumbens)*	8
Pine Swamp Rd. 4B	Left	Mt. laurel (*Kalmia latifolia)*	16
		lowbush blueberry (*Vaccinium angustifolium*)	18
		Teaberry (*Gaultheria procumbens)*	12
	Right	Mt. laurel (*Kalmia latifolia)*	22

		lowbush blueberry (*Vaccinium angustifolium*)	14
		Teaberry (*Gaultheria procumbens)*	11

Pine Swamp Rd. 4C	Left	Mt. laurel (*Kalmia latifolia)*	16
		lowbush blueberry (*Vaccinium angustifolium*)	8
		Teaberry (*Gaultheria procumbens)*	17
	Right	Mt. laurel (*Kalmia latifolia)*	16
		lowbush blueberry (*Vaccinium angustifolium*)	18
		Teaberry (*Gaultheria procumbens)*	27

Tree Sapling Inventory

Road	Side	Spp.	Diameter (inches)	#
Crowfield Rd. 1A	Left	witch hazel (*Hamamelis virginiana*)	<4	3
		red maple (*Acer rubrum)*	<4	24
		white oak (*Quercus alba)*	14	1
		barberry (*Berberis thunbergii)*	-	19
		red maple *(Acer rubrum)*	6	1
	Right	white oak (*Quercus alba)*	16	1
		red maple (*Acer rubrum)*	15	1
		red maple (*Acer rubrum)*	13	1
		red maple (*Acer rubrum)*	6	2
		red maple (*Acer rubrum)*	5	1
		red maple (*Acer rubrum)*	<4	12
		witch hazel (*Hamamelis virginiana)*	<4	3
		red maple (*Acer rubrum)*	7	1
		red maple (*Acer rubrum)*	13	1
Crowfield Rd. 1B	Left	red maple (*Acer rubrum)*	<4	18
		red maple (*Acer rubrum)*	8	1
		red maple (*Acer rubrum)*	6	1
		barberry (*Berberis thunbergii)*	-	17
	Right	witch hazel (*Hamamelis virginiana)*	<4	13
		eastern white pine (*Pinus strobus)*	5	1
		red maple (*Acer rubrum)*	<4	47
		red maple (*Acer rubrum)*	5	1
		barberry (*Berberis thunbergii)*	<4	3
Crowfield Rd. 1C	Left	black cherry (*Prunus serotina)*	<4	6
		red maple (*Acer rubrum)*	6	1
		red maple (*Acer rubrum)*	<4	26
		witch hazel (*Hamamelis virginiana*)	<4	2
		barberry (*Berberis thunbergii)*	<4	12
		white oak (*Quercus alba)*	14	1
	Right	red maple (*Acer rubrum)*	<4	15
		black cherry (*Prunus serotina)*	<4	3

		red maple (*Acer rubrum)*	6	1
		red oak (*Quercus rubra)*	5	1
		red oak (*Quercus rubra)*	4	1
		Mt. laurel (*Kalmia latifolia)*	<4	8
		barberry (*Berberis thunbergii)*	<4	4
		lowbush blueberry (*Vaccinium angustifolium)*	<4	48

Crowfield Rd. 2A	Left	eastern white pine (*Pinus strobus)*	<4	3
		witch hazel (*Hamamelis virginiana)*	<4	4
		red maple (*Acer rubrum)*	9	2
		red maple (*Acer rubrum)*	7	2
		Mt. laurel (*Kalmia latifolia)*	<4	1
	Right	eastern white pine (*Pinus strobus)*	<4	2
		eastern white pine (*Pinus strobus)*	6	1
		red maple (*Acer rubrum)*	<4	27
		lowbush blueberry (*Vaccinium angustifolium)*	<4	18

Crowfield Rd. 2B	Left	Mt. laurel (*Kalmia latifolia)*	<4	17
		red maple (*Acer rubrum)*	12	1
		eastern white pine (*Pinus strobus)*	10	1
		eastern white pine (*Pinus strobus)*	<4	2
		eastern white pine (*Pinus strobus)*	9	1
		Eastern hemlock (*Tsuga canadensis)*	<4	1
		red maple (*Acer rubrum)*	8	1
	Right	eastern white pine (*Pinus strobus)*	<4	2
		eastern white pine (*Pinus strobus)*	9	1
		eastern white pine (*Pinus strobus)*	6	1
		red maple (*Acer rubrum)*	<4	2
		Mt. laurel (*Kalmia latifolia)*	<4	42
		lowbush blueberry (*Vaccinium angustifolium)*	<4	48

Crowfield Rd. 2C	Left	eastern white pine (*Pinus strobus)*	8	1
		Mt. laurel (*Kalmia latifolia)*	<4	7
		black birch (*Betula lenta)*	<4	1
		eastern white pine (*Pinus strobus)*	<4	1
		barberry (*Berberis thunbergii)*	<4	21
		eastern white pine (*Pinus strobus)*	5	1
		red maple (*Acer rubrum)*	7	1
	Right	Mt. laurel (*Kalmia latifolia)*	<4	4

		red maple (*Acer rubrum)*	<4	2
		eastern white pine (*Pinus strobus)*	8	3
		eastern white pine (*Pinus strobus)*	9	1
		eastern white pine (*Pinus strobus)*	5	1
		eastern white pine (*Pinus strobus)*	<4	3
Sand Mt. Rd. 3A	Left	Mt. laurel (*Kalmia latifolia)*	<4	11
		chestnut oak (*Quercus montana*)	14	1
		chestnut oak (*Quercus montana*)	16	1
		red oak (*Quercus rubra*)	22	1
		witch hazel (*Hamamelis virginiana*)	<4	3
	Right	red oak (*Quercus rubra*)	9	1
		red oak (*Quercus rubra*)	12	1
		red oak (*Quercus rubra*)	8	1
		witch hazel (*Hamamelis virginiana*)	<4	1
		Mt. laurel (*Kalmia latifolia*)	<4	2
		barberry (*Berberis thunbergii*)	<4	1
Sand Mt. Rd. 3B	Left	red maple (*Acer rubrum*)	<4	1
		Mt. laurel (*Kalmia latifolia*)	<4	3
		red maple (*Acer rubrum*)	5	1
		red oak (*Quercus rubra*)	18	1
		red oak (*Quercus rubra*)	18	1
	Right	Mt. laurel (*Kalmia latifolia)*	<4	1
		chestnut oak (*Quercus montana*)	9	1
		chestnut oak (*Quercus montana*)	8	1
		white oak (*Quercus alba*)	8	1
Sand Mt. Rd. 3C	Left	Mt. laurel (*Kalmia latifolia*)	<4	4
		striped maple (*Acer pennsylvanicum*)	<4	42
		chestnut oak (*Quercus montana)*	12	1
		chestnut oak (*Quercus montana)*	13	1
		red maple (*Acer rubrum*)	7	1
		chestnut oak (*Quercus montana*)	12	1
		chestnut oak (*Quercus montana*)	13	1
	Right	red oak (*Quercus rubra)*	8	1
		striped maple (*Acer pennsylvanicum*)	<4	16
		eastern white pine (*Pinus strobus*)	6	1
		chestnut oak (*Quercus montana*)	10	1
		Mt. laurel (*Kalmia latifolia*)	<4	2
		multi-flora rose (*Rosa multiflora*)	<4	2

Pine Swamp Rd. 4A	Left	red maple (*Acer rubrum*)	6	1
		red maple (*Acer rubrum*)	8	5
		red maple (*Acer rubrum*)	9	2
		red maple (*Acer rubrum*)	7	1
		red maple (*Acer rubrum)*	5	1
		red maple (*Acer rubrum*)	12	1
		chestnut oak (*Quercus montana*)	<4	2
		chestnut oak (*Quercus montana*)	<4	1
		Mt. laurel (*Kalmia latifolia*)	<4	22
	Right	black birch (*Betula lenta*)	5	1
		eastern white pine (*Pinus strobus*)	9	1
		chestnut oak (*Quercus montana*)	18	1
		chestnut oak (*Quercus montana*)	15	1
		eastern white pine (*Pinus strobus*)	<4	1
		chestnut oak (*Quercus montana*)	<4	2
		Mt. laurel (*Kalmia latifolia*)	<4	72

Pine Swamp Rd. 4B	Left	red maple (*Acer rubrum*)	7	1
		eastern white pine (*Pinus strobus*)	16	1
		red maple (*Acer rubrum*)	<4	2
		red maple (*Acer rubrum*)	5	1
		white oak *(Quercus alba*)	<4	8
		Mt. laurel (*Kalmia latifolia*)	<4	18
	Right	quaking aspen (*Populus tremuloides*)	11	1
		red maple (*Acer rubrum*)		5
		red maple (*Acer rubrum*)	8	1
		red maple (*Acer rubrum*)	<4	18
		chestnut oak (*Quercus montana*)	<4	1
		scotch pine (*Pinus sylvestris*)	<4	1
		quaking aspen (*Populus tremuloides*)	8	1
		Mt. laurel (*Kalmia latifolia*)	<4	24

Pine Swamp Rd. 4C	Left	white oak (*Quercus alba*)	11	1
		chestnut oak (*Quercus montana*)	10	1
		chestnut oak (*Quercus montana*)	13	1
		chestnut oak (*Quercus montana*)	14	1
		red maple (*Acer rubrum*)	6	1
		red maple (*Acer rubrum*)	10	1
		red oak (*Quercus rubra*)	16	1

		Mt. laurel (*Kalmia latifolia*)	<4	22
	Right	red maple (*Acer rubrum*)	6	1
		red maple (*Acer rubrum*)	8	1
		chestnut oak (*Quercus montana*)	12	1
		scotch pine (*Pinus sylvestris*)	<4	1
		red maple (*Acer rubrum*)	<4	1
		red maple (*Acer rubrum*)	9	1
		chestnut oak (*Quercus montana*)	8	1
		red maple (*Acer rubrum*)	5	2
		Mt. laurel (*Kalmia latifolia*)	4	17
		autumn olive (*Elaeagnus umbellata*)	<4	1

Appendix C: Phtotographs of Road Surfaces & Vegetation Inventory

Crowfield Limestone DSA Roadway

Crowfield Limestone DSA 1A Left

Crowfield Limestone 1A Right

Crowfield Native Driving Aggregate Roadway

Crowfield Rd. Native Driving Aggregate 2A Left

Crowfield Rd. Native Driving Aggregate 2A Right

Sand Mountain Rd. Limestone DSA Roadway

Sand Mountain Rd. Limestone DSA 3A Left

Sand Mountain Rd. Limestone DSA 3A Right

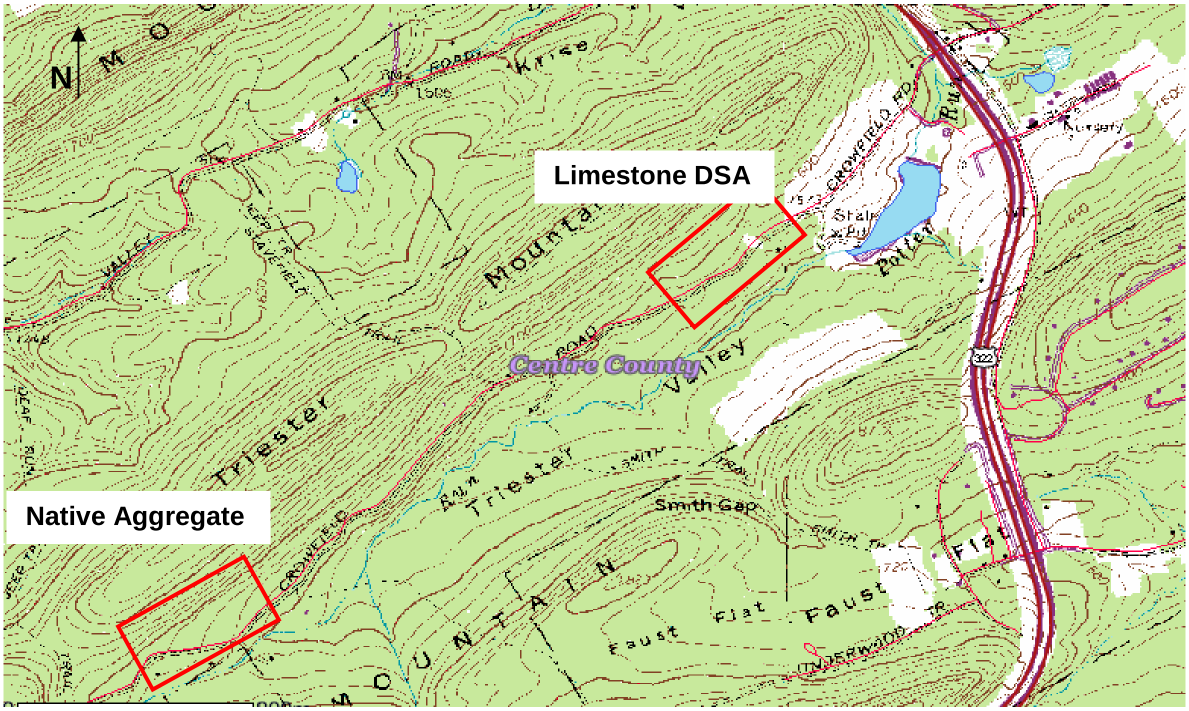
Pine Swamp Rd. Native Aggregate Roadway

Pine Swamp Rd. Native Aggregate 4A Left

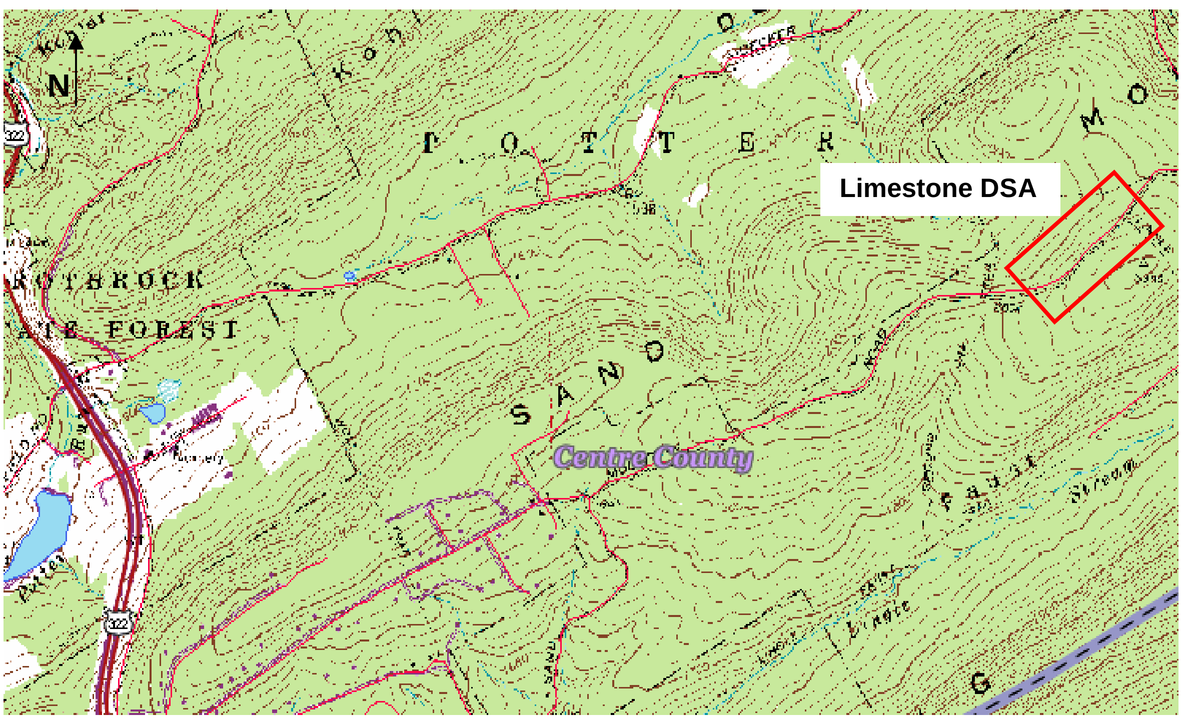
Pine Swamp Rd. Native Aggregate 4A Right

Appendix D: Road Segment Location Maps

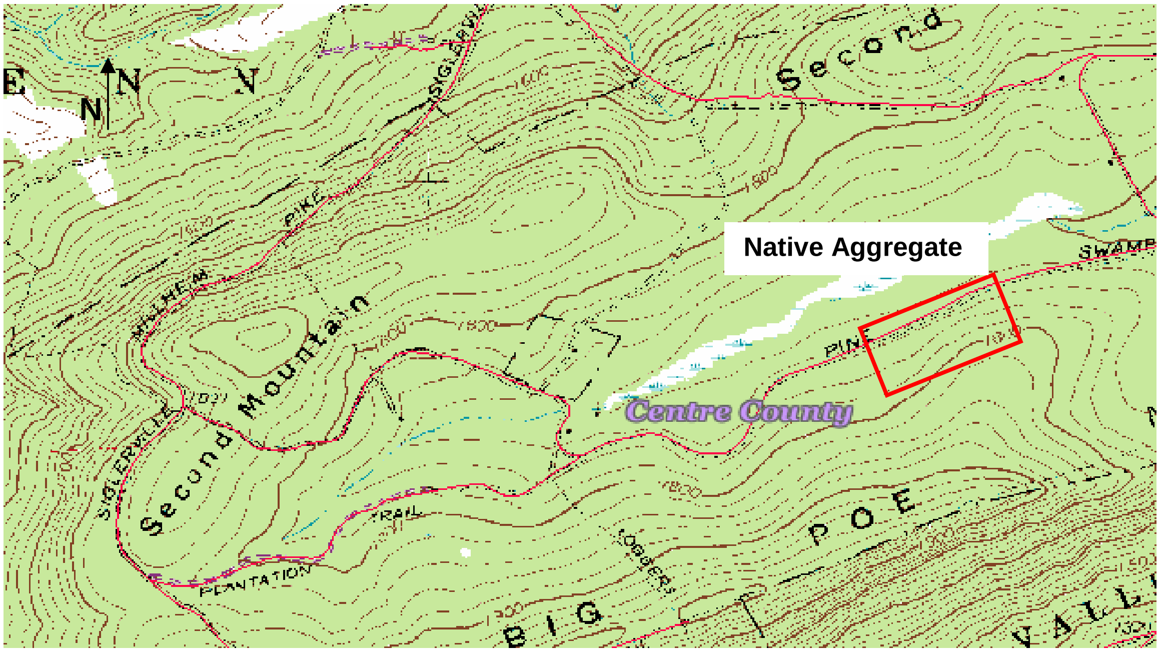
Crowfield Road – Limestone DSA and Native Aggregate Segments



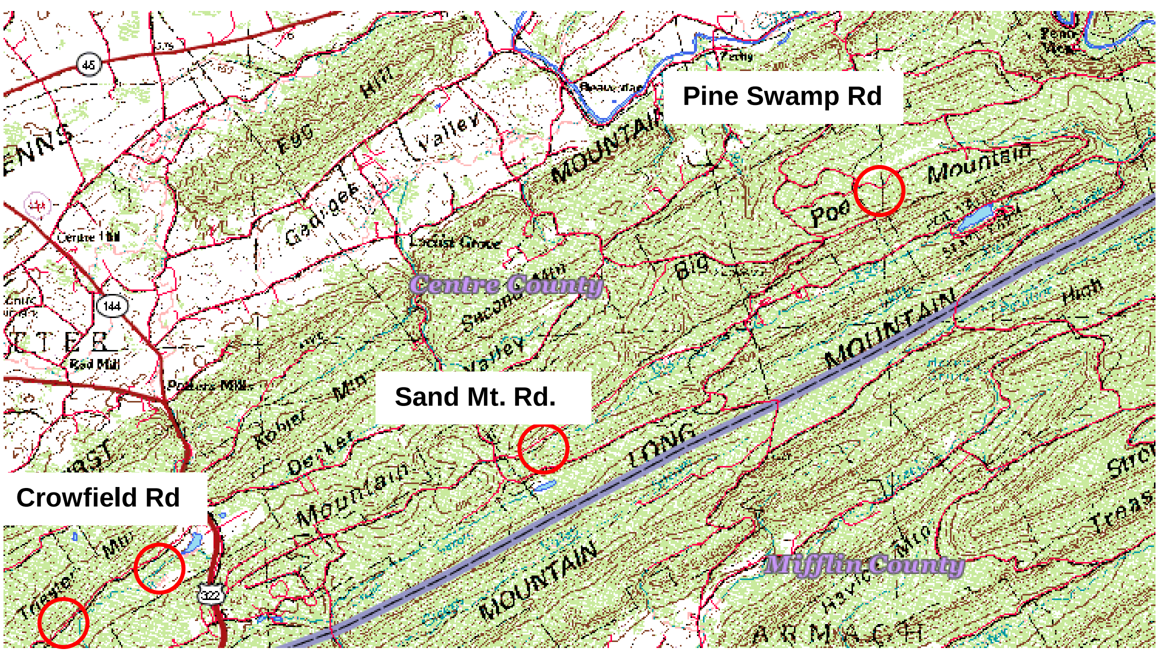
Sand Mountain Road



Pine Swamp Road



Road Locations



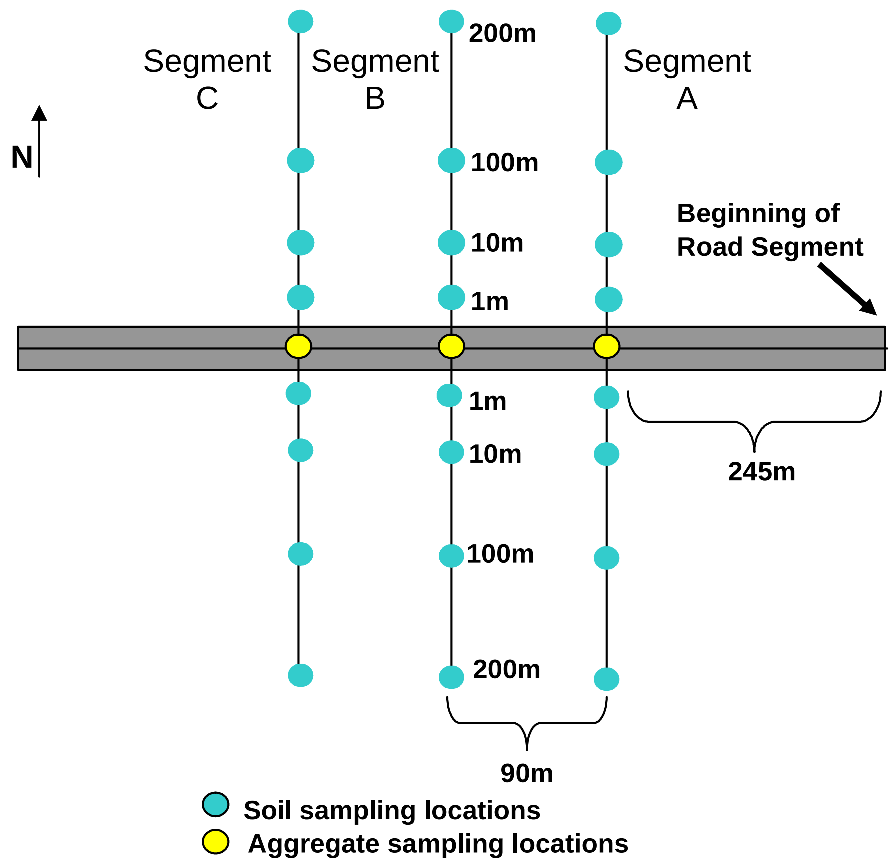
****Locations of road segments are approximate****

All Location Maps are from www.soilmap.psu.edu

Appendix E: Soil Sample Data Listing

Sampling Location Codes

Cross-sections and Sampling Layout



Sample ID Code Description

The sampling code number corresponds to the road, the letter corresponds to the segment, left/right corresponds to the side of the road the sample was collected on and the last number is the distance in meters the sample was collected at. Road segments were delineated from east to west.

#1 - Crowfield Road Limestone DSA Aggregate Segment
#2 - Crowfield Road Native Aggregate Segment
#3 - Sand Mountain Road Limestone DSA Aggregate Segment
#4 - Pine Swamp Road Native Aggregate

Example Sample ID

Code: Left-1A-1m = Left side of road, Crowfield Rd., Segment A, 1m sampling point

Crowfield Road Limestone DSA Segment: Soil Fertility Test Results

							% Saturation of the CEC			
Sample ID	**PH**	**H+ ions**	**Ca (ppm)**	**Mg (ppm)**	**P (ppm)**	**K (ppm)**	**%K**	**%Mg**	**%Ca**	**Sum**
Left-1A-1m	7.5	3.1623E-08	10722	592	65	305	3.8	23.8	72.4	100
Left-1A-10m	6.3	5.0119E-07	6790	884	70	598	5.6	27.1	55.1	87.8
Left-1A-100m	5	0.00001	4646	457	62	554	4.4	11.9	47	63.3
Left-1A-200m	4.9	1.2589E-05	3779	376	80	644	5.2	10	47.6	62.8
Right-1A-1m	7.7	1.9953E-08	11051	646	64	331	4	25.4	70.6	100
Right-1A-10m	6.6	2.5119E-07	8424	1184	107	665	5.7	33	50.2	88.9
Right-1A-100m	5.9	1.2589E-06	5505	895	146	919	7.6	24	48.2	79.8
Right-1A-200m	4.9	1.2589E-05	3497	402	60	602	5	10.8	48.4	64.2
Left-1B-1m	6.9	1.2589E-07	8500	833	87	332	3.7	30.5	65.8	100
Left-1B-10m	5.8	1.5849E-06	5619	824	183	598	5.4	24.1	52.6	82.1
Left-1B-100m	4.1	7.9433E-05	2064	201	35	429	4.1	6.3	38.8	49.2
Left-1B-200m	4.6	2.5119E-05	3832	278	76	646	4.9	6.9	44.5	56.3
Right-1B-1m	7.3	5.0119E-08	9466	1212	86	465	4.5	38.4	57.1	100
Right-1B-10m	6.6	2.5119E-07	7866	1357	74	522	4.4	37.1	49.3	90.8
Right-1B-100m	5	0.00001	2889	303	138	660	6.1	9	51.7	66.8
Right-1B-200m	5.2	6.3096E-06	2949	649	128	814	6.5	16.8	45.9	69.2
Left-1C-1m	6.1	7.9433E-07	5675	985	132	568	5.2	29.4	53.6	88.2
Left-1C-10m	6.2	6.3096E-07	6556	1059	135	493	4.5	31.1	52.8	88.4
Left-1C-100m	4.8	1.5849E-05	3158	450	167	755	6.3	12.3	49	67.6
Left-1C-200m	4.7	1.9953E-05	3445	373	173	683	5.7	10	48.5	64.2
Right-1C-1m	6.9	1.2589E-07	6786	1179	44	368	3.7	38.1	58.2	100
Right-1C-10m	5.9	1.2589E-06	5087	970	35	312	2.8	27.9	51.8	82.5
Right-1C-100m	5	0.00001	3046	622	73	911	7.3	16.3	47.1	70.7
Right-1C-200m	4.9	1.2589E-05	6864	509	87	779	6.2	13.1	46.4	65.7

Crowfield Road Limestone DSA Segment: AL Stress Test

Sample ID	Ca (mg/kg)	Al (mg/kg)	Ca:Al Ratio (Molar)
Left-1A-1m	292.5	0.02	9667.24
Left-1A-10m	238.91	0.02	7895.91
Left-1A-100m	205.74	0.02	6799.68
Left-1A-200m	166.24	0.08	1339.21
Right-1A-1m	265.88	0.59	296.13
Right-1A-10m	251.51	0.31	541.48
Right-1A-100m	197.07	0.56	233.64
Right-1A-200m	181.67	0.02	6004.04
Left-1B-1m	247.79	0.21	770.16
Left-1B-10m	215.98	0.47	303.82
Left-1B-100m	113.78	0.19	395.8
Left-1B-200m	192.14	0.02	6350.23
Right-1B-1m	262.09	0.02	8661.97
Right-1B-10m	252.67	0.02	8350.82
Right-1B-100m	159.06	0.59	177.98
Right-1B-200m	159.35	1.05	99.91
Left-1C-1m	208.58	0.02	6893.49
Left-1C-10m	230.23	0.02	7609.11
Left-1C-100m	143.44	0.46	205.61
Left-1C-200m	170.91	0.02	5648.73
Right-1C-1m	201.03	0.11	1223.33
Right-1C-10m	184.89	0.06	1946.37
Right-1C-100m	144.13	0.43	221.37
Right-1C-200m	170	0.38	294.33

Crowfield Road Limestone DSA Segment :
Foliar Results - Top leaf layer (Oi)

Sample ID	P%	K%	Ca%	Mg%	Mn (ug/g)	Fe (ug/g)	Cu (ug/g)	B (ug/g)	Al (ug/g)	Zn (ug/g)	Na (ug/g)
Left-1A-1m	0.05	0.09	7.09	0.27	1414	609	5	36	533	16	41
Left-1A-10m	0.06	0.13	1.80	0.18	2287	172	7	33	125	30	32
Left-1A-100m	0.04	0.12	1.30	0.14	1931	116	7	21	87	40	25
Left-1A-200m	0.08	0.11	1.14	0.08	4399	163	8	23	149	31	24
Right-1A-1m	0.08	0.09	3.16	0.44	1256	4777	10	20	3630	35	40
Right-1A-10m	0.08	0.13	1.54	0.18	1491	277	6	30	255	25	25
Right-1A-100m	0.08	0.10	1.30	0.10	5351	107	6	32	409	25	21
Right-1A-200m	0.07	0.12	1.01	0.08	4756	149	7	26	136	28	26
Left-1B-1m	0.07	0.10	2.34	0.17	1738	156	6	31	126	21	24
Left-1B-10m	0.08	0.13	1.36	0.16	2365	93	7	27	74	29	18
Left-1B-100m	0.06	0.12	0.85	0.08	4287	89	6	26	112	24	29
Left-1B-200m	0.07	0.11	0.98	0.07	4655	68	7	28	71	24	26
Right-1B-1m	0.06	0.08	1.52	0.16	1750	86	6	28	84	20	21
Right-1B-10m	0.08	0.11	1.43	0.18	1517	94	6	26	88	24	30
Right-1B-100m	0.08	0.12	1.00	0.07	4064	72	7	23	149	27	28
Right-1B-200m	0.06	0.10	1.09	0.08	5055	60	6	30	79	24	27
Left-1C-1m	0.06	0.07	2.16	0.14	1559	126	5	30	128	19	26
Left-1C-10m	0.07	0.11	1.45	0.16	1949	186	8	27	160	26	24
Left-1C-100m	0.05	0.09	0.77	0.09	3546	73	6	25	83	21	16
Left-1C-200m	0.07	0.11	1.06	0.08	4579	86	7	24	81	25	22
Right-1C-1m	0.07	0.09	1.65	0.17	1220	104	6	25	86	21	19
Right-1C-10m	0.06	0.09	1.22	0.17	2024	77	5	25	78	21	20
Right-1C-100m	0.08	0.11	0.92	0.08	4692	65	6	28	83	24	45
Right-1C-200m	0.08	0.12	0.92	0.08	4667	69	6	31	67	26	24

Crowfield Road Native Aggregate: Soil Fertilty Test Results

							% Saturation of the CEC			
Sample ID	PH	H+ ions	Ca (ppm)	Mg (ppm)	P (ppm)	K (ppm)	%K	%Mg	%Ca	Sum
Left-2A-1m	7.2	6.3096E-08	7298	2376	81	796	5.5	53.7	40.7	99.9
Left-2A-10m	6.1	7.9433E-07	5346	1119	57	838	6.9	30.1	48.4	85.4
Left-2A-100m	4.7	1.9953E-05	3365	926	58	667	4.7	21	40.8	66.5
Left-2A-200m	4.4	3.9811E-05	3050	293	54	971	7.3	7.2	44.1	58.6
Right-2A-1m	7	0.0000001	6352	1597	39	515	4.5	44.9	50.6	100
Right-2A-10m	5.6	2.5119E-06	5150	1567	49	586	4.1	35.8	41.1	81
Right-2A-100m	4.4	3.9811E-05	2240	231	48	335	3.4	7.7	44.7	55.8
Right-2A-200m	4.6	2.5119E-05	2801	221	63	415	3.7	6.4	49	59.1
Left-2B-1m	6.4	3.9811E-07	5565	1402	52	570	4.8	38.8	49.8	93.4
Left-2B-10m	6	0.000001	6213	1344	92	717	5.7	34.4	46.1	86.2
Left-2B-100m	5	0.00001	3808	532	103	905	7.5	14.3	48.3	70.1
Left-2B-200m	4.4	3.9811E-05	1964	172	70	464	4.6	5.5	37.8	47.9
Right-2B-1m	6.4	3.9811E-07	4001	1426	37	434	3.7	39.6	50	93.3
Right-2B-10m	5.8	1.5849E-06	3666	974	32	390	3.5	28.4	52.4	84.3
Right-2B-100m	5.1	7.9433E-06	3745	516	71	893	7.3	13.7	47.6	68.6
Right-2B-200m	4.3	5.0119E-05	1893	160	71	393	3.8	5	35.7	44.5
Left-2C-1m	6.7	1.9953E-07	6937	1817	83	335	2.6	45.9	45.5	94
Left-2C-10m	5.9	1.2589E-06	6667	1518	94	636	4.7	36.2	42.9	83.8
Left-2C-100m	5.1	7.9433E-06	2503	567	147	1160	9.5	15.1	40	64.6
Left-2C-200m	4.8	1.5849E-05	3018	485	85	887	7	12.5	46.3	65.8
Right-2C-1m	7.1	7.9433E-08	6087	1135	60	276	2.8	37.6	59.6	100
Right-2C-10m	7	0.0000001	7600	1904	64	363	2.9	49.9	47.2	100
Right-2C-100m	6.6	2.5119E-07	8271	991	50	703	6.1	27.9	50.7	84.7
Right-2C-200m	6.1	7.9433E-07	8021	802	34	608	5	21.3	47.9	74.2

Crowfield Road Native Aggregate:
ALuminum Stress Test

Sample ID	Ca (mg/kg)	Al (mg/kg)	Ca:Al Ratio (Molar)
Left-2A-1m	212.85	0.12	1194.4
Left-2A-10m	191.39	0.02	6325.29
Left-2A-100m	146.94	0.89	109.63
Left-2A-200m	197	0.47	234.51
Right-2A-1m	204.37	0.5	269.17
Right-2A-10m	167.07	0.5	220.31
Right-2A-100m	118.3	0.41	189.06
Right-2A-200m	148.61	0.41	239.65
Left-2B-1m	182.76	0.05	2553.52
Left-2B-10m	201.23	0.02	6650.73
Left-2B-100m	173.83	0.43	269.54
Left-2B-200m	112.98	0.65	114.44
Right-2B-1m	149.36	0.18	541.78
Right-2B-10m	169.61	0.18	613.69
Right-2B-100m	177.31	0.4	295.74
Right-2B-200m	117.39	0.74	105
Left-2C-1m	208.98	0.11	1265.22
Left-2C-10m	221.09	0.09	1549.1
Left-2C-100m	134.5	1.95	45.5
Left-2C-200m	161.82	0.83	128.46
Right-2C-1m	187.01	0.19	638.97
Right-2C-10m	216.38	0.15	930.55
Right-2C-100m	244.88	0.02	9453.98
Right-2C-200m	245.97	0.13	1217.33

Crowfield Road Native Aggregate Segment: Foliar Results - Top leaf layer (Oi) -

Sample ID	P%	K%	Ca%	Mg%	Mn (ug/g)	Fe (ug/g)	Cu (ug/g)	B (ug/g)	Al (ug/g)	Zn (ug/g)	Na (ug/g)
Left-2A-1m	0.08	0.11	2.89	0.69	1957	1111	7	30	759	28	30
Left-2A-10m	0.08	0.16	1.12	0.21	3454	251	5	31	178	31	23
Left-2A-100m	0.06	0.13	1.02	0.17	3906	177	6	26	223	43	22
Left-2A-200m	0.06	0.15	0.90	0.09	4336	92	5	30	73	26	25
Right-2A-1m	0.07	0.12	1.53	0.36	2935	301	5	34	166	29	29
Right-2A-10m	0.07	0.11	1.09	0.21	1878	185	7	23	179	35	21
Right-2A-100m	0.07	0.10	0.95	0.07	4460	106	8	25	121	29	15
Right-2A-200m	0.05	0.07	0.97	0.06	4375	59	6	24	122	21	15
Left-2B-1m	0.07	0.15	1.76	0.53	1207	252	5	28	180	36	24
Left-2B-10m	0.07	0.12	1.25	0.24	1709	98	5	28	158	42	24
Left-2B-100m	0.07	0.11	0.95	0.09	5478	69	6	32	320	28	17
Left-2B-200m	0.08	0.11	0.84	0.06	5539	93	7	26	118	31	15
Right-2B-1m	0.07	0.10	1.57	0.37	1391	211	5	27	210	36	27
Right-2B-10m	0.06	0.09	1.10	0.20	2688	104	5	27	112	28	17
Right-2B-100m	0.07	0.13	1.00	0.09	5310	76	6	29	104	32	19
Right-2B-200m	0.08	0.10	0.87	0.07	4731	87	6	25	265	31	15
Left-2C-1m	0.09	0.09	1.94	0.32	887	146	7	26	434	33	17
Left-2C-10m	0.08	0.09	1.62	0.16	1255	94	6	27	278	45	27
Left-2C-100m	0.07	0.14	0.89	0.15	1955	117	6	24	107	31	38
Left-2C-200m	0.08	0.15	0.92	0.17	2696	94	6	27	100	32	21
Right-2C-1m	0.08	0.10	2.50	0.71	1602	708	7	28	1401	75	27
Right-2C-10m	0.10	0.17	1.35	0.29	2394	171	6	34	468	70	23
Right-2C-100m	0.09	0.12	1.37	0.16	2782	73	6	35	699	62	20
Right-2C-200m	0.13	0.13	1.79	0.19	3801	143	10	37	3948	140	23

Sand Mt. Road Limestone DSA Segment: Soil Fertilty Test Results

							% Saturation of the CEC			
Sample ID	PH	H+ ions	Ca (ppm)	Mg (ppm)	P (ppm)	K (ppm)	%K	%Mg	%Ca	Sum
Left-3A-1m	7.3	5.0119E-08	15940	390	37	139	1.9	17.5	80.6	100
Left-3A-10m	7.3	5.0119E-08	12757	1168	68	360	3.6	37.9	58.5	100
Left-3A-100m	5.3	5.0119E-06	3526	513	121	839	7.4	14.8	51.9	74.1
Left-3A-200m	4.3	5.0119E-05	1618	396	113	773	7.2	12	29.5	48.7
Right-3A-1m	7.4	3.9811E-08	16376	499	42	269	3.5	21	75.6	100.1
Right-3A-10m	7	0.0000001	9842	897	89	499	5.4	31.5	63.1	100
Right-3A-100m	5.5	3.1623E-06	3726	508	139	1190	10.2	14.2	50.4	74.8
Right-3A-200m	4.9	1.2589E-05	2471	452	115	826	7.1	12.6	41.3	61
Left-3B-1m	7.6	2.5119E-08	12248	405	54	206	2.8	17.9	79.4	100.1
Left-3B-10m	7.1	7.9433E-08	10409	958	94	531	5.6	32.8	61.6	100
Left-3B-100m	5.3	5.0119E-06	4978	665	124	719	5.9	17.8	48.3	72
Left-3B-200m	5.1	7.9433E-06	4526	677	165	1199	9.8	18.1	48.1	76
Right-3B-1m	7.4	3.9811E-08	11142	619	49	233	2.9	24.9	72.3	100.1
Right-3B-10m	7	0.0000001	10083	1183	81	534	5.2	37.6	57.2	100
Right-3B-100m	4.8	1.5849E-05	2697	392	106	782	6.1	9.9	41	57
Right-3B-200m	5.4	3.9811E-06	4179	556	147	1005	8.3	15	48.5	71.8
Left-3C-1m	7.5	3.1623E-08	18522	438	60	277	3.7	18.9	77.5	100.1
Left-3C-10m	7.5	3.1623E-08	13115	455	55	326	4.3	19.3	76.4	100
Left-3C-100m	5.2	6.3096E-06	5002	464	112	827	7	12.8	49.5	69.3
Left-3C-200m	4.9	1.2589E-05	4565	463	116	801	6.5	12.3	47.8	66.6
Right-3C-1m	7.6	2.5119E-08	11758	411	49	305	4.1	17.8	78.1	100
Right-3C-10m	6.3	5.0119E-07	8355	778	70	784	6.6	21.3	49.4	77.3
Right-3C-100m	4.1	7.9433E-05	2249	387	69	1030	82	10	35	127
Right-3C-200m	3.9	0.00012589	1647	513	90	1073	9.1	14.1	27.2	50.4

Sand Mt. Road Limestone DSA Segment:
Aluminum Stress Test

Sample ID	Ca (mg/kg)	Al (mg/kg)	Ca:Al Ratio (Molar)
Left-3A-1m	246.96	0.02	8162.01
Left-3A-10m	314.13	0.02	10854.23
Left-3A-100m	173.95	0.02	5749.08
Left-3A-200m	107.14	2.68	26.44
Right-3A-1m	275.2	0.02	9095.35
Right-3A-10m	304.86	0.02	10075.63
Right-3A-100m	196.81	0.02	6104.74
Right-3A-200m	149.98	0.17	566.8
Left-3B-1m	264.55	0.02	8743.32
Left-3B-10m	315.36	0.02	10422.57
Left-3B-100m	213.84	0.02	7067.38
Left-3B-200m	224.42	0.58	255.54
Right-3B-1m	303.99	0.02	10047.03
Right-3B-10m	287.51	0.02	9502.08
Right-3B-100m	143.82	1.41	67.52
Right-3B-200m	195.83	0.02	6472.33
Left-3C-1m	306.06	0.02	10115.32
Left-3C-10m	321.27	0.02	10618.12
Left-3C-100m	237.2	0.02	7839.6
Left-3C-200m	230.49	0.12	1220.57
Right-3C-1m	307.54	0.02	10164.34
Right-3C-10m	270.56	0.12	1492.42
Right-3C-100m	124.21	1.02	80.35
Right-3C-200m	110.62	1.12	65.27

Sand Mt. Road Limestone DSA Segment: Foliar Results - Top leaf layer (Oi)

Sample ID	P%	K%	Ca%	Mg%	Mn (ug/g)	Fe (ug/g)	Cu (ug/g)	B (ug/g)	Al (ug/g)	Zn (ug/g)	Na (ug/g)
Left-3A-1m	0.07	0.08	6.90	0.32	457	795	6	30	431	26	39
Left-3A-10m	0.07	0.10	2.68	0.21	707	285	5	32	203	26	20
Left-3A-100m	0.08	0.11	1.21	0.14	3812	90	5	31	91	26	16
Left-3A-200m	0.06	0.09	0.85	0.08	2961	86	6	23	284	40	20
Right-3A-1m	0.06	0.08	4.36	0.21	708	486	5	30	206	21	24
Right-3A-10m	0.08	0.11	1.75	0.21	1316	149	5	30	116	24	17
Right-3A-100m	0.07	0.12	0.88	0.11	3997	78	5	29	107	29	15
Right-3A-200m	0.07	0.10	0.86	0.10	4042	92	6	27	108	33	17
Left-3B-1m	0.06	0.08	2.04	0.16	459	165	4	31	112	25	17
Left-3B-10m	0.08	0.11	1.68	0.21	742	157	5	32	114	23	19
Left-3B-100m	0.06	0.08	1.08	0.15	2804	102	4	33	102	28	16
Left-3B-200m	0.07	0.09	1.01	0.15	2657	80	5	31	85	30	16
Right-3B-1m	0.06	0.09	2.28	0.20	1145	258	5	28	171	32	23
Right-3B-10m	0.06	0.11	1.84	0.22	1214	162	4	32	106	30	18
Right-3B-100m	0.07	0.12	1.00	0.13	3431	98	6	29	137	33	22
Right-3B-200m	0.08	0.12	0.93	0.10	4470	80	6	28	83	37	21
Left-3C-1m	0.08	0.13	2.97	0.17	877	276	5	35	186	29	29
Left-3C-10m	0.07	0.09	2.72	0.16	729	297	5	31	202	33	22
Left-3C-100m	0.09	0.10	1.50	0.11	3920	133	8	25	122	29	20
Left-3C-200m	0.07	0.10	1.11	0.11	3549	66	5	28	85	25	16
Right-3C-1m	0.06	0.08	3.27	0.16	912	392	5	29	267	30	33
Right-3C-10m	0.08	0.13	1.60	0.17	1897	153	6	29	122	33	31
Right-3C-100m	0.07	0.11	1.02	0.10	4895	96	5	29	103	32	17
Right-3C-200m	0.09	0.11	0.91	0.11	4024	112	7	26	134	68	27

Pine Swamp Road Native Aggregate Segment: Soil Fertilty Test Results

							% Saturation of the CEC			
Sample ID	**PH**	**H+ ions**	**Ca (ppm)**	**Mg (ppm)**	**P (ppm)**	**K (ppm)**	**%K**	**%Mg**	**%Ca**	**Sum**
Left-4A-1m	4.3	5.0119E-05	2560	154	51	770	6.7	4.3	43.3	54.3
Left-4A-10m	4.3	5.0119E-05	3161	243	79	812	6.6	6.4	47.8	60.8
Left-4A-100m	3.9	0.00012589	3579	466	62	654	4.7	10.9	42.2	57.8
Left-4A-200m	3.7	0.00019953	2981	494	55	683	4.9	11.5	41.7	58.1
Right-4A-1m	4.7	1.9953E-05	2260	211	30	316	3.3	7.2	46.4	56.9
Right-4A-10m	4	0.0001	2713	251	43	559	4.5	6.5	42.3	53.3
Right-4A-100m	4.1	7.9433E-05	2976	481	93	937	6.6	11	41	58.6
Right-4A-200m	4	0.0001	2845	371	84	766	5.8	9.1	41.9	56.8
Left-4B-1m	4.4	3.9811E-05	4097	421	52	559	4.3	10.5	44.9	59.7
Left-4B-10m	4.3	5.0119E-05	4119	456	56	609	4.5	10.8	42.8	58.1
Left-4B-100m	3.6	0.00025119	1781	243	41	588	5.5	7.4	32.5	45.4
Left-4B-200m	3.6	0.00025119	2232	256	25	427	3.7	7.3	38	49
Right-4B-1m	4.3	5.0119E-05	3060	303	50	564	4.4	7.6	45.4	57.4
Right-4B-10m	3.7	0.00019953	2358	320	54	612	5.1	8.6	38	51.7
Right-4B-100m	4	0.0001	2766	358	82	1001	7.5	8.7	40.2	56.4
Right-4B-200m	3.9	0.00012589	2003	346	73	1333	10.9	9.2	32	52.1
Left-4C-1m	5	0.00001	4397	484	66	625	5.5	13.7	51.1	70.3
Left-4C-10m	4.6	2.5119E-05	5289	545	61	635	4.9	13.6	44.8	63.3
Left-4C-100m	4.1	7.9433E-05	1302	115	24	117	1.3	4.2	28.6	34.1
Left-4C-200m	3.9	0.00012589	3068	378	74	707	5.2	9	42.9	57.1
Right-4C-1m	4.8	1.5849E-05	3965	504	122	882	7.5	13.9	49.7	71.1
Right-4C-10m	4.4	3.9811E-05	2382	319	78	717	6.5	9.5	42.4	58.4
Right-4C-100m	4.1	7.9433E-05	3076	472	125	900	6.6	11.3	43.2	61.1
Right-4C-200m	4.1	7.9433E-05	2713	429	131	927	7.1	10.6	40.4	58.1

Pine Swamp Road Native Aggregate Segment:
Aluminum Stress Test

Sample ID	Ca (mg/kg)	Al (mg/kg)	Ca:Al Ratio (Molar)
Left-4A-1m	155.96	0.96	107.13
Left-4A-10m	179.42	0.92	129.2
Left-4A-100m	182.86	0.37	330.52
Left-4A-200m	161.43	0.7	151.74
Right-4A-1m	133.38	0.54	163.48
Right-4A-10m	153.48	0.57	177.48
Right-4A-100m	135.36	0.48	188.13
Right-4A-200m	149.49	0.42	232.61
Left-4B-1m	192.56	0.53	240.33
Left-4B-10m	185.02	0.35	347.6
Left-4B-100m	104.32	3.18	21.66
Left-4B-200m	115.38	1.63	46.7
Right-4B-1m	160.04	1.14	92.77
Right-4B-10m	137.18	1.16	78.26
Right-4B-100m	148.27	0.62	158.4
Right-4B-200m	107.74	0.87	81.65
Left-4C-1m	202.83	0.16	857.82
Left-4C-10m	246.77	0.35	461.01
Left-4C-100m	90.11	0.47	125.68
Left-4C-200m	168.09	0.55	200.3
Right-4C-1m	208.41	0.48	288.38
Right-4C-10m	137.27	0.92	98.37
Right-4C-100m	170.21	0.43	264.32
Right-4C-200m	159.8	0.53	198.78

Pine Swamp Road Native Aggregate Segment: Foliar Results - Top leaf layer (Oi)

Sample ID	P%	K%	Ca%	Mg%	Mn (ug/g)	Fe (ug/g)	Cu (ug/g)	B (ug/g)	Al (ug/g)	Zn (ug/g)	Na (ug/g)
Left-4A-1m	0.07	0.12	1.37	0.06	1414	339	6	26	330	20	35
Left-4A-10m	0.09	0.11	1.39	0.07	1732	407	8	21	396	26	26
Left-4A-100m	0.06	0.09	0.84	0.09	953	173	9	16	172	57	25
Left-4A-200m	0.08	0.13	1.05	0.11	1631	117	10	22	117	77	24
Right-4A-1m	0.06	0.08	0.93	0.09	1193	1605	7	20	1172	31	24
Right-4A-10m	0.07	0.09	0.94	0.09	1498	545	7	21	422	50	19
Right-4A-100m	0.08	0.10	0.88	0.09	2294	133	6	23	133	26	20
Right-4A-200m	0.10	0.10	0.88	0.07	2350	144	7	19	135	26	19
Left-4B-1m	0.05	0.08	1.22	0.08	1070	538	5	17	618	26	24
Left-4B-10m	0.06	0.10	1.19	0.10	1565	150	5	22	133	30	18
Left-4B-100m	0.04	0.07	0.65	0.06	508	149	7	16	167	67	19
Left-4B-200m	0.04	0.06	0.60	0.06	681	131	8	13	160	53	16
Right-4B-1m	0.07	0.09	0.92	0.08	1291	692	7	17	484	29	20
Right-4B-10m	0.06	0.09	0.81	0.08	1306	253	6	18	282	30	27
Right-4B-100m	0.07	0.09	0.77	0.08	1556	103	5	22	118	22	17
Right-4B-200m	0.08	0.10	0.88	0.07	1829	139	6	19	145	27	19
Left-4C-1m	0.06	0.09	1.58	0.16	1530	65	5	29	69	20	18
Left-4C-10m	0.07	0.11	1.34	0.09	1605	174	8	19	158	34	34
Left-4C-100m	0.05	0.09	0.72	0.09	915	143	5	20	153	41	23
Left-4C-200m	0.07	0.07	0.72	0.07	758	232	10	15	273	55	23
Right-4C-1m	0.07	0.10	1.13	0.09	1538	197	5	26	249	24	21
Right-4C-10m	0.08	0.08	1.18	0.08	1637	819	6	18	972	27	21
Right-4C-100m	0.09	0.12	0.91	0.10	2015	144	8	23	156	27	17
Right-4C-200m	0.08	0.09	0.85	0.08	1722	83	7	21	111	21	20