

University of Tennessee, Knoxville

Senior Design Project

for Chancellor's Honors Program

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Part I

Overview

For my senior design project, my group and I were tasked with designing a sidewalk network in a low income neighborhood in the City of Cleveland, Tennessee as part of the University of Tennessee Smart Community Initiative program. The objective of the project was to evaluate existing neighborhood conditions, suggest alternative routes to connect the Family Support Center to the Blythe-Bower Elementary School, suggest neighborhood connector options for the neighborhood, compare the different alternative routes and options through a comparative analysis, select a route and neighborhood connector option, and to design the chosen route and connector option while addressing drainage issues in the area.

For this project, I have performed a site subsurface investigation to obtain soil samples. I tested the soil samples and determined the soil parameters were obtained through the following tests: unconfined compression, Atterberg's limits, unit weight, and water content. To satisfy my honors thesis requirement, I am serving as the technical editor for the project report. As the technical editor, I have compiled separate reports from different team members into a single report, restructured the report into a cohesive technical document, made grammatical corrections, and addressed revision comments to the content to create an in-depth and conclusive technical report. With the guidance of Dr. Jennifer Retherford, I have revised the group's report to develop a more thorough document than required for typical course documents.

Part II



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Final Report

Cleveland Sidewalk Studies

Plan for Blythe Avenue Area Sidewalk

Extension to 20th Street SE

And

Plan for Neighborhood Connector Sidewalks

to Wildwood Avenue

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1.0 Introduction

Southeast of downtown Cleveland exists a low income neighborhood enclosed by Blythe Avenue, Wildwood Avenue, 9th Street SE, and 20th Street SE. Figure 1, below, depicts the location of the neighborhood of interest and indicates the streets that border the neighborhood.



Figure 1 Neighborhood of interest in Cleveland, TN

Currently, the neighborhood has scattered sidewalks that exist throughout the neighborhood but the sidewalks lack connectivity. The neighborhood lacks proper sidewalks and safe routes to places such as schools, churches, and local businesses.

Recently, the city of Cleveland submitted sidewalk proposals to the Tennessee Department of Transportation (TDOT) Multi-modal Access grant program in order to receive funding for sidewalks. A sidewalk route, coupled with renovations of older sidewalks that lack curbs, will create a safe north-south pedestrian access route that will connect the Family Support Center to the Blythe-Bower Elementary School and lead to a pedestrian-friendly neighborhood. In the past, existing infrastructure has complicated implementation of such a route. Therefore, neighborhood issues, such as narrow right of way and damaged infrastructures, must be addressed in developing this route.

Neighborhood connector sidewalks will be placed in the neighborhood to create a more pedestrian friendly perimeter and connect the neighborhood to school, employment, and shopping centers along Wildwood Ave and Dalton Pike. The neighborhood sidewalk connectors will have to coordinate with existing and planned bus routes, stops, and shelters to maximize pedestrian access to bus routes.

The objective of this project is to create alternative pedestrian routes for the Blythe Avenue Sidewalk extension which mitigate impact on existing infrastructures and drainage. The design team will evaluate potential routes through a comparative analysis and choose the most effective and economical route to ultimately develop. This project will also require analysis of alternative neighborhood connectors. Analysis will include evaluation of the neighborhood connectors through a comparative analysis, which will serve as a decision making tool to review preferred neighborhood connector sidewalk routes based on user need, number of users, and connections to key network elements.

The amount of work to develop a sidewalk extension from Blythe Avenue to 20th Street SE and neighborhood connector sidewalks to Wildwood Avenue and Dalton Pike should be sufficient to establish National Environmental Policy Act (NEPA) “purpose and need” if future federal funding is required.

Ideally, this report will help support efforts to acquire this funding.

2.0 Site Investigation

The exiting site is enclosed by Blythe Ave SE on the west, 20th Street SE on the south, Wildwood Ave and Dalton Pike on the east, and 9th Street SE on the north, as shown below in Figure 1.



Figure 2 Site boundaries for neighborhood of interest.

The Family Support Center and Blythe-Bower Elementary School are important destinations within this site and are highlighted in Figure 2. The existing site is a low income neighborhood with the following type of infrastructures: factories, single family dwellings, churches, an elementary school, and small businesses. The neighborhood also has a retention pond that is enclosed by a fence to keep civilians off the property. Depicted below in Figure 3 are the general types of infrastructures in the neighborhood and the surrounding areas.

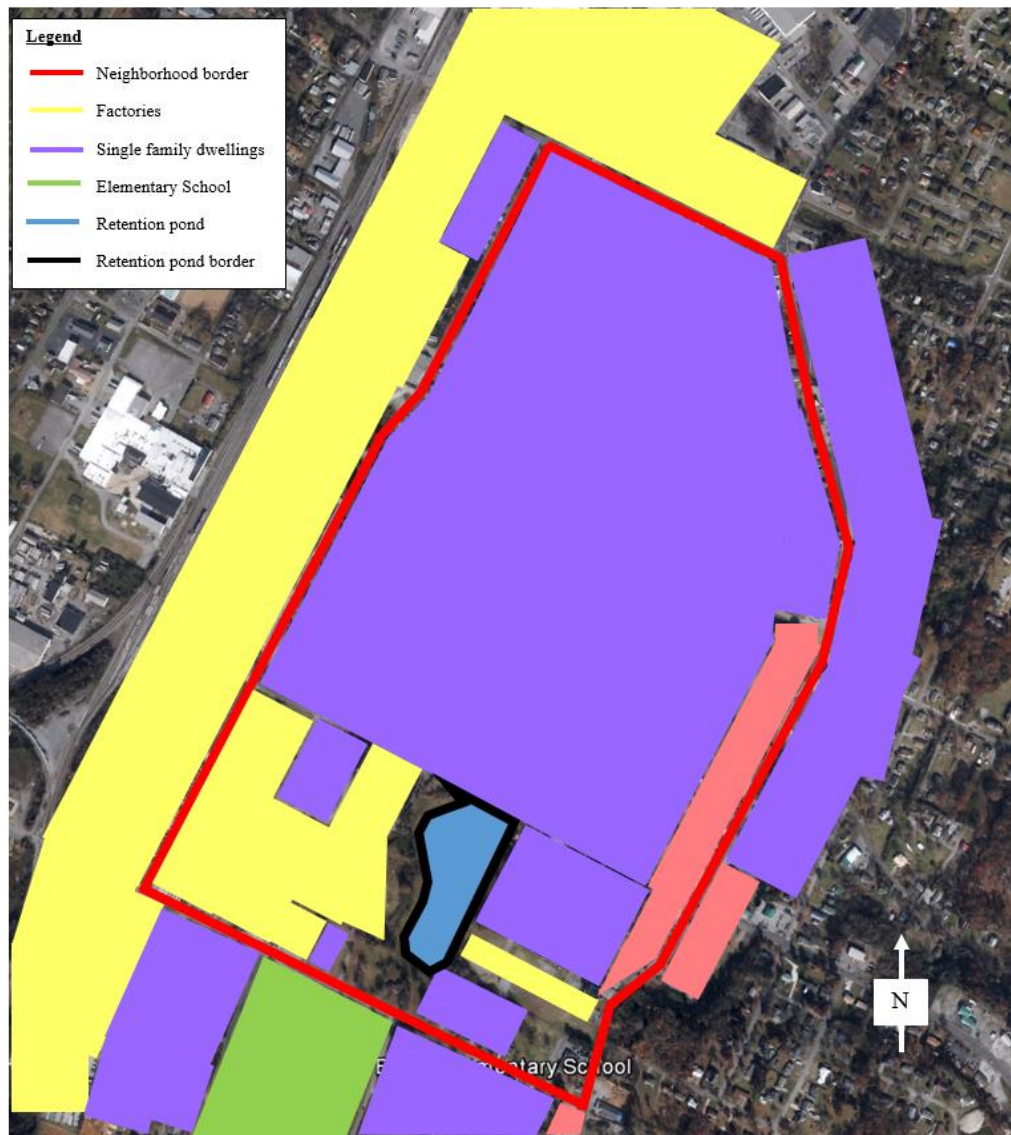


Figure 3 General types of infrastructures in the neighborhood and the surrounding areas

Overall, the site is a residential area bordered by small businesses, warehouses, and an elementary school.

The following sections examine the different alternative routes from the Family Support Center to the Blythe-Bower Elementary School and any observed potential conflicts for the routes based on current site conditions.

3.0 Blythe Avenue Area Sidewalk Extension

Based on a preliminary investigation of the site and information from the “CE 595 Sustainable Transportation SCI Project –Final Report”, the following four routes were purposed as alternatives for connecting the Family Support Center to the Blythe-Bower Elementary School [1]. It should be noted that all four routes will connect the Family Support Center, by way of Blythe Avenue, to 18th Street SE. Currently, sidewalk infrastructure exists on Blythe Avenue from the Family Support Center to 13th Street SE. Due to the poor conditions of the existing infrastructure, recommendations will be proposed and incorporated into the project analysis for the sidewalk extension.

Three alternate routes have been evaluated as potential sidewalk extensions for the area. These routes were selected as the most viable as analyzed by the “CE 595” engineering team. The evaluation is finalized in this project. A description of the routes is included in this section. Analysis and selection of the preferred route is presented in section 5.0 of this report.

3.1 Blythe Avenue Route

This proposed route will start at the Family Support Center and continue along Blythe Avenue until 20th Street SE. At the intersection of Blythe Avenue and 20th Street SE, the route will veer left onto 20th Street SE. On 20th Street SE, the route will continue adjacent to Blythe-Bower Elementary School. Figure 4 shows the proposed route.

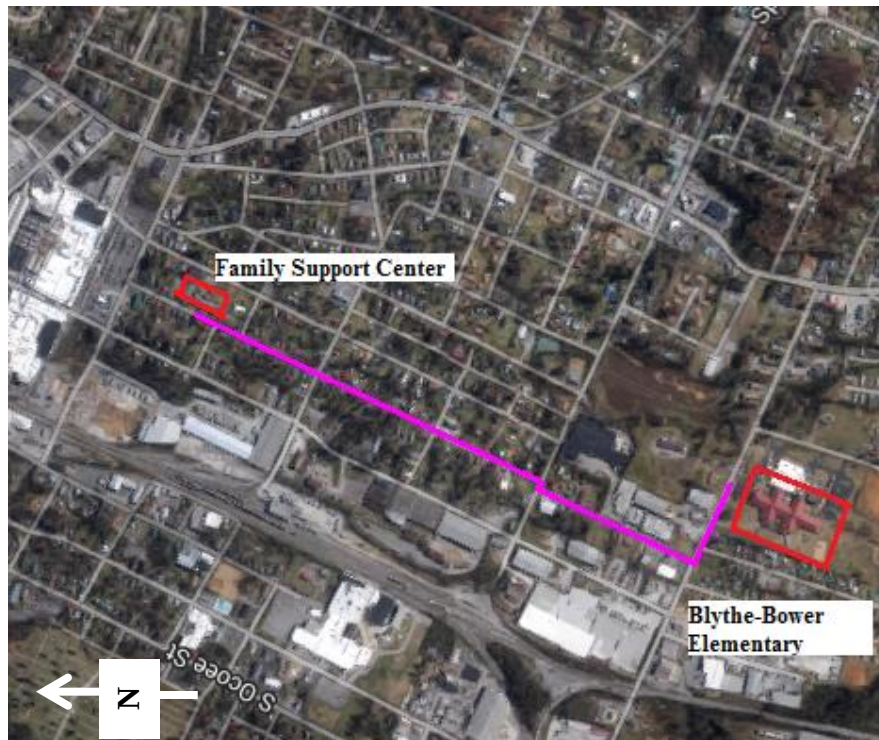


Figure 4 Blythe Avenue Route

Currently, there exist sidewalks on the east side of Blythe Ave in front of the Family Support Center that continues to 13th Street SE and the north side of 20th street between Blythe Avenue and Dalton Pike. Sidewalks will be installed along Blythe Avenue from 13th Street SE to 20th Street SE to connect the existing sidewalks on Blythe Avenue and 20th Street SE for the proposed route.

3.2 Dalton Pike Route

This proposed route will start at the Family Support Center and continue along Blythe Avenue until 18th Street SE. At the intersection of Blythe Avenue and 18th Street SE, the route will veer left onto 18th Street SE and continue until Dalton Pike. At the intersection of Dalton Pike and 18th Street SE, the route will veer right onto Dalton Pike and continue until 20th Street SE. On 20th Street SE, the route will continue adjacent to Blythe-Bower Elementary School. Figure 5 shows the proposed route.



Figure 5 Dalton Pike Route

For this route, sidewalks will be installed along Blythe Avenue from 13th Street SE to 18th Street SE and on 18th Street. Sidewalks currently exist on Dalton Pike and 20th Street for the proposed route. Sidewalks exist on Blythe Avenue from the Family Support Center to 13th Street and will be renovated as needed.

3.3 Greenway Route

The greenway route includes two proposed greenway options that circumvent the fenced retention pond, as shown in Figure 6.



Figure 6 Greenway routes with Option 1 in green and Option 2 in blue

This route will begin at the Family Support Center where a sidewalk on the east side of the road will continue down to 18th street. On 18th street, the sidewalk will veer right and continue on the southwest side of the road and connect to a greenway. Both greenways will connect perpendicular to the 18th and 20th Street SE. Figure 6a portrays a detailed view of the two options around the retention pond.



Figure 6a Greenway Routes through retention pond

It is important to note that the greenway paths are located outside of the retention pond in order to prevent the paths from flooding and for safety reasons, such as pedestrians slipping and falling into the retention pond. There are no current plans to modify the retention pond infrastructure to install a greenway path as the cost of such a project is likely prohibitive.

3.3.1 Greenway Option 1

The first proposed greenway option will veer right off 18th Street SE into an area with a small parking lot adjacent to Aurora Street, shown below in Figure 7.



Figure 7 Asphalt paved area at proposed Greenway Option 1 near 18th St SE

The route will continue adjacent to the west side of the fenced retention pond, as illustrated above in Figure 6a. Small businesses and warehouses will be adjacent to the east side of the route. There exist approximately 25 feet, or more, of soil between the fence and existing infrastructure that can be developed into a pedestrian route. A short path currently exists within this space, evidence that pedestrians are likely already traversing this route. Although there is space on this route to construct a greenway, there also exist steep slope and over-grown shrubs that must be addressed, as illustrated in Figure 8.



Figure 8 Over-grown shrubs on pathway

The area must be cleared in order to evaluate the slope of the hill between the business and fence and to create a passable greenway route. Based on visual inspection from the edges of the pathway, the slope of the hill varies along the path and can potential cause conflicts in the pathway. Existing conditions of the site are currently difficult to assess. Further investigation is needed to determine accurate slopes throughout the path to determine potential conflicts. For this project, estimations will be made pertaining to the slope in the area from GIS contour files, provided by the City of Cleveland.

Presently, greenway route option 1 is the preferred option based on the city of Cleveland's intent to develop an extended greenway to serve as a pedestrian highway that would connect centers of activity to outlying neighborhoods. Developing a section of greenway and connecting it to sidewalks in the Blythe Avenue neighborhood would extend this goal into a lower income section of Cleveland and connect the neighborhood with the rest of the city, while also adding an aesthetic community feature.

3.3.1.1 Route 1 Slope Conflicts

Steep inclines border the greenway on the east and west side. The slopes on the east side of the greenway will not cause safety issues because they are blocked by a fence. The slopes on the west side of the greenway may cause safety unless slope stability analyses verify the site as suitable for new loading conditions. Construction issues may arise due to the steep inclines from both sides.

The distance between the top of the incline and the fence is approximately 7 feet. The average width of space for greenway route option 1 is approximately 30 feet, with some areas requiring shorter widths than others. As a result, the fence will have to be removed at some areas for construction purposes. For construction and safety purposes, the fence should be moved to be perpendicular to the top of the sloped sides of the retention pond.

Figure 9 illustrates the steep inclines that border the retention pond on the lower side of the greenway.



Figure 9 Steep inclines between the fence and bottom of retention pond

A slope stability analysis, as well as grading efforts, during construction is necessary; however, current plant over-growth prohibits adequate access to the site to perform these tasks.

3.3.2 Greenway Option 2

The second proposed greenway option will veer right off 18th Street SE and span along the outside of the east side of the fenced retention pond, as shown above in Figure 10.



Figure 10 Greenway routes with Option 2

The area between the retention pond fence and the adjacent structures (single family homes) is approximately five feet, which is a very limited space that can be used for development. In order to construct a pathway along the east side of the fence, property will need to be acquired and demolished. The process of acquiring land for this greenway path will be costly. As a result, this route is not suitable for a greenway.

3.4 Observed Potential Conflicts

In order to objectively evaluate each greenway option, a variety of qualitative and quantitative metrics must be defined and assessed. These metrics attempt to quantify the impact of site conflicts that exist for each route. Observed potential conflicts at the existing site that will need to be addressed during the design process and those conflicts that will be used in the comparative analysis of the routes, include: sight distance, location of existing crosswalk, small lots, houses near the street, street signage, and curb design.

3.4.1 Small lots and Houses Near the Street

Currently, the east side of Blythe Avenue has an existing sidewalk that is in poor conditions and needs to be reconstructed and widened approximately one foot. Figure 11 shows the location of the sidewalk on Blythe Avenue while Figure 12 and 12a show the conditions of the sidewalk.



Figure 11 Sidewalk widening and improvement



Figure 12 Cracks occurring on existing sidewalks on Blythe Avenue



Figure 12a Close up of the cracks occurring on existing sidewalks on Blythe

As seen in Figure 12, portions of the existing sidewalks are cracked because the sidewalks were constructed atop a tree root. Figure 12a exhibits a detailed picture of the cracks of the sidewalks that is adjacent to the tree and surrounds a water utility box. As highlighted in both figures, the cracks that are occurring on the sidewalks are extremely severe and are creating indentions in the sidewalks, causing it to be a trip hazard for pedestrians. The sidewalks lack a curb which is

recommended infrastructure for roadways. Curbs are important because they serve the following purposes: drainage control, roadway edge delineation, and right-of-way reduction. Vertical curbs are desirable for sidewalks located in urban areas because it discourages vehicles from driving close to sidewalks, thus reducing the risk to a person walking on the sidewalk. Overall, the sidewalks will have to be renovated.

The State of Tennessee has a 50 foot right of way (ROW) that can be utilized for roadways and sidewalks. During a site visit, it was determined on visual inspection that many residents' properties are encroaching on the State's 50 foot ROW. Further research will need to be conducted to verify where the residential property lines and the State's ROW conflicts. If it is verified that resident's properties encroach on the State's ROW, the State can legally use the properties for sidewalks.

Further investigation will be needed to determine the location of existing utility lines which also appear to conflict with preferred sidewalk locations. Utility lines will be relocated if they obstruct the construction of the sidewalks.

3.4.2 Pedestrian-related Street Signs

Due to high pedestrian traffic at the intersections, pedestrian safety will need to be addressed for all proposed routes. Crosswalks will be incorporated into the design of the sidewalks as necessary to address pedestrian safety. Specifically, 18th Street SE has been observed as a location that will require new infrastructure to improve visibility of pedestrian crossing. Crosswalk lines will be white with a minimum line width of 8 inches and a minimum crosswalk width of 6 feet [2].

Stop lines or yield lines are commonly used to address pedestrian safety at crosswalks. A stop line will typically be 12 to 24 inches wide [3]. The individual triangles that comprise a yield line have a base of 12 to 24 inches wide and a height equal to 1.5 times the based [2][3]. The space between the triangles is recommended to be 3 to 12 inches [2, 3]. Figure 13 illustrates recommended yield line layouts.

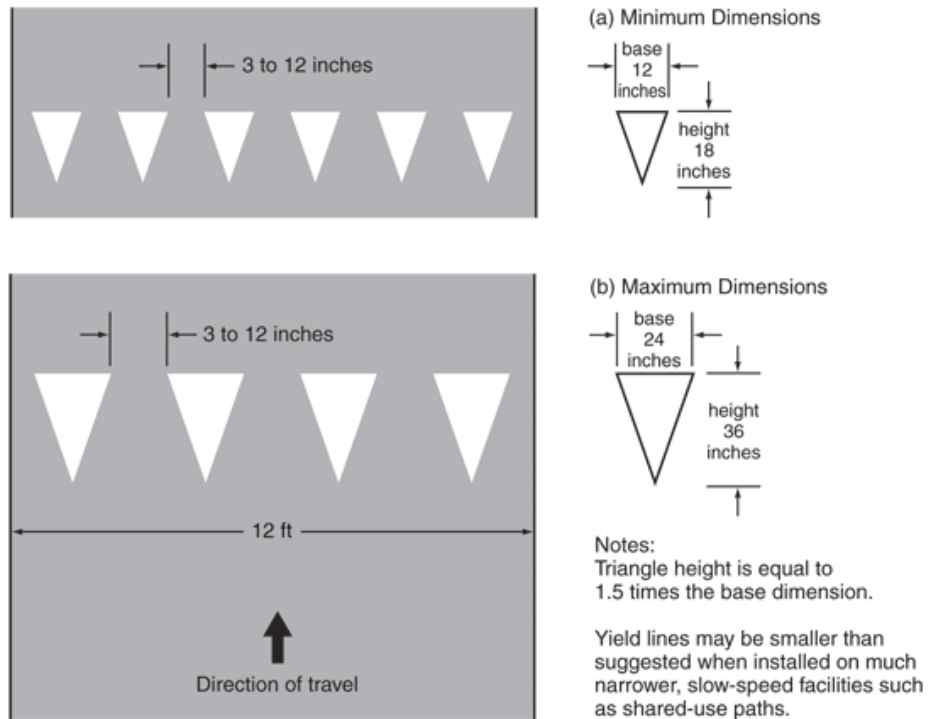


Figure 13 Recommended yield line layouts

Vehicles that are approaching a crosswalk require an appropriate amount of time to react to pedestrian crossing. Crosswalk signs are necessary to allow sufficient reaction time for drivers. Figure 14 portrays unsignalized pedestrian crosswalk signs that are often placed at crosswalks to improve general safety.

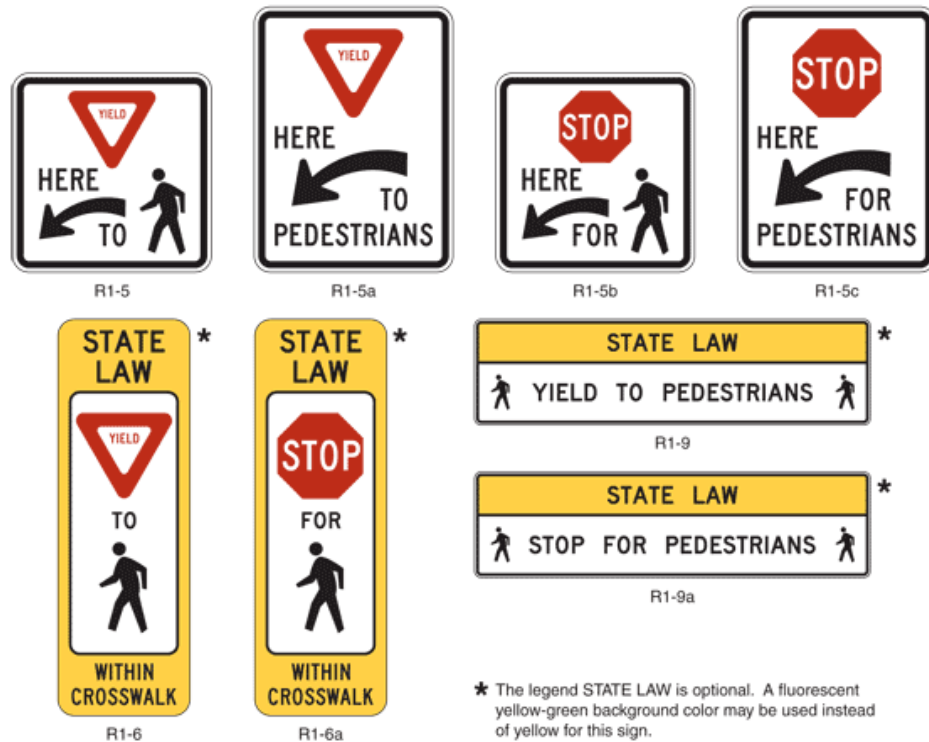


Figure 14 Unsignalized pedestrian crosswalk signs

Figure 14 portrays the types of unsignalized yield crosswalk signs that can be placed at yield lines. The types of unsignalized stop crosswalk signs that can be placed at stop lines are also depicted.

For an uncontrolled multi-lane approach road, the stop or yield line shall be placed 20 to 50 feet in advance of the nearest crosswalk line [3]. Figure 15 illustrates an example of yield lines at unsignalized midblock crosswalks for two-way roadways.

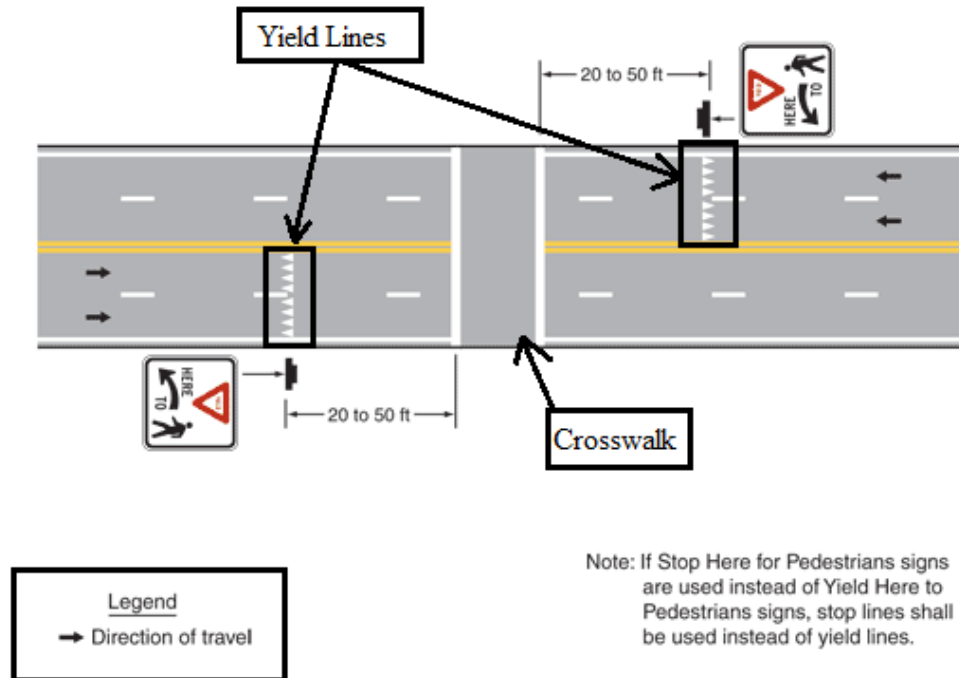


Figure 15 Yield lines at unsignalized midblock crosswalks

Figure 15 depicts a crosswalk as two parallel, solid lines that cross all approaching lines. On both sides of a crosswalk, a “Yield to pedestrians” sign is shown adjacent to the right side of the roadway in advance of the crosswalk. On both sides of the crosswalk, a yield line, placed 20 to 50 feet in advance of the crosswalk, is shown across the approach lanes.

3.4.3 Drainage

Retrofitting sidewalks into the Blythe Ave neighborhood will increase the amount of stormwater runoff if not handled appropriately. Using stormwater control measures (SCMs) onsite will prevent the sidewalks from causing drainage issues. Due to limited space, permeable pavements or bioretention cells are the most attractive options to improve stormwater runoff conditions.

4.0 Neighborhood Connector Sidewalks to Wildwood Avenue and Dalton Pike

Based on a preliminary site investigation, the following two neighborhood connector options were proposed. Both options seek to provide connectivity between the residential and commercial destinations throughout the neighborhood.

4.1 Neighborhood Connector Option A

Sidewalks for connector Option A are recommended as shown in Figure 16 along the following streets: 9th Street SE, 12th Street S, Winnetawaka Avenue, Wilson Avenue, 13th Street SE, 14th Street SE, Aurora Avenue, 15th Street SE, 18th Street SE, 16th Street SE, 11th Street SE, and Blythe Avenue. The streets for neighborhood connector option A were chosen based on street width and accessibility to factories, businesses, and churches.



Figure 16 Neighborhood connector option A

4.2 Neighborhood Connector Option B

Connector Option B, shown in Figure 17 requires construction of sidewalks along the following streets: 9th Street SE, 12th Street S, Hardwick Avenue, Wilson Avenue, 13th Street SE, 14th Street SE, Aurora Avenue, 15th Street SE, 18th Street SE, and Blythe Avenue. The streets for neighborhood connector option B were chosen based on accessibility to businesses and churches, easement, and the quantity of single family dwellings that surround the streets



Figure 17 Neighborhood connector option B

5.0 Comparative Analysis

A comparative analysis was performed to determine the advantages and disadvantages of each route and neighborhood connector. Each alternative was evaluated based on connected node ratio, link-node ratio, percentage 4-way intersections, pedestrian route directness, effective walk area, stopping sight distance, number of crosswalks per route, ROW conflicts, cost, and total distance. The comparative analysis matrix will be used to evaluate the best school route alternative and neighborhood connector alternative. The following sections explain the metrics and methods for each component of the analysis. The comparative analysis performed on the network alternatives was used to develop the most effective network for the neighborhood. Sample calculations and are provided in the appendix for each metric.

The following sections describe the fundamental parameters and definitions for each metric and summarize assumptions utilized during the comparative matrix analysis.

5.1 Connected Node Ratio

Connected node ratio (CNR) is a measure of network connectivity. The analysis required division of the neighborhood into five zones to simplify the analysis. The following lists the division of neighborhood and proposed route options into the five zones:

1. Bound by SE King Edward Ave, 9th Street SE, Chippewa Ave SE, and 13th Street (Top left)
2. Bound by 9th Street SE, Wildwood Ave SE, 15th St SE, Wiggins St SE, and 13th St SE (Top right)
3. Bound by SE King Edward Ave, 13th Street SE, Aurora Ave SE, and 18th Street SE (Center left)
4. Bound by Aurora Ave SE, 13th St SE, Wiggins St SE, 15th St SE, Wildwood Ave SE, and 18th St SE (Center right)
5. Bound by SE King Edward Ave, 18th Ave SE, Wildwood Ave SE, and 20th St SE (Bottom)

Figure 18 illustrates the five zones.



Figure 18 Neighborhood zones

The combinations of sidewalk routes that were considered for a comparative analysis are shown below in Figures 19 through 24.



Figure 19 Blythe Ave School Connector Route and Neighborhood Connectors Option A



Figure 20 Blythe Ave School Connector Route and Neighborhood Connectors Option B

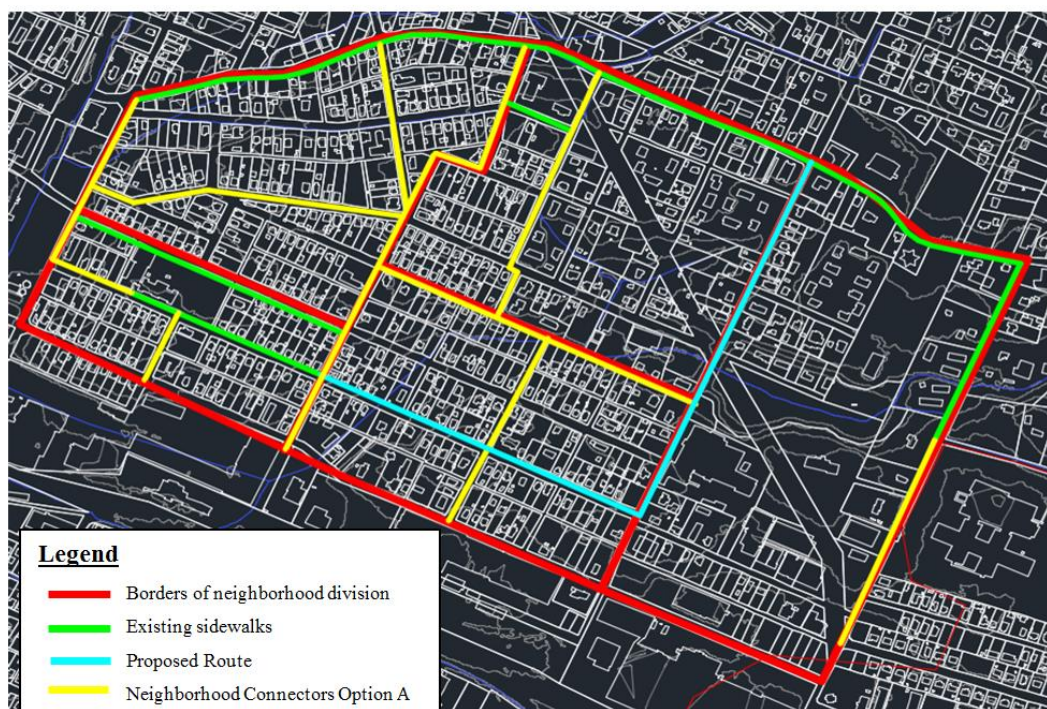


Figure 21 Wildwood Ave School Connector Route and Neighborhood Connectors Option A



Figure 22 Wildwood Ave School Connector Route and Neighborhood Connectors Option B



Figure 23 Greenway School Connector Route and Neighborhood Connectors Option A

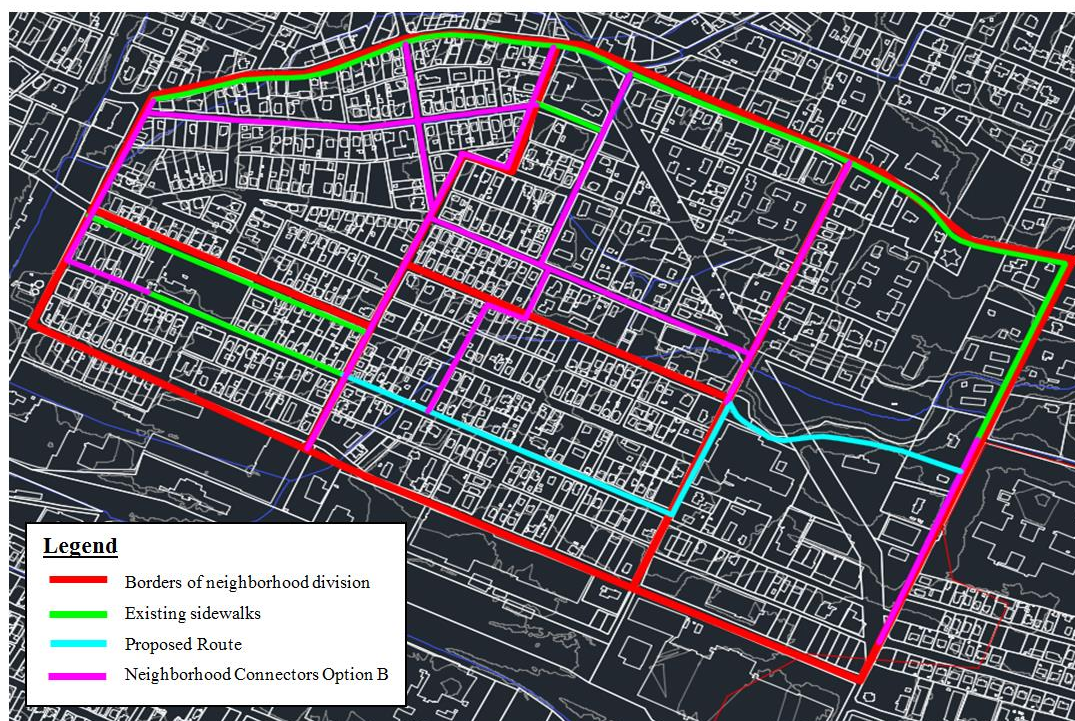


Figure 24 Greenway School Connector Route and Neighborhood Connectors Option B

For each neighborhood division and for the total neighborhood, the number of cul-de-sacs and intersections were counted and used to calculate the CNR. A cul-de-sac is where a sidewalk link terminates with a dead end. An intersection is where two or more sidewalk links intersect. The CNR was then calculated for each as follows:

$$\text{Connected Node Ratio} = \frac{\text{Number of street intersections}}{\text{Number of intersections} + \text{Number of cul-de-sacs}} \quad (1)$$

The tabulation of cul-de-sac, intersection, and CNR data are shown for each route option in Tables 14, 15, and 16 in the Appendix A. Sample calculations for the CNR is provided in Appendix A.

CNR values of 0.7 are preferred for sidewalk networks [4]. All the route options achieved and exceeded this threshold. The route options did not vary significantly within the neighborhood divisions. For the whole neighborhood, the Blythe Ave school connector route coupled with the neighborhood connector option B yielded the highest CNR.

5.2 Link-Node Ratio

The link-node ratio (LNR) is a measure of network connectivity. Links are defined by the Tennessee Road Builder (TRB) as segments of sidewalk connecting nodes. Nodes are defined as intersections or cul-de-sacs. To simplify the process, the neighborhood was divided into five zones. The number of links and nodes was counted for each neighborhood division and for the total neighborhood. The LNR was then calculated for each as follows:

$$\text{Link Node Ratio} = \frac{\text{Number of links}}{\text{Number of nodes}} \quad (2)$$

The tabulation of link, node, and LNR data is shown for each route option in Tables 14, 15, and 16 in Appendix A. Sample calculations are the LNR is provided in Appendix A.

A link-node ratio of 1.4 is recommended as a goal for sidewalk network connectivity [4]. The LNRs for the two route options did not vary significantly within the neighborhood divisions. For the whole neighborhood, the Blythe Ave school connector route coupled with the neighborhood connector option B yielded the highest LNR in the 1.4 range.

5.3 Percentage Four-Way Intersection

The percentage 4-way intersection is a measure of network connectivity. This method determines the percentage of 4-way intersections based on the total number of intersections on a route. The total number of intersections and the number of 4-way intersections was counted for the whole neighborhood. The number of 4-way intersections is divided by total number of intersections to yield a percentage of 4-way intersections per route. The percentage of 4-way intersections does not yield relevant data for comparison when calculated on the neighborhood zone scale.

Based on this analysis, all the route option combinations yielded fairly low 4-way intersection percentages due to a lack of uniform grid layout in the neighborhood. Option B yielded a significantly higher 4-way intersection percentages than option A. The Blythe Ave school route with neighborhood connector option B yielded the highest percentage of any option combination.

5.4 Pedestrian Route Analysis

Pedestrian route directness is a measure of how effectively a proposed route travels from point A to point B. The route distance is measured against the straight line distance from A to B, creating a ratio of route distance to straight line distance from A to B. The closer the value of the ratio is to 1, the more efficient the route.

The route and straight line distances were found by plotting the routes along a scaled map. The route distances were then measured and scaled to their true distances. For the

Greenway route, the distance was measured with several connected straight line segments simulating the curve. The route distance was then placed over the straight line distance to find pedestrian route directness. The pedestrian route directness was then calculated for each route as followed:

$$\text{Pedestrian Route Directness} = \frac{\text{Route Distance}}{\text{Straight Line Distance}} \quad (3)$$

Sample calculations for pedestrian route directness are provided in Appendix B.

The straight line distance between the starting point at Blythe-Bower Elementary School and the ending point at the intersection of Blythe Avenue and 9th Street SE is 0.852 miles. Both the proposed Blythe Avenue and Greenway routes measured approximately a mile while the Dalton Pike route was approximately 1.3 miles. Table 1 displays the results of the pedestrian route directness for the different alternative routes.

Primary Route	Route Distance (mile)	Straight Line Distance (mile)	Pedestrian Route Directness
Blythe Avenue	1.004	0.852	1.178
Greenway	0.963	0.852	1.130
Wildwood	1.312	0.852	1.539

Table 1 Pedestrian Route Directness for Route Alternatives

The American Association of State Highway and Transportation Officials (AASHTO) Green Book states that pedestrians are unwilling to walk more than 1 mile to reach their final destination [5]. Based on the AASHTO standard, the Wildwood Ave route does not satisfy pedestrian needs. Based on the AASHTO standard, the Blythe Ave and Greenway route does satisfy pedestrian needs. Between these two options, the Greenway has a slight advantage. Although, neither option should be discounted solely on account of pedestrian route directness based on the closeness of the observed results.

5.5 Effective Walk Area

Effective walk area (EWA) is the ratio of the number of parcels within a one-quarter mile walking distance of a node to the total number of parcels within a one-quarter mile radius of that node. Values for EWA range between 0 and 1. A higher value is desirable as it shows more parcels are within walking distance of the node, reflecting a more connected network. Effective walk area was determined for the various nodes in the interest area for two different connector plans, summarized in Tables 17 and 18 in the Appendix C. The EWA was then calculated for each route as followed:

$$\text{Effective Walk Area (EWA)} = \frac{\text{Accesible Parcels}}{\text{Total Parcels}} \quad (4)$$

Sample calculations for effective walk area are provided in Appendix C.

To measure effective walk area, the nodes affecting the areas of interest for neighborhood connector options A and B were identified. These chosen nodes are found in Tables 8 and 9 in Appendix C. The nodes along the primary Blythe Avenue route were given priority as they were assumed as the primary area of interest. The reason for this assumption is due to the large number of nodes identified. A quarter mile radius circle was then placed over each node and the number of parcels falling within that radius was counted. This number was held constant between the two neighborhood connector options. From each node, the number of parcels that could be accessed from the proposed sidewalk option was counted. The different sidewalk plans meant that a different number of parcels would be accessed by each node based on the pedestrian's path choices. A sidewalk that reached more parcels in a smaller distance theoretically provides a higher level of service to pedestrians. This value provided the point of comparison between neighborhood connector option A and B. The higher the number of accessible parcels for each node, the higher its effective walk area was and the more desirable the option overall. Table 2 below portrays the average EWA for the main proposed routes and each neighborhood connector option.

	Average EWA
Main proposed routes and connector option A	0.591
Main proposed routes and connector option B	0.565

Table 2 EWA for Main Proposed Routes and Neighborhood Connector Options

Based on the average EWA of both neighborhood connector options, neighborhood connector option A is slightly more effective than neighborhood connector option B. Based on the EWA, neighborhood connector option A portrayed a higher EWA value. Neighborhood connector option A also better serves many of the Blythe Avenue nodes by a large margin. These nodes have been deemed to have a higher importance than the smaller nodes along the connectors as they will receive higher traffic and are directly addressed within the scope of work. Based on these factors, neighborhood connector option A is superior to neighborhood connector option B. It should be noted that the benefits of each plan can vary based on a street-by-street analysis. Neither plan will greatly alter the numbers of parcels accessible by pedestrians relative to the other.

5.6 Stopping Sight Distance

Stopping sight distance (SSD) is defined as the summation of the distance required for a driver to make the decision to break and the distance it takes for the vehicle to reach a complete stop. SSD is calculated using the following equation:

$$\text{Stopping Sight Distance, SSD} = 1.47 \times (V) \times (t) \times \left[\frac{V^2}{A_0 (f + G)} \right] \quad (5)$$

where V is speed of the car in miles per hour (mph), t is the brake reaction time in seconds, A_0 is the deceleration rate in miles per second squared (m/s^2), f is the coefficient of friction of the road, and G is the percent grade of the road. Conservative values for the coefficient of friction and perception time are accounted for in the SSD calculations. A conservative coefficient of

friction of 0.7, at which road conditions are assumed to be wet, minimizing the friction between the wheels and the car was utilized in this analysis. A conservative perception time of 2.5 seconds was used for design purposes, which represents perception-reaction time research which concludes that approximately 90% of drivers can react to a given situations in 2.5 seconds [6]. Equation 6 was used to calculate the percent grade of the road at each intersection:

$$Grade, G = \frac{(Elevation\ at\ crosswalk) - (Elevation\ of\ vehicle)}{Absolute\ distance} \quad (6)$$

Sample calculations for stopping sight distance and percent grade of the road are provided in Appendix C.

The first line of sight from a vehicle to a proposed crosswalk and the absolute distance between the two is necessary to measure and was determined using Google Earth. The elevations of the proposed crosswalks and the approaching vehicle were also determined through Google Earth for use in the computation. The stopping sight distances at 51 locations were calculated. These locations represent the crosswalk sites along the proposed routes susceptible to visibility constraints which may require infrastructure to guarantee pedestrian safety. Table 19 in Appendix D summarizes the information for each location.

On neighborhood connector option A, the crosswalk at the intersection of Wilson Avenue SE and 11th Street SE has a stopping sight distance conflict. As the vehicle approaches the intersection, the stopping sight distance, 153.6 feet, is greater than the absolute distance, 132ft, between the vehicle and the first sight the crosswalk at the intersection. A vehicle can only react to the crosswalk after passing the curve, as demonstrated in Figure 25.



Figure 25 Stopping sight distance conflict at crosswalk at intersection of Wilson Avenue SE and 11th Street SE

Based on the stopping sight distances for all other crosswalks proposed, vehicles driving on the roads at designed speed will have enough time to react and reach a complete stop. A sign located before the curve approaching Wilson Ave to inform the driver a crosswalk is approaching will alleviate the safety concern at this known SSD conflict area.

5.7 Right of Way

Right of way (ROW) data for Cleveland, Tennessee was obtained from a GIS file provided by the City of Cleveland. The GIS data files were transferred into ArcMap, which was used to measure the distance on all roads that lie on proposed routes. ROW was calculated as the linear width, in feet, that is allowed for construction of a sidewalk, road, or other transportation related structure. The distances found with ArcMap from the parcels file was an approximate estimation of the existing ROW in a designated area.

A ROW distance of 40 feet was estimated as the required minimum width to construct the designed roadway and sidewalk. With the width of the designed sidewalk only requiring 5 feet, and the width of the roadway only requiring 10 feet per a lane, a minimum ROW of 25 feet is needed to install a sidewalk on one side of the roadway. A ROW of 30 feet will allow sidewalks to be installed on both sides of the road. A maximum ROW of 40 feet will allow extra room for design alterations, such as utility relocations and the additions of curbs. Sample calculations for ROW are provided in Appendix E.

At the following three locations, ROW conflicts arise: Blythe Avenue between 20th & 18th Street SE, 15th Street SE between Blythe Avenue & Aurora Avenue SE, and 18th Street SE between Blythe Avenue & Wildwood Avenue. Ideally, it is recommended to avoid constructing sidewalk infrastructure on Blythe Avenue SE between 20th and 18th Street SE and 18th Street SE between Blythe Avenue SE and Wildwood Avenue, but sidewalks along these routes can still be constructed if the minimum design road and sidewalk width is accommodated. Fifteenth Street SE between Blythe Avenue SE and Aurora Avenue SE should be avoided altogether as there is inadequate ROW distance for implementation of a sidewalk and two-way road. Significant roadway infrastructure modifications would be necessary and is not recommended at this time.

5.8 Distance and Cost Estimations

The total distance of each route, the length of sidewalks required, and the length of required sidewalk renovations were measured for each alternative. For the length of sidewalk required and length of required sidewalk renovations, a cost analysis was performed.

5.8.1 Total Distance

The distance of each route and neighborhood connector was obtained with the assistance of Google Maps. The approximate total distances, in miles, for each route and neighborhood connector was obtained through the summation of the linear distances of the roads. Distance measurements assume the following: (1) each fragment of road measured is linear and (2)

minimal overlapping of measurements occurred. The approximate linear measurements will disregard any horizontal curvature that likely exists along the proposed sidewalk routes. While it is understood that slight deviations in curvature will exist, it is understood that slight deviations in curvature will exist, it is assumed that these are small compared to overall length of sidewalk infrastructure. They are also assumed relatively constant amongst routes and therefore have minimal impact on the comparative analysis. Similarly, Google Maps distance measuring tools are not precise, so small errors in route overlaps will exist within this report. Again, these errors are assumed small and consistent across routes such that the comparative metrics are not significantly impacted.

The length of sidewalk required for each route and neighborhood connector was obtained with the assistance of Google Maps. The approximate distances, in miles, for each route and neighborhood connector was obtained through the summation of the linear distances of the roads.

Table 3 depicts the required length of sidewalks for each alternative.

	Route Distance (mi.)	Route Distance (ft.)
Blythe Avenue	0.54	2851.2
Dalton Pike	0.7	3696
Greenway	0.66	3484.8
Greenway Railing	0.16	844.8
Neighborhood Connector Option A	2.33	12302.4
Neighborhood Connector Option B	2.28	12038.4

Table 3 Length of required sidewalks

Table 3 also includes the distance of railing for one side on the greenway, which will be required when an elevated boardwalk or concrete sidewalk is built. The distance for only one side of the railing is considered because it is assumed that the route is a concrete sidewalk that requires a railing on the east side. This length will be included in the cost-estimating for this design option.

5.8.1.1 Total Distance Results

The approximated total distance for the Blythe Avenue and Greenway routes have the same approximate total distance, 0.8 miles. The Dalton Pike route has the longest approximate walking

distance, 1.4 miles. The neighborhood connector option A has approximately 3 miles of needed sidewalk. The neighborhood connector option B has approximately 2.4 miles of needed sidewalk. Table 4 shows the distances of the routes and neighborhood connectors.

Route or Neighborhood Connector	Distances (miles)
Blythe Avenue Route	0.85
Greenway Route	0.85
Dalton Pike Route	1.32
Neighborhood Connector Option A	2.33
Neighborhood Connector Option B	2.28

Table 4 Distances of Routes and Neighborhood Connectors Options

The AASHTO Green Book states that pedestrians are unwilling to walk more than 1 mile to reach their final destination [5]. Based on the distance analysis for each route, pedestrians would prefer either the Blythe Avenue Route or Greenway Route over the Dalton Pike Route because they are each less than 1 mile [5].

5.8.1.2 Repaired Sidewalk Repairs

Currently, the existing sidewalk infrastructure between the Family Support Center and 13th Avenue SE is in poor condition. It is suggest that the existing sidewalk be removed and replaced with new sidewalk infrastructure. *RSMeans* was used to obtained approximate values for sidewalk demolition and construction [7]. All cost values assume a standard 5 feet sidewalk with a 4 inch thick slab and minimum reinforcement. The cost of new sidewalk construction includes a sidewalk structure as recommended by TDOT Standard details which do not include slab reinforcement. The total cost for demolition and reinstalling sidewalks along Blythe Avenue from the Family Support Center to 13th Street SE will be added to the total cost of sidewalk construction. The cost for the removal and replacement of the existing sidewalk infrastructure is shown in Table 5.

	Old sidewalk
Demolition cost (\$/yd ³)	\$ 247,891.60
Formwork cost (\$/ft)	\$ 17,517.98
Construction cost (\$/ft ²)	\$27,144.48
Total construction based cost (\$)	\$ 292,554.06

Table 5 Demolition and reinstallation cost of sidewalk along Blythe Avenue from Family Support Center to 13th Street SE

5.8.2 Total Cost

A cost was estimated for infrastructure along the routes and neighborhood connectors, excluding labor and earthwork fees. The cost of each route and neighborhood connector was calculated based on the approximate length that required new sidewalks. The cost is a summation of the number of crosswalks and the linear foot, as needed, of concrete sidewalk, railing, curbs, and gutter for each route and neighborhood connector. The cost values are conservative and portray that all routes will have concrete sidewalks, including the greenway.

The *Costs for Pedestrian and Bicyclist Infrastructure Improvements* was used to obtain average cost for each striped crosswalk and average cost per linear foot for the concrete sidewalk, railing, curb, and gutter [8]. The total cost for each neighborhood connector includes the average cost of crosswalks necessary for Wildwood Avenue, a cost that applies to all connector routes. Sample calculations for the cost of the Blythe Avenue route and neighborhood connector option A is provided in Appendix F. Table 20 in Appendix F shows the average cost for each element of required infrastructure. Table 21 in Appendix F shows the number and costs of crosswalks for each route, neighborhood connector, and Wildwood Avenue.

Table 6 summarizes the total cost for each route and neighborhood connector option.

	Proposed Route Names	Total Cost
Sidewalk Extension Routes	Blythe Avenue	\$563,723
	Greenway	\$684,610
	Dalton Pike	\$615,691
Connector Routes	Neighborhood Connector Option A	\$865,450
	Neighborhood Connector Option B	\$847,440

Table 6 Total Cost for Each Route and Neighborhood Connector Option

5.8.3 Route Length and Cost Conclusion

Based on the cost analysis for each route sidewalk extension, the Blythe Avenue Route is the least expensive alternative. The greenway route is the most expensive sidewalk alternative. The additional cost for the greenway route is due to the addition of railings on the east side of the concrete sidewalks.

Based on the cost analysis of the two neighborhood connectors, neighborhood connector option B is the least expensive option.

Based on an approximately estimation of cost and length for the three routes and two neighborhood connector options, the Blythe Avenue Route paired with the neighborhood connector option B is the least expensive and has the shortest distance for pedestrians to walk from the Family Support Center to the Blythe Bower Elementary School.

5.9 Comparative Analysis Conclusion

A comparative analysis matrix was created to compile the results from the preceding metric discussed herein. The results of each analysis compiled in the comparative analysis are displayed in Table 7.

Sidewalk Extension:	Blythe Ave		Greenway		Dalton Pike	
Connector:	Option A	Option B	Option A	Option B	Option A	Option B
Design Consideration						
Pedestrian Route Directness	1.178		1.13		1.539	
Effective Walk Area	0.590553	0.564576	0.590553	0.564576	0.590553	0.564576
Stopping Sight Distance	1.00	0.00	1.00	0.00	1.00	0.00
Number of Crosswalks	40	40	40	40	42	42
ROW Conflicts	3	4	3	4	4	5
Cost (\$)	\$1,429,173	\$1,411,163	\$1,550,059	\$1,532,049	\$1,481,141	\$1,463,131
Required Sidewalk Length (miles)	3.07	3.02	2.93	2.88	3.21	3.16
Cumulative Route Length (miles)	0.85		0.85		1.32	
Connected Node Ratio	0.889	0.958	0.857	0.929	0.852	0.92
Link-Node Ratio	1.333	1.625	1.321	1.286	1.296	1.36

Table 7 Results of Comparative Matrix Analysis

The comparative analysis shows that the preferred route is the Blythe Avenue Route coupled with neighborhood connector option B. The system requires the least number of new crosswalks, is the least expensive, has the highest connectivity results, and has the shortest cumulative length.

Through discussions with Cleveland representatives, the greenway route is a preferred route. This route provides the opportunity for physical activities that will improve mental and physical health, the beautification of the community, and the preservation and restoration of open space. In conclusion, the pairing of the greenway route and neighborhood connector option B is recommended by the design team.

6.0 Greenway Design

Greenway design guidelines were researched and compiled to ensure the requirements for a greenway trail are understood and implemented for safe construction of the trail. Information about the type and characteristics of soil was obtained through a site subsurface investigation between 18th Street SE and 20th Street SE for soil capacity calculations for the safe construct of the greenway trail. Different greenway path options are compared based on cost, durability, and aesthetics.

6.1 Greenway Design Guidelines

The greenway path intersects 18th Street SE at a small parking lot area, as shown in Figure 7. A sign to marking the entrance of the greenway and to indicate that motor vehicles are prohibited on the trail will be placed at the intersection of the Greenway and 18th Street SE [9]. Figure 27 illustrates a typical greenway safety signage.



Figure 26 Typical greenway safety signage [9]

The path will have a minimum of a two foot wide grass shoulder on either side of the pathway where vegetation is kept low and a minimum overhead clearance space of 10 feet is needed in

which branches and obstacles are to be cleared and maintained [9]. Clearing and grubbing will be required for the width of the path and a certain length on either side of the path prior to construction [9]. Selective thinning will also be required for maintenance purposes. Selective thinning will require the removal of selected individual trees around to allow for more resources for other greenery [10]. Table 8 outlines the clearing and grubbing width and the selective thinning width based on trail width. Figure 27 illustrates the general areas for clearing, grubbing, and thinning width and heights.

Trail Width	Clearing and grubbing width	Selective thinning width
6 foot	10 feet	20 feet
8 foot	14 feet	24 feet
10 foot	16 feet	26 feet

Table 8 Trail width, Clearing and Grubbing width, and Selective thinning width

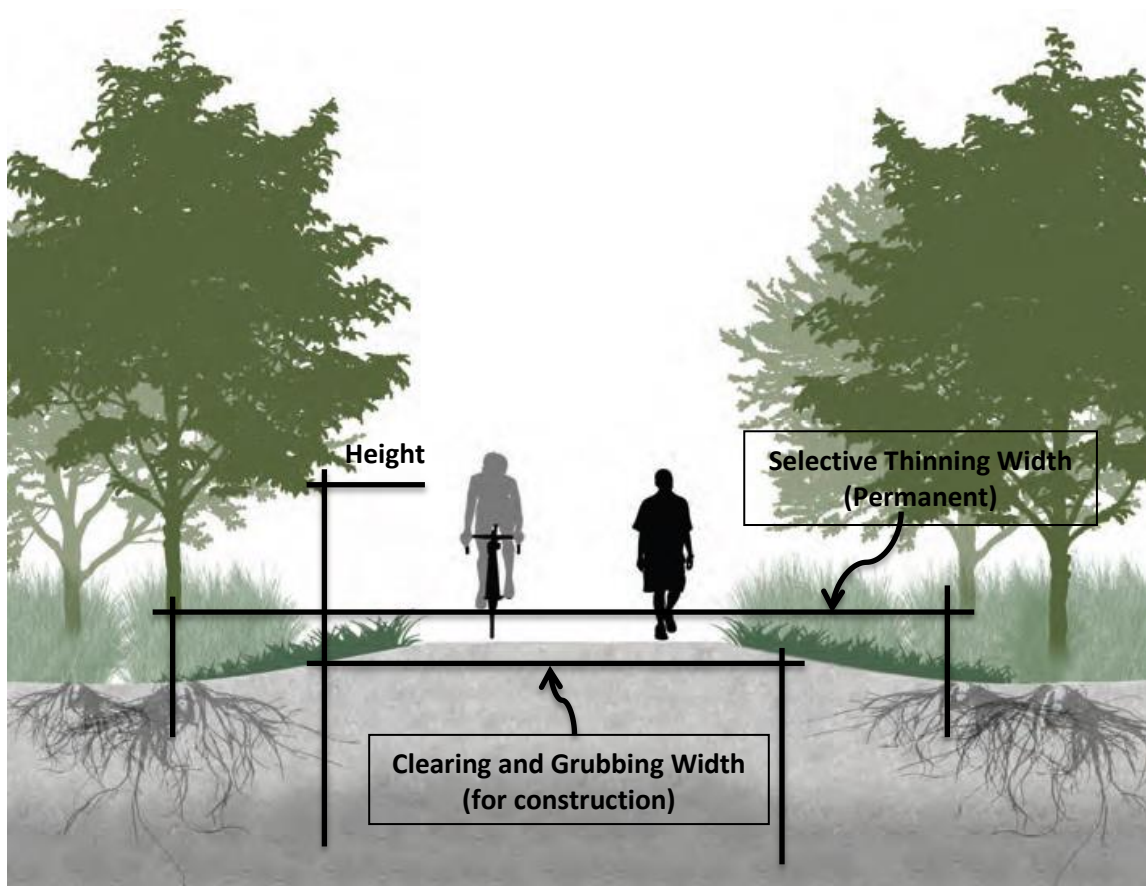


Figure 27 Illustration of general clearing, grubbing, and thinning width and heights [9]

A maintained natural vegetation area for runners on at least one side of the trail is recommended [11]. In addition to the two feet shoulder, a minimum of five feet of cleared natural area on both sides of the path is recommended [11]. Figure 28 illustrates the general shoulder and cleared natural area guidelines for the trail.

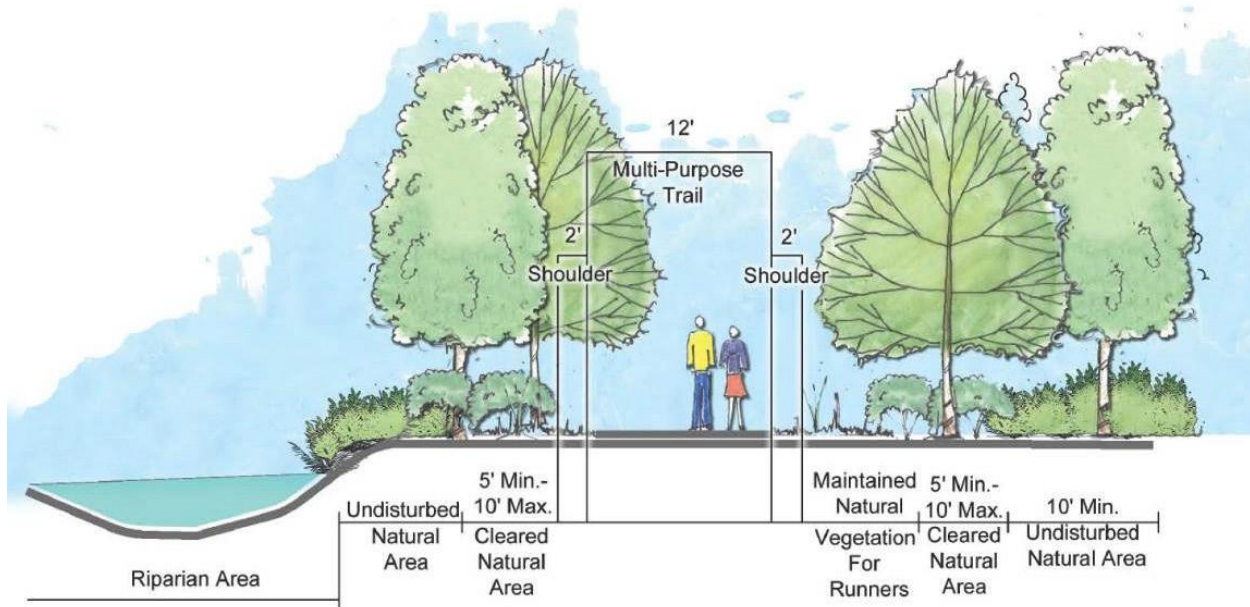


Figure 28 Greenway trail guidelines for shoulders and cleared natural areas close to a body of water [11]

6.2 Subsurface Investigation of Proposed Greenway Route

Soil sampling methods and tests were performed to evaluate existing subsurface conditions. Discussion of these procedures and results are included in the subsequent sections.

6.2.1 Soil Sampling

Relatively undisturbed soil samples using Shelby tubes were obtained from the proposed greenway site using an auger, a manual driver, a handle bar, a sampler, different length metal

rods, six inch metal tubes that resembled Shelby tubes, and rubber caps for the tubes. An auger, a five foot long metal rod, and a handlebar was use to manually drill a hole approximately one foot into the soil. Once soil was removed from the one foot hole, a sampler containing a six inch metal tube was placed into the hole to collect a soil sample. A manual driver was use to drive the sampler and tube into the soil approximately six inches into the soil to collect a soil sample. The manual driver was use as a reverse hammer to remove the sampler, metal tube, and soil sample from the soil. Caution was taken while retrieving the soil sample minimize disturbance of the sample. The metal tube and soil sample was removed from the metal rod, with caution, to prevent the soil sample from escaping the tube. The metal tube and soil sample were capped with rubber caps on each ends and labeled according to borehole number, soil sample number, and the depth the soil sample was extruded.

This method was repeated approximately five times to obtain undisturbed soil samples at five different locations. The depth of the soil sample varied based on location and length of the soil sample varied based on the stiffness of soil. A total of four soil samples were obtained at the following boreholes: 1, 2, 3, and 5. The soil sample from borehole 4 was not obtainable because the soil crumbled as it was being extruded. Figure 29 shows the greenway are and 29a and 29b highlight the approximate location of the boreholes.



Figure 29 Greenway area with borehole locations highlighted as A and B



Figure 29a Borehole locations



Figure 29b Borehole locations

As illustrated in Figure 29a, soil samples from boreholes 1 and 2 were obtained on the south side of the greenway. As depicted in Figure 29b, soil samples from boreholes 3, 4, and 5 were collected on the north side of the greenway.

The length of the soil sample from borehole 1 does not meet the diameter to length ratio required for testing by ASTM [12]. The soil sample from borehole 2 and 3 did not meet the diameter to length ratio but were adequate for soil testing [12]. Results of the soil testing are preliminary and a final subsurface investigation is recommended prior to construction

6.2.2 In-Situ Van Shear Test

The vane shear test is used to measure in-situ undrained shear strength in clay soils and was performed based on the instruction manual for an E-286 inspection vane set [13]. A four-bladed vane is connected to extension rods to the inspection vane instrument. The four-bladed vane is then placed and pushed into the ground. Once the instrument is situated into the soil, the graduated scale is set to the zero position. The handle is then turned clockwise at a slow speed in order to maintain constant speed. Once the upper and lower parts of the instrument moved at the same rate, failure has occurred and the maximum shear strength has been attained in the clay at the vane.

This method was used once to obtain the undrained shear strength of only borehole 1 because the soil at the other boreholes was too stiff. The undrained shear strength of borehole1 is 1670 lb/ft² (psf). Due to the stiffness of the soil, the vane shear device is not able to penetrate the soil in order to measure the undrained shear strength of the soil.

6.3 Soil Sample Testing

The soil samples from borehole 2 and 3 were used to perform the unconfined compression test and Atterberg's limits test. The unconfined compression test was used to determine the unconfined compressive strength of the soil. The Atterberg's limit tests were used to determine the liquid limit, plastic limit, and plasticity index. The unit weight was obtained for the soil samples in borehole 2 and 3. The water content was obtained for the soil sample in borehole 1, 2, and 3.

6.3.1 Unconfined Compressive Test

An unconfined compression test was performed, in accordance to ASTM D2166, on the undisturbed soil samples obtained from borehole 2 and borehole 3 [12]. Strain, stress, and unconfined compressive strength values were obtained based on the following equations:

$$\text{Strain, } \varepsilon = \frac{\text{Change in length}}{\text{Original length}} \quad (7)$$

$$\text{Original Area (inches}^2\text{)} = \frac{\pi}{4} \times (\text{diameter})^2 \quad (8)$$

$$\text{Corrected Area (inches}^2\text{)} = \frac{\text{Original Area}}{1 - \varepsilon}$$

(9)

$$\text{Stress (psi)} = \frac{\text{Load}}{\text{Corrected area}}$$

(10)

The stress and strain values were plotted, as shown in Figure 35 and 36 in Appendix H. From the results, excluding the outliers, the maximum value of compressive stress is obtained from the peak values. The maximum value of compressive stress determined was the unconfined compressive strength, q_u . Mohr's circle was drawn using the unconfined compressive strength and values for shear stress and cohesion were obtained from the Mohr's circle. Without using the Mohr's circle, the value for undrained shear stress can be obtained through the following equation:

$$\text{Shear Stress (psf)} = \frac{\text{Unconfined compressive strength}}{2}$$

(11)

Sample calculations for the unconfined compressive test for borehole 3, sample 3 are illustrated in Appendix H. The friction angle was assumed to be zero for both soil samples. The results for the unconfined compressive strength and shear strength are listed in Table 9.

	Borehole 2 Soil Sample 2	Borehole 3 Soil Sample 3
Unconfined Compressive, q_u (psf)	1425.600	2736.00
Shear Stress, S_u (psf)	712.800	1368.000
Bearing Capacity, q_{ult} (psf)	5449.006	10304.038
Allowable Bearing Capacity, q_{all} (psf)	1816.335	3434.679

Table 9 Results for Unconfined Compression Test

6.3.1.1 Experimental Error

While testing the soil sample, the load on the soil sample was applied at a sloped angle, as shown in Figure 30 and 31.

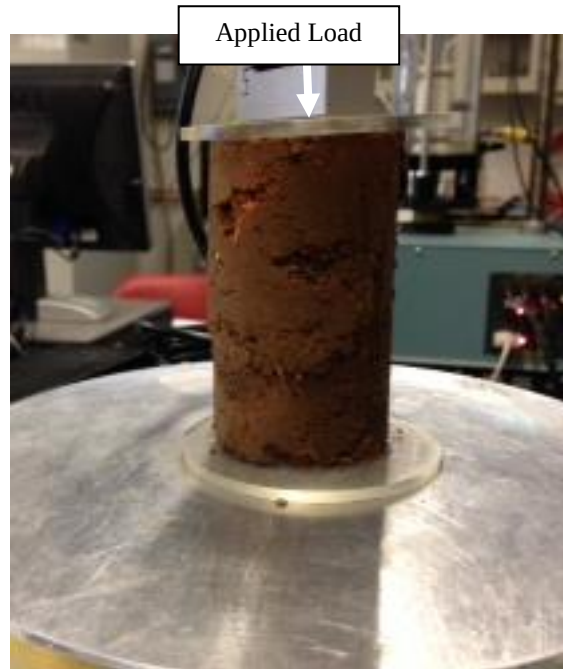


Figure 30 Soil sample from borehole 2



Figure 31 Soil sample from borehole 3

The slope surfaces were caused during the transportation of the soil samples for testing. Though the sloped surfaces could be trimmed to a flat surface, doing so would compromise the reliability of the testing data. Furthermore, specimens retrieved at shallow depths are difficult to trim. Though data obtained from the soil samples may not be accurate, it is still assumed to be acceptable for the purpose of this project. There is confidence that the unconfined compressive strengths obtained err in favor of conservative design. The sample's sloped testing surface likely results in lower tested soil properties. Had the tested soil samples remained intact, the unconfined compressive strength would have been much higher.

6.3.1.2 Recommendations

It is recommended that for future subsurface investigations of site, a pentameter should be used to obtain on-site unconfined compressive strengths of soils to verify laboratory data.

6.3.2 Unit Weight

The unit weight of the soil sample was obtained in accordance to ASTM D 7263 [14]. Method B, direct measurement was used. The volumes of the soil samples were obtained from the following equation:

$$Volume (in^3) = \pi \times Height \times Radius^2 \quad (12)$$

Unit weights of the soil samples were obtained from the following equation:

$$Unit\ weight\ (\frac{lb}{ft^3}) = \frac{Mass\ of\ sample}{Volume\ of\ sample} \quad (13)$$

Sample calculations for the unit weight of borehole 2, sample 2 are illustrated in Appendix H. Unit weight values for borehole 2 and 3 are shown in Table 23 in Appendix H.

6.3.2.1 Experimental Error

While performing the test, the soil sample weight was not obtained. Therefore, the weight of the air-dried sample was used to estimate the moist weight of the sample, resulting in a lower in-situ unit weight of the soil. The reason the value is lower is because water has partially evaporated from the soil, causing the soil to weigh less than its in-situ weight. With a lower mass and constant volume, the unit weight will be lower.

6.3.3 Water Content

The water content of the soil was obtained in accordance to ASTM D2216 [15]. The water content for the soil samples were in accordance with method B in ASTM D2216 [15]. The water contents for the soil samples were obtained using the following equation:

$$\text{Water Content (\%)} = \frac{\text{Mass of water}}{\text{Mass of oven dry specimen}} \times 100 \quad (14)$$

Sample calculations for the water content of borehole 2, sample 2 are illustrated in Appendix H. Water content values for borehole 2 and 3 are shown in Table 23 in Appendix H.

6.3.4 Atterberg's Limits Test

The Atterberg's limits of the soil samples were obtained in accordance to ASTM D4318 [16].

6.3.4.1 Liquid Limit

The soil samples for the liquid limit test soil were prepared based on the dry preparation method. The soil samples were left out to dry in a metal pan at room temperature for approximately a week. Once the soil samples were dried, the soil samples were pulverized, separately, with a rubber pestle in a mortar until the soil samples passed through a 425 μm (No. 40) sieve [16]. After the soil samples passed through the sieve, the soil samples were prepared based on the wet preparation method, as instructed in ASTM D4318 [16].

Following the wet preparation method, 150 to 200 grams of each soil sample was measured out into a small container [16]. Because there was excess amount of soil from both samples, each soil sample had two batches of material that were tested. The two batches will be referred to as a specimen to avoid confusion. After the specimen was measured out, distilled water was mixed into the specimen until an even consistency, as determined by ASTM D4318, was obtained [16]. This was repeated for all remaining specimen. The specimens were then left to dry for at least 16 hours [16].

Once the specimens were prepared, the liquid limit test was performed based on method A, the multipoint liquid limit, using a hand-operated liquid limit device, flat grooving tool, gauge, and spatula [16]. The gauge was used to calibrate the device [16]. Then, a small piece of the prepared specimen was scooped into the device and smoothed using the spatula [16]. The specimen was then tested according to ASTM D4318 [16]. The testing was repeated at least 4 times for each specimen. The number of blows required for the groove to close and the water content were measured for each trial on each specimen. The water content for a given trial was obtained using equation 14. The water content and number of blows causing groove closure for a given trial were used to obtain the liquid limit through the following equation [16]:

$$\text{Liquid Limit} = (\text{Water content } \%) \times \left(\frac{\text{Number of blows}}{25} \right)^{0.121} \quad (15)$$

Sample calculations for the liquid limit for a borehole 2, soil sample 2, specimen 51-1 are shown in Appendix H. The average liquid limit was obtained from each specimen. Table 24 in

Appendix H shows the liquid limit for borehole 2, soil sample 2. Table 26 in Appendix H shows the liquid limit for borehole 3, soil sample 3.

6.3.4.1.1 Experimental Error

While performing the liquid limit test, the soil sample was flooded with distilled water. A hairdryer was used to dry the flood sample in order to correct the amount of water in the soil and follow the ASTM D4318 [16].

Only the liquid limit value for specimen 2-3 from borehole 3, soil sample 3 was used to obtain the liquid limit for that specimen. Specimen 2-4 from borehole 3, soil sample 3 was disregarded because the low water content and low number of blows is erroneous. As the water content increased, the expected number of blows to bring the groove to closure would decrease because the specimen is liquidized. Specimen 2-4 from borehole 3, soil sample 3 did not show this behavior. Specimen 2-2 and specimen 2-5 from borehole 3, soil sample 3 were disregarded because the water content for both specimen was below zero. This caused the liquid limit to be zero, which is incorrect.

6.3.4.2 Plastic Limit

The soil samples for the plastic limit test were prepared in accordance to ASTM D 4318 [16]. The plastic limit tests were performed in accordance to ASTM D 4318 [16]. The plastic limit value is the water content of the soil. Equation 14 was used to obtain the water content percent of the specimens for each soil sample. Table 25 in Appendix H shows the plastic limit for borehole 2, soil sample 2. Table 27 in Appendix H shows the plastic limit for borehole 3, soil sample 3.

6.3.4.2.1 Experimental Error

Specimen 2-3 from borehole 2, soil sample 2 was disregarded in the average calculation of the plastic limit because large pieces of stones were found in the specimen. The stones made it difficult to roll the specimen into a 3.2 mm thread. Therefore, this trial did not meet the

requirements of ASTM D4318 [16]. Specimen 2-2 from borehole 2, soil sample 2 was not used in the average calculation because the water content value was low and was not in the allowable usable range as determined per ASTM D4318 [16]. Specimen 2-2 from borehole 2, soil sample 2 was not used in the average calculation because it was not within the clay standard deviation of 1.2 or 2.0 for multilaboratory results, as stated in ASTM D4318 [16]. Specimen 2-2 from borehole 3, soil sample 3 was not used in the average calculation of the plastic limit because it was not within the clay standard deviation of 1.2 or 2.0 for multilaboratory results, as stated in ASTM D4318 [16].

6.3.4.3 Plasticity Index

The plasticity index was acquired based on the following equation [16]:

$$\text{Plasticity Index} = \text{Liquid limit} - \text{Plastic limit} \quad (16)$$

Sample calculations for the plasticity index for a borehole 2, soil sample 2, specimen 1 are shown in Appendix H.

Based on the Atterberg's limits tests results shown in Table 10 and 11 for borehole 2, soil sample 2 and borehole 3, soil sample 3, respectively, the soil at the proposed site is a low plasticity clay [16].

Soil Sample	Liquid Limit	Plastic Limit	Plasticity Index
Specimen 1 - Bowl 51	38	24	14
Specimen 2 - Bowl 134	41	24	17

Table 10 Results for Atterberg's Limits Test on Borehole 2, Soil Sample 2

Soil Sample	Liquid Limit	Plastic Limit	Plasticity Index
Specimen 1 - Bowl 12	38	20	18
Specimen 2 - Bowl 53	39	20	10

Table 11 Results for Atterberg's Limits Test on Borehole 3, Soil Sample 3

6.3.5 Bearing Capacity

The bearing capacity of the two soil samples were calculated with the following assumptions: (1) the soil exhibits undrained behavior, (2) the effective cohesion of the soil is equal to the undrained shear strength of the soil ($c' = C_u = S_u$), (3) effective unit weight is not used in the calculation, and (4) the foundation of the structure will be at least 2 feet below the soil. The first three assumptions are made because the soil is a fine grained soil (clay soil). Because the soil is a clay, the soil can exhibit undrained condition [17]. By assuming that the soil has undrained behavior, the friction angle, ϕ will be taken as 0 [17]. When the friction angle becomes 0, N_c will be taken as 5.7, N_q will be taken as 1.0, and N_γ will be taken as 0.0 [17]. By assuming that the foundation of the structure will be at least 2 feet below the soil, the design ensures that the foundation will be below the frost line.

To calculate the bearing capacity of the soil, Terzaghi's bearing capacity equation was used, as followed [17]:

$$\text{Bearing Capacity (psf)} = 1.3 * c' * N_c + \sigma' z d * N_q + 0.4 * \gamma' * B * N_\gamma \quad (17)$$

It should be noted that Terzaghi's bearing capacity equation is conservative compared to other bearing capacity equations. Furthermore, the bearing capacity equation used adheres to the assumptions that Terzaghi developed in creating his theory. The assumptions are as followed: (1) the depth of the foundation is less than or equal to the base ($D \leq B$), (2) the bottom of the foundation is rough, (3) the soil beneath the foundation homogeneous, (4) the general shear mode governs, (5) shear strength does not exist in the soil between the ground surface and depth D , (6) the applied load is compressive, (7) the applied load is vertical to the centroid of the foundation and does not create a moment, (8) the foundation is rigid, (9) the foundation of the structure will be either square, rectangular, or circular, and (10) the foundation is not continuous [17].

Sample calculations for the bearing capacity for a borehole 2, soil sample 2 are shown in Appendix H. Table 12 shows the bearing capacity values for borehole 2, soil sample 2 and borehole 3, soil sample 3. An allowable bearing capacity was calculated from the ultimate

bearing capacity. A factor of safety of 3 was used [17]. The following equation was used to calculate the allowable bearing capacity:

$$\text{Allowable Bearing Capacity (psf)} = \frac{\text{Ultimate bearing capacity}}{3} \quad (18)$$

Sample calculations for the bearing capacity for a borehole 2, soil sample 2 are shown in Appendix H. The results for the ultimate and allowable bearing capacity values for borehole 2, soil sample 2 and borehole 3, soil sample 3 are displayed in Table 12.

	Borehole 2 Soil Sample 2	Borehole 3 Soil Sample 3	Average
(Ultimate) Bearing Capacity (psf)	5449	10,304	7877
Factor of Safety	3	3	-
Allowable Bearing Capacity (psf)	1816	3435	2626

Table 12 Bearing Capacity Values for Soil Samples

Based on the bearing capacity of borehole 2 and 3, it can be determined that the strength of the soil varies quite significantly along the proposed greenway route. To be conservative, the allowable bearing capacity value of 2600 psf will be used for design purposes.

6.4 Greenway Trail Type

The main goal for the greenway path is to decrease the pedestrian walking distance between 20th street and 18th street and to further enhance the area. The following section compares two options for the type of greenway trail for the proposed pathway. The first option is a boardwalk trail. The second option is a concrete sidewalk on grade.

6.4.1 Boardwalk

One greenway trail option is a raised boardwalk. A boardwalk was designed in accordance with the AASHTO LRFD Guide Specifications for Design of Pedestrian Bridges [18]. International Building Code (IBC) and ASCE 7 were referenced to define applicable live loads and dead loads [19-20]. The boardwalk design considers southern yellow pine timber and TimberTech. The timber is specified for the structural elements of the structure while the TimberTech has been considered for the handrail and decking. TimberTech is recommended for the handrail and decking because it is a composite wood material, has a longer lifespan, and will incur a lower maintenance cost. The boardwalk was designed as 10 feet wide with a handrail 42 inches tall, which will provide safety for pedestrians. The boardwalk is supported with 6x6 columns that sit atop concrete piers. Some of the advantages with the boardwalk include easy installation of material and minimal required excavation. The cost was estimated based on a 1,267 foot long boardwalk. Preliminary cost estimations of only the TimberTech decking and rail, at a cost of \$18.06 per square foot, yield a price of \$228,820.20. This price only includes material and does not include labor, substructure, excavation, or footings.

6.4.2 Concrete Sidewalk

A second option is a concrete sidewalk with a Keystone Gravity Wall system. This option will require extensive excavation to obtain a desirable terrain to build a suitable AOA-compliant sidewalk. Elevations were obtained from a topographic map to estimate the required cut and fill for the proposed pathway. The total cut volume is estimated to be 1,797 cubic yards and the total fill volume is estimated to be 1,074 cubic yards. A retaining wall will be required on the upper and lower side of the sidewalk to prevent the soil from shifting and displacing the sidewalk. The concrete sidewalk option is appealing because of the longevity of the sidewalk and the lack of maintenance costs required. *RSMeans* was used to generate the cost of the concrete sidewalk [7, 21]. Factors in the total cost that were included: excavation, coarse aggregate, concrete, retaining wall materials, hauling, grading, and compaction costs. The total cost estimation was \$178,598.08. Table 13 shows the cost estimations for the retaining wall.

	Volume (yd ³)	Area (ft ²)	Cost (\$)
Cut Volume	1797.33	-	26,744.27
Fill Volume	1074.44	-	1,987.72
West Retaining Wall	-	4307.75	53,114.56
West Wall Backfill	120.70	-	4,365.85
East Retaining Wall	-	3439.25	42,405.95
#57 West Wall Backfill	91.42	-	3,306.54
Concrete for Sidewalk	-	10,140	30,825.60
Fine-Grading Cost	-	-	1,115.40
Compaction Cost	-	-	8,615.31
Hauling Cost	-	-	6,116.87
Total Cost	-	-	178,598.08

Table 13 Cost Estimation for Retaining Wall

6.4.2 Conclusion of Trail Type

As a result cost comparison between the boardwalk and the concrete sidewalk, the concrete sidewalk is the preferred design for the greenway path that will connect 18th Street SE to 20th Street SE. While a comprehensive cost analysis was not performed, the cost of a composite material recommended for the boardwalk was significantly higher than the concrete sidewalk option. While an all-wood boardwalk would be feasible, and the cost more comparable, it is recommended that the concrete option be installed based on the assumption of lesser life cycle costs.

6.5 Greenway Trail Design

The concrete sidewalk option requires construction of retaining walls along the route length to address topographic changes. The following section discusses preliminary design calculations of the pressure acting on the retaining walls from the soil and the factor of safety against overturning and sliding in order to estimate a minimum wall thickness for a concrete retaining wall. Aesthetic design considerations for a concrete retaining wall and block retaining wall were

examined and compared to determine the most suitable type of retaining wall for the greenway trail. Safety and cost factors were explored to determine the suitability of the chosen type of retaining wall.

6.5.1 Preliminary Retaining Wall Calculations

The proposed retaining wall design will be a concrete wall with a unit weight of 150lb/ft^3 . Rankine's theory was used to determine the wall's stability. The wall stability equations used adheres to the assumptions that Rankine developed creating his theory. The assumptions are as followed: (1) the soil is homogeneous and isotropic, (2) the most critical shear surface is a plane, (3) the ground surface is a plane, (4) the wall is infinitely long so that plane strain conditions can be assumed, (5) the wall moves sufficiently to develop the active or passive conditions, and (6) the resultant of the normal and shear forces that act on the back of the wall is inclined at an angle parallel to the ground surface [17]. Furthermore, Rankine's theory does not account for friction between the soil and the wall.

To determine the wall stability, driving and resisting forces and moments acting on the wall were calculated. The following assumptions were made to calculate wall stability: (1) the at-grade surface behind the west and east retaining wall are leveled, (2) the fill material is #57 stone, and (3) a minimum wall embedment depth of 1 foot is required. The slope at the ground surface will be taken as 0 because the soil surface is leveled. The unit weight of the fill material will be taken as 92.2 lb/ft^3 . A minimum wall embedment depth of 1 foot is assumed for safety. The following assumptions were made with respect to the fill material to calculate active force: (1) the friction angle will be taken as 34° , the cohesion will be taken as 0, and pore water pressure was taken as 0 [22]. The in-situ soil parameters were obtained from the subsurface investigation. The friction angle, cohesion, and pore water pressure of the soil were taken as 0.

To determine the wall stability, factor of safety for overturning and sliding are calculated. To ensure that the wall is stable, the factor of safety for overturning and sliding must exceed 1.5. The factor of safety for overturning and sliding, respectively, were determined with the following equations:

$$FS = \frac{\sum M_r}{\sum M_d} \quad (19)$$

$$FS = \frac{\sum P_r}{\sum P_d} \quad (20)$$

where M_r and M_d are the moments of the resisting and driving forces, respectively, and P_r and P_d are the resisting and driving forces. The moment of the resisting force is calculated as follow:

$$M_r = (Moment\ arm) * P_r \quad (21)$$

where P_r is the summation of the resisting forces preventing the retaining wall from overturning. For this project, resisting force is considered to be the weight of the wall and passive force is negligible due to its susceptibility to be altered during usage the design life. The weight of the wall is calculated with the following equation:

$$Weight\ of\ wall, W = (Height) * (Length) * (Width) * \gamma \quad (22)$$

where the length of the wall will be taken as a unit length.

The driving moment is calculated as follow:

$$M_d = (Moment\ arm) * P_d \quad (23)$$

where P_d is the summing of the driving forces causing the retaining wall to overturn. For this project, active force is the driving force and is calculated as follow:

$$P_a = \frac{H}{2} * \sigma_a \quad (24)$$

where H is the height of the retaining wall and σ_a is the active pressure. The active pressure is calculated by the following equation:

$$\sigma_a = K_a * \sigma'_v \quad (25)$$

where K_a is the dimensionless K-active and σ'_v is the effective stress in lb/ft². K_a and σ'_v are calculated as follow:

$$K_a = \frac{1 - \sin(\varphi)}{1 + \sin(\varphi)} \quad (26)$$

$$\sigma'_v = (Height) * \gamma \quad (27).$$

Sample calculations for the factor of safety for sliding and overturning are shown in Appendix J. With a minimum thickness of 3.5 feet, the retaining walls on both sides of will meet the factor of safety requirement for overturning and sliding. While this analysis disregards construction of a footing for this retaining wall, which will reduce the required thickness, alternative options to a traditional concrete retaining wall are likely to be more cost effective and are discussed in the following section.

6.5.2 Retaining Wall Decision

Two types of retaining walls were considered for the greenway route, a concrete retaining wall or a block gravity retaining wall. The two walls were compared to determine which wall should be constructed.

The City of Cleveland showed a preference for a greenway route due the beneficial features that will be adding to the community. Based on aesthetics, it is suggested that the block retained wall will be used to create a more natural atmosphere along the pathway. Additionally, it is presumed that the likely added cost of a block system will be minimal and that the aesthetic along the route warrants the additional cost. To determine the type of block retaining wall, the required overall height of 6 feet for the designed retaining wall was taken into consideration. As a result, the Redi-Rock and Keystone block retaining walls were considered.

The Redi-Rock retaining wall has large units that weigh up to a ton and will be able to retain soil for very high heights. Unfortunately, the Redi-Rock retaining wall will require large equipment, which is unsuitable for the greenway area and will cause slope stability concerns during construction. Furthermore, the capability of the Redi-Rock retaining wall over-exceeds the required capability of the designed retaining wall and therefore should not be used.

The Keystone retaining wall has small units that weight approximately 115 pounds. The units can be installed manually and therefore will not require large equipment or create slope stability concerns. Though the wall units are lightweight, the Keystone retaining wall will be able to withstand the applied wall pressures up to 6 feet. Therefore, the Keystone block retaining wall system was chosen. From the available types of Keystone units, the standard unit was chosen for cost reasons.

The SRWalls software was used to determine wall stability. Vendor product data was obtained from Keystone Retaining Walls System. A minimum friction angle value was required in order to utilize the SRWalls software, and therefore a friction angle of 0.05 was used. Results from the SRWalls software confirmed that the proposed retaining wall design exceeds the factor of overturning and sliding requirement of 1.5.

8.0 Rain Garden Design

In addition to inadequate pedestrian infrastructure, the neighborhood lacks drainage features to collect and convey stormwater that accumulates on the roadways. Feasibility, rationality, maintenance, and aesthetics were considered in order to compare and choose between two types of drainage systems, swales and rain gardens. Both designs were determined to be equally feasible because Blythe Avenue has 50 feet of ROW and a large drainage channel at a central location.

Scattered throughout the neighborhood exists poorly constructed and maintained drainage swales that are inefficient. The swales will need to be redesigned and properly maintained to be free of obstruction in order to create an effective storm water system that provides drainage to the neighborhood.

The type of bioretention cell considered for this project is rain gardens. A rain garden is a planted depression designed to retain, filter, and treat storm water runoff before it infiltrates the soil or discharges downstream, therefore reducing runoff [23]. Blythe Avenue was selected as the location for a representative design of rain gardens due to three reasons. The first reason is because the Cleveland representatives expressed an interest in developing this portion of the neighborhood as part of a greenway extension program. Secondly, the Family Support Center located on Blythe Avenue is a community focal point. Lastly, the ROW along Blythe Avenue provides a generous amount of space for the design and allows for design flexibility.

The rain garden design was the preferred design because it had the best balance of maintenance, functionality, and aesthetic appeal. Although the rain gardens will require more maintenance than a traditional swale, such as plant upkeep, trash mitigation, and sediment removal, the design provides more functionality and attractive features. In addition to providing runoff collection and conveyance, rain gardens are capable of cleaning and infiltration of urban runoff.

9.0 Sidewalk Design

Sidewalks will be built in accordance to TDOT Standards. Sidewalk placement decisions were based on: (1) the space available in the ROW, (2) minimizing the amount of crosswalks added, and (3) minimizing conflict with existing utility poles. The space available in the ROW was considered because sidewalks could not be placed on roads that did not have adequate space. If a road was too narrow and lacked an adequate amount of ROW, the road was avoided in the sidewalk placement decision. Minimizing the amount of added crosswalks was considered to minimize costs and to improve pedestrian safety. By minimizing the amount of crosswalks added, pedestrians will be required to cross the street will less and therefore decreasing the chance of exposing pedestrians to oncoming traffic. Sidewalk placement decisions also minimized conflicts with existing utility pole in order to minimize construction cost for relocating utility poles. Figure 32 portrays the placements of sidewalks in the neighborhood.



Figure 32 Placement of sidewalks in the neighborhood

10.0 Conclusion

Based on the comparative analysis, greenway trail type comparison, and engineering calculations, it can be concluded that the greenway alternative with a slab on grade sidewalk, with a block gravity retaining wall on both sides of the pathway paired with the neighborhood connector option B are the best options that will meet the required needs of neighborhood and the City of Cleveland Blythe Sidewalk Extension and neighborhood connector plan. Furthermore, sidewalks that will be added will adhere to TDOT standards and result in the minimal numbers of crosswalk needed across the sidewalk system.

As a result of the implementation of the greenway alternative, some pedestrian safety concerns will have to be addresses due to increase pedestrian traffic. A lack of crosswalks and street signs at intersections throughout the neighborhood will cause safety concerns for pedestrian. To address this issue, a crosswalk and stop lines shall be added. An unsignalized pedestrian stop sign is recommended to be placed a minimum of 50 feet from the intersection of 11th Street SE and Wilson Avenue on 11th Street SE. The sign will inform approaching drivers of a crosswalk on 11th Street SE and will alert drivers to pedestrians crossing. An uncontrolled multi-lane approach design is recommended at the intersections of 18th Street SE and Blythe Avenue. The crosswalk will connect the sidewalk on the east side of Blythe Avenue to the sidewalk on the south side of 18th Street SE to address pedestrian traffic, as indicated in Figure 33.

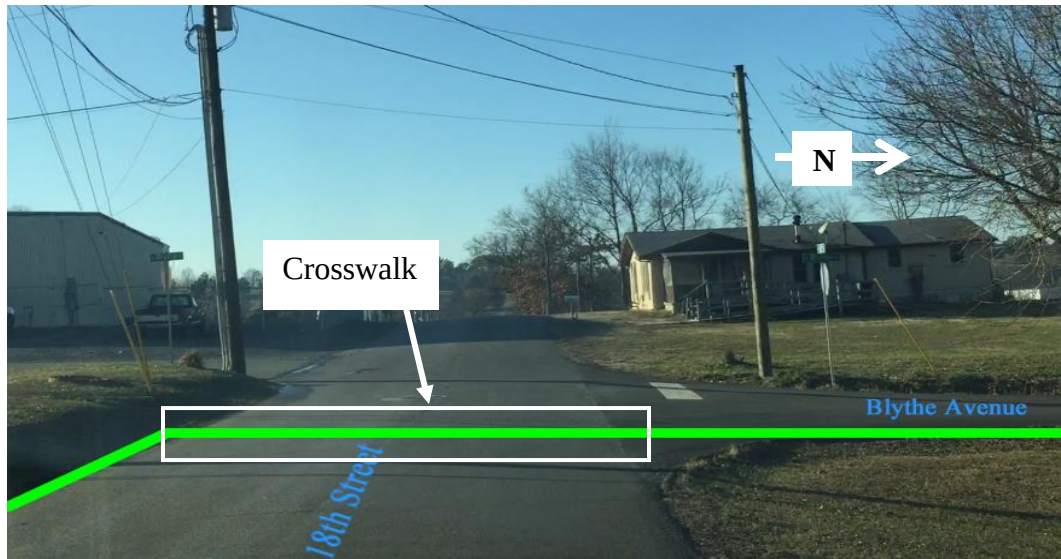


Figure 33 18th Street SE crosswalk

Due to a lack of stop signs on 18th Street SE, stop lines will be added to ensure pedestrian safety. Based on the crosswalk sign options in Figure 14, the following unsignalized crosswalk stop sign will be used for the 18th Street SE crosswalk, as portrayed in Figure 34 below.



Figure 34 Unsignalized pedestrian crosswalk stop sign

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APPENDIX PART I

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APPENDIX A

Sample Calculations

[The following provides sample calculations for connected node ratio (CNR) and link node ratio (LNR)]

Sample Calculation for Blythe Ave School Connector Route & Option A

$$\begin{aligned} \text{Connected Node Ratio} &= \frac{\text{Number of street intersections}}{\text{Number of intersections} + \text{Number of cul-de-sacs}} \\ &= \frac{5}{5 + 2} = 0.714286 \end{aligned}$$

Sample Calculation for Blythe Ave School Connector Route & Option A

$$\begin{aligned} \text{Link Node Ratio} &= \frac{\text{Number of links}}{\text{Number of nodes}} \\ &= \frac{7}{7} = 1.0 \end{aligned}$$

	School Connector Route: Blythe Ave											
	Neighborhood Zone											
	1		2		3		4		5		Total	Total
Option	A	B	A	B	A	B	A	B	A	B	A	B
# of Links	7	5	13	14	11	8	14	16	5	5	36	39
# of Nodes	7	5	11	11	10	7	12	12	5	5	27	24
# of Cul-de-Sacs	2	1	0	0	2	1	0	0	0	0	3	1
# of Intersections	5	4	11	11	8	6	12	12	5	5	24	23
Link-Node Ratio	1	1	1.181818	1.272727	1.1	1.142857	1.166667	1.333333	1	1	1.333333	1.625
Connected Node Ratio	0.714286	0.8	1	1	0.8	0.857143	1	1	1	1	0.888889	0.958333
% 4-Way Intersections	-	-	-	-	-	-	-	-	-	-	16.66667	21.73913

Table 14 Link-Node Ratio, Connected Node Ratio, and Percent 4-Way Intersections for Blythe Ave School Connector Route

	School Connector Route: Greenway											
	Neighborhood Zone											
	1		2		3		4		5		Total	Total
Option	A	B	A	B	A	B	A	B	A	B	A	B
# of Links	7	5	13	14	11	8	14	16	6	7	37	36
# of Nodes	7	5	11	11	10	8	12	13	6	7	28	28
# of Cul-de-Sacs	2	1	0	0	2	1	0	0	1	1	4	2
# of Intersections	5	4	11	11	8	7	12	13	5	6	24	26
Link-Node Ratio	1	1	1.181818	1.272727	1.1	1	1.166667	1.230769	1	1	1.321429	1.285714
Connected Node Ratio	0.714286	0.8	1	1	0.8	0.875	1	1	0.833333	0.857143	0.857143	0.928571
% 4-Way Intersections	-	-	-	-	-	-	-	-	-	-	16.66667	19.23077

Table 15 Link-Node Ratio, Connected Node Ratio, and Percent 4-Way Intersections for Greenway School Connector Route

	School Connector Route: Wildwood Ave											
	Neighborhood Zone											
	1		2		3		4		5		Total	Total
Option	A	B	A	B	A	B	A	B	A	B	A	B
# of Links	7	5	13	14	11	8	14	16	4	4	35	34
# of Nodes	7	5	11	11	10	7	12	12	5	5	27	25
# of Cul-de-Sacs	2	1	0	0	2	1	0	0	1	1	4	2
# of Intersections	5	4	11	11	8	6	12	12	4	4	23	23
Link-Node Ratio	1	1	1.181818	1.272727	1.1	1.142857	1.166667	1.333333	0.8	0.8	1.296296	1.36
Connected Node Ratio	0.714286	0.8	1	1	0.8	0.857143	1	1	0.8	0.8	0.851852	0.92
% 4-Way Intersections	-	-	-	-	-	-	-	-	-	-	13.04348	17.3913

Table 16 Link-Node Ratio, Connected Node Ratio, and Percent 4-Way Intersections for Dalton Pike School Connector Route

APPENDIX B

Sample Calculations

[The following provides sample calculations for pedestrian route directness]

Sample calculation for Blythe Avenue Route

$$\begin{aligned} \text{Pedestrian Route Directness} &= \frac{\text{Route Distance}}{\text{Straight Line Distance}} \\ &= \frac{1.004 \text{ miles}}{.852 \text{ miles}} = 1.178 \end{aligned}$$

APPENDIX C

Sample Calculations

[The following provides sample calculations for effective walk area (EWA)]

Sample calculation for EWA on 20th Street Blythe Avenue intersection

$$\text{Effective Walk Area (EWA)} = \frac{\text{Accessible Parcels}}{\text{Total Parcels}}$$

$$= \frac{47}{112} = .420$$

Node	Parcel within Walking Distance	Total Parcels	EWA
20th Street/Blythe Ave	47	112	0.419643
18th Street/Blythe Ave	121	165	0.733333
16th Street/Blythe Ave	174	246	0.707317
13th Street/Blythe Ave	222	271	0.819188
11th Street/Blythe Ave	191	223	0.856502
9th Street/Blythe Ave	125	158	0.791139
18th street/Aurora Ave	114	191	0.596859
20th Street/Greenway	33	100	0.33
18th street/Wilson Ave	116	184	0.630435
13th Street/Wilson Ave	236	342	0.690058
East Street/Hardwick St	154	264	0.583333
14th Street/Hardwick St	140	251	0.557769
15th Street/Hardwick St	145	257	0.564202
9th Street/Hardwick St	110	202	0.544554
16th Street/Aurora Ave	191	316	0.60443
15th Street/Aurora Ave	213	343	0.620991
9th Street/Wildwood Ave	110	202	0.544554
East Street/Wildwood Ave	142	239	0.594142
14th Street/Wildwood Ave	95	198	0.479798
15th Street/Wildwood Ave	87	196	0.443878
18th Street/Wildwood Ave	67	185	0.362162
20th Street/Wildwood Ave	30	95	0.315789
13th Street/Aurora Ave	225	338	0.66568
13th Street/SE King Edward Ave	150	214	0.700935
9th Street/Aurora Ave	136	224	0.607143
Average EWA			0.590553

Table 17 EWA for Main Proposed Routes and Connector Option A

Node	Parcel within Walking Distance	Total Parcels	EWA
20th Street/Blythe Ave	23	112	0.205357
18th Street/Blythe Ave	96	165	0.581818
16th Street/Blythe Ave	153	246	0.621951
13th Street/Blythe Ave	194	271	0.715867
11th Street/Blythe Ave	200	223	0.896861
9th Street/Blythe Ave	112	158	0.708861
18th street/Aurora Ave	114	191	0.596859
20th Street/Greenway	33	100	0.33
18th street/Wilson Ave	93	184	0.505435
13th Street/Wilson Ave	229	342	0.669591
East Street/Hardwick St	160	264	0.606061
14th Street/Hardwick St	144	251	0.573705
15th Street/Hardwick St	144	257	0.560311
9th Street/Hardwick St	105	202	0.519802
16th Street/Aurora Ave	176	316	0.556962
15th Street/Aurora Ave	195	343	0.568513
9th Street/Wildwood Ave	105	202	0.519802
East Street/Wildwood Ave	132	239	0.552301
14th Street/Wildwood Ave	127	198	0.641414
15th Street/Wildwood Ave	120	196	0.612245
18th Street/Wildwood Ave	61	185	0.32973
20th Street/Wildwood Ave	25	95	0.263158
13th Street/Aurora Ave	237	338	0.701183
13th Street/SE King Edward Ave	149	214	0.696262
9th Street/Aurora Ave	130	224	0.580357
Average EWA			0.564576

Table 18 EWA for Main Proposed Routes and Connector Option B

APPENDIX D

Sample Calculations

[The following provides sample calculations for stopping sight distance (SSD)]

Calculation of Stopping Sight Distance at Crosswalk 46

Coefficient of friction (when road is wet), $f = 0.7$

Perception of time, $t = 2.5$ seconds

Speed Limit, $v = 30$ mph

Gradient between Vehicle 46 and Pedestrian 46, G

$$\begin{aligned} \text{Grade, } G &= \frac{(\text{Elevation at crosswalk}) - (\text{Elevation of vehicle})}{\text{Absolute distance}} \\ &= \frac{(909 \text{ ft}) - (910 \text{ ft})}{132 \text{ ft}} = -0.007575 \end{aligned}$$

$$\begin{aligned} \text{Stopping Sight Distance, } SSD &= 1.47 \times (V) \times (t) \times \left[\frac{V^2}{Ao (f + G)} \right] \\ &= 1.47 \times (30 \text{ mph}) \times (2.5 \text{ seconds}) \times \left[\frac{(30 \text{ mph})^2}{(30)(0.7 - 0.007575)} \right] \\ &= \boxed{153.6 \text{ ft}} \end{aligned}$$

Stopping Sight Distance Conflict:

Absolute Distance > SSD

132 ft > 153.6 ft

FALSE

, thus there is a stopping sight distance conflict.

Stopping Sight Distance (ft)	Crosswalk #	Elevation from Car Vie (ft)	Absolute Distance (ft)	Elevation from Pedestrian Crossing (ft)	Dalton Pike Route	Blythe Avenue Route	Greenway Route	Crosswalk #	Connector Route A	Connector Route B	If Absolute Distance > SSD?
183.8	1	898	353	912				1			T
120.9	2	910	230	914	120.92	120.92	120.92	2			T
151.8	3	902	365	910				3			T
149.9	4	885	404	908				4			T
152.2	5	900	458	907				5		112.50	T
151.8	6	933	188	937				6			T
157.8	7	936	349	912				7			T
154.6	8	924	375	915				8	152.19	152.19	T
151.6	9	909	428	920				9	151.84	151.84	T
154.2	10	909	285	904				10	157.78	157.78	T
148.0	11	875	298	903				11	154.63	154.63	T
119.9	12	893	267	904				12			T
184.9	13	906	706	924	184.91	184.91	184.91	13			T
151.6	14	917	233	923				14			T
149.4	15	886	302	906	149.40	149.40	149.40	15	149.40		T
157.1	16	909	285	892				16			T

150.1	17	873	268	887	150.13	150.13	150.13	17			T
152.5	18	869	389	873				18			T
153.5	19	902	312	900				19			T
153.8	20	904	277	901	153.78	153.78	153.78	20			T
155.9	21	890	547	866	155.97	155.97	155.97	21			T
158.3	22	888	291	866				22	158.29	158.29	T
154.6	23	899	255	893				23			T
156.1	24	876	219	866				24	156.09	156.09	T
153.3	25	873	375	872				25		153.27	T
157.5	26	895	321	874				26		157.53	T
154.6	27	921	390	912				27		154.57	T
151.2	28	913	388	926				28	153.27	153.27	T
159.6	29	904	270	879				29			T
157.2	30	907	281	890				30			T
161.6	31	913	147	896				31			F
160.1	32	925	276	898				32			T
152.2	33	930	286	934				33	112.58	112.58	T
156.1	34	934	281	921				34	116.45	116.45	T
118.8	35	923	174	936	118.77			35			T
150.2	36	926	314	942	150.19			36			T
152.5	37	922	304	925	152.51			37	152.51	152.51	T
152.9	38	909	305	910				38	152.91		T
153.4	39	925	219	924				39	153.39	153.3	T
152.0	40	916	277	921				40	152.03		T
148.5	41	905	188	921				41	148.46	148.46	T
151.1 2	42	903	240	911				42	151.16	151.16	T
151.3	43	899	165	904				43	151.16	151.16	T

151.7	44	902	173	906				44	151.74		T
150.6	45	874	303	887				45	150.63		T
153.6	46	910	132	909				46	153.58		F
150.7	47	886	242	896				47	150.72		T
149.9	48	881	227	894				48	149.87		T
157.9	49	904	241	887				49	157.91		T
148.0	50	893	211	913				50		147.99	T
157.2	51	909	298	891				51		157.15	T
		Sum (ft)			1336.6	915.1	915.1		3438.6	2952.8	
		Average (ft)			148.5	152.5	152.51		149.5	155.4	
		Cross Walks #			9.0	6.0	6.0		23.0	19.0	

Table 19 Stopping Sight Distance Results

APPENDIX E

Sample Calculations

[The following provides sample calculations for right of way (ROW)]

Right of Way for Blythe Ave SE between 20th & 18th Street:

ROW > 40 ft

35 ft > 40 ft

FALSE

, thus there is a ROW conflict

Right of Way for 15th St. between Blythe Ave SE & Aurora Ave SE:

ROW > 40 ft

20 ft > 40 ft

FALSE

, thus there is a ROW conflict

Right of Way for 18th St. between Blythe Ave SE & Wildwood Ave SE:

ROW > 40 ft

35 ft > 40 ft

FALSE

, thus there is a ROW conflict

APPENDIX F

Sample Calculations

[The following provides sample calculations for cost and distance]

Sample Calculation for Blythe Ave School Connector Route & Neighborhood Sidewalk Connector A

Mileage of Blythe Avenue that requires sidewalk converted into linear foot

Mileage of Blythe Avenue route that requires sidewalk
Sidewalk Required (miles) = 0.54 miles

Mileage of Blythe Avenue route that requires sidewalk converted into linear foot

$$\begin{aligned} \text{Sidewalk Required (feet)} &= \text{Length of route} \times \left(\frac{5280 \text{ feet}}{\text{mile}} \right) \\ &= 0.54 \text{ miles} \times \left(\frac{5280 \text{ feet}}{\text{mile}} \right) = 2851.2 \text{ feet} \end{aligned}$$

Average cost for sidewalk based on linear foot on Blythe Avenue Route

$$\begin{aligned} \text{Average Cost of Sidewalk (\$)} &= \sum (\text{Length of sidewalk} \times \text{Average cost per linear foot}) \\ &= (2851.2 \text{ feet}) \times \left(\$21 \frac{\text{average cost of curb and gutter}}{\text{linear foot}} \right) \\ &\quad + (2851.2 \text{ feet}) \times \left(\$32 \frac{\text{average cost of concrete sidewalk}}{\text{linear foot}} \right) \\ &= \$151,113.6 \text{ average cost of sidewalk} \end{aligned}$$

Average cost of stripped crosswalk for Blythe Avenue

$$\begin{aligned} \text{Average Cost of Stripped Crosswalk} &= (\text{Amount for stripped crosswalks}) \times \left(\frac{\$770}{\text{stripped crosswalk}} \right) \end{aligned}$$

$$\begin{aligned}
 &= (6 \text{ stripped crosswalk}) \times \left(\frac{\$770}{\text{stripped crosswalk}} \right) \\
 &= \$4620
 \end{aligned}$$

Formwork cost for Blythe Avenue

$$\begin{aligned}
 \text{Formwork Cost} &= (\text{Linear footage of sidewalk}) \times 2 \text{ sides} \times \left(\frac{\$2.76}{\text{feet}} \right) \\
 &= (3907.2 \text{ feet}) \times 2 \text{ sides} \times \left(\frac{\$2.76}{\text{feet}} \right) \\
 &= \$21,567.74
 \end{aligned}$$

Construction cost for Blythe Avenue

$$\begin{aligned}
 \text{Construction Cost} &= (\text{Linear footage of sidewalk}) \times 5 \text{ feet wide sidewalks} \times \left(\frac{\$1.94}{\text{feet}} \right) \\
 &= (3907.2 \text{ feet}) \times 5 \text{ feet wide sidewalks} \times \left(\frac{\$1.94}{\text{feet}} \right) \\
 &= \$37,899.84
 \end{aligned}$$

Total average cost for Blythe Avenue Route

$$\begin{aligned}
 \text{Total Average Cost (\$)} &= \text{Average cost of sidewalk} \\
 &\quad + \text{Average cost of stripped crosswalk} \\
 &= \$151,113.6 + \$4620 + \$21,567.74 + \$37,899.84 \\
 &= \$215,201.18
 \end{aligned}$$

Mileage of Neighborhood Sidewalk Connector A that requires sidewalk converted into linear foot

$$\begin{aligned}
 \text{Sidewalk Required (feet)} &= \text{Length of route} \times \left(\frac{5280 \text{ feet}}{\text{mile}} \right) \\
 &= 2.33 \text{ miles} \times \left(\frac{5280 \text{ feet}}{\text{mile}} \right) = 12,302.4 \text{ feet}
 \end{aligned}$$

Average cost of sidewalk based on linear foot

Average Cost of Sidewalk (\$)

$$\begin{aligned}
 &= \sum (\text{Length of sidewalk} \times \text{Average cost per linear foot}) \\
 &= (12,302.4 \text{ feet}) \times \left(\$21 \frac{\text{average cost of curb and gutter}}{\text{linear foot}} \right) \\
 &\quad + (12,302.4 \text{ feet}) \times \left(\$32 \frac{\text{average cost of concrete sidewalk}}{\text{linear foot}} \right) \\
 &= \$652,027.2 \text{ average cost of sidewalk}
 \end{aligned}$$

Average cost of stripped crosswalk for Neighborhood Connector A

Average Cost of Stripped Crosswalk

$$\begin{aligned}
 &= (\text{Amount for stripped crosswalks}) \times \left(\frac{\$770}{\text{stripped crosswalk}} \right) \\
 &= (27 \text{ stripped crosswalk}) \times \left(\frac{\$770}{\text{stripped crosswalk}} \right) \\
 &= \$20,790
 \end{aligned}$$

Average cost of stripped crosswalk for Wildwood Avenue

Average Cost of Stripped Crosswalk

$$\begin{aligned}
 &= (\text{Amount for stripped crosswalks}) \times \left(\frac{\$770}{\text{stripped crosswalk}} \right) \\
 &= (7 \text{ stripped crosswalk}) \times \left(\frac{\$770}{\text{stripped crosswalk}} \right) \\
 &= \$5,390
 \end{aligned}$$

Formwork cost for Neighborhood Connector A

$$\begin{aligned}
 \text{Formwork Cost} &= (\text{Linear footage of sidewalk}) \times 2 \text{ sides} \times \left(\frac{\$2.76}{\text{feet}} \right) \\
 &= (12,302.4 \text{ feet}) \times 2 \text{ sides} \times \left(\frac{\$2.76}{\text{feet}} \right) \\
 &= \$67,909.25
 \end{aligned}$$

Construction cost for Neighborhood Connector A

Construction Cost

$$= (\text{Linear footage of sidewalk}) \times 5 \text{ feet wide sidewalks} \times \left(\frac{\$1.94}{\text{feet}} \right)$$

$$\begin{aligned}
 &= (12,302.4 \text{ feet}) \times 5 \text{ feet wide sidewalks} \times \left(\frac{\$1.94}{\text{feet}} \right) \\
 &= \$119,333.28
 \end{aligned}$$

Total average cost for Neighborhood Connector A based

$$\begin{aligned}
 &\textit{Total Average Cost} (\$) \\
 &= \textit{Average cost of sidewalk} \\
 &+ \sum \textit{Average cost of stripped crosswalk} \\
 &= \$652,027.2 + \$20,790 + \$5,390 + \$67,909.25 \\
 &\quad + \$119,333.28 \\
 &= \$865,449.73
 \end{aligned}$$

Mileage of required sidewalk repairs converted into linear foot

Mileage of required sidewalk repairs

$$\textit{Sidewalk Required (miles)} = 0.53 \text{ miles}$$

Mileage of Blythe Avenue route that requires sidewalk converted into linear foot

$$\begin{aligned}
 \textit{Sidewalk Required (feet)} &= \textit{Length of route} \times \left(\frac{5280 \text{ feet}}{\text{mile}} \right) \\
 &= 0.53 \text{ miles} \times \left(\frac{5280 \text{ feet}}{\text{mile}} \right) = 2798.4 \text{ feet}
 \end{aligned}$$

Average cost for required sidewalk based on linear foot

$$\begin{aligned}
 &\textit{Average Cost of Sidewalk} (\$) \\
 &= \sum (\textit{Length of sidewalk} \times \textit{Average cost per linear foot}) \\
 &= (2798.4 \text{ feet}) \times \left(\$21 \frac{\textit{average cost of curb and gutter}}{\textit{linear foot}} \right) \\
 &+ (2798.4 \text{ feet}) \times \left(\$32 \frac{\textit{average cost of concrete sidewalk}}{\textit{linear foot}} \right) \\
 &= \$148,315.2 \text{ average cost of sidewalk}
 \end{aligned}$$

Cost Category	Cost (\$)
Average cost of curb and gutter per linear foot	21
Average cost of concrete sidewalk per linear foot	32
Average railing cost per linear foot	100
Average cost for each striped crosswalk	770

Table 20 Average cost for infrastructures

	Number of Crosswalks	Cost of Crosswalks (\$)
Blythe Avenue	6	4620
Greenway	6	4620
Dalton Pike	8	6160
Wildwood Avenue	7	5390
Neighborhood Connector Option A	27	20790
Neighborhood Connector Option B	27	20790

Table 21 Number and cost of Crosswalks per Route and Neighborhood Connector

APPENDIX G

Design Consideration	Blyth Ave Alternatives						Neighborhood Connector Alternatives	
	Blythe Ave		Greenway		Dalton Pike		Option A	Option B
Pedestrian Route Directness	1.178		1.13		1.539		-	-
Effective Walk Area	-		-		-		0.590553	0.564576
Stopping Sight Distance	0		0		0		1.00	0.00
Number of Crosswalks	6		6		8		27	27
ROW Conflicts	1		1		2		2	3
Cost	\$563,723		\$684,610		\$615,691		\$865,450	\$847,440
Cumulative Route Length	0.85		0.85		1.32		2.33 miles of sidewalk	2.28 miles in sidewalk
		Option A	Option B	Option A	Option B	Option A	Option B	
Connected Node Ratio	0.889	0.958	0.857	0.929	0.852	0.92		
Link-Node Ratio	1.333	1.625	1.321	1.286	1.296	1.360		

Table 22 Results of Comparative Matrix Analysis for Each Route and Connector Option

APPENDIX H

Sample Calculations

[The following provides sample calculations for the undrained shear strength, unconfined compression test, and the soil's unit weight, water content, liquid limit, plastic limit, plasticity index, and bearing capacity]

Undrained Shear Strength Reading

Reading on graduated scale was 0.8.

Each mark on graduate scale equals 1kPa.

Undrained shear strength = 80kPa

Conversion:

$$\begin{aligned} \text{Undrained Shear Strength, } Su \left(\frac{\text{lb}}{\text{ft}^2} \right) &= (80 \text{ kPa}) \times \left(\frac{1000 \text{ Pa}}{\text{kPa}} \right) \times \frac{0.0208854342 \frac{\text{lb}}{\text{ft}^2}}{\text{Pa}} \\ &= 1670.835 \frac{\text{lb}}{\text{ft}^2} \end{aligned}$$

Sample calculations for unconfined compression test for borehole 3, sample 3:

$$\begin{aligned} \text{Strain, } \varepsilon &= \frac{\text{Change in length}}{\text{Original length}} \\ &= \frac{0.00060826 \text{ in.}}{2.407 \text{ in.}} = 0.0002527 \end{aligned}$$

$$\begin{aligned} \text{Original Area (inches}^2\text{)} &= \frac{\pi}{4} \times (\text{diameter})^2 \\ &= \frac{\pi}{4} \times (1.869 \text{ in.})^2 = 2.7435 \text{ in.}^2 \end{aligned}$$

$$\begin{aligned} \text{Corrected Area (inches}^2\text{)} &= \frac{\text{Original Area}}{1 - \varepsilon} \\ &= \frac{2.7435 \text{ in.}^2}{1 - 0.0002527} = 2.74422 \text{ in.}^2 \end{aligned}$$

$$\begin{aligned} \text{Stress (psi)} &= \frac{\text{Load}}{\text{Corrected area}} \\ &= \frac{1.382 \text{ lbs.}}{2.74422 \text{ in.}^2} = 0.5036 \frac{\text{lb}}{\text{in.}^2} \end{aligned}$$

$$\begin{aligned} \text{Shear Stress (psf)} &= \frac{\text{Unconfined compressive strength}}{2} \\ &= \frac{19 \frac{\text{lb}}{\text{in.}^2}}{2} \times \frac{144 \text{ in.}^2}{\text{ft.}^2} = 2736 \frac{\text{lb}}{\text{ft.}^2} \end{aligned}$$

Sample calculations for unit weight borehole 2, sample 2:

Mass of sample = 320.5134 g

$$\begin{aligned} \text{Volume (in}^3\text{)} &= \pi \times \text{Height} \times \text{Radius}^2 \\ &= \pi \times (5.406 \text{ in.}^2) \times \left(\frac{1.853 \text{ inches}}{2} \right)^2 = 14.5786 \text{ in.}^3 \end{aligned}$$

$$\begin{aligned} \text{Unit Weight} \left(\frac{\text{lb}}{\text{in}^3} \right) &= \frac{\text{Mass of sample}}{\text{Volume}} \\ &= \frac{320.5134 \text{ g}}{14.5786 \text{ in.}^3} \times \frac{.0022 \text{ lbs.}}{\text{grams}} \times \left(\frac{12 \text{ in.}}{\text{ft}} \right)^3 = 83.5789 \frac{\text{lb.}}{\text{in.}^3} \end{aligned}$$

Sample calculations for water content for borehole 2, sample 2:

Mass of water = 2.47 grams (g)

Mass of solids = 11.91 g

$$\begin{aligned} \text{Water Content (\%)} &= \frac{\text{Mass of water}}{\text{Mass of oven dry specimen}} \times 100 \\ &= \frac{2.47 \text{ g}}{11.91 \text{ g}} \times 100\% = 20.739\% \end{aligned}$$

Sample calculations for liquid limit for borehole 2, sample 2, specimen 51-1:

Water content = 34.91%

Number of blows for groove closure = 64

$$\begin{aligned} \text{Liquid Limit} &= (\% \text{ water content}) \times \left(\frac{\text{Number of blows}}{25} \right)^{0.121} \\ &= (34.91\%) \times \left(\frac{64}{25} \right)^{0.121} = 39.12 = 39 \end{aligned}$$

Sample calculations for plastic limit for borehole 2, sample 2, specimen 51-1:

Mass of water = 0.57 g

Mass of solids = 2.42 g

$$\begin{aligned} \text{Water Content (\%)} &= \frac{\text{Mass of water}}{\text{Mass of oven dry specimen}} \times 100 \\ &= \frac{0.57 \text{ g}}{2.42 \text{ g}} \times 100\% = 23.55\% \end{aligned}$$

Plastic limit = 24

Sample calculations for plasticity index for borehole 2, sample 2, specimen 1 in bowl 51:

Liquid limit = 38

Plastic limit = 24

$$\begin{aligned} \text{Plasticity Index} &= \text{Liquid limit} - \text{Plastic limit} \\ &= 38 - 24 = 14 \end{aligned}$$

Sample calculations for bearing capacity for borehole 2, sample 2:

Ultimate Bearing Capacity, qult (psf)

$$\begin{aligned}
 &= (1.3 \times c' \times Nc) + (\sigma_{zd} \times Nq) + (0.4 \times \gamma' \times B \times N\gamma) \\
 &= \left(1.3 \times 712.8 \frac{lb}{ft^2} \times 5.7\right) + \left(83.5789 \frac{lb}{ft^2} \times 2 ft \times 1.0\right) + 0 \\
 &= 5449.0058 \frac{lb}{ft^2}
 \end{aligned}$$

$$\text{Allowable Bearing Capacity} = \frac{\text{Ultimate bearing capacity}}{\text{Factor of safety}}$$

$$= \frac{5449.0058 \frac{lb}{ft^2}}{3} = 1816.335 \frac{lb}{ft^2}$$

	Borehole 2, Sample 2	Borehole 3, Sample 3
Unit weight (lb/ft ³)	83.58	105.89
Water content (%)	20.7	21.45

Table 23 Unit Weight and Water Content for Borehole 2 and Borehole 3

Specimen 1 - Bowl 51	Water Content (%)	Number of Blows	Liquid Limit
1	34.91	64	39
2	34.12	54	37
3	35.23	39	37
4	35.63	30	36
5	36.24	27	37
6	41.67	15	39
Specimen 2 - Bowl 134			
1	35.61	74	41
2	35.65	69	40
3	41.35	33	43
4	38.26	29	39
5	44.13	18	42

Table 24 Liquid Limit for Borehole 2, Soil Sample 2

Specimen 1 -Bowl 51	Water content (%)	Plastic Limit
1	23.55	24
2	23.88	24
4	22.75	23
3	21.59	22
Specimen 2 - Bowl 134		
2	18.64	19
3	22.78	23
4	25	25
5	24.7	25

Table 25 Plastic Limit for Borehole 2, Soil Sample 2

Specimen 1 - Bowl 12	Water Content (%)	Number of Blows	Liquid Limit
2	38.03	28	39
3	42.18	14	39
4	38.05	34	39
5	30.37	79	35
Specimen 2 - Bowl 53			
2	0	38	0
3	38.56	28	39
4	22.4	17	21
5	0	91	0

Table 26 Liquid Limit for Borehole 3, Soil Sample 3

Specimen 1 - Bowl 12	Water Content (%)	Plastic Limit
1	20.45	20
2	21.25	21
3	19.37	19
4	19.03	19
Specimen 2 - Bowl 53		
1	21.3	21
3	20.83	21
4	19.09	19
2	15.97	16

Table 27 Plastic Limit for Borehole 3, Soil Sample 3

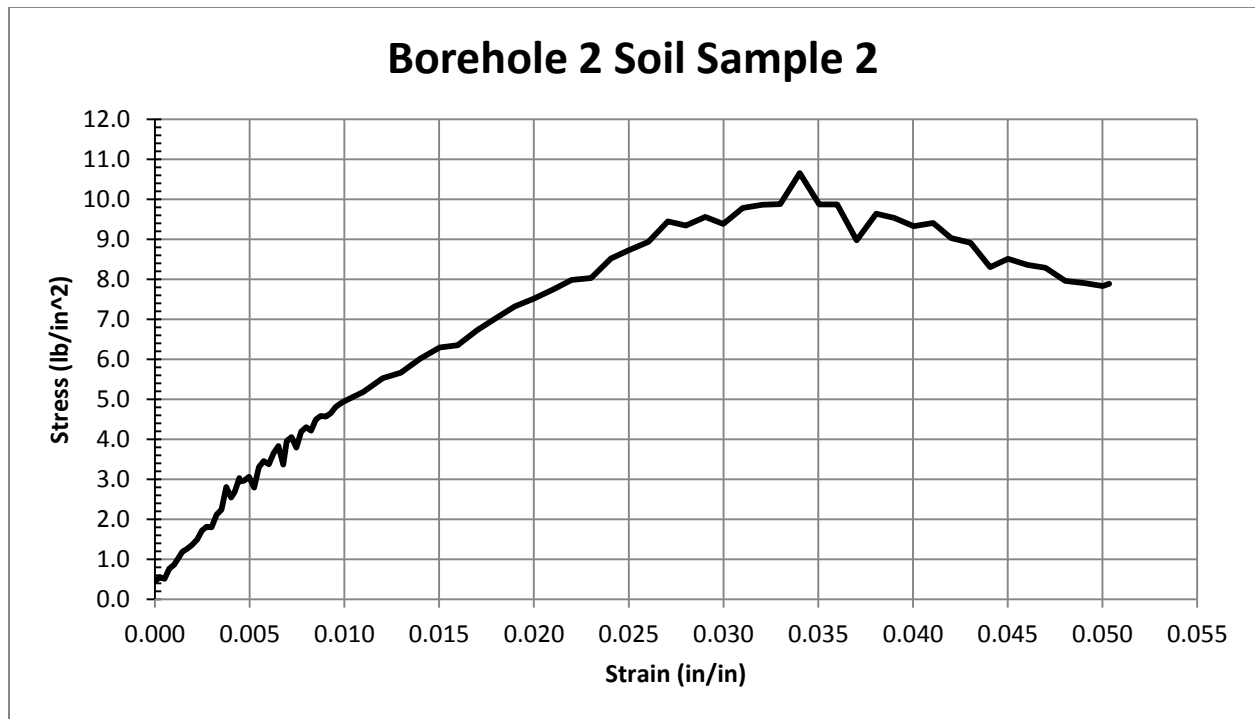


Figure 35

Stress vs. strain graph for borehole 2, sample 2

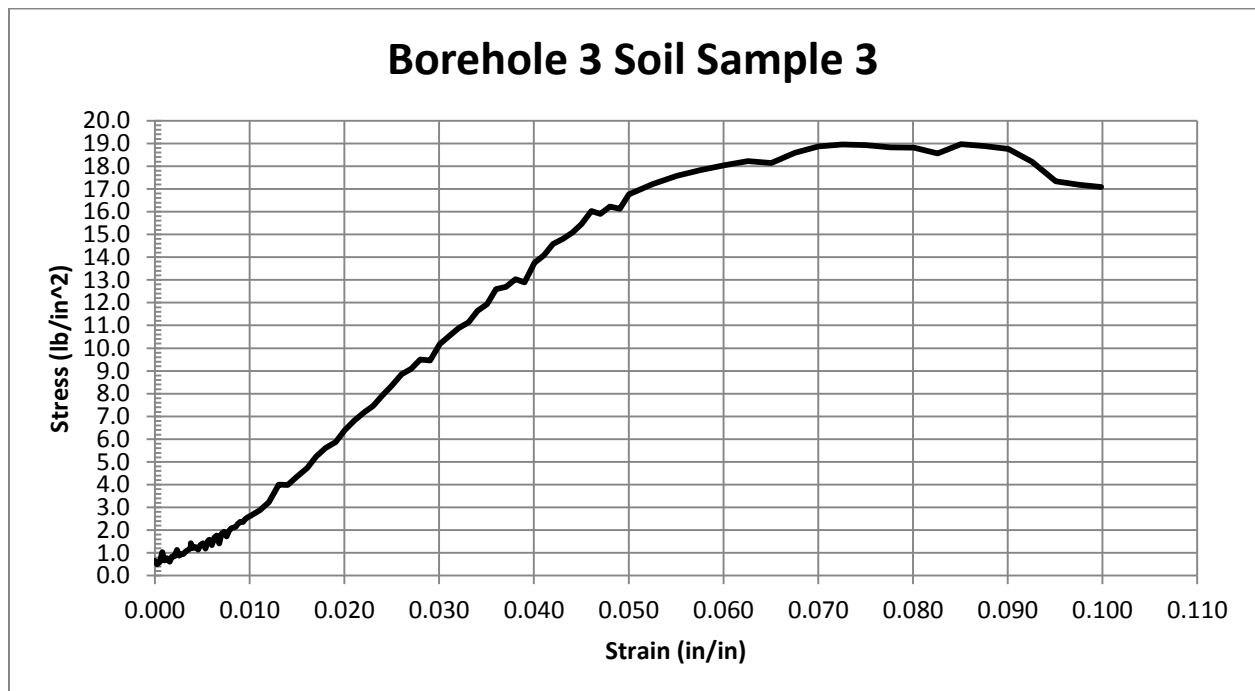


Figure 36

Stress vs. strain graph for borehole 3, sample 3

APPENDIX I

Sample Calculations

[The following provides sample calculations for factor of safety]

Sample calculations for weight of wall, resisting moment, effective stress, K_a , active pressure, active force, driving moment, and factor of safety for overturning and sliding on a 4 feet high east retaining wall

Wall weight

$$\begin{aligned} P_r &= \text{Weight of wall}, W = (\text{Height}) * (\text{Length}) * (\text{Width}) * \gamma \\ &= (4 \text{ feet}) * (\text{Unit length}) * (3.5 \text{ feet}) * \left(150 \frac{\text{lb}}{\text{ft}^3}\right) \\ &= 2100 \frac{\text{lb}}{\text{ft}} \end{aligned}$$

Resisting moment

$$M_r = (\text{Moment arm}) * P_r = \left(\frac{4}{2} \text{ feet}\right) * \left(2100 \frac{\text{lb}}{\text{ft}}\right) = 4200 \frac{\text{lb} - \text{ft}}{\text{ft}}$$

Effective stress

$$\sigma'_v = (\text{Height}) * \gamma = (4 \text{ feet}) * \left(\frac{105.890 \text{ lb}}{\text{ft}^3}\right) = 423.56 \frac{\text{lb}}{\text{ft}^2}$$

K_a

$$K_a = \frac{1 - \sin(\phi)}{1 + \sin(\phi)} = \frac{1 - \sin(0)}{1 + \sin(0)} = 1$$

Active pressure

$$\sigma_a = K_a * \sigma'_v = (1) * \left(423.56 \frac{\text{lb}}{\text{ft}^2}\right) = 423.56 \left(\frac{\text{lb}}{\text{ft}^2}\right)$$

Active force

$$P_a = P_d = \frac{H}{2} * \sigma_a = \left(\frac{1}{2}\right) * \left(423.56 \frac{lb}{ft^2}\right) * (4 \text{ feet}) = 847.12 \frac{lb}{ft}$$

Driving moment

$$M_d = (\text{Moment arm}) * P_d = \left(\frac{4}{3} \text{ feet}\right) * \left(847.12 \frac{lb}{ft}\right) = 1129.49 \frac{lb-ft}{ft}$$

Factor of safety against sliding

$$FS = \frac{\sum P_r}{\sum P_d} = \frac{2100 \frac{lb}{ft}}{847.12 \frac{lb}{ft}} = 2.47 > 1.5$$

Factor of safety against overturning

$$FS = \frac{\sum M_r}{\sum M_d} = \frac{4200 \frac{lb-ft}{ft}}{1129.49 \frac{lb-ft}{ft}} = 3.72 > 1.5$$



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APPENDIX PART II

Cleveland Sidewalk Studies

Plan for Blythe Avenue Area Sidewalk

Extension to 20th Street SE

And

Plan for Neighborhood Connector Sidewalks

to Wildwood Avenue

CONNECTED NODE RATIO ANALYSIS

LEGEND



LINKS



CUL-DE-SACS



Blythe Route with Neighborhood Connector Option A, Zone 1



Blythe Route with Neighborhood Connector Option A, Zone 2



Blythe Route with Neighborhood Connector Option A, Zone 3



Blythe Route with Neighborhood Connector Option A, Zone 4



Blythe Route with Neighborhood Connector Option A, Zone 5



Blythe Avenue Route with Neighborhood Connector Option B, Zone 1



Blythe Avenue Route with Neighborhood Connector Option B, Zone 2



Blythe Avenue Route with Neighborhood Connector Option B, Zone 3



Blythe Avenue Route with Neighborhood Connector Option B, Zone 4



Blythe Avenue Route with Neighborhood Connector Option B, Zone 5



Blythe Route with Neighborhood Connector Option A, Zone 1



Blythe Route with Neighborhood Connector Option A, Zone 3



Blythe Avenue Route with Neighborhood Connector Option B, Zone 1



Blythe Avenue Route with Neighborhood Connector Option B, Zone 3

NEIGHBORHOOD CONNECTOR OPTION A/B

	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	TOTAL
# OF LINKS	7/5	13/14	11/8	14/16	5/5	36/39
# OF NODES	7/5	11/11	10/7	12/12	5/5	27/24
# OF CDS	2/1	0/0	2/1	0/0	0/0	3/1
# OF INTER.	5/4	11/11	8/6	12/12	5/5	24/23

NEIGHBORHOOD CONNECTOR OPTION A

$$\text{ZONE 1: } \text{CNR} = \frac{5}{5+2} = \frac{5}{7} = \boxed{0.7143}$$

$$\text{ZONE 2: } \text{CNR} = \frac{11}{11+0} = \frac{11}{11} = \boxed{1}$$

$$\text{ZONE 3: } \text{CNR} = \frac{8}{8+2} = \frac{8}{10} = \boxed{0.8}$$

$$\text{ZONE 4: } \text{CNR} = \frac{12}{12+0} = \frac{12}{12} = \boxed{1}$$

$$\text{ZONE 5: } \text{CNR} = \frac{5}{5+0} = \frac{5}{5} = \boxed{1}$$

NEIGHBORHOOD CONNECTOR OPTION B

$$\text{ZONE 1: } \text{CNR} = \frac{4}{4+1} = \frac{4}{5} = \boxed{0.8}$$

$$\text{ZONE 2: } \text{CNR} = \frac{11}{11+0} = \frac{11}{11} = \boxed{1}$$

$$\text{ZONE 3: } \text{CNR} = \frac{6}{6+1} = \frac{6}{7} = \boxed{0.8571}$$

$$\text{ZONE 4: } \text{CNR} = \frac{12}{12+0} = \frac{12}{12} = \boxed{1}$$

$$\text{ZONE 5: } \text{CNR} = \frac{5}{5+0} = \frac{5}{5} = \boxed{1}$$



Dalton Pike Route with Neighborhood Connector Option A, Zone 1



Dalton Pike Route with Neighborhood Connector Option A, Zone 2



Dalton Pike Route with Neighborhood Connector Option A, Zone 3



Dalton Pike Route with Neighborhood Connector Option A, Zone 4



Dalton Pike Route with Neighborhood Connector Option A, Zone 5



Dalton Pike Route with Neighborhood Connector Option B, Zone 1



Dalton Pike Route with Neighborhood Connector Option B, Zone 2



Dalton Pike Route with Neighborhood Connector Option B, Zone 3



Dalton Pike Route with Neighborhood Connector Option B, Zone 4



Dalton Pike Route with Neighborhood Connector Option B, Zone 5



Dalton Pike Route with Neighborhood Connector Option A, Zone 1



Dalton Pike Route with Neighborhood Connector Option A, Zone 3



Dalton Pike Route with Neighborhood Connector Option A, Zone 5



Dalton Pike Route with Neighborhood Connector Option B, Zone 1



Dalton Pike Route with Neighborhood Connector Option B, Zone 3



Dalton Pike Route with Neighborhood Connector Option B, Zone 5

DALTON PIKE

CNR

NICHOLAS, TRICU

NEIGHBORHOOD CONNECTOR OPTION A:

<u>ZONE</u>	<u># OF NODES</u>	<u># OF CDS</u>	<u># OF INTERS.</u>	<u>CNR</u>
1	7	2	$7 - 2 = 5$	$\frac{5}{2+5} = \boxed{0.7143}$
2	11	0	$11 - 0 = 11$	$\frac{11}{1+0} = \boxed{1}$
3	10	2	$10 - 2 = 8$	$\frac{8}{2+8} = \boxed{0.8}$
4	12	0	$12 - 0 = 12$	$\frac{12}{12+0} = \boxed{1}$
5	5	1	$5 - 1 = 4$	$\frac{4}{1+4} = \boxed{0.8}$

NEIGHBORHOODS CONNECTOR OPTION B:

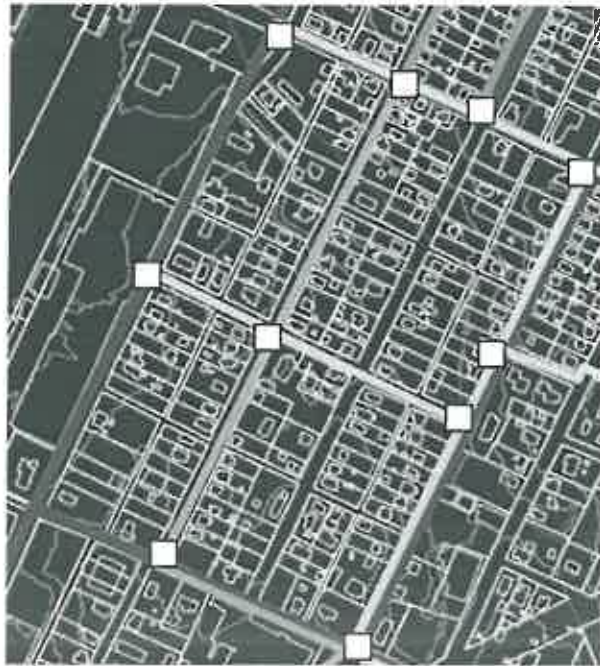
<u>ZONE</u>	<u># OF NODES</u>	<u># OF CDS</u>	<u># OF INTERS.</u>	<u>CNR</u>
1	5	1	$5 - 1 = 4$	$\frac{4}{1+4} = \boxed{0.8}$
2	11	0	$11 - 0 = 11$	$\frac{11}{11+0} = \boxed{1}$
3	7	1	$7 - 1 = 6$	$\frac{6}{1+6} = \boxed{0.857}$
4	12	0	$12 - 0 = 12$	$\frac{12}{12+0} = \boxed{1}$
5	5	1	$5 - 1 = 4$	$\frac{4}{1+4} = \boxed{0.8}$



Greenway Route with Neighborhood Connector Option A, Zone 1



Greenway Route with Neighborhood Connector Option A, Zone 2



Greenway Route with Neighborhood Connector Option A, Zone 3



Greenway Route with Neighborhood Connector Option A, Zone 4



Greenway Route with Neighborhood Connector Option A, Zone 5



Greenway Route with Neighborhood Connector Option B, Zone 1



Greenway Route with Neighborhood Connector Option B, Zone 2



Greenway Route with Neighborhood Connector Option B, Zone 3



Greenway Route with Neighborhood Connector Option B, Zone 4



Greenway Route with Neighborhood Connector Option B, Zone 5



Greenway Route with Neighborhood Connector Option B, Zone 1



Greenway Route with Neighborhood Connector Option B, Zone 3



Greenway Route with Neighborhood Connector Option B, Zone 5



Greenway Route with Neighborhood Connector Option A, Zone 1



Greenway Route with Neighborhood Connector Option A, Zone 3



Greenway Route with Neighborhood Connector Option A, Zone 5

GREENWAY

CNR

NICHOLAS, TRIEU

NEIGHBORHOOD CONNECTOR OPTION A:

<u>ZONE</u>	<u># OF NODES</u>	<u># OF S.D.</u>	<u># OF INT.</u>	<u>CNR</u>
1	7	2	$7 - 2 = 5$	$\frac{5}{5+2} =$
2	11	0	$11 - 0 = 11$	$\frac{11}{11+0} = \boxed{1}$
3	10	2	$10 - 2 = 8$	$\frac{8}{2+8} = \boxed{0.8}$
4	12	0	$12 - 0 = 12$	$\frac{12}{12+0} = \boxed{1}$
5	6	1	$6 - 1 = 5$	$\frac{5}{5+1} = \boxed{0.833}$

NEIGHBORHOOD CONNECTOR OPTION B:

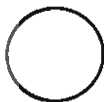
<u>ZONE</u>	<u># OF NODES</u>	<u># OF S.D.</u>	<u># OF INT.</u>	<u>CNR</u>
1	5	1	$5 - 1 = 4$	$\frac{4}{4+1} = \boxed{0.8}$
2	11	0	$11 - 0 = 11$	$\frac{11}{11+0} = \boxed{1}$
3	8	1	$8 - 1 = 7$	$\frac{7}{2+7} = \boxed{0.875}$
4	13	0	$13 - 0 = 13$	$\frac{13}{13+0} = \boxed{1}$
5	7	1	$7 - 1 = 6$	$\frac{6}{6+1} = \boxed{0.857}$

LINK-NODE RATIO ANALYSIS

LEGEND



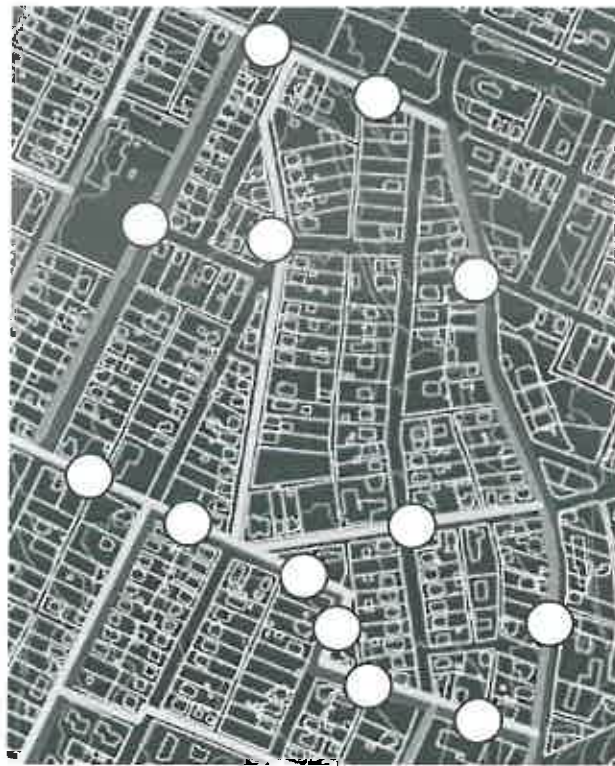
LINKS



NODES



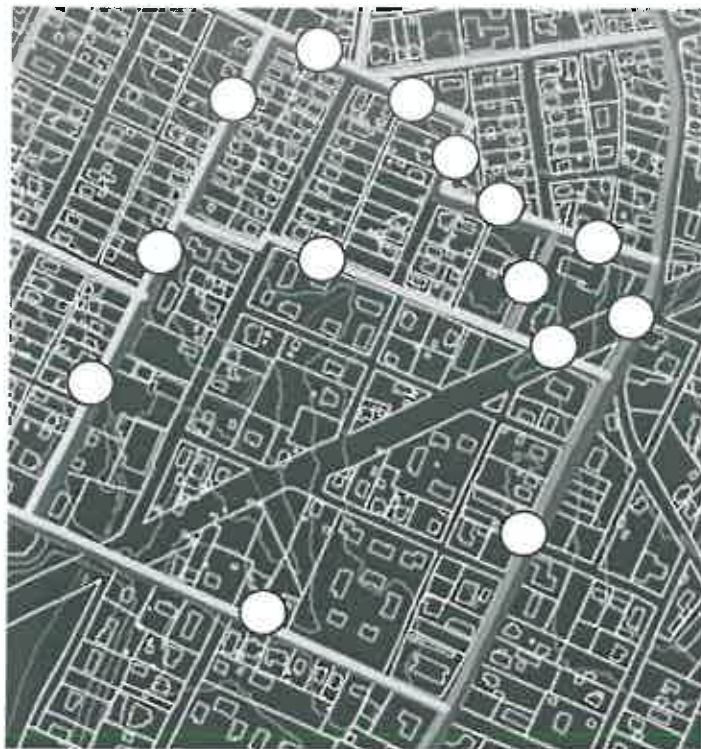
Blythe Route with Neighborhood Connector Option A, Zone 1



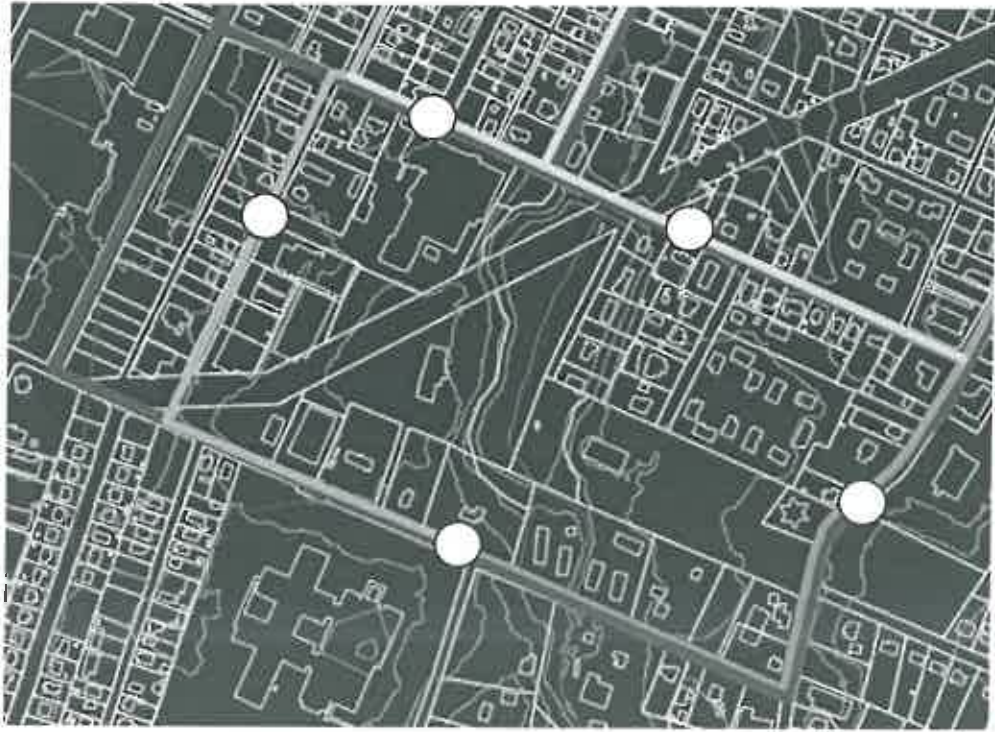
Blythe Route with Neighborhood Connector Option A, Zone 2



Blythe Route with Neighborhood Connector Option A, Zone 3



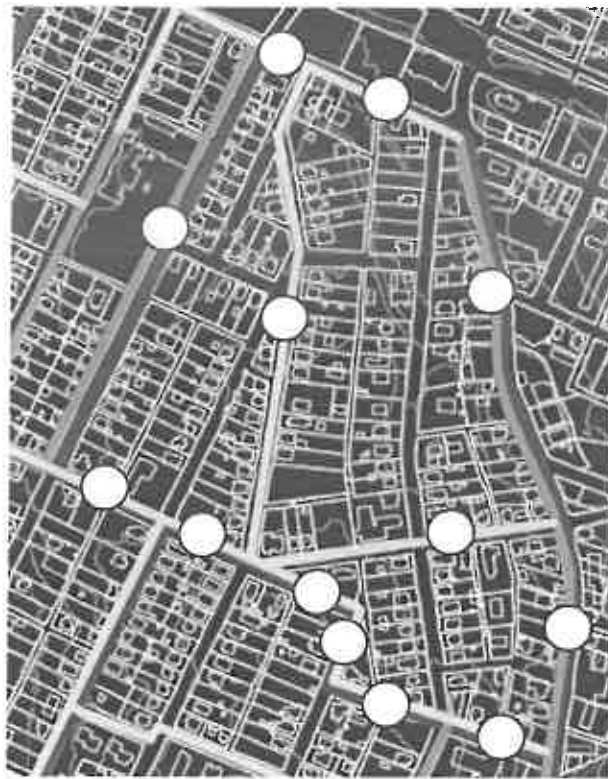
Blythe Route with Neighborhood Connector Option A, Zone 4



Blythe Route with Neighborhood Connector Option A, Zone 5



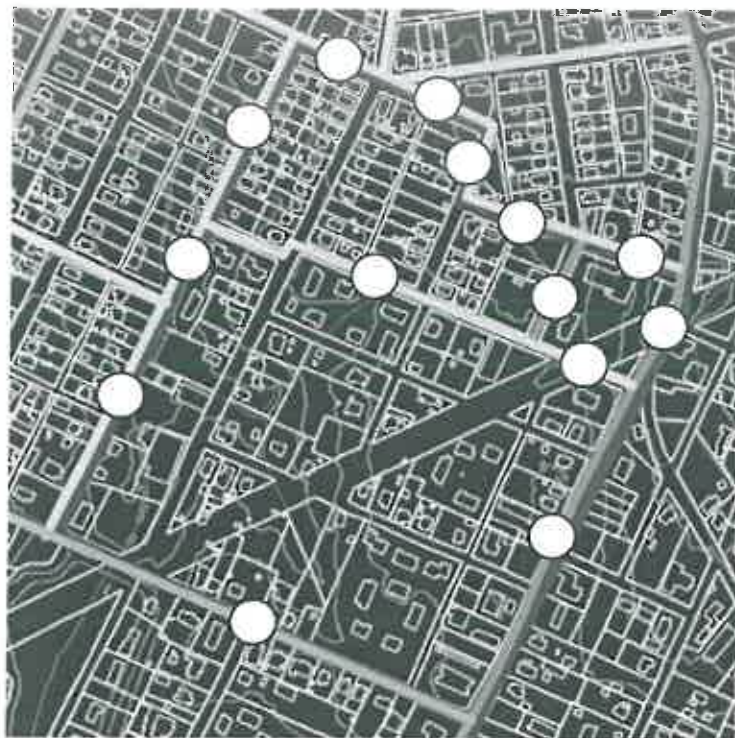
Dalton Pike Route with Neighborhood Connector Option A, Zone 1



Dalton Pike Route with Neighborhood Connector Option A, Zone 2



Dalton Pike Route with Neighborhood Connector Option A, Zone 3



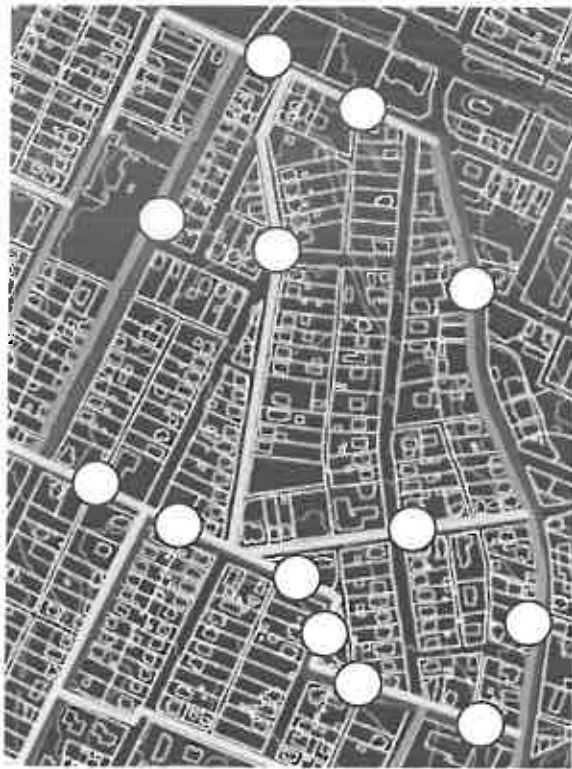
Dalton Pike Route with Neighborhood Connector Option A, Zone 4



Dalton Pike Route with Neighborhood Connector Option A, Zone 5



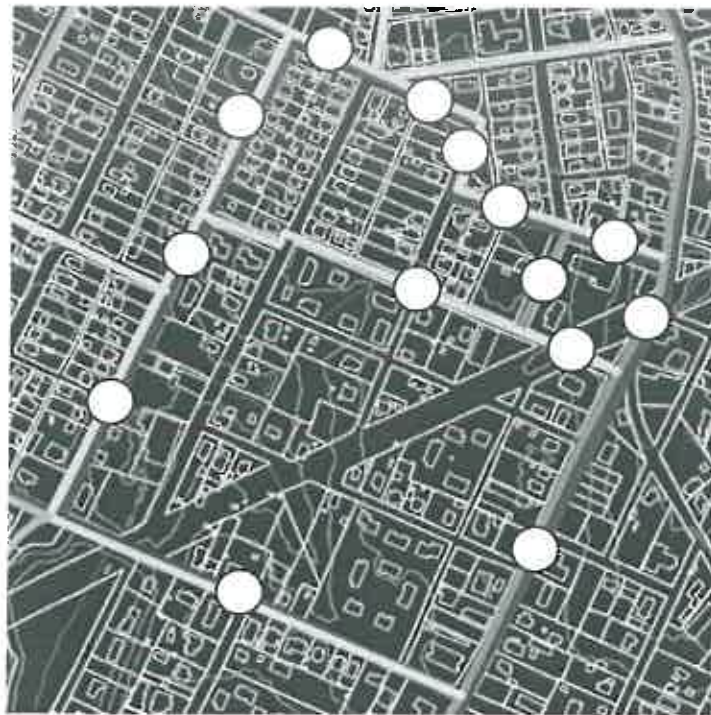
Greenway Route with Neighborhood Connector Option A, Zone 1



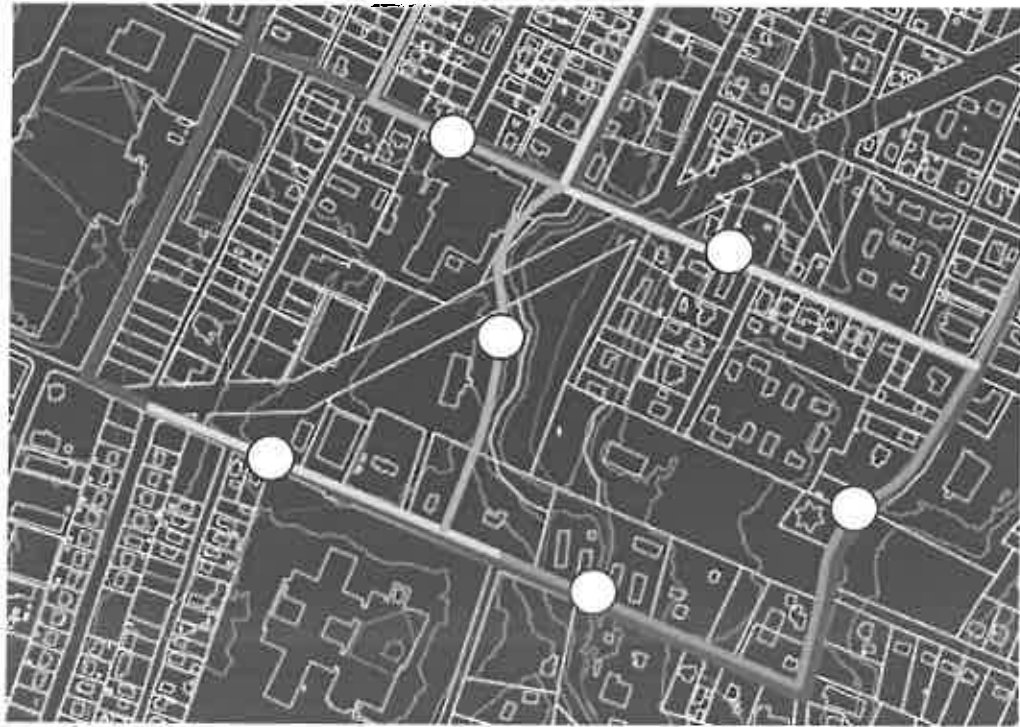
Greenway Route with Neighborhood Connector Option A, Zone 2



Greenway Route with Neighborhood Connector Option A, Zone 3



Greenway Route with Neighborhood Connector Option A, Zone 4



Greenway Route with Neighborhood Connector Option A, Zone 5

BLYTHE AVENUE ROUTE

<u>ZONE</u>	<u># OF LINKS</u>	<u># OF NODES</u>	<u>LNR</u>
1	7	7	$\frac{7}{7} = 1$
2	13	11	$\frac{13}{11} = 1.182$
3	11	10	$\frac{11}{10} = 1.1$
4	14	12	$\frac{14}{12} = 1.167$
5	5	5	$\frac{5}{5} = 1$

DALTON PIKE ROUTE

<u>ZONE</u>	<u># OF LINKS</u>	<u># OF NODES</u>	<u>LNR</u>
1	7	7	$\frac{7}{7} = 1$
2	13	11	$\frac{13}{11} = 1.182$
3	11	10	$\frac{11}{10} = 1.1$
4	14	12	$\frac{14}{12} = 1.167$
5	4	5	$\frac{4}{5} = 0.8$

GREENWAY ROUTE :

<u>ZONE</u>	<u># OF LINKS</u>	<u># OF NODES</u>	<u>LNR</u>
1	7	7	$\frac{7}{7} = 1$
2	13	11	$\frac{13}{11} = 1.182$
3	11	10	$\frac{11}{10} = 1.1$
4	14	12	$\frac{14}{12} = 1.167$
5	6	6	$\frac{6}{6} = 1$



1

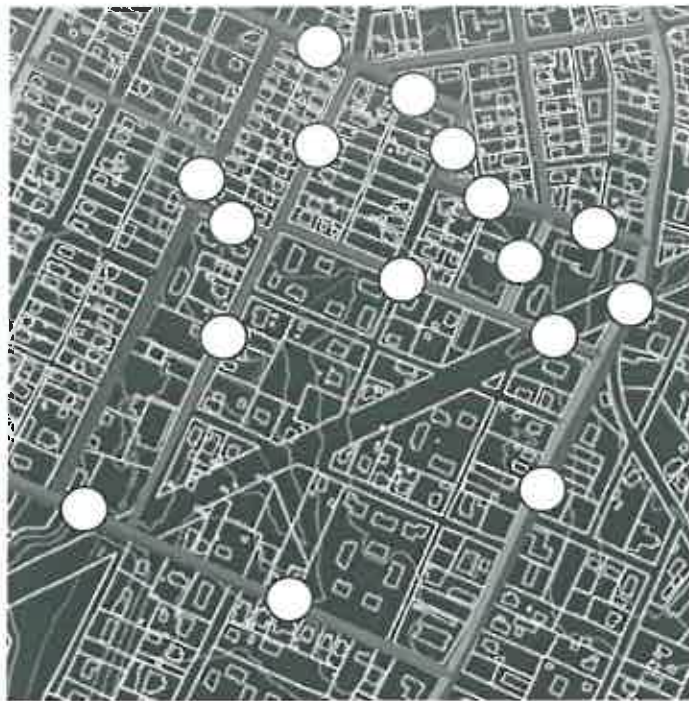
Blythe Avenue Route with Neighborhood Connector Option B, Zone 1



Blythe Avenue Route with Neighborhood Connector Option B, Zone 2



Blythe Avenue Route with Neighborhood Connector Option B, Zone 3



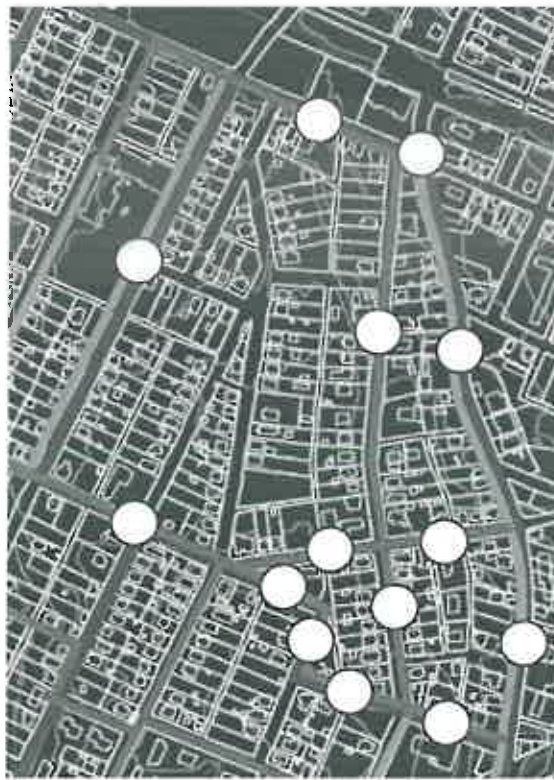
Blythe Avenue Route with Neighborhood Connector Option B, Zone 4



Blythe Avenue Route with Neighborhood Connector Option B, Zone 5



Dalton Pike Route with Neighborhood Connector Option B, Zone 1



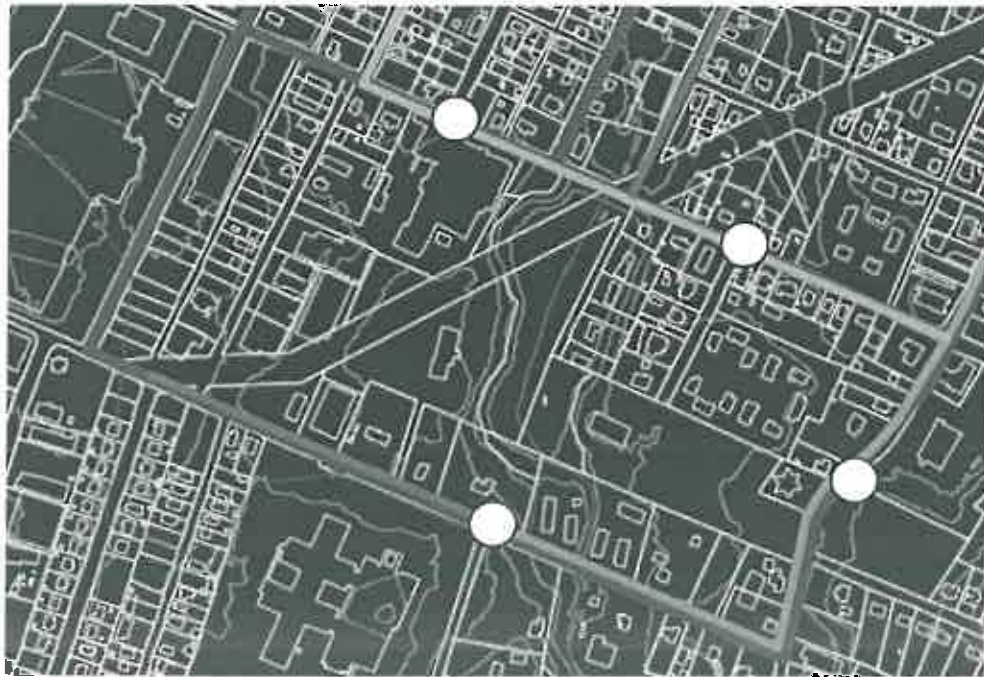
Dalton Pike Route with Neighborhood Connector Option B, Zone 2



Dalton Pike Route with Neighborhood Connector Option B, Zone 3



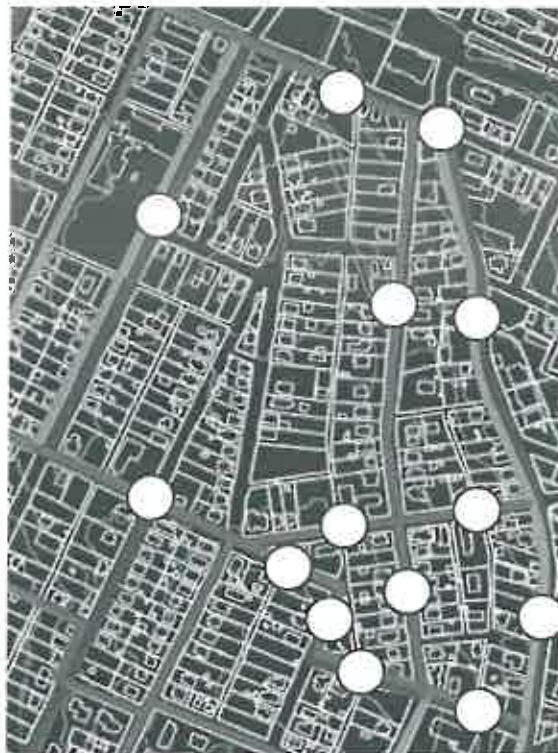
Dalton Pike Route with Neighborhood Connector Option B, Zone 4



Dalton Pike Route with Neighborhood Connector Option B, Zone 5



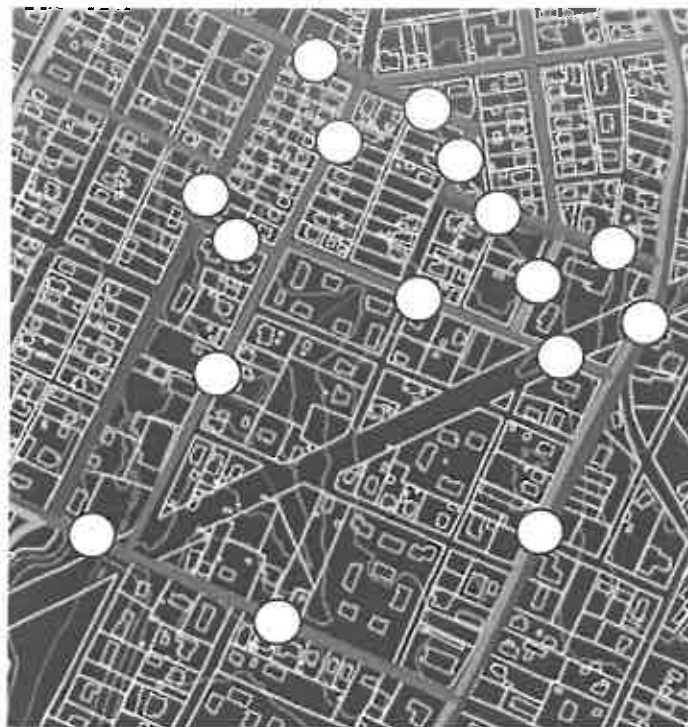
Greenway Route with Neighborhood Connector Option B, Zone 1



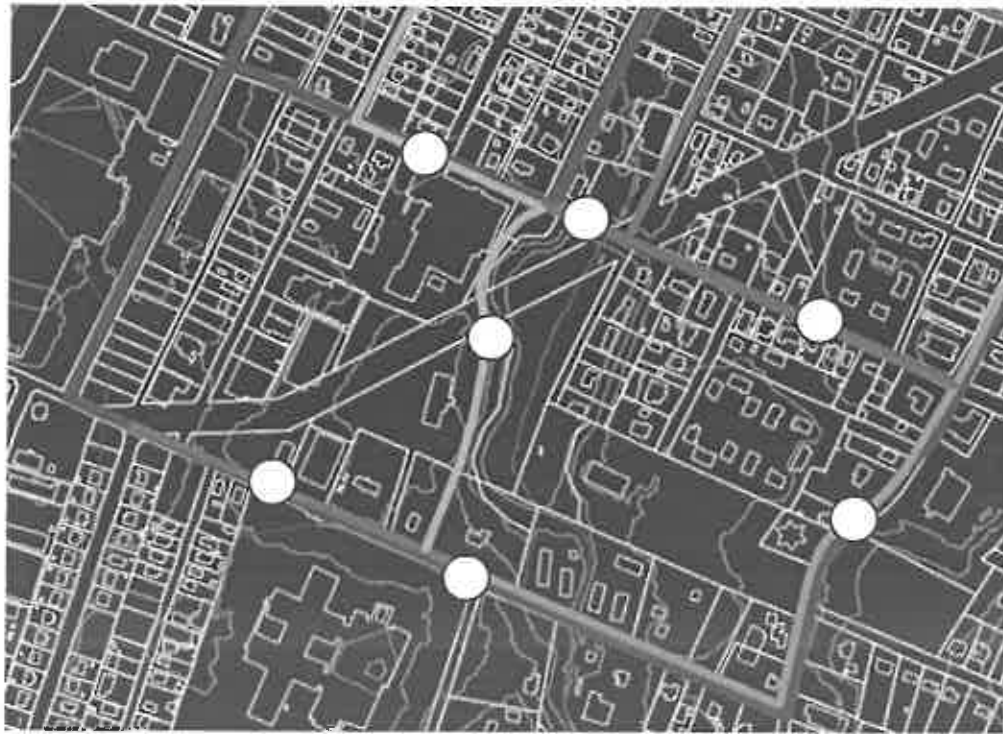
Greenway Route with Neighborhood Connector Option B, Zone 2



Greenway Route with Neighborhood Connector Option B, Zone 3



Greenway Route with Neighborhood Connector Option B, Zone 4



Greenway Route with Neighborhood Connector Option B, Zone 5

BLYTHE AVENUE ROUTE

<u>ZONE</u>	<u># OF LINKS</u>	<u># OF NODES</u>	<u>LNR</u>
1	5	5	$\frac{5}{5} = 1$
2	14	11	$\frac{14}{11} = 1.278$
3	8	8	$\frac{8}{8} = 1$
4	16	13	$\frac{16}{13} = 1.231$
5	7	7	$\frac{7}{7} = 1$

DALTON PIKE ROUTE

<u>ZONE</u>	<u># OF LINKS</u>	<u># OF NODES</u>	<u>LNR</u>
1	5	5	$\frac{5}{5} = 1$
2	14	11	$\frac{14}{11} = 1.278$
3	8	7	$\frac{8}{7} = 1.143$
4	16	12	$\frac{16}{12} = 1.33$
5	4	5	$\frac{4}{5} = 0.8$

GREENWAY ROUTE:

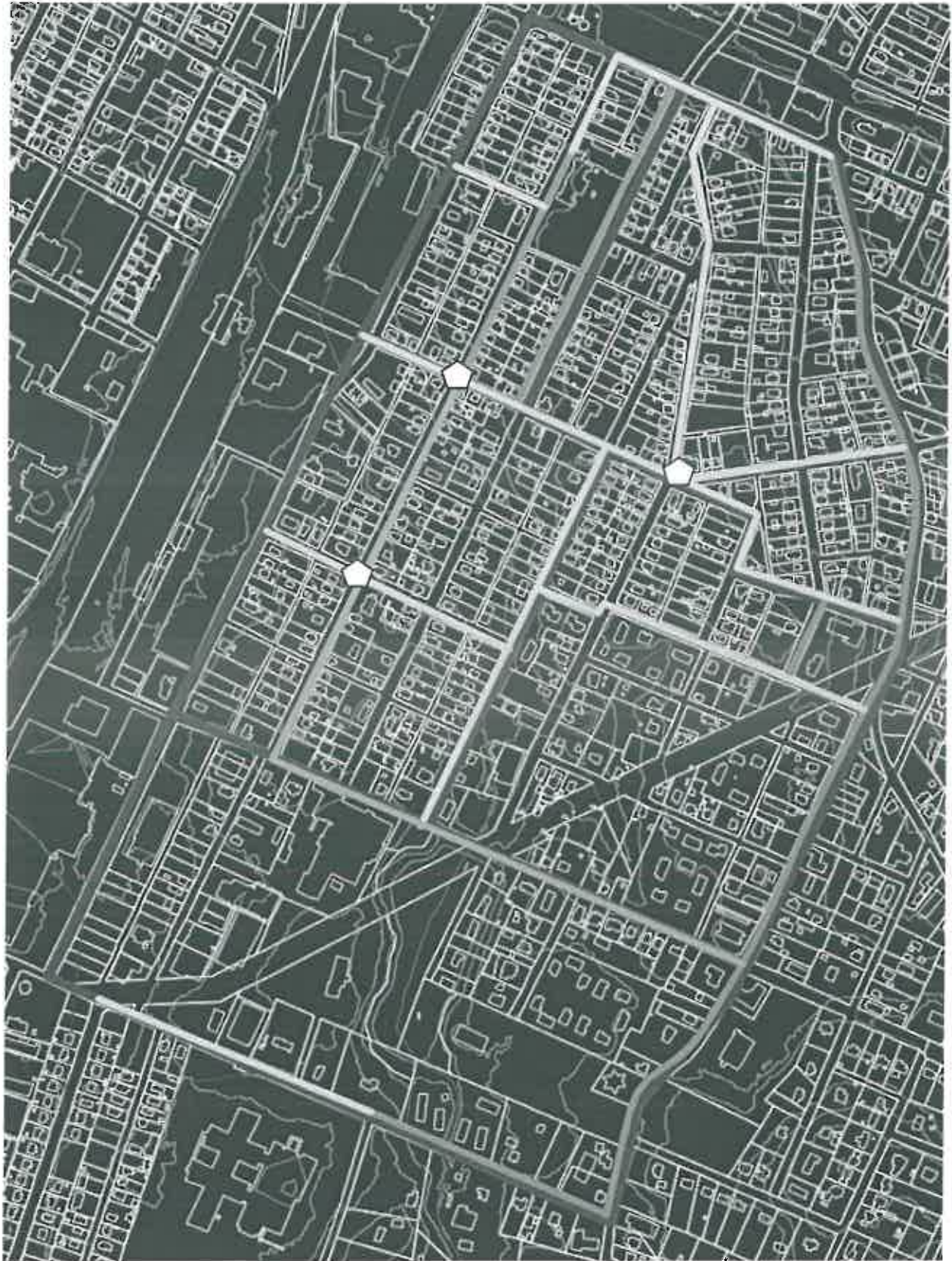
<u>ZONE</u>	<u># OF UNITS</u>	<u># OF NODES</u>	<u>LNR</u>
1	5	5	$\frac{5}{5} = 1$
2	14	11	$\frac{14}{11} = 1.273$
3	8	8	$\frac{8}{8} = 1$
4	16	13	$\frac{16}{13} = 1.231$
5	7	7	$\frac{7}{7} = 1$

PERCENTAGE FOUR-WAY INTERSECTION ANALYSIS

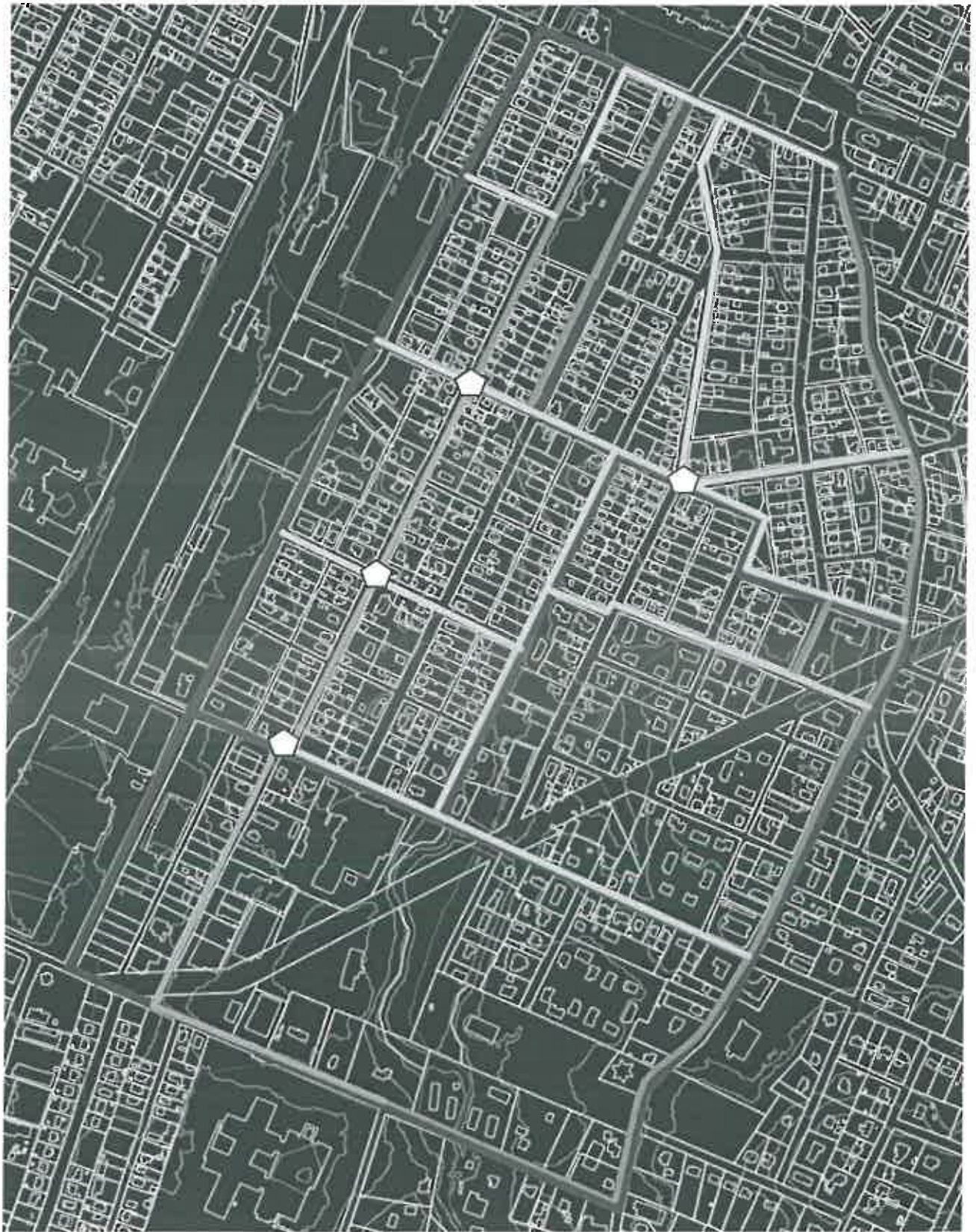
LEGEND



4-WAY INTERSECTION



Dalton Pike Route with Neighborhood Connector Option A



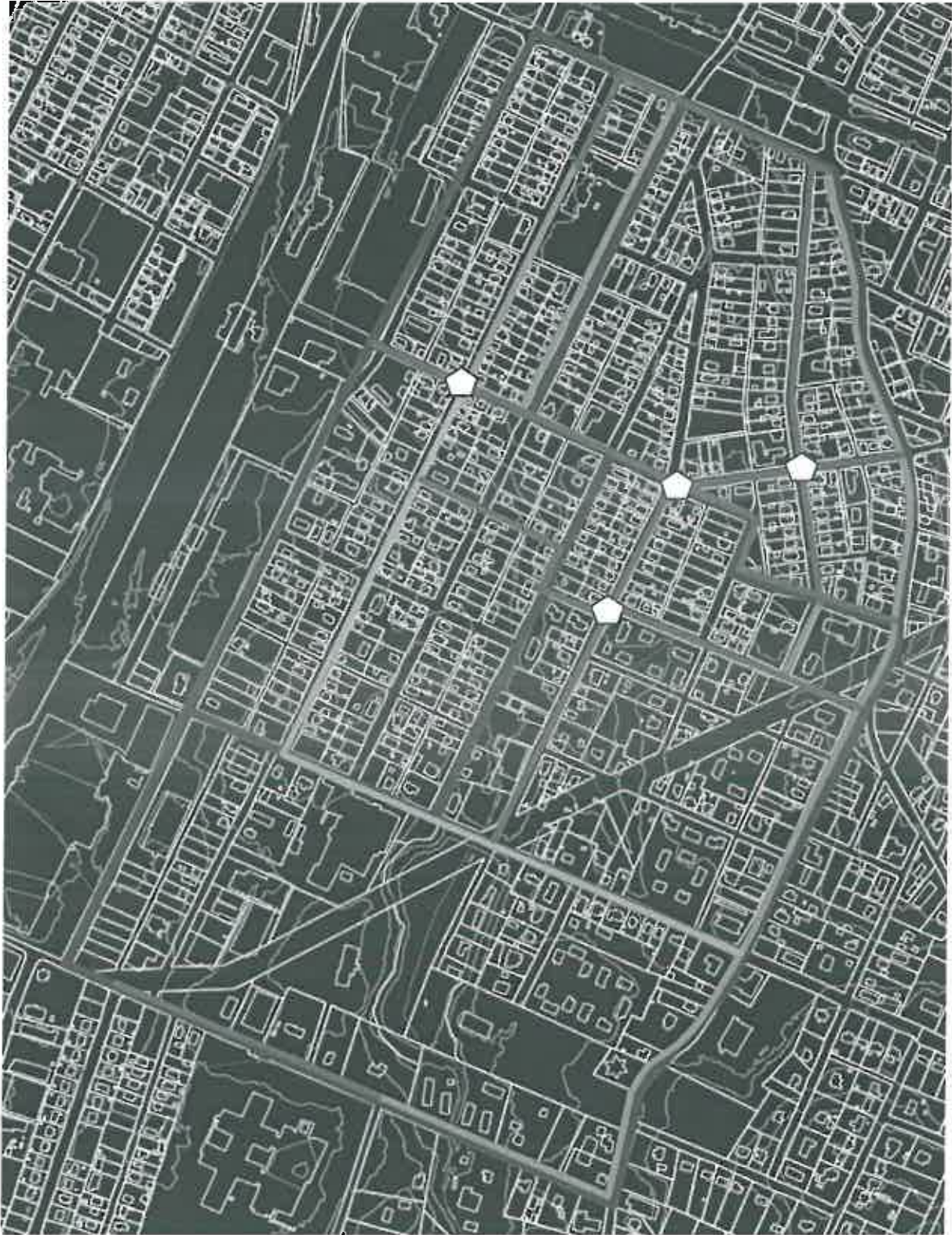
Blythe Route with Neighborhood Connector Option A



Greenway Route with Neighborhood Connector Option A



Blythe Avenue Route with Neighborhood Connector Option B



Dalton Pike Route with Neighborhood Connector Option B



Greenway Route with Neighborhood Connector Option B

$$\% \text{ 4-way} = \frac{\# \text{ OF 4-WAYS}}{\# \text{ OF INTERSECTIONS}} \times 100$$

NEIGHBORHOOD CONNECTOR OPTION B :

<u>ROUTE</u>	<u># OF 4WAYS</u>	<u># OF INTERS.</u>	<u>% 4-WAY INTER.</u>
BLYTHE	4	24	$\left(\frac{4}{24}\right) 100 = \boxed{16.67\%}$
DALTON	3	23	$\left(\frac{3}{23}\right) 100 = \boxed{13.04\%}$
GREENWAY	4	24	$\left(\frac{4}{24}\right) 100 = \boxed{16.67\%}$

NEIGHBORHOOD CONNECTOR OPTION A :

<u>ROUTE</u>	<u># OF 4WAYS</u>	<u># OF INTERS.</u>	<u>% 4-WAY INTER.</u>
BLYTHE	5	23	$\left(\frac{5}{23}\right) 100 = \boxed{21.74\%}$
DALTON	5	26	$\left(\frac{5}{26}\right) 100 = \boxed{19.23\%}$
GREENWAY	4	23	$\left(\frac{4}{23}\right) 100 = \boxed{17.39\%}$

***PEDESTRIAN
ROUTE
ANALYSIS***

Pedestrian Route Directness

route distance

Blythe 1.004 miles

Greenway .963 miles

Wildwood 1.312 miles

straight line distance

.852 miles

PRD = route distance / straight line distance

Blythe = $1.004 / .852 = 1.178$

Greenway = $.963 / .852 = 1.130$

Wildwood = $1.312 / .852 = 1.539$

***EFFECTIVE
WALK AREA
ANALYSIS***

Effective Walk Area

EWA = Parcels within walking distance / total parcels

Node	Total Parcels	PWD #		EWA _A	PWD _B		EWA _B
20 th /Blythe	112	47	47/112 =	.42	23	23/112 =	.21
18 th /Blythe	165	121	121/165 =	.73	96	96/165 =	.58
16 th /Blythe	246	174	174/246 =	.71	153	153/246 =	.62
13 th /Blythe	271	222	222/271 =	.82	194	194/271 =	.71
11 th /Blythe	223	191	191/223 =	.86	200	200/223 =	.89
9 th /Blythe	158	125	125/158 =	.79	112	112/158 =	.70
18 th /Aurora	191	114	114/191 =	.60	114	114/191 =	.60
20 th /Greenway	100	33	33/100 =	.33	33	33/100 =	.33
18 th /Wilson	184	116	116/184 =	.63	93	93/184 =	.51
13 th /Wilson	342	236	236/342 =	.69	229	229/342 =	.67
East/Hardwick	264	154	154/264 =	.58	160	160/264 =	.61
14 th /Hardwick	251	146	146/251 =	.56	144	144/251 =	.57
15 th /Hardwick	257	145	145/257 =	.56	144	144/257 =	.56
9 th /Hardwick	202	110	110/202 =	.54	105	105/202 =	.52
16 th /Aurora	316	191	191/316 =	.60	176	176/316 =	.56
15 th /Aurora	343	213	213/343 =	.62	195	195/343 =	.57
9 th /Wildwood	202	110	110/202 =	.54	105	105/202 =	.52
East/Wildwood	239	142	142/239 =	.59	132	132/239 =	.55
14 th /Wildwood	198	95	95/198 =	.48	127	127/198 =	.64
15 th /Wildwood	196	87	87/196 =	.44	120	120/196 =	.61
18 th /Wildwood	186	67	67/186 =	.36	61	61/186 =	.33
20 th /Wildwood	95	30	30/95 =	.32	25	25/95 =	.26
13 th /Aurora	338	225	225/338 =	.67	237	237/338 =	.70
13 th /SE King E	214	156	156/214 =	.73	149	149/214 =	.70
9 th /Aurora	224	136	136/224 =	.61	130	130/224 =	.58

$$\text{Average EWA}_A = [.42 + .73 + .71 + .82 + .86 + .79 + .60 + .33 + .63 + .69 + .58 + .56 + .56 + .54 + .62 + .54 + .59 + .48 + .44 + .36 + .32 + .67 + .7 + .61] / 25 = .591$$

$$\text{Average EWA}_B = [.21 + .58 + .62 + .71 + .89 + .71 + .6 + .33 + .51 + .67 + .61 + .57 + .50 + .52 + .56 + .57 + .52 + .55 + .64 + .61 + .33 + .26 + .7 + .7 + .58] / 25 = .565$$

***STOPPING
SIGHT DISTANCE
ANALYSIS***



Intersection of Blythe Ave SE & 18th St. SE

Vehicle: Longitude = $84^{\circ}52'38.82''\text{W}$

Latitude = $35^{\circ} 8'36.10''\text{N}$

Elevation = 910ft

Pedestrian: Longitude = $84^{\circ}52'41.31''\text{W}$

Latitude = $35^{\circ} 8'37.05''\text{N}$

Elevation = 914ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 230ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 18th St. SE = 25 mph

Stopping Sight Distance, SSD = 120.91ft

SSD < AD Therefore, safe.



Intersection of Wilson Ave SE & 18th St. SE

Vehicle: Longitude = $84^{\circ}52'28.51''\text{W}$

Latitude = $35^{\circ} 8'37.56''\text{N}$

Elevation = 900ft

Pedestrian: Longitude = $84^{\circ}52'30.72''\text{W}$

Latitude = $35^{\circ} 8'33.44''\text{N}$

Elevation = 907ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 458ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Wilson Ave SE = 30 mph

Stopping Sight Distance, SSD = 152.19ft

SSD < AD Therefore, safe.



Intersection of Wildwood Ave SE & 17th St. SE

Vehicle: Longitude = $84^{\circ}52'18.85''\text{W}$

Latitude = $35^{\circ}8'33.31''\text{N}$

Elevation = 933ft

Pedestrian: Longitude = $84^{\circ}52'16.75''\text{W}$

Latitude = $35^{\circ}8'32.54''\text{N}$

Elevation = 937ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 188ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Winnetawka Ave SE = 30 mph

Stopping Sight Distance, SSD = 151.84ft

SSD < AD Therefore, safe.



Intersection of Wildwood Ave SE & 15th St. SE

Vehicle: Longitude = $84^{\circ}52'17.33''\text{W}$

Latitude = $35^{\circ}8'40.04''\text{N}$

Elevation = 936ft

Pedestrian: Longitude = $84^{\circ}52'13.45''\text{W}$

Latitude = $35^{\circ}8'38.55''\text{N}$

Elevation = 912ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 349ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 15th St. SE = 30 mph

Stopping Sight Distance, SSD = 157.77ft

SSD < AD Therefore, safe.



Intersection of Wildwood Ave SE & 17th St. SE

Vehicle: Longitude = $84^{\circ}52'23.19''\text{W}$

Latitude = $35^{\circ}8'46.35''\text{N}$

Elevation = 924ft

Pedestrian: Longitude = $84^{\circ}52'25.59''\text{W}$

Latitude = $35^{\circ}8'42.58''\text{N}$

Elevation = 915ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 375ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Wildwood Ave SE = 30 mph

Stopping Sight Distance, SSD = 154.62ft

$\text{SSD} < \text{AD}$ Therefore, safe.



Intersection of Wilson Ave SE & 15th St. SE

Vehicle: Longitude = $84^{\circ}52'21.47''\text{W}$

Latitude = $35^{\circ} 8'51.16''\text{N}$

Elevation = 909ft

Pedestrian: Longitude = $84^{\circ}52'22.40''\text{W}$

Latitude = $35^{\circ} 8'47.64''\text{N}$

Elevation = 920ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 428ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Wilson Ave SE = 30 mph

Stopping Sight Distance, SSD = 151.58ft

$\text{SSD} < \text{AD}$ Therefore, safe.



Intersection of Aurora Ave SE & 13th St. SE

Vehicle: Longitude = $84^{\circ}52'26.93''\text{W}$

Latitude = $35^{\circ} 8'46.15''\text{N}$

Elevation = 909ft

Pedestrian: Longitude = $84^{\circ}52'25.46''\text{W}$

Latitude = $35^{\circ} 8'48.65''\text{N}$

Elevation = 904ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 285ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Aurora Ave SE = 30 mph

Stopping Sight Distance, SSD = 154.20ft

SSD > AD Therefore, safe.



Crossing 20th St. SE (Across from Blythe Elementary School)

Vehicle: Longitude = $84^{\circ}52'47.86''\text{W}$

Latitude = $35^{\circ} 8'26.90''\text{N}$

Elevation = 906ft

Pedestrian: Longitude = $84^{\circ}52'40.12''\text{W}$

Latitude = $35^{\circ} 8'23.92''\text{N}$

Elevation = 924ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 706ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 20th St. SE = 35 mph

Stopping Sight Distance, SSD = 184.90ft

SSD < AD Therefore, safe.



Intersection of King Edward Ave SE & 16th St. SE

Vehicle: Longitude = $84^{\circ}52'38.30''\text{W}$

Latitude = $35^{\circ} 8'44.56''\text{N}$

Elevation = 909ft

Pedestrian: Longitude = $84^{\circ}52'41.35''\text{W}$

Latitude = $35^{\circ} 8'45.95''\text{N}$

Elevation = 892ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 285ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 16th St. SE = 30 mph

Stopping Sight Distance, SSD = 156.10ft

$\text{SSD} < \text{AD}$ Therefore, safe.



Intersection of King Edward Ave SE & 13th St. SE

Vehicle: Longitude = $84^{\circ}52'40.32''\text{W}$

Latitude = $35^{\circ}8'54.93''\text{N}$

Elevation = 869ft

Pedestrian: Longitude = $84^{\circ}52'36.02''\text{W}$

Latitude = $35^{\circ}8'53.33''\text{N}$

Elevation = 873ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 389ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 13th St. SE = 30 mph

Stopping Sight Distance, SSD = 152.48ft

SSD < AD Therefore, safe.



Intersection of King Edward Ave SE & 11th St. SE

Vehicle: Longitude = $84^{\circ}52'28.63''\text{W}$

Latitude = $35^{\circ}8'58.83''\text{N}$

Elevation = 902ft

Pedestrian: Longitude = $84^{\circ}52'32.00''\text{W}$

Latitude = $35^{\circ}9'0.08''\text{N}$

Elevation = 900ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 312ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 11th St. SE = 30 mph

Stopping Sight Distance, SSD = 153.50ft

SSD < AD Therefore, safe.



Intersection of Blythe Ave SE & 11th St. SE

Vehicle: Longitude = $84^{\circ}52'31.53''\text{W}$

Latitude = $35^{\circ}8'59.87''\text{N}$

Elevation = 904ft

Pedestrian: Longitude = $84^{\circ}52'28.44''\text{W}$

Latitude = $35^{\circ}8'58.77''\text{N}$

Elevation = 901ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 277ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 11th St. SE = 30 mph

Stopping Sight Distance, SSD = 153.78ft

$\text{SSD} < \text{AD}$ Therefore, safe.



Intersection of Blythe Ave SE & 9th St. SE

Vehicle: Longitude = $84^{\circ}52'26.40''\text{W}$

Latitude = $35^{\circ}9'2.14''\text{N}$

Elevation = 890ft

Pedestrian: Longitude = $84^{\circ}52'25.11''\text{W}$

Latitude = $35^{\circ}9'4.38''\text{N}$

Elevation = 866ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 547ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Blythe Ave SE = 30 mph

Stopping Sight Distance, SSD = 155.97ft

SSD < AD Therefore, safe.



Intersection of Chippewa Ave SE & 9th St. SE

Vehicle: Longitude = $84^{\circ}52'23.31''\text{W}$

Latitude = $35^{\circ}9'0.43''\text{N}$

Elevation = 888ft

Pedestrian: Longitude = $84^{\circ}52'21.72''\text{W}$

Latitude = $35^{\circ}9'3.05''\text{N}$

Elevation = 867ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 291ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Chippewa Ave SE = 30 mph

Stopping Sight Distance, SSD = 158.29

SSD < AD Therefore, safe.



Intersection of Winnetawka Ave SE & 9th St.

Vehicle: Longitude = $84^{\circ}52'21.15''\text{W}$

Latitude = $35^{\circ}9'0.49''\text{N}$

Elevation = 876ft

Pedestrian: Longitude = $84^{\circ}52'20.16''\text{W}$

Latitude = $35^{\circ}9'2.45''\text{N}$

Elevation = 866ft

Distance between Pedestrian and Vehicle: Absolute Distance, $AD=219\text{ft}$

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Winnetawka Ave SE = 35 mph

Stopping Sight Distance, $SSD = 156.10\text{ft}$

$SSD < AD$ Therefore, safe.



Intersection of Hardwick St. SE & 9th St. SE

Vehicle: Longitude = $84^{\circ}52'15.75''\text{W}$

Latitude = $35^{\circ}8'56.94''\text{N}$

Elevation = 873ft

Pedestrian: Longitude = $84^{\circ}52'15.42''\text{W}$

Latitude = $35^{\circ}9'0.68''\text{N}$

Elevation = 872ft

Distance between Pedestrian and Vehicle: Absolute Distance, $AD = 375\text{ft}$

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Hardwick St. SE = 30 mph

Stopping Sight Distance, $SSD = 153.27$

$SSD < AD$ Therefore, safe.



Intersection of Hardwick St. SE & 11th St. SE

Vehicle: Longitude = $84^{\circ}52'19.53''\text{W}$

Latitude = $35^{\circ}8'57.01''\text{N}$

Elevation = 895ft

Pedestrian: Longitude = $84^{\circ}52'15.97''\text{W}$

Latitude = $35^{\circ}8'56.60''\text{N}$

Elevation = 874ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 321ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 11th St. SE = 30 mph

Stopping Sight Distance, SSD = 157.52ft

SSD < AD Therefore, safe.



Intersection of Hardwick St. SE & 14th St. SE

Vehicle: Longitude = $84^{\circ}52'15.84''\text{W}$

Latitude = $35^{\circ} 8'47.03''\text{N}$

Elevation = 913ft

Pedestrian: Longitude = $84^{\circ}52'15.24''\text{W}$

Latitude = $35^{\circ} 8'43.25''\text{N}$

Elevation = 926ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 388ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Hardwick St. SE = 30 mph

Stopping Sight Distance, SSD = 151.14ft

SSD < AD Therefore, safe.



Intersection of Wildwood Ave SE & 11th St. SE

Vehicle: Longitude = $84^{\circ}52'15.90''\text{W}$

Latitude = $35^{\circ}8'51.63''\text{N}$

Elevation = 904ft

Pedestrian: Longitude = $84^{\circ}52'12.71''\text{W}$

Latitude = $35^{\circ}8'52.03''\text{N}$

Elevation = 904ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 270ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 11th St. SE = 30 mph

Stopping Sight Distance, SSD = 159.64

SSD < AD Therefore, safe.



Intersection of Wildwood Ave SE & 12th St. SE

Vehicle: Longitude = $84^{\circ}52'14.66''\text{W}$

Latitude = $35^{\circ}8'48.46''\text{N}$

Elevation = 907

Pedestrian: Longitude = $84^{\circ}52'11.33''\text{W}$

Latitude = $35^{\circ}8'48.86''\text{N}$

Elevation = 890ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 281ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 12th St. SE = 30 mph

Stopping Sight Distance, SSD = 157.16

SSD < AD Therefore, safe.



Intersection of Wildwood Ave SE & 13th St. SE

Vehicle: Longitude = $84^{\circ}52'12.81''\text{W}$

Latitude = $35^{\circ}8'44.78''\text{N}$

Elevation = 913ft

Pedestrian: Longitude = $84^{\circ}52'11.11''\text{W}$

Latitude = $35^{\circ}8'44.29''\text{N}$

Elevation = 896ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 147ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 13th St. SE = 30 mph

Stopping Sight Distance, SSD = 161.58ft

SSD > AD Therefore, **NOT Safe**



Intersection of Wildwood Ave SE & 14th St. SE

Vehicle: Longitude = $84^{\circ}52'14.59''\text{W}$

Latitude = $35^{\circ} 8'42.90''\text{N}$

Elevation = 925ft

Pedestrian: Longitude = $84^{\circ}52'11.47''\text{W}$

Latitude = $35^{\circ} 8'41.91''\text{N}$

Elevation = 898ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 276ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 14th St. SE = 30 mph

Stopping Sight Distance, SSD = 160.06ft

$\text{SSD} < \text{AD}$ Therefore, safe.



Intersection of Hardwick St. SE & 15th St. SE

Vehicle: Longitude = $84^{\circ}52'15.43''\text{W}$

Latitude = $35^{\circ} 8'42.61''\text{N}$

Elevation = 930ft

Pedestrian: Longitude = $84^{\circ}52'16.75''\text{W}$

Latitude = $35^{\circ} 8'39.95''\text{N}$

Elevation = 934ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 286ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Hardwick St. SE = 30 mph

Stopping Sight Distance, SSD = 152.26

$\text{SSD} < \text{AD}$ Therefore, safe.



Intersection of Wiggins St. SE & 15th St. SE

Vehicle: Longitude = $84^{\circ}52'19.46''\text{W}$

Latitude = $35^{\circ} 8'43.96''\text{N}$

Elevation = 934ft

Pedestrian: Longitude = $84^{\circ}52'20.73''\text{W}$

Latitude = $35^{\circ} 8'41.38''\text{N}$

Elevation = 921ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 281ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Wiggins St. SE = 30 mph

Stopping Sight Distance, SSD = 156.14

SSD < AD Therefore, safe.



Intersection of Wildwood Ave SE & 18th St. SE

Vehicle: Longitude = $84^{\circ}52'21.18''\text{W}$

Latitude = $35^{\circ}8'29.50''\text{N}$

Elevation = 923ft

Pedestrian: Longitude = $84^{\circ}52'19.25''\text{W}$

Latitude = $35^{\circ}8'28.74''\text{N}$

Elevation = 936ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 174ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 18th St. SE = 25 mph

Stopping Sight Distance, SSD = 118.76ft

SSD < AD Therefore, safe.



Intersection of Fisher St. SE & 18th St. SE

Vehicle: Longitude = $84^{\circ}52'28.73''\text{W}$

Latitude = $35^{\circ} 8'28.67''\text{N}$

Elevation = 922ft

Pedestrian: Longitude = $84^{\circ}52'27.06''\text{W}$

Latitude = $35^{\circ} 8'31.42''\text{N}$

Elevation = 925ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 304ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Fisher St. SE = 30 mph

Stopping Sight Distance, SSD = 152.51ft

SSD < AD Therefore, safe.



Intersection of Wiggins St. SE & 12th St. SE

Vehicle: Longitude = $84^{\circ}52'18.94''\text{W}$

Latitude = $35^{\circ} 8'46.42''\text{N}$

Elevation = 925ft

Pedestrian: Longitude = $84^{\circ}52'21.33''\text{W}$

Latitude = $35^{\circ} 8'47.38''\text{N}$

Elevation = 924

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 219ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 13th St. SE = 30 mph

Stopping Sight Distance, SSD = 153.38ft

SSD < AD Therefore, safe.



Intersection of Hardwick St. SE & 12th St. SE

Vehicle: Longitude = $84^{\circ}52'16.35''\text{W}$

Latitude = $35^{\circ} 8'51.12''\text{N}$

Elevation = 903ft

Pedestrian: Longitude = $84^{\circ}52'16.00''\text{W}$

Latitude = $35^{\circ} 8'48.73''\text{N}$

Elevation = 911ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 240ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Hardwick St. SE = 30 mph

Stopping Sight Distance, SSD = 151.15

$\text{SSD} < \text{AD}$ Therefore, safe.



Intersection of Godfrey St. SE & 12th St. SE

Vehicle: Longitude = $84^{\circ}52'13.65''\text{W}$

Latitude = $35^{\circ}8'50.34''\text{N}$

Elevation = 899ft

Pedestrian: Longitude = $84^{\circ}52'13.09''\text{W}$

Latitude = $35^{\circ}8'48.91''\text{N}$

Elevation = 904ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 165ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Godfrey St. SE = 30 mph

Stopping Sight Distance, SSD = 151.32

SSD < AD Therefore, safe.



Intersection of Blythe Ave SE & 13th St. SE

Vehicle: Longitude = $84^{\circ}52'34.33''\text{W}$

Latitude = $35^{\circ} 8'48.86''\text{N}$

Elevation = 874ft

Pedestrian: Longitude = $84^{\circ}52'32.67''\text{W}$

Latitude = $35^{\circ} 8'51.53''\text{N}$

Elevation = 887ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 303ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Blythe Ave SE = 30 mph

Stopping Sight Distance, SSD = 150.63

SSD < AD Therefore, safe.



Intersection of Wilson Ave SE & 15th St. SE

Vehicle: Longitude = $84^{\circ}52'17.24''W$

Latitude = $35^{\circ} 8'43.55''N$

Elevation = 893ft

Pedestrian: Longitude = $84^{\circ}52'25.97''W$

Latitude = $35^{\circ} 8'42.65''N$

Elevation = 913ft

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 211ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on 15th St. SE = 30 mph

Stopping Sight Distance, SSD = 147.99ft

SSD < AD Therefore, safe.



Intersection of Aurora Ave SE & 15th St. SE

Vehicle: Longitude = $84^{\circ}52'26.68''\text{W}$

Latitude = $35^{\circ}8'46.61''\text{N}$

Elevation = 909ft

Pedestrian: Longitude = $84^{\circ}52'28.30''\text{W}$

Latitude = $35^{\circ}8'43.89''\text{N}$

Elevation = 891

Distance between Pedestrian and Vehicle: Absolute Distance, AD= 298ft

Coeff. Of Friction wet, $f = 0.7$

Perception Time (seconds), $t = 2.5$

Speed limit on Aurora Ave SE = 30 mph

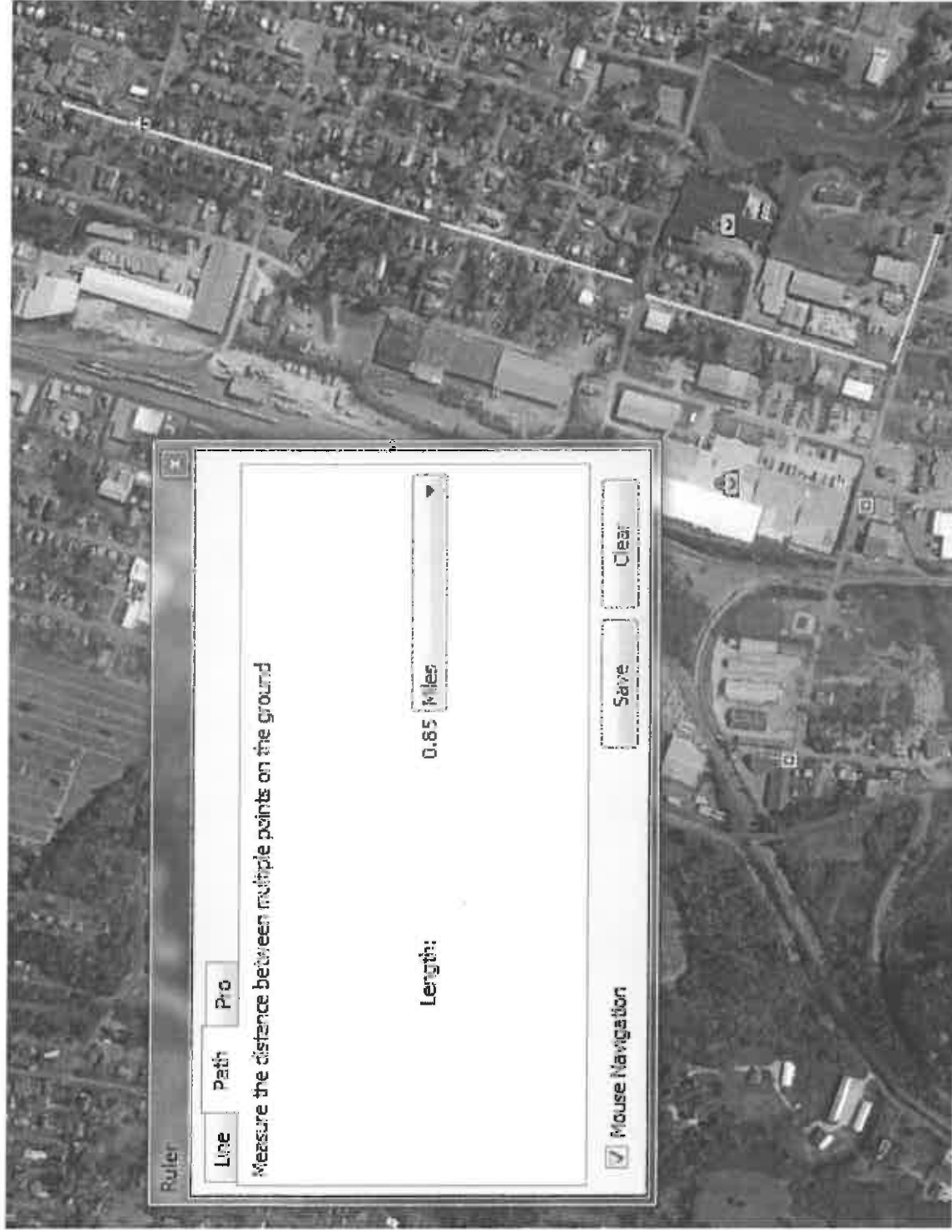
Stopping Sight Distance, SSD = 157.15ft

SSD < AD Therefore, safe.

***RIGHT OF WAY
ANALYSIS***

Right of Ways	Part of Street?	Dalton Pike Route, ft (Grey)	ROW > or = 40?	Blythe Avenue Route, ft (Light Blue)	ROW > or = 40?	Greenway Route, ft (Dark Blue)	ROW > or = 40?	Connector Route A, ft (Yellow)	ROW > or = 40?	Connector Route B, ft (Pink)	ROW > or = 40?
Blythe Avenue	Between 20th & 18th Street	35	TRUE	35	TRUE	35	TRUE	35	FALSE	35	FALSE
Blythe Avenue	Between 18th & 9th Street	50	TRUE	50	TRUE	50	TRUE	50	TRUE	50	TRUE
Aurora		-	N/A	-	N/A	-	N/A	45	TRUE	45	TRUE
Hardwick Street SE		-	N/A	-	N/A	-	N/A	-	N/A	50	TRUE
Wilson Avenue SE		-	N/A	-	N/A	-	N/A	50	TRUE	50	TRUE
Wiggins ST SE		-	N/A	-	N/A	-	N/A	45	TRUE	45	TRUE
11th street		-	N/A	-	N/A	-	N/A	50	TRUE	-	TRUE
12th street	Between Wilson & Hardwick	-	N/A	-	N/A	-	N/A	45	TRUE	45	TRUE
12th street	Between Hardwick & Wildwood	-	N/A	-	N/A	-	N/A	50	TRUE	50	TRUE
13th street		-	N/A	-	N/A	-	N/A	45	TRUE	45	TRUE
14th street		-	N/A	-	N/A	-	N/A	-	N/A	-	TRUE
15th street	Between Blythe & Aurora	-	N/A	-	N/A	-	N/A	-	N/A	20	FALSE
15th street	Between Aurora & Wildwood	-	N/A	-	N/A	-	N/A	40	TRUE	40	TRUE
16th street		-	N/A	-	N/A	-	N/A	45	TRUE	-	TRUE
18th street	Between Blythe & Wildwood	32	FALSE	-	N/A	-	N/A	35	FALSE	35	FALSE

DISTANCE AND COST ANALYSIS



Length of proposed Blythe Avenue route measured with Google Earth



Length of sidewalk needed on proposed Blythe Avenue route measured with Google Earth

BY THE AVE

COST : DISTANCE

T. TRIEU

1/1

DISTANCE OF ROUTE = 0.85 MILE

REQ'D SIDEWALK DISTANCE = 0.54 MILES

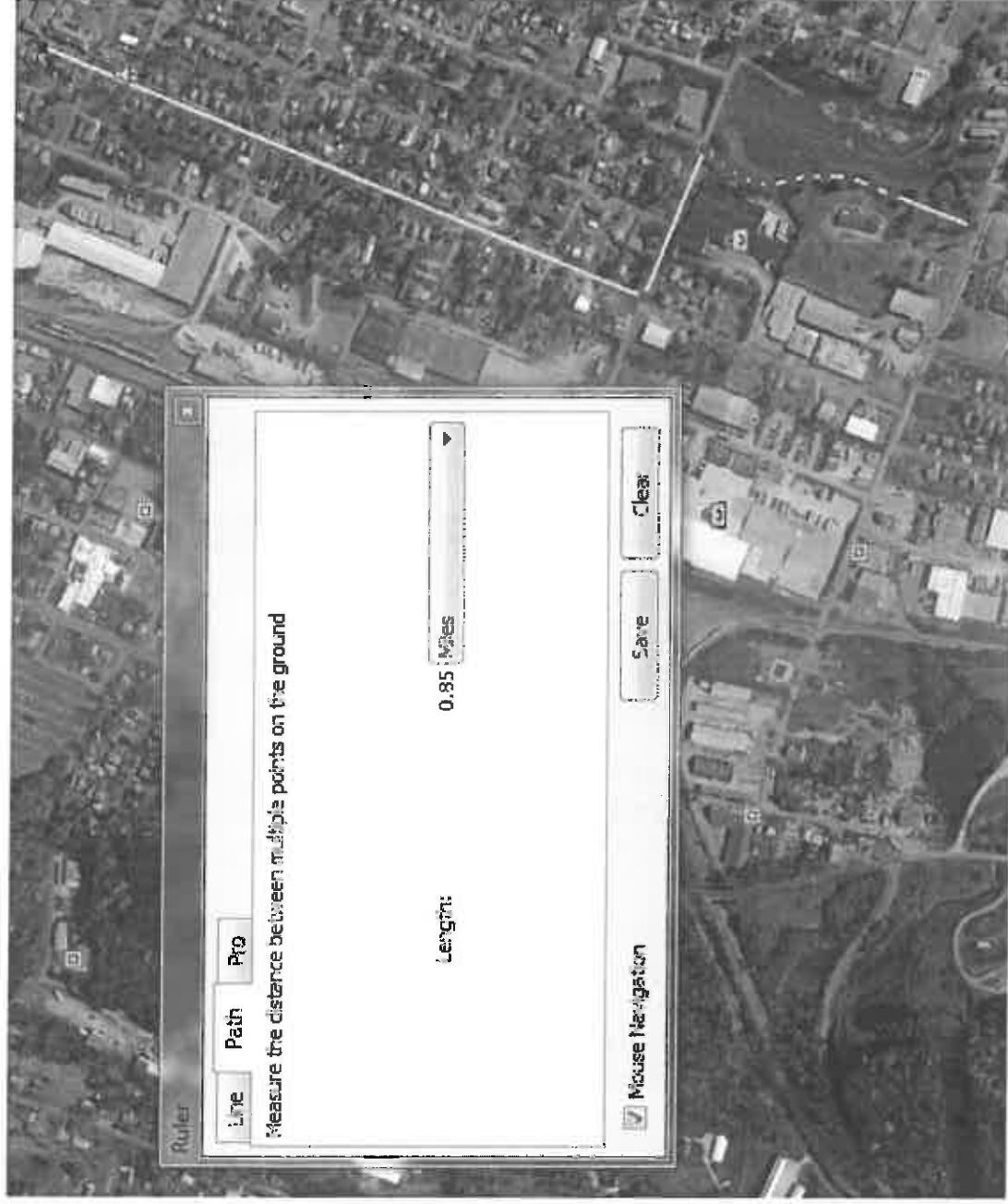
CONVERSION TO LINEAR FT = 0.54 MILES $\left(\frac{5280 \text{ FT}}{\text{MILE}} \right) = 2851.2 \text{ ft}$

AVG. COST OF SIDEWALK ON ROUTE = $(2851.2 \text{ ft})(\$21) + (2851.2)(\$32)$
 $= \underline{\$151,114}$

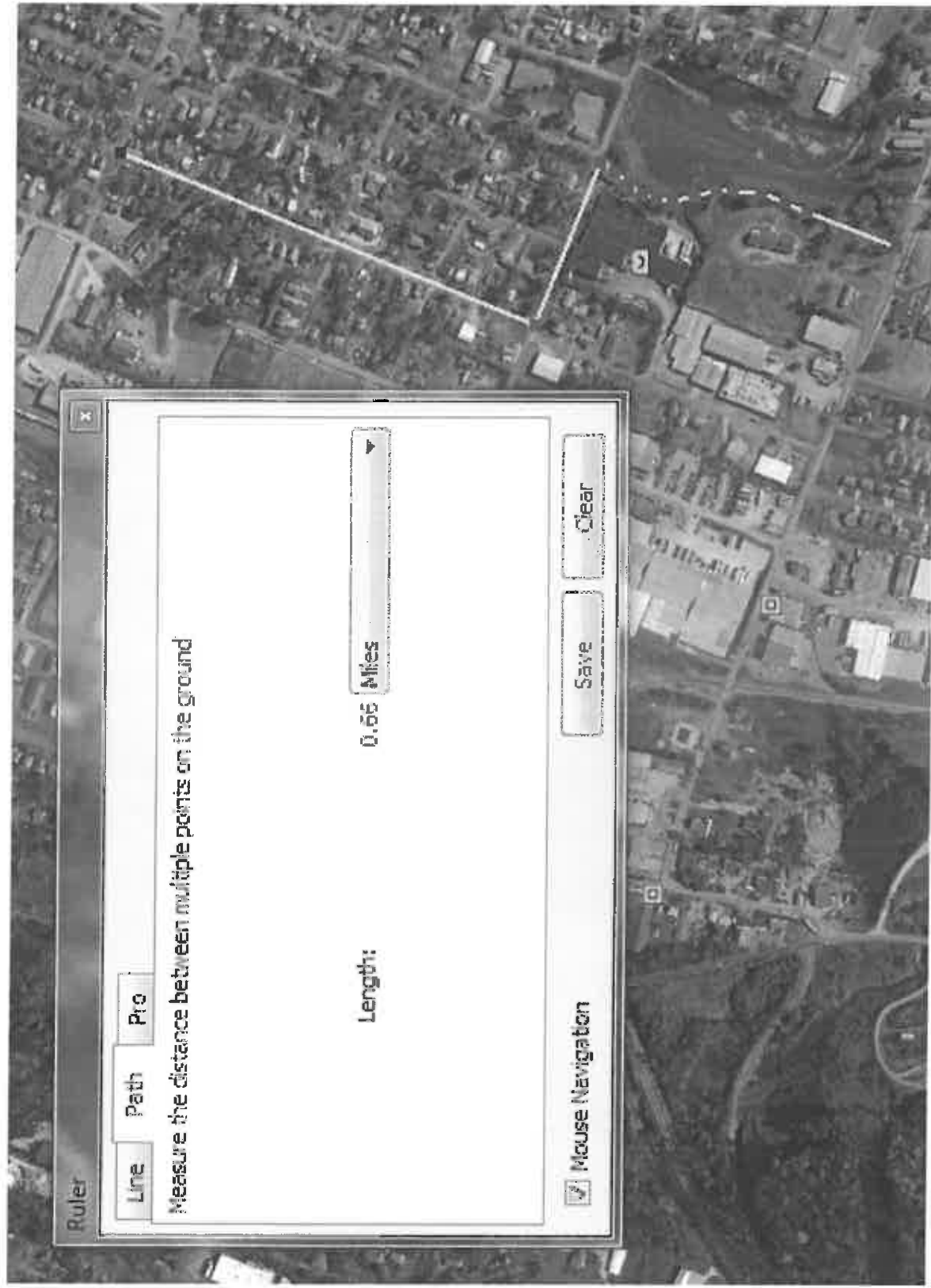
AVG COST OF STRIPPED CROSSWALK = $6(\$770) = \$4620$

TOTAL AVG. COST = $\$151,114 + \$4620 = \$155,734$

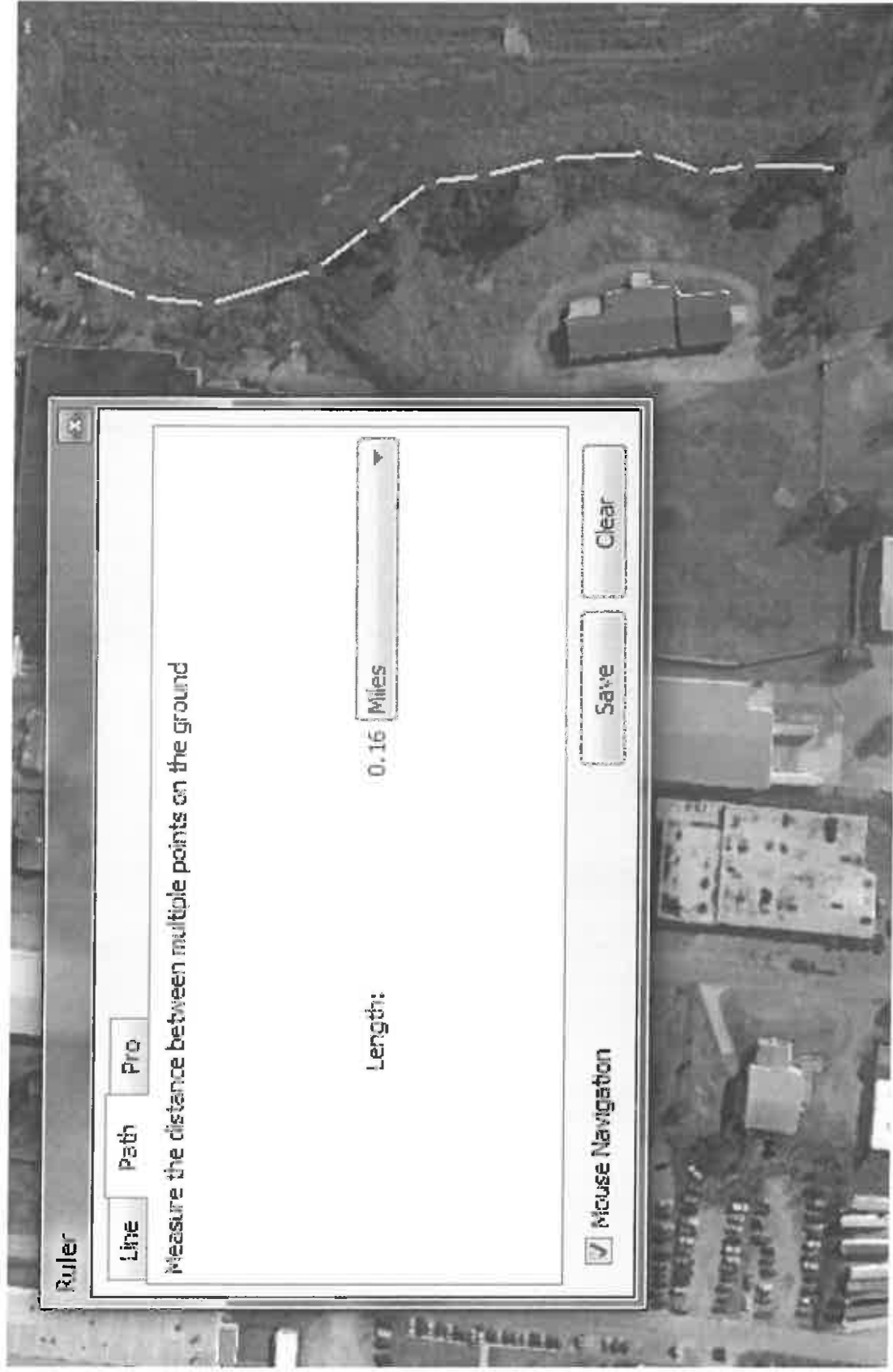
$= \$155,734$



Length of proposed Greenway route measured with Google Earth



Length of sidewalk needed on proposed Greenway route measured with Google Earth



Length of railing needed on proposed Greenway trail measured with Google Earth

DISTANCE OF ROUTE = 0.85 MILES

REQ'D SIDEWALK DISTANCE = 0.66 MILES

CONVERSION TO LINEAR FOOTAGE = 0.66 MILES $\left(\frac{5280 \text{ ft}}{\text{MILE}} \right)$

$$= 3484.4 \text{ ft}$$

AVG. COST OF SIDEWALK ON ROUTE

$$= (3484.4 \text{ ft}) (821) - (3484.4 \text{ ft}) (832)$$

$$= \$184,673.2$$

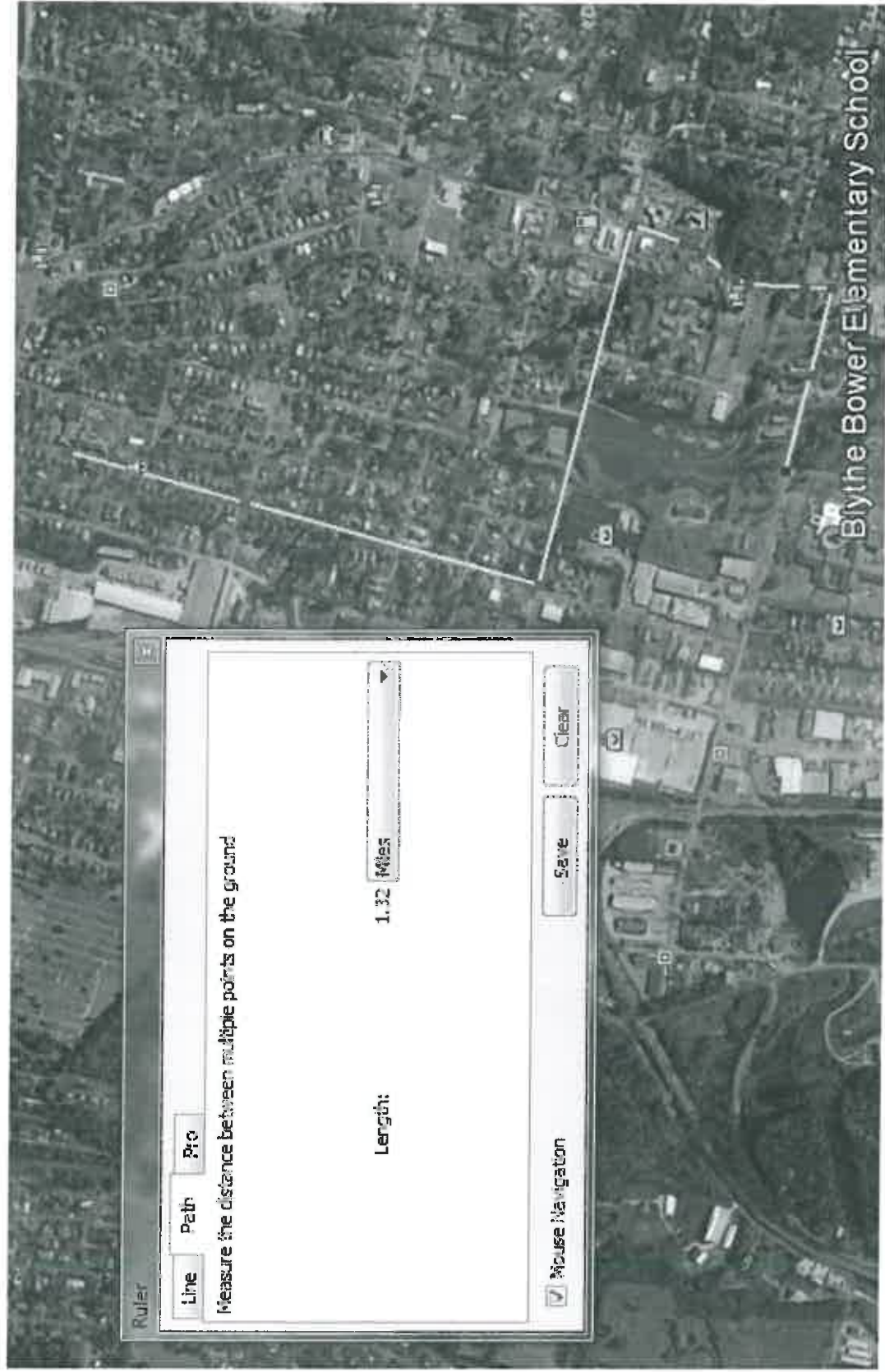
REQ'D RAILING DISTANCE = 0.16 MILES $\left(\frac{5280 \text{ ft}}{\text{MILE}} \right) = 844.8 \text{ ft}$

$$\text{AVG. COST OF RAILING} = 844.8 \text{ ft} (100) = \$84,480$$

$$\text{AVG. COST OF STRIPPED CROSSWALK} = 6(770) = \$4,620$$

$$\text{TOTAL AVG. COST} = \$184,673.2 + \$84,480 + \$4,620$$

$$= \$273,774.2 = \boxed{\$273,774}$$



Length of proposed Dalton Pike route measured with Google Earth



Length of sidewalk needed on proposed Dalton Pike route measured with Google Earth

DALTON PIKE

COST & DISTANCE

T. TRILU

1/1

DISTANCE OF ROUTE = 1.32 MILES

REQ'D SIDEWALK DISTANCE = 0.70 MILES

CONVERSION TO LINEAR FOOTAGE = 0.70 MILES $\left(\frac{5280 \text{ ft}}{\text{MILE}} \right)$
= 3696 ft

AVG. COST OF SIDEWALK ON ROUTE

$$= (3696 \text{ ft}) (\$21/\text{ft}) + (3696 \text{ ft}) (\$32/\text{ft}) \\ = \$195,888$$

AVG. COST OF STRIPPED SIDEWALKS = $(\$770)(8) = \$6160$

$$\text{TOTAL AVG. COST} = \$195,888 + \$6160 = \boxed{\$202,048}$$

SIDEWALK DEMO
& REINSTALL

COST & DIST.

TRIEU, T.

7/1

$$\text{LENGTH} = 0.20 \text{ MILES} \left(\frac{5280 \text{ ft}}{\text{MILE}} \right) = 1056 \text{ ft}$$

$$\begin{aligned} \text{DEMO. COST} &= 1056 \text{ ft} \left(\frac{9}{12} \text{ ft} \right) (5 \text{ ft}) \left(\frac{\$84}{\text{YDS}} \right) \left(\frac{\text{YD}^3}{27 \text{ FT}^3} \right) \\ &= \$5475.52 \end{aligned}$$

REINSTALL COST

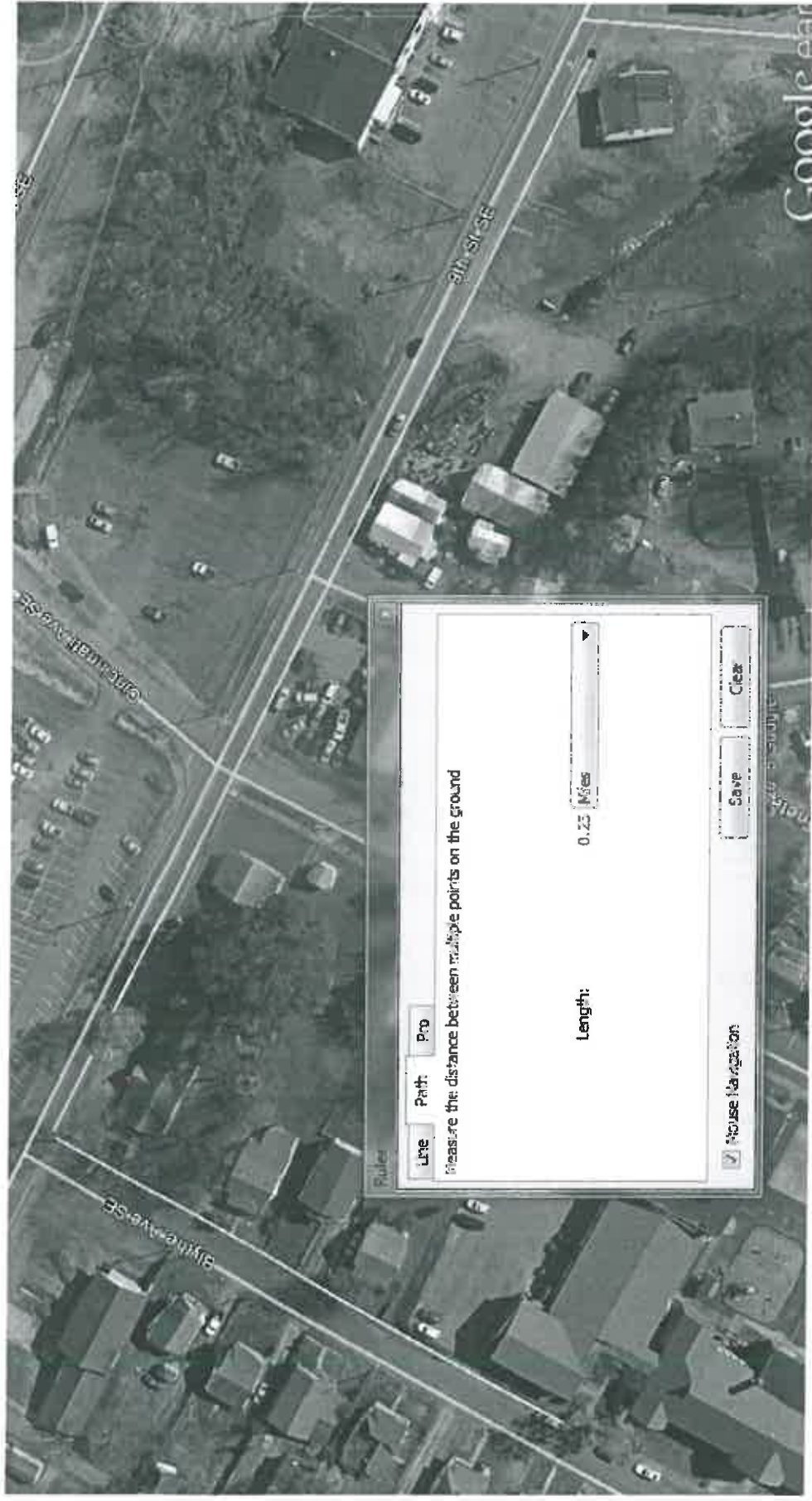
$$\begin{aligned} \text{BULK HEAD} &= (2 \text{ SIDES}) (\$3.13) (1056 \text{ ft}) \\ &= \$6610.56 \end{aligned}$$

$$\begin{aligned} \text{TROWELED FINISHED} &= (\$2.40) (5 \text{ ft}) (1056 \text{ ft}) \\ &= \$12,672 \end{aligned}$$

TOTAL DEMO & REINSTALL COST

$$= \$5475.52 + \$6610.56 + \$12,672 = \boxed{\$24,758.12}$$

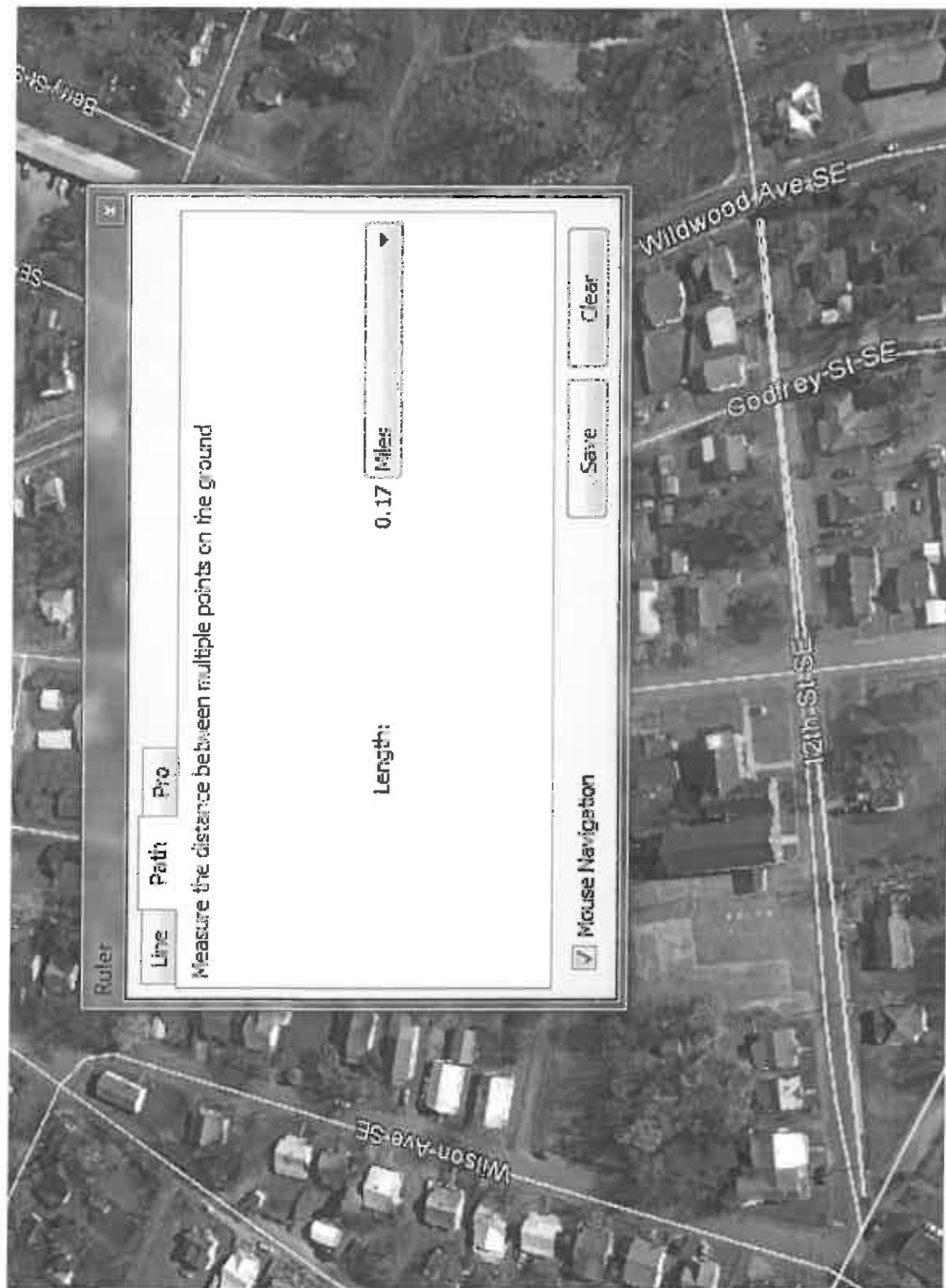
Length measured by Google Earth for segments of Neighborhood Connector A



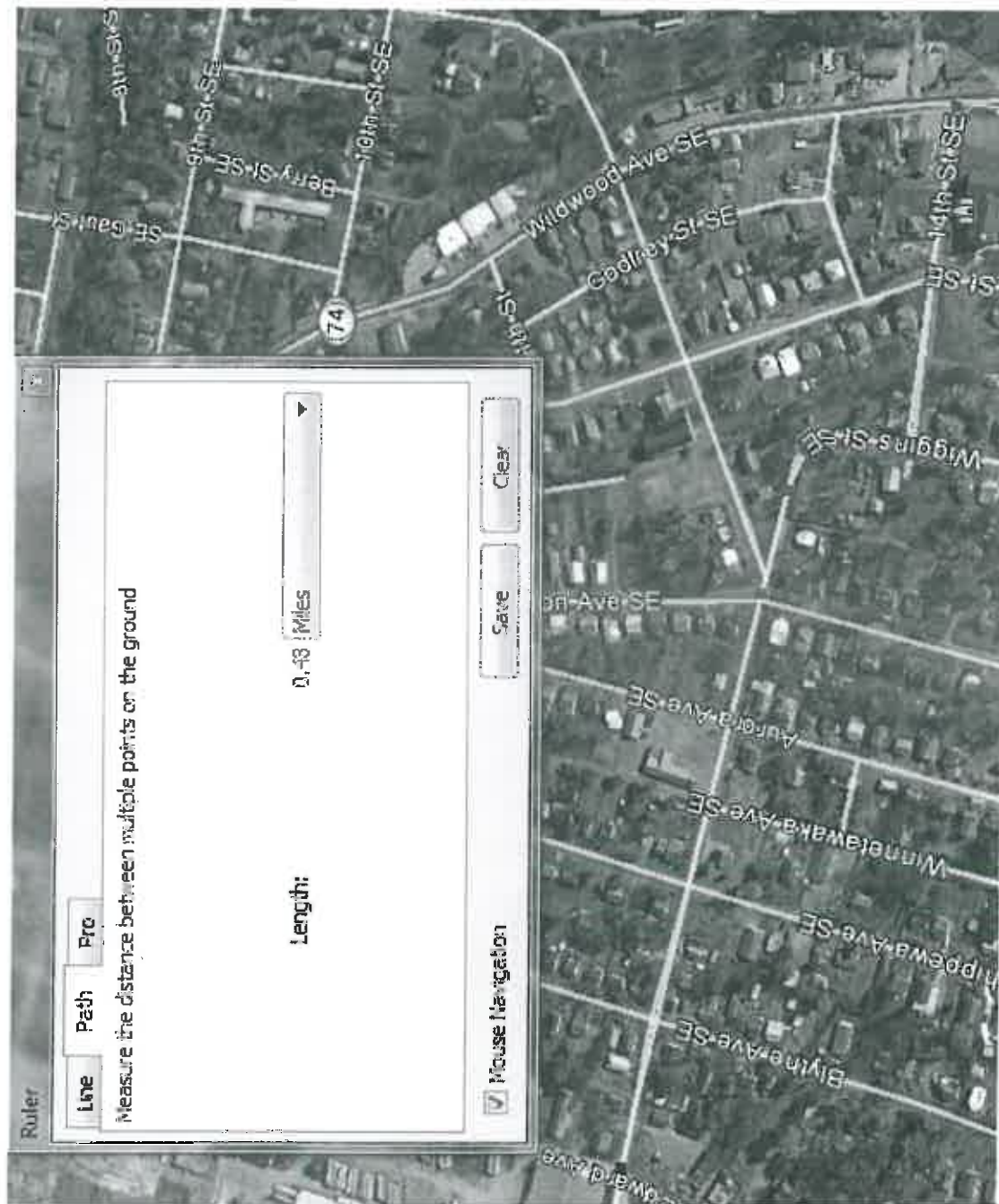
Length measured from Family Support Center going to Wildwood Avenue from 9th Street SE



Length measured from 9th Street SE to 13th Street SE going through Winnetawka Avenue SE and Wilson Avenue SE



Length measured from 13th Street SE to Wildwood Avenue going through 12th Street SE



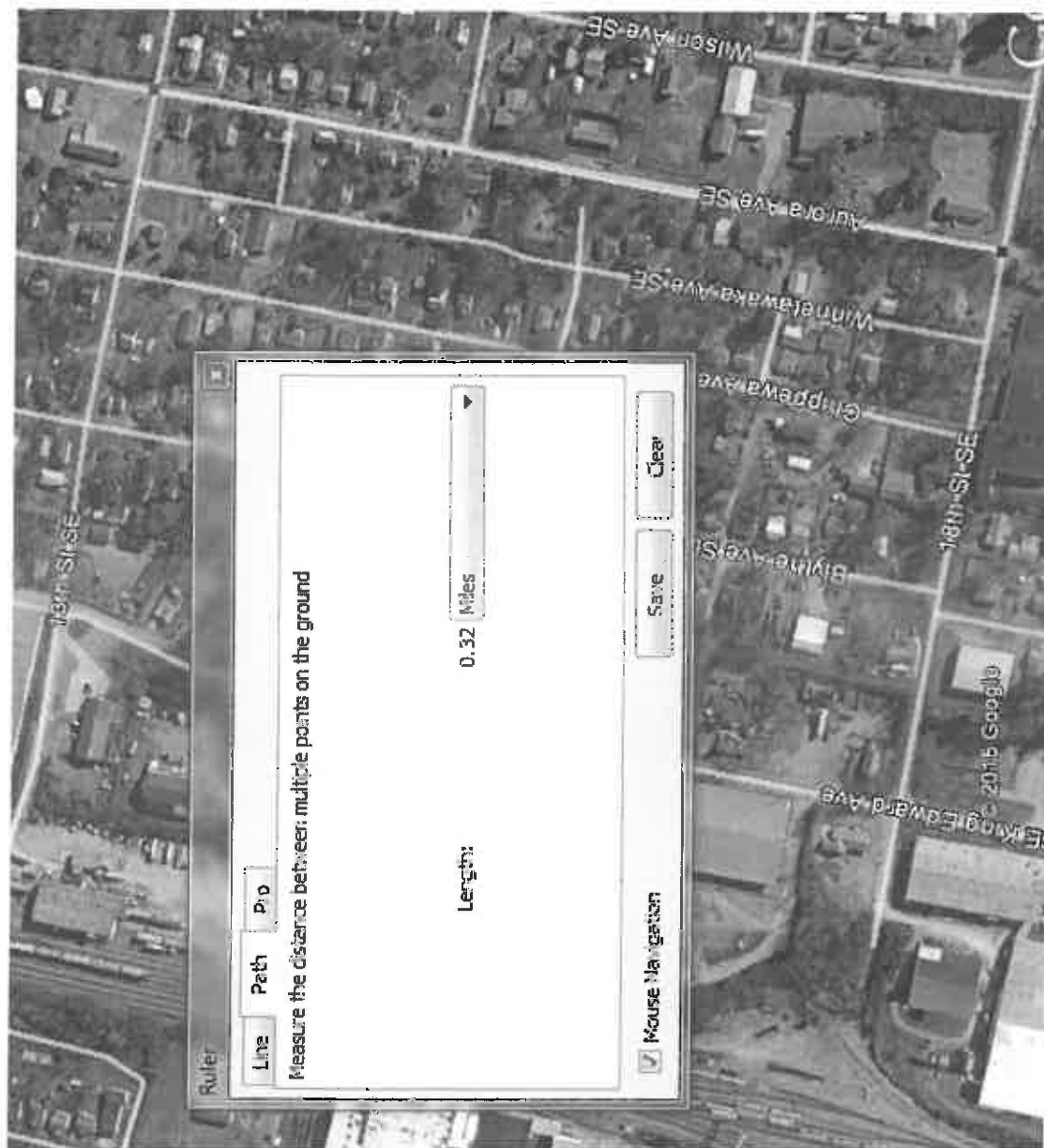
Length measured from SE King Edward Avenue to Wildwood Avenue going through 13th Street SE, Wiggins Street SE, and 14th Street SE



Length measured from Aurora Avenue SE to Wildwood Avenue going through 15th Street SE and Wilson Avenue SE



Length measured from SE King Edward Avenue to Winnetawka Avenue SE going through 16th Street SE



Length measured from 13th Street SE to 18th Street SE going through Aurora Avenue SE



Length measured from Blythe Avenue SE to Wildwood Avenue going through 18th Street SE



DISTANCE OF NEIGHBORHOOD CONNECTOR (MILES)

$$= 0.23 + 0.30 + 0.17 + 0.48 + 0.27 + 0.17 + 0.32 + 0.34$$

$$= 2.33 \text{ MILES}$$

CONVERSION TO LINEAR FOOTAGE = 2.33 MILES $\left(\frac{5280 \text{ ft}}{\text{MILE}}\right)$

$$= 12,302.4 \text{ ft}$$

AVG. COST OF SIDEWALK

$$= (12,302.4 \text{ ft})(\$21) + (12,302.4 \text{ ft})(\$32) = \$652,027.2$$

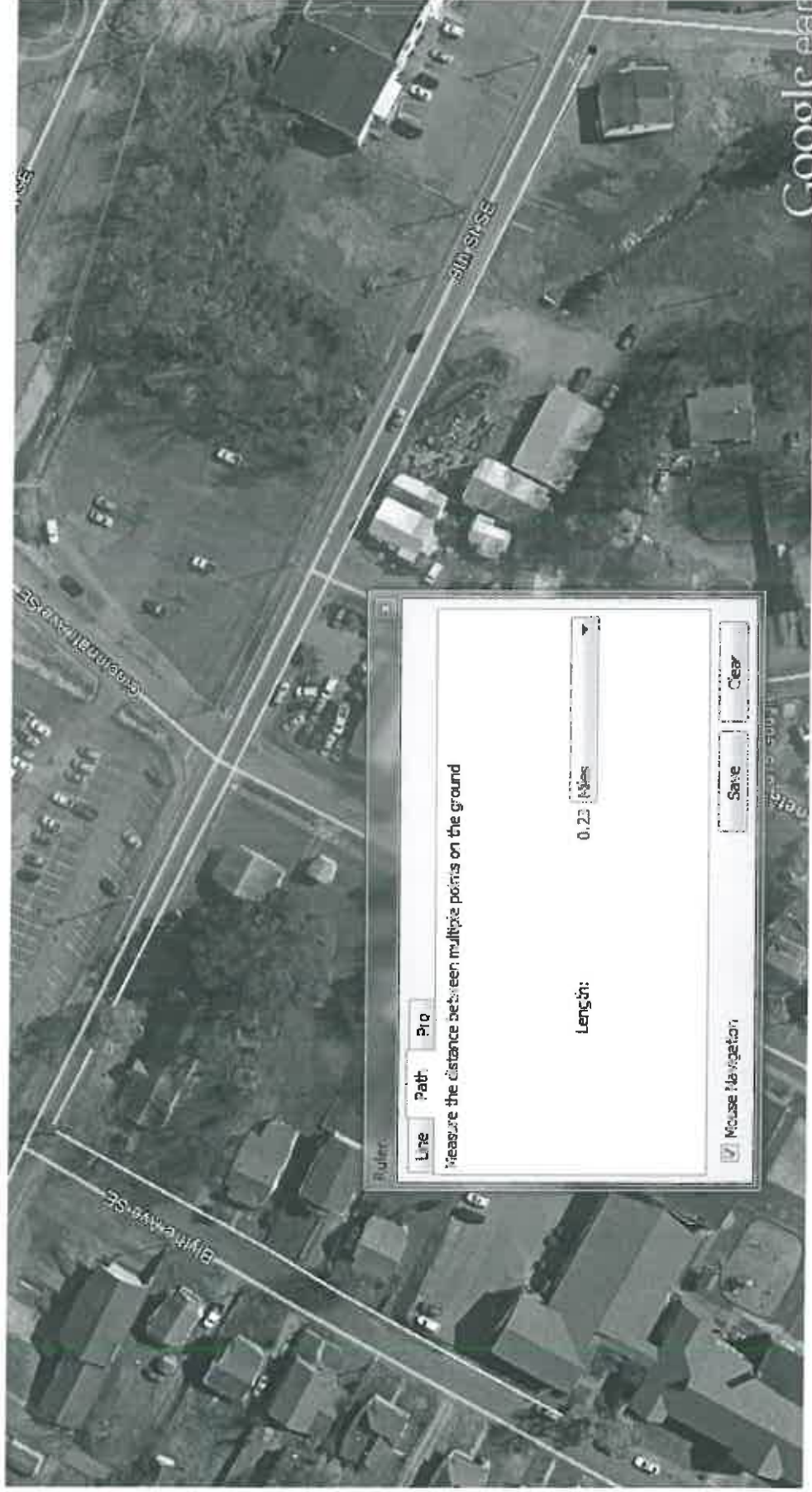
AVG. COST OF STRIPPED CROSSWALKS

$$= (27)(\$770) + (7)(\$770) = \$26,180$$

TOTAL AVG. COST = \$652,027.2 + 26,180 = \$678,207.2

$$\boxed{= \$678,207}$$

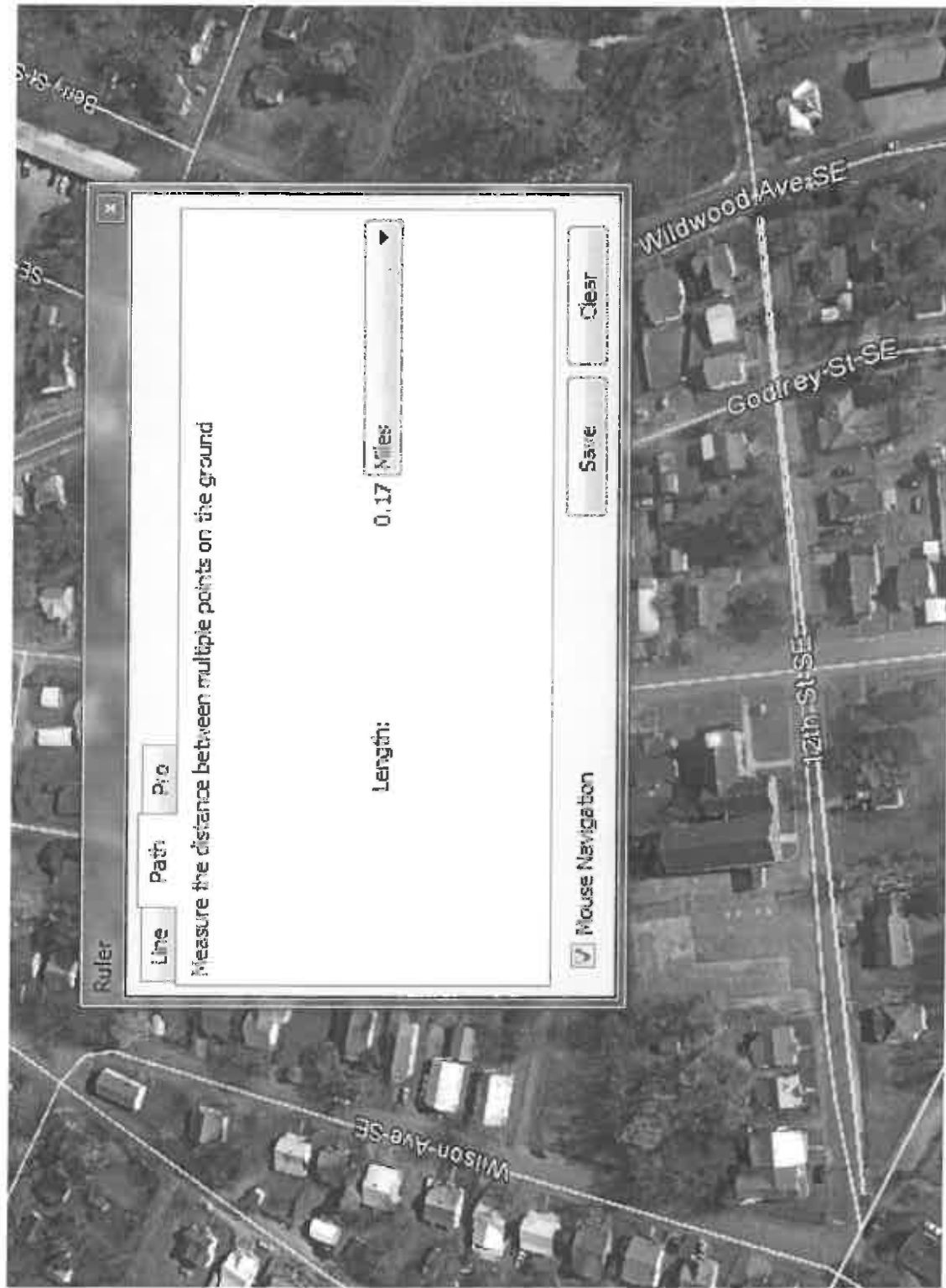
Length measured by Google Earth for segments of Neighborhood Connector B



Length measured from Family Support Center going to Wildwood Avenue from 9th Street SE



Length measured from 9th Street SE to 14th Street SE going through Hardwick Street SE



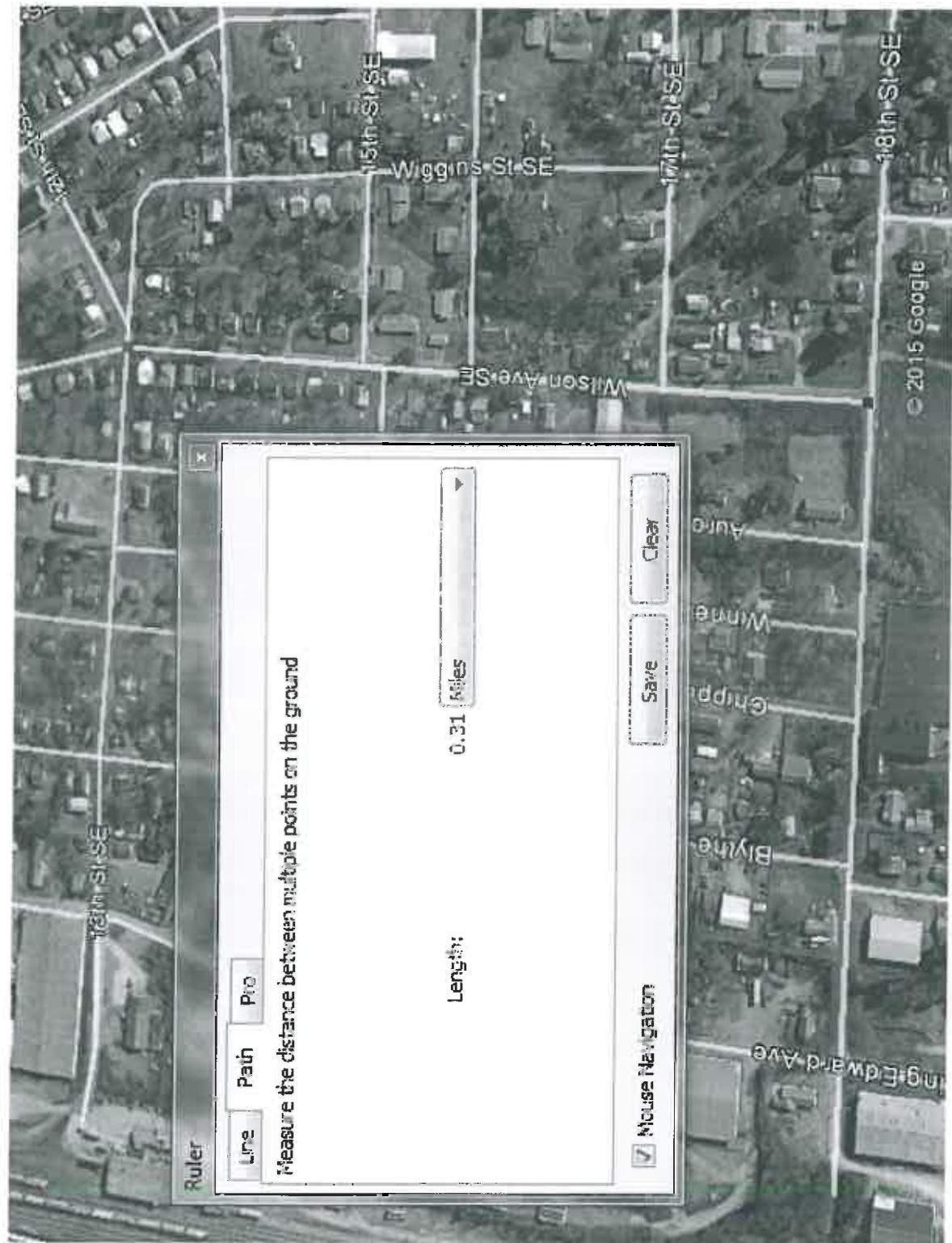
Length measured from 13th Street SE to Wildwood Avenue going through 12th Street SE



Length measured from Blythe Avenue to Wildwood Avenue going through 13th Street SE, Wiggins Street SE, and 14th Street SE



Length measured from Blythe Avenue to Wildwood Avenue SE going through easements, Aurora Avenue SE, 15th Street SE, and Wilson Avenue SE



Length measured from 13th Street SE to 18th Street SE going through Wilson Avenue SE



Length measured from Blythe Avenue SE to Wildwood Avenue going through 18th Street SE



NO OPTION B

COST

DISTANCE

T. TRILEW

1/1

DISTANCE OF NEIGHBORHOOD CONNECTOR (MILES)

$$= 0.23 + 0.35 + 0.17 + 0.42 + 0.42 + 0.31 + 0.38 = 2.28 \text{ MILES}$$

$$\text{CONVERSION TO LINEAR FOOTAGE} = 2.28 \text{ MILES} \left(\frac{5280 \text{ ft}}{\text{MILE}} \right) = 12,038.4 \text{ ft}$$

AVG. COST OF SIDEWALK

$$= (12,038.4 \text{ ft}) (\$21) + (12,038.4 \text{ ft}) (\$32) = \$638,035.2$$

AVG. COST OF STRIPPED CROSSWALKS

$$= (27) (\$770) + (7) (\$770) = \$26,180$$

$$\text{TOTAL AVG. COST} = \$638,035.2 + \$26,180 = \$664,215.2$$

$$\boxed{= \$664,215}$$



Length of existing sidewalk on Blythe from the Family Support Center to 13th Avenue SE



Length of existing sidewalk on Chippewa Street from 9th Street SE to 13th Street SE



Length of existing sidewalk on Hardwick Street from 14th Street SE to 15th Street SE

EXISTING SIDEWALK COST : DISTANCE

TRIEU, THUY

1/1

DISTANCE OF EXISTING SIDEWALK (BLYTHE) = 0.20 MILES

DISTANCE OF EXISTING SIDEWALK (HARDWICK) = 0.06 MILES

DISTANCE OF EXISTING SIDEWALK (CHIPPEWA) = 0.27 MILES

TOT. DIST. REQ'D TO BE REINSTALLED = 0.53 MILES

CONVERSION TO LINEAR FOOTAGE

$$= \left(\frac{\$280}{\text{ft}} \right) 0.53 \text{ MILES} = 2,798.4 \text{ ft}$$

AVG. COST OF SIDEWALK REQ'D

$$= (2798 \text{ ft}) (\$21) + (2798 \text{ ft}) (\$32)$$

$$= \$148,315.2$$

03 30 Cast-In-Place Concrete

03 30 53 - Miscellaneous Cast-In-Place Concrete

03 30 53.40 Concrete In Place			Crew	Daily Output	Labor Hours	Unit	Material	2011 Bare Costs			Total	Total Incl O&P
								Labor	Equipment			
0010	CONCRETE IN PLACE	R033053-10										
0020	Including forms (4 uses), reinforcing steel, concrete, placement, and finishing unless otherwise indicated	R033053-60										
0050		R033105-10										
0500	Chimney foundations (5000 psi), industrial, minimum	R033105-20	G-14C	32.22	3.476	C.Y.	144	111	.73	255.73	345	
0510	Maximum	R033105-50	"	23.71	4.724	"	168	151	.99	319.99	440	
3540	Equipment pad (3000 psi), 3' x 3' x 6" thick	R033105-70	G-14H	45	1.067	Ea.	40.50	35	.51	76.01	104	
3550	4' x 4' x 6" thick			30	1.600		62	52.50	.77	115.27	157	
3560	5' x 5' x 8" thick			18	2.667		111	87.50	1.28	199.78	270	
3570	6' x 6' x 8" thick			14	3.429		150	113	1.65	264.65	355	
3580	8' x 8' x 10" thick			8	6		320	197	2.88	519.88	690	
3590	10' x 10' x 12" thick			5	9.600		550	315	4.61	869.61	1,150	
3800	Footings (3000 psi), spread under 1 C.Y.		G-14C	28	4	C.Y.	158	128	.84	286.84	390	
3825	1 C.Y. to 5 C.Y.			43	2.605		185	83	.55	268.55	345	
3850	Over 5 C.Y.	R033105-80		75	1.493		171	47.50	.31	218.81	268	
3900	Footings, strip (3000 psi), 18" x 9", unreinforced		G-14L	40	2.400		119	75	.58	194.58	257	
3920	18" x 9", reinforced	R033105-85	G-14C	35	3.200		141	102	.67	243.67	330	
3925	20" x 10", unreinforced		G-14L	45	2.133		116	66.50	.51	183.01	240	
3930	20" x 10", reinforced		G-14C	40	2.800		134	89.50	.59	224.09	298	
3935	24" x 12", unreinforced		G-14L	55	1.745		114	54.50	.42	168.92	217	
3940	24" x 12", reinforced		G-14C	48	2.333		132	74.50	.49	206.99	271	
3945	36" x 12", unreinforced		G-14L	70	1.371		111	43	.33	154.33	194	
3950	36" x 12", reinforced		G-14C	60	1.867		127	59.50	.39	186.89	240	
4000	Foundation mat (3000 psi), under 10 C.Y.			38.67	2.896		192	92.50	.61	285.11	365	
4050	Over 20 C.Y.			56.40	1.986		169	63.50	.42	232.92	292	
4520	Handicap access ramp (4000 psi), railing both sides, 3' wide		G-14H	14.58	3.292	L.F.	278	108	1.58	387.58	490	
4525	5' wide			12.22	3.928		288	129	1.89	418.89	535	
4530	With 6" curb and rails both sides, 3' wide			8.55	5.614		287	185	2.69	474.69	630	
4535	5' wide			7.31	6.566		292	216	3.15	511.15	685	
4751	Slab on grade (3500 psi), incl. troweled finish, not incl. forms											
4760	or reinforcing, over 10,000 S.F., 4" thick		G-14F	3425	.021	S.F.	1.29	.64	.01	1.94	2.46	
4820	6" thick		"	3350	.021	"	1.89	.65	.01	2.55	3.14	
5000	Slab on grade (3000 psi), incl. textured finish, not incl. forms											
5001	or reinforcing, 4" thick		G-14G	2873	.019	S.F.	1.29	.58	.01	1.88	2.37	
5010	6" thick			2590	.022		2.01	.64	.01	2.66	3.27	
5020	8" thick			2320	.024		2.62	.72	.01	3.35	4.07	
6800	Stairs (3500 psi), not including safety treads, free standing, 3'-6" wide		G-14H	83	.578	L.F. Nose	5	19	.28	24.28	38	
6850	Cast on ground			125	.384	"	4.28	12.65	.18	17.11	26	
7000	Stair landings, free standing			200	.240	S.F.	4.03	7.90	.12	12.05	17.75	
7050	Cast on ground			475	.101	"	3.29	3.32	.05	6.66	9.20	

03 31 Structural Concrete

03 31 05 - Normal Weight Structural Concrete

03 31 05.35 Normal Weight Concrete, Ready Mix

0010	NORMAL WEIGHT CONCRETE, READY MIX, delivered	R033105-10									
0012	Includes local aggregate, sand, Portland cement, and water										
0015	Excludes all additives and treatments	R033105-20									
0020	2000 psi					C.Y.	91.50			91.50	101
0030	2500 psi	R033105-30					94			94	103
0040	3000 psi						99			99	109
0050	3500 psi						99.50			99.50	110
0060	4000 psi	R033105-40					103			103	113

03 01 Maintenance of Concrete

03 01 30 – Maintenance of Cast-In-Place Concrete

03 01 30.64 Floor Patching		Daily Crew	Output	Labor-Hours	Unit	Material	2011 Bare Costs		Total	Total Incl O&P
0010 FLOOR PATCHING							Labor	Equipment		
0012	Floor patching, 1/4" thick, small areas, regular	1 Celi	170	.047	S.F.	2.44	1.50		3.94	5.05
0100	Epoxy	"	100	.080	"	5.75	2.55		8.30	10.40

03 05 Common Work Results for Concrete

03 05 05 – Selective Concrete Demolition

03 05 05.10 Selective Demolition, Concrete

0010	SELECTIVE DEMOLITION, CONCRETE	R024119-10								
0012	Excludes saw cutting, torch cutting, loading or hauling									
0050	Break up into small pieces, minimum reinforcing		8-9	24	1.667	C.Y.	45	8.15	53.15	84
0060	Average reinforcing			16	2.500		67	12.20	79.20	125
0070	Maximum reinforcing			8	5		134	24.50	158.50	252
0150	Remove whole pieces, up to 2 tons per piece		E-18	36	1.111	Ea.	40.50	29	69.50	107
0160	2 – 5 tons per piece			30	1.333		48.50	34.50	83	129
0170	5 – 10 tons per piece			24	1.667		61	43	104	161
0180	10 – 15 tons per piece			18	2.222		81	57.50	138.50	213
0250	Precast unit embedded in masonry, up to 1 C.F.		D-1	16	1		30.50		30.50	50
0260	1 – 2 C.F.			12	1.333		40.50		40.50	66.50
0270	2 – 5 C.F.			10	1.600		48.50		48.50	80
0280	5 – 10 C.F.			8	2		61		61	100

03 05 13 – Basic Concrete Materials

03 05 13.85 Winter Protection

0010	WINTER PROTECTION									
0012	For heated ready mix, add, minimum				C.Y.	4.25			4.25	4.68
0050	Maximum				"	5.30			5.30	5.85
0100	Temporary heat to protect concrete, 24 hours, minimum	2 Clab	50	.320	M.S.F.	525	8.45		533.45	595
0200	Temporary shelter for slab on grade, wood frame/polyethylene sheeting									
0201	Build or remove, minimum	2 Corp	10	1.600	M.S.F.	268	53.50		321.50	385
0210	Maximum	"	3	5.333	"	325	179		504	655
0710	Electrically, heated pads, 15 watts/S.F., 20 uses, minimum				S.F.	.21			.21	.23
0800	Maximum				"	.35			.35	.39

03 11 Concrete Forming

03 11 13 – Structural Cast-In-Place Concrete Forming

03 11 13.45 Forms In Place, Footings

0010	FORMS IN PLACE, FOOTINGS	R031113-40								
0020	Continuous wall, plywood, 1 use		C-1	375	.085	SFCA	5	2.54	7.54	9.75
0150	4 use		"	485	.066	"	1.63	1.96	3.59	5.10
1500	Keyway, 4 use, tapered wood, 2" x 4"	R031113-60	1 Corp	530	.015	L.F.	.18	.51	.69	1.05
1550	2" x 6"		"	500	.016	"	.26	.54	.80	1.19
5000	Spread footings, job-built lumber, 1 use		C-1	305	.105	SFCA	1.79	3.12	4.91	7.15
5150	4 use		"	414	.077	"	.58	2.30	2.88	4.48

03 11 13.65 Forms In Place, Slab On Grade

0010	FORMS IN PLACE, SLAB ON GRADE	R031113-40								
1000	Bulkhead forms w/keyway, wood, 6" high, 1 use	R031113-60	C-1	510	.063	L.F.	.86	1.87	2.73	4.06
1400	Bulkhead form for slab, 4-1/2" high, exp metal, incl keyway & stakes	[G]		1200	.027		1.64	.79	2.43	3.13
1410	5-1/2" high	[G]		1100	.029		1.90	.86	2.76	3.9
1420	7-1/2" high	[G]		960	.033		2.31	.99	3.30	4.29

<u>Cost Category</u>	<u>Cost</u>
Average cost of curb and gutter per linear foot =	\$ 21.00
Average cost of concrete sidewalk per linear foot =	\$ 32.00
Average railing cost per linear foot =	\$ 100.00
Average cost for each striped crosswalk =	\$ 770.00
Slab on grade, troweled finish per square foot =	\$ 1.94
Bulkhead per linear footage =	\$ 2.76
Break up into small pieces per cubic yard =	\$ 53.15

	<u>Required Sidewalk Length (mi)</u>	<u>Required Sidewalk Length (feet)</u>	<u>Cost of required sidewalk Length (\$)</u>
Conversion	1	5280	279840
Blythe Ave	0.74	3907.2	207081.6
Greenway	0.6	3168	167904
Dalton Pike	0.88	4646.4	246259.2
Option A	2.33	12302.4	652027.2
Option B	2.28	12038.4	638035.2
Existing	0.53	2798.4	148315.2

	<u>Number of crosswalk per route</u>	<u>Cost of crosswalks</u>	<u>Total Cost</u>
Wildwood	7	5390	
Blythe	6	4620	563723.25
Greenway	6	4620	684609.64
Dalton	8	6160	615691.47
NCA	27	20790	865449.73
NCB	27	20790	847439.65

	Old sidewalk	
Demolition/excavation cost	\$	247,891.60
Bulk head cost	\$	17,517.98
Construction cost	\$	27,144.48
Total construction based cost	\$	292,554.06

	Blythe		Greenway		Dalton	
Demolition/excavation cost		-	\$	171,314.62		-
Bulk head cost	\$	21,567.74	\$	17,487.36	\$	25,648.13
Construction cost	\$	37,899.84	\$	30,729.60	\$	45,070.08
Total construction based cost	\$	59,467.58	\$	219,531.58	\$	70,718.21

	NCA		NCB	
Demolition/excavation cost		-		-
Bulk head cost	\$	67,909.25	\$	66,451.97
Construction cost	\$	119,333.28	\$	116,772.48
Total construction based cost	\$	187,242.53	\$	183,224.45

BOARDWALK

Governing Design Code: AASHTO LRFD Guide Specifications
for Design of Pedestrian Bridges

1. Pedestrian Live Load

• 80 psf

2. Other Load Types Rain Load:

• Wind = 105 psf

• Seismic =

• Snow = 10 psf

Handrail

- Have a minimum height of 36 in
- Be designed to resist a load of 50 plf
- Be able to resist a single concentrated load of 200 lbs
- Possess no openings large enough to pass a 4" diameter sphere through.

Materials

- Floor Joist = 2 x 12
- Girders = Double 2 x 12
- Pickets = 2 x 2
- Decking = 2 x 6
- Columns = 6 x 6
- Handrail Posts = 4 x 4
- Top Rail = 2 x 6

ASCE-7 - Load Combinations

- 1) $U = 1.4(D)$
- 2) $U = 1.2(D) + 1.6(L) + 0.5(L_r \text{ or } S \text{ or } R)$
- 3) $U = 1.2(D) + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.5W)$
- 4) $U = 1.2(D) + 1.0(W) + 0.5(L) + 0.5(L_r \text{ or } S \text{ or } R)$
- 5) $U = 1.2(D) + 1.0(E) + 0.5(L) + 0.2(S)$
- 6) $U = 0.9(D) + 1.0(W)$
- 7) $U = 0.9(D) + 1.0(E)$

- For all lumber, assume using pressure-treated Southern Yellow Pine.
- Assume density = 45 lb/ft³
- Wooden joist and girder DL. Assume 2x12 @ 45 pcf from Table 1B NDS Supplement

$$DL = 5.273 \text{ lb/ft}$$

- Decking DL. Assume 2x6 @ 45 pcf from Table 1B NDS Supplement.

$$DL = \frac{2.578 \text{ lb/ft}^2}{5.5/12} = 5.625 \text{ psf}$$

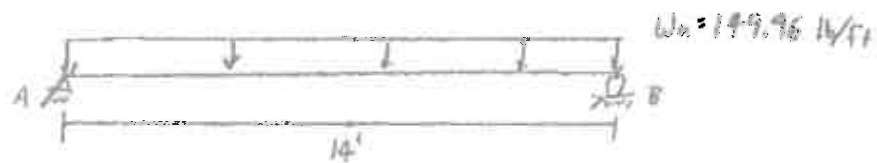
- Live Loads - LL = 60 psf for elevated platforms (boardwalks) (IBC 2012 Table 1607.1 #39)
- Snow Loads - S = 10 psf (IBC 2012 Figure 1608.2)
- Wind Loads - W = 105 mph (IBC 2012 Figure 1609.8)
 $W = 28.224 \text{ psf}$
- Due to the type of structure, wind loads, rain loads, and earthquake loads will not be taken into account.
- For Interior Joists spaced @ 16" O.C.

Load Combination: 1) $W_u = 1.4(D) = 1.4(1.333 \text{ ft} \times 5.625 \text{ lb/ft}^2 + 5.273 \text{ lb/ft})$
 $= 1.4(12.77 \text{ lb/ft}) = \underline{17.88 \text{ lb/ft}}$

2) $W_u = 1.2(D) + 1.6(L) + 0.5(S) = 1.2(12.77 \text{ lb/ft}) + 1.6(1.333 \times 60 \text{ lb/ft}^2) + 0.5(1.333 \times 10 \text{ lb/ft}^2)$
 $= 1.2(12.77 \text{ lb/ft}) + 1.6(79.98 \text{ lb/ft}) + 0.5(13.33 \text{ lb/ft})$
 $= \underline{149.96 \text{ lb/ft}}$

$$\begin{aligned}
 5) W_u &= 1.2D + 1.6S + 0.5(L) \\
 &= 1.2(12.77 \text{ lb/ft}) + 1.6(13.53 \text{ lb/ft}) + 0.5(79.98 \text{ lb/ft}) \\
 &= \underline{76.63 \text{ lb/ft}}
 \end{aligned}$$

- Load Combinations 4-7 will not control due to wind, rain, and earthquake loads not being taken into account.
- Load Combination #2 controls @ $W_u = 149.96 \text{ lb/ft}$
- With joint span of $14'$, taken as simply supported beam



$$\begin{aligned}
 \uparrow + \sum M_A = 0 &= B_y(14) + 149.96(14)(7) \Rightarrow B_y = \underline{1049.72 \text{ lb} \uparrow} \\
 \uparrow + \sum F_y = 0 &= 1049.72 \text{ lb} - 149.96(14) + A_y \Rightarrow A_y = \underline{1049.72 \text{ lb} \uparrow}
 \end{aligned}$$

- For Exterior Joists

Handrail weight = 100.9 lb to each column spaced @ $7'$

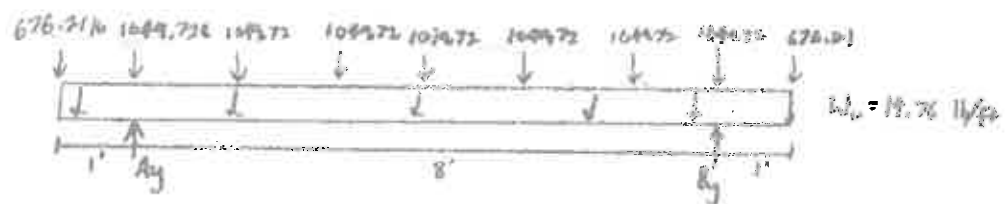
$$W_u = 149.96 \text{ lb/ft} / 2 = 74.98 \text{ lb/ft}$$

Due to half tributary area of interior joists



$$\begin{aligned}
 \uparrow + \sum M_A = 0 &= B_y(14) + 74.98(14)(7) + 100.9(7) + 100.9(14) \Rightarrow B_y = \underline{676.21 \text{ lb} \uparrow} \\
 \uparrow + \sum F_y = 0 &= 676.21 - 74.98(14) - 100.9(2) + A_y \Rightarrow A_y = \underline{676.21 \text{ lb} \uparrow}
 \end{aligned}$$

- For Girders - Assume using $4 \times 12 @ 45 \text{ lb/ft}^2 = 12.30 \text{ lb/ft}$
 Weight of girder, add in $DL = 1.2(12.3 \text{ lb/ft}) = 14.76 \text{ lb/ft} = W_D$



Due to the girder being uniformly distributed, $A_y = B_y \therefore$

$$A_y = B_y = \frac{7(1049.72 \text{ lb}) + 2(676.21 \text{ lb}) + 14.76 \text{ lb/ft}(10 \text{ ft})}{2}$$

$$= 4424.03 \text{ lb} \uparrow$$

- For Columns - Assume using 6×6 column with a max length of 14 ft.

Axially loaded column capacity for $6 \times 6 = 12,600 \text{ lbs}$

$$4424.03 \text{ lbs} < 12,600 \text{ lbs} \therefore \text{O.K.}$$

- Check Bending Stresses in Joists (2×12)

$$f_b = \frac{M}{S} \quad (\text{NDS 2.3.2})$$

$$M = \frac{wL^2}{8} = \frac{14.76 \text{ lb/ft}(14 \text{ ft})^2}{8} = 3674.02 \text{ lb-ft}$$

$$S = 31.64 \text{ in}^3 \quad (\text{NDS Supplement Table 1-B})$$

$$f_b = \frac{3674.02 \text{ lb-ft}(12 \text{ in/ft})}{31.64 \text{ in}^3} = 1393.44 \text{ psi}$$

- $F_b' = F_b \times C_D \times C_M \times C_t \times C_i \times C_F \times C_{H_1} \times C_{H_2} \times C_r \times C_e$

$$F_b = 1700 \text{ psi} \quad (\text{NDS Supplement Table 4B})$$

$$C_D = 1.0 \quad (\text{NDS Table 2.3.2})$$

$$C_M = 1.0 \quad (\text{NDS Supplement, p. 20})$$

$$C_t = 1.0 \quad (\text{NDS Table 2.3.3})$$

$$C_i = 1.0 \quad (\text{NDS 3.3.3})$$

$$C_r = 1.0 \quad (\text{NDS Supplement Table 4-A})$$

$$C_R = 1.0 \quad (\text{NDS Supplement Table 4A})$$

$$C_i = 0.8 \quad (\text{NDS Table 4.3.8})$$

$$C_r = 1.15 \quad (\text{NDS Table 4.3.9})$$

$$C_t = 1.0 \quad (\text{NDS 3.3.4})$$

$$F'_b = 1700 \text{ psi} (1.0)(1.0)(1.0)(1.0)(1.0)(0.8)(1.15)(1.0) = \underline{1564 \text{ psi}}$$

$$1564 \text{ psi} > 1391.44 \text{ psi} \quad \therefore \text{O.K.}$$

Check for Shear Stresses in Joists (2x12)

$$f_v = \frac{3V}{2bd} = \frac{3(1049.72 \text{ lb})}{2(11.25)(1.5)} = \underline{93.31 \text{ lb/in}^2}$$

$$F'_v = F_v \times C_D \times C_M \times C_t \times C_i$$

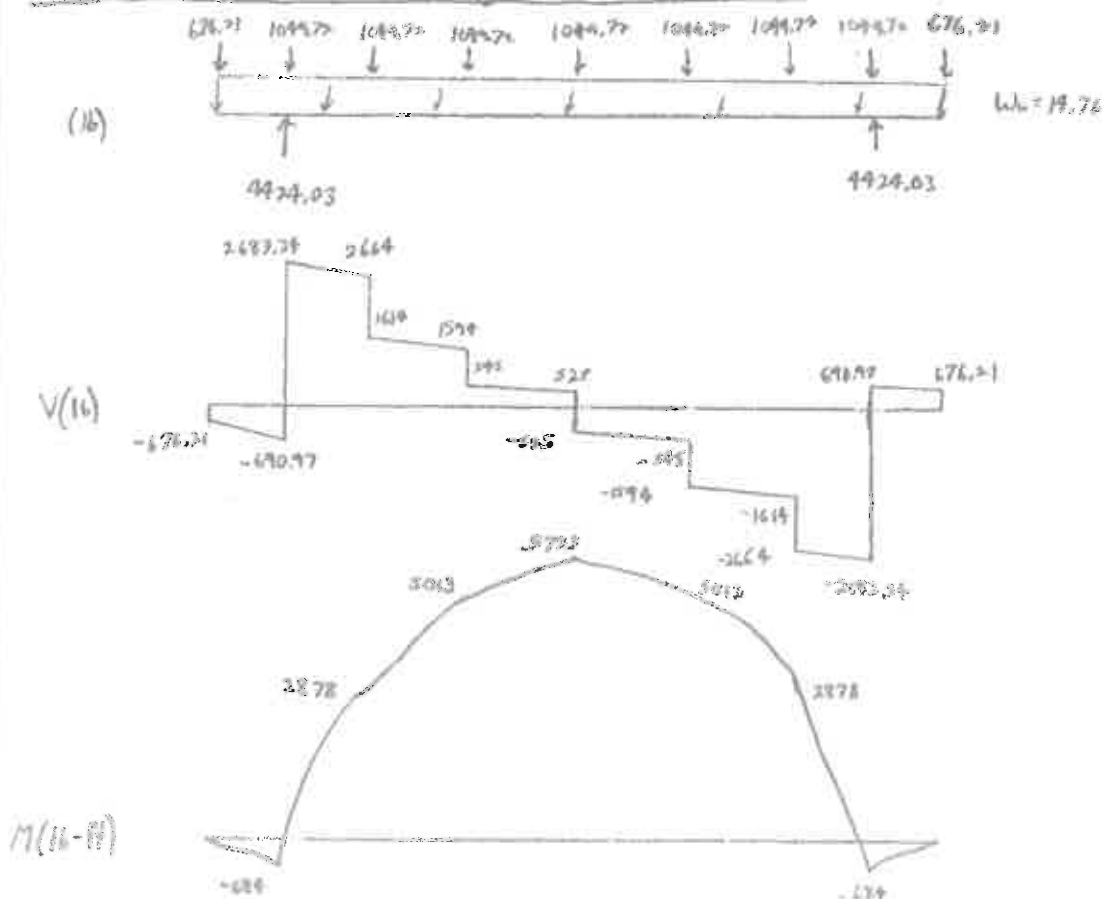
$$F_v = 175 \text{ psi} \quad (\text{NDS Supplement Table 4B})$$

$$C_D = 1.0, C_M = 1.0, C_t = 1.0, C_i = 0.8$$

$$F'_v = 175(1.0)(1.0)(1.0)(0.8) = \underline{140 \text{ lb/in}^2}$$

$$140 \text{ psi} > 93.31 \text{ psi} \quad \therefore \text{O.K.}$$

Shear and Moment Diagrams for Girders



Check for Bending Stress in Girders

$$f_b = \frac{M}{S} \quad (\text{NDS 3.3.2})$$

$$M_{max} = 5723.16 \text{ ft-lb}$$

$$S = 73.83 \text{ in}^3 \quad (\text{NDS Supplement Table 1-B})$$

$$f_b = \frac{5723.16 \text{ ft-lb} (12 \text{ in/ft})}{73.83 \text{ in}^3} = \underline{930.19 \text{ psi}}$$

$$F'_b(\text{girder}) = F'_b(\text{joint}) = \underline{1564 \text{ psi}}$$

$$1564 \text{ psi} > 930.19 \text{ psi} \quad \therefore \text{O.K.}$$

Check for Shear Stresses in Girders (4x12)

$$f_v = \frac{3V}{2bd} = \frac{3(2683.24 \text{ lb})}{2(11.25)(3.5'')} = \underline{102.22 \text{ lb/in}^2}$$

$$- F_v(\text{girder}) = F_v(\text{joist}) = \underline{110 \text{ lb/in}^2}$$

$$110 \text{ psi} > 102.22 \text{ psi} \quad \therefore \text{O.K.}$$

Boardwalk Calculations

Estimated cost for a 12' x 18' wood plastic composite deck is \$3900.

$$\$3900 / (12' \times 18') = \$18.06 / \text{SF}$$

Boardwalk Length= 1,267 ft

Boardwalk Width= 10 ft

$$\text{Boardwalk cost (just for decking and railing)} = (1267 \times 10) \times 18.06 = \$228,820.20$$

Decking Cost Comparison by Material

	Wood Plastic Composite	Pressure Treated Lumber	Plastic	Redwood/ Cedar	Hardwood
Total Deck*	\$3,900	\$2,540	\$4,400	\$3,250	\$4,165
Annual Maintenance**	\$75	\$375	\$75	\$375	\$375
Five Year Ownership	\$4,275	\$4,325	\$4,775	\$5,125	\$6,040

*Based on 12' x 18' deck. **Based on 12' x 18' deck. ***Based on 12' x 18' deck. ****Based on 12' x 18' deck. *****Based on 12' x 18' deck.

References

<http://timbertech.com/straighttalk/how-much-does-a-composite-deck-cost->

RETAINING WALL

Line Number	Description	Cost Data Title	Unit	Base Material	Base Labor	Base Equipment	Total	Total Cost
000505100000	Selective concrete demolition, reinforcing less than 1% of cross-sectional area, break up into 1	Concrete and Masonry	C.Y.		40.99	9.48	50.47	79.10
001100125900	CIP concrete form liner, 455 plastic, add to wall forming cost, fractured base etc, 2 use, includ	Concrete and Masonry	SFCA	1.94	1.20		3.14	1.86
012200100100	Fine grading, fine grade for 650 sq yards, machine	Site Work and Landscaping	S.Y.		0.59	0.02	1.09	1.07
012316166100	Structural excavation for minor structures, bank machine, for spaced and non-forming elevat	Concrete and Masonry	S.C.Y.		8.99	0.95	14.89	19.39
012320120700	Backfill, bulk, 6" to 12" lifts, cover backfilling, compaction with standard roller	Concrete and Masonry	E.C.Y.		0.04	2.36	3.00	2.93
012320170000	Fill, dumped material, raised, by dozer, exclude compaction	Concrete and Masonry	L.C.Y.		0.49	1.56	1.85	1.19
012320170500	Fill, gravel fill, compacted, under footpaths, 6" deep	Concrete and Masonry	S.F.	0.52	0.19	0.02	0.73	0.89
012320190000	Cycle hauling (wet, load, travel, unload or dump & return) one per cycle, excavated or borrow	Concrete and Masonry	L.C.Y.		0.87	1.08	1.11	1.70
021220120700	Segmental retaining walls, unit masonry including wall system, straight 5540, 8" high x 15"	Concrete and Masonry	S.F.	9.95	1.95	0.42	12.33	14.93
021220100100	Retaining wall accessories, gravel backfill, dune and spread by hand	Concrete and Masonry	C.Y.	19.14	17.03		26.17	47.19

RS Means data for retaining wall cost calculations

31 05 Common Work Results for Earthwork

31 05 13 – Soils for Earthwork

31 05 13.10 Borrow		Crew	Daily Output	Labor-Hours	Unit	Material	2011 Bare Costs		Total
							Labor	Equipment	
0010	BORROW								
0020	Spread, 200 H.P. dozer, no compaction, 2 mi. RT haul								
0200	Common borrow	B-15	600	.047	C.Y.	15	1.37	3.44	19.81

31 05 16 – Aggregates for Earthwork

31 05 16.10 Borrow

0010	BORROW								
0020	Spread, with 200 H.P. dozer, no compaction, 2 mi. RT haul								
0100	Bank run gravel	B-15	600	.047	C.Y.	22	1.37	3.44	26.81
0300	Crushed stone (1.40 tons per CY), 1-1/2"		600	.047		38	1.37	3.44	42.81
0320	3/4"		600	.047		38	1.37	3.44	42.81
0340	1/2"		600	.047		47	1.37	3.44	51.81
0360	3/8"		600	.047		32	1.37	3.44	36.81
0400	Sand, washed, concrete		600	.047		41	1.37	3.44	45.81
0500	Dead or bank sand		600	.047		15	1.37	3.44	19.81

31 11 Clearing and Grubbing

31 11 10 – Clearing and Grubbing Land

31 11 10.10 Clear and Grub Site

0010	CLEAR AND GRUB SITE								
0020	Cut & chip light trees to 6" diam.	B-7	1	48	Acre		1,350	1,300	2,650
0150	Grub stumps and remove	B-30	2	12			355	980	1,335
0200	Cut & chip medium, trees to 12" diam.	B-7	.70	68.571			1,925	1,875	3,800
0250	Grub stumps and remove	B-30	1	24			715	1,950	2,665
0300	Cut & chip heavy, trees to 24" diam.	B-7	.30	160			4,500	4,350	8,850
0350	Grub stumps and remove	B-30	.50	48			1,425	3,925	5,350
0400	If burning is allowed, reduce cut & chip								

31 13 Selective Tree and Shrub Removal and Trimming

31 13 13 – Selective Tree and Shrub Removal

31 13 13.10 Selective Clearing

0010	SELECTIVE CLEARING								
0020	Clearing brush with brush saw	A-1C	.25	32	Acre		845	103	948
0100	By hand	1 Clab	.12	66.667			1,775		1,775
0300	With dozer, ball and chain, light clearing	B-11A	2	8			245	525	770
0400	Medium clearing	"	1.50	10.667			325	700	1,025

31 22 Grading

31 22 16 – Fine Grading

31 22 16.10 Finish Grading

0010	FINISH GRADING								
0012	Finish grading area to be paved with grader, small area	B-11L	400	.040	S.Y.		1.23	1.36	2.59
1050	For small irregular areas	B-32C	2000	.024			.74	.91	1.65
1100	Fine grade for slab on grade, machine	B-11L	1040	.015			.47	.52	.99
1160	Hand grading	1 Clab	500	.016	S.F.		.42		.42
3300	Finishing grading slopes, gentle	B-11L	8900	.002	S.Y.		.06	.06	.12
3500	Finish grading lagoon bottoms	"	4	4	M.S.F.		123	136	259

West and East Retaining Wall Cut and Fill Approximations and Cost Estimations

Section	Width (ft)	Length (ft)	Area (yd ²)	Avg. West Ele. (ft)	Avg. East Ele. (ft)	Base Elevation (ft)
Sta. 0+00 - 0+42.50	24	42.5	37.73	915.5	915	915
Sta. 0+42.50 - 1+02.50	24	60	53.33	915.5	915	915
Sta. 1+02.50 - 1+52.25	24	49.75	44.22	915	914	914
Sta. 1+52.25 - 1+96.50	24	44.25	39.33	915	913	913
Sta. 1+96.50 - 2+30.00	24	33.5	29.78	914	911	911
Sta. 2+30.00 - 2+62.25	24	32.25	28.67	912	908	909
Sta. 2+62.25 - 2+93.25	24	31	27.56	911	907	909
Sta. 2+93.25 - 3+24.25	24	31	27.56	911	907	909
Sta. 3+24.25 - 3+62.25	24	38	33.78	915	905	909
Sta. 3+62.25 - 4+01.25	24	39	34.67	915	905	909
Sta. 4+01.25 - 4+39.00	24	37.75	33.56	913	904	909
Sta. 4+39.00 - 5+00.00	24	61	54.22	912	905	909
Sta. 5+00.00 - 5+62.75	24	62.75	55.78	911	907	909
Sta. 5+62.75 - 6+13.50	24	50.75	45.11	911	906	909
Sta. 6+13.50 - 6+67.25	24	53.75	47.78	911	906	909
Sta. 6+67.25 - 7+09.25	24	42	37.33	912	908	909
Sta. 7+09.25 - 7+64.50	24	55.25	49.11	911	907	909
Sta. 7+64.50 - 8+26.00	24	61.5	54.67	912	908	909
Sta. 8+26.00 - 8+85.50	24	59.5	52.89	911	907	909
Sta. 8+85.50 - 9+27.25	24	41.75	37.11	913	908	909
Sta. 9+27.25 - 9+69.00	24	41.75	37.11	911	905	909
Sta. 9+69.00 - 10+32.25	24	63.25	56.22	912	905	909
Sta. 10+32.25 - 10+88.25	24	56	49.78	915	907	909
Sta. 10+88.25 - 11+47.25	24	59	52.44	914	907	909
Sta. 11+47.25 - 12+01.00	24	53.75	47.78	911	907	909
Sta. 12+01.00 - 12+40.00	24	39	34.67	909	908	908
Sta. 12+40.00 - 12+67.50	24	27.5	24.44	909	908	908
Total:		1267.5	1126.67			

Section	Cut Height (ft)	Cut Volume (yd ³)	Fill Height (ft)	Fill Volume (yd ³)
Sta.0+00 - 0+42.50	0.5	9.44	0	0
Sta.0+42.50 - 1+02.50	0.5	13.33	0	0
Sta. 1+02.50 - 1+52.25	1	22.11	0	0
Sta. 1+52.25 - 1+96.50	2	39.33	0	0
Sta. 1+96.50 - 2+30.00	3	44.67	0	0
Sta. 2+30.00 - 2+62.25	3	64.50	1	7.17
Sta. 2+62.25 - 2+93.25	2	27.56	2	27.56
Sta. 2+93.25 - 3+24.25	2	27.56	2	27.56
Sta. 3+24.25 - 3+62.25	6	121.60	4	54.04
Sta. 3+62.25 - 4+01.25	6	124.80	4	55.47
Sta. 4+01.25 - 4+39.00	4	59.65	5	93.21
Sta. 4+39.00 - 5+00.00	3	69.71	4	123.94
Sta. 5+00.00 - 5+62.75	2	55.78	2	55.78
Sta. 5+62.75 - 6+13.50	2	36.09	3	81.20
Sta. 6+13.50 - 6+67.25	2	38.22	3	86.00
Sta. 6+67.25 - 7+09.25	3	84.00	1	9.33
Sta. 7+09.25 - 7+64.50	2	49.11	2	49.11
Sta. 7+64.50 - 8+26.00	3	123.00	1	13.67
Sta. 8+26.00 - 8+85.50	2	52.89	2	52.89
Sta. 8+85.50 - 9+27.25	4	118.76	1	7.42
Sta. 9+27.25 - 9+69.00	2	24.74	4	98.96
Sta. 9+69.00 - 10+32.25	3	72.29	4	128.51
Sta. 10+32.25 - 10+88.25	6	224.00	2	24.89
Sta. 10+88.25 - 11+47.25	5	187.30	2	29.97
Sta. 11+47.25 - 12+01.00	2	47.78	2	47.78
Sta. 12+01.00 - 12+40.00	1	34.67	0	0.00
Sta. 12+40.00 - 12+67.50	1	24.44	0	0.00
Total:		1797.33		1074.44

Cost: \$ 26,744.27

\$ 1,987.72

Based off bare total of 1 C.Y.
hydraulic excavator in clay soil in
RS Means

Using dozer assuming fill
taken from cut without
factoring compaction -
from RS Means

Wall needed at 2' cut height or higher

Adds 1' to cut height to account for embedment depth of base

Based off 1' min. drainage stone from keystone specs

Section	West Retaining Wall Needed?	West Retaining Design Height (ft)	West Retaining Wall Area (ft ²)	#57 Stone West Wall Backfill (yd ³)
Sta.0+00 - 0+42.50	no	-	-	-
Sta.0+42.50 - 1+02.50	no	-	-	-
Sta. 1+02.50 - 1+52.25	no	-	-	-
Sta. 1+52.25 - 1+96.50	yes	3	132.75	3.28
Sta. 1+96.50 - 2+30.00	yes	4	134.00	3.72
Sta. 2+30.00 - 2+62.25	yes	4	129.00	3.58
Sta. 2+62.25 - 2+93.25	yes	3	93.00	2.30
Sta. 2+93.25 - 3+24.25	yes	3	93.00	2.30
Sta. 3+24.25 - 3+62.25	yes	7	266.00	8.44
Sta. 3+62.25 - 4+01.25	yes	7	273.00	8.67
Sta. 4+01.25 - 4+39.00	yes	5	188.75	5.59
Sta. 4+39.00 - 5+00.00	yes	4	244.00	6.78
Sta. 5+00.00 - 5+62.75	yes	3	188.25	4.65
Sta. 5+62.75 - 6+13.50	yes	3	152.25	3.76
Sta. 6+13.50 - 6+67.25	yes	3	161.25	3.98
Sta. 6+67.25 - 7+09.25	yes	4	168.00	4.67
Sta. 7+09.25 - 7+64.50	yes	3	165.75	4.09
Sta. 7+64.50 - 8+26.00	yes	4	246.00	6.83
Sta. 8+26.00 - 8+85.50	yes	3	178.50	4.41
Sta. 8+85.50 - 9+27.25	yes	5	208.75	6.19
Sta. 9+27.25 - 9+69.00	yes	3	125.25	3.09
Sta. 9+69.00 - 10+32.25	yes	4	253.00	7.03
Sta. 10+32.25 - 10+88.25	yes	7	392.00	12.44
Sta. 10+88.25 - 11+47.25	yes	6	354.00	10.93
Sta. 11+47.25 - 12+01.00	yes	3	161.25	3.98
Sta. 12+01.00 - 12+40.00	no	-	-	-
Sta. 12+40.00 - 12+67.50	no	-	-	-
Total:			4307.75	120.70

Cost:	\$	53,114.56	\$	4,365.25
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Assuming medium, lt. wt., 8" high x 18" wide x 12' deep, straight split - RS Means

Retaining wall gravel backfill, place, spread by hand - RS Means

Wall needed at 1' fill height or larger

Adds 1' to fill height to account for embedment depth

Based off 1' min. drainage stone from keystone specs

Based off of 8' sidewalk and 4" thickness from TDOT Spec

<u>Section</u>	<u>East Retaining Wall Needed?</u>	<u>East Retaining Design Height (ft)</u>	<u>East Retaining Wall Area (ft²)</u>	<u>#57 Stone West Wall Backfill (yd³)</u>	<u>Concrete for Sidewalk (ft²)</u>
Sta.0+00 - 0+42.50	no	-	-	-	340
Sta.0+42.50 - 1+02.50	no	-	-	-	480
Sta. 1+02.50 - 1+52.25	no	-	-	-	398
Sta. 1+52.25 - 1+96.50	no	-	-	-	354
Sta. 1+96.50 - 2+30.00	no	-	-	-	268
Sta. 2+30.00 - 2+62.25	yes	2	64.5	1.19	258
Sta. 2+62.25 - 2+93.25	yes	3	93	2.30	248
Sta. 2+93.25 - 3+24.25	yes	3	93	2.30	248
Sta. 3+24.25 - 3+62.25	yes	5	190	5.63	304
Sta. 3+62.25 - 4+01.25	yes	5	195	5.78	312
Sta. 4+01.25 - 4+39.00	yes	6	226.5	6.99	302
Sta. 4+39.00 - 5+00.00	yes	5	305	9.04	488
Sta. 5+00.00 - 5+62.75	yes	3	188.25	4.65	502
Sta. 5+62.75 - 6+13.50	yes	4	203	5.64	406
Sta. 6+13.50 - 6+67.25	yes	4	215	5.97	430
Sta. 6+67.25 - 7+09.25	yes	2	84	1.56	336
Sta. 7+09.25 - 7+64.50	yes	3	165.75	4.09	442
Sta. 7+64.50 - 8+26.00	yes	2	123	2.28	492
Sta. 8+26.00 - 8+85.50	yes	3	178.5	4.41	476
Sta. 8+85.50 - 9+27.25	yes	2	83.5	1.55	334
Sta. 9+27.25 - 9+69.00	yes	5	208.75	6.19	334
Sta. 9+69.00 - 10+32.25	yes	5	316.25	9.37	506
Sta. 10+32.25 - 10+88.25	yes	3	168	4.15	448
Sta. 10+88.25 - 11+47.25	yes	3	177	4.37	472
Sta. 11+47.25 - 12+01.00	yes	3	161.25	3.98	430
Sta. 12+01.00 - 12+40.00	no	-	-	-	312
Sta. 12+40.00 - 12+67.50	no	-	-	-	220
Total:			3439.25	91.42	10140

Cost: \$ 42,405.95 \$ 3,306.54 \$ 30,825.60

Assuming medium, lt. wt., 8" high x 18" wide x 12' deep, straight split - RS Means

Retaining wall gravel backfill, place, spread by hand - RS Means

Based off 4" thick cast-in-place concrete - RS Means

Fine-Grading Cost:	\$ 1,115.40	Fine-grading for slab on grade from RS Means
Compaction Cost:	\$ 8,615.31	Using 6" lifts, dozer backfill, compaction with sheepfoot roller - RS Means
Hauling Cost:	\$ 6,116.87	Assuming hauling all cut and fill using 8 C.Y. truck, 15 mph, cycle 0.5 mile, wait 10 min. - RS Means
Total Cost:	\$178,598.08	

11

SUME CONCRETE WALL

$\gamma = 150 \text{ lb/ft}^3$

$B=0$

$B=0$

$B=0$

Concrete	
γ (concrete) =	150.000 lb/ft ³
Wall thickness =	3.400 ft

Soil Parameters	
γ_m	105.890 lb/ft ³
β =	0.000 degrees
C_u =	1250.533 lb/ft ²
K_a =	1.000
K_p =	1.000

Fill Parameters	
γ_m	92.400 lb/ft ³
β =	0.000 degrees
ϕ =	35.000 degrees
K_a =	0.271
K_p =	3.690

East wall

Wall ht. (ft)	Wall weight (lb/ft)	σ_v (psf)	σ_a (psf)	τ (psf)	Area of pressure (ft ²)	Moment arm (ft)	P_a (lb/ft)	Moments (lb-ft)/ft
1.000	510.000	105.890	105.890	0.000	52.945	0.333	52.945	17.648
1.667	850.000	176.483	176.483	0.000	147.069	0.556	147.069	81.705
2.333	1190.000	247.077	247.077	0.000	288.256	0.778	288.256	224.199
3.000	1530.000	317.670	317.670	0.000	476.505	1.000	476.505	476.505
3.667	1870.000	388.263	388.263	0.000	711.816	1.222	711.816	869.997
4.000	2040.000	423.560	423.560	0.000	847.120	1.333	847.120	1129.493
4.333	2210.000	458.857	458.857	0.000	994.189	1.444	994.189	1436.051
5.000	2550.000	529.450	529.450	0.000	1323.625	1.667	1323.625	2206.042
5.667	2890.000	600.043	600.043	0.000	1700.123	1.889	1700.123	3211.343
6.333	3230.000	670.637	670.637	0.000	2123.683	2.111	2123.683	4483.330
1.000	510.000	105.890	105.890	-	-	-	8665.332	14136.315

Embedment

East wall

Wall ht. (ft)	Wall weight (lb/ft)	σ_v (psf)	σ_p (psf)	τ (psf)	Area of pressure (ft ²)	Moment arm (ft)	P_p (lb/ft)	Moments (lb-ft)/ft	FS (Overturning)	FS (Sliding)
1.000	510.000	105.890	-	-	-	-	-	255.000	14.449	9.632637643
1.667	850.000	176.483	-	-	-	-	-	708.333	8.669	5.779582586
2.333	1190.000	247.077	-	-	-	-	-	1388.333	6.192	4.128273276
3.000	1530.000	317.670	-	-	-	-	-	2295.000	4.816	3.210879214
3.667	1870.000	388.263	-	-	-	-	-	3428.333	3.941	2.627082994
4.000	2040.000	423.560	-	-	-	-	-	4080.000	3.612	2.408159411
4.333	2210.000	458.857	-	-	-	-	-	4788.333	3.334	2.222916379
5.000	2550.000	529.450	-	-	-	-	-	6375.000	2.890	1.926527529
5.667	2890.000	600.043	-	-	-	-	-	8188.333	2.550	1.699877231
6.333	3230.000	670.637	-	-	-	-	-	10228.333	2.281	1.520942786
1.000	510.000	105.890	105.890	0.000	52.945	0.333	52.945	17.648	18922.345	

Embedment

Assumptions:- Soil Properties - $\gamma = 125 \text{ lb/ft}^3$

$\phi = 35^\circ$

$u_0 = 0$

$c' = 400 \text{ lb/ft}^2$

Backfill - $\gamma = 120 \text{ lb/ft}^3$

$\phi = 28^\circ$

$c' = 200$

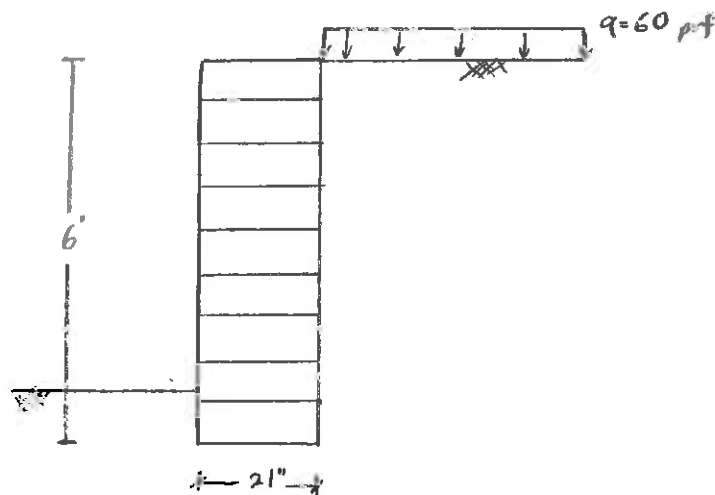
- Use Rankine Theory

- Vertical Wall without factoring in 1" setback.

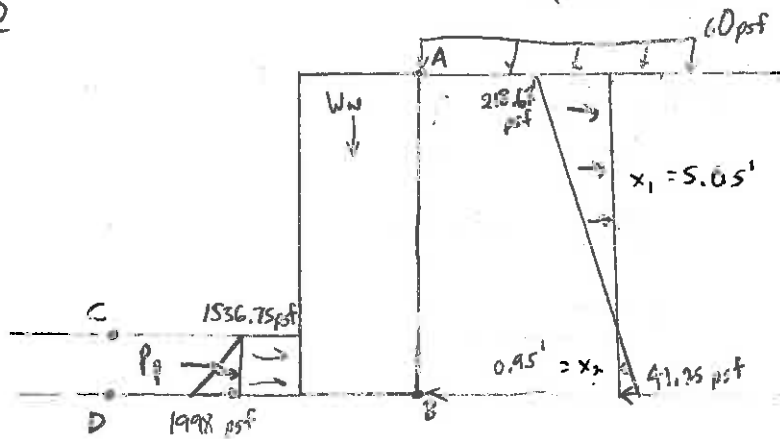
- Design height of wall = 6 feet

- Embedment Depth of wall = 1 foot

- Keystone Standard units used for wall - weight of unit = 114 lbs

Units dimensions are $8" \text{ h} \times 18" \text{ w} \times 21" \text{ d}$ - Backslope assumed level $\Rightarrow \beta = 0$ - $q = 60 \text{ psf}$ Solution:

$$\text{Wall Unit Weight} = 114 \text{ lb} / (8" \times 18" \times 21") \times (1728 \text{ in}^3/\text{ft}^3) = 65.14 \text{ lb/ft}^3$$

FBD

$$\frac{218.67}{x_1} = \frac{41.25}{x_2}$$

$$x_1 + x_2 = 6$$

$$x_1 + \frac{41.25 x_1}{218.67} = 6$$

$$x_1 = 5.05'$$

$$x_2 = 0.95'$$

Soil Active Pressure

$$K_a = \frac{1 - \sin \phi}{1 + \sin \phi} = \frac{1 - \sin(28)}{1 + \sin(28)} = 0.361$$

$$\begin{aligned} @ A \Rightarrow (\sigma_a)_A &= [K_a \sigma'_v - 2c' \sqrt{K_a}] \cos \beta^0 \\ &= 0.361(60 \text{ psf}) - 2(300 \text{ psf}) \sqrt{0.361} = -218.67 \text{ psf} \end{aligned}$$

$$@ B \Rightarrow (\sigma_a)_B = 0.361(60 + 6(120 \text{ lb/ft}^3)) - 2(300) \sqrt{0.361} = 41.25 \text{ psf}$$

Soil Passive Pressure

$$K_p = \frac{1 + \sin \phi}{1 - \sin \phi} = \frac{1 + \sin(35)}{1 - \sin(35)} = 3.69$$

$$\begin{aligned} @ C \Rightarrow (\sigma_p)_C &= [K_p \sigma'_v + 2c' \sqrt{K_p}] \\ &= 3.69(0) + 2(400 \text{ psf}) \sqrt{3.69} = 1536.75 \text{ psf} \end{aligned}$$

$$@ D \Rightarrow (\sigma_p)_D = 3.69(1' \times 125 \text{ lb/ft}^3) + 2(400 \text{ psf}) \sqrt{3.69} = 1998.00 \text{ psf}$$

$$P_{a1} = 218.67 \text{ psf} (5.05 \text{ ft}) \left(\frac{1}{2}\right) = 552.14 \text{ lb/ft}$$

$$P_{a2} = 41.25 \text{ psf} (0.95 \text{ ft}) \left(\frac{1}{2}\right) = 19.59 \text{ lb/ft}$$

$$P_p = 1536.75 \text{ psf} (1 \text{ ft}) + (1998.0 - 1536.75) \left(\frac{1 \text{ ft}}{2}\right) = 1767.375 \text{ lb/ft}$$

$$M_{\text{driving}} = 19.59 (0.32') = 3.07 \text{ lb-ft/ft}$$

$$M_{\text{passive}} = 1536.75 (1)(0.5) + (1998 - 1536.75) \left(\frac{1 \text{ ft}}{2}\right) \left(\frac{1 \text{ ft}}{3}\right) = 845.25 \text{ lb-ft/ft}$$

$$M_{\text{resisting}} = 552.14 (0.32') + 845.25 + 65.14 \left(\frac{2 \text{ ft}}{3}\right) \left(\frac{1 \text{ ft}}{2}\right) = 3157.89 \text{ lb-ft/ft}$$

$$F.S. = \frac{M_{\text{Resisting}}}{M_{\text{driving}}} \geq 1.5 \Rightarrow \frac{3157.89}{3.07} = 1029 \therefore \boxed{\text{OK}}$$



KEYSTONE SPECIFICATION GUIDE



KEYSTONE
RETAINING WALL SYSTEMS
A CONTECH COMPANY



For over 25 years, Keystone Retaining Wall Systems has set the worldwide standard in soil retention, erosion control and landscape systems. By working with the finest network of manufacturers, product developers, engineers and sales professionals in the business; Keystone ensures that its products and services offer the best site solutions for residential, commercial, recreational, industrial and governmental applications.

Architects, engineers and contractors around the world rely on Keystone's industry leading product performance and aesthetics to fulfill the unique requirements of their projects. Offering a broad family of products, Keystone has the right solution for even the most challenging structural and landscape sites.

The Keystone difference lies in its outer beauty and inner strength. Keystone's patented, interlocking fiberglass pin system ensures a positive connection from wall unit to wall unit, and between wall units and soil reinforcement. In addition, Keystone's pinned system aids in horizontal alignment, as well as providing for the ability to vary wall set-back.



KEYSTONE® STANDARD

The Keystone Standard is an American original and remains the industry leader. The Keystone Standard unit's height-to-depth ratio delivers a structurally sound, engineered wall system with superior construction stability, durability, and strength. This product is the preferred choice for tall walls and critical structures.



94 - 106 lbs (43 - 48 kg)

Standard I



92 - 97 lbs (42 - 44 kg)

Standard II



82 - 93 lbs (37 - 42 kg)

Standard III

Tri-Plane

Face Area • 1 sq. ft. per unit
8" h x 18" w x 18 - 21" d
(203 x 457 x 457 - 533 mm)

Straight Split

102 - 114 lbs (46 - 52 kg)



99 - 105 lbs (45 - 48 kg)



85 - 96 lbs (39 - 44 kg)



Supporting products that can be used with both the Standard and Compac units.



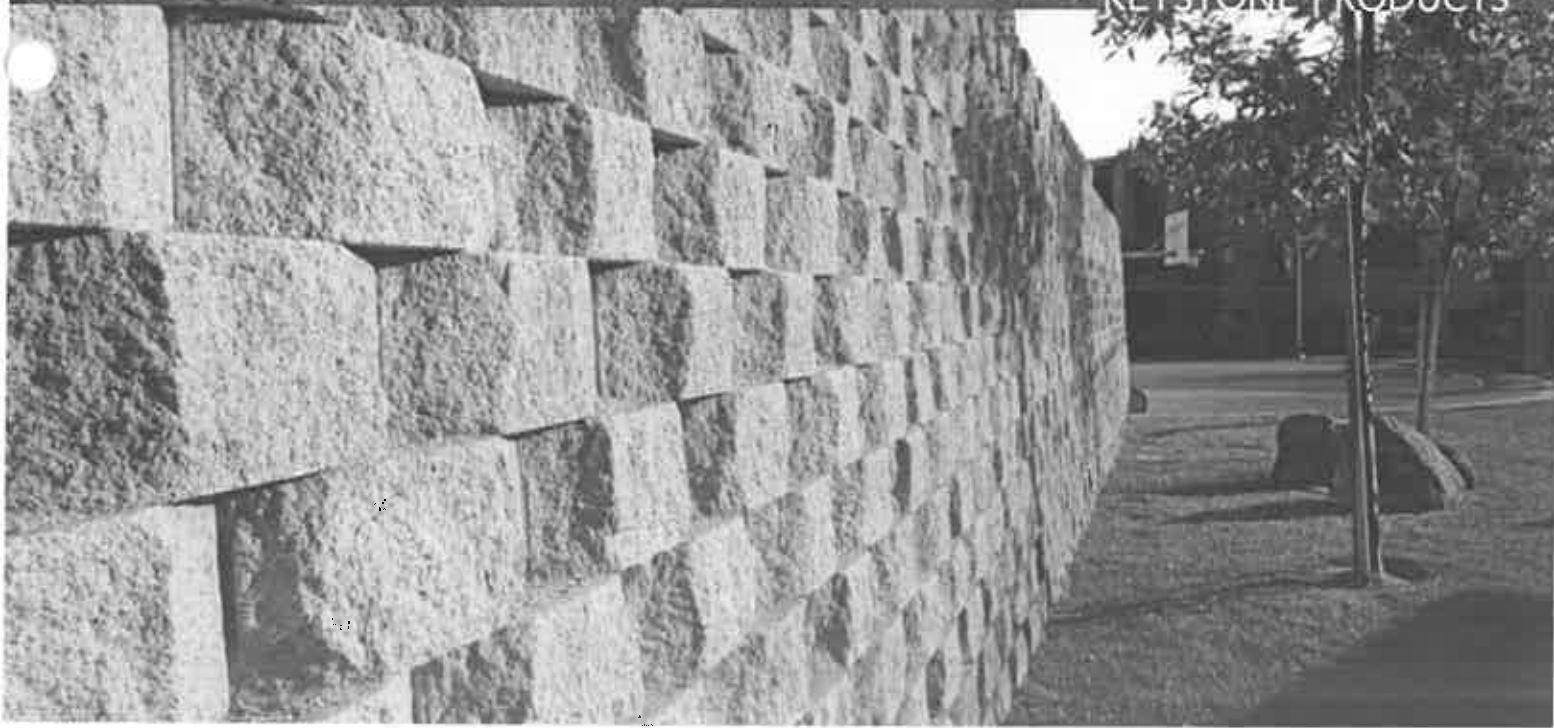
2 Connection Pins
required per unit



8" 90° Corner unit
Face Area • 1 sq. ft.
8" h x 18" w x 9" d
(203 x 457 x 228 mm)
96 - 102 lbs (44 - 46 kg)



8" 90° Corner unit*
Face Area • .83 sq. ft.
8" h x 15" w x 6" d
(203 x 381 x 152 mm)
44 - 48 lbs (20 - 22 kg)
*Left & right corner units available.



KEYSTONE® COMPAC

Featuring unrivaled aesthetic options, cost saving versatility and proven wall performance; the Keystone Compac retains its position as the most specified unit on the market. An installer's favorite, the Compac's lighter weight and shorter tail design make it easy to handle.

Face Area • 1 sq. ft. per unit
8" h x 18" w x 12" d
(203 x 457 x 305 mm)



76 - 81 lbs (34 - 37 kg)



67 - 72 lbs (30 - 33 kg)

TN-Plane

Compac II

Compac III

Straight Split

84 - 89 lbs (38 - 40 kg)

71 - 76 lbs (32 - 34 kg)



Alternative face options available:

Hewnstone

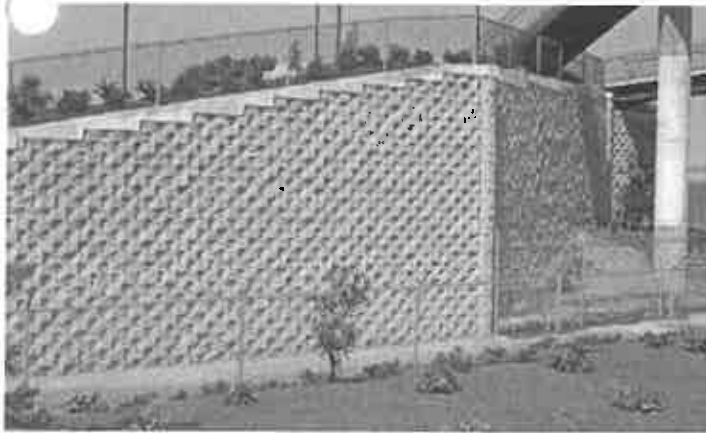


Victorian



Random Score





SQ FT KEYSTEEL PANEL SYSTEM by Contech

The KeySteel SQ FT Panel System is a high performance retaining wall system designed specifically for use in transportation and tall walls with high load applications. This system has been used extensively for structures supporting railroads, multi-story buildings, bridge approach and abutments, and mining applications. The KeySteel SQ FT Panel System has been evaluated by HITEC (CERF report #40478) and found to be in accordance with the high standards of the AASHTO bridge specification manual. The system utilizes the Keystone KeySteel SQ FT Panel and inextensible KeyStrip soil reinforcement.

Face Area • 1 sq. ft. per unit
8" h x 18" w x 12" d
(203 x 457 x 305 mm)
90 - 95 lbs (41 - 43 kg)



Steel Pins



Fiberglass Pins

2 required per unit
(steel pins required at reinforcement locations)



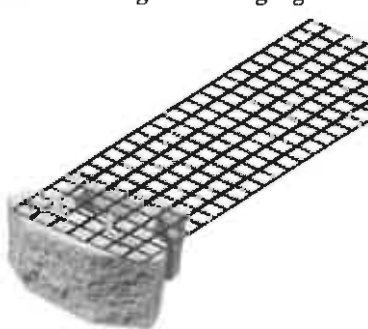
Tri-Plane



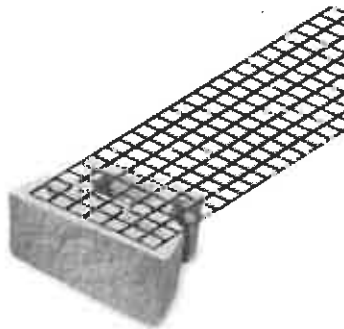
Straight Split

KEYSTONE KEYGRID SYSTEM

The KeyGrid System has been developed, designed and tested to meet the highest standards of the transportation market. The System was evaluated by HITEC and found to be in accordance with the most current AASHTO LRFD Bridge Design Specifications and Federal Highway Administration design requirements for transportation applications. The system utilizes the patented Keystone Compac II unit and Miragrid® XT geogrids.



Tri-Plane



Straight Split

Face Area • 1 sq. ft. per unit
8" h x 18" w x 12" d
(203 x 457 x 305 mm)
76 - 89 lbs (34 - 40 kg)



2 Connection Pins
required per unit



133ELITE

The Keystone 133Elite is perfect for large wall applications. The 8" x 24" face dimension creates a larger-scale appearance, aesthetically matching the larger wall look while reducing the number of units required to complete the job. From corners to sweeping curves, the Keystone 133Elite is able to satisfy a wide array of design requirements. Quite simply, the Keystone 133Elite is the best combination of strength, beauty and efficiency on the market.



Hewnstone



Random Score

*Note: Units shown have chamfer on three sides.

Face Area • 1.33 sq. ft. per unit
 8" h x 24" w x 11.5 - 12" d
 (203 x 610 x 292 - 305 mm)
 92 - 97 lbs (42 - 44 kg)



133Elite® 90° Hewnstone Corner*

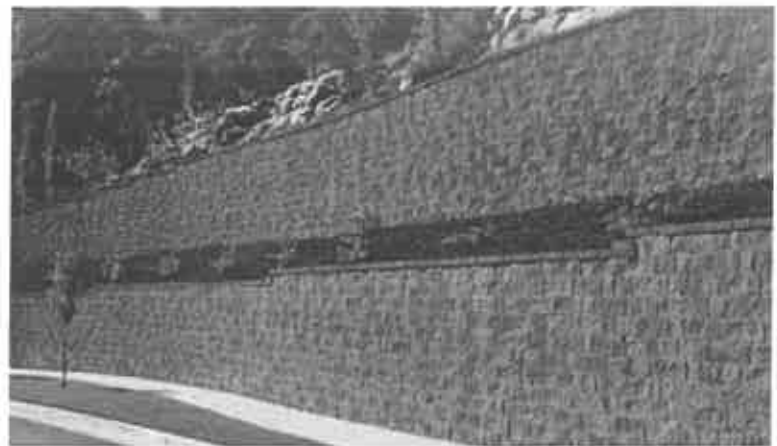
8" h x 18" w x 6" d
 (203 x 457 x 152 mm)
 53 - 57 lbs (24 - 26 kg)
 *Left & right corner units available.



2 Shouldered Pins
 required per unit

KEYSTONE CENTURY WALL®

Designed specifically for medium to large wall loading conditions, Keystone Century Wall combines the distinctive look and character of a natural stone three-piece system* with superior structural integrity. For projects where aesthetics are paramount, Keystone Century Wall allows you to build with confidence.



Large unit

Face Area • 1 sq. ft.
 8" h x 18" w x 12" d
 (203 x 457 x 305 mm)
 82 - 87 lbs (37 - 39 kg)



Medium unit

Face Area • .62 sq. ft.
 8" h x 11" w x 12" d
 (203 x 279 x 305 mm)
 54 - 58 lbs (24 - 26 kg)



Small unit

Face Area • .38 sq. ft.
 8" h x 7" w x 12" d
 (203 x 177 x 305 mm)
 41 - 45 lbs (19 - 20 kg)



1 to 2 Shouldered Pins
 required per unit

**In select markets, Half-Century Wall (4" h) units are available to combine with the 8" versions; to achieve an ashlar pattern wall design.*

KEYSTONE® Country Manor

Keystone Country Manor offers the appearance of rustic, hand-laid stone walls with the strength and ease of installation provided by the latest in dry-stacked, modular, pin-connected technology. With three finished sides on each unit, Country Manor offers endless building possibilities.



3 - piece Country Manor



Unit 16/14

16" Face Area • .66 sq. ft.
14" Face Area • .58 sq. ft.
6"h x 16"/14"w x 10"d
(152 x 406/355 x 254 mm)
60 - 65 lbs (27 - 29 kg)



Unit 12/10**

12" Face Area • .50 sq. ft.
10" Face Area • .42 sq. ft.
6"h x 12"/10"w x 10"d
(152 x 305/254 x 254 mm)
47 - 51 lbs (20 - 23 kg)



Unit 6/4

6" Face Area • .25 sq. ft.
4" Face Area • .17 sq. ft.
6"h x 6"/4"w x 10"d
(152 x 152/101 x 254 mm)
21 - 24 lbs (10 - 11 kg)



Keystone Country Manor Cap Unit

*3"h x 12"/10"w x 11"d
(76 x 305/255 x 279 mm)
27 - 30 lbs (12 - 14 kg)

Optional Country Manor Unit Sizes*



Unit 8/6

8" Face Area • .33 sq. ft.
6" Face Area • .25 sq. ft.
6"h x 8"/6"w x 10"d
(152 x 203/152 x 254 mm)
30 - 33 lbs (14 - 15 kg)



Unit 10/8

10" Face Area • .42 sq. ft.
8" Face Area • .33 sq. ft.
6"h x 10"/8"w x 10"d
(152 x 254/203 x 254 mm)
38 - 42 lbs (17 - 19 kg)



Unit 12/12**

12" Face Area • .50 sq. ft.
6"h x 12"/12"w x 10"d
(152 x 305/305 x 254 mm)
51 - 55 lbs (23 - 25 kg)
(90° ends for vertical stacking capability)



1-2 Shouldered Pins
required per unit

*The number of units in the Keystone Country Manor system vary by manufacturer.

**The use of unit cores vary by manufacturer.

Contact your local representative for further details.



KEYSTONE® Stonegate COUNTRY MANOR®

Reminiscent of the walls found scattered throughout the European countryside, Keystone Stonegate Country Manor features a smooth, weathered stone appearance. Stonegate delivers all of the best features of the original Keystone Country Manor, with a refined look.



Unit 16/14

16" Face Area • .66 sq. ft.
14" Face Area • .58 sq. ft.
6"h x 16"/14"w x 10"d
(152 x 406/355 x 254 mm)
60 - 65 lbs (27 - 29 kg)



Unit 12/10

12" Face Area • .50 sq. ft.
10" Face Area • .42 sq. ft.
6"h x 12"/10"w x 10"d
(152 x 305/254 x 254 mm)
47 - 51 lbs (21 - 23 kg)



Unit 6/4

6" Face Area • .25 sq. ft.
4" Face Area • .17 sq. ft.
6"h x 6"/4"w x 10"d
(152 x 152/101 x 254 mm)
21 - 24 lbs (9 - 11 kg)



1-2 Shouldered Pins
required per unit

Gravity Walls

One of the most basic types of retaining walls, the gravity wall, relies on unit mass, depth, and setback to resist the earth pressure that is attempting to move the structure in a lateral direction. Keystone units are able to resist lateral pressure with their weight and embedment depth. The mortarless, yet structurally interconnected, Keystone units also permit water drainage to prevent hydrostatic loads. For low, non-critical applications, Keystone products can be used to build cost-effective gravity wall structures.

Maximum wall height for non-critical walls is dependent on wall batter, soil loads affecting the walls, and site conditions including drainage considerations. For more information on specific maximum gravity wall heights refer to to www.keystonewalls.com/pages/TECH_DesignCharts.html.



Reinforced Soil Walls

For taller walls, Keystone units are combined with soil reinforcement (such as geogrids, earth anchors or galvanized steel grid reinforcing) to create larger composite reinforced soil structures. With a properly designed combination, the reinforced soil mass can support greater earth pressure and surcharge loads. These composite structures have been constructed to heights over 70' (21 m) high. Call your local Keystone Representative to see which option will work best for your project.



Geogrid

Since the 1980's, geogrid has proven successful in providing durable soil reinforcement for the retaining wall industry. Proper design methodology today incorporates laboratory tested connection strength of Keystone concrete units and specific geogrid types for reinforced retaining wall systems. Geogrids are made from high tenacity polyester yarns or high-density polyethylene.

Key properties of geogrid include:

- High tensile strength
- Long-term creep resistance
- Open geometry for interlock
- Non-degradable
- "Off-the-shelf" availability

The advantages of geogrid-reinforced structures include:

- Construct walls faster without waiting for forming, steel placement and curing time of site cast concrete; the wall structure and backfill are constructed at the same time.
- Eliminates the need for deep structural footing and deeper excavations.
- Provides durability; long term performance resists effects of water, micro-organisms, alkali or acidic soils.



Soil Properties

The very purpose of a retaining wall system is to safely hold soil in place to make a grade or elevation change in the shortest possible horizontal distance. The soil's shear strength (angle of internal friction) and moist soil weight determines the design characteristics of the soil for use within the wall structure. The design properties of the geogrid zone (the retained zone of reinforced soil mass and sloping embedment soils) as well as the foundation zone (soils beneath the Keystone units and reinforced zone), must be determined. A qualified geotechnical engineer should be consulted to establish site-specific soil properties. Taller walls or difficult site conditions will typically require a more extensive geotechnical investigation including laboratory testing of soil.

Note: Granular soils typically exhibit higher friction angles and better drainage capability, thus offer a more efficient and cost effective wall design and soil reinforcement solution. Better quality soils are more easily placed and compacted resulting in superior structure performance.



Engineering Properties

A retaining wall is a structural system which, when properly designed, retains a soil mass and safely supports any surcharge loadings applied to the structure. The engineering properties of the system components are determined by laboratory testing which provide the technical data necessary to complete the design in accordance with accepted design standards. Typical engineering data requirements are:

- Unit dimensions, shape/weight
- Unit to unit shear strength
- Unit to geogrid connection strength
- Geogrid long-term design strength
- Geogrid soil interaction
- Soil Design Properties
- Surcharge loadings/slope conditions

*Keystone test data is available for all material requirements.

Section 02834 (32 32 23) KEYSTONE CONCRETE RETAINING WALL

PART 1: GENERAL

1.01 Description

- A. Work shall consist of designing, furnishing and construction of a KEYSTONE® Retaining Wall System in accordance with these specifications and to the lines, grades, design, and dimensions shown on the plans. No alternate wall systems will be considered.
- B. Work includes preparing foundation soil, furnishing and installing leveling pad, unit drainage fill and backfill to the lines and grades shown on the construction drawings.
- C. Work includes furnishing and installing geogrid soil reinforcement of the type, size, location, and lengths designated on the construction drawings.

1.02 Related Sections

- A. Section 02300 (31 00 00) - Earthwork

1.03 Reference Documents

- A. American Society for Testing and Materials (ASTM)

1. ASTM C140 Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
2. ASTM C1262 Standard Test Method for Evaluating the Freeze-Thaw Durability
3. ASTM C1372 Standard Specification for Dry-Cast Segmental Retaining Wall Units
4. ASTM D422 Standard Test Method for Particle-Size Analysis of Soils
5. ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³))
6. ASTM D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³))
7. ASTM D3034 Standard Specification for Type PSM Poly Vinyl Chloride (PVC) Sewer Pipe and Fittings
8. ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
9. ASTM D4475 Horizontal Shear Strength of Pultruded Reinforced Plastic Rods
10. ASTM D4476 Flexural Properties of Fiber Reinforced Pultruded Plastic Rods
11. ASTM D4595 Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
12. ASTM D5262 Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics
13. ASTM D5818 Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics
14. ASTM D6637 Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method
15. ASTM D6638 Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)
16. ASTM D6706 Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil
17. ASTM D6916 Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks)

- B. American Association of State Highway and Transportation Officials (AASHTO)

1. AASHTO M 252 Corrugated Polyethylene Drainage Pipe
2. AASHTO M 288 Standard Specification for Geotextile Specification for Highway Applications

1.04 Submittals/Certification

- A. Contractor shall submit a Manufacturer's certification, prior to start of work, that the retaining wall system components meet the requirements of this specification and the structure design.
- B. Contractor shall submit construction drawings and design calculations for the retaining wall system as prepared and stamped by a Professional Engineer registered in the state of the project. The engineering designs, techniques, and material evaluations shall be in accordance with the Keystone Design Manual.

1.05 Quality Assurance

- A. Contractor shall submit a list of five (5) previously constructed projects of similar size and magnitude by the wall installer where the specific retaining wall system has been constructed successfully. Contact names and telephone numbers shall be listed for each project.
- B. Contractor shall provide evidence that the design engineer has a minimum of five years of documented experience in the design for reinforced soil structures. The design engineer shall provide proof of current professional liability insurance with an aggregate coverage limit of not less than \$2,000,000.
- C. Owner shall provide soil testing and quality assurance inspection during earthwork and wall construction operations. Contractor shall provide quality control testing and inspection during construction. Owner's quality assurance program does not relieve the contractor of responsibility for quality control and wall performance.

1.06 Delivery, Storage and Handling

- A. Contractor shall check all materials upon delivery to assure that the proper type, grade, color, and certification have been received.
- B. Contractor shall protect all materials from damage due to job site conditions and in accordance with manufacturer's recommendations. Damaged materials shall not be incorporated into the work.

PART 2: PRODUCTS

2.01 Definitions

- A. Keystone Unit: a concrete retaining wall element machine made from Portland cement, water, and aggregates.
- B. Structural Geogrid: a structural element formed of high tenacity woven/ knitted polyester yarns or high-density polyethylene (HDPE) into a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, or earth and function primarily as reinforcement.
- C. Unit Drainage Fill: drainage aggregate that is placed within and immediately behind the Keystone concrete units.
- D. Reinforced Backfill: compacted soil that is placed within the reinforced soil volume as outlined on the plans.

2.02 Keystone Concrete Retaining Wall Units

- A. Keystone concrete units shall conform to the following architectural requirements:
 1. Face color: concrete gray, unless otherwise specified. The Owner may specify standard manufacturers' color.
 2. Face finish: sculptured rock face in angular tri-plane or straight-face configuration. Other face finishes will not be allowed without written approval of Owner.
 3. Bond configuration: running with bonds nominally located at midpoint of vertically adjacent units, in both straight and curved alignments.
 4. Exposed surfaces of units shall be free of chips, cracks or other imperfections when viewed from a distance of 10 feet (3 m) under diffused lighting.

B. Keystone concrete materials shall conform to the requirements of ASTM C1372 - Standard Specifications for Segmental Retaining Wall Units.

C. Keystone concrete units shall conform to the following structural and geometric requirements measured in accordance with ASTM C140 Sampling and Testing Concrete Masonry Units, ASTM D6916 Determining the Shear Strength Between Segmental Concrete Units and ASTM D6638 Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units:

1. Compressive strength: ≥ 3000 psi (21 MPa)
2. Absorption: $\leq 8\%$ for standard weight aggregates. *Note to Specifier: Select appropriate unit(s) below and delete others.*
3. Keystone Standard Units:
 - a. Width: 18" (457 mm).
 - b. Depth: 18" - 21" (457 - 533 mm), not including rough split face.
 - c. Height: 8" (203 mm).
 - d. Weight: 82 - 114 pounds (37 - 52 kg) per unit minimum using standard weight aggregates.
4. Keystone Compac Units:
 - a. Width: 18" (457 mm).
 - b. Depth: 12" (305 mm), not including rough split face.
 - c. Height: 8" (203 mm).
 - d. Weight: 67 - 89 pounds (30 - 40 kg) per unit minimum using standard weight aggregates.
5. Keystone Century Wall Units:
 - a. Width: Varies - 7 - 18" (178 - 457 mm).
 - b. Depth: 12" (305 mm) minimum, not including rough split face.
 - c. Height: 8" (203 mm) and 4" (101 mm).
 - d. Weight: 20 - 90 pounds (9 - 41 kg) per unit minimum using standard weight aggregates.
6. Keystone Country Manor Units:
 - a. Width: 4" - 16" (101 - 406 mm).
 - b. Depth: 10" (254 mm) minimum, not including rough split face.
 - c. Height: 6" (152 mm).
 - d. Weight: 21 - 65 pounds (10 - 29 kg) per unit minimum using standard weight aggregates.
7. Keystone 133Elite Units:
 - a. Width: 24" (610 mm).
 - b. Depth: 11.5 - 12" (292 - 305 mm).
 - c. Height: 8" (203 mm).
 - d. Weight: 92 - 97 pounds (42 - 44 kg) per unit minimum using standard weight aggregates.
8. Accessory Units: Provide matching units.
 - a. Corners: Provide 90 degree corners, finished two sides, where indicated.
 - b. Cap units: Provide solid cap units.

D. Keystone concrete units shall conform to the following construction requirements:

1. Vertical setback: $1/8"$ (3 mm) $\pm$ per course (near vertical) or $1"$ (25 mm) $\pm$ per course per the design (3/8" 133Elite);
2. Alignment and grid positioning mechanism fiberglass pins, two per unit minimum (one pin for small units).
3. Maximum horizontal gap between erected units shall be $\leq 1/2"$ (13 mm).

2.03 Shear Connectors

A. Shear connectors shall be $1/2"$ (12 mm) diameter thermoset isophthalic polyester resin pultruded fiberglass reinforcement rods to provide connection between vertically and horizontally adjacent units with the following requirements:

1. Flexural Strength in accordance with ASTM D4476: 128,000 psi (882 MPa) minimum;
2. Short Beam Shear in accordance with ASTM D4475: 6,400 psi (44 MPa) minimum.

B. Shear connectors shall be capable of holding the geogrid in the proper design position during grid pre tensioning and backfilling.

2.04 Base Leveling Pad Material

A. Material shall consist of a compacted crushed stone base or non-reinforced concrete as shown on the construction drawings.

2.05 Unit Drainage Fill

A. Unit drainage fill shall consist of clean $1"$ (25 mm) minus crushed stone or crushed gravel meeting the following gradation tested in accordance with ASTM D-422:

Sieve Size	Percent Passing
1" (25 mm)	100
3/4" (19 mm)	75 - 100
No. 4 (4.75mm)	0 - 10
No. 50 (300um)	0 - 5

B. Drainage fill shall be placed within the cores of, between, and behind the units as indicated on the design drawings. Not less than one cubic foot (0.028 m³), of drainage fill shall be used for each square foot (0.093 m²) of wall face unless otherwise specified.

2.06 Reinforced Backfill

A. Reinforced backfill shall be free of debris and organic material; meeting the following gradation tested in accordance with ASTM D-422:

Sieve Size	Percent Passing
3/4" (19 mm)	100 - 75
No. 40 (425um)	0 - 60
No. 200 (75um)	0 - 35

Plasticity Index (PI) <15 and Liquid Limit (LL) <40 per ASTM D-4318.

B. The maximum aggregate size shall be limited to $3/4"$ (19 mm) unless field tests have been performed to evaluate potential strength reductions to the geogrid design due to damage during construction.

C. Material can be site-excavated soils where the above requirements can be met. Unsuitable soils for backfill (high plastic clays or organic soils) shall not be used in the backfill or in the reinforced soil mass.

D. Contractor shall submit reinforced fill sample and laboratory test results to the Architect/Engineer for approval prior to the use of any proposed reinforced fill material.

2.07 Geogrid Soil Reinforcement

A. Geosynthetic reinforcement shall consist of geogrids manufactured specifically for soil reinforcement applications and shall be manufactured from high tenacity polyester yarn or high density polyethylene. Polyester geogrid shall be knitted from high tenacity polyester filament yarn with a molecular weight exceeding 25,000 g/m and a carboxyl end group values less than 30. Polyester geogrid shall be coated with an impregnated PVC coating that resists peeling, cracking, and stripping.

B. T_a , Long Term Allowable Tensile Design Load, of the geogrid material shall be determined as follows:

$$T_a = T_{ult} / (RF_{cr} * RF_d * RF_{id} * FS)$$

T_a shall be evaluated based on a 75-year design life.

1. T_{ult} , Short Term Ultimate Tensile Strength shall be determined in accordance with ASTM D4595 or ASTM D6637.

T_{ult} is based on the minimum average roll values (MARV).

2. RF_{cr} , Reduction Factor for Long Term Tension Creep

RF_{cr} shall be determined from 10,000-hour creep testing performed in accordance with ASTM D5262 - RF_{cr} can typically vary from 1.50 to 5.0.

3. RF_d , Reduction Factor for Durability

RF_d shall be determined from polymer specific durability testing covering the range of expected soil environments. RF_d can typically vary from 1.10 to 2.0.

4. RF_{id} , Reduction Factor for Installation Damage

RF_{id} shall be determined from product specific construction damage testing performed in accordance with ASTM D5818. Test results shall be provided for each product to be used with project specific or more severe soil type. RF_{id} can typically vary from 1.05 to 2.0.

5. FS, Overall Design Factor of Safety

FS shall be 1.5 unless otherwise noted for the maximum allowable working stress calculation.

C. The maximum design tensile load of the geogrid shall not exceed the laboratory tested ultimate strength of the geogrid/facing unit connection divided by a factor of safety of 1.5. The connection strength testing and computation procedures shall be in accordance with ASTM D6638 Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units.

D. Soil Interaction Coefficient, C_i

C_i values shall be determined per ASTM D6706 at a maximum 3/4" (19 mm) displacement.

E. Manufacturing Quality Control

The geogrid manufacturer shall have a manufacturing quality control program that includes QC testing by an independent laboratory.

The QC testing shall include:

Tensile Strength Testing
Melt Flow Index (HDPE)
Molecular Weight (Polyester)

2.08 Drainage Pipe

A. If required, the drainage pipe shall be perforated or slotted PVC pipe manufactured in accordance with ASTM D-3034 or corrugated HDPE pipe manufactured in accordance with AASHTO M252.

2.09 Geotextile Filter Fabric

A. When required, Geotextile filter fabric shall be 4.0 oz/sy, polypropylene, needle-punched nonwoven fabric in accordance with AASHTO M288.

PART 3: EXECUTION

3.01 Excavation

A. Contractor shall excavate to the lines and grades shown on the construction drawings. Owner's representative shall inspect the excavation and approve the foundation soils prior to placement of leveling material or fill soils.

B. Over excavation and replacement of unsuitable foundation soils and replacement with approved compacted fill will be compensated as agreed upon with the Owner.

3.02 Base Leveling Pad

A. Leveling pad material shall be placed to the lines and grades shown on the construction drawings, to a minimum thickness of 6" (150 mm) and extend laterally a minimum of 6" (150 mm) in front and behind the Keystone wall unit.

B. Soil leveling pad materials shall be compacted to a minimum of 95% Standard Proctor density per ASTM D-698 or 92% Modified Proctor Density per ASTM D1557.

C. Leveling pad shall be prepared to insure full contact to the base surface of the concrete units.

3.03 Keystone Unit Installation

A. First course of units shall be placed on the leveling pad at the appropriate line and grade. Alignment and level shall be checked in all directions; insuring that all units are in full contact with the base and properly seated.

B. Place the front of units side-by-side. Do not leave gaps between adjacent units. Layout of corners and curves shall be in accordance with manufacturer's recommendations.

C. Install shear/connecting devices per manufacturer's recommendations.

D. Place drainage fill within and behind wall units. Place and compact backfill soil behind drainage fill. Follow wall erection and drainage fill closely with structure backfill.

E. Maximum stacked vertical height of wall units, prior to unit drainage fill and backfill placement and compaction, shall not exceed two courses.

3.04 Structural Geogrid Installation

A. Geogrid shall be oriented with the highest strength axis perpendicular to the wall alignment.

B. Geogrid reinforcement shall be placed at the strengths, lengths, and elevations shown on the construction design drawings or as directed by the Engineer.

C. The geogrid shall be laid horizontally on compacted backfill and attached to the Keystone wall units. Place the next course of Keystone concrete units over the geogrid. The geogrid shall be pulled taut, and anchored prior to backfill placement on the geogrid.

D. Geogrid reinforcements shall be continuous throughout their embedment lengths and placed side-by-side to provide 100% coverage at each level. Spliced connections between shorter pieces of geogrid or gaps between adjacent pieces of geogrid are not permitted.

3.05 Reinforced Backfill Placement

- A. Reinforced backfill shall be placed, spread, and compacted in such a manner that minimizes the development of slack in the geogrid and installation damage.
- B. Reinforced backfill shall be placed and compacted in lifts not to exceed 6" (150 mm) where hand compaction is used, or 8 - 10" (200 to 250 mm) where heavy compaction equipment is used. Lift thickness shall be decreased to achieve the required density, as needed.
- C. Reinforced backfill shall be compacted to a minimum of 95% Standard Proctor density per ASTM D-698 or 92% Modified Proctor Density per ASTM D1557. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer.
- D. Only lightweight hand operated equipment shall be allowed within 3 feet (1 m) from the tail of the Keystone concrete unit.
- E. Tracked construction equipment shall not be operated directly upon the geogrid reinforcement. A minimum fill thickness of 6" (150 mm) is required prior to operation of tracked vehicles over the geogrid. Tracked vehicle turning should be kept to a minimum to prevent tracks from displacing the fill and damaging the geogrid.
- F. At the end of each day's operation, the Contractor shall slope the last lift of reinforced backfill away from the wall units to direct runoff away from wall face. The Contractor shall not allow surface runoff from adjacent areas to enter the wall construction site.

3.06 Cap Installation

- A. Cap units shall be glued to underlying units with an all-weather adhesive recommended by the manufacturer such as Keystone Kapseal.

3.07 As-built Construction Tolerances

- A. Vertical alignment: $\pm 1.5"$ (40 mm) over any 10' (3 m) distance.
- B. Wall Batter: within 2 degrees of design batter.
- C. Horizontal alignment: $\pm 1.5"$ (40 mm) over any 10' (3 m) distance.
Corners, bends & curves: ± 1 foot (300 mm) to theoretical location.
- D. Maximum horizontal gap between erected units shall be $\leq 1/2"$ (13 mm).

3.08 Field Quality Control

- A. Wall construction shall be monitored by a qualified Engineer to verify field conditions. If this work is not performed by the site geotechnical engineer, the geotechnical engineer shall be consulted in those matters pertaining to soil conditions and wall performance.
- B. The foundation soils at each wall location shall be inspected by the Engineer and any unsuitable soils or improperly compacted embankment material removed and replaced as directed by the Engineer prior to wall construction to provide adequate bearing capacity and minimize settlement.
- C. All wall excavation and retained soils shall be inspected for groundwater conditions and any additional drainage provisions required in the field shall be incorporated into the wall construction as directed by the Engineer.
- D. Wall backfill material shall be tested and approved by the Engineer for use in the reinforced soil zone meeting the minimum requirements of the approved design plans.
- E. All soil backfill shall be tested by the Engineer for moisture, density, and compaction periodically (every 2' vertically, 100'-200' c/c) meeting the minimum requirements of the approved design plans or project specifications.
- F. Wall construction shall be periodically inspected by the Engineer to ensure the geogrid reinforcement elevations and lengths are installed in accordance with the approved design plans.
- G. All wall elevations, grades, and backslope conditions shall be verified by the Engineer in the field for conformance with the approved design plans. Any revisions to the structure geometry or design criteria shall require design modification prior to proceeding with construction.

Since introducing its first concrete segmental retaining wall products to the marketplace, Keystone has led the industry in providing site solutions for erosion control and soil retention methods. Our focus is to provide customers with solutions to successfully complete their project through effective utilization of Keystone's superior product, and outstanding, support services.

The Keystone website, www.keystonewalls.com, is an interactive resource offering all of Keystone's product information and marketing support tools. The website also offers information about our unique design software for retaining wall layout and design, including AUTOCAD details and product specifications.

Here are some of the many excellent resource materials to help you get the job done:

Literature

- Keystone Product Portfolio
- Construction and Design Manuals
- Product Specifications
- CAD details (AUTOCAD)
- Technical CD
- Project & Case Studies

Software

- KeyEstimator™
- KeyWall™ Engineering Software & Manual



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product and application specific.



SPECIFICATIONS



CAD DETAILS

Distributed By:

We reserve the right to improve our products and make changes in the specifications and design without notice. The information contained herein has been compiled by KEYSTONE and to the best of our knowledge, accurately represents the KEYSTONE product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user.



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Keystone Specifications

Section 02834 (32 32 23)

MODULAR CONCRETE RETAINING WALL

PART 1: GENERAL

1.01 Description

- A. Work shall consist of furnishing and construction of a KEYSTONE Standard Unit Retaining Wall System or equal in accordance with these specifications and in reasonably close conformity with the lines, grades, design, and dimensions shown on the plans.
- B. Work includes preparing foundation soil, furnishing and installing leveling pad, unit drainage fill and backfill to the lines and grades shown on the construction drawings.
- C. Work includes furnishing and installing geogrid soil reinforcement of the type, size, location, and lengths designated on the construction drawings.

1.02 Related Sections

- A. Section 02300 (31 00 00) - Earthwork

1.03 Reference Documents

- A. American Society for Testing and Materials (ASTM)
 - 1. ASTM C140 Sampling and Testing Concrete Masonry Units
 - 2. ASTM C1372 Specification for Dry-Cast Segmental Retaining Wall Units
 - 3. ASTM D422 Particle-Size Analysis of Soils
 - 4. ASTM D698 Laboratory Compaction Characteristics of Soil -Standard Effort
 - 5. ASTM D1557 Laboratory Compaction Characteristics of Soil -Modified Effort
 - 6. ASTM D3034 Polyvinyl Chloride Pipe (PVC)
 - 7. ASTM D4318 Liquid Limit, Plastic Limit and Plasticity Index of Soils
 - 8. ASTM D4475 Horizontal Shear Strength of Pultruded Reinforced Plastic Rods
 - 9. ASTM D4476 Flexural Properties of Fiber Reinforced Pultruded Plastic Rods
 - 10. ASTM D4595 Tensile Properties of Geotextiles - Wide Width Strip
 - 11. ASTM D5262 Unconfined Tension Creep Behavior of Geosynthetics
 - 12. ASTM D5818 Evaluate Installation Damage of Geosynthetics
 - 13. ASTM D6637 Tensile Properties of Geogrids – Single or Multi-Rib
 - 14. ASTM D6638 Connection Strength - Reinforcement/Segmental Units
 - 15. ASTM D6706 Geosynthetic Pullout Resistance in Soil
 - 16. ASTM D6916 Shear Strength Between Segmental Concrete Units
- B. American Association of State Highway and Transportation Officials (AASHTO)
 - 1. AASHTO M 252 Corrugated Polyethylene Drainage Pipe
- C. Geosynthetic Research Institute (GRI)
 - 1. GRI-GG4 Determination of Long Term Design Strength of Geogrids
 - 2. GRI-GG5 Determination of Geogrid (soil) Pullout
- D. National Concrete Masonry Association (NCMA)

1. NCMA SRWU-1 Test Method for Determining Connection Strength of SRW
2. NCMA SRWU-2 Test Method for Determining Shear Strength of SRW

1.04 Submittals/Certification

- A. Contractor shall submit a Manufacturer's certification, prior to start of work, that the retaining wall system components meet the requirements of this specification and the structure design.
- B. Contractor shall submit construction drawings and design calculations for the retaining wall system prepared and stamped by a Professional Engineer registered in the state of the project. The engineering designs, techniques, and material evaluations shall be in accordance with the Manufacturer's Design Manual, NCMA Design Guidelines For Segmental Retaining Walls, or the AASHTO Standard Specifications for Highway Bridges (whichever is applicable to designer).
- C. Contractor shall submit a test report documenting strength of specific modular concrete unit and geogrid reinforcement connection. The maximum design tensile load of the geogrid shall be equal to the laboratory tested ultimate strength of geogrid / facing unit connection at a maximum normal force limited by the "Hinge Height" of the structure divided by a safety factor of 1.5. The connection strength evaluation shall be performed in accordance with ASTM D6638 (NCMA SRWU-1).

1.05 Quality Assurance

- A. Contractor shall submit certification, prior to start of work, that the retaining wall system (modular concrete units and specific geogrid):
 - 1) Has been successfully utilized on a minimum of five (5) similar projects, i.e., height, soil fill types, erection tolerances, etc.; and
 - 2) Has been successfully installed on a minimum of 1 million (1,000,000) square feet of retaining walls.
- B. Contractor shall submit a list of five (5) previously constructed projects of similar size and magnitude by the wall installer where the specific retaining wall system has been constructed successfully. Contact names and telephone numbers shall be listed for each project.
- C. Contractor shall provide evidence that the design engineer has a minimum of five years of documentable experience in the design for reinforced soil structures. The design engineer shall provide proof of current professional liability insurance with an aggregate coverage limit of not less than \$2,000,000.
- D. Owner shall/may provide soil testing and quality assurance inspection during earthwork and wall construction operations. Contractor shall provide any quality control testing or inspection not provided by the Owner. Owner's quality assurance program does not relieve the contractor of responsibility for quality control and wall performance.

1.06 Delivery, Storage and Handling

- A. Contractor shall check all materials upon delivery to assure that the proper type, grade, color, and certification has been received.

- B. Contractor shall protect all materials from damage due to jobsite conditions and in accordance with manufacturer's recommendations. Damaged materials shall not be incorporated into the work.

PART 2: PRODUCTS

2.01 Definitions

- A. Modular Unit - a concrete retaining wall element machine made from Portland cement, water, and aggregates.
- B. Structural Geogrid - a structural element formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, or earth and function primarily as reinforcement.
- C. Unit Drainage Fill - drainage aggregate, which is placed within and immediately behind the modular concrete units.
- D. Reinforced Backfill - compacted soil, which is placed within the reinforced soil volume as outlined on the plans.

2.02 Modular Concrete Retaining Wall Units

- A. Modular concrete units shall conform to the following architectural requirements:
 - 1. Face color - concrete gray, unless otherwise specified. The Owner may specify standard manufacturers' color.
 - 2. Face finish - sculptured rock face in angular tri-planer configuration. Other face finishes will not be allowed without written approval of Owner.
 - 3. Bond configuration - running with bonds nominally located at midpoint vertically adjacent units, in both straight and curved alignments.
 - 4. Exposed surfaces of units shall be free of chips, cracks or other imperfections when viewed from a distance of 10 feet under diffused lighting.
- B. Modular concrete materials shall conform to the requirements of ASTM C1372 - Standard Specifications for Segmental Retaining Wall Units.
- C. Modular concrete units shall conform to the following structural and geometric requirements measured in accordance with ASTM C140 Sampling and Testing Concrete Masonry Units:
 - 1. Compressive strength: ≥ 3000 psi (21 MPa);
 - 2. Absorption: 8 % (6% in northern states) for standard weight aggregates;
 - 3. Dimensional tolerances: $\pm 1/8$ " (3 mm) from nominal unit dimensions not including rough split face, $\pm 1/16$ " (1.5 mm) unit height - top and bottom planes;
 - 4. Unit size: 8" (203 mm) (H) x 18" (457 mm)(W) x 18" (457 mm)(D) minimum;
 - 5. Unit weight: 100 lbs/unit (45 kg) minimum for standard weight aggregates.
- D. Modular concrete units shall conform to the following performance testing:
 - 1. Inter -unit shear strength in accordance with ASTM D6916 (NCMA SRWU-2): 1500 plf (21 kN/m) minimum at 2 psi (13 MPa) normal pressure;

2. Geogrid/unit peak connection strength in accordance with ASTM D6638 (NCMA SRWU-1): 900 plf (13 kN/m) minimum at 2-psi (13 MPa) normal force.

E. Modular concrete units shall conform to the following constructability requirements:

1. Vertical setback: 1/8" (3 mm) ± per course (near vertical) or 1" (25 mm) + per course per the design;
2. Alignment and grid positioning mechanism - fiberglass pins, two per unit minimum;
3. Maximum horizontal gap between erected units shall be ≤ 1/2 inch (13 mm).

2.03 Shear Connectors

A. Shear connectors shall be 1/2-inch (12 mm) diameter thermoset isophthalic polyester resin-pultruded fiberglass reinforcement rods or equivalent to provide connection between vertically and horizontally adjacent units with the following requirements:

1. Flexural Strength in accordance with ASTM D4476: 128,000 psi (882 MPa) minimum;
2. Short Beam Shear in accordance with ASTM D4475: 6,400 psi (44 MPa) minimum.

B. Shear connectors shall be capable of holding the geogrid in the proper design position during grid pre-tensioning and backfilling.

2.04 Base Leveling Pad Material

A. Material shall consist of a compacted crushed stone base or non-reinforced concrete as shown on the construction drawings.

2.05 Unit Drainage Fill

A. Unit drainage fill shall consist of clean 1" (25 mm) minus crushed stone or crushed gravel meeting the following gradation tested in accordance with ASTM D-422:

<u>Sieve Size</u>	<u>Percent Passing</u>
1 inch (25 mm)	100
3/4-inch (19 mm)	75-100
No. 4	0 - 10
No. 50	0 - 5

B. One cubic foot (0.028 m³), minimum, of drainage fill shall be used for each square foot (0.093 m²) of wall face. Drainage fill shall be placed within cores of, between, and behind units to meet this requirement.

2.06 Reinforced Backfill

A. Reinforced backfill shall be free of debris and meet the following gradation tested in accordance with ASTM D-422:

<u>Sieve Size</u>	<u>Percent Passing</u>
-------------------	------------------------

2-inch (50 mm)	100
3/4-inch (19 mm)	100-75
No. 40	0-60
No. 200	0-35

Plasticity Index (PI) <15 and Liquid Limit <40 per ASTM D-4318.

- B. The maximum aggregate size shall be limited to 3/4 inch (19 mm) unless field tests have been performed to evaluate potential strength reductions to the geogrid design due to damage during construction.
- C. Material can be site-excavated soils where the above requirements can be met. Unsuitable soils for backfill (high plastic clays or organic soils) shall not be used in the backfill or in the reinforced soil mass.
- D. Contractor shall submit reinforced fill sample and laboratory test results to the Architect/Engineer for approval prior to the use of any proposed reinforced fill material.

2.07 Geogrid Soil Reinforcement

- A. Geosynthetic reinforcement shall consist of geogrids manufactured specifically for soil reinforcement applications and shall be manufactured from high tenacity polyester yarn or high-density polyethylene. Polyester geogrid shall be knitted from high tenacity polyester filament yarn with a molecular weight exceeding 25,000 Meg/m and a carboxyl end group values less than 30. Polyester geogrid shall be coated with an impregnated PVC coating that resists peeling, cracking, and stripping.
- B. Ta, Long Term Allowable Tensile Design Load, of the geogrid material shall be determined as follows:

$$Ta = Tult / (RFcr * RFd * RFid * FS)$$

Ta shall be evaluated based on a 75-year design life.

1. Tult, Short Term Ultimate Tensile Strength shall be determined in accordance with ASTM D4595 or ASTM D6637.
Tult is based on the minimum average roll values (MARV).
2. RFcr, Reduction Factor for Long Term Tension Creep
RFcr shall be determined from 10,000-hour creep testing performed in accordance with ASTM D5262. Reduction value = 1.45 minimum.
3. RFd, Reduction Factor for Durability
RFd shall be determined from polymer specific durability testing covering the range of expected soil environments. RFd = 1.10 minimum.
4. RFid, Reduction Factor for Installation Damage
RFid shall be determined from product specific construction damage testing performed in accordance with ASTM D5818 (GRI-GG4). Test results shall be provided for each product to be used with project specific or more severe soil type. RFid = 1.05 minimum.
5. FS, Overall Design Factor of Safety
FS shall be 1.5 unless otherwise noted for the maximum allowable working stress calculation.

- C. The maximum design tensile load of the geogrid shall not **exceed** the laboratory tested ultimate strength of the geogrid/facing unit connection as limited by the "Hinge Height" divided by a factor of safety of 1.5. The connection strength testing and computation procedures shall be in accordance with ASTM D6638 Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units (NCMA SRWU-1).
- D. Soil Interaction Coefficient, C_i
C_i values shall be determined per ASTM D6706 (GRI:GG5) at a maximum 0.75-inch (19 mm) displacement.
- E. Manufacturing Quality Control
The geogrid manufacturer shall have a manufacturing quality control program that includes QC testing by an independent laboratory.
The QC testing shall include:
 - Tensile Strength Testing
 - Melt Flow Index (HDPE)
 - Molecular Weight (Polyester)

2.08 Drainage Pipe

- A. If required, the drainage pipe shall be perforated or slotted PVC pipe manufactured in accordance with ASTM D-3034 or corrugated HDPE pipe manufactured in accordance with AASHTO M252.

2.09 Geotextile Filter Fabric

- A. When required, Geotextile filter fabric shall be 4.0 oz/sy, polypropylene, needlepunched nonwoven fabric.

PART 3: EXECUTION

3.01 Excavation

- A. Contractor shall excavate to the lines and grades shown on the construction drawings. Owner's representative shall inspect the excavation and approve prior to placement of leveling material or fill soils. Proof roll foundation area as directed to determine if remedial work is required.
- B. Over-excavation and replacement of unsuitable foundation soils and replacement with approved compacted fill will be compensated as agreed upon with the Owner.

3.02 Base Leveling Pad

- A. Leveling pad material shall be placed to the lines and grades shown on the construction drawings, to a minimum thickness of 6 inches (150 mm) and extend laterally a minimum of 6" (150 mm) in front and behind the modular wall unit.
- B. Soil leveling pad materials shall be compacted to a minimum of 95 % Standard Proctor density per ASTM D-698 or 92% Modified Proctor Density per ASTM D1557.

- C. Leveling pad shall be prepared to insure full contact to the base surface of the concrete units.

3.03 Modular Unit Installation

- A. First course of units shall be placed on the leveling pad at the appropriate line and grade. Alignment and level shall be checked in all directions and insure that all units are in full contact with the base and properly seated.
- B. Place the front of units side-by-side. Do not leave gaps between adjacent units. Layout of corners and curves shall be in accordance with manufacturer's recommendations.
- C. Install shear/connecting devices per manufacturer's recommendations.
- D. Place and compact drainage fill within and behind wall units. Place and compact backfill soil behind drainage fill. Follow wall erection and drainage fill closely with structure backfill.
- E. Maximum stacked vertical height of wall units, prior to unit drainage fill and backfill placement and compaction, shall not exceed two courses.

3.04 Structural Geogrid Installation

- A. Geogrid shall be oriented with the highest strength axis perpendicular to the wall alignment.
- B. Geogrid reinforcement shall be placed at the strengths, lengths, and elevations shown on the construction design drawings or as directed by the Engineer.
- C. The geogrid shall be laid horizontally on compacted backfill and attached to the modular wall units. Place the next course of modular concrete units over the geogrid. The geogrid shall be pulled taut, and anchored prior to backfill placement on the geogrid.
- D. Geogrid reinforcements shall be continuous throughout their embedment lengths and placed side-by-side to provide 100% coverage at each level. Spliced connections between shorter pieces of geogrid or gaps between adjacent pieces of geogrid are not permitted.

3.05 Reinforced Backfill Placement

- A. Reinforced backfill shall be placed, spread, and compacted in such a manner that minimizes the development of slack in the geogrid and installation damage.
- B. Reinforced backfill shall be placed and compacted in lifts not to exceed 6 inches (150 mm) where hand compaction is used, or 8 - 10 inches (200 to 250 mm) where heavy compaction equipment is used. Lift thickness shall be decreased to achieve the required density as required.
- C. Reinforced backfill shall be compacted to a minimum of 95 % Standard Proctor density per ASTM D-698 or 92% Modified Proctor Density per ASTM D1557. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer and shall be dry of optimum, + 0%, - 3%.

- D. Only lightweight hand-operated equipment shall be allowed within 3 feet (1m) from the tail of the modular concrete unit.
- E. Tracked construction equipment shall not be operated directly upon the geogrid reinforcement. A minimum fill thickness of 6 inches (150 mm) is required prior to operation of tracked vehicles over the geogrid. Tracked vehicle turning should be kept to a minimum to prevent tracks from displacing the fill and damaging the geogrid.
- F. Rubber tired equipment may pass over geogrid reinforcement at slow speeds, less than 10 MPH (15 KPH). Sudden braking and sharp turning shall be avoided.
- G. At the end of each day's operation, the Contractor shall slope the last lift of reinforced backfill away from the wall units to direct runoff away from wall face. The Contractor shall not allow surface runoff from adjacent areas to enter the wall construction site.

3.06 Cap Installation

- A. Cap units shall be glued to underlying units with an all-weather adhesive recommended by the manufacturer.

3.07 As-built Construction Tolerances

- A. Vertical alignment: $\pm 1.5"$ (40 mm) over any 10' (3 m) distance.
- B. Wall Batter: within 2 degrees of design batter.
- C. Horizontal alignment: $\pm 1.5"$ (40 mm) over any 10' (3 m) distance.
Corners, bends & curves: ± 1 ft (300 mm) to theoretical location.
- D. Maximum horizontal gap between erected units shall be $\leq 1/2$ inch (13 mm).

3.08 Field Quality Control

- A. Quality Assurance - The Owner shall/may engage inspection and testing services, including independent laboratories, to provide quality assurance and testing services during construction. This does not relieve the Contractor from securing the necessary construction control testing.
- B. Quality assurance should include foundation soil inspection. Verification of geotechnical design parameters, and verification that the contractor's quality control testing is adequate as a minimum. Quality assurance shall also include observation of construction for general compliance with design drawings and project specifications. Quality assurance is best performed by the site geotechnical engineer.
- C. Quality Control - The Contractor shall engage inspection and testing services to perform the minimum quality control testing described in the retaining wall design plans and specifications. Only qualified and experienced technicians and engineers shall perform testing and inspection services.
- D. Quality control testing shall include soil and backfill testing to verify soil types and compaction and verification that the retaining wall is being constructed in accordance with the design plans and project specifications.

PART 4: MEASUREMENT AND PAYMENT



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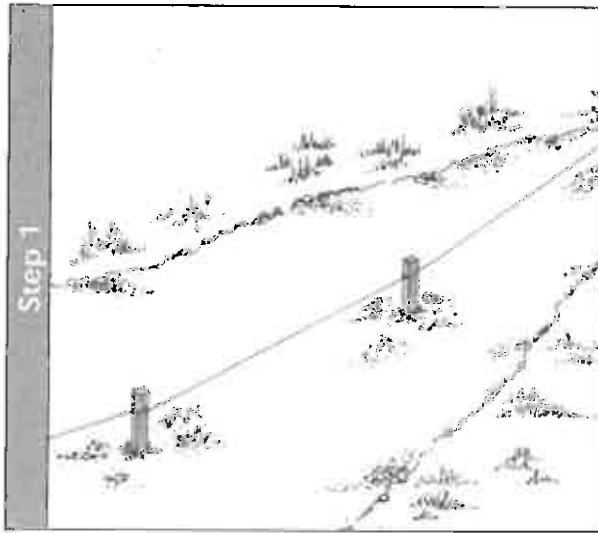
BASIC INSTALLATION

You have chosen your preferred Keystone unit for installation, so now it is time to begin installation of your retaining wall. This section will take you through the step-by-step process of installing your retaining wall. Covered in this section is a basic gravity wall installation and also installation procedures for geogrid reinforced walls. While this section may not cover every construction issue you may encounter on your project, it gives a basic overview and helpful hints for the installation of a Keystone retaining wall.

Tools and materials that will be required:

- 12 inch and 48 inch levels
- Tape measure
- Shovel
- Excavating equipment
- Personal protective equipment
- 5 lb dead blow hammer
- Keystone structural units, caps and fiberglass pins
- Structural geogrid, if required
- Unit drainage fill (¾ inch clean crushed stone)
- Backfill material
- Leveling pad material
- Keystone KapSeal™ concrete adhesive

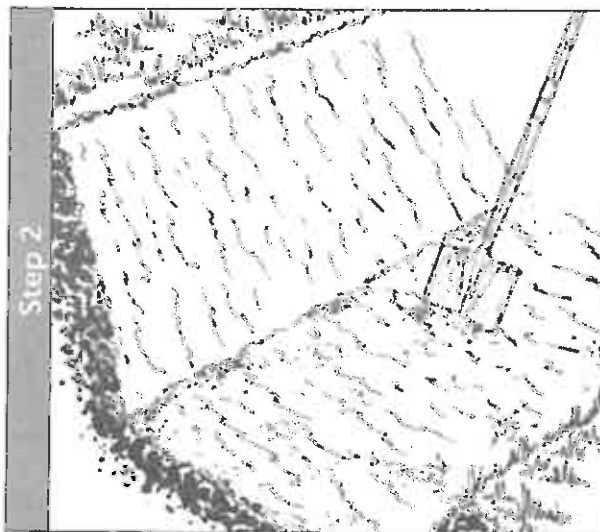
Installation: Step-by-Step



1. Site Examination / Permitting

Select the location and length for the retaining wall. Call before you dig! Calling 811 before every digging job gets your underground utility lines marked for free and helps prevent undesired consequences. Digging without calling can disrupt service to an entire neighborhood, harm you and those around you and potentially result in fines and repair costs.

Take the necessary measurements, prepare plans, research zoning requirements for your area and obtain proper building permits for your project. Local permitting may require a soils investigation and/or engineered documentation and drawings.



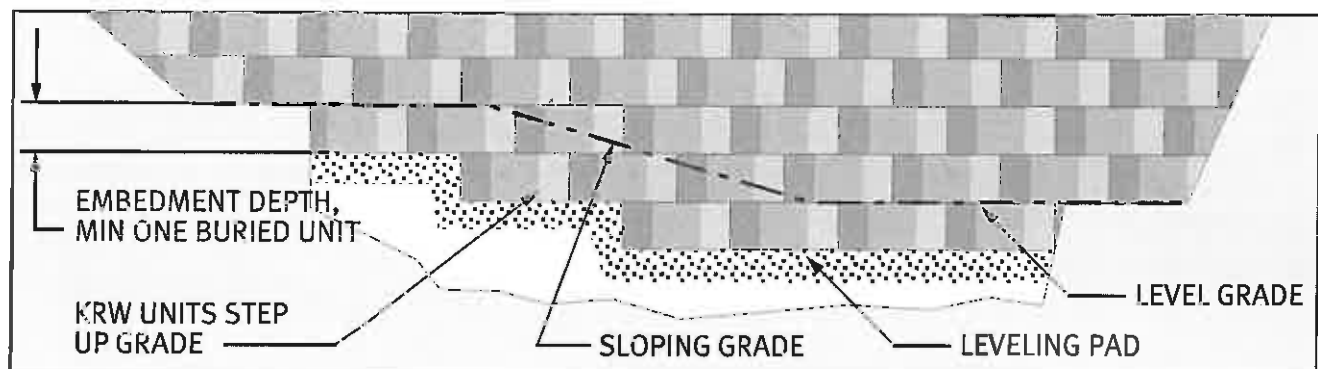
2. Excavation / Embedment

Verify that the layout dimensions are correct and excavate to the lines and grades shown on the construction drawings or to field dimensions. Remove all surface vegetation, organic soils and debris; verify that the foundation subgrade is in proper condition prior to leveling pad installation. Do not proceed with installation until unsatisfactory conditions have been corrected.

Embedment Recommendations

For small Keystone gravity walls, a minimum 1 inch (25mm) of embedment is recommended for every unit of height (i.e., $H/8$) or 6 inches minimum, which ever is greater. For reinforced soil Keystone walls, the minimum depth of embedment as a ratio to wall may be determined in the following table from the NCMA Design Manual for Segmental Walls (2009):

FIGURE A:1



The information contained herein has been compiled by Keystone® Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and the manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.

Slope in Front of Wall	Min. Embedment
Minimum Requirement	0.5 ft (150mm)
Horizontal (walls)	H/20
Horizontal (Abutments)	H/10
3H:1V	H/10
2H:1V	H/7

Note:

Project plans, specifications, and design codes may require minimum embedments that exceed the minimums recommended by NCMA.

Sloping Toe

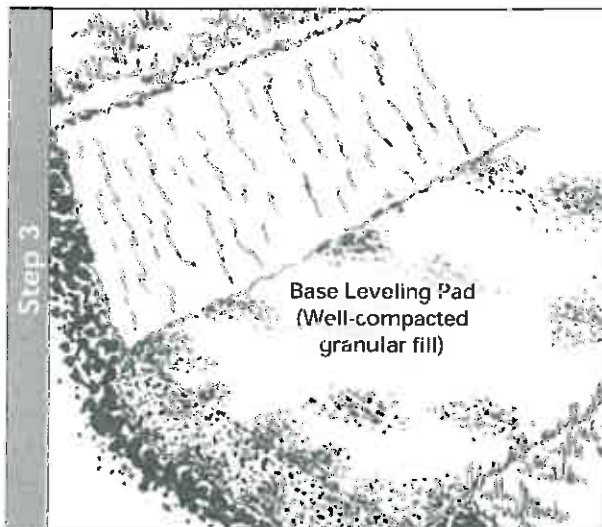
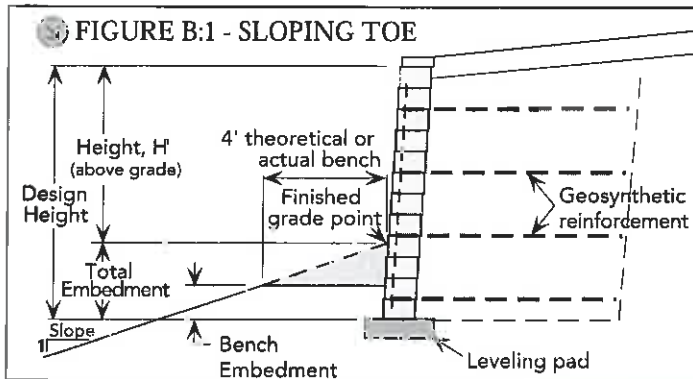
The minimum embedment required with a slope in front of the wall should be based on the establishment of a minimum 4 feet (1.2m) horizontal bench in front of the wall and establishing a minimum embedment from that point. Fill slopes usually have poor compaction near the edge of slope and all slopes are subject to erosion and surficial instability (see figure B:1).

The depth of embedment should be increased when any of the following conditions occur:

- Weak bearing soils
- Potential scour of wall toe
- Submerged wall applications
- Significant shrink/swell/frost properties of foundation soils

Note:

The required embedment depth for Keystone walls may become a controversial issue. The International Building Code (IBC) recommends a 1 foot minimum or below prevailing frost depth, which ever is greater for foundations. AASHTO recommends a 2 foot minimum or below prevailing frost depth which ever is greater for retaining structures. These minimum recommended depths are based on rigid foundation systems and are not totally applicable to flexible systems, which function properly with significantly less embedment. The proper embedment depth is a function of the structure size and type, the underlying soils, and the site geometry, especially toe slopes. It is significantly more important to properly inspect the foundation area when excavated, determine the limits of removal and replacement of unsuitable materials, and then confirm the final embedment depth for stability and bearing given the site conditions.

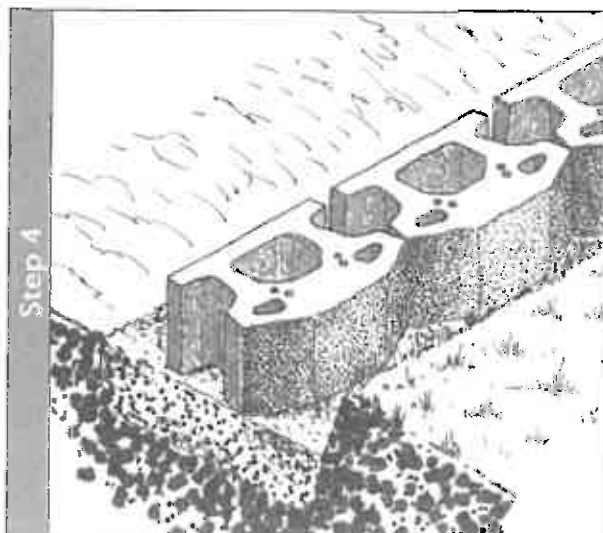


3. Prepare the Base Leveling Pad

Start the leveling pad at the lowest elevation along the wall alignment (see Figure A:1). The minimum leveling pad width shall be unit depth + 12 inches. The leveling pad shall consist of 6 inches of well compacted (95% Standard Proctor or greater) angular granular fill (road base or 1/2 inch to 3/4 inch {10-20mm} crushed stone). Concrete is also acceptable to use as a leveling pad. Step the leveling pad up in 8 inch increments at the appropriate elevation change in the foundation. Do not use rounded material, i.e. PEA GRAVEL or SAND for leveling pad material.

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Installation: Step-by-Step



4. Install the Base Course

Place the first course of Keystone units (Compac II Units shown) end to end (with face of wall corners touching, do not leave gaps between units) on the prepared base. The pin holes should face upward, as shown. Ensure that all units are in full contact with the base and properly seated by gently pounding each block corner, and level as required. At base elevation changes (see Figure C:1) for installation reference. Leveling the first course is critical for accurate and acceptable results. Lay out corners and curves in accordance with the "Corners and Curves" section of this manual (p. 37).

FIGURE C:1

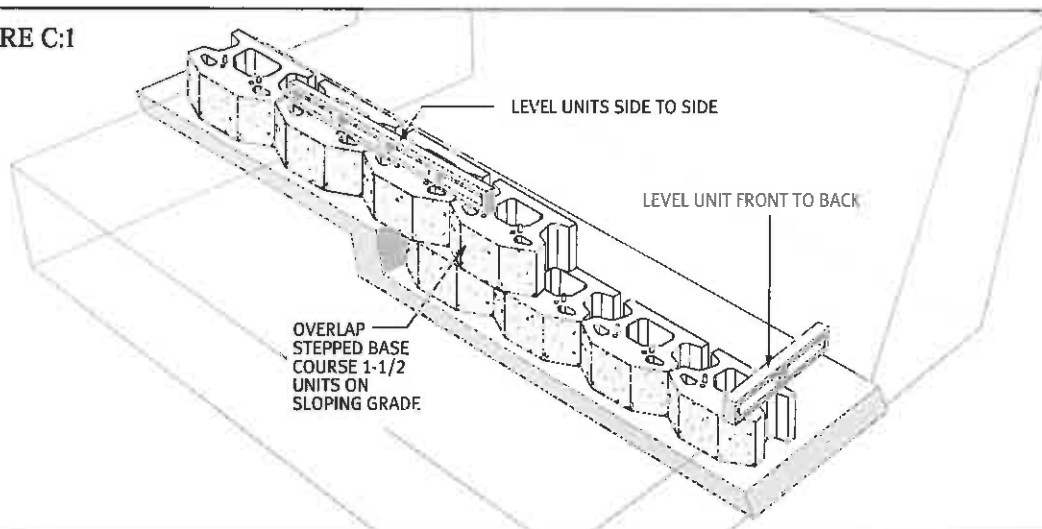
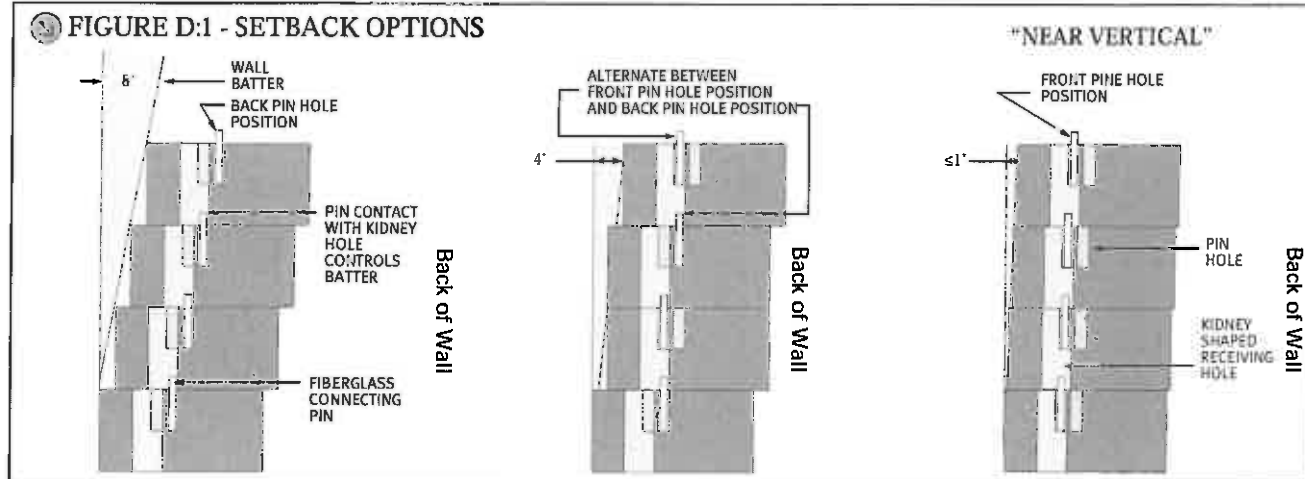
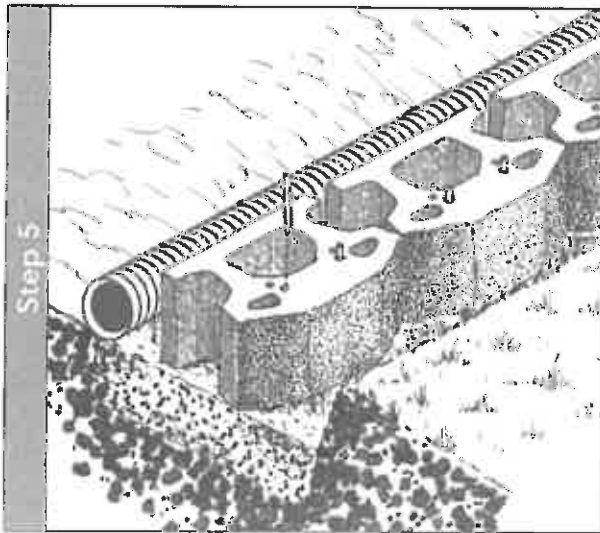


FIGURE D:1 - SETBACK OPTIONS

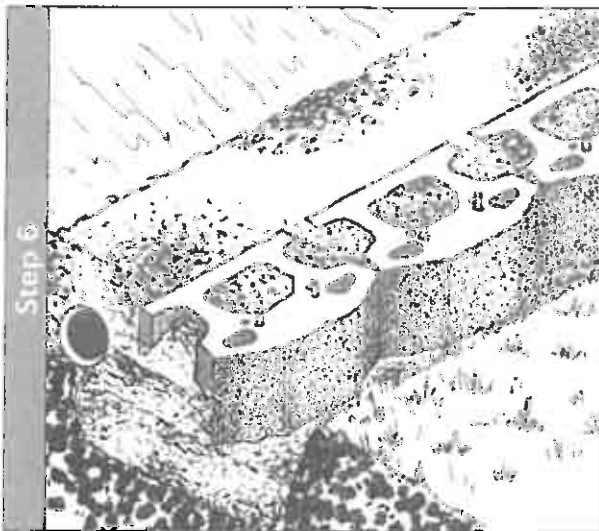


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5. Insert the Fiberglass Pins/Drainage Pipe

Keystone units have 3 setback options, near vertical, ½ inch setback and 1 inch setback (see Figure D:1). For the near vertical option, place the pins in the front pin holes, or for the 1 inch minimum setback, place the pins in the rear pin holes (see Figure E:1). Once placed, the pins create an automatic setback and alignment for the additional courses (see Figure F:1). When required, install drainage pipe behind wall unit and outlet drain to storm system or daylight as required.



6. Install Unit Drainage Fill/Backfill and Compaction.

Once the pins have been installed, provide ½-¾ inch (10-20mm) crushed stone unit drainage material to a minimum total distance of 24 inch (610mm) from wall face. Fill all open spaces between units and open cavities/cores with the same unit drainage material. Place the wall backfill behind the unit drainage fill in maximum 8 inch (200mm) lifts and compact to 95% Standard Proctor Density or 92% Modified Proctor Density with the appropriate compaction equipment. Use only hand operated equipment within 3 feet of the retaining wall face.

FIGURE E:1 - PIN INSTALLATION DIAGRAM

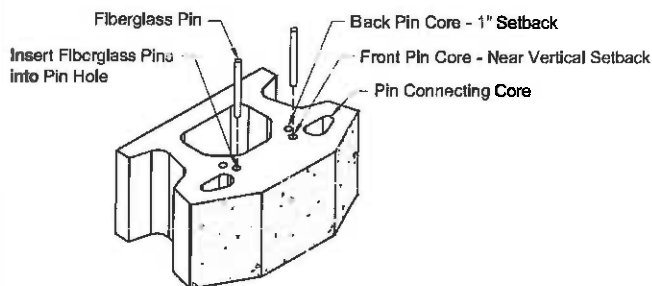
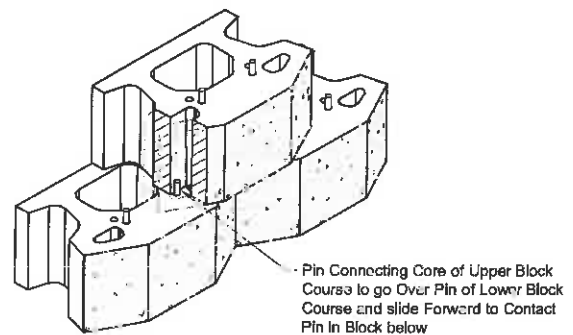
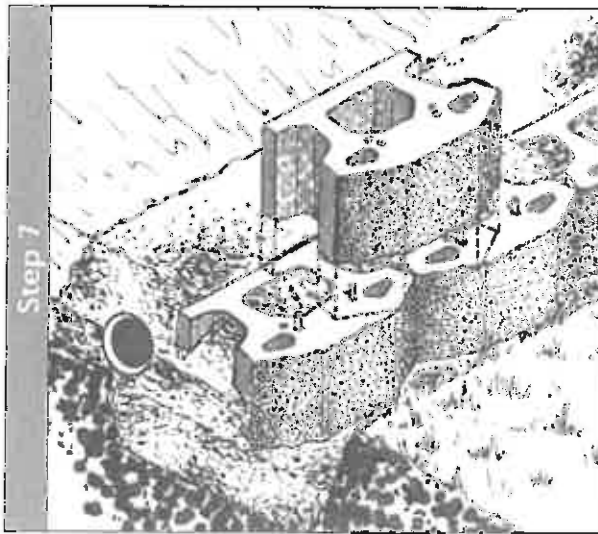


FIGURE F:1 - CONNECTION DIAGRAM



If drainage is required due to excess water or the design engineer's plans, call for a drainage pipe to be installed, add the drain tile behind the tails on the base course. Drainage pipe should maintain positive drainage to daylight, outlet the drainpipe at low point or ends of wall.

Installation: Step-by-Step

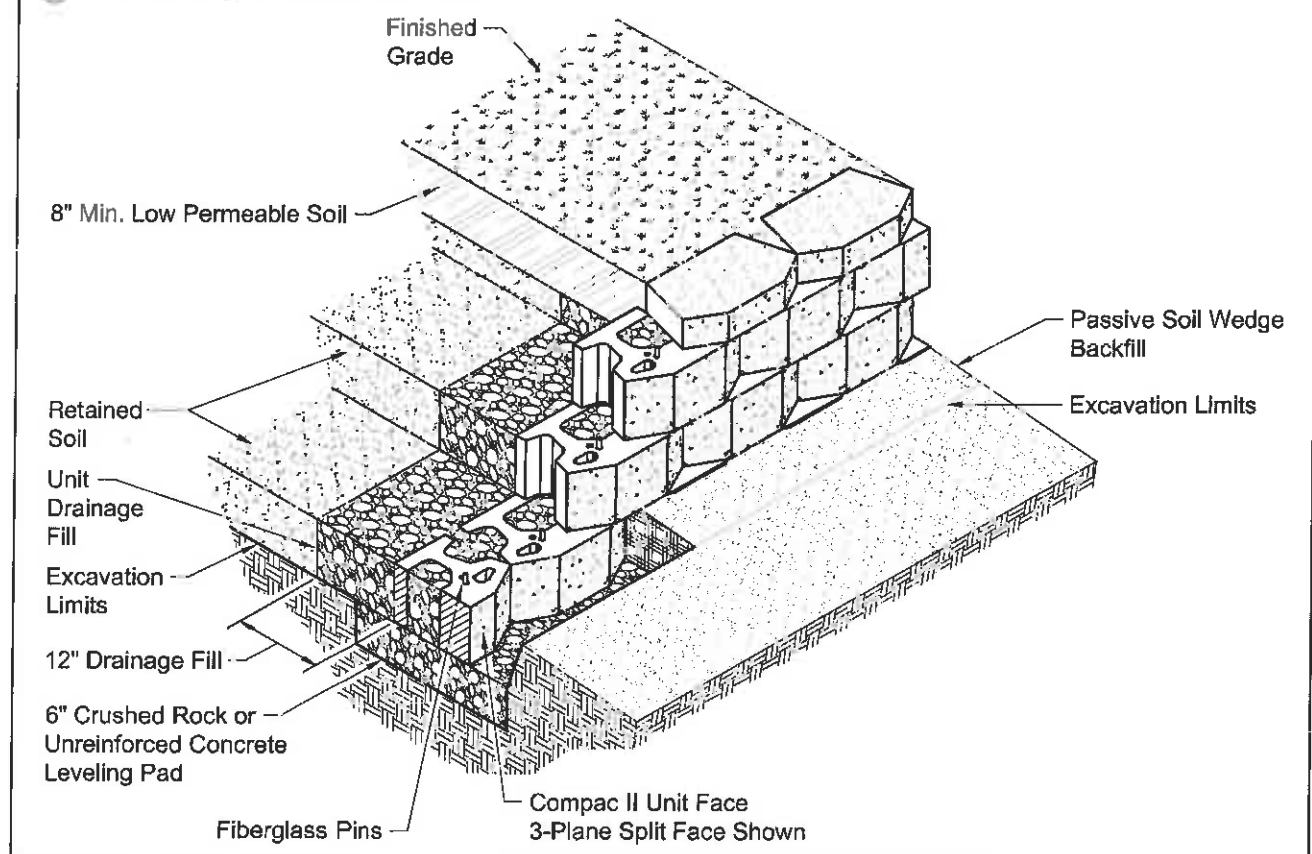


7. Install Additional Courses.

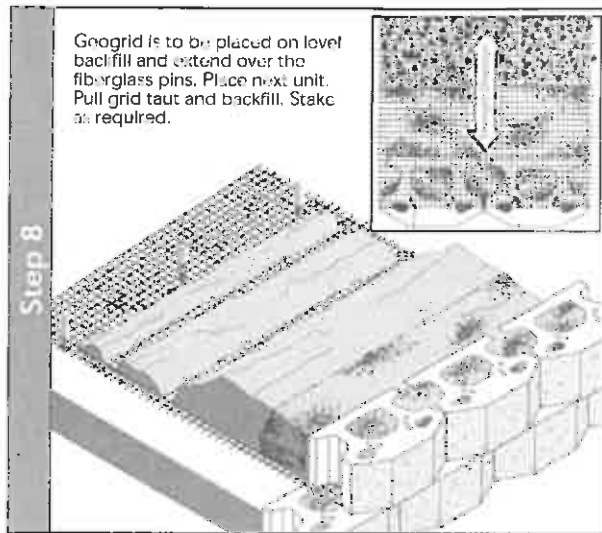
Remove all excess unit drainage material from the top surface of the all units. Center the next unit in front of the point where the two units below meet, fitting the pins into the pin connecting core of the above unit. Push the units toward the face of the wall until they make full contact with the pins (see Figure F:1). Check level front to back and side to side, shim the units or grind as necessary. It is important to check level front to back and side to side on every course to maintain proper wall batter and alignment. Proper shimming materials can be any non-degradable material including but not limited to, asphalt shingles, scrap pieces of geogrid, polyester rope, etc...

Continue backfilling, installing additional units and checking level to the desired top elevation (see Figure G:1). Follow wall unit and unit drainage fill installation closely with backfill. Maximum stacked vertical height of wall units prior to unit drainage fill and backfill placement and compaction shall not exceed 2 courses, unless special construction techniques are employed to insure complete filling of all units with unit drainage fill. For gravity walls continue this construction sequence to complete the wall, and proceed to Step 10. For geogrid reinforced walls, continue with Step 8 and Step 9.

FIGURE G:1 - 3D CROSS SECTION WITHOUT REINFORCEMENT

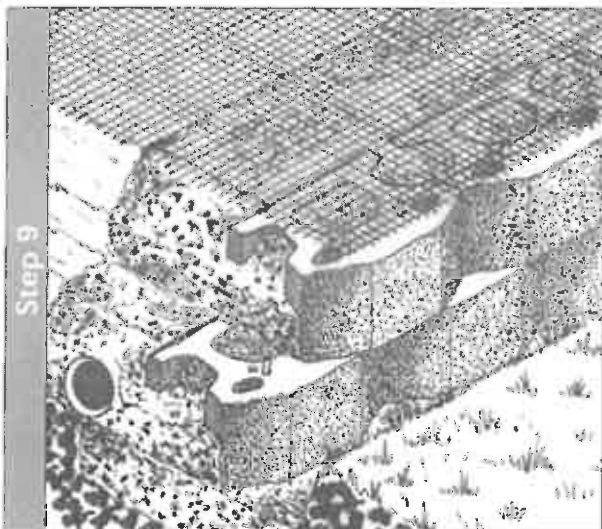


The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge accurately represents the Keystone product use in the applications which are illustrated. Final determination of suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.



8. Structural Geogrid Installation

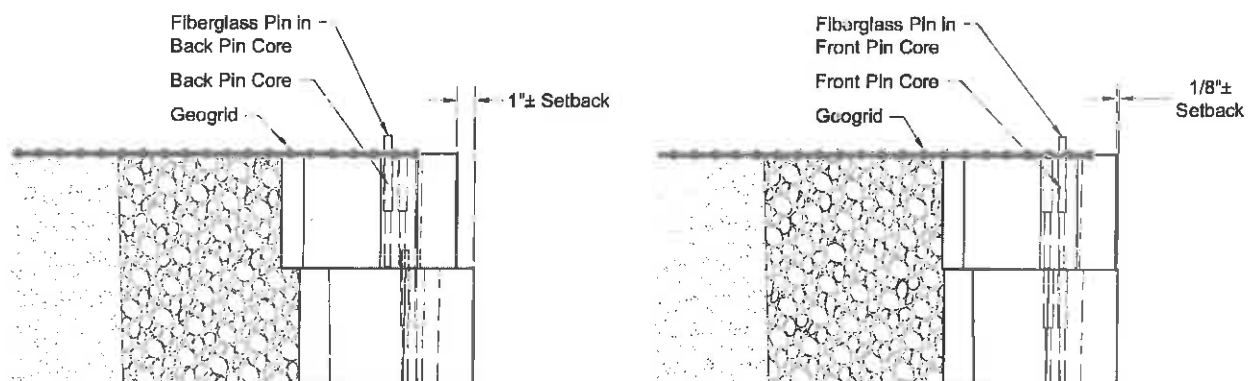
Start at the lowest wall elevation where a geogrid layer will be placed. The geogrid elevations, depths, and strength will be specified in the engineered design for the wall.* Measure and cut the geogrid material to the specified length. Orient geogrid with highest strength axis perpendicular to the wall alignment. Lay geogrid horizontally on compacted backfill and hook over the pins of the units (see Figure H:1). In general, geogrid will be placed in pieces side-by-side with no gapping, and in a continuous layer along the length of design geogrid elevation, unless a change in elevation is specified in the design. Tension the geogrid by pulling it towards the embankment. Place a stake through the end of the geogrid into the ground to hold it taut and in place. Do not excessively tension geogrid; this may pull units out of proper alignment. Install an additional course of units over the geogrid and insert pins.



9. Reinforced Backfill Placement

Proceed with placement of the unit drainage fill and the backfill in the reinforced zone. Specifications for the material to be used as backfill in the reinforced zone should be defined in the engineered plans. Place this material nearest to the units, moving progressively toward the staked end of the geogrid. This procedure will keep the geogrid under tension. Compact the reinforced fill material to 95% Standard Proctor Density (ASTM D698), or 92% Modified Proctor Density (ASTM D1557) or to the compaction requirements in the engineered plans. Install additional courses as described in step 7, until the next reinforcement elevation. Repeat Step 8 and Step 9 (see Figure G:1.1, page 18). Only hand operated compaction equipment shall be allowed within 3 feet of the back surface of the units. At the end of each day's operation, grade the backfill away from the wall and direct runoff away from the wall face.

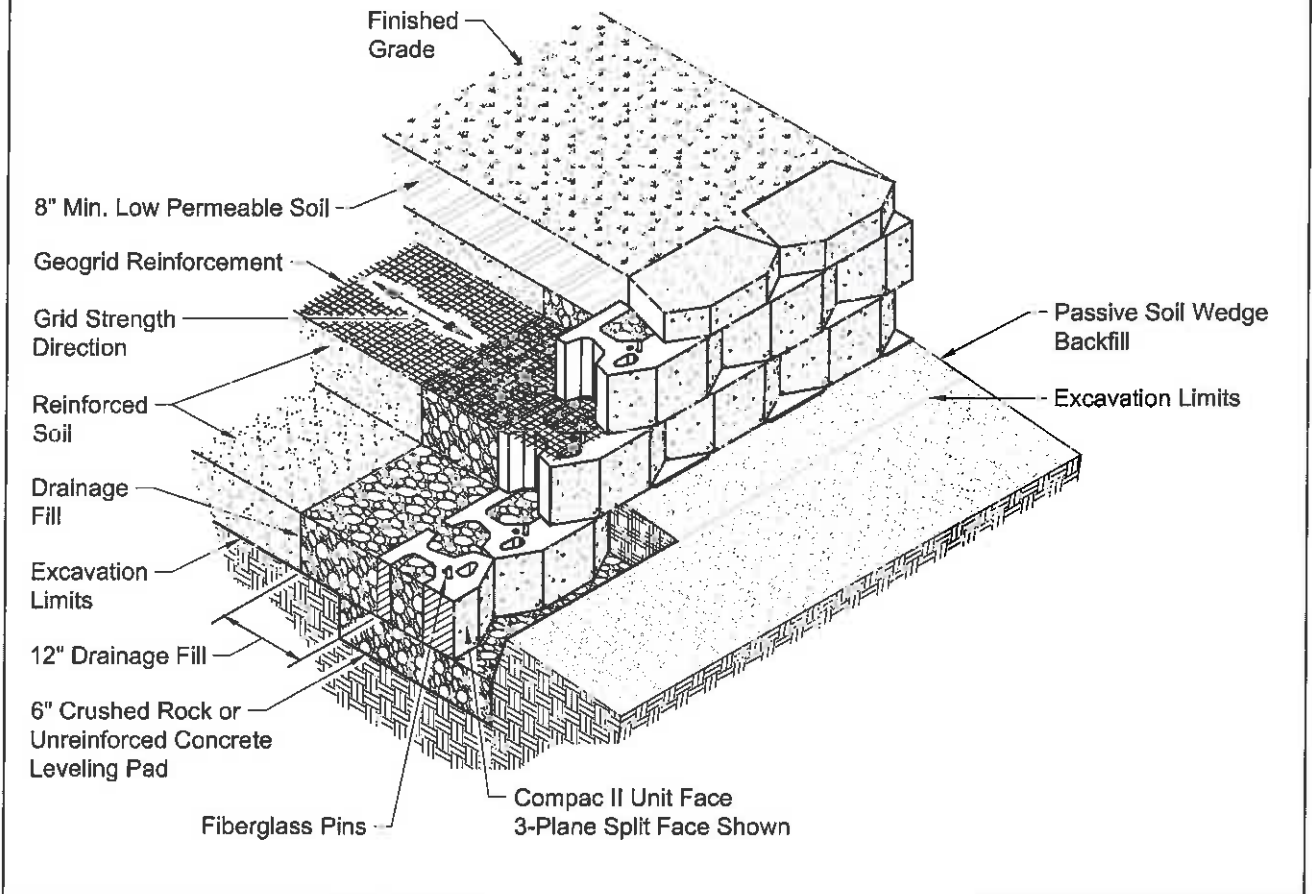
FIGURE H:1 - SETBACK OPTIONS WITH REINFORCEMENT



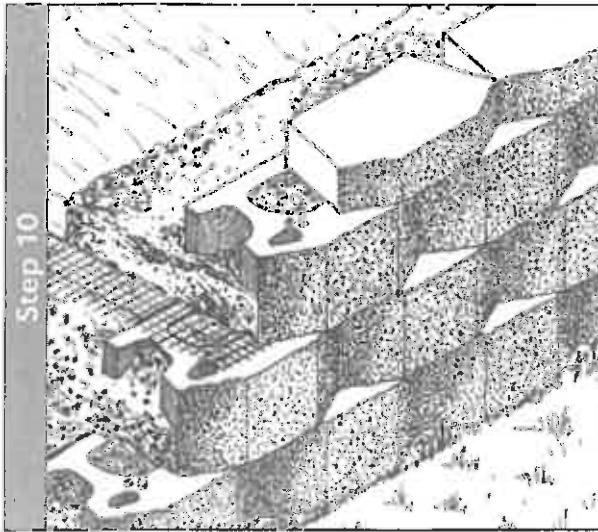
For assistance in obtaining engineered drawings for your project, please contact your local Keystone representative.

Installation: Step-by-Step

FIGURE G.1.1 - 3D CROSS SECTION WITH REINFORCEMENT

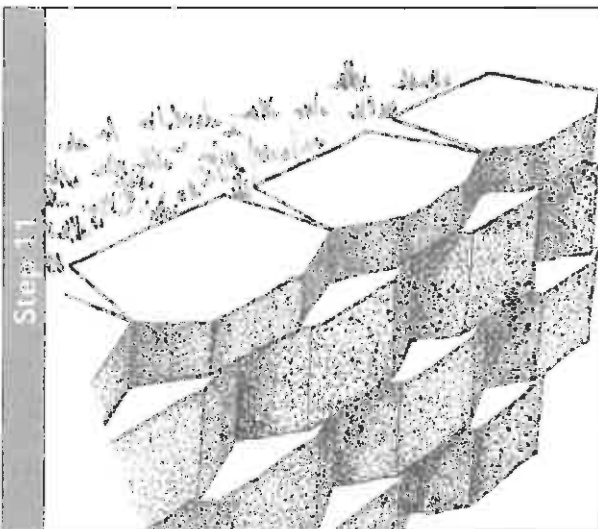


The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product line in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.



10. Capping the Wall

Follow the same procedures described in Step 6 for proper placement and positioning of the cap units. Complete your wall with the appropriate Keystone capping units. These units are available in a variety of sizes and shapes, including 4 inch (100mm) and 8 inch (200mm) high units. Availability of these units will vary by region. For cap unit descriptions and placement variations see the section, "Wall Finishing", page 65 of this manual. Sweep the lower units clean and make sure they are dry. Use construction adhesive (Keystone KapSeal™) on the top surface of the last course before applying cap units (see Figure I:1).



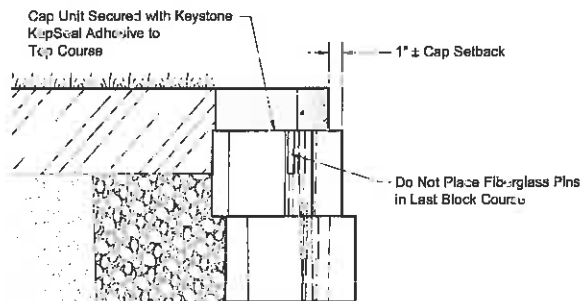
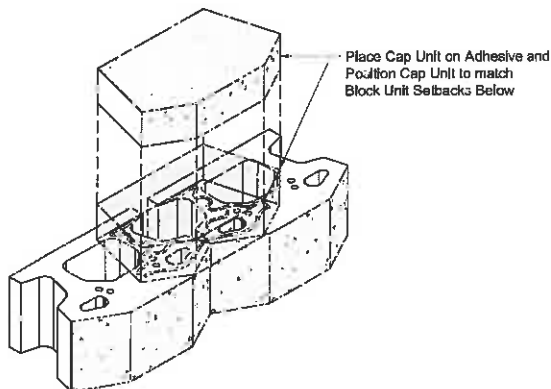
11. Finished Grade and Landscaping

The Keystone Retaining wall is now complete. Final grading, planting or other surface material can now be put into place. Typically an 8 inch thick layer of low permeable soil is installed as the final layer of material. This is to help prevent water infiltration to the retained or reinforced zone of the retaining wall. Remember that finished grade conditions affect the wall's performance. Such conditions should not be altered from the original design. Loading with slopes, parking lots and buildings should be maintained as designed. Any changes to the top of wall finished grade must be evaluated prior to wall completion (see Figures J:1-L:1 for typical cross section details).*

Note:

See Additional Construction Details "Planting Guidelines" for details on proper planting installations for a Keystone retaining wall. Also See Additional Construction Details for other types of top of wall treatment details.

FIGURE I:1 - SECURE THE CAPS



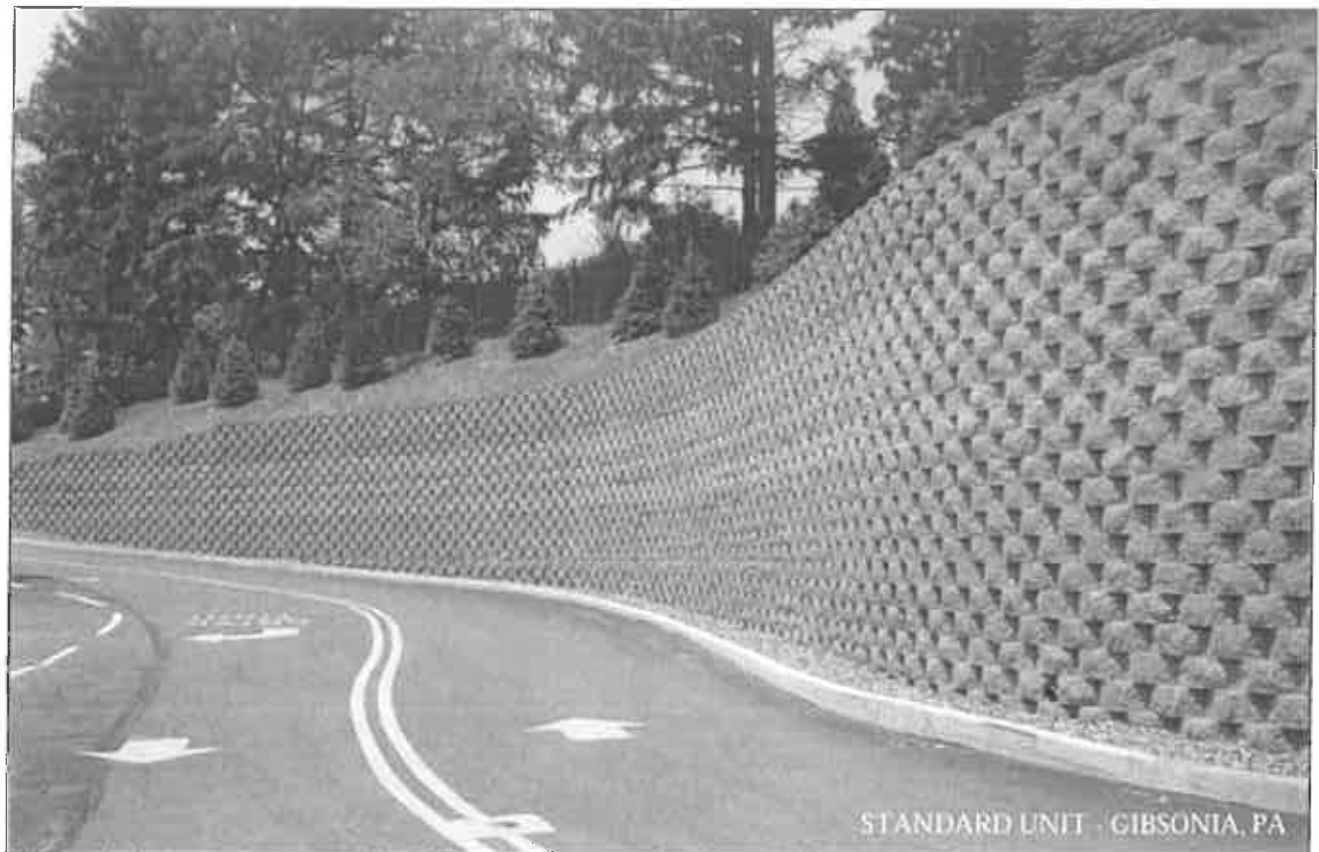
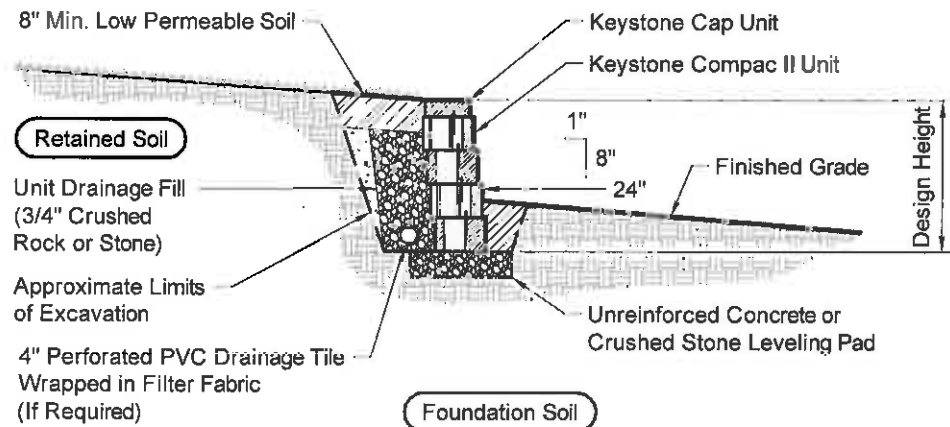
Note:

Capping options vary by manufacturer

The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.

Completed Gravity Wall Section

FIGURE J:1 - (GRAVITY WALL) CROSS SECTION



The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.

FIGURE K:1 - (REINFORCED WALL) NEAR VERTICAL SETBACK

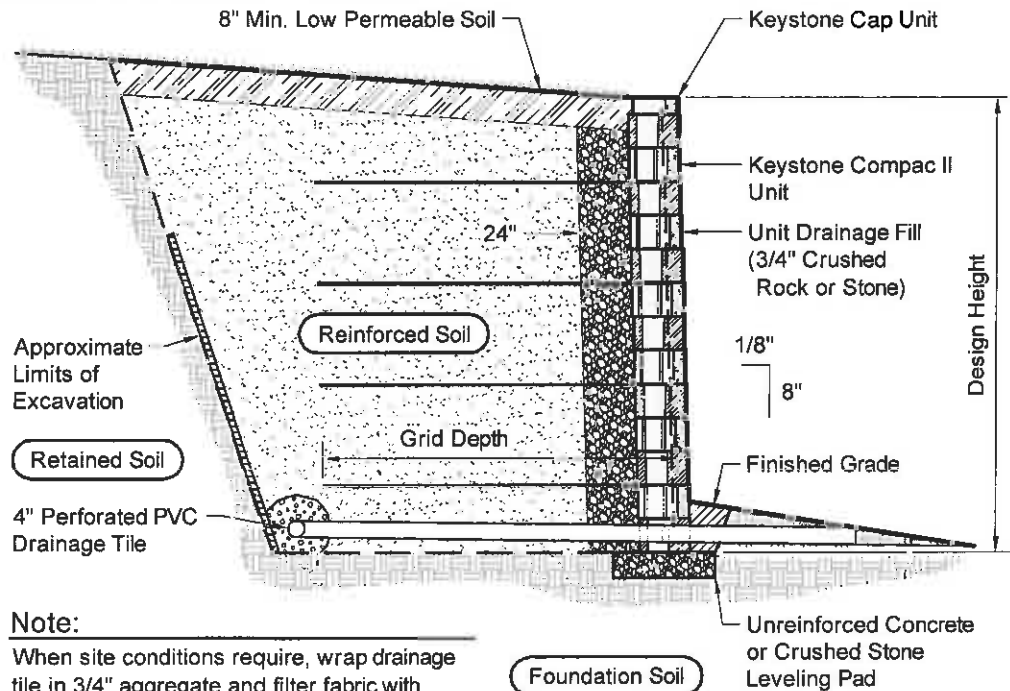
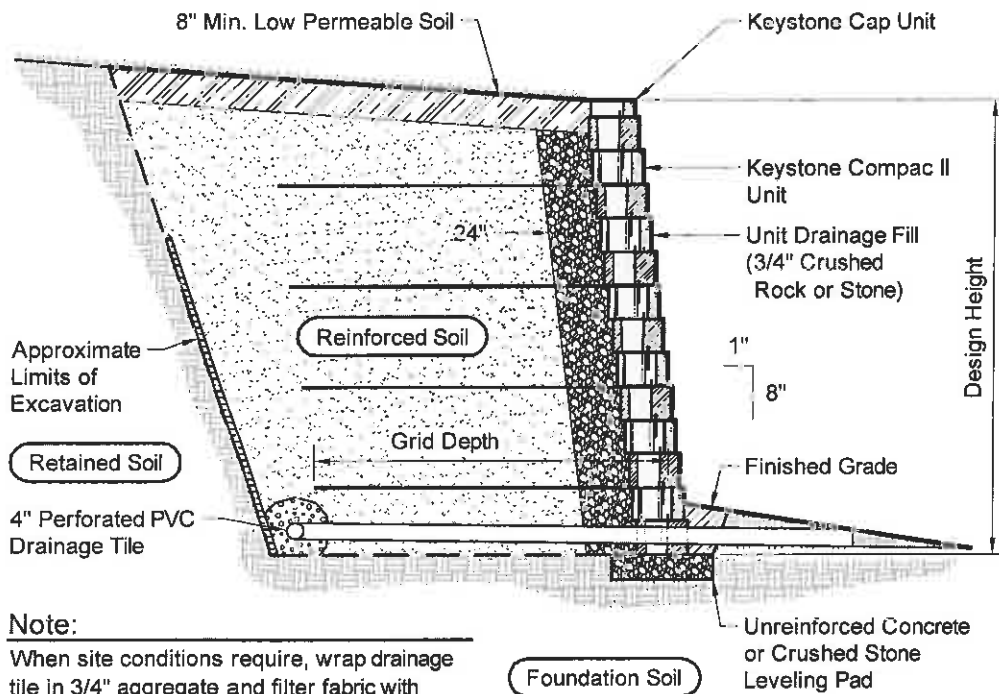


FIGURE L:1 - (REINFORCED WALL) 1" SETBACK



The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use and the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.

SR WALLS
SOFTWARE DATA

SRWall (Version 4) Report**Project Identification**

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Project File	: 3.prj
Vendor Data File	: Synteen 011012.vdf
Date and Time	: 04/29/2015 15:29:36

-----Trial Version-----

Type of Structure	: Reinforced Wall
-------------------	-------------------

-----Trial Version-----

Wall Geometry

Design Wall Height(ft)	: 2.67
Embedment Wall Height(ft)	: 1.00
Exposed Wall Design Height(ft)	: 1.67
Number of Segmental Wall Units	: 4
Wall Inclination(degrees)	: 7.97

-----Trial Version-----

Grades

Top Slope(degrees)	: 0.00
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-----Trial Version-----

Uniform Distributed Surcharge

Live Load Surcharge(Psf)	: 0.00
Dead Load Surcharge(Psf)	: 0.00

-----Trial Version-----

Soil Data

Soil Zone	Description	Cohesion (c) (psf)	Friction Angle(Φ) (degrees)	Unit Weight (γ)(pcf)
Reinforced Soil		N/A	34.00	92.40
Retained Soil		N/A	34.00	92.40
Leveling Pad Soil		N/A	0.00	105.89
Foundation Soil		1040.00	0.05	105.89

-----Trial Version-----

Segmental Unit Data

Segmental Unit Name : **Standard21 Unit - 8.0 Degree Batter**
 Cap Height (Inches) : **4.00**
 Unit Height (Hu)(Inches) : **8.00**
 Unit Width (Wu)(Inches) : **21.00**
 Unit Length (Inches) : **18.00**
 Setback (Inches) : **1.12**
 Weight (Infilled)(lb) : **210.00**
 Unit Weight (Infilled)(pcf) : **120.00**
 Center of Gravity(Inches) : **10.50**

-----Trial Version-----

Geosynthetic Reinforcement Type and Number

Supplier	Product Name	Number
Synteon	SF110	0
Synteon	SF35	0
Synteon	SF55	0
Synteon	SF80	3

-----Trial Version-----

Geosynthetic Properties

Geosynthetic Product	Tult (lb/ft)	RFcr	RFd	RFid	LTDS (lb/ft)	Ci	Cds
SF110	10250.00	1.57	1.10	1.40	4239.39	0.90	0.90
SF35	3435.00	1.54	1.10	1.63	1244.02	0.90	0.90
SF55	4670.00	1.54	1.10	1.55	1778.57	0.90	0.90
SF80	7400.00	1.55	1.10	1.50	2893.45	0.90	0.90

-----Trial Version-----

Unit-Unit Interface Properties

Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
2427.00	17.40	5586.00

-----Trial Version-----

Geosynthetic-SRW Unit Connection Strength properties

Geosynthetic Product	Minimum Conn. Capacity (lb/ft)	1st Inflection Point (lb/ft)		2nd Inflection Point (lb/ft)	
		Normal Load (lb/ft)	Connection Capacity (lb/ft)	Normal Load (lb/ft)	Max Connection Capacity(lb/ft)
SF110	3885.00	7720.00	5455.65	8000.00	5455.65
SF35	1741.00	4080.00	1741.00	6000.00	1741.00
SF55	2925.00	5100.00	2925.00	6000.00	2925.00
SF80	3244.00	6120.00	3244.00	8000.00	3244.00

-----Trial Version-----

Geosynthetic-SRW Unit Shear Strength properties

Geosynthetic Product	Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
SF110	1550.00	17.40	4709.00
SF35	1550.00	17.40	4709.00
SF55	1550.00	17.40	4709.00
SF80	1550.00	17.40	4709.00

-----Trial Version-----

Vertical Components

Vertical Components of Earth Pressures Used : No

-----Trial Version-----

Coefficients of Earth Pressure and Failure Plane Orientation

Reinforcement Soil(Static)(Ka)	: 0.202
Reinforcement Soil(Static)(Kah Horizontal Component)	: 0.195
Internal Modified Back Slope(Bint)	: 0.000
Orientation of failure plane from horizontal(degrees) for Internal Stability	: 55.303
Retained Soil(Static)(Ka)	: 0.202
Retained Soil(Static)(Kah Horizontal Component)	: 0.182
External Modified Back Slope(Bext)	: 0.000
Orientation of failure plane from horizontal(degrees) for External Stability	: 54.202

-----Trial Version-----

Result of External Stability Static Analysis

	Calculated	Design Criteria
FOS Sliding	69.87	> 1.50
FOS Overturning	39.84	> 2.00
FOS Bearing Capacity	22.18	> 3.00
Base Reinforcement Length (L)(ft)	4.00	
Base Reinforcement Ratio (L/H)	1.50	> 0.60

-----Trial Version-----

Results of Internal Stability Static Analysis

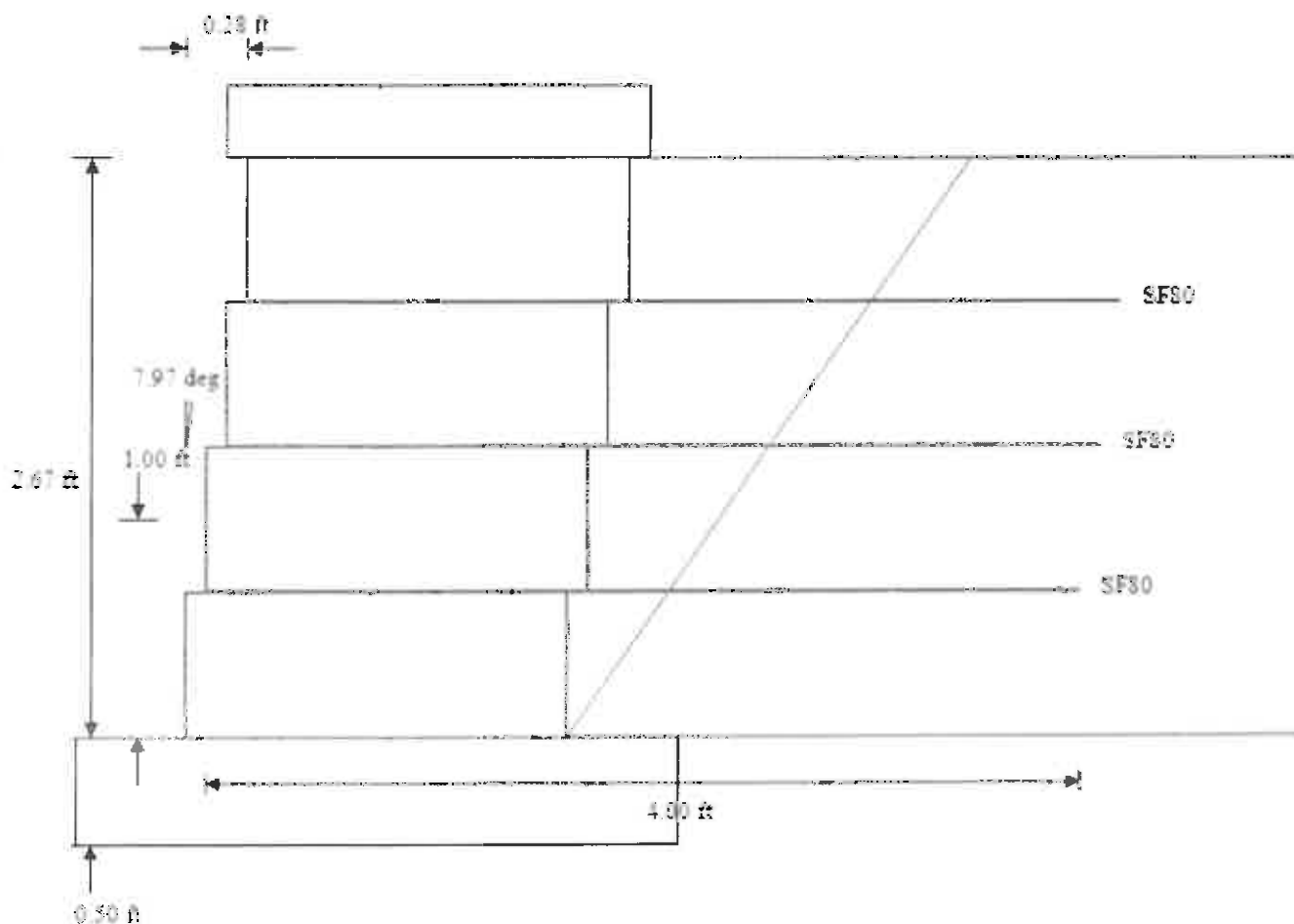
SRW Unit #	Geosynthetic Product	Elevation (ft)	Length (ft)	Anchor Length (ft)	FOS Overstress ≥1.50	FOS Pullout ≥1.50	FOS Slide ≥1.50	Layer Spacing (ft) ≥2.67
4	SF80	2.00	4.00	1.15	319.69	9.46	450.81	OK
3	SF80	1.33	4.00	1.52	180.76	14.20	120.74	OK
2	SF80	0.67	4.00	1.88	74.02	10.77	57.91	OK

-----Trial Version-----

Results of Facing Stability Static Analysis

SRW Unit #	Heel Elev (ft)	Geosynthetic Product	FOS Crest Toppling ≥1.50	FOS Connection ≥1.50
4	2.00	SF80	137.49	358.42
3	1.33	SF80		202.66
2	0.67	SF80		82.99

-----Trial Version-----

Wall Reinforcement Layout

-----Trial Version-----

Project Identification

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Vendor Data File	: Synteen 011012.vdf
Project File	: 3.prj
Date and Time	: 04/29/2015 15:29:36

SRWall (Version 4) Report**Project Identification**

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Project File	: 3.8.prj
Vendor Data File	: Synteen 011012.vdf
Date and Time	: 04/29/2015 15:29:36

-----Trial Version-----

Type of Structure	: Reinforced Wall
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-----Trial Version-----

Wall Geometry

Design Wall Height(ft)	: 3.33
Embedment Wall Height(ft)	: 1.00
Exposed Wall Design Height(ft)	: 2.33
Number of Segmental Wall Units	: 5
Wall Inclination(degrees)	: 7.97

-----Trial Version-----

Grades

Top Slope(degrees)	: 0.00
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-----Trial Version-----

Uniform Distributed Surcharge

Live Load Surcharge(Psf)	: 0.00
Dead Load Surcharge(Psf)	: 0.00

-----Trial Version-----

Soil Data

Soil Zone	Description	Cohesion (c) (psf)	Friction Angle(Φ) (degrees)	Unit Weight (γ)(pcf)
Reinforced Soil		N/A	34.00	92.40
Retained Soil		N/A	34.00	92.40
Leveling Pad Soil		N/A	0.00	105.89
Foundation Soil		1040.00	0.05	105.89

-----Trial Version-----

Segmental Unit Data

Segmental Unit Name : **Standard21 Unit - 8.0 Degree Batter**
 Cap Height (Inches) : **4.00**
 Unit Height (Hu)(Inches) : **8.00**
 Unit Width (Wu)(Inches) : **21.00**
 Unit Length (Inches) : **18.00**
 Setback (Inches) : **1.12**
 Weight (Infilled)(lb) : **210.00**
 Unit Weight (Infilled)(pcf) : **120.00**
 Center of Gravity(Inches) : **10.50**

-----Trial Version-----

Geosynthetic Reinforcement Type and Number

Supplier	Product Name	Number
Synteon	SF110	0
Synteon	SF35	0
Synteon	SF55	0
Synteon	SF80	3

-----Trial Version-----

Geosynthetic Properties

Geosynthetic Product	Tult (lb/ft)	RFcr	RFd	RFid	LTDS (lb/ft)	CI	Cds
SF110	10250.00	1.57	1.10	1.40	4239.39	0.90	0.90
SF35	3435.00	1.54	1.10	1.63	1244.02	0.90	0.90
SF55	4670.00	1.54	1.10	1.55	1778.57	0.90	0.90
SF80	7400.00	1.55	1.10	1.50	2893.45	0.90	0.90

-----Trial Version-----

Unit-Unit Interface Properties

Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
2427.00	17.40	5586.00

-----Trial Version-----

Geosynthetic-SRW Unit Connection Strength properties

Geosynthetic Product	Minimum Conn. Capacity (lb/ft)	1st Inflection Point (lb/ft)		2nd Inflection Point (lb/ft)	
		Normal Load (lb/ft)	Connection Capacity (lb/ft)	Normal Load (lb/ft)	Max Connection Capacity(lb/ft)
SF110	3885.00	7720.00	5455.65	8000.00	5455.65
SF35	1741.00	4080.00	1741.00	6000.00	1741.00
SF55	2925.00	5100.00	2925.00	6000.00	2925.00
SF80	3244.00	6120.00	3244.00	8000.00	3244.00

-----Trial Version-----

Geosynthetic-SRW Unit Shear Strength properties

Geosynthetic Product	Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
SF110	1550.00	17.40	4709.00
SF35	1550.00	17.40	4709.00
SF55	1550.00	17.40	4709.00
SF80	1550.00	17.40	4709.00

-----Trial Version-----

Vertical Components

Vertical Components of Earth Pressures Used : No

-----Trial Version-----

Coefficients of Earth Pressure and Failure Plane Orientation

Reinforcement Soil(Static)(Ka)	: 0.202
Reinforcement Soil(Static)(Kah Horizontal Component)	: 0.195
Internal Modified Back Slope(Bint)	: 0.000
Orientation of failure plane from horizontal(degrees) for Internal Stability	: 55.303
Retained Soil(Static)(Ka)	: 0.202
Retained Soil(Static)(Kah Horizontal Component)	: 0.182
External Modified Back Slope(Bext)	: 0.000
Orientation of failure plane from horizontal(degrees) for External Stability	: 54.202

-----Trial Version-----

Result of External Stability Static Analysis

	Calculated	Design Criteria
FOS Sliding	47.18	> 1.50
FOS Overturning	28.87	> 2.00
FOS Bearing Capacity	17.75	> 3.00
Base Reinforcement Length (L)(ft)	4.22	
Base Reinforcement Ratio (L/H)	1.27	> 0.60

-----Trial Version-----

Results of Internal Stability Static Analysis

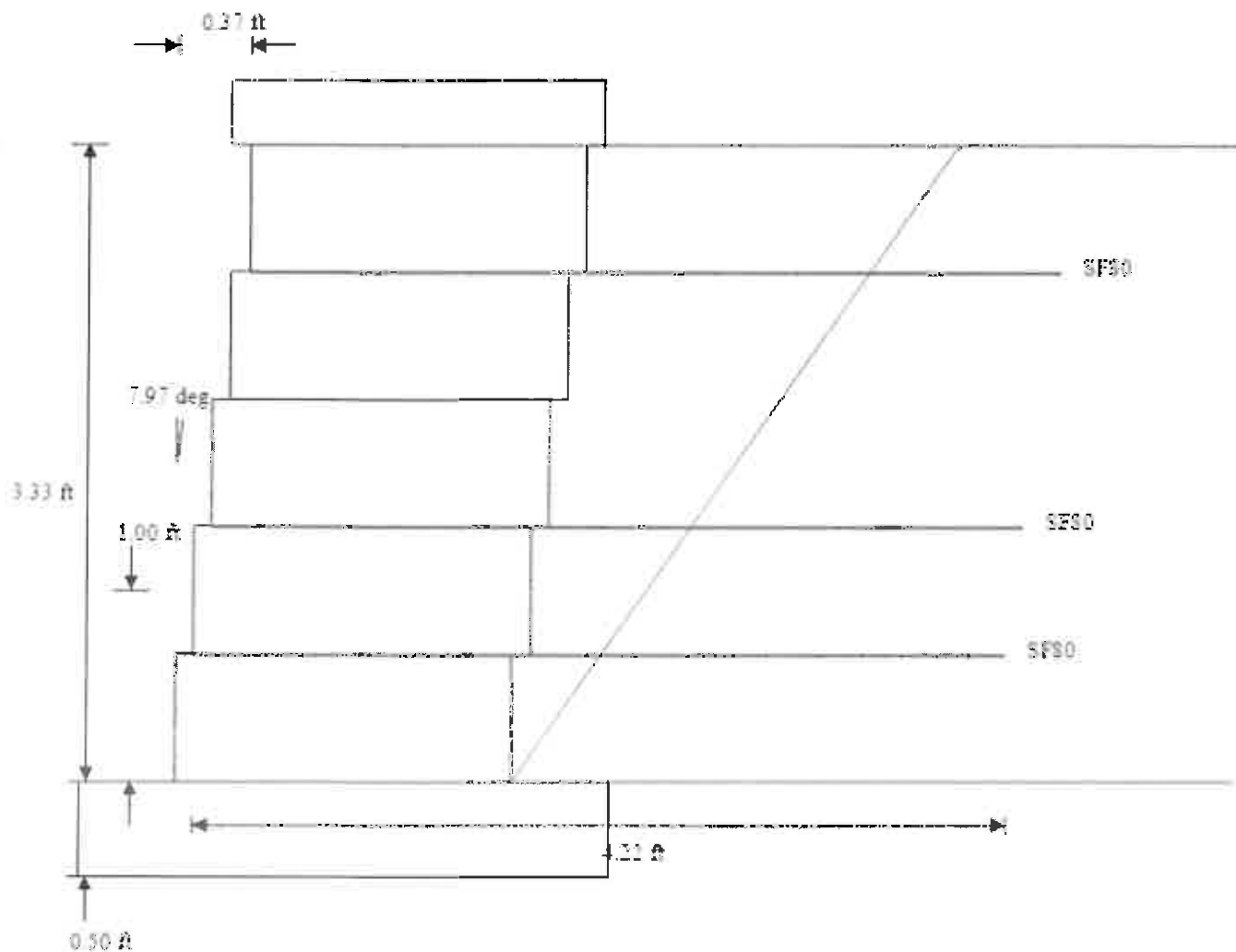
SRW Unit #	Geosynthetic Product	Elevation (ft)	Length (ft)	Anchor Length (ft)	FOS Overstress >=1.50	FOS Pullout >=1.50	FOS Slide >=1.50	Layer Spacing (ft) >=2.67
5	SF80	2.67	4.22	1.00	180.42	4.64	457.40	OK
3	SF80	1.33	4.22	1.74	87.48	11.79	58.30	OK
2	SF80	0.67	4.22	2.10	56.60	12.27	35.25	OK

-----Trial Version-----

Results of Facing Stability Static Analysis

SRW Unit #	Heel Elev (ft)	Geosynthetic Product	FOS Crest Toppling >=1.50	FOS Connection >=1.50
5	2.67	SF80	138.84	202.28
3	1.33	SF80		98.08
2	0.67	SF80		63.46

-----Trial Version-----

Wall Reinforcement Layout

Trial Version

Project Identification

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Vendor Data File	: Synteen 011012.vdf
Project File	: 3.8.prj
Date and Time	: 04/29/2015 15:29:36

SRWall (Version 4) Report**Project Identification**

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Project File	: 4.4.prj
Vendor Data File	: Synteen 011012.vdf
Date and Time	: 04/29/2015 15:29:36

-----Trial Version-----

Type of Structure	: Reinforced Wall
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-----Trial Version-----

Wall Geometry

Design Wall Height(ft)	: 4.00
Embedment Wall Height(ft)	: 1.00
Exposed Wall Design Height(ft)	: 3.00
Number of Segmental Wall Units	: 6
Wall Inclination(degrees)	: 7.97

-----Trial Version-----

Grades

Top Slope(degrees)	: 0.00
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-----Trial Version-----

Uniform Distributed Surcharge

Live Load Surcharge(Psf)	: 0.00
Dead Load Surcharge(Psf)	: 0.00

-----Trial Version-----

Soil Data

Soil Zone	Description	Cohesion (c) (psf)	Friction Angle(Φ) (degrees)	Unit Weight (γ)(pcf)
Reinforced Soil		N/A	34.00	92.40
Retained Soil		N/A	34.00	92.40
Leveling Pad Soil		N/A	0.00	105.89
Foundation Soil		1040.00	0.05	105.89

-----Trial Version-----

Segmental Unit Data

Segmental Unit Name : Standard21 Unit - 8.0 Degree Batter
 Cap Height (Inches) : 4.00
 Unit Height (Hu)(Inches) : 8.00
 Unit Width (Wu)(Inches) : 21.00
 Unit Length (Inches) : 18.00
 Setback (Inches) : 1.12
 Weight (Infilled)(lb) : 210.00
 Unit Weight (Infilled)(pcf) : 120.00
 Center of Gravity(Inches) : 10.50

-----Trial Version-----

Geosynthetic Reinforcement Type and Number

Supplier	Product Name	Number
Synteon	SF110	0
Synteon	SF35	0
Synteon	SF55	0
Synteon	SF80	4

-----Trial Version-----

Geosynthetic Properties

Geosynthetic Product	Tult (lb/ft)	RFcr	RFd	RFid	LTDS (lb/ft)	Ci	Cds
SF110	10250.00	1.57	1.10	1.40	4239.39	0.90	0.90
SF35	3435.00	1.54	1.10	1.63	1244.02	0.90	0.90
SF55	4670.00	1.54	1.10	1.55	1778.57	0.90	0.90
SF80	7400.00	1.55	1.10	1.50	2893.45	0.90	0.90

-----Trial Version-----

Unit-Unit Interface Properties

Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
2427.00	17.40	5586.00

-----Trial Version-----

Geosynthetic-SRW Unit Connection Strength properties

Geosynthetic Product	Minimum Conn. Capacity (lb/ft)	1st Inflection Point (lb/ft)		2nd Inflection Point (lb/ft)	
		Normal Load (lb/ft)	Connection Capacity (lb/ft)	Normal Load (lb/ft)	Max Connection Capacity(lb/ft)
SF110	3885.00	7720.00	5455.65	8000.00	5455.65
SF35	1741.00	4080.00	1741.00	6000.00	1741.00
SF55	2925.00	5100.00	2925.00	6000.00	2925.00
SF80	3244.00	6120.00	3244.00	8000.00	3244.00

-----Trial Version-----

Geosynthetic-SRW Unit Shear Strength properties

Geosynthetic Product	Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
SF110	1550.00	17.40	4709.00
SF35	1550.00	17.40	4709.00
SF55	1550.00	17.40	4709.00
SF80	1550.00	17.40	4709.00

-----Trial Version-----

Vertical Components

Vertical Components of Earth Pressures Used : No

-----Trial Version-----

Coefficients of Earth Pressure and Failure Plane Orientation

Reinforcement Soil(Static)(Ka)	: 0.202
Reinforcement Soil(Static)(Kah Horizontal Component)	: 0.195
Internal Modified Back Slope(Bint)	: 0.000
Orientation of failure plane from horizontal(degrees) for Internal Stability	: 55.303
Retained Soil(Static)(Ka)	: 0.202
Retained Soil(Static)(Kah Horizontal Component)	: 0.182
External Modified Back Slope(Bext)	: 0.000
Orientation of failure plane from horizontal(degrees) for External Stability	: 54.202

-----Trial Version-----

Result of External Stability Static Analysis

	Calculated	Design Criteria
FOS Sliding	35.64	> 1.50
FOS Overturning	24.01	> 2.00
FOS Bearing Capacity	14.79	> 3.00
Base Reinforcement Length (L)(ft)	4.59	
Base Reinforcement Ratio (L/H)	1.15	> 0.60

-----Trial Version-----

Results of Internal Stability Static Analysis

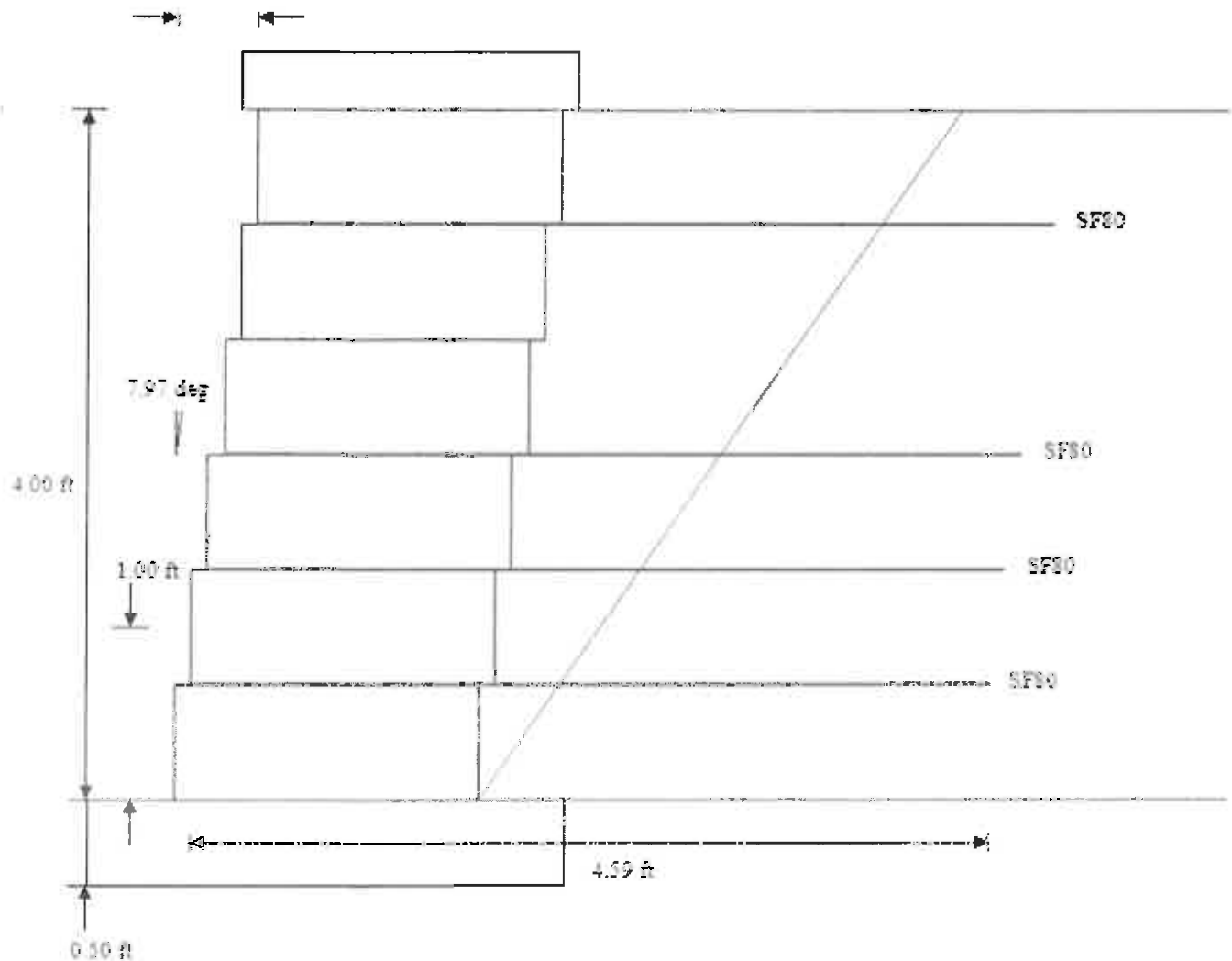
SRW Unit #	Geosynthetic Product	Elevation (ft)	Length (ft)	Anchor Length (ft)	FOS Overstress ≥1.50	FOS Pullout ≥1.50	FOS Slide ≥1.50	Layer Spacing (ft) ≥2.67
6	SF80	3.33	4.59	1.00	179.97	4.68	452.41	OK
4	SF80	2.00	4.59	1.74	87.40	11.76	59.71	OK
3	SF80	1.33	4.59	2.11	90.41	19.70	36.03	OK
2	SF80	0.67	4.59	2.47	45.82	14.61	24.76	OK

-----Trial Version-----

Results of Facing Stability Static Analysis

SRW Unit #	Heel Elev (ft)	Geosynthetic Product	FOS Crest Toppling ≥1.50	FOS Connection ≥1.50
6	3.33	SF80	136.17	201.78
4	2.00	SF80		97.99
3	1.33	SF80		101.36
2	0.67	SF80		51.37

-----Trial Version-----

Wall Reinforcement Layout

Trial Version

Project Identification

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Vendor Data File	: Synteen 011012.vdf
Project File	: 4.4.prj
Date and Time	: 04/29/2015 15:29:36

SRWall (Version 4) Report**Project Identification**

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Project File	: 5.prj
Vendor Data File	: Synteen 011012.vdf
Date and Time	: 04/29/2015 15:29:36

-----Trial Version-----

Type of Structure	: Reinforced Wall
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-----Trial Version-----

Wall Geometry

Design Wall Height(ft)	: 4.67
Embedment Wall Height(ft)	: 1.00
Exposed Wall Design Height(ft)	: 3.67
Number of Segmental Wall Units	: 7
Wall Inclination(degrees)	: 7.97

-----Trial Version-----

Grades

Top Slope(degrees)	: 0.00
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-----Trial Version-----

Uniform Distributed Surcharge

Live Load Surcharge(Psf)	: 0.00
Dead Load Surcharge(Psf)	: 0.00

-----Trial Version-----

Soil Data

Soil Zone	Description	Cohesion (c) (psf)	Friction Angle(Φ) (degrees)	Unit Weight (γ)(pcf)
Reinforced Soil		N/A	34.00	92.40
Retained Soil		N/A	34.00	92.40
Leveling Pad Soil		N/A	0.00	105.89
Foundation Soil		1040.00	0.05	105.89

-----Trial Version-----

Segmental Unit Data

Segmental Unit Name : Standard21 Unit - 8.0 Degree Batter
 Cap Height (Inches) : 4.00
 Unit Height (Hu)(Inches) : 8.00
 Unit Width (Wu)(Inches) : 21.00
 Unit Length (Inches) : 18.00
 Setback (Inches) : 1.12
 Weight (Infilled)(lb) : 210.00
 Unit Weight (Infilled)(pcf) : 120.00
 Center of Gravity(Inches) : 10.50

-----Trial Version-----

Geosynthetic Reinforcement Type and Number

Supplier	Product Name	Number
Synteon	SF110	0
Synteon	SF35	0
Synteon	SF55	0
Synteon	SF80	4

-----Trial Version-----

Geosynthetic Properties

Geosynthetic Product	Tult (lb/ft)	RFcr	RFd	RFld	LTDS (lb/ft)	Ci	Cds
SF110	10250.00	1.57	1.10	1.40	4239.39	0.90	0.90
SF35	3435.00	1.54	1.10	1.63	1244.02	0.90	0.90
SF55	4670.00	1.54	1.10	1.55	1778.57	0.90	0.90
SF80	7400.00	1.55	1.10	1.50	2893.45	0.90	0.90

-----Trial Version-----

Unit-Unit Interface Properties

Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
2427.00	17.40	5586.00

-----Trial Version-----

Geosynthetic-SRW Unit Connection Strength properties

Geosynthetic Product	Minimum Conn. Capacity (lb/ft)	1st Inflection Point (lb/ft)		2nd Inflection Point (lb/ft)	
		Normal Load (lb/ft)	Connection Capacity (lb/ft)	Normal Load (lb/ft)	Max Connection Capacity (lb/ft)
SF110	3885.00	7720.00	5455.65	8000.00	5455.65
SF35	1741.00	4080.00	1741.00	6000.00	1741.00
SF55	2925.00	5100.00	2925.00	6000.00	2925.00
SF80	3244.00	6120.00	3244.00	8000.00	3244.00

-----Trial Version-----

Geosynthetic-SRW Unit Shear Strength properties

Geosynthetic Product	Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
SF110	1550.00	17.40	4709.00
SF35	1550.00	17.40	4709.00
SF55	1550.00	17.40	4709.00
SF80	1550.00	17.40	4709.00

-----Trial Version-----

Vertical Components

Vertical Components of Earth Pressures Used : No

-----Trial Version-----

Coefficients of Earth Pressure and Failure Plane Orientation

Reinforcement Soil(Static)(Ka)	: 0.202
Reinforcement Soil(Static)(Kah Horizontal Component)	: 0.195
Internal Modified Back Slope(Bint)	: 0.000
Orientation of failure plane from horizontal(degrees) for Internal Stability	: 55.303
Retained Soil(Static)(Ka)	: 0.202
Retained Soil(Static)(Kah Horizontal Component)	: 0.182
External Modified Back Slope(Bext)	: 0.000
Orientation of failure plane from horizontal(degrees) for External Stability	: 54.202

-----Trial Version-----

Result of External Stability Static Analysis

	Calculated	Design Criteria
FOS Sliding	30.40	> 1.50
FOS Overturning	23.86	> 2.00
FOS Bearing Capacity	12.68	> 3.00
Base Reinforcement Length (L)(ft)	5.33	
Base Reinforcement Ratio (L/H)	1.14	> 0.60

-----Trial Version-----

Results of Internal Stability Static Analysis

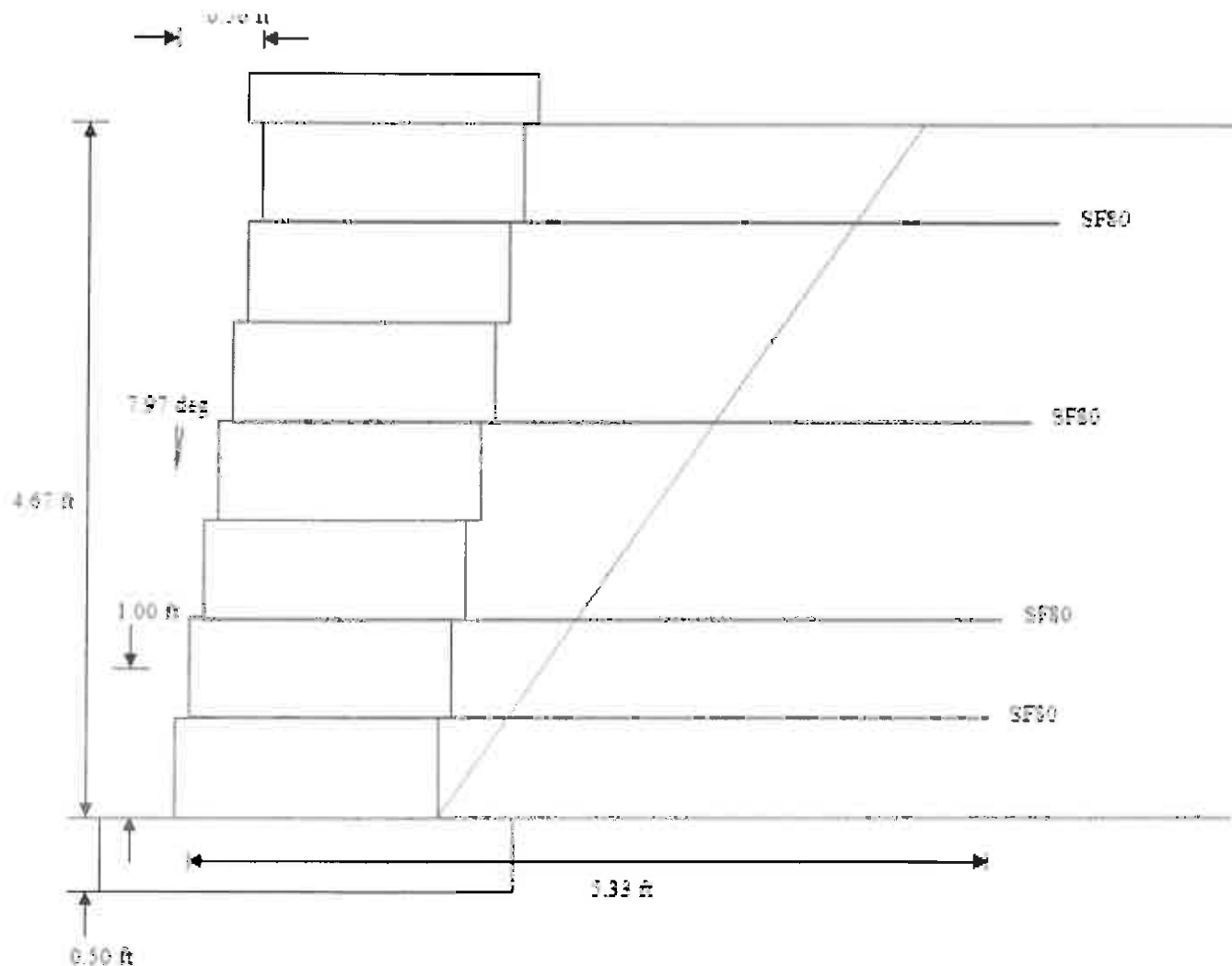
SRW Unit #	Geosynthetic Product	Elevation (ft)	Length (ft)	Anchor Length (ft)	FOS Overstress ≥1.50	FOS Pullout ≥1.50	FOS Slide ≥1.50	Layer Spacing (ft) ≥2.67
7	SF80	4.00	5.33	1.37	180.87	6.41	464.18	OK
5	SF80	2.67	5.33	2.11	60.09	9.79	62.37	OK
3	SF80	1.33	5.33	2.85	50.65	18.64	26.16	OK
2	SF80	0.67	5.33	3.21	38.49	19.15	19.55	OK

-----Trial Version-----

Results of Facing Stability Static Analysis

SRW Unit #	Heel Elev (ft)	Geosynthetic Product	FOS Crest Toppling ≥1.50	FOS Connection ≥1.50
7	4.00	SF80	137.49	202.79
5	2.67	SF80		67.37
3	1.33	SF80		56.78
2	0.67	SF80		43.15

-----Trial Version-----

Wall Reinforcement Layout

-----Trial Version-----

Project Identification

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Vendor Data File	: Synteen 011012.vdf
Project File	: 5.prj
Date and Time	: 04/29/2015 15:29:36

SRWall (Version 4) Report**Project Identification**

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Project File	: 5.8.prj
Vendor Data File	: Synteen 011012.vdf
Date and Time	: 04/29/2015 15:29:36

-----Trial Version-----

Type of Structure	: Reinforced Wall
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-----Trial Version-----

Wall Geometry

Design Wall Height(ft)	: 5.33
Embedment Wall Height(ft)	: 1.00
Exposed Wall Design Height(ft)	: 4.33
Number of Segmental Wall Units	: 8
Wall Inclination(degrees)	: 7.97

-----Trial Version-----

Grades

Top Slope(degrees)	: 0.00
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-----Trial Version-----

Uniform Distributed Surcharge

Live Load Surcharge(Psf)	: 0.00
Dead Load Surcharge(Psf)	: 0.00

-----Trial Version-----

Soil Data

Soil Zone	Description	Cohesion (c) (psf)	Friction Angle(Φ) (degrees)	Unit Weight (γ)(pcf)
Reinforced Soil		N/A	34.00	92.40
Retained Soil		N/A	34.00	92.40
Leveling Pad Soil		N/A	0.00	105.89
Foundation Soil		1040.00	0.05	105.89

-----Trial Version-----

Segmental Unit Data

Segmental Unit Name : **Standard21 Unit - 8.0 Degree Batter**
 Cap Height (Inches) : **4.00**
 Unit Height (Hu)(Inches) : **8.00**
 Unit Width (Wu)(Inches) : **21.00**
 Unit Length (Inches) : **18.00**
 Setback (Inches) : **1.12**
 Weight (Infilled)(lb) : **210.00**
 Unit Weight (Infilled)(pcf) : **120.00**
 Center of Gravity(Inches) : **10.50**

-----Trial Version-----

Geosynthetic Reinforcement Type and Number

Supplier	Product Name	Number
Synteon	SF110	0
Synteon	SF35	0
Synteon	SF55	0
Synteon	SF80	5

-----Trial Version-----

Geosynthetic Properties

Geosynthetic Product	Tult (lb/ft)	RFcr	RFd	RFid	LTDS (lb/ft)	Ci	Cds
SF110	10250.00	1.57	1.10	1.40	4239.39	0.90	0.90
SF35	3435.00	1.54	1.10	1.63	1244.02	0.90	0.90
SF55	4670.00	1.54	1.10	1.55	1778.57	0.90	0.90
SF80	7400.00	1.55	1.10	1.50	2893.45	0.90	0.90

-----Trial Version-----

Unit-Unit Interface Properties

Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
2427.00	17.40	5586.00

-----Trial Version-----

Geosynthetic-SRW Unit Connection Strength properties

Geosynthetic Product	Minimum Conn. Capacity (lb/ft)	1st Inflection Point (lb/ft)		2nd Inflection Point (lb/ft)	
		Normal Load (lb/ft)	Connection Capacity (lb/ft)	Normal Load (lb/ft)	Max Connection Capacity(lb/ft)
SF110	3885.00	7720.00	5455.65	8000.00	5455.65
SF35	1741.00	4080.00	1741.00	6000.00	1741.00
SF55	2925.00	5100.00	2925.00	6000.00	2925.00
SF80	3244.00	6120.00	3244.00	8000.00	3244.00

-----Trial Version-----

Geosynthetic-SRW Unit Shear Strength properties

Geosynthetic Product	Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
SF110	1550.00	17.40	4709.00
SF35	1550.00	17.40	4709.00
SF55	1550.00	17.40	4709.00
SF80	1550.00	17.40	4709.00

-----Trial Version-----

Vertical Components

Vertical Components of Earth Pressures Used : No

-----Trial Version-----

Coefficients of Earth Pressure and Failure Plane Orientation

Reinforcement Soil(Static)(Ka)	: 0.202
Reinforcement Soil(Static)(Kah Horizontal Component)	: 0.195
Internal Modified Back Slope(Bint)	: 0.000
Orientation of failure plane from horizontal(degrees) for Internal Stability	: 55.303
Retained Soil(Static)(Ka)	: 0.202
Retained Soil(Static)(Kah Horizontal Component)	: 0.182
External Modified Back Slope(Bext)	: 0.000
Orientation of failure plane from horizontal(degrees) for External Stability	: 54.202

-----Trial Version-----

Result of External Stability Static Analysis

	Calculated	Design Criteria
FOS Sliding	23.28	> 1.50
FOS Overturning	18.55	> 2.00
FOS Bearing Capacity	11.09	> 3.00
Base Reinforcement Length (L)(ft)	5.33	
Base Reinforcement Ratio (L/H)	1.00	> 0.60

-----Trial Version-----

Results of Internal Stability Static Analysis

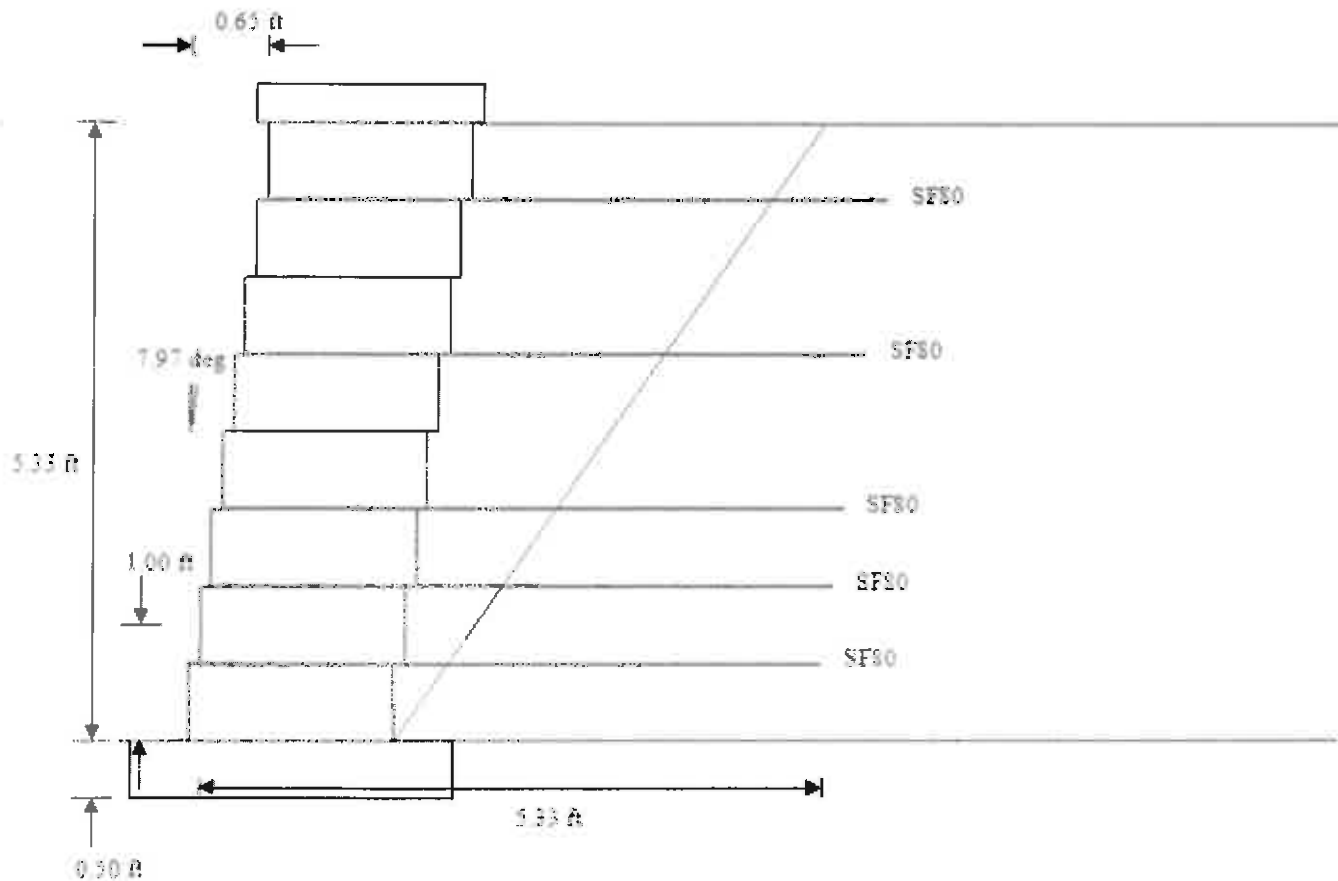
SRW Unit #	Geosynthetic Product	Elevation (ft)	Length (ft)	Anchor Length (ft)	FOS Overstress ≥1.50	FOS Pullout ≥1.50	FOS Slide ≥1.50	Layer Spacing (ft) ≥2.67
8	SF80	4.67	5.33	1.00	180.42	4.64	468.61	OK
6	SF80	3.33	5.33	1.74	60.04	8.12	62.01	OK
4	SF80	2.00	5.33	2.48	50.62	16.19	26.21	OK
3	SF80	1.33	5.33	2.85	60.28	26.62	19.50	OK
2	SF80	0.67	5.33	3.21	33.18	19.26	15.34	OK

-----Trial Version-----

Results of Facing Stability Static Analysis

SRW Unit #	Heel Elev (ft)	Geosynthetic Product	FOS Crest Toppling ≥1.50	FOS Connection ≥1.50
8	4.67	SF80	138.84	202.28
6	3.33	SF80		67.32
4	2.00	SF80		56.75
3	1.33	SF80		67.58
2	0.67	SF80		37.20

-----Trial Version-----

Wall Reinforcement Layout

 Trial Version
Project Identification

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Vendor Data File	: Synteen 011012.vdf
Project File	: 5.8.prj
Date and Time	: 04/29/2015 15:29:36

SRWall (Version 4) Report**Project Identification**

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Project File	: 6.4.prj
Vendor Data File	: Synteen 011012.vdf
Date and Time	: 04/29/2015 15:29:36

-----Trial Version-----

Type of Structure	: Reinforced Wall
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-----Trial Version-----

Wall Geometry

Design Wall Height(ft)	: 6.00
Embedment Wall Height(ft)	: 1.00
Exposed Wall Design Height(ft)	: 5.00
Number of Segmental Wall Units	: 9
Wall Inclination(degrees)	: 7.97

-----Trial Version-----

Grades

Top Slope(degrees)	: 0.00
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-----Trial Version-----

Uniform Distributed Surcharge

Live Load Surcharge(Psf)	: 0.00
Dead Load Surcharge(Psf)	: 0.00

-----Trial Version-----

Soil Data

Soil Zone	Description	Cohesion (c) (psf)	Friction Angle(Φ) (degrees)	Unit Weight (γ)(pcf)
Reinforced Soil		N/A	34.00	92.40
Retained Soil		N/A	34.00	92.40
Leveling Pad Soil		N/A	0.00	105.89
Foundation Soil		1040.00	0.05	105.89

-----Trial Version-----

Segmental Unit Data

Segmental Unit Name : Standard21 Unit - 8.0 Degree Batter
 Cap Height (Inches) : 4.00
 Unit Height (Hu)(Inches) : 8.00
 Unit Width (Wu)(Inches) : 21.00
 Unit Length (Inches) : 18.00
 Setback (Inches) : 1.12
 Weight (Infilled)(lb) : 210.00
 Unit Weight (Infilled)(pcf) : 120.00
 Center of Gravity(Inches) : 10.50

-----Trial Version-----

Geosynthetic Reinforcement Type and Number

Supplier	Product Name	Number
Synteon	SF110	0
Synteon	SF35	0
Synteon	SF55	0
Synteon	SF80	5

-----Trial Version-----

Geosynthetic Properties

Geosynthetic Product	Tult (lb/ft)	RFcr	RFd	RFid	LTDS (lb/ft)	Ci	Cds
SF110	10250.00	1.57	1.10	1.40	4239.39	0.90	0.90
SF35	3435.00	1.54	1.10	1.63	1244.02	0.90	0.90
SF55	4670.00	1.54	1.10	1.55	1778.57	0.90	0.90
SF80	7400.00	1.55	1.10	1.50	2893.45	0.90	0.90

-----Trial Version-----

Unit-Unit Interface Properties

Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
2427.00	17.40	5586.00

-----Trial Version-----

Geosynthetic-SRW Unit Connection Strength properties

Geosynthetic Product	Minimum Conn. Capacity (lb/ft)	1st Inflection Point (lb/ft)		2nd Inflection Point (lb/ft)	
		Normal Load (lb/ft)	Connection Capacity (lb/ft)	Normal Load (lb/ft)	Max Connection Capacity(lb/ft)
SF110	3885.00	7720.00	5455.65	8000.00	5455.65
SF35	1741.00	4080.00	1741.00	6000.00	1741.00
SF55	2925.00	5100.00	2925.00	6000.00	2925.00
SF80	3244.00	6120.00	3244.00	8000.00	3244.00

-----Trial Version-----

Geosynthetic-SRW Unit Shear Strength properties

Geosynthetic Product	Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
SF110	1550.00	17.40	4709.00
SF35	1550.00	17.40	4709.00
SF55	1550.00	17.40	4709.00
SF80	1550.00	17.40	4709.00

-----Trial Version-----

Vertical Components

Vertical Components of Earth Pressures Used : No

-----Trial Version-----

Coefficients of Earth Pressure and Failure Plane Orientation

Reinforcement Soil(Static)(Ka)	: 0.202
Reinforcement Soil(Static)(Kah Horizontal Component)	: 0.195
Internal Modified Back Slope(Bint)	: 0.000
Orientation of failure plane from horizontal(degrees) for Internal Stability	: 55.303
Retained Soil(Static)(Ka)	: 0.202
Retained Soil(Static)(Kah Horizontal Component)	: 0.182
External Modified Back Slope(Bext)	: 0.000
Orientation of failure plane from horizontal(degrees) for External Stability	: 54.202

-----Trial Version-----

Result of External Stability Static Analysis

	Calculated	Design Criteria
FOS Sliding	19.67	> 1.50
FOS Overturning	16.89	> 2.00
FOS Bearing Capacity	9.86	> 3.00
Base Reinforcement Length (L)(ft)	5.70	
Base Reinforcement Ratio (L/H)	0.95	> 0.60

-----Trial Version-----

Results of Internal Stability Static Analysis

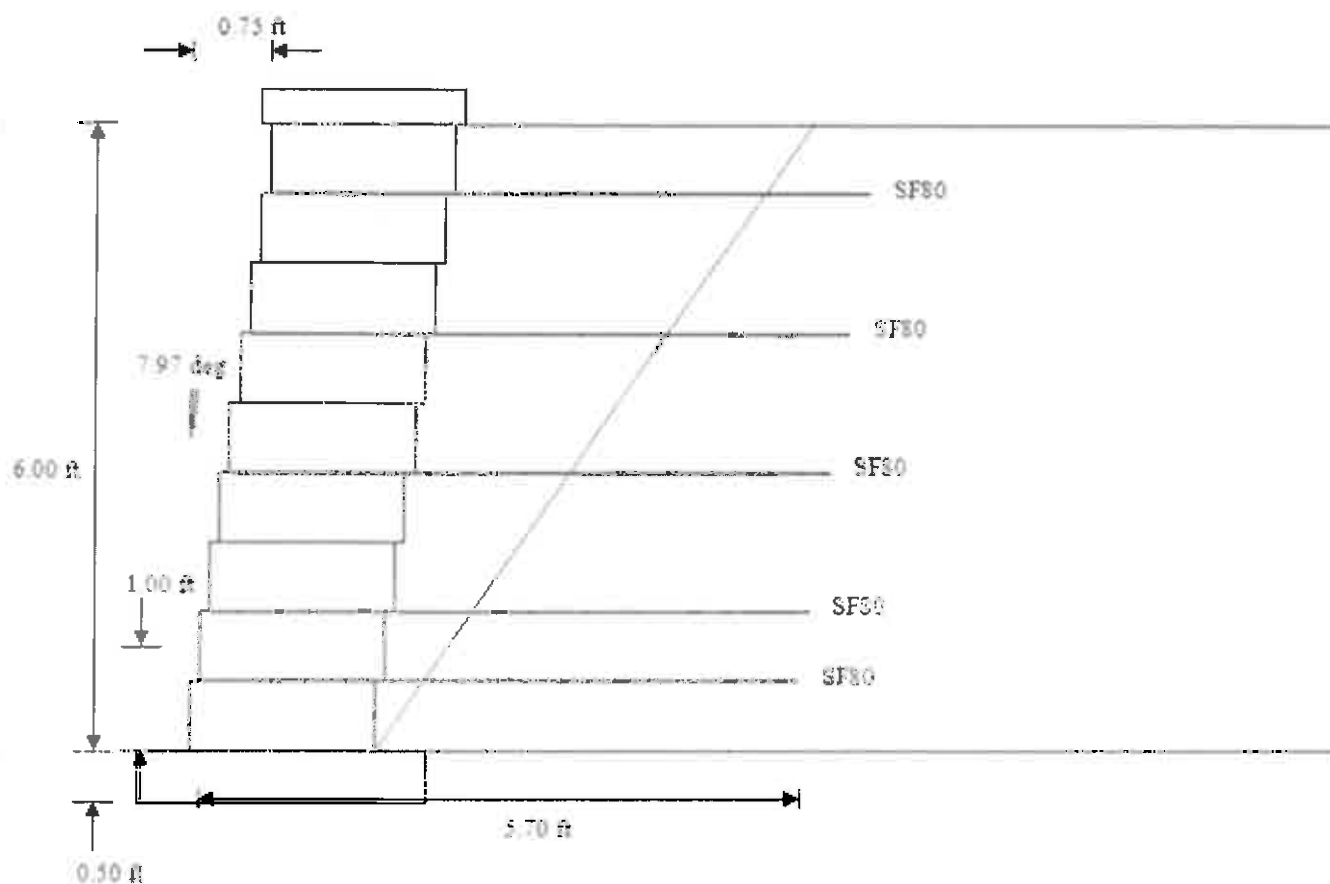
SRW Unit #	Geosynthetic Product	Elevation (ft)	Length (ft)	Anchor Length (ft)	FOS Overstress ≥1.50	FOS Pullout ≥1.50	FOS Slide ≥1.50	Layer Spacing (ft) ≥2.67
9	SF80	5.33	5.70	1.01	179.97	4.70	463.50	OK
7	SF80	4.00	5.70	1.74	60.29	8.14	63.43	OK
5	SF80	2.67	5.70	2.48	36.05	11.52	26.99	OK
3	SF80	1.33	5.70	3.22	35.64	20.75	15.83	OK
2	SF80	0.67	5.70	3.58	29.16	21.57	12.95	OK

-----Trial Version-----

Results of Facing Stability Static Analysis

SRW Unit #	Heel Elev (ft)	Geosynthetic Product	FOS Crest Toppling ≥1.50	FOS Connection ≥1.50
9	5.33	SF80	136.17	201.78
7	4.00	SF80		67.60
5	2.67	SF80		40.42
3	1.33	SF80		39.96
2	0.67	SF80		32.69

-----Trial Version-----

Wall Reinforcement Layout

-----Trial Version-----

Project Identification

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Vendor Data File	: Synteen 011012.vdf
Project File	: 6.4.prj
Date and Time	: 04/29/2015 15:29:36

SRWall (Version 4) Report**Project Identification**

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Project File	: 7.prj
Vendor Data File	: Synteen 011012.vdf
Date and Time	: 04/29/2015 15:29:36

-----Trial Version-----

Type of Structure	: Reinforced Wall
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-----Trial Version-----

Wall Geometry

Design Wall Height(ft)	: 6.67
Embedment Wall Height(ft)	: 1.00
Exposed Wall Design Height(ft)	: 5.67
Number of Segmental Wall Units	: 10
Wall Inclination(degrees)	: 7.97

-----Trial Version-----

Grades

Top Slope(degrees)	: 0.00
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-----Trial Version-----

Uniform Distributed Surcharge

Live Load Surcharge(Psf)	: 0.00
Dead Load Surcharge(Psf)	: 0.00

-----Trial Version-----

Soil Data

Soil Zone	Description	Cohesion (c) (psf)	Friction Angle(Φ) (degrees)	Unit Weight (γ)(pcf)
Reinforced Soil		N/A	34.00	92.40
Retained Soil		N/A	34.00	92.40
Leveling Pad Soil		N/A	0.00	105.89
Foundation Soil		1040.00	0.05	105.89

-----Trial Version-----

Segmental Unit Data

Segmental Unit Name : Standard21 Unit - 8.0 Degree Batter
 Cap Height (Inches) : 4.00
 Unit Height (Hu)(Inches) : 8.00
 Unit Width (Wu)(Inches) : 21.00
 Unit Length (Inches) : 18.00
 Setback (Inches) : 1.12
 Weight (Infilled)(lb) : 210.00
 Unit Weight (Infilled)(pcf) : 120.00
 Center of Gravity(Inches) : 10.50

-----Trial Version-----

Geosynthetic Reinforcement Type and Number

Supplier	Product Name	Number
Synteon	SF110	0
Synteon	SF35	0
Synteon	SF55	0
Synteon	SF80	6

-----Trial Version-----

Geosynthetic Properties

Geosynthetic Product	Tult (lb/ft)	RFcr	RFd	RFid	LTDS (lb/ft)	Ci	Cds
SF110	10250.00	1.57	1.10	1.40	4239.39	0.90	0.90
SF35	3435.00	1.54	1.10	1.63	1244.02	0.90	0.90
SF55	4670.00	1.54	1.10	1.55	1778.57	0.90	0.90
SF80	7400.00	1.55	1.10	1.50	2893.45	0.90	0.90

-----Trial Version-----

Unit-Unit Interface Properties

Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
2427.00	17.40	5586.00

-----Trial Version-----

Geosynthetic-SRW Unit Connection Strength properties

Geosynthetic Product	Minimum Conn. Capacity (lb/ft)	1st Inflection Point (lb/ft)		2nd Inflection Point (lb/ft)	
		Normal Load (lb/ft)	Connection Capacity (lb/ft)	Normal Load (lb/ft)	Max Connection Capacity(lb/ft)
SF110	3885.00	7720.00	5455.65	8000.00	5455.65
SF35	1741.00	4080.00	1741.00	6000.00	1741.00
SF55	2925.00	5100.00	2925.00	6000.00	2925.00
SF80	3244.00	6120.00	3244.00	8000.00	3244.00

-----Trial Version-----

Geosynthetic-SRW Unit Shear Strength properties

Geosynthetic Product	Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
SF110	1550.00	17.40	4709.00
SF35	1550.00	17.40	4709.00
SF55	1550.00	17.40	4709.00
SF80	1550.00	17.40	4709.00

-----Trial Version-----

Vertical Components

Vertical Components of Earth Pressures Used : No

-----Trial Version-----

Coefficients of Earth Pressure and Failure Plane Orientation

Reinforcement Soil(Static)(Ka)	: 0.202
Reinforcement Soil(Static)(Kah Horizontal Component)	: 0.195
Internal Modified Back Slope(Bint)	: 0.000
Orientation of failure plane from horizontal(degrees) for Internal Stability	: 55.303
Retained Soil(Static)(Ka)	: 0.202
Retained Soil(Static)(Kah Horizontal Component)	: 0.182
External Modified Back Slope(Bext)	: 0.000
Orientation of failure plane from horizontal(degrees) for External Stability	: 54.202

-----Trial Version-----

Result of External Stability Static Analysis

	Calculated	Design Criteria
FOS Sliding	16.94	> 1.50
FOS Overturning	15.57	> 2.00
FOS Bearing Capacity	8.87	> 3.00
Base Reinforcement Length (L)(ft)	6.06	
Base Reinforcement Ratio (L/H)	0.91	> 0.60

-----Trial Version-----

Results of Internal Stability Static Analysis

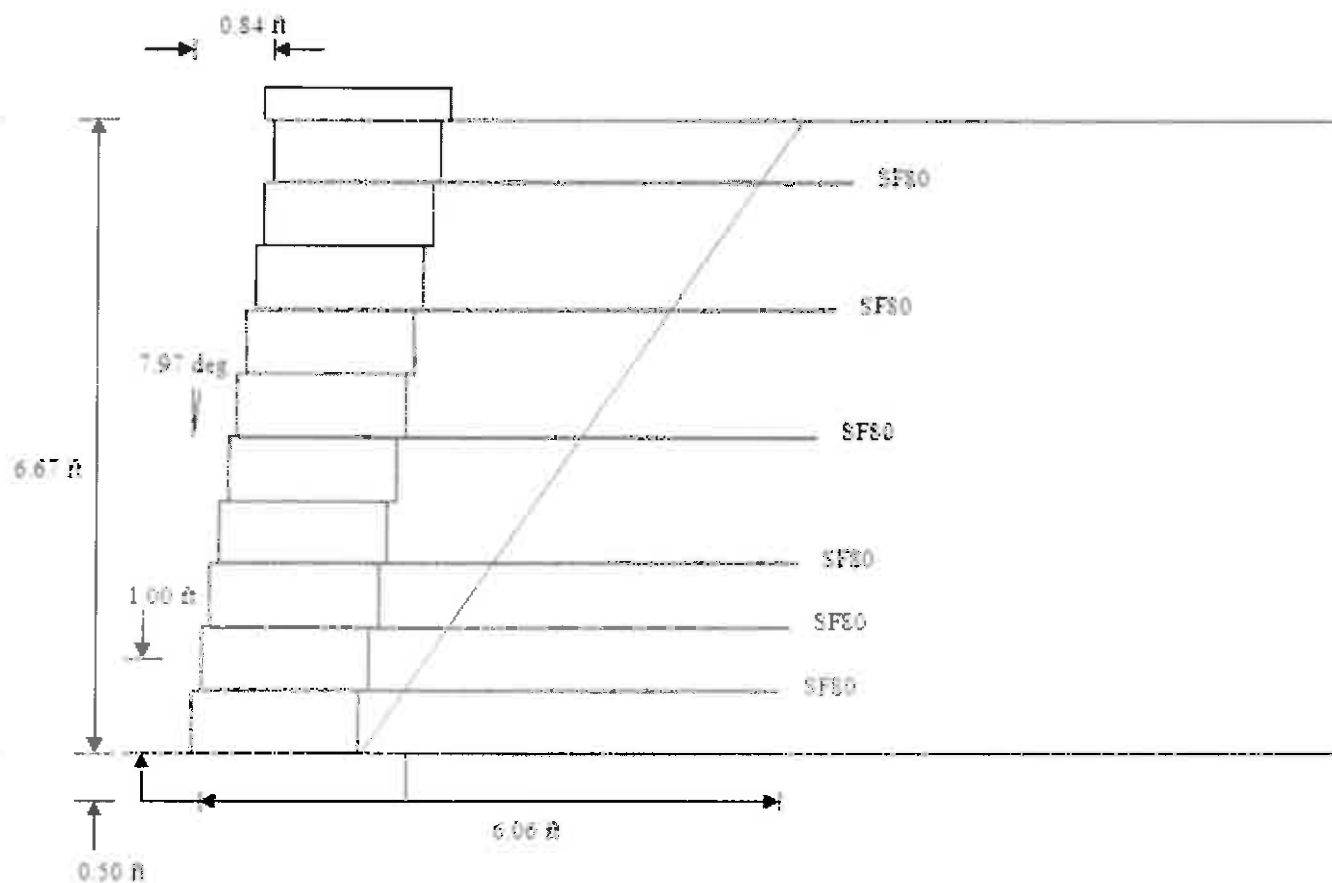
SRW Unit #	Geosynthetic Product	Elevation (ft)	Length (ft)	Anchor Length (ft)	FOS Overstress ≥1.50	FOS Pullout ≥1.50	FOS Slide ≥1.50	Layer Spacing (ft) ≥2.67
10	SF80	6.00	6.06	1.00	180.87	4.68	471.51	OK
8	SF80	4.67	6.06	1.73	60.09	8.05	64.82	OK
6	SF80	3.33	6.06	2.47	36.03	11.52	27.63	OK
4	SF80	2.00	6.06	3.21	35.63	20.66	16.37	OK
3	SF80	1.33	6.06	3.58	45.21	33.45	13.38	OK
2	SF80	0.67	6.06	3.94	26.01	23.82	11.27	OK

-----Trial Version-----

Results of Facing Stability Static Analysis

SRW Unit #	Heel Elev (ft)	Geosynthetic Product	FOS Crest Toppling ≥1.50	FOS Connection ≥1.50
10	6.00	SF80	137.49	202.79
8	4.67	SF80		67.37
6	3.33	SF80		40.40
4	2.00	SF80		39.94
3	1.33	SF80		50.69
2	0.67	SF80		29.16

-----Trial Version-----

Wall Reinforcement Layout

-----Trial Version-----

Project Identification

Project ID	: Senior Project
Project Name	: MSE wal design
Owner	: Heath
Client	:
Prepared By	:
Company	:
Address	:
Telephone	:
Section	:
Vendor Data File	: Synteen 011012.vdf
Project File	: 7.prj
Date and Time	: 04/29/2015 15:29:36

***SOIL
INVESTIGATION***

CE 432 SUBSURFACE INVESTIGATION

Date: 02-13-15

Site: AREA WEST OF RETENTION POND,

CLEVELAND, TN

Name: TRISTEN NICHOLAS, REAGAN, WILLIAM

Rig:

Weather: SUNNY, WINDY - 39°F

Bore Hole: BH1 - 14 FT FROM BREE 1

SPT/DCP Correlation

Sand	Blows	Cohesive	Blows
very loose	0-4	very soft	0-2
loose	4-10	soft	2-4
med. dense	10-17	medium	4-6
dense	17-32	stiff	8-15
very dense	32+	hard	15-30
		very hard	30+

Depth	Soil Description	Sample	SPT/DCP N	Water Content					
				10	20	30	40	50	60
0	PIPE								
1	ATTENTION TO WEST SIDE STAKE								
2	CLAY								
3	CLAY								
4	CLAY								
5	CLAY								
6	CLAY								
7	CLAY								
8	CLAY								
9	CLAY								
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100	CLAY								

Date: 02-13-15

Name: GUINTEA

Fig. 1.

Weather: SUNNY, WINDY ~ 34°F

Bore Hole: BH 3 - 50/4 7 W

SPT/DCP Correlation

Sand	Blows	Coheave	Blows
very loose	0-4	very soft	0-2
loose	4-10	soft	2-4
med. dense	10-17	medium	4-8
dense	17-32	stiff	8-15
very dense	32+	hard	15-30
		very hard	30+

X(2)

[illegible]

Date: 02-13-15

Bore Hole: 1314

Sand	Blows	Cohesive	Blows
very loose	0-4	very soft	0-2
loose	4-10	soft	2-4
med. dense	10-17	medium	4-8
dense	17-32	stiff	8-15
very dense	32+	hard	15-30
		very hard	30+

[illegible]

COLOR :
BROWN TIT
WITH TINTS
OF ~~RED~~ RED
THROUGHOUT
OCCASIONAL
BLACK SPOTS

Test date: 02/20/15

(e.g., Boring No., Sample No., Sample Depth)

1.705, 1.549, 1.545

~~1.879~~ 1.891, 1.879, 1.864

14.75

Tare #: ~~57~~ C11

20.44 9

140.22 g 15.27

Displacement (inches)	Force (lbs)
(Refer to computer data file)	(Refer to computer data file)
Sketch of sample before testing	Sketch of sample after testing

Calculate: $\gamma = \underline{\hspace{2cm}} \text{ lb/ft}^3$

$$\omega = 20.5 \%$$
$$\gamma_d = \underline{\hspace{2cm}} \text{ lb/ft}^3$$

ASTM D2166

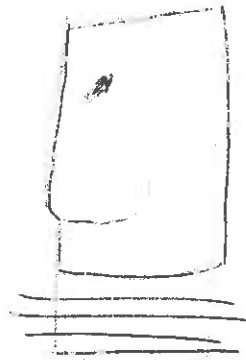
COLOR: BROWN w/
GRAY - RED
PACLS

Unconfined compression test

Analyst name: TRIEU
 Test date: 02/20/15
 Sample description: BH2, SS2, 26" -
 (e.g., Boring No., Sample No., Sample Depth)
 Initial Mass = 14.38 g
 Initial height h_0 = 1.453 in
 Initial diameter d_0 = 1.853 in
 Mass of wet sample and tare M_i = 30.02 g
 Mass of dry sample and tare M_d = 27.55 g
 Mass of tare M_t = 15.64 g
 Specific gravity G_s =

5.471, 5.374, 5.372
 1.857, 1.862, 1.834
 Tare #: AS

BASED ON 1:2.5 RATIO
 $\phi = 1.853$, $h_{MAX} = 4.6325$
 $h_{MIN} = 3.706$

Displacement (inches)	Force (lbs)
(Refer to computer data file)	(Refer to computer data file)
Sketch of sample before testing	Sketch of sample after testing
	

NOTES:

- SAMPLE ALREADY HAS FAILURE PLANE @ ≈ 3.7 "
- SAMPLE HT WILL HAVE TO BE LESS THAN 1:2 RATIO
- 3.262, 3.335, 3.355
 AVG HT. OF TESTED SAMPLE = 3.317 IN
- LOAD @ 1%/MIN

Calculate:
 $\gamma = \underline{83.58}$ lb/ft³
 $\omega = \underline{20.7}$ %
 $\gamma_d = \underline{69.22}$ lb/ft³

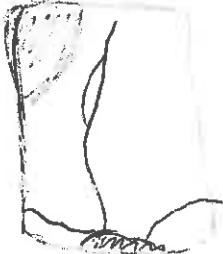
ASTM D2166

Unconfined compression test

Analyst name: TRIEU
 Test date: 02/20/15
 Sample description: BH3, SS3, @ 24" - 30"
 (e.g., Boring No., Sample No., Sample Depth)
 Initial Mass = 22.55 g
 Initial height h_0 = 5.032 in
 Initial diameter d_0 = 1.864 in
 Mass of wet sample and tare M_i = 33.02 g
 Mass of dry sample and tare M_d = 28.86 g
 Mass of tare M_t = 9.47 g
 Specific gravity G_s = _____

COLOR: DARK
 BROWN w/ LINES
 OF LIGHT BROWN,
 AROUND 3", SOIL
 BECOMES ~~TO~~ LIGHT
 BROWN MIXED w/
 PATCHES OF DARK
 YELLOW

5.070, 4.943, 5.082
 1.903, 1.885, 1.820
 Tare #: L 208

Displacement (Inches)	Force (lbs)
(Refer to computer data file)	(Refer to computer data file)
Sketch of sample before testing	Sketch of sample after testing
	

NOTE:

- SAMPLE ALREADY HAD
 FAILURE PLANE @ ~2.5 IN
 3. SAMPLE HT WILL HAVE
 TO BE $\geq$ THE REQ'D
 1:2 RATIO (1.869" : 3.73)

- $HT_{MIN} = 3.731$
 $HT_{MAX} = 4.6725$

- IN FIRST ~2.5", THERE
 IS A LEAF @ TOP AND
 A BLACK-ROCK-LIKE
 MATERIAL IN SOIL

- 2.294, 2.474, 2.453
 AVG. HT. OF TESTED
 SAMPLE = 2.407 IN

- SMALL ASPECT RATIO
 $\therefore$ MAY NOT HAVE
 SHEAR PLANE

- SPECIMEN HT/ϕ RATIO
 ASTM D2166 IS OUTSIDE NORMAL
 RANGE
 (TOO SHORT)

Calculate:
 $\gamma = \underline{105.89}$ lb/ft³
 $\omega = \underline{21.45}$ %
 $\gamma_d = \underline{87.14}$ lb/ft³

DARK CHOCOLATE

→ TOP SOIL

Analyst name: TR/EU

Test date: 02/20/15

Sample description: ~~BH 4~~ BH5, SS4, (P) 0-5.5.2

(e.g., Boring No., Sample No., Sample Depth)

Initial Mass = 5.49 g

Initial height $h_0 = 4.20 \text{ m}$ i

Initial diameter $d_0 = 1.4551$ in

Mass of wet sample and tare $M_1 = 25.42$ g

Mass of dry sample and tare $M_d = 22.44$ g

Mass of tare $M_t = 01.43$ g

Specific gravity $G_s =$ _____

NOTE :

SAMPLE HAS A
SMALL BRANCH AND
SOME ROOTS IN IT,
WILL AFFECT X

- DURING TRANSFER OF SOIL FROM PVC PIPE TO TABLE, TOP ^{PARTS} OF SOIL FELL APART & CREATED A FAILURE PLANE @ 4.65"

- BASED ON 1:2/2.5 RATIO

$$\pi T_{MIN} = 3.7021 \text{ V}$$
$$H_{TMAX} = 4.6275 \text{ IN}$$

- NOT POSSIBLE TO ACHIEVE
HT MIN B/C SOIL HAS
FAILURE PLANE 1/2 WAY
THROUGH SPECIMEN

- SMELLS LIKE PLANT ROOTS

Calculate: $\gamma =$ _____ lb/ft³

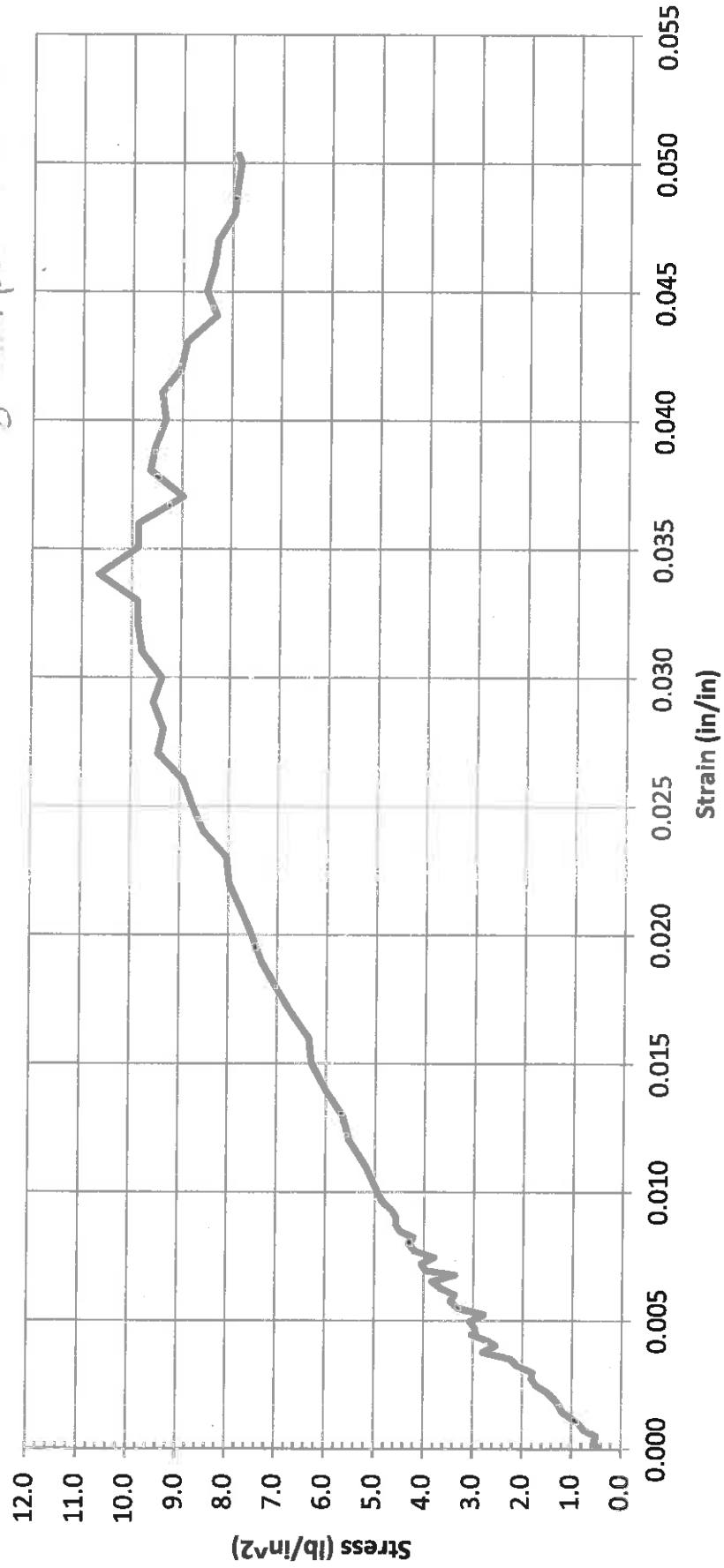
 $\omega = \quad \%$
$$\gamma_d = \underline{\hspace{2cm}} \text{ lb/ft}^3$$

ASTM D2166

NOTE: IGNORE OUTLIERS,
LOOK FOR SMOOTH
CURVE

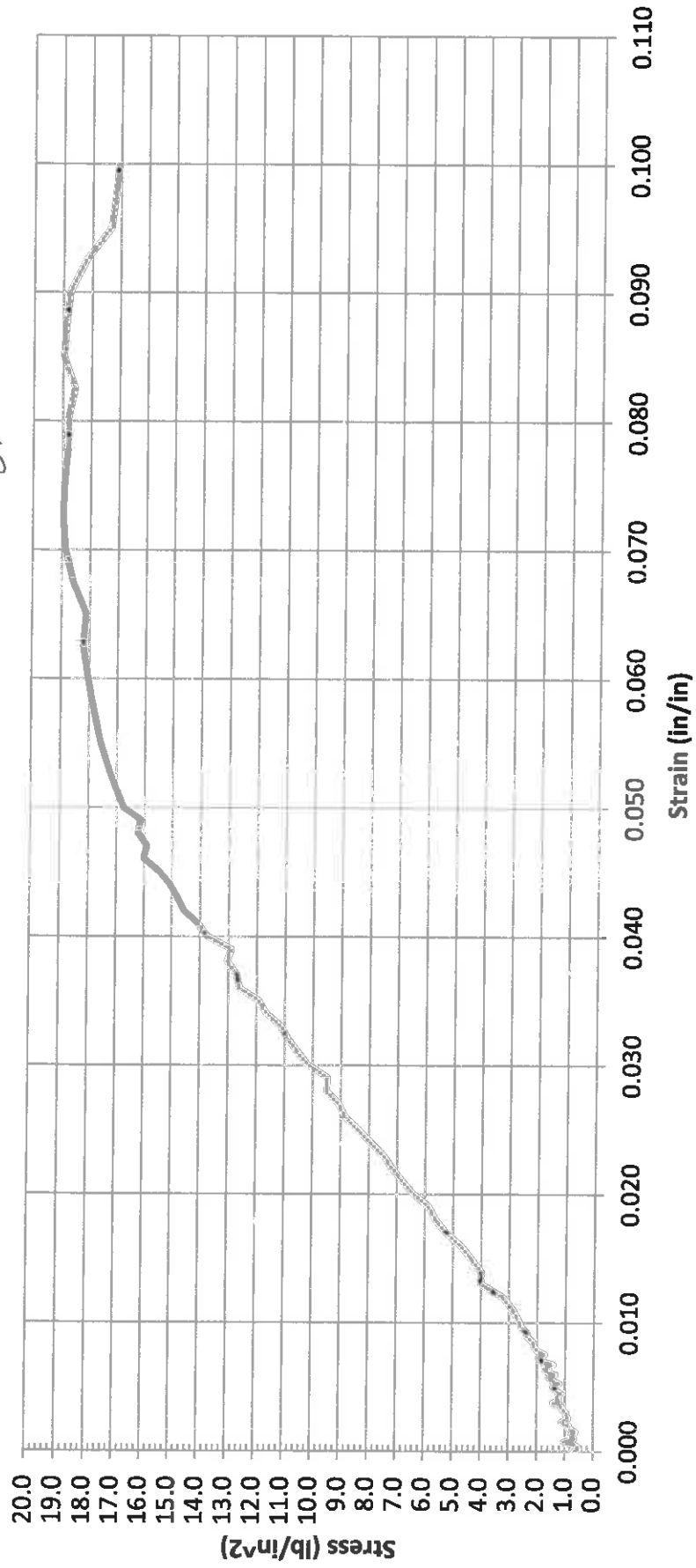
B2 SS2

$\sigma = 9.4 \text{ psi}$



B3 SS3

$\sigma_{max} = 19 \text{ psi}$



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Atterberg Limits

Project: _____ Job Location: _____

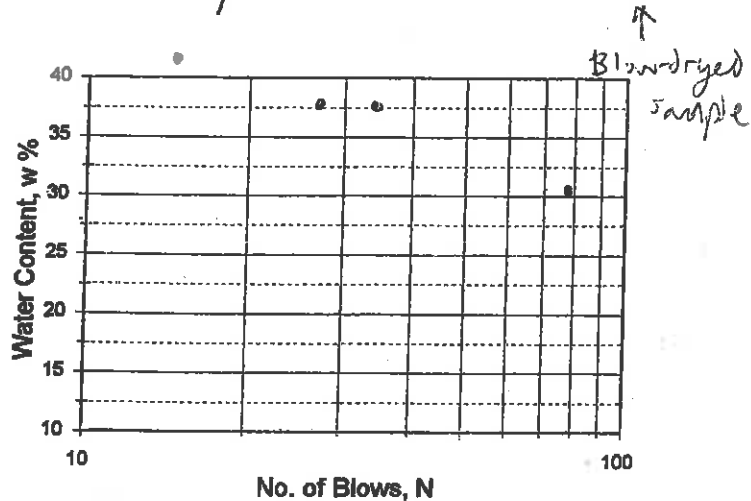
Boring No. 23 Sample No. 23

Description of Soil: _____ (2)

Tested by: SWTT RICE Date: 02/27/15

Liquid Limit Determination

Determination No.	1	2	3	4	5
Tare No.		L170	L178	L205	L181
Mass of Wet Soil + Tare	~~15.82g~~	15.82g	15.42g	15.14g	14.33g
Mass of Dry Soil + Tare		14.04	13.64	13.58	13.17
Mass of Water		1.78	1.78	1.56	1.16
Mass of Tare	~~9.36g~~	9.36g	9.42g	9.48g	9.35g
Mass of Dry Soil		4.68	4.22	4.1	3.82
Water Content (%)		38.03%	42.18%	38.05%	30.37%
No. of Blows	124 bl	28 bl	14 bl	34 bl	79 bl



Plastic Limit Determination

Determination No.	1	2	3	4
Tare No.	L204	37	32	L203
Mass of Wet Soil + Tare	12.34g	20.3g	15.23g	12.59g
Mass of Dry Soil + Tare	11.85	19.45	14.55	12.08g
Mass of Water	0.49	0.85	0.68	0.51
Mass of Tare	9.43g	15.45g	11.04g	9.4g
Mass of Dry Soil	2.42	4	3.51	2.68
Water Content % (PL)	20.45%	21.25%	19.37%	19.03%

PL = 20.025%

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Geotechnical Engineering Laboratory

Atterberg Limits

Project: _____ Job Location: _____

Boring No. ~~2~~ 3 Sample No. ~~2~~ 3

Description of Soil: _____ (53)

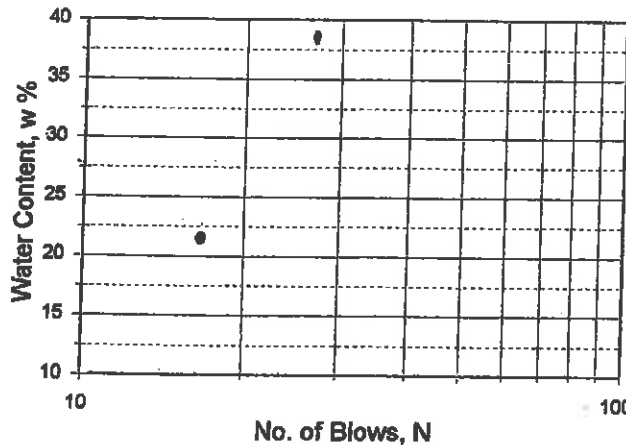
Tested by: Michael Williams Date: Feb 27, 2015

Liquid Limit Determination

Determination No.	1	2	3	4	5
Tare No.	L107	A12	L194	C8	L187
Mass of Wet Soil + Tare	14.48	16.46	18.84	25.61	14.48
Mass of Dry Soil + Tare	14.02	23.59	16.21	22.64	14.62
Mass of Water	~~5.06~~ 0.46	-7.13	2.63	2.97	-0.14
Mass of Tare	9.40	9.37	9.39	9.38	9.40 9.42 -
Mass of Dry Soil	~~5.22~~ 4.56	~~7.04~~ 16.46	4.6.82	13.26	5.22
Water Content (%)	~~92.22%~~ 4.78%	~~40.9%~~ 62.10%	38.56%	22.40%	~~2.68%~~ 2.68%
No. of Blows	41	38	28	17	91

← MISTAKE

< 0%



Plastic Limit Determination

Determination No.	1	2	3	4
Tare No.	L209	10	L199	L208
Mass of Wet Soil + Tare	10.75	13.21	10.87	10.69
Mass of Dry Soil + Tare	10.52	13.02	10.62	10.48
Mass of Water	0.23	0.19	0.25	0.21
Mass of Tare	9.44	11.83	9.42	9.38
Mass of Dry Soil	1.08	1.19	1.2	1.1
Water Content % (PL)	21.3%	15.97%	20.83%	14.09%

AVG = 19.2475
AVG_{1,3,4} = 20.41%

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Atterberg Limits

Project: _____ Job Location: _____

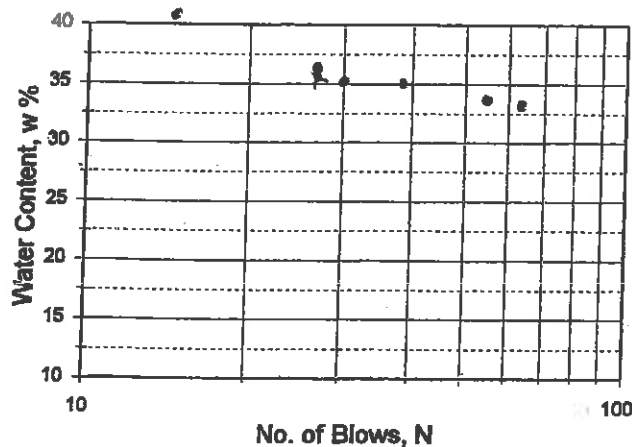
Boring No. 2 2 Sample No. 2 2

Description of Soil: _____

Tested by: TRIEU Date: 02/27/14 (51)

Liquid Limit Determination

Determination No.	1	2	3	4	5	
Tare No.	33	29	L200	D12	45	L193
Mass of Wet Soil + Tare	22.62g	18.01g	16.52g	23.79g	18.38g	15.99g
Mass of Dry Soil + Tare	20.78	16.28	14.68	21.51	16.47	14.09
Mass of Water	1.84	1.73	1.86	2.28	1.91	1.9
Mass of Tare	15.51	11.21g	9.40g	15.11g	11.20g	9.53g
Mass of Dry Soil	5.27	5.07	5.28	6.4	5.27	4.56
Water Content (%)	34.91%	34.12%	35.23%	35.63%	36.24%	41.67%
No. of Blows	2364	2054	2334	30	27	2515



Plastic Limit Determination

Determination No.	1	2	3	4
Tare No.	B15	D2	D10	L171
Mass of Wet Soil + Tare	18.40g	17.82g	19.09g	12.44g
Mass of Dry Soil + Tare	17.83	17.34	18.44	11.86
Mass of Water	0.57	0.48	0.65	0.58
Mass of Tare	15.41g	15.33g	15.43g	9.31g
Mass of Dry Soil	2.42	2.01	3.01	2.55
Water Content % (PL)	23.55%	23.88%	21.57%	22.75%

KEPT FINDING LARGE PIECES OF
STUNG

$$N_4 = 22.9425\%$$

$$N_{4,2,4} = 23.28\%$$

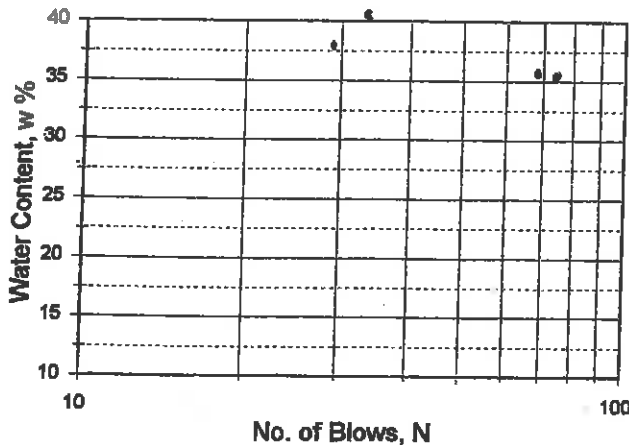
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Department of Civil and Environmental Engineering
Geotechnical Engineering Laboratory

Atterberg Limits

Project: PROPOSED GREENWAY Job Location: CLEVELAND, TN
Boring No. 2 2 Sample No. 2 2
Description of Soil: LT BROWN MIXED w/ SOME PEACH 134
Tested by: TRIEU Date: 02/27/15

Liquid Limit Determination

Determination No.	1	2	3	4	5
Tare No.	1342 L208	1343 L203	1344 L204	L206	L199
Mass of Wet Soil + Tare	20.53g	21.14g	19.19g	17.96g	19.08g
Mass of Dry Soil + Tare	17.61g	18.06g	16.87g	15.58g	16.11g
Mass of Water	2.92	3.08	2.32	2.38	2.97
Mass of Tare	9.41g	9.42g	11.26g	9.36g	9.38g
Mass of Dry Soil	8.2	8.64	5.61	6.22	6.73
Water Content (%)	35.61%	35.65%	41.35%	38.26%	44.13%
No. of Blows	74	69	33	29	18



NOTE:

- BLEW DRY SAMPLE
B/C IT WAS TOO
TOO MOIST

A5 - TARE WT = 15.62g
TARE SOIL WT =
28.38g

Plastic Limit Determination

Determination No.	1	2	3	4	5
Tare No.	A5	C11	C1	L206	C3
Mass of Wet Soil + Tare	28.38g	17.36g	18.96g	11.00g	18.65g
Mass of Dry Soil + Tare	25.23g	17.03g	18.32g	10.67g	18.03g
Mass of Water	3.15	0.33	0.64	0.33	0.62
Mass of Tare	15.62g	15.26g	15.57g	9.35g	15.52g
Mass of Dry Soil	9.61	1.77	2.81	1.32	2.51
Water Content % (PL)	32.79%	18.64%	22.78%	25.00%	24.70%

↑
DON'T
USE

AVG = 22.78

AVG 3,4,5 = 24.16%

LOAD AND DEFLECTION GIVEN IN EXCEL FILE FROM TEST

SAMPLE HT = 2.407 INCHES

SAMPLE DIAMETER = 1.869 INCHES

$$\text{SAMPLE AREA} = \frac{\pi}{4} (1.869 \text{ INCHES})^2 = 2.7435 \text{ IN}^2$$

- STRAIN CALCULATION:

$$\epsilon = \frac{\Delta L}{L} = \frac{0.00060826 \text{ IN}}{2.407 \text{ IN}} = 0.0002527$$

$$\% \epsilon = \frac{\Delta L}{L} \times 100\% = 0.0002527 (100\%) = 0.02527\%$$

- CORRECTED AREA:

$$A_c = \frac{A_0}{1 - \epsilon} = \frac{2.7435 \text{ IN}^2}{1 - 0.0002527} = 2.74422 \text{ IN}^2$$

- STRESS:

$$\sigma = \frac{P}{A_c} = \frac{1.342 \text{ lb}}{2.74419 \text{ IN}^2} = 0.5036 \text{ psi}$$

- UNCONFINED COMPRESSIVE STRENGTH, q_u (psi)

→ MAX VALUE OF σ , EXCLUDING OUTLIERS

→ B3-SS3, $q_u = 14 \text{ psi} = 2736 \text{ psf}$

→ B2-SS2, $q_u = 9.9 \text{ psi} = 1425.6 \text{ psf}$

} QUALITY NOT GOOD
∴ USE $q_u = 7000 \text{ psf}$

- SHEAR STRESS, S_u (psi)

FOR UNCONFINED COMPRESSIVE TEST, $S_u = q_u/2$ RADIUS

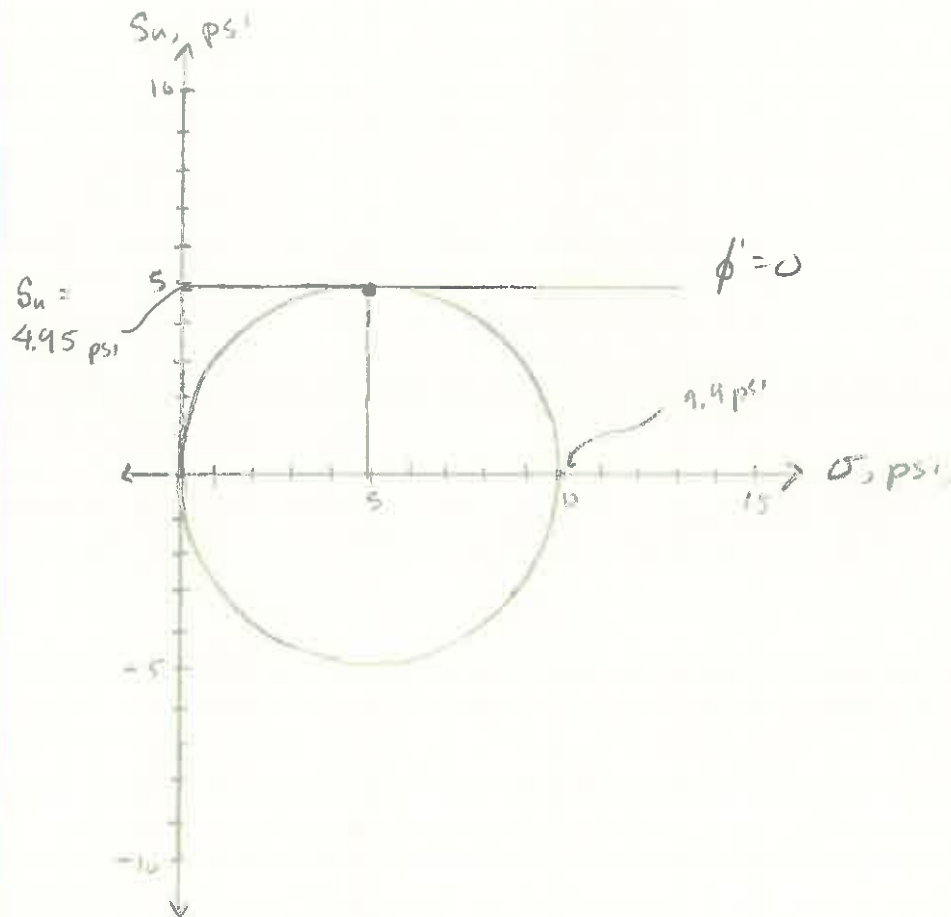
→ B3-SS3, $S_u = 1368 \text{ psf}$

→ B2-SS2, $S_u = 712.8 \text{ psf}$

} QUALITY NOT GOOD
∴ USE $S_u = 1500 \text{ psf}$

→ VALUES PROVEN w/ MOHR CIRCLE

$$\text{RADIUS } \odot \frac{9.9 - 0}{2} = 4.95 \text{ psi}$$



= BEARING CAPACITY :

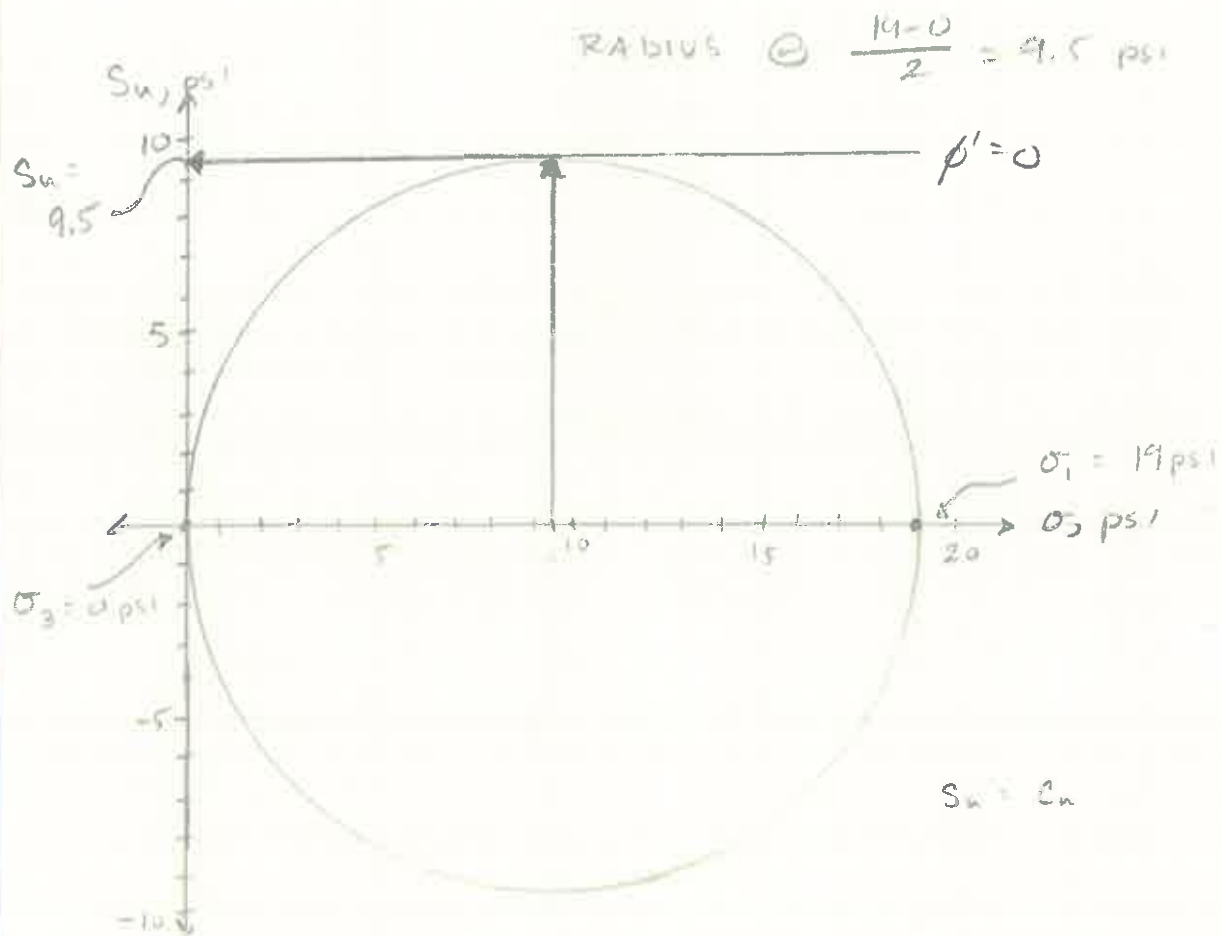
- ASSUMING UNDRAINED BEHAVIOR, $\phi = 0$: $N_c = 5.7$
- DO NOT USE γ' $N_q = 1.0$
- ASSUMING FOUNDATION WILL BE 2ft $N_\gamma = 0.0$
BELOW SOIL
- ASSUME $c' = c_u = S_u$

= w/ SQUARE OR CIRCULAR FOUNDATION "

$$\begin{aligned}
 q_{ult} &= 1.3c' N_c + \sigma'_{zn} N_q + 0.4 \gamma'_{zn} N_\gamma \\
 &= 1.3 (712.8 \text{ lb/ft}^2) (5.7) + (83.5789 \text{ lb/ft}^3) (2 \text{ ft}) (1.0) \\
 &= 5449.0058 \text{ psf}
 \end{aligned}$$

$$q_{all} = \frac{q_{ult}}{FS} = \frac{5449.0058 \text{ psf}}{3} = 1816.335 \text{ psf}$$

ASSUME F.S. = 3 FROM GEOTECH II BINDER



- BEARING CAPACITY :

- ASSUMING UNDRAINED BEHAVIOR, $\phi = 0$: $N_c = 5.7$
- DO NOT USE γ : $N_q = 1.0$
- ASSUMING FOUNDATION WILL BE 2 ft BELOW SOIL : $N_\gamma = 0.0$
- ASSUME $c' = c_u = s_u$

= w/ SQUARE OR CIRCULAR FOUNDATION :

$$\begin{aligned}
 q_{ult} &= 1.3c N_c + 0.20 N_q + 0.4 \gamma \sqrt{A} N_\gamma \\
 &= 1.3 (1368^{1/2} \text{ ft}) (5.7) + (105.89^{1/2} \text{ ft}) (2 \text{ ft}) (1.0) \\
 &= 10,304.0378 \text{ psf}
 \end{aligned}$$

$$q_{all} = \frac{q_{ult}}{3} = \frac{10304.0378 \text{ psf}}{3} = 3434.679 \text{ psf}$$

ASSUME F.S. = 3 FROM GEOTECH II BINDER

02/23/15

SD: γ, γ_{dry}, w

TRIEU, THUY

4/5

BH2 - SS2:

$$MASS_{H_2O} = M_{H_2O} = 30.02 - 27.55 = 2.47g$$

$$M_{SOLID} = 27.55 - 15.64 = 11.91g$$

$$\rightarrow w = \frac{M_{H_2O}}{M_{SOLID}} \times 100 = \left(\frac{2.47}{11.91} \right) 100 = 20.739\%$$

$$VOLUME = \pi r^2 h = \pi \left(\frac{1.853in}{2} \right)^2 (5.406in) = 14.5786in^3$$

$$MASS \text{ OF SAMPLE} = 320.5134g$$

$$\rightarrow \gamma_m = \frac{M_t}{V} = \frac{320.5134g}{14.5786in^3} \left(\frac{0.0022lb}{1g} \right) \left(\frac{12in}{ft} \right)^3 = 83.5789lb/ft^3$$

$$\rightarrow \gamma_{dry} = \frac{\gamma_m}{1 + \frac{w}{100}} = \frac{83.5789lb/ft^3}{\left(1 + \frac{20.739}{100} \right)} = 69.2228lb/ft^3$$

BH3 - SS3:

$$MASS_{H_2O} = M_{H_2O} = 38.02 - 28.86 = 9.16g$$

$$M_{SOLID} = 28.86 - 9.47 = 19.39g$$

$$\rightarrow w = \frac{M_{H_2O}}{M_{SOLID}} \times 100 = \left(\frac{9.16g}{19.39g} \right) 100 = 21.4544\%$$

$$VOLUME = \pi r^2 h = \pi \left(\frac{1.869in}{2} \right)^2 (5.032in) = 13.8054in^3$$

$$MASS \text{ OF SAMPLE} = 384.5676g$$

$$\rightarrow \gamma_m = \frac{M_t}{V} = \frac{384.5676g}{13.8054in^3} \left(\frac{0.0022lb}{1g} \right) \left(\frac{12in}{ft} \right)^3 = 105.8989lb/ft^3$$

$$\rightarrow \gamma_{dry} = \frac{\gamma_m}{1 + \frac{w}{100}} = \frac{105.8989lb/ft^3}{\left(1 + \frac{21.4544}{100} \right)} = 87.1920lb/ft^3$$

02/23/15

SD: H₂O CONTENT

TRIEU, THU

5/5

BH1 - SS1 :

$$\text{MASS}_{\text{H}_2\text{O}} = 33.55 - 30.44 = 3.11 \text{ g} = M_{\text{H}_2\text{O}}$$

$$\text{MASS}_{\text{OVEN-DRY}} = 30.44 - 15.27 = 15.17 \text{ g} = M_{\text{solid}}$$

$$\rightarrow w = \frac{M_{\text{H}_2\text{O}}}{M_{\text{solid}}} \times 100 = \left(\frac{3.11}{15.17} \right) 100 = 20.5\%$$

BH5 - SS4 :

$$\text{MASS}_{\text{H}_2\text{O}} = 25.42 - 22.44 = 2.98 \text{ g}$$

$$\text{MASS}_{\text{OVEN-DRY}} = 22.44 - 9.43 = 13.01 \text{ g}$$

$$\rightarrow w = \frac{M_{\text{H}_2\text{O}}}{M_{\text{solid}}} \times 100 = \left(\frac{2.98}{13.01} \right) 100 = 22.9055\%$$

ASSUME $G_s = 2.72$ FOR CLAY

$$\text{EXPECTED } \gamma = G_s \gamma_{\text{H}_2\text{O}} = 2.72 (62.4 \text{ lb/ft}^3) = 169.728 \text{ lb/ft}^3$$

RAIN GARDENS

15th St to 1235 Blythe Ave

Kelly Nicholas
2/25/15

$$C = \frac{.007(nL) \cdot 8}{P_2 \cdot 5 \cdot 5.4}$$

$$P_2 = 358 \text{ in.}$$

$$S = .0391 \%$$

$$n = .011$$

$$L = 60'$$

$$T_c = .0097 \text{ hr}$$

$$= .582 \text{ min}$$

$$\frac{0.5}{5 - .582} = \frac{0.575}{.575 - x} \Rightarrow x = 0.06695 \text{ in.}$$

$$\hookrightarrow i = 6.9 \text{ in./hr}$$

- same as other segment of road

$$Q = 0.242 \text{ ft}^3/\text{sec}$$

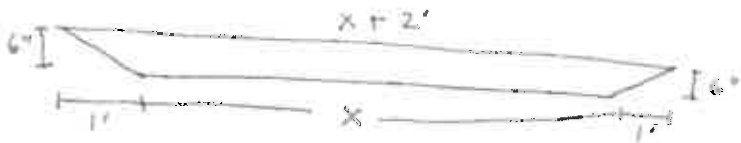
inflow $\Rightarrow$ 4" ϕ concrete pipe, 2% slope

Cross-Section Sizing

KLN
2/26/05

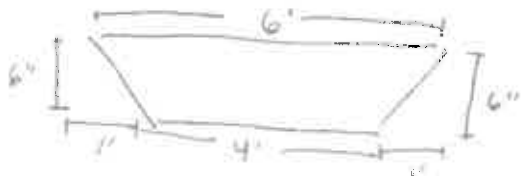
2/4

$$\begin{aligned}\text{Treated Volume} &= d \times L \times W \\ &= 1''/12''/\text{ft} \times 60' \times 30' \\ &= 150 \text{ ft}^3\end{aligned}$$



$$150 \text{ ft}^3 = 60 \times \frac{x + (x + 2)}{2} \times 6''/12''/\text{ft}$$

$$x = 4'$$



$$T_c = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} S^{0.4}}$$

$$T_c = 0.0092 \text{ hr}$$

$$T_c = 0.553 \text{ min}$$

$$P_2 = 2 \text{ yr}, 24 \text{ hr} = 3.58 \text{ in.}$$

$$S = 0.0444 \%$$

$$n = 0.011$$

$$L = 60'$$

KLN

2/23/15

1553 3146 to
15th St

3/4

$$\frac{0.5}{5 - 1.83} = \frac{0.575}{0.575 - X} \Rightarrow X = 0.0636 \text{ in.}$$

$$\Rightarrow i = 6.9 \text{ in/hr}$$

$$Q = C_i A$$

$$= 0.85 (6.9 \text{ in/hr}) (60' \times 30') / 43560 \text{ ft}^2/\text{acre}$$

$$= 0.242 \text{ ft}^3/\text{sec}$$

$$0.242 \text{ ft}^3/\text{sec} = \frac{1.49}{n} \pi r^2 r^{2/3} S^{1/2}$$

$$\Rightarrow r = 1.57'$$

$$S = 0.02 \%$$

$$n = 0.012 \text{ concrete}$$

nflow $\Rightarrow$ 4" ϕ concrete pipe, 2% slope

$$\text{velocity} = \frac{Q_p}{A} = \frac{0.242 \text{ ft}^3/\text{sec}}{\pi (\frac{4}{12} \text{ ft})^2} = 2.78 \text{ ft/sec} < \text{erosive vel.} = 4 \text{ ft/s}$$

Soil Group - C

Land Use - Streets/Row

Slope - 2 to 6%

$$C = 0.85$$

Overflow Pipe Sizing

Kelly Nicholas
2/24/15

4/4

Family Center to 15th St - $L = 1400'$

$$Q = C_i A \\ = (0.85)(6.9 \text{ in/hr})(1400' \times 30' / 43560 \text{ ft}^2/\text{ac}) \\ = 5.655 \text{ cfs}$$

Drainage Pipe: $5.655 \text{ cfs} = Q = \frac{1.49}{n} \pi r^2 r^{2/3} S^{1/2}$ $S = .02\%$
 ~~$r = 10.2$~~ $r = 5.108''$ $n = .012 \text{ concrete}$
 $d = 10.215''$

12" ϕ concrete pipe

Overflow Structure: $Q = CLH^{1.5}$ $C = 3.33$ $Q = .242 \text{ cfs}$
 $.242 = (3.33)(\frac{\pi d^2}{4})^{1.5}$ $n = 2.5''$
 $d = .244' = 2.92''$ $L = 2\pi r$ $= \pi d$ $3'' \phi \text{ conc. pipe}$

1553 Blythe Ave to 15th St - ~~$L = 550'$~~ $L = 340'$

$$Q = (.85)(6.9 \text{ in/hr})(\frac{340'}{550'} \times 30' / 43560) \\ = 1.373 \text{ cfs}$$

Drainage Pipe: $1.373 \text{ cfs} = Q = \frac{1.49}{n} \pi r^2 r^{2/3} S^{1/2}$ $S = .02\%$
 $r = 3.004''$ $n = .012 \text{ concrete}$
 $d = 6.007''$

6" ϕ concrete pipe

Overflow Structure: Same as other segment
3" ϕ conc. pipe