Soil, defined as "The unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants," (What is Soil?, n.d.) is a non-living component of the environment made up of broken rocks, minerals, living organisms, humus, air, and water and is a vital part of all the earth's ecosystems. The soil provides a habitat for a variety of organisms and controls water flow between the earth and the atmosphere. Although these contributions are very important, the soil's primary role is to secure and hold plant roots, and in doing so, help vegetation (What is Soil?, n.d.). Ecosystems in which soil is not healthy have a lower change of supporting a thriving population of flora and fauna. Soil is also a natural record for human activities. Due to the fact that soil constantly adjusts and adapts to changes within its environment, it can accurately record changes from both the past and the present. Such changes in the soil can be small and reversible while others can be extremely detrimental to soil's health and leave permanent damage. (Why is Soil So Important?, n.d.). Therefore, people must be extremely careful when changing soil, even slightly.

There are certain characteristics, such as levels of phosphorus, calcium, magnesium, and bacteria, that serve as indicators of soil's well being. High levels of these constituents indicate that the soil that is well off and able to support life (Soil Basics - Creating Fertile, Healthy Soil. , 2005). Phosphorus is essential for plant growth, and significant fluxes of this element can be damaging to soil health. Calcium and magnesium are soil nutrients necessary for plant development and overall soil health. Magnesium is essential for several plant functions. Plants rely on magnesium to undergo photosynthesis, to synthesize oils and fats, to synthesize and activate enzymes and to carry phosphorus throughout the plant (Magnesium Basics., (n.d.)). The ideal calcium to magnesium ratios range between 1:5 and 1:8 and a magnesium-deficient soil can be detected by the color of the plants growing in the soil. If the plants growing in a particular soil are a lighter shade of green, this is an indicator of magnesium deficiency in that soil. Darker plants indicate that a magnesium surplus (Sawyer, 2003). Bacteria, on the other hand, are *living* matter crucial in all kinds of soil. Bacteria carry out important chemical reactions that lead to the degradation of organic matter, disease suppression, and nutrient transformation in roots, processes that are all critical to soil health (Soil Bacteria, 2004). All of the above processes, as well as levels of magnesium, calcium and phosphorus, can be negatively affected by conditions like erosion, construction and gas emissions. In this project, we will focus on the effects of building construction on soil's overall health.

Bacteria are also responsible for transforming inorganic constituents from one chemical form to another. Their external digestion system allows some of the metabolites released by extracellular enzymes to be used by other organisms, such as plants. The bacteria get nutrients and energy from these processes and supply other organisms with suitable forms of chemicals that they need for their own processes. Healthy soil is rich in bacteria, and the amount of the bacteria present in soil is dependent on the health of the soil. In addition to these functions, bacteria also play an important role in the nitrogen cycle (Soil Bacteria, 2004).

Nitrogen is present in all living organisms as a building block of amino acids and other important molecules. Although this is true, the textbook Biology: Exploring Life claims that, "Although almost 80 percent of Earth's atmosphere is nitrogen gas (N_2), most producers can only use nitrogen in the form of compounds such as ammonium (NH_4) and nitrate (NO_3)" (2004). Nitrogen goes through a series of conversions in order to be utilized by living organisms. This series of transformations is known as the nitrogen cycle. In the course of the nitrogen cycle, many different elements bind with the nitrogen, creating new compounds. Bacteria found in soil are essential in helping these conversions take place, as they transform nitrogen gas into ammonia (NH_3) throughout a process known as nitrogen fixation. Ammonium (ionized ammonia) is essential because it is the only form of nitrogen that organisms can absorb directly from the environment. Bacteria convert ammonium into nitrates through nitrification. Producers absorb ammonium and nitrates from the soil and are later eaten by consumers. Consumers then receive their nitrogen in the form of organic molecules. When the consumers die, decomposers release nitrogen in the form of ammonium. Following that, a process called dentrification, in which dentrifying bacteria in soil transform nitrates into nitrogen gas and release it back into the atmosphere, takes place. The cycle subsequently repeats itself. Due to the fact that bacteria are crucial elements in the nitrogen cycle and thus support life, greater numbers of soil bacteria indicate soil health (Harrison, 2003).

All living organisms have four characteristics, known as the four properties of life, which distinguish them from non-living things. These distinctions include the ability to reproduce, grow, maintain homeostasis, and transform energy. As a result of construction, the chemical balance in soil is interrupted. This means that the soil is no longer as healthy, and therefore is not able to easily sustain living organisms. In a way, construction disrupts the “homeostasis” of soil, ultimately affecting the organisms the soil supports. The imbalance of chemicals in the soil hinders the living organisms from being able to carry out the four properties of life, which is why organisms in unhealthy soil often begin to die. Healthy soil, on the other hand, is balanced so that it is able to support life, and therefore has a higher level of living organisms. Although soil and construction may not be directly related to the four properties of life, construction’s effects on soil affect the ability for organisms to carry out the four properties, indirectly connecting the two.

As stated before, factors like calcium, magnesium, phosphorus and bacteria can be affected by many different processes. One of these developments, construction, is known to be exceptionally damaging to soil’s well being. Removing native plants from soil, which is usually the first step in many construction processes, can alter millions of years of microbial activity. Construction typically removes up to three feet of native soil and only two to three inches are later replaced (Disturbed Construction Sites and Their Impact On Healthy Ecosystems. , 2009). In addition to these harmful effects, soil is frequently compacted to simplify construction. Soil compaction can be defined as the “method of mechanically increasing the density of soil” (Soil Compaction Handbook., n.d.). This process restricts air and water pockets, hindering the ability of micro and macro-nutrients to survive and prosper. This hindrance causes shallow root growth and low surface water diffusion. In addition, heavy equipment such as tractors, bulldozers, and cranes used during construction can also cause compaction and destroy soil life. It is believed that, “When we build, we disturb. Urbanization and agriculture disturb soils…Ultimately, this disturbance of beneficial soil microbes will affect the quality of the water we drink and the air we breathe” (Disturbed Construction Sites and Their Impact On Healthy Ecosystems. , 2009).

Three years ago, the Roland Park Country School in Baltimore, Maryland began an extensive building project in the hopes of creating a new Athletic Center. The new gym, which was completed in 2008, is a certified “Green Building.” This means that, supposedly, as many eco-friendly products were used in the construction of the Athletic Center as possible. Some of the “green aspects” of this gym include a recycling irrigation system, a rooftop garden and recycled floors. In contrast, there were also several unavoidable aspects of the construction process, which most likely had a very negative impact on the soil. Before beginning the actual building process of the Athletic Center, the construction workers dug several feet into the earth and removed all the organic matter from the soil in order to build the gym. They also had to compact all the soil in the area to build turf fields and assure that the foundation of the Athletic Center would adequately support the edifice. Therefore, with all the widespread knowledge of construction’s negative effects on soil health, we must ask the question: just how “green” was our Athletic Center’s construction?

In order to test whether or not the soil near the gym was affected by the two-year-long construction campaign, we will compare soil near the Athletic Center to soil near the Ward House, which was built over 150 years ago and has not been altered since then. We will have six testing plots: three near the Ward House, and three near the new gym. To measure the overall health of the soil, we will do a series of chemical tests. We will test for calcium, magnesium and phosphorus levels. We will also determine the number of bacteria in the soil. These chemical and bacteria tests will provide insight on levels of health indicators in the soil. In addition, we will test for a negative characteristic – the compaction of the soil. Healthy soil is 50% pores, and these pores allow water and air to circulate throughout the soil and reach plants roots in order to nourish the plants. Compacted soil has a lower presence of pores, and as a result, water travels through the soil with difficulty. We will test compaction by weighing one cubic centimeter of soil from each one of our six plots. The test location with the heavier or denser average soil will be more compact, and therefore, less healthy. By determining the magnesium, calcium, phosphorus and bacteria levels of the soil and measuring its density, we will be able to determine which soil ecosystem is healthier, the one near the Athletic Center or the one near the Ward House.

The outcome of our experiment will be very important not only to the school, but also to the general public. The results of our experiments will determine whether or not the construction of the new Athletic Center, and all construction for that matter, is truly “green” or not. Perhaps, depending on our results, our school will be motivated to change its future construction processes in order to lessen the impact on the environment. In addition, our research could help construction workers further their “green construction”. This movement may be crucial, because with the environment slowly deteriorating, and global warming evidently on the rise, the earth is in danger. It is essential that, as a community, we make an effort to slow down these processes, and possibly reverse some of them, through transition into environmental construction.

I. Procedure:

A. Independent Variable:

The independent variable in this experiment is the presence of construction.

B. Dependant Variable:
The dependent variables are the bacteria, phosphorous, calcium and magnesium levels in the 6 different plots of soil.

C. Control:
The control in this experiment is the plots near the Ward House that have not been constructed on for over 150 years.

D. List of Controlled Variables: The controlled variables in this experiment include how many plots and samples are used, the area where the plots are located, the fact that the plots are on the same sides of the building in the shade, the amounts of water, and vegetation, the slope, and the amount of human traffic by the samples.

E. Hypothesis: Based on our research, we hypothesize that the soil near the gym will be less healthy the soil near the Ward House as a result of the recent construction.

F. Procedures:

1. GPS

1. Go to soil sample area
2. Press the red button to turn on GPS
3. When screen comes up, press enter twice
4. Find satellites; gray bars will come up
5. Wait for 3 black bars to show up
6. Hit "page" button until the screen with numbers comes up
7. Record these numbers as the coordinates of the spot
8. Hold red button to turn off

2. Soi

COORDINATES:

Athletic Center Coordinates: N 39° 21.502' AND W 76° 38.219'

Ward House: N 39° 21.4' AND W 76° 38.187'

Athletic Center Plots **Ward House Plots**

2. Flag the square, by inserting a flag in the soil at each corner of your plots (squares)
3. use soil cylinders 10-15 cm deep
4. Insert the soil cylinder up to the first marked line into one of the plots and turn the soil cylinder clockwise several times
5. Pull the soil cylinder up out of the ground and remove the soil from the cylinder
6. Place the soil in a fresh plastic bag (don’t reuse to avoid contamination)
7. Repeat steps 4-6 two more times for each square plot (three times per plot)
8. Repeat steps 1-7 for each of the plots at each location
9. Make sure to collect all samples on the same day & time
10. Diagram of our plots:

Ward House (Control Plot)

C1	T2	T3

Athletic Center (Test Plot)	T1	T2	T3

3. Bacteria Test

1. Put on goggles and gloves.
2. Use a clean, new transfer pipette to add 10 ml to a 15 ml culture tube. Label the tube “100.”.
3. Use the same pipette to add 9 ml to a second 15 ml culture tube. Label the tube“10-1.”
4. Repeat step 2 three more times to three additional 15 ml culture tubes, only label them “10-2,” “10-3", and “10-4" respectively
5. Place 1 cc of your soil sample into the “100”culture tube.
6. Cap the tube and shake vigorously.
7. Using a new clean pipette, remove 1 ml of the soil/water mixture from the “100” tube and place into the “10-1” tube.
8. Cap and shake vigorously.
9. Using the same pipette in step 5, remove 1 ml of the soil/water mixture from the“10-1” tube and place into the “10-2” tube.
10. Cap and shake vigorously.
11. Using the same pipette in step 5, remove 1 ml of the soil/water mixture from the “10-2” tube and place into the “10-3” tube.
12. Cap and shake vigorously.
13. Using the same pipette in step 5, remove 1 ml of the soil/water mixture from the “10-3” tube and place into the “10-4” tube.
14. You should now have a total of five culture tubes.
15. Plate 100 µl samples from the 4th and 5th tubes (dilutions 10-3 & 10-4) onto their own separate, labeled petri plates containing nutrient agar (NOTE: on your first sample, plate ALL 5 dilutions to determine which two dilution values will give you

the best data; dilutions 10-3 & 10-4 are only the most probable ones).

16. Allow to grow for 48 to 72 hours.

17. Examine each of the plates for individual bacteria colonies and choose the plate with the fewest colonies (but at least 5) to make your estimates of the number of bacteria in the original 1 cc soil sample using the following formula: # Microbes in 1 cc of soil = # Colonies on sheet x 10^2 x $10^{|\text{dilution \# at which these colonies were found}|}$.

18. If there are not individual colonies but still a "lawn" at the 10-4 dilution, repeat the dilution adding a 5th (10-5) & 6th (10-6) dilutions, etc. as necessary until individual colonies are observed.

4. Making a Universal Soil Extract

1. Fill an Extraction Tube (0704) to the 7 mL line with Universal Extracting Solution (5173).
2. Use the plastic sol measure (0819) to add 1 level measures of the soil sample. Cap and shake for one minute.
3. Use a piece of filter paper (0465) and a plastic funnel (0459) to filter the soil suspension into a second extraction tube (0704). (Fold the filter paper in half and then in half again to form a cone which is fitted into the funnel.) The filtrate in the second extraction tube is the general soil extract for use in the 11 individual test procedures listed previously.

5. Phosphorous Test:

1. Put on goggles and gloves.
2. Use a transfer pipette (90364) to fill a "Phosphorous B" Tube (0244) to the mark with the general soil extract.
3. Add 6 drops of Phosphorous Test Reagent #2 (5156). Cap and shake to mix.
4. Add one Phosphorous Reagent #3 Tablet (5157). Cap and shake until dissolved

5. Immediately compare the color chart that develops in the test tube against the Phosphorous Color Chart (1312). Hold the tube about one inch in front of the white surface in the center of the color chart. View the chart and sample under natural light for optimum color comparison. The test result is read in pounds per acre Available Phosphorous.

6. **Magnesium Test:**

   1. Put on goggles and gloves.
   2. Use a transfer pipette (0364) to transfer 10 drops of the general soil extract to one of the larger depressions on a spot plate (0159)
   3. Add 1 drop of Magnesium Test Solution #1 (5140). Stir with a clean rod. A pale yellow color will develop.
   4. Add Manganese-Magnesium Test Solution #2 (5145) one drop at a time with stirring, until the pale yellow color changes to one of the darker shades indicated on the Magnesium Color Chart (1306). About two drops are usually required. Under some conditions, a precipitate will form shortly after Manganese-Magnesium Test Solution #2 has been added. This will not effect the test reading. The test result is expressed in relative values of Magnesium from very low to very high.

7. **Calcium Test:**

   1. Put on goggles and gloves.
   2. Use a transfer pipette (0364) to transfer 5 drops of the general soil extract to a flat bottomed glass turbidity vial (0242)
   3. Add 1 drop of Calcium test Solution (5108). Swirl gently to mix.
   4. Match the milky turbidity of the test sample against the turbidity standards on the Replaceable Calcium Chart (1303). Lay the chart flat under the natural light and hold the turbidity vial one-half inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. The test result is read in parts per million replaceable calcium.

5. If the test sample turbidity corresponds to or exceeds the lightest standard (2800 ppm), repeat the test on a diluted sample. Transfer one drop of the general extract to a clean turbidity vial and add four drops of demineralized water. Then follow Steps 2 and 3 as above. Multiply the test result by 5 to obtain parts per million replaceable calcium.

8. **Soil Compaction:**

   1. Take 1 cm^3 from each of the soil samples
   2. Weigh each sample
   3. Compare weights to see which is more compacted

II. Data and Analysis

Bacteria Test:

Test Sample	# of Bacteria in 10^{-3} plates	# Microbes in 1 cc of soil	Average
C1	9	900,000	2,600,000
C2	58	5,800,000	
C3	11	1,100,000	
T1	7	700,000	1,033,333.333
T2	22	2,200,000	
T3	2	200,000	

Phosphorous Test:

Test Sample	Phosphorous Level (lbs/acre)	Average
C1	150	150
C2	150	
C3	150	
T1	75	108.333
T2	150	
T3	100	

Calcium Test:

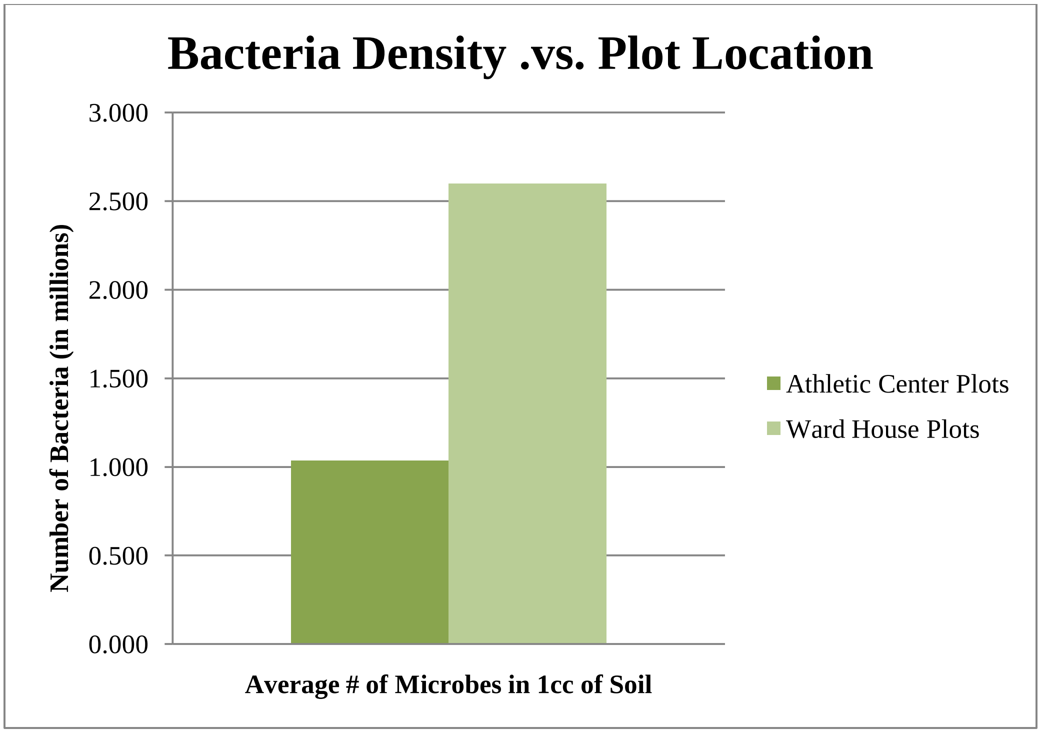
Test Sample	Calcium Level	Parts per mill. Replaceable Calcium	Average
C1	1400	7,000	9,333.333
C2	1400	7,000	
C3	2800	14,000	
T1	1000	5,000	6,333.333
T2	1400	7,000	
T3	1400	7,000	

Soil Compaction:

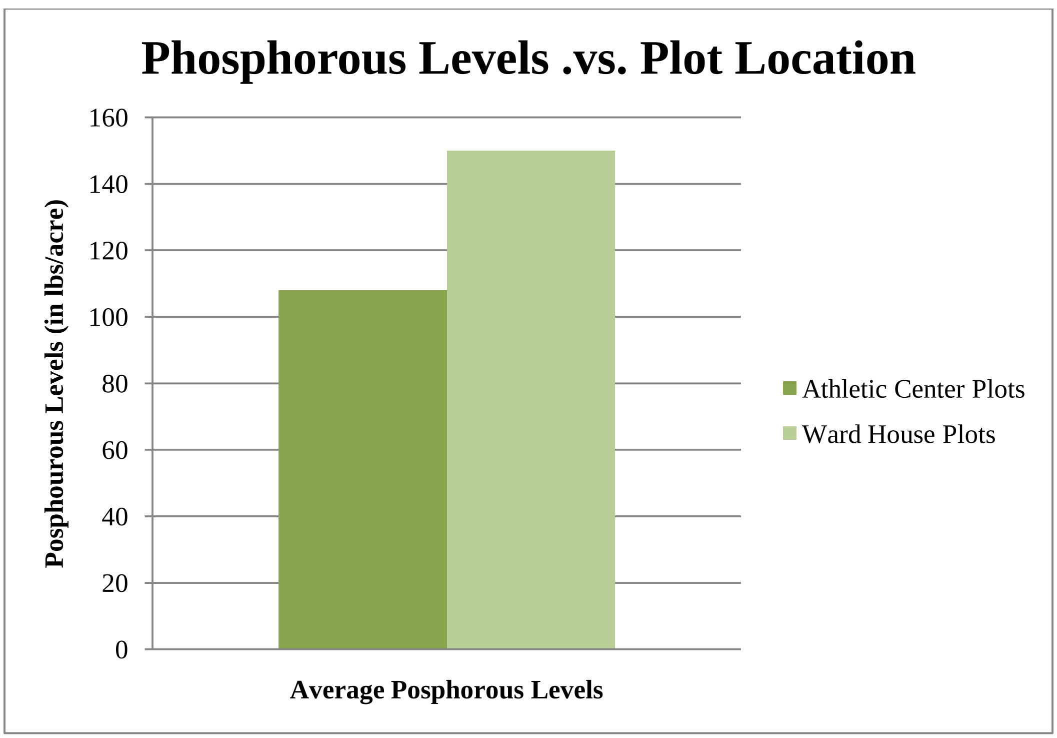
Test Sample	Compaction (in oz)	Average
C1	0.0545 oz	0.0527 oz
C2	0.0485 oz	
C3	0.0550 oz	
T1	0.0595 oz	0.0617 oz
T2	0.0565 oz	
T3	0.0600 oz	

III. Graphs

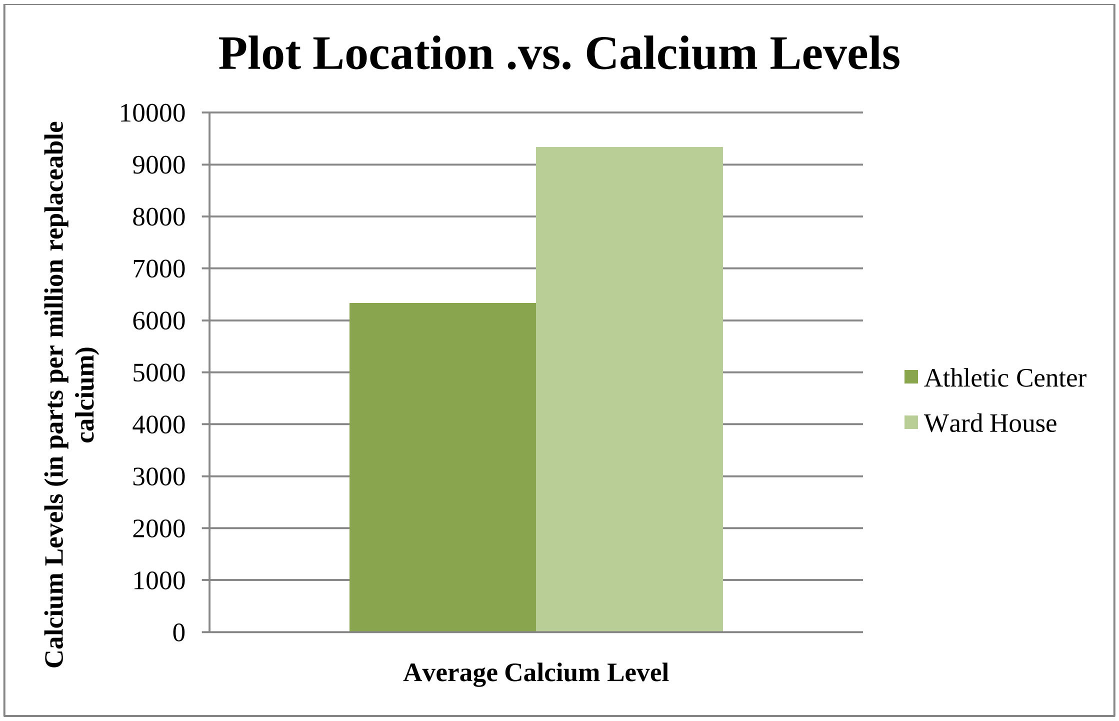
Bacteria:



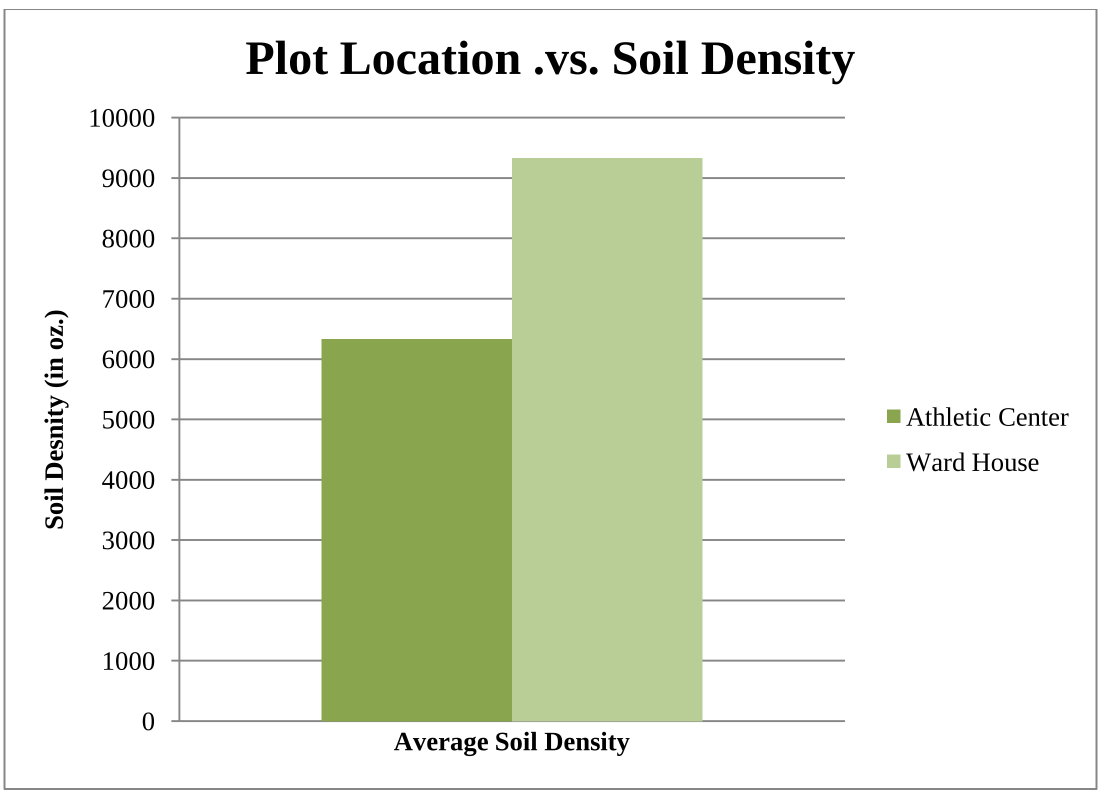
Phosphorous:



Calcium:



Soil Compaction:



Magnesium test:

Test Sample	**Magnesium Level**
C1	Low
C2	Medium
C3	Very low
T1	Low
T2	Very low
T3	Very low

As seen in the chart, the control plots (the plots from the Ward House), had an overall higher level of Magnesium than the test plots had (the plots near the Athletic Center). This shows that the soil near the Ward House is healthier than the soil near the Athletic Center, based on the magnesium levels.

IV. Conclusion

Our hypothesis was supported through the findings of our experiment. The data we collected confirmed our original belief that the soil near the Ward House is healthier than the soil near the Athletic Center. Various tests proved that the Ward House soil had higher levels of magnesium, calcium, phosphorous and bacteria than those found in the soil near the Athletic Center. Since high levels of all these constituents indicate a healthy soil, we concluded that the soil near the Ward House is indeed healthier than that near the new gym. In addition to soil constituents, we also tested for soil compaction, a factor that is also important to soil health. We found that the soil near the Athletic Center is more compact than the soil near the Ward House, which is most likely a direct result of the construction associated with the new Athletic Center. Therefore, all of the tests supported the fact that the soil by the Ward house is healthier than the soil by the Athletic Complex.

The Roland Park Country School prides itself for being a "Green School." The school strives to be environmentally friendly in many aspects such as composting, recycling, and maintaining an all-natural ecosystem in the backwoods. The gym's construction process was intended to be as eco-friendly as possible, and the school made an admirable effort to make as small an impact on the environment as possible. Despite efforts to leave the environment unharmed, the construction has proven to have had a more adverse effect on the environment than previously thought. Because levels of magnesium, calcium, phosphorus and bacteria in the soil near the Athletic Center are relatively low, this soil is less capable of supporting and producing vegetation (What is Soil?, n.d.). This inability to help shrubbery may cause the school to use additional fertilizers and other non-natural stimulants, which are often harmful to the environment, to help the growth of plants near the gym (Specht, 2001). These negative aspects show that the "ecological" construction was not as ecological as it could have been.

Our experiments not only bring to question how worthy Roland Park is of its "green" status, but also provide the school with crucial information concerning the negative effects of various building campaigns on the campus. Many parts of the school have undergone construction in the last ten years, including a ten-million dollar building campaign in 2001 and the construction of brand new tennis courts in 2005. Based on our research on the gym's soil, it is reasonable to assume that these other construction projects negatively affected the soil in a way similar to the construction of the gym. Testing these areas can teach us just how much damage these building campaigns have caused the soil on the RPCS campus. Researchers state that soil health after construction can be restored to 44% of its original state after 10 years (SpringerLink, 2008). Taking this into consideration, it will take approximately 23 years before RPCS has fully recovered from the gym's construction. If other building campaigns take place in the upcoming years, the date for soil restoration may be pushed back even further.

In conclusion, our hypothesis was supported by our experiments. The information we gathered shows that even though Roland Park created buildings with the best of intentions, and in the most eco-friendly way thought possible, there was still a negative effect on the environment. Even our best efforts cannot prevent all the negative environmental effects of our actions, and it is very difficult to be truly green.

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