2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering
Education for 130 Years
Paper ID #37314

Geotechnical Site Characterization in a Box: Bringing the Full Site Characterization Experience to the Classroom

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Abstract

Geotechnical site characterization and the design and interpretation of idealized soil-profiles is a critical part of geotechnical engineering practice. In this classroom experience, students complete every aspect of a geotechnical site characterization except for soils testing (typically well covered by a geotechnical lab course). Each student group is given a project site: layers of colored PlayDoh in a clear airtight box. Students then walk through the stages of site characterization: background and web soil survey, field reconnaissance, boring layout, field explorations, fence diagrams and an idealized soil profile. The instructor introduces each step using traditional PowerPoint slides to provide real life context while instructing students in stylized scale information gathering on their project site. The final investigation method uses clear straws to perform model Shelby tube sampling. Students can then prepare a 2D fence diagram of their site based on a selection of "borings" with various colors associated with different soil types. Finally, students use their engineering judgement to develop a one-dimensional idealized soil profile completing the site characterization process. The actual class activity can be completed in 30 to 45 minutes yet provides a comprehensive overview suitable for a freshman introduction to engineering course. For upper-level geotechnical courses, the classroom experience can springboard a more traditional site characterization activity at full scale but with an engaging overview of the complete process. Faculty perspectives and assignment documentation outline the usefulness of the activity particularly in freshman introductory courses.

Introduction

Geotechnical site characterization and the design and interpretation of idealized soil-profiles is a critical part of geotechnical engineering practice. But, regardless of the level, classroom explorations of these concepts frequently trend toward dry, contextless PowerPoint presentations. Occasionally, instructors might engage in some “big teaching” practice [1] like problem-based learning around technical case studies provided by industry partners [2], or a single site visit [3], or a demonstration boring near campus [4]. These experiences are valuable, giving students a chance to see one part of the geotechnical process, but students may still struggle to fully synthesize the complete site characterization process. By expanding a K-12 earth science class activity [5], college students can experience every step of a site investigation by exploring a model site and connecting classroom model observations and manipulations by analogy to its engineering practice counterpart. The first section of this paper describes the class activity. The second section contains faculty reflections on the active learning and interaction in the classroom. Finally, the appendices to this paper include a Directive Memo distributed to students at the beginning of class and an example Submission Memo for the application of the activity to a freshman introduction to civil engineering course.

Geotechnical Site Characterization in a Box

Learning Objectives

This activity has been used to support the achievement of several learning objectives. For a freshman-level introduction to engineering course, the outcomes are low on Bloom's Taxonomy [6] and include:

- Describe and illustrate formative content, comparative analysis, design outcomes, design cycle, societal impacts, and career opportunities for geotechnical engineering.
- Outline and describe the engineering design process for geotechnical engineering.

In a senior foundation design course, the activity provides tangible context for the following higher level learning outcomes:

- Synthesize soil engineering properties from subsurface exploration data.
    - Describe the site characterization process.
    - Synthesize soil properties from subsurface exploration.

Overview

Table 1 provides an outline of model and full-scale site characterization activities and the estimated duration for each step in the classroom. Each phase is couples photos of the full-scale events with the analogous classroom activity.

Table 1. Outline of activities and estimated duration.

Full Scale Event	*Classroom Model Activity*	*Approx. Duration*
Background / web soil survey	Observation of model sides	3-5 min.
Field reconnaissance	Observation of model surface	3-5 min.
Synthesis of expected findings	Estimated 2D cross-section sketch	3-5 min.
Boring layout and testing plan	Boring location selection	3-5 min.
Field exploration	Clear straw sampling	5-10 min.
Fence diagram	Fence diagram	5-10 min.
Idealized soil profile	Idealized soil profile	5-10 min.

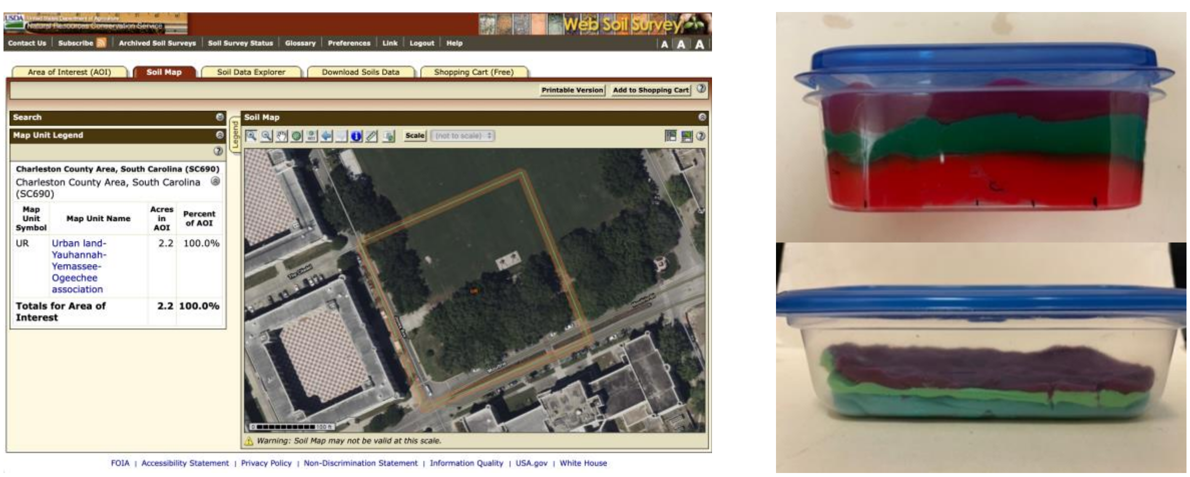
Setup

At the beginning of class, students are told they will be performing a geotechnical site investigation of a nearby green space for the construction of a building for the campus community. Depending on the learning objectives for the class, students briefly list and discuss the common objectives and outcomes of site characterization including quantification of surface and subsurface conditions, development of a subsurface profile, identification of groundwater, collection of soil samples, etc. Students then receive their model "site" for the class: PlayDoh layered in an airtight box that models the green space as seen in Figure 1. Typically, one model will be assigned to each group of three to five students. Students are not to touch or open the model until instructed to do so.

Figure 1: Sample "sites" used in classes featuring layers of PlayDoh in different colors.

Background

The instructor begins by presenting an overview of how geotechnical engineers begin a site characterization through background research on the site. This presentation follows the standard PowerPoint and web-driven review of background information gathering. Data sources may include previous site investigations, local experience, and/or an exploration of geologic and soil maps like those provided by the NRCS Web Soil Survey. An example of a NRCS Web Soil Survey is shown in Figure 2.a.



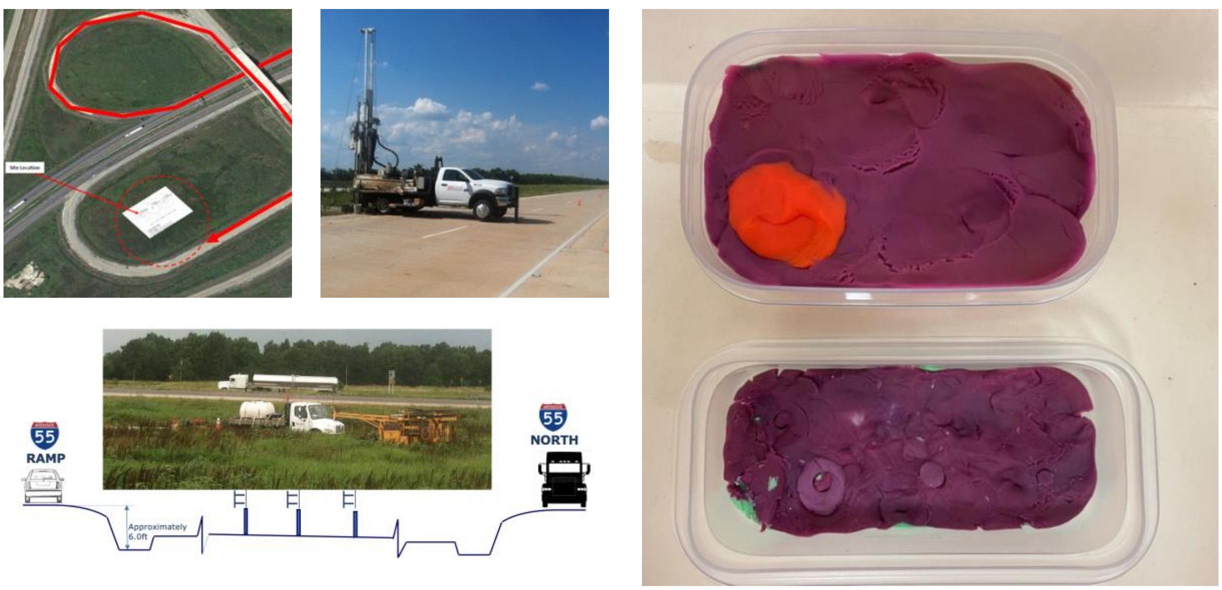
(a) (b)

Figure 2. Background research example: a) from NRCS Web Soil Survey and b) on the model.

The students perform a background review of their site, by observing the layers of soil visible through the sides of the container. For a senior-level course, each color of PlayDoh may be given an analogous soil type to create meaningful connections to the real site they are investigating. Students are asked to describe what they can observe from each side of the site, illustrated in Figure 2.b, and note the soil types/colors they expect to find as part of the site characterization.

Field Reconnaissance

In the next portion of the activity, students are introduced to the field reconnaissance step of site characterization. Again, PowerPoint allows for the presentation of various real sites where concerns about accessibility, slopes, drainage, rocks, vegetation, and traffic inform the site characterization (though only slope is modeled on their sites). Students then remove the lid of their model site and make observations about what they can learn from observing the top of the site as seen in Figure 3. They may need to update their expectations of what types of soil they may find, observe various changes in typology and identify specific areas of interest on their model.



(a) (b)

Figure 3. Examples of concerns identified during reconnaissance: a) from real projects and b) on the model.

Estimated 2D Cross Section

From the limited information gathered in the initial stages, the students are asked to sketch a 2D cross section that estimates the configuration of soil layer found on their site. This provides an excellent opportunity to introduce the limitations and uncertainties inherent in geotechnical data.

Boring Layout and In-situ Testing Plan

In the next phase, students receive an introduction to boring plans. As part of this discussion, PowerPoint provides a course appropriate introduction to the range of geotechnical drilling rigs and types of soil tests. As students consider capabilities and limitations of geotechnical drilling, they must then create a boring plan for their site. Soil investigation budgets are limited, and geotechnical drilling is costly, so students are only allowed to take three borings. Based on their background and field reconnaissance work, students must sketch a scaled plan of their boring locations for the site. Student my then flag their drilling locations with toothpicks. Figure 4 shows the site flagged for geotechnical drilling.

Figure 4. Model site with boring plan flagged for geotechnical drilling

Field Explorations

In the next step, student perform a field investigation by pushing clear straws (simulating Shelby tubes) into the PlayDoh. There is a bit of practice and technique required to get a clean sample, not unlike actual geotechnical drilling. By using a clear straw, students can see the layers of soil in the boring. Additionally, most of the model sites have been prepared with a color of PlayDoh not visible from the sides of the box. Sometimes students discover this surprise layer, sometimes they do not. This intermittent surprise provides an additional opportunity to discuss the variability and uncertainty of a site characterization. Depending on the level uncertainty, students might request permission to perform additional borings to better understand the subsurface conditions. Figure 5 shows borings from a student field exploration. In a freshman-level course, it is sufficient to simply note the relative thickness of the layers. In a senior-level course, students might be asked to prepare boring logs for each of their borings and/or justify requests for additional borings.

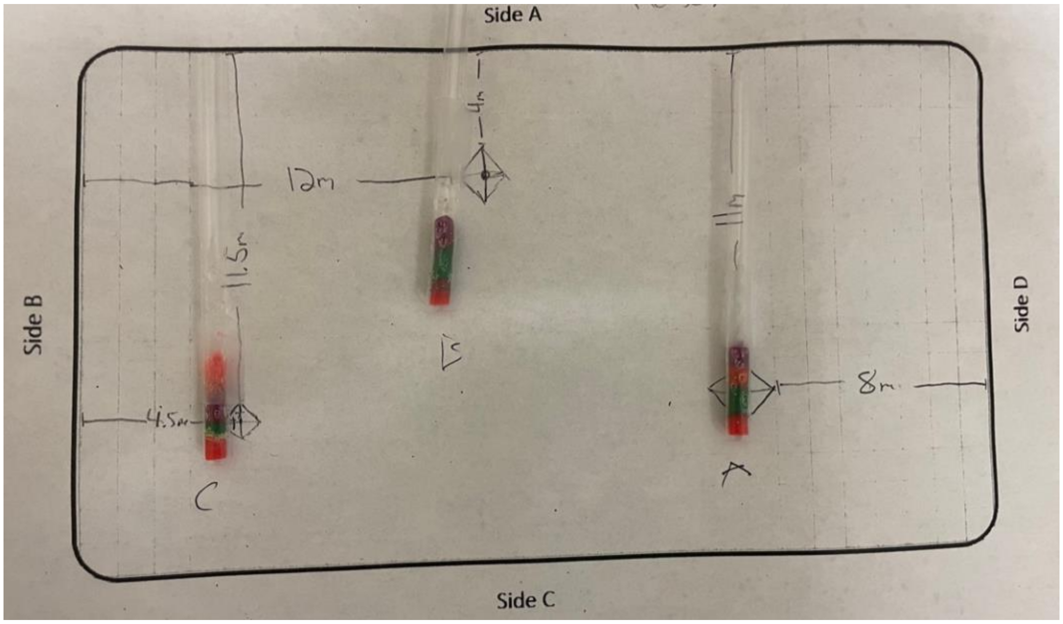


Figure 5. Borings arranged on boring plan.

Fence Diagram

Once students have taken their field borings, they are asked to prepare a fence diagram. For the freshman intro course, this is a simple pencil and ruler exercise. For a senior-level course, students might be asked to prepare a CAD fence diagram seeking to capture the nature of the soil on the site.

One Dimensional Idealized Profile

As a final step, students then make the judgement calls required to prepare an idealized soil profile for the whole site. This requires a comprehensive synthesis of all the information gathered during the activity. For a freshman-level course, this exercise supports conversations on engineering judgement and a final touch point on the uncertainty of geotechnical engineering. For a senior-level course, PlayDoh colors may be correlated with actual soil properties to facilitate students making more informed engineering judgment calls as they develop a reasonable and conservative soil profile for the site.

Faculty Perspective

The authors have used the activity in classes of 15-25 student in two sections of a senior foundation design course in one semester, and in twelve sections of a freshman intro to civil engineering course across five semesters. In all cases, the students have responded well, feeling that they have a fuller understanding of both the tasks involved in a site characterization as well as the inherent uncertainty in geotechnical engineering. As a freshman-level exercise, the activity provides a contextualized learning experience that incorporates a breadth of principles applied to the geotechnical engineering discipline. The actual class activity can be completed in 30 to 45 minutes leaving time for simple reporting in a freshman-level course or more time for discussion and critical evaluation in a senior-level course.

Faculty assess student learning through a review of student reports. In the senior-level course, students prepared reports of reasonable geotechnical site characterization with justifications and clear explanations of simplifying assumptions. Alternatively, the classroom experience could springboard a more traditional site characterization activity at full scale but with an engaging overview of the complete process. In the freshman-level course, merely completing the activity and preparing a brief handwritten report was sufficient to achieve the lower-level learning objectives. In each case, students make connections across a range of technical and non-technical critical thinking required to prepare a reasonable model of soil beneath a site. At this time, no direct or nominal assessment of the activity has been performed beyond the complete reports.

Conclusion

A geotechnical site investigation in a box grants students the opportunity to experience the full cycle of activities involved in geotechnical site characterization in a single class period. By connecting model-scale class activities to PowerPoint presentations of actual site characterizations, a passive learning activity can be made active, constructive, and interactive [7]. The authors have enjoyed introducing geotechnical engineering to freshman students and encouraging critical thinking in senior students using this activity. The attached appendices include handouts for use in a freshman introductory course.

References

[1] J. M. Lang, *Small Teaching: Everyday Lessons from the Science of Learning*, 1st edition. San Francisco, CA: Jossey-Bass, 2016.

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[3] O. A. Owolabi, “The Impact of Construction Site Tour During the First Week of Class on Student Learning in an Introductory Geotechnical Engineering Class,” presented at the 2017 ASEE Mid Atlantic Section Spring Conference, Apr. 2017. Accessed: Feb. 02, 2023. [Online]. Available: https://peer.asee.org/the-impact-of-construction-site-tour-during-the-first-week-of-class-on-student-learning-in-an-introductory-geotechnical-engineering-class

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[5] J. VanCleave, *Janice VanCleave’s 201 Awesome, Magical, Bizarre, & Incredible Experiments*, 1st edition. New York: Jossey-Bass, 1994.

[6] L. W. Anderson *et al.*, *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom’s Taxonomy of Educational Objectives, Abridged Edition*, 1 edition. New York: Pearson, 2000.

[7] M. T. H. Chi and R. Wylie, “The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes,” *Educational Psychologist*, vol. 49, no. 4, pp. 219–243, Oct. 2014, doi: 10.1080/00461520.2014.965823.

MEMORANDUM

TO:	CIVL103 Intro to Civil and Construction Students
CLASS:	CIVL103 Introduction to Civil and Construction Engineering
SUBJECT:	Project – Geotechnical Engineering (6th Battalion Site Investigation)

Your geotechnical engineering firm has been contracted to work on the proposed 6th Battalion building project. Working in teams of three, students must prepare a site investigation memo including background, site reconnaissance, and field exploration information including a 2D fence diagram and a 1D idealized profile.

****Note that the scale for taking the site measurement should 10 mm to 2 meters****

1 Background

Write a brief statement describing the soil types (color) expected at the proposed 6th battalion site based on investigations. Looking at the sides of the site (A, B, C and D), describe what you see. Note any potential local variations.

2 Field Reconnaissance

Write a brief statement about the nature of the proposed 6th Battalion site looking at it from above. Comment on any notable features and any differences from what was observed in the side views.

3 Estimated two-dimensional Cross Section Diagram from Background Work

Create a 2D sketch (like Figure 1) that shows the initial elevation and changes in soil layers with depth. Choose one side of the site and record the elevations every 2 meter to sketch the layers.
****Note that the scale for taking the site measurement should 10 mm to 1 meter****

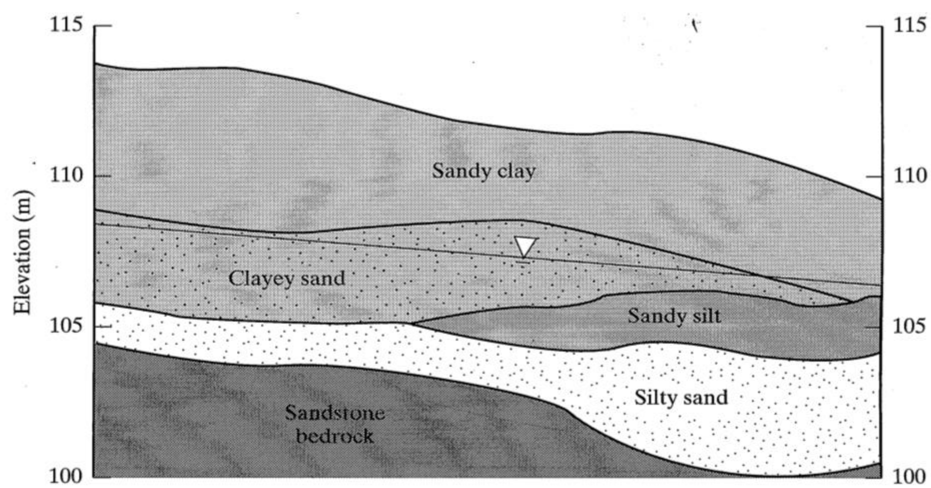

Figure 1 – Typical Two-Dimensional Cross-Section Through A Site

4 Boring Layout Plan

Prepare a boring layout plan by marking three drilling locations. Use the knowledge gained from the background and field reconnaissance to develop the boring layout plan. Sketch the layout plan similar to Figure 2.

Measure how far away each selected drilling site is from the face of side C and include this measurement on your sketch.

****Note that the scale for taking the site measurement should 10 mm to 2 meter****

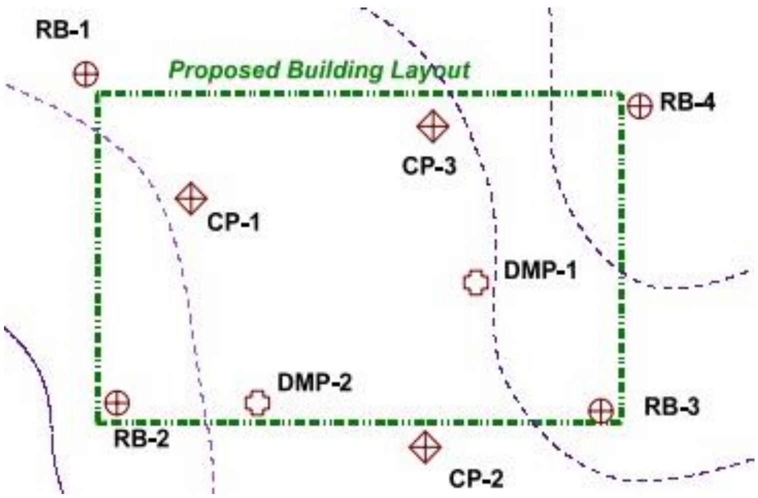

Figure 2 – Typical Boring Layout Plan

5 Field Exploration

Push Shelby tubes (transparent drinking straws) at the three boring locations. Measure thickness of each layer. ****Note that the scale for taking the site measurement should 10 mm to 1 meter****

6 2D Fence Diagram

Create a 2D sketch relating initial elevation and changes in layers with depth with boring position. Figure 3 shows an example of a typical fence diagram.

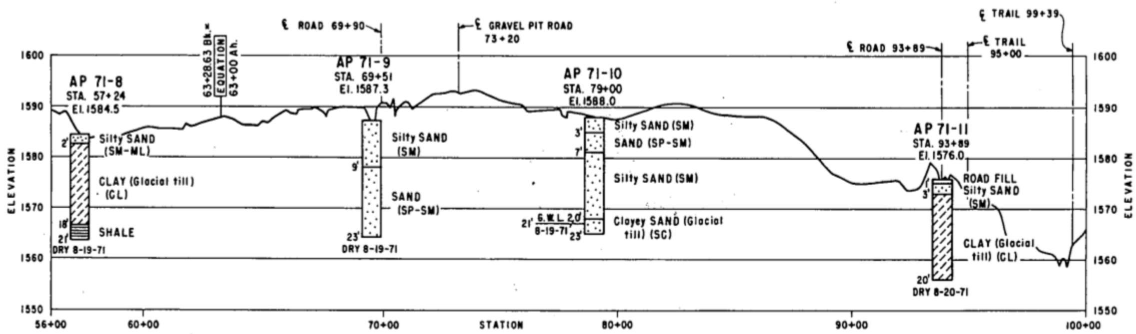

Figure 3 - Typical Fence Diagram

7 1D Idealized Profile

Simplify your fence diagram into an idealized soil profile like the one shown below. The dominate soil properties for this project are soil color.

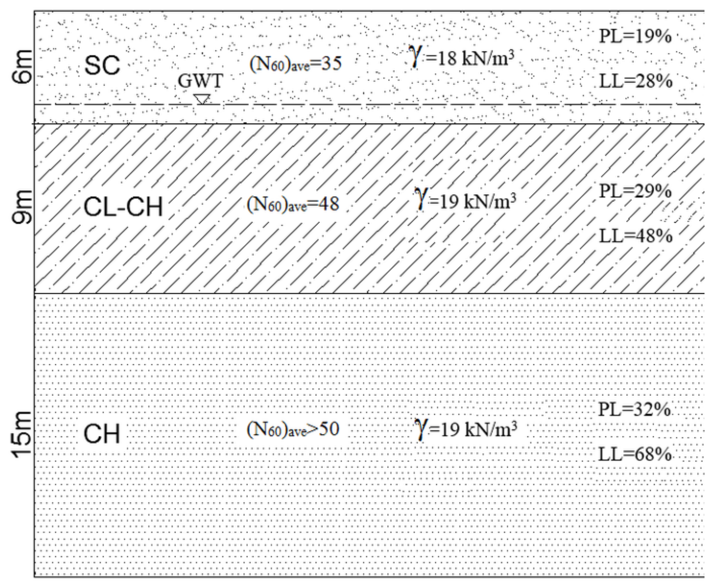

Figure 4 – Typical Idealized Soil Profile

MEMORANDUM

TO:
DATE:
FROM:
SUBJECT: Project – Geotechnical Engineering (6th Battalion Site Investigation)

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1 Background

2 Field Reconnaissance

3 Estimated two-dimensional Cross Section Diagram from Background Work

****Note that one (1) square on the graph sheet represents one (1) meter****

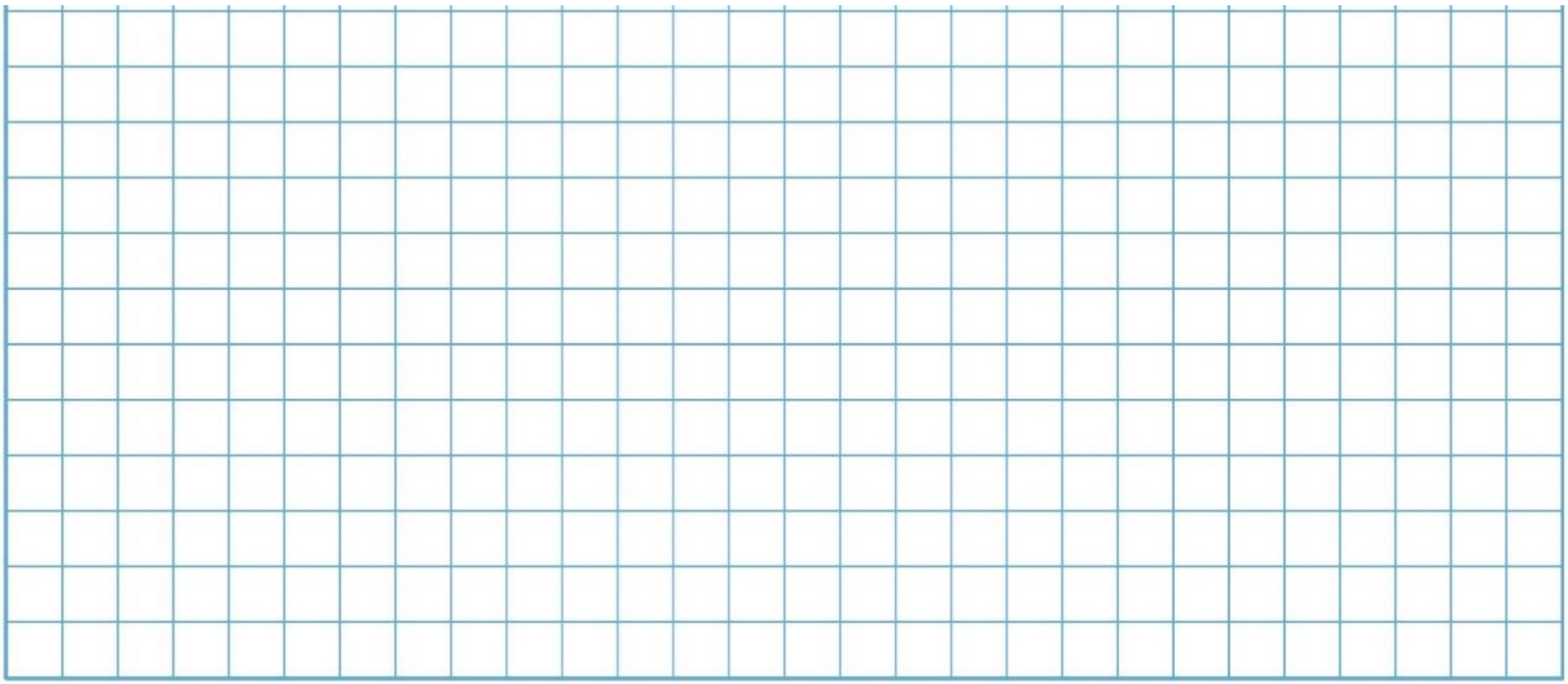

Figure 1 – Two-Dimensional Cross-Section of 6th Battalion Site

****Note that one (1) square on the graph sheet represents one (1) meter****

4 Boring Layout Plan

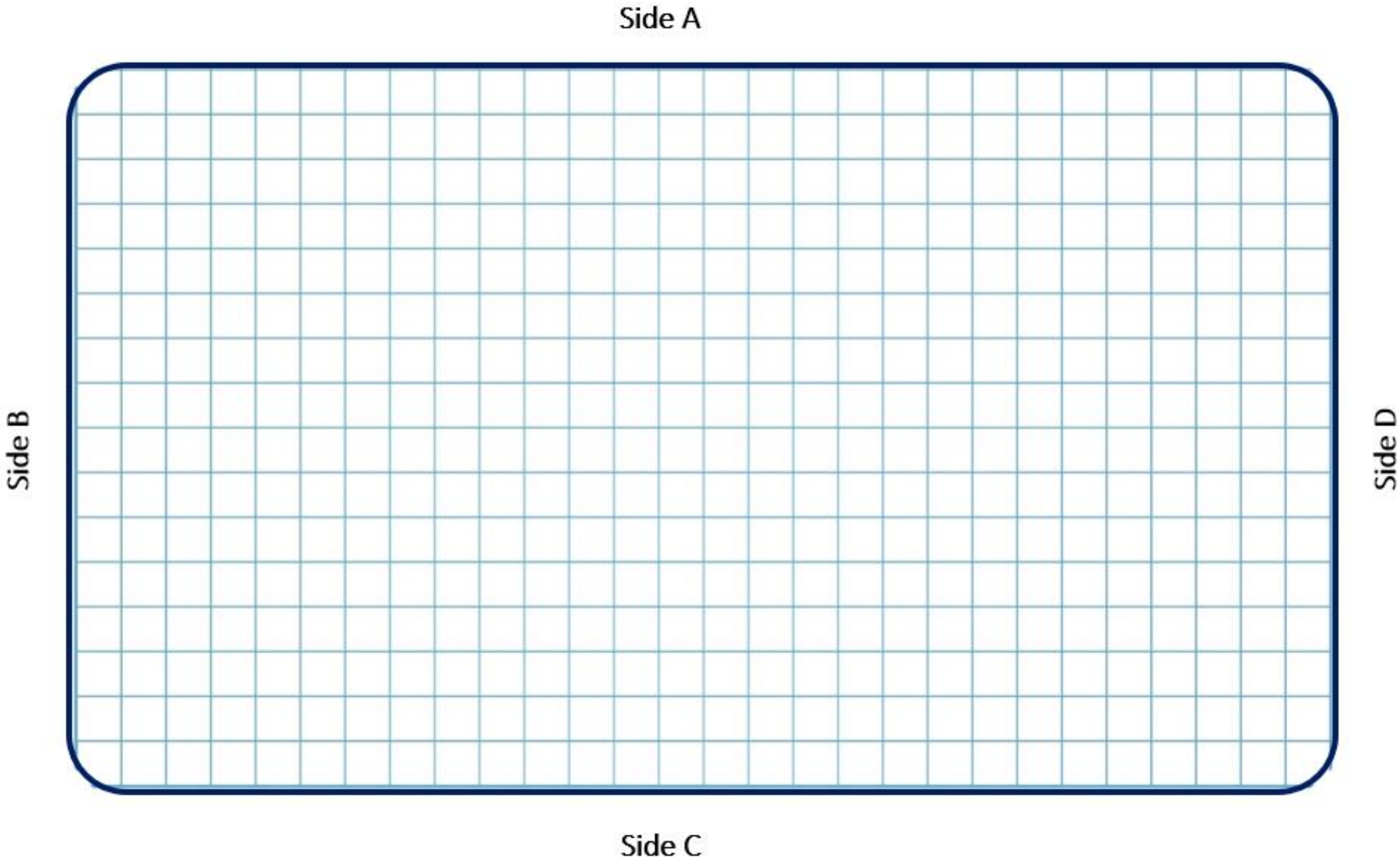

Figure 2 – Typical Boring Layout Plan of 6th Battalion Site

5 Field Exploration

6 2D Fence Diagram

****Note that one (1) square on the graph sheet represents one (1) meter****

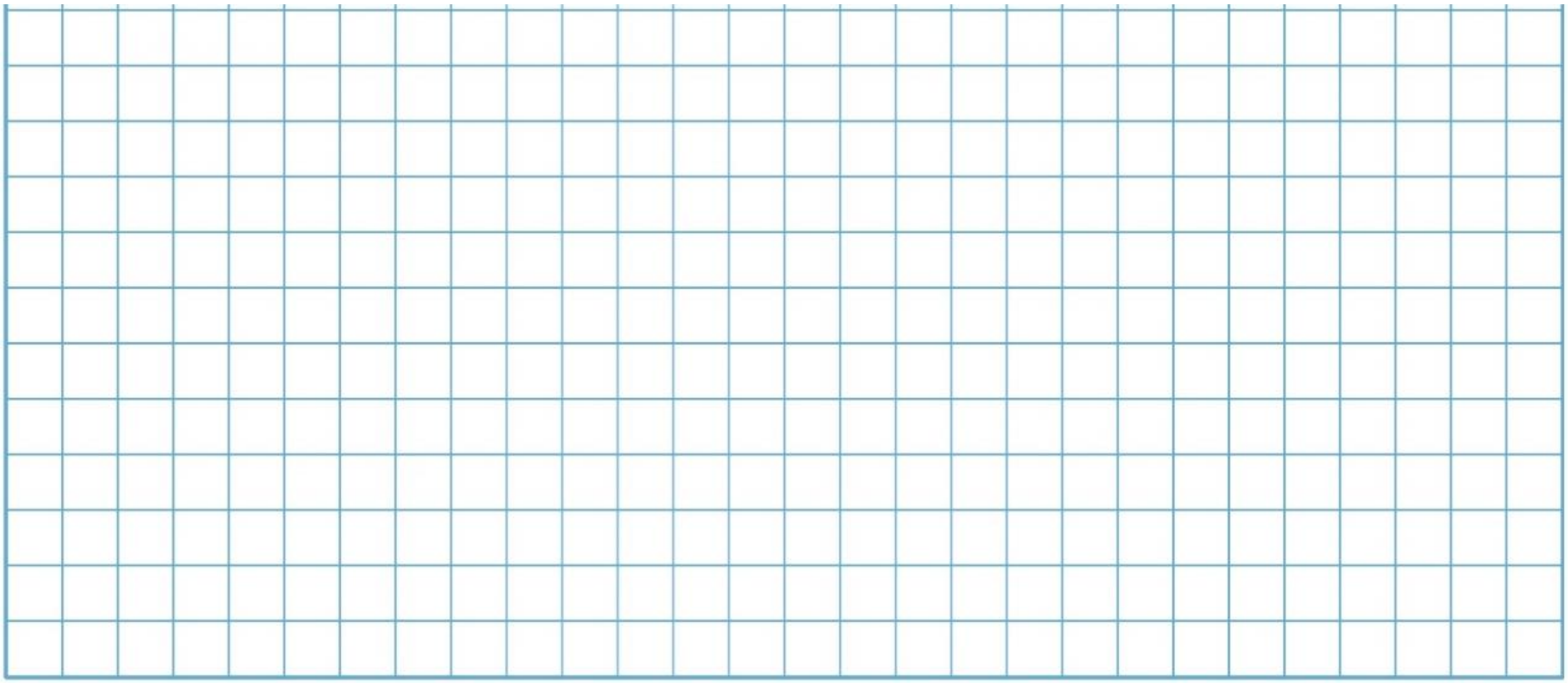

Figure 3 – 2D Fence Diagram of 6th Battalion Site

****Note that one (1) square on the graph sheet represents one (1) meter****

7 1D Idealized Profile

****Note that one (1) square on the graph sheet represents one (1) meter****

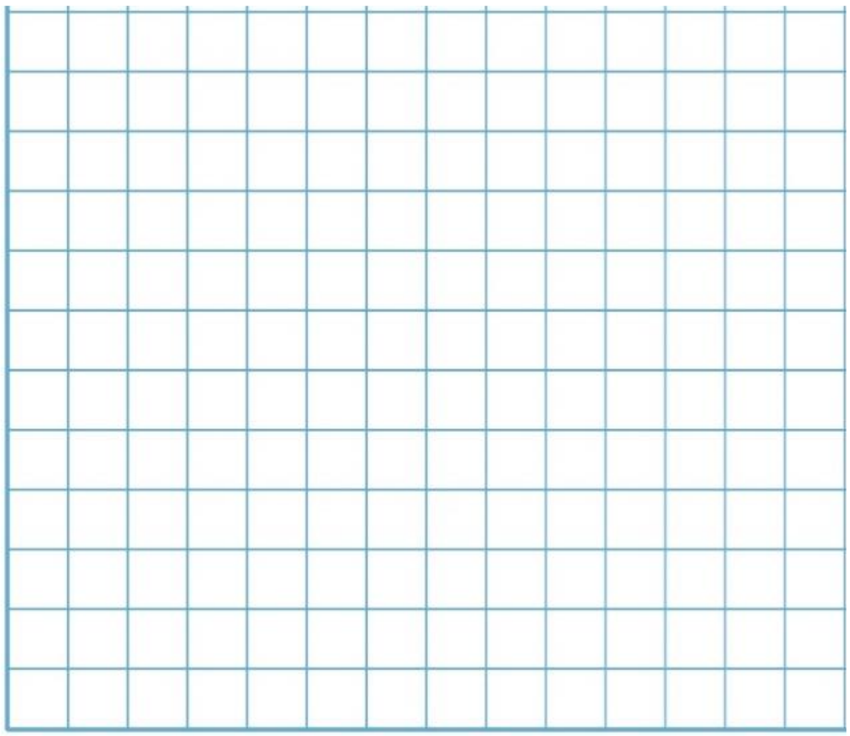

Figure 3 – One-Dimensional Idealized Profile of 6th Battalion Site